Lappala, E.G., Healy, R.W., and Weeks, E.P., 1987, Documentation of computer program VS2D to solve the equations of fluid flow in variably saturated porous media: U.S. Geological Survey Water-Resources Investigations Report 83-4099.

Table 3.--*Input data formats*--Continued

Card	Variable	Description
B-14--Continued		
	ETSIM	Logical variable = T if evapotranspiration (plant-root extraction) is to be simulated at any time during the simulation; otherwise = F.
Line B-15 is present only if BCIT = T or ETSIM = T.		
B-15	NPV	Number of ET periods to be simulated. NPV values for each variable required for the evaporation and/or evapotranspiration options must be entered on the following lines. If ET variables are to be held constant throughout the simulation code, NPV = 1.
	ETCYC	Length of each ET period, T.
Note: For example, if a yearly cycle of ET is desired and monthly values of PEV, PET, and the other required ET variables are available, then code NPV = 12 and ETCYC = 30 days. Then 12 values must be entered for PEV, SRES, HA, PET, RTDPTH, RTBOT, RTTOP, and HROOT. Actual values, used in the program, for each variable are determined by linear interpolation based on time.		
Line B-16 to B-18 are present only if BCIT = T.		
B-16	PEVAL	Potential evaporation rate (PEV) at beginning of each ET period. Number of entries must equal NPV, LT^{-1}.
To conform with the sign convention used in most existing equations for potential evaporation, all entries must be greater than or equal to 0. The program multiplies all nonzero entries by -1 so that the evaporative flux is treated as a sink rather than a source.		
B-17	RDC(1,J)	Surface resistance to evaporation (SRES) at beginning of ET period, L^{-1}. For a uniform soil, SRES is equal to the reciprocal of the distance from the top active node to land surface, or 2./DELZ(2). If a surface crust is present, SRES may be decreased to account for the added resistance to water movement through the crust. Number of entries must equal NPV.
B-18	RDC(2,J)	Pressure potential of the atmosphere (HA) at beginning of ET period; may be estimated using equation 6, L. Number of entries must equal NPV.

Table 3.--*Input data formats*--Continued

Card	Variable	Description
Lines B-19 to B-23 are present only if ETSIM = T.		
B-19	PTVAL	Potential evapotranspiration rate (PET) at beginning of each ET period, LT^{-1}. Number of entries must equal NPV. As with PEV, all values must be greater than or equal to 0.
B-20	RDC(3,J)	Rooting depth at beginning of each ET period, L. Number of entries must equal NPV.
B-21	RDC(4,J)	Root activity at base of root zone at beginning of each ET period, L^{-2}. Number of entries must equal NPV.
B-22	RDC(5,J)	Root activity at top of root zone at beginning of each ET period, L^{-2}. Number of entries must equal NPV.
Note: Values for root activity generally are determined empirically, but typically range from 0 to 3.0 cm/cm^3. As programmed, root activity varies linearly from land surface to the base of the root zone, and its distribution with depth at any time is represented by a trapezoid. In general, root activities will be greater at land surface than at the base of the root zone.		
B-23	RDC(6,J)	Pressure head in roots (HROOT) at beginning of each ET period, L. Number of entries must equal NPV.
[Line group C read by subroutine VSTMER, NRECH sets of C lines are required]		
C-1	TPER	Length of this recharge period, T.
	DELT	Length of initial time step for this period, T.
C-2	TMLT	Multiplier for time step length.
	DLTMX	Maximum allowed length of time step, T.
	DLTMIN	Minimum allowed length of time step, T.
	TRED	Factor by which time-step length is reduced if convergence is not obtained in ITMAX iterations. Values usually should be in the range 0.1 to 0.5. If no reduction of time-step length is desired, input a value of 0.0.
C-3	DSMAX	Maximum allowed change in head per time step for this period, L.
	STERR	Steady-state head criterion; when the maximum change in head between successive time steps is less than STERR, the program assumes that steady state has been reached for this period and advances to next recharge period, L.

Table 3.--*Input data formats*--Continued

Card	Variable	Description
C-4	POND	Maximum allowed height of ponded water for constant flux nodes. See text for detailed discussion of POND, L.
C-5	PRNT	Logical variable = T if heads, moisture contents, and/or saturations are to be printed to file 6 after each time step; = F if they are to be written to file 6 only at observation times and ends of recharge periods.
C-6	BCIT	Logical variable = T if evaporation is to be simulated for this recharge period; otherwise = F.
	ETSIM	Logical variable = T if evapotranspiration (plant-root extraction) is to be simulated for this recharge period; otherwise = F.
	SEEP	Logical variable = T if seepage faces are to be simulated for this recharge period; otherwise = F.
C-7 to C-9 cards are present only if SEEP = T,		
C-7	NFCS	Number of possible seepage faces.
C-8	JJ	Number of nodes on the possible seepage face.
	JLAST	Number of the node which initially represents the highest node of the seep; value can range from 0 (bottom of the face) up to JJ (top of the face).
C-9	J,N	Row and column of each cell on possible seepage face, in order from the lowest to the highest elevation; JJ pairs of values are required.
C-10	IBC	Code for reading in boundary conditions by individual node (IBC=0) or by row or column (IBC=1). Only one code may be used for each recharge period, and all boundary conditions for period must be input in the sequence for that code.
Line set C-11 is read only if IBC = 0. One line should be present for each node for which new boundary conditions are specified,		
C-11	JJ	Row number of node.
	NN	Column number of node.

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Table 3.--*Input data formats*--Continued

Card	Variable	Description
C-11--Continued	NTX	Node type identifier for boundary conditions. = 0 for no specified boundary (needed for resetting some nodes after intial recharge period); = 1 for specified pressure head; = 2 for specified flux per unit horizontal surface area in units of LT^{-1}; = 3 for possible seepage face; = 4 for specified total head; = 5 for evaporation; = 6 for specified volumetric flow in units of L^3T^{-1}.
	PFDUM	Specified head for NTX = 1 or 4 or specified flux for NTX = 2 or 6. If codes 0, 3, or 5 are specified, the line should contain a dummy value for PFDUM or should be terminated after NTX by a blank and a slash.
C-12 is present only if IBC = 1. One card should be present for each row or column for which new boundary conditions are specified,		
C-12	JJT	Top node of row or column of nodes sharing same boundary condition.
	JJB	Bottom node of row or column of nodes having same boundary condition. Will equal JJT if a boundary row is being read.
	NNL	Left column in row or column of nodes having same boundary condition.
	NNR	Right column of row or column of nodes having same boundary condition. Will equal NNL if a boundary column is being read in.
	NTX	Same as line C-11.
	PFDUM	Same as line C-11.
C-13		Designated end of recharge period. Must be included after line C-12 data for each recharge period. Two C-13 lines must be included after final recharge period. Line must always be entered as 999999 /.

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4. VSTMER — Controls the time sequence of simulation:
   a. At the start of each period having new boundary conditions or source/sink strength values, reads them, and adjusts material properties at the affected boundaries.
   b. Saves heads and moisture contents from previous time step.
   c. Computes proper time-step length to: (1) minimize oscillations; (2) end precisely at specified times when results are to be saved; and (3) end precisely at the end of the current recharge or evapotranspiration period.

5. VSCOEF — Computes values of nonlinear coefficients using current values of pressure head.

6. VSHCMP — Computes intercell conductances for each node.

7. VSMGEN — Computes values of coefficients in matrix form of flow equation and calls the solution routine.

8. VSSIP — Uses the Strongly Implicit Procedure (SIP) to solve matrix equation.

9. VSFLUX — Computes a fluid mass balance for each time step including flux rates across Dirichlet and Neumann boundaries, and prints the results to files 6 and 9.

10. VSFLX1 — Computes intercell mass flux rates for Dirichlet boundary nodes.

11. VSOUTP — Controls output of arrays to file 6, 8, and 11.

12. VSOUT — General output of array data to file 6. Prints a header and desired array to file 6.

13. VSEVAP — Computes evaporation from land surface as a function of potential evaporation, the hydraulic conductivity of the surface layer, the pressure-potential difference between the soil and the air, and a surface-resistance factor.

14. VSPLNT — Computes transpiration by plants as a function of potential evapotranspiration, root-activity function, hydraulic conductivity of the soil, and the difference in pressure head between the roots and the soil.

15. VSPOND — Checks to see if ponding has occurred during infiltration.

16. VSSFAC — Computes the position of the top of seepage-face boundaries.

17. VSPET — Computes the potential evaporation rate, potential evapotranspiration rate, and other variables required for calculation of evaporation and/or evapotranspiration.

18. VSRDF — Computes root activities by interpolating between the activity at land surface and that at the maximum depth at rooting.

Separate groups of function subprograms are required to evaluate the soil hydraulic properties.

19. Function subprograms for soil hydraulic properties are:

a. VSTHNV: — Pressure head as a function of volumetric moisture content: $h(\theta)$.

b. VSTHU: — Volumetric moisture content as a function of pressure head: $\theta(h)$.

c. VSDTHU: — First derivative of volumetric moisture content as a function of pressure head, or specified moisture capacity:

$$\frac{d[\theta(h)]}{dh}.$$

d. <u>VSHKU</u> Relative hydraulic conductivity as a function of pressure head: K_r (h).

Four sets of function subprograms are listed separately with VS2D: Brooks-Corey, van Genuchten, Haverkamp, and tabular interpolation. Only one of these should be compiled and loaded with VS2D for any given problem. These sets are listed in Attachment I.

File Definition

I. INPUT FILE: File 5.

II. OUTPUT FILES: File 6, printer file:

Echo all input data, initial conditions, boundary conditions; write pressure heads, total heads, moisture contents, and/or saturations, as selected by user for all time steps or user-selected times. Optional mass balance for each time step, but mass balance and pressure head profile at end of simulation. Written to from VSEXEC, VSREAD, VSTMER, VSOUT, and VSOUTP.

File 7:

Time step number, elapsed simulation time, and maximum head change for each iteration. Written to from VSOUTP if F7P = T.

File 8:

Pressure head at all nodes at selected observation times; written to from VSOUTP if F8P = T; includes one header record per observation time. Format is 8E10.4.

Note: File 8 may be used to provide initial conditions for restarting a simulation. The pressure-head profile for the selected time should be placed in file IU, and read using option 1 for initial head conditions (see input data description).

File 9:

Mass-balance summary as a function of elapsed time written to from VSFLUX if F9P = T; this summary contains evaporation, and evapotranspiration rates from each time step; includes 3 header records.

File 11:

Total head, pressure head, moisture content, and saturation at selected observation points for each time step; written to from VSOUTP if F11P = T.

Note: All header records include problem title, file identification, and column headings.

MODEL VERIFICATION

The computer code was verified on five test problems. Owing to the nonlinearity of the descriptive flow equation (equation 13) closed-form analytic solutions are not available for most problems to which the code might be applied. Two tests of linear forms of equation 13 were made to verify the code for rectangular and radial coordinates. The third verification test involves the comparison of simulated results to an analytical solution for a steady-state nonlinear problem. Finally, two nonlinear simulations are compared to experimental data.

When the conductance and storage terms in equation 13 are constant, it can be written in the horizontal direction as the linear diffusion equation:

$$\frac{\partial H}{\partial t} = D \frac{\partial^2 H}{\partial x^2} \tag{53}$$

where:

$$D = \frac{K}{S_s} ;$$

K = saturated hydraulic conductivity LT^{-1}; and

S_s = specific storage, L^{-1};

with the initial condition $H = H_o$ at $t = 0$; and the boundary conditions $H = H_i$ at $x = 0$, and $H = H_o$ at $x = L$, where L is the length of the system. If L is large enough that it can be considered infinite for the problem of interest, the solution to equation 53 is (Carslaw and Jaeger, 1959):

$$\frac{H - H_o}{H_i - H_o} = \text{erfc} \left(\sqrt{\frac{x^2}{4Dt}}\right), \tag{54}$$

where erfc is the complementary error function.

The computer code was applied to a one-dimensional column for which $D = 0.3118$ cm²/min, with a grid spacing of $\Delta x = 0.05$ cm. Results are shown in figure 19 for an elapsed time of 5 minutes. The boundary conditions used were $H_i = 0$ m; $H_o = 3$ m.

The second linear test of the computer code was designed to evaluate the adequacy of the cylindrical geometry option. By making the hydraulic properties constant, equation 13 can be written as the radial diffusion equation:

$$\frac{\partial H}{\partial t} = \frac{D}{r}\frac{\partial H}{\partial r} + D \frac{\partial^2 H}{\partial r^2} . \tag{55}$$

With the Neumann boundary conditions due to withdrawal of water at the origin at the rate, $\hat{q}$:

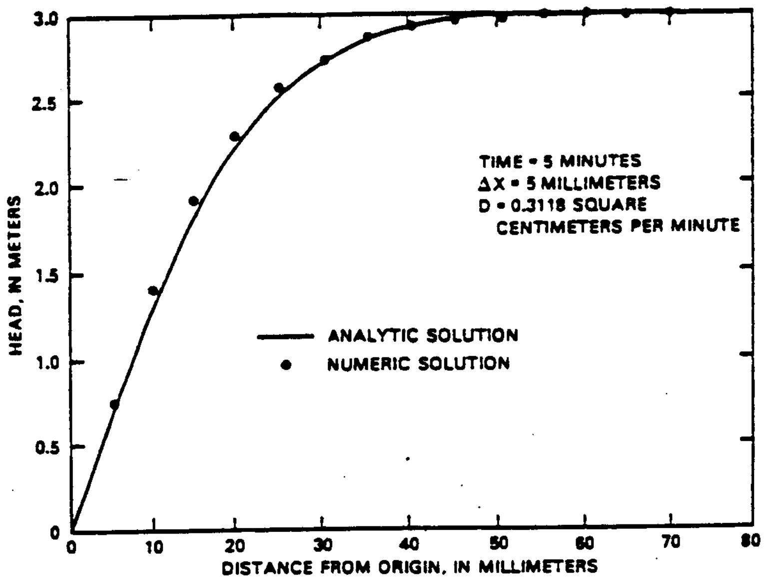

Figure 19.--Comparison of analytical and numerical solutions for one-dimensional linear diffusion.

$$\lim_{r \to 0} r \frac{\partial H}{\partial r} = \frac{\hat{q}}{2\pi K b} , \qquad (56)$$

where b is the thickness of the aquifer, L; with the Dirichlet condition at $r = \infty$ of H_o and the initial condition, $H = H_o$, the solution to this problem is (Theis, 1935):

$$H_o - H = \frac{\hat{q}}{4\pi K b} \int_{\frac{r^2 S_s}{4K t}}^{\infty} \frac{e^{-u}}{u} du . \qquad (57)$$

The exponential integral was evaluated by series expansion using constants given by Abramowitz and Stegun (1964).

The computer code was applied to the problem described by equation 55, subject to the following conditions:

H_o = 100 meters;

K = 0.03472 meters per minute;

b = 10 meters.

$\hat{q}$ = 13.369 cubic meters per minute; and

$S_s = 3.0 \times 10^{-5}$ per meter.

The comparison between the analytic and numerical solutions is shown in figure 20 for r = 3.94 m. For the numerical solution, a variable time step was used, computed with $\Delta t^{i} = 1.5\ \Delta t^{i-1}$. The initial time step size was 0.001 minute. A variable radial grid spacing (Δr) was used starting with 0.05 m at the origin and increasing Δr by a factor of 1.2 with each radial increment.

The third verification problem involved the comparison of steady upward flux to the atmosphere as determined by simulation to that computed by an analytical equation. That equation is based on a Haverkamp-type equation relating unsaturated hydraulic conductivity to pressure head (equation 26) with the restriction that the exponent B' is an integer varying from 2 to 5.

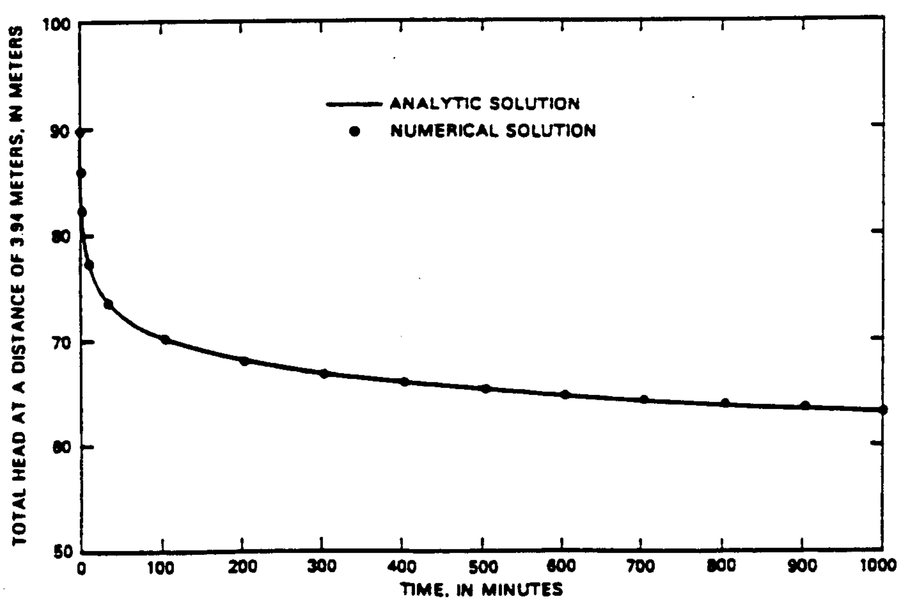

Figure 20.--Comparison of analytical and numerical solutions for one-dimensional radial flow to a well in a confined aquifer.

Based on this relation, the steady evaporation rate is given by the equation (Ripple and others, 1972):

$$\frac{E_\infty}{K} = \left(\frac{A'}{L}\right)^{B'} \left[\frac{\pi}{B' \sin \frac{\pi}{B'}}\right]^{B'}, \tag{58}$$

where E_∞ = evaporation rate at land surface when the pressure head is equal to minus infinity, LT^{-1}; and

L = distance from the water table to land surface, L.

This equation is strictly valid only when $E_\infty << K$.

The following fixed parameters were used in the verification problem:

K = 0.10 m/day;

L = 1.00 m;

A' = -0.10 m;

B' = 3; and

SRES = 2./ΔZ

Results of several simulations are listed in table 4. Only three-place accuracy is listed because the analytical equation itself may be in error in the fourth place, due to an approximating assumption in its evaluation.

Other runs, not listed, showed that the program could achieve about 1-percent accuracy using arithmetic mean weighting and a variable grid spacing starting with a vertical increment of 5 mm at land surface.

Table 4.--*Simulation results for steady evaporation*

[mm, millimeters; m, meters]

Grid spacing, mm	Weighting scheme	Pressure head in atmosphere, m	Evaporation rate, mm/dayx10^{-1}
20	Geometric	-100	1.77
20	Do	-500	1.73
20	Do	-1,000	1.71
40	Do	-100	1.77
40	Do	-500	1.70
20	Arithmetic	-100	1.92
20	Do	-500	1.96
20	Do	-1,000	1.97
20	Upstream	-100	2.23
20	Do	-1,000	2.11
Analytical solution			1.77

Table 4 illustrates some of the problems involved in numerically simulating highly nonlinear equations. Under some conditions, the simulated flux matched that computed using the analytical equation exactly, indicating that the program is performing correctly. However, the results are highly dependent on the node spacing, weighting scheme, and imposed pressure head in the atmosphere. The results suggest that use of the geometric mean weighting scheme with a fairly small grid spacing, at least at the land-surface boundary, is advisable.

For the fourth verification problem, simulation results were compared to experimental results by Haverkamp and others (1977) for vertical infiltration of water into sand. The hydraulic properties and Haverkamp function values listed for soil in table 1 were used to simulate the sand.

The initial and boundary conditions are as follows:

$t < 0$	$0 < z < 0.70$ m	$h = -0.615$ m
$t \geq 0$	$z = 0$	Infiltration rate at top of column = 0.1369 m/h.
$t \geq 0$	$z \geq 0.70$ m	$h = -0.615$ m.

The geometric mean was used to determine the interblock relative hydraulic conductivity. Vertical grid spacing was uniformly set at 1 cm. As figure 21 shows, the model-computed results match reasonably well with the experimental data, especially at larger times.

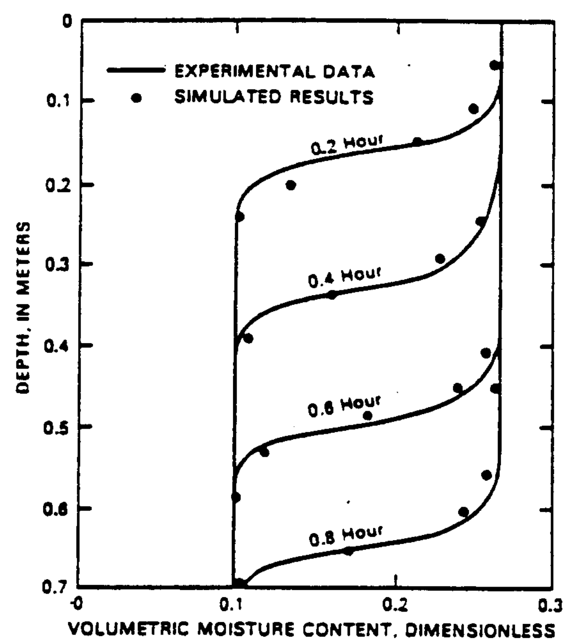

Figure 21.--Comparison of moisture content profiles with those measured by Haverkamp and others (1977, p. 285) for one-dimensional vertical infiltration.

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Use of upstream weighting, arithmetic mean, and geometric mean to compute the interblock relative hydraulic conductivity are compared for this problem in figure 22. Unlike the problem involving bare soil evaporation, the results are not significantly affected by the weighting scheme. In fact, results are virtually identical for the geometric and arithmetic means. Both show a sharper front than that determined using upstream weighting.

Verification problem 5 illustrates the seepage face option. The problem was based on an experiment reported by Duke (1973) and Hedstrom and others (1971). This experiment was also simulated by Davis and Neuman (1983). For the experiment, a 12.20 m long flume was packed to a height of 1.22 m with Poudre Sand. A constant rate of infiltration was applied to the soil surface and water levels were kept equal to the bottom of the flume at its ends. The objective of the experiment was to determine the location of the free-water surface once steady-state conditions were achieved.

The hydraulic properties of the Poudre Sand are described by functions of the Brooks-and-Corey-type (equations 18, 23, and 27) with the values:

$\theta_s = 0.348$;

$h_b = -.19$ m;

$\lambda = 1.6$;

$\theta_r = 0$;

$K = 5.564$ m/d;

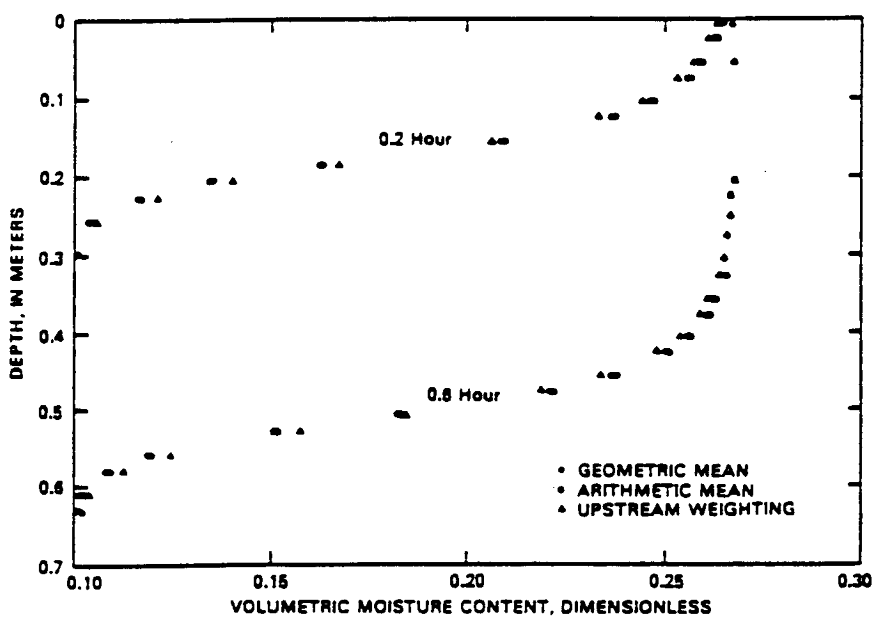

Figure 22.--Comparison of effects of using different methods for determining interblock relative hydraulic conductivity in vertical infiltration problems.

The simulated cross section was 1.22 m high and 6.10 m long (because of symmetry, it was necessary to simulate only one-half of the flume). The bottom and right hand boundaries were impermeable. The soil surface nodes were assigned a constant flux of 0.1035 m/d. The left-hand boundary was specified as a possible seepage face. Initial heads were set at static equilibrium.

A total of 1,344 nodes (42 rows by 32 columns) was used for the simulation. Grid spacing was variable in both dimensions, being fine (a minimum of 0.01 m) near the soil surface and near the seepage face.

The simulation was run until steady state was reached, as determined by specifying that the maximum head change between sequential time steps be less than 10^{-6} m. Steady state was reached at approximately 5.89 days (136 time steps). Figure 23 shows the steady state location of the free-water surface as simulated by VS2D and as measured by Duke (1973). The simulation results match the experimental data closely, but not exactly. According to Duke (1973), local nonhomogeneity may have added some scatter to the experimental data. Figure 24 shows the vertical distribution of pressure heads at the left hand boundary as computed by VS2D and by Davis and Neuman (1983). Agreement is good between the two simulations, with VS2D producing slightly higher pressures throughout the vertical.

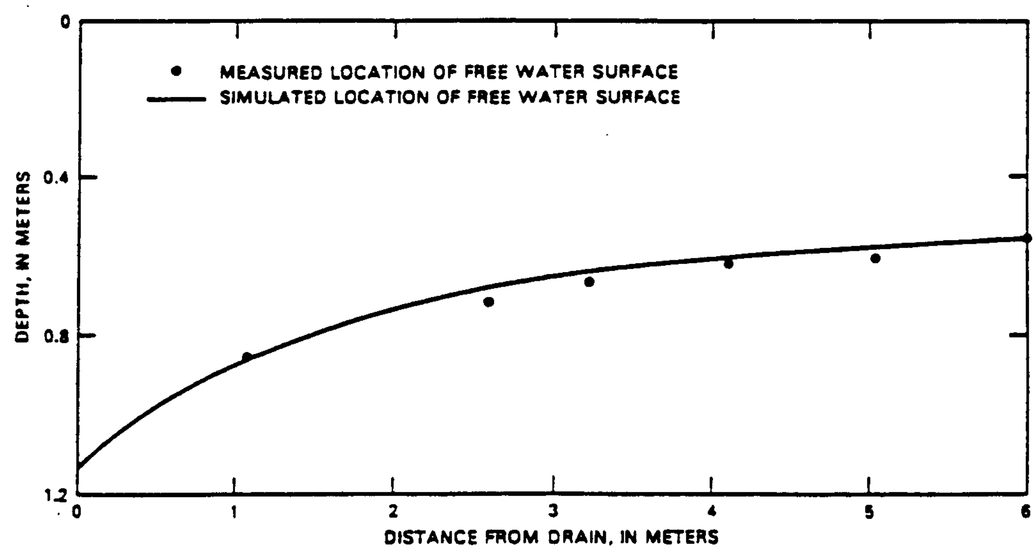

Figure 23.--Comparison of simulated and measured location of the free-water surface for the drainage problem of Duke (1973).

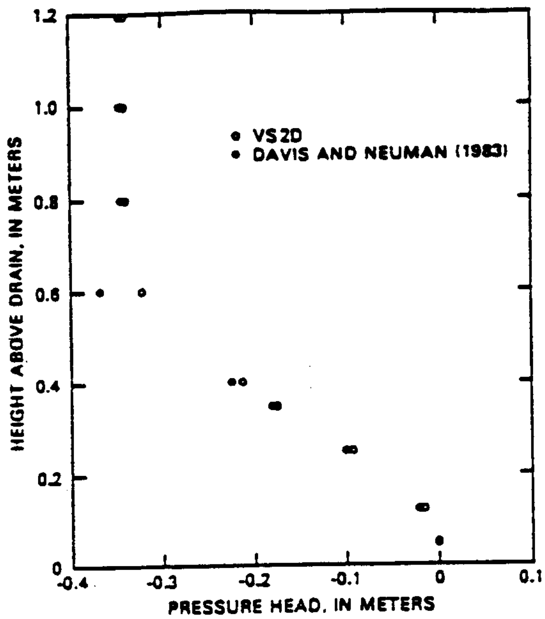

Figure 24.--Comparison of pressure head profiles at the left hand boundary as computed by VS2D and Davis and Neuman (1983) for the drainage problem of Duke (1973).

Example Problems

Two example problems follow. These are designed to check out the program after it has been installed on a particular computer system. Complete listings of input data and partial listings of program output are given for each example.

Example Problem 1

Example 1 is a problem of one-dimensional vertical infiltration into a medium of uniform initial pressure head (Baca and King, 1978). The porous medium is Glendale clay loam; its hydraulic properties are described by the Brooks and Corey equations with the following constants:

h_b = -0.054 m;

λ = 0.2;

θ_s = 0.52;

θ_r = 0.0; and

K = 0.0375 m/h.

Initial pressure head is uniformly set at -1.31 m. At 0 hours a constant pressure head, equal to -0.054 m, is applied to the uppermost node. The simulation then proceeds for 3.0 hours. The length of the simulated column is 0.60 m. A uniform grid spacing of 0.01 m is used. Time step size is constant at 0.1 hours. Depth profiles of saturation are computed at four times, and time profiles of heads, saturations and moisture contents are output for six points in the profile.

Input data for this problem are listed in table 5. In addition to the input data, each line except the first is keyed to the input descriptions in table 3, followed by a short description on the line itself. This information does not interfere with the running of the program.

A partial listing of output to file 6 is given in table 6. The first pages of this table represent the echoed input data. These are followed by one-line summaries of each time step until the time designated for depth-profile output to files 6 and 8 is reached. The saturation profile (since SPNT is TRUE) is then printed to file 6. Had PPNT, HPNT, and/or PPNT been set to TRUE, moisture content and/or head profiles would also have been listed in file 6 at this point. Also printed out at this time is a table showing the mass balance. Mass balance summaries for each time step could have been obtained by setting F6P = TRUE. In general, this output would be designated only when the user was trying to diagnose the cause of convergence problems.

A partial listing of output to file 8 is given in table 7. Note that this table lists the pressure head values for all nodes, including the inactive ones, at the user-designated times. The main purpose of this file is to provide initial conditions for restarting a simulation. For example, assume that the simulation failed to converge shortly after an hour had been simulated, and a new shorter time step was desired after that time. In this case, the TIME = and the following blank line would be deleted, and the file renumbered for use as input to VSREAD, specifying the file number and format in card B-13.

A listing of output to file 9 is given in table 8. This file summarizes the mass balance for each time step in concise form. The meanings of the abbreviated column headings are as follows:

Heading	Description
FLXIN1	Flux into domain across specified pressure head boundaries.
FLXOUT1	Flux out of domain across specified pressure head boundaries.
FLXIN2	Flux into domain across specified flux boundaries.
FLXOUT2	Flux out of domain across specified flux boundaries.
TOTAL ET	Total evapotranspiration flux (the sum of plant transpiration and evaporation) into domain (thus negative).
TRANSP	Plant transpiration.
EVAP	Bare soil evaporation.
DELS	Time rate of change in storage in domain.
ERROR	Sum of fluxes (including evapotranspiration) minus the rate of storage change.
%ERROR	Error divided by the change in storage, the quotient multiplied by 100.

The main uses of file 9 are to provide data on total evapotranspiration, evaporation, and transpiration rates, and to provide a concise summary of the mass balance for each time step.

The output to file 11 for example problem 1 is shown in table 8. For this table, H signifies total head, P, pressure head; THETA, moisture content; and SAT, saturation. A major use of file 11 is to provide data for preparing graphic output.

Example problem 1 was selected as a relatively simple problem, both conceptually and for data input, that nonetheless provides a good demonstration of the ability of the code to solve severely nonlinear problems. However, simulation results have differed slightly, particularly in the number of iterations required and in the mass balance, between the Prime[1] Model 750 and Prime Model 9950 computers. Other slight differences occurred between object codes generated by the Prime F77 revision 19.2.10 and the F77 revision 19.4 that were run on the Prime Model 9950 computer. Thus, the user should not concern himself with small variations in the mass balance or in variations in the total number of iterations required so long as the mass balances, the generated profiles, and the time histories, are in reasonable agreement with the equivalent output generated by his machine.

[1]Use of brand names in this report is for identification purposes only and does not constitute an endorsement by the U.S. Geological Survey.

Table 5.--*Input data for example problem 1*

```
 ONE-DIMENSIONAL INFILTRATION    EXAMPLE 1
      3.00      0.00                  A2--MAX SIMULATION TIME, INITIAL TIME
   CM  HRGRAM                         A3--UNITS
 3  62                                A4--NO. OF COLUMNS, NO. OF ROWS
1  40                                 A5--NO. OF RECHARGE PERIODS, NO. OF TIME STEPS
F T                                   A6--RADIAL? ITSTOP?
T T T T F                             A7--OUTPUT TO FILE 11? 7? 8? 9? MASS BAL TO 6?
F T F F                               A8--PRINT THETA? SATURATION? PRSS. HEAD? TOTAL HEAD?
         1        1.0                 A9--IFAC,FACX
         1        1.0                 A11--JFAC,FACZ
         4                            A13--NO. OF TIMES TO PRINT PROFILES
0.5  1.0  2.0  3.0                    A14--TIMES TO PRINT PROFILES
         6                            A15--NO. OF POINTS FOR OUTPUT DATA
5 2  10 2  16 2  22 2  30 2  40 2     A16--ROW,COLUMN FOR EACH POINT
 .002  .50  0.0                       B1--CLOSURE CRITERION, HMAX, WEIGHTING FOR KR
      1.0                             B2--FLUID DENSITY
       2        200                   B3--MIN ITS, MAX ITS
T                                     B4--HEADS READ AS INITIAL CONDITIONS?
1  6                                  B5--NO. OF TEXTURES, NO. OF PROPERTIES FOR EACH TEXTURE
         1                            B6--TEXTURE CLASS
1.0  3.125  0.0  0.52  -5.4  0.0  0.20  B7--ANIZ, KSAT,SS,POR,HB,RSAT,LMDA
         1                            B8--TEXTURE CLASS READ BY BLOCK
1  3  62  1                           B10--FIRST COL, LAST COL, LAST ROW, CLASS CODE
0  -130.0                             B11--HEAD CODE, INITIAL HEAD OR FACTOR
F,F                                   B14--EVAPORATION ? PLANT TRANSPIRATION ?
      3.00       0.10                 C1--TPER,DELT
      1.00       0.10      0.10   0.00  C2--TMULT,DELTMAX,DELTMIN,TRED
      100.         0                  C3--OSMAX,STERR
        0                             C4--POND
F                                     C5--RESULTS TO FILE 6 EVERY TIME STEP?
F F F                                 C6--EVAP?  TRANSPIRATION? SEEPAGE FACES?
0                                     C10--BOUNDARY CONDITION BY POINT
2  2  1  -5.4                         C11--ROW COLUMN CODE PFDUM
999999 /                              C13 END OF BOUNDARY CONDITIONS FOR TPER
999999 /                              C13 END OF FILE
```

Table 6.--*Partial listing of output to file 6, the main output file, for example problem 1*

```
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                           VS2D                          +
+    SIMULATION OF 2-DIMENSIONAL VARIABLY                 +
+    SATURATED HEAD AND FLUID SATURATION                  +
+    DISTRIBUTIONS. IMPLICIT FINITE DIFFERENCE            +
+    BODY-CENTERED CELLS USED                             +
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++


*****************************************************************************************************
    ONE-DIMENSIONAL INFILTRATION    EXAMPLE 1
*****************************************************************************************************

        SPACE AND TIME CONSTANTS
        -----------------------
   MAXIMUM SIMULATION TIME =     3.0000   HR
   STARTING TIME =     0.0000
   NUMBER OF RECHARGE PERIODS =          1
   MAXIMUM NUMBER OF TIME STEPS =          40
   NUMBER OF ROWS =    62
   NUMBER OF COLUMNS =     3
         SOLUTION OPTIONS
        ----------------
   WRITE ALL PRESSURE HEADS TO FILE 8 AT OBSERVATION TIMES? T
   STOP SOLUTION IF MAXIMUM NO. OF ITERATIONS EXCEEDED IN ANY TIME STEP?,T
   WRITE MAXIMUM CHANGE IN HEAD FOR EACH ITERATION TO FILE 7? T
   WRITE RESULTS AT SELECTED OBSERVATION POINTS TO FILE 11? T
   WRITE MASS BALANCE RATES TO FILE 9? T
   WRITE MASS BALANCE RATES TO FILE 6? F
   WRITE MOISTURE CONTENTS TO FILE 6? F
   WRITE SATURATIONS TO FILE 6? T
   WRITE PRESSURE HEADS TO FILE 6? F
   WRITE TOTAL HEADS TO FILE 6? F
                                          GRID SPACING IN VERTICAL DIRECTION, IN   CM
    1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
    1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
    1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
    1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
    1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
    1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
    1.000     1.000
                                          GRID SPACING IN HORIZONTAL OR RADIAL DIRECTION, IN   CM
```

Table 6.--*Partial listing of output to file 6, the main output file, for example problem 1*--Continued

```
 1.000     1.000     1.000
 TIMES AT WHICH H WILL BE WRITTEN TO FILE 08
   0.5000    1.0000    2.0000    3.0000
 ROW AND COLUMN OF OBSERVATION POINTS:
   5   2    10   2    16   2    22   2    30   2    40   2
 COORDINATE SYSTEM IS RECTANGULAR
 MATRIX EQUATIONS TO BE SOLVED BY SIP
      INITIAL MOISTURE PARAMETERS
     ____________________________

 CONVERGENCE CRITERIA FOR SIP  =   2.000E-02   CM
 DAMPING FACTOR, HMAX =    5.000E-01
 FLUID DENSITY AT ZERO PRESSURE =   1.000E+00 GRAM/  CM**3
 GEOMETRIC MEAN USED FOR INTERCELL CONDUCTIVITY
 NUMBER OF SOIL TEXTURAL CLASSES =          1
 NUMBER OF SOIL PARAMETERS FOR EACH CLASS =          6
 MINIMUM PERMITTED NO. OF ITERATIONS/TIME STEP =          2
 MAXIMUM PERMITTED NO. OF ITERATIONS/TIME STEP =        200
                                      CONSTANTS FOR SOIL TEXTURAL CLASSES

      ANISOTROPY        KSAT      SPECIFIC     POROSITY
                                  STORAGE
CLASS # 1
          1.0000D+00   3.1250D+00   0.0000D-01   5.2000D-01  -5.4000D+00   0.0000D-01   2.0000D-01
    TEXTURAL CLASS INDEX MAP


 TEXTURAL CLASSES READ IN BY BLOCK
    1  111
    2  111
    3  111
    4  111
    5  111
    6  111
    7  111
    8  111
    9  111
   10  111
   11  111
   12  111
   13  111
   14  111
   15  111
```

Table 6.--Partial listing of output to file 6, the main output file, for example problem 1--Continued

```
       .
       .
   56  111
   57  111
   58  111
   59  111
   60  111
   61  111
   62  111
                                          DEPTH FROM SURFACE
Z, IN
 CM                  X OR R DISTANCE, IN   CM
           0.50
  0.50     0.500
  1.50     1.500
  2.50     2.500
  3.50     3.500
  4.50     4.500
  5.50     5.500
  6.50     6.500
  7.50     7.500
  8.50     8.500
  9.50     9.500
 10.50    10.500
 11.50    11.500
 12.50    12.500
 13.50    13.500
 14.50    14.500
 15.50    15.500
       .
       .
       .
 56.50    56.500
 57.50    57.500
 58.50    58.500
 59.50    59.500
  INITIAL PRESSURE HEAD OR MOISTURE CONTENT WAS SET TO A CONSTANT VALUE OF  -1.300E+02
 5SIP ITERATION PARAMETERS:  0.1421085D-13  0.8471332D+00  0.9766318D+00  0.9964278D+00  0.9994539D+00
   ONE-DIMENSIONAL INFILTRATION    EXAMPLE 1
 TOTAL ELAPSED TIME =   0.000E-01   HR
 TIME STEP     0

                                          SATURATION
```

Table 6.--*Partial listing of output to file 6, the main output file, for example problem 1*--Continued

```
Z, IN
 CM                    X OR R DISTANCE, IN   CM
           0.50
  0.50    0.529
  1.50    0.529
  2.50    0.529
  3.50    0.529
  4.50    0.529
  5.50    0.529
  6.50    0.529
  7.50    0.529
  8.50    0.529
  9.50    0.529
 10.50    0.529
 11.50    0.529
 12.50    0.529
 13.50    0.529
 14.50    0.529
 15.50    0.529
      .
      .
      .
 56.50    0.529
 57.50    0.529
 58.50    0.529
 59.50    0.529
  DATA FOR RECHARGE PERIOD      1

      LENGTH OF THIS PERIOD =    3.000E+00   HR
      LENGTH OF INITIAL TIME STEP FOR THIS PERIOD = 1.000E-01   HR
      MULTIPLIER FOR TIME STEP =  1.000E+00
      MAXIMUM TIME STEP SIZE =  1.000E-01   HR
      MINIMUM TIME STEP SIZE =  1.000E-01   HR
      TIME STEP REDUCTION FACTOR =  0.000E-01
           MAXIMUM PRESSURE HEAD CHANGE ALLOWED IN ONE TIME STEP = 100.000
           STEADY-STATE CLOSURE CRITERION =  0.000E-01
           MAXIMUM DEPTH OF PONDING =     0.000
           PRINT SOLUTION AFTER EVERY TIME STEP? F
           SIMULATE EVAPORATION? F
           SIMULATE EVAPOTRANSPIRATION? F
           SIMULATE SEEPAGE FACES? F

  NODE TYPE AND INITIAL BOUNDARY CONDITIONS FOR PERIOD    1
 LEGEND:
```

Table 6.--*Partial listing of output to file 6, the main output file, for example problem 1*--Continued

```
          0 = INTERIOR CELL
          1 = SPECIFIED PRESSURE HEAD CELL
          2 = SPECIFIED FLUX CELL
          3 = POTENTIAL SEEPAGE FACE NODE
          5 = NODE FOR WHICH EVAPORATION IS PERMITTED

  1     000
  2     010
  3     000
  4     000
  5     000
  6     000
  7     000
  8     000
  9     000
 10     000
 11     000
 12     000
 13     000
 14     000
 15     000
         .
         .
         .
 56     000
 57     000
 58     000
 59     000
 60     000
 61     000
 62     000
  TIME STEP NUMBER =    1  RECHARGE PERIOD =    1 ELAPSED TIME =   1.000E-01  HR REQUIRED ITERATIONS =  66

  TIME STEP NUMBER =    2  RECHARGE PERIOD =    1 ELAPSED TIME =   2.000E-01  HR REQUIRED ITERATIONS =  41

  TIME STEP NUMBER =    3  RECHARGE PERIOD =    1 ELAPSED TIME =   3.000E-01  HR REQUIRED ITERATIONS =  36

  TIME STEP NUMBER =    4  RECHARGE PERIOD =    1 ELAPSED TIME =   4.000E-01  HR REQUIRED ITERATIONS =  34

  TIME STEP NUMBER =    5  RECHARGE PERIOD =    1 ELAPSED TIME =   5.000E-01  HR REQUIRED ITERATIONS =  32

   ONE-DIMENSIONAL INFILTRATION    EXAMPLE 1
 TOTAL ELAPSED TIME =   5.000E-01   HR
```

Table 6.--*Partial listing of output to file 6, the main output file, for example problem 1*--Continued

```
TIME STEP     5


                                    SATURATION
Z, IN
  CM                 X OR R DISTANCE, IN   CM
           0.50
  0.50    1.000
  1.50    0.998
  2.50    0.994
  3.50    0.988
  4.50    0.978
  5.50    0.964
  6.50    0.943
  7.50    0.912
  8.50    0.866
  9.50    0.799
 10.50    0.707
 11.50    0.606
 12.50    0.548
 13.50    0.532
 14.50    0.530
 15.50    0.529
 16.50    0.529
 17.50    0.529
 18.50    0.529
 19.50    0.529
      .
      .
      .
 50.50    0.529
 51.50    0.529
 52.50    0.529
 53.50    0.529
 54.50    0.529
 55.50    0.529
 56.50    0.529
 57.50    0.529
 58.50    0.529
 59.50    0.530
           ---------- MASS BALANCE SUMMARY FOR TIME STEP   5 ----------
              PUMPING PERIOD NUMBER    1
              TOTAL ELAPSED SIMULATION TIME =  5.000E-01   HR
```

Table 6.--*Partial listing of output to file 6, the main output file, for example problem 1*--Continued

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                                                    +
+                                                                      MASS  THIS     RATE FOR THIS  +
+                                                     TOTAL  MASS      TIME STEP       TIME STEP     +
+                                                        GRAM          GRAM            GRAM/  HR     +
+   FLUX INTO DOMAIN ACROSS SPECIFIED PRESSURE HEAD BOUNDARIES --  2.05757E+00  3.27883E-01  3.27883E+00  +
+ FLUX OUT OF DOMAIN ACROSS SPECIFIED PRESSURE HEAD BOUNDARIES --  0.00000E-01  0.00000E-01  0.00000E-01  +
+            FLUX INTO DOMAIN ACROSS SPECIFIED FLUX BOUNDARIES --  0.00000E-01  0.00000E-01  0.00000E-01  +
+          FLUX OUT OF DOMAIN ACROSS SPECIFIED FLUX BOUNDARIES --  0.00000E-01  0.00000E-01  0.00000E-01  +
+                                       TOTAL FLUX INTO DOMAIN --  2.05757E+00  3.27883E-01  3.27883E+00  +
+                                     TOTAL FLUX OUT OF DOMAIN --  0.00000E-01  0.00000E-01  0.00000E-01  +
+                                                  EVAPORATION --  0.00000E-01  0.00000E-01  0.00000E-01  +
+                                                TRANSPIRATION --  0.00000E-01  0.00000E-01  0.00000E-01  +
+                                     TOTAL EVAPOTRANSPIRATION --  0.00000E-01  0.00000E-01  0.00000E-01  +
+                              CHANGE IN FLUID STORED IN DOMAIN --  2.30255E+00  3.27959E-01  3.27959E+00  +
+                                           FLUID MASS BALANCE -- -2.44982E-01 -7.56095E-05 -7.56095E-04  +
+                                                                                                    +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
       .
       .
       .
       .

   TIME STEP NUMBER =   28  RECHARGE PERIOD =    1 ELAPSED TIME =   2.800E+00   HR REQUIRED ITERATIONS =   26

   TIME STEP NUMBER =   29  RECHARGE PERIOD =    1 ELAPSED TIME =   2.900E+00   HR REQUIRED ITERATIONS =   26

   TIME STEP NUMBER =   30  RECHARGE PERIOD =    1 ELAPSED TIME =   3.000E+00   HR REQUIRED ITERATIONS =   28

    ONE-DIMENSIONAL INFILTRATION    EXAMPLE 1
  TOTAL ELAPSED TIME =    3.000E+00   HR
  TIME STEP    30

                                            SATURATION
 Z, IN
  CM                       X OR R DISTANCE, IN   CM
            0.50
   0.50    1.000
   1.50    1.000
   2.50    1.000
   3.50    1.000
   4.50    1.000
   5.50    1.000
```

Table 6.--Partial listing of output to file 6, the main output file, for example problem 1--Continued

6.50	1.000
7.50	1.000
8.50	1.000
9.50	1.000
10.50	1.000
11.50	1.000
12.50	1.000
13.50	1.000
14.50	1.000
15.50	1.000
16.50	1.000
17.50	1.000
18.50	1.000
19.50	1.000
20.50	1.000
21.50	1.000
22.50	1.000
23.50	1.000
24.50	1.000
25.50	1.000
26.50	0.999
27.50	0.999
28.50	0.999
29.50	0.998
30.50	0.997
31.50	0.996
32.50	0.994
33.50	0.991
34.50	0.987
35.50	0.980
36.50	0.971
37.50	0.958
38.50	0.939
39.50	0.910
40.50	0.869
41.50	0.810
42.50	0.727
43.50	0.627
44.50	0.556
45.50	0.534
46.50	0.530
47.50	0.529
48.50	0.529
49.50	0.529

Table 6.--*Partial listing of output to file 6, the main output file, for example problem 1*--Continued

```
 50.50    0.529
 51.50    0.529
 52.50    0.529
 53.50    0.529
 54.50    0.529
 55.50    0.530
 56.50    0.530
 57.50    0.530
 58.50    0.530
 59.50    0.531
                ---------- MASS BALANCE SUMMARY FOR TIME STEP  30 ----------
                    PUMPING PERIOD NUMBER     1
                    TOTAL ELAPSED SIMULATION TIME =  3.000E+00   HR

++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                                                          +
+                                                                          MASS  THIS      RATE FOR THIS   +
+                                                           TOTAL  MASS    TIME STEP        TIME STEP      +
+                                                             GRAM         GRAM             GRAM/  HR      +
+   FLUX INTO DOMAIN ACROSS SPECIFIED PRESSURE HEAD BOUNDARIES --   9.89276E+00    3.12500E-01    3.12500E+00   +
+ FLUX OUT OF DOMAIN ACROSS SPECIFIED PRESSURE HEAD BOUNDARIES --   0.00000E-01    0.00000E-01    0.00000E-01   +
+            FLUX INTO DOMAIN ACROSS SPECIFIED FLUX BOUNDARIES --   0.00000E-01    0.00000E-01    0.00000E-01   +
+          FLUX OUT OF DOMAIN ACROSS SPECIFIED FLUX BOUNDARIES --   0.00000E-01    0.00000E-01    0.00000E-01   +
+                                      TOTAL FLUX INTO DOMAIN --   9.89276E+00    3.12500E-01    3.12500E+00   +
+                                    TOTAL FLUX OUT OF DOMAIN --   0.00000E-01    0.00000E-01    0.00000E-01   +
+                                                 EVAPORATION --   0.00000E-01    0.00000E-01    0.00000E-01   +
+                                               TRANSPIRATION --   0.00000E-01    0.00000E-01    0.00000E-01   +
+                                    TOTAL EVAPOTRANSPIRATION --   0.00000E-01    0.00000E-01    0.00000E-01   +
+                             CHANGE IN FLUID STORED IN DOMAIN --   1.01394E+01    3.12593E-01    3.12593E+00   +
+                                          FLUID MASS BALANCE --  -2.46647E-01   -9.27823E-05   -9.27823E-04   +
+                                                                                                          +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
  ****************************************************************************************
  END OF SIMULATION
  ****************************************************************************************
TOTAL NUMBER OF ITERATIONS =    984
```

Table 7.--*Partial listing of output to file 8 for example problem 1*

```
 TIME =      0.5000E+00    HR

-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.466E+00-1.300E+02
-1.300E+02-5.573E+00-1.300E+02
-1.300E+02-5.746E+00-1.300E+02
-1.300E+02-6.023E+00-1.300E+02
-1.300E+02-6.473E+00-1.300E+02
-1.300E+02-7.226E+00-1.300E+02
-1.300E+02-8.548E+00-1.300E+02
-1.300E+02-1.107E+01-1.300E+02
-1.300E+02-1.655E+01-1.300E+02
-1.300E+02-3.059E+01-1.300E+02
-1.300E+02-6.600E+01-1.300E+02
-1.300E+02-1.095E+02-1.300E+02
-1.300E+02-1.263E+02-1.300E+02
-1.300E+02-1.294E+02-1.300E+02
-1.300E+02-1.299E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
              .
              .
              .
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.299E+02-1.300E+02
-1.300E+02-1.298E+02-1.300E+02
-1.300E+02-1.293E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02

 TIME =      0.1000E+01    HR

-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.405E+00-1.300E+02
-1.300E+02-5.413E+00-1.300E+02
-1.300E+02-5.425E+00-1.300E+02
-1.300E+02-5.444E+00-1.300E+02
-1.300E+02-5.473E+00-1.300E+02
-1.300E+02-5.517E+00-1.300E+02
-1.300E+02-5.583E+00-1.300E+02
```

Table 7.--*Partial listing of output to file 8 for example problem 1*--Continued

```
-1.300E+02-5.683E+00-1.300E+02
-1.300E+02-5.835E+00-1.300E+02
-1.300E+02-6.068E+00-1.300E+02
-1.300E+02-6.431E+00-1.300E+02
-1.300E+02-7.011E+00-1.300E+02
-1.300E+02-7.974E+00-1.300E+02
-1.300E+02-9.677E+00-1.300E+02
-1.300E+02-1.300E+01-1.300E+02
-1.300E+02-2.056E+01-1.300E+02
-1.300E+02-4.053E+01-1.300E+02
-1.300E+02-8.322E+01-1.300E+02
-1.300E+02-1.182E+02-1.300E+02
-1.300E+02-1.280E+02-1.300E+02
-1.300E+02-1.297E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
              .
              .
              .
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.299E+02-1.300E+02
-1.300E+02-1.298E+02-1.300E+02
-1.300E+02-1.295E+02-1.300E+02
-1.300E+02-1.289E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
              .
              .
              .

 TIME =      0.3000E+01   HR

-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
-1.300E+02-5.400E+00-1.300E+02
```

Table 7.--*Partial listing of output to file 8 for example problem 1*--Continued

```
-1.300E+02-5.401E+00-1.300E+02
-1.300E+02-5.401E+00-1.300E+02
-1.300E+02-5.401E+00-1.300E+02
-1.300E+02-5.402E+00-1.300E+02
-1.300E+02-5.402E+00-1.300E+02
-1.300E+02-5.403E+00-1.300E+02
-1.300E+02-5.405E+00-1.300E+02
-1.300E+02-5.408E+00-1.300E+02
-1.300E+02-5.411E+00-1.300E+02
-1.300E+02-5.416E+00-1.300E+02
-1.300E+02-5.424E+00-1.300E+02
-1.300E+02-5.436E+00-1.300E+02
-1.300E+02-5.453E+00-1.300E+02
-1.300E+02-5.478E+00-1.300E+02
-1.300E+02-5.515E+00-1.300E+02
-1.300E+02-5.570E+00-1.300E+02
-1.300E+02-5.653E+00-1.300E+02
-1.300E+02-5.776E+00-1.300E+02
-1.300E+02-5.963E+00-1.300E+02
-1.300E+02-6.249E+00-1.300E+02
-1.300E+02-6.698E+00-1.300E+02
-1.300E+02-7.421E+00-1.300E+02
-1.300E+02-8.646E+00-1.300E+02
-1.300E+02-1.089E+01-1.300E+02
-1.300E+02-1.551E+01-1.300E+02
-1.300E+02-2.678E+01-1.300E+02
-1.300E+02-5.625E+01-1.300E+02
-1.300E+02-1.016E+02-1.300E+02
-1.300E+02-1.243E+02-1.300E+02
-1.300E+02-1.291E+02-1.300E+02
-1.300E+02-1.299E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
-1.300E+02-1.299E+02-1.300E+02
-1.300E+02-1.298E+02-1.300E+02
-1.300E+02-1.297E+02-1.300E+02
-1.300E+02-1.295E+02-1.300E+02
-1.300E+02-1.291E+02-1.300E+02
-1.300E+02-1.286E+02-1.300E+02
-1.300E+02-1.278E+02-1.300E+02
-1.300E+02-1.300E+02-1.300E+02
```

Table 8.--Partial listing of output to file 9 for example problem 1

ONE-DIMENSIONAL INFILTRATION EXAMPLE 1
MASS BALANCE RATE COMPONENTS

TIME, HR	FLXIN1	FLXOUT1	FLXIN2	FLXOUT2	TOTAL ET	TRANSP	EVAP	DELS	ERROR	%ERROR
1.0000E-01	6.1127E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	8.5593E+00	-2.4466E+00	-2.8584E+01
2.0000E-01	4.1680E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	4.1691E+00	-1.0573E-03	-2.5360E+02
3.0000E-01	3.6221E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.6229E+00	-8.1142E-04	-2.2397E-02
4.0000E-01	3.3940E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.3947E+00	-6.2962E-04	-1.8547E-02
5.0000E-01	3.2788E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.2796E+00	-7.5609E-04	-2.3055E-02
6.0000E-01	3.2154E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.2158E+00	-3.8685E-04	-1.2030E-02
7.0000E-01	3.1790E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1796E+00	-6.2869E-04	-1.9773E-02
8.0000E-01	3.1574E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1599E+00	-2.4276E-03	-7.6824E-02
9.0000E-01	3.1446E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1458E+00	-1.1588E-03	-3.6838E-02
1.0000E+00	3.1369E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1382E+00	-1.2646E-03	-4.0298E-02
1.1000E+00	3.1322E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1331E+00	-8.2179E-04	-2.6229E-02
1.2000E+00	3.1294E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1301E+00	-7.2548E-04	-2.3177E-02
1.3000E+00	3.1277E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1278E+00	-1.1193E-04	-3.5786E-03
1.4000E+00	3.1266E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1266E+00	1.7429E-05	5.5743E-04
1.5000E+00	3.1260E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1261E+00	-1.0008E-04	-3.2013E-03
1.6000E+00	3.1256E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1257E+00	-5.8942E-05	-1.8857E-03
1.7000E+00	3.1254E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1250E+00	3.6241E-04	1.1597E-02
1.8000E+00	3.1252E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1266E+00	-1.3192E-03	-4.2193E-02
1.9000E+00	3.1251E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1268E+00	-1.6506E-03	-5.2790E-02
2.0000E+00	3.1251E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1264E+00	-1.2787E-03	-4.0901E-02
2.1000E+00	3.1251E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1264E+00	-1.3347E-03	-4.2693E-02
2.2000E+00	3.1250E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1243E+00	6.8408E-04	2.1895E-02
2.3000E+00	3.1250E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1265E+00	-1.4718E-03	-4.7075E-02
2.4000E+00	3.1250E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1251E+00	-6.6067E-05	-2.1141E-03
2.5000E+00	3.1250E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1248E+00	2.2822E-04	7.3037E-03
2.6000E+00	3.1250E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1242E+00	8.3104E-04	2.6600E-02
2.7000E+00	3.1250E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1251E+00	-1.3054E-04	-4.1770E-03
2.8000E+00	3.1250E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1264E+00	-1.4049E-03	-4.4936E-02
2.9000E+00	3.1250E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1265E+00	-1.5067E-03	-4.8192E-02
3.0000E+00	3.1250E+00	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.1259E+00	-9.2782E-04	-2.9682E-02

Table 9.--*Partial listing of output to file 11 for example problem 1*

ONE-DIMENSIONAL INFILTRATION EXAMPLE 1
MONITORING POINT FILE

TIME, HR	XR, CM	Z, CM	H, CM	P, CM	THETA	SAT
0.000E-01	5.000E-01	3.500E+00	-1.335E+02	-1.300E+02	2.752E-01	5.293E-01
0.000E-01	5.000E-01	8.500E+00	-1.385E+02	-1.300E+02	2.752E-01	5.293E-01
0.000E-01	5.000E-01	1.450E+01	-1.445E+02	-1.300E+02	2.752E-01	5.293E-01
0.000E-01	5.000E-01	2.050E+01	-1.505E+02	-1.300E+02	2.752E-01	5.293E-01
0.000E-01	5.000E-01	2.850E+01	-1.585E+02	-1.300E+02	2.752E-01	5.293E-01
0.000E-01	5.000E-01	3.850E+01	-1.685E+02	-1.300E+02	2.752E-01	5.293E-01
1.000E-01	5.000E-01	3.500E+00	-2.318E+01	-1.968E+01	4.015E-01	7.721E-01
1.000E-01	5.000E-01	8.500E+00	-1.383E+02	-1.298E+02	2.753E-01	5.294E-01
1.000E-01	5.000E-01	1.450E+01	-1.445E+02	-1.300E+02	2.752E-01	5.293E-01
1.000E-01	5.000E-01	2.050E+01	-1.505E+02	-1.300E+02	2.752E-01	5.293E-01
1.000E-01	5.000E-01	2.850E+01	-1.585E+02	-1.300E+02	2.752E-01	5.293E-01
1.000E-01	5.000E-01	3.850E+01	-1.685E+02	-1.300E+02	2.752E-01	5.293E-01
2.000E-01	5.000E-01	3.500E+00	-1.208E+01	-8.581E+00	4.740E-01	9.115E-01
2.000E-01	5.000E-01	8.500E+00	-1.305E+02	-1.220E+02	2.787E-01	5.360E-01
2.000E-01	5.000E-01	1.450E+01	-1.445E+02	-1.300E+02	2.752E-01	5.293E-01
2.000E-01	5.000E-01	2.050E+01	-1.505E+02	-1.300E+02	2.752E-01	5.293E-01
2.000E-01	5.000E-01	2.850E+01	-1.585E+02	-1.300E+02	2.752E-01	5.293E-01
2.000E-01	5.000E-01	3.850E+01	-1.685E+02	-1.300E+02	2.752E-01	5.293E-01
3.000E-01	5.000E-01	3.500E+00	-1.017E+01	-6.669E+00	4.985E-01	9.587E-01
3.000E-01	5.000E-01	8.500E+00	-7.041E+01	-6.191E+01	3.192E-01	6.139E-01
3.000E-01	5.000E-01	1.450E+01	-1.445E+02	-1.300E+02	2.752E-01	5.293E-01
3.000E-01	5.000E-01	2.050E+01	-1.505E+02	-1.300E+02	2.752E-01	5.293E-01
3.000E-01	5.000E-01	2.850E+01	-1.585E+02	-1.300E+02	2.752E-01	5.293E-01
3.000E-01	5.000E-01	3.850E+01	-1.685E+02	-1.300E+02	2.752E-01	5.293E-01
4.000E-01	5.000E-01	3.500E+00	-9.531E+00	-6.031E+00	5.086E-01	9.781E-01
4.000E-01	5.000E-01	8.500E+00	-2.906E+01	-2.056E+01	3.980E-01	7.654E-01
4.000E-01	5.000E-01	1.450E+01	-1.445E+02	-1.300E+02	2.752E-01	5.293E-01
4.000E-01	5.000E-01	2.050E+01	-1.505E+02	-1.300E+02	2.752E-01	5.293E-01
4.000E-01	5.000E-01	2.850E+01	-1.585E+02	-1.300E+02	2.752E-01	5.293E-01
4.000E-01	5.000E-01	3.850E+01	-1.685E+02	-1.300E+02	2.752E-01	5.293E-01
5.000E-01	5.000E-01	3.500E+00	-9.246E+00	-5.746E+00	5.136E-01	9.877E-01
5.000E-01	5.000E-01	8.500E+00	-1.957E+01	-1.107E+01	4.505E-01	8.663E-01
5.000E-01	5.000E-01	1.450E+01	-1.439E+02	-1.294E+02	2.755E-01	5.298E-01
5.000E-01	5.000E-01	2.050E+01	-1.505E+02	-1.300E+02	2.752E-01	5.293E-01
5.000E-01	5.000E-01	2.850E+01	-1.585E+02	-1.300E+02	2.752E-01	5.293E-01
5.000E-01	5.000E-01	3.850E+01	-1.685E+02	-1.300E+02	2.752E-01	5.293E-01
6.000E-01	5.000E-01	3.500E+00	-9.098E+00	-5.598E+00	5.163E-01	9.928E-01
6.000E-01	5.000E-01	8.500E+00	-1.660E+01	-8.099E+00	4.795E-01	9.221E-01
6.000E-01	5.000E-01	1.450E+01	-1.371E+02	-1.226E+02	2.785E-01	5.355E-01

Table 9.--Partial listing of output to file 11 for example problem 1--Continued

2.400E+00	5.000E-01	3.500E+00	-8.900E+00	-5.400E+00	5.200E-01	1.000E+00
2.400E+00	5.000E-01	8.500E+00	-1.390E+01	-5.400E+00	5.200E-01	1.000E+00
2.400E+00	5.000E-01	1.450E+01	-1.990E+01	-5.403E+00	5.199E-01	9.999E-01
2.400E+00	5.000E-01	2.050E+01	-2.593E+01	-5.431E+00	5.194E-01	9.988E-01
2.400E+00	5.000E-01	2.850E+01	-3.464E+01	-6.135E+00	5.069E-01	9.748E-01
2.400E+00	5.000E-01	3.850E+01	-1.668E+02	-1.283E+02	2.760E-01	5.307E-01
2.500E+00	5.000E-01	3.500E+00	-8.900E+00	-5.400E+00	5.200E-01	1.000E+00
2.500E+00	5.000E-01	8.500E+00	-1.390E+01	-5.400E+00	5.200E-01	1.000E+00
2.500E+00	5.000E-01	1.450E+01	-1.990E+01	-5.402E+00	5.200E-01	9.999E-01
2.500E+00	5.000E-01	2.050E+01	-2.592E+01	-5.419E+00	5.196E-01	9.993E-01
2.500E+00	5.000E-01	2.850E+01	-3.434E+01	-5.837E+00	5.120E-01	9.845E-01
2.500E+00	5.000E-01	3.850E+01	-1.521E+02	-1.136E+02	2.827E-01	5.437E-01
2.600E+00	5.000E-01	3.500E+00	-8.900E+00	-5.400E+00	5.200E-01	1.000E+00
2.600E+00	5.000E-01	8.500E+00	-1.390E+01	-5.400E+00	5.200E-01	1.000E+00
2.600E+00	5.000E-01	1.450E+01	-1.990E+01	-5.401E+00	5.200E-01	1.000E+00
2.600E+00	5.000E-01	2.050E+01	-2.591E+01	-5.412E+00	5.198E-01	9.996E-01
2.600E+00	5.000E-01	2.850E+01	-3.416E+01	-5.663E+00	5.151E-01	9.905E-01
2.600E+00	5.000E-01	3.850E+01	-9.917E+01	-6.067E+01	3.205E-01	6.164E-01
2.700E+00	5.000E-01	3.500E+00	-8.900E+00	-5.400E+00	5.200E-01	1.000E+00
2.700E+00	5.000E-01	8.500E+00	-1.390E+01	-5.400E+00	5.200E-01	1.000E+00
2.700E+00	5.000E-01	1.450E+01	-1.990E+01	-5.401E+00	5.200E-01	1.000E+00
2.700E+00	5.000E-01	2.050E+01	-2.591E+01	-5.407E+00	5.199E-01	9.997E-01
2.700E+00	5.000E-01	2.850E+01	-3.406E+01	-5.559E+00	5.170E-01	9.942E-01
2.700E+00	5.000E-01	3.850E+01	-6.241E+01	-2.391E+01	3.862E-01	7.426E-01
2.800E+00	5.000E-01	3.500E+00	-8.900E+00	-5.400E+00	5.200E-01	1.000E+00
2.800E+00	5.000E-01	8.500E+00	-1.390E+01	-5.400E+00	5.200E-01	1.000E+00
2.800E+00	5.000E-01	1.450E+01	-1.990E+01	-5.400E+00	5.200E-01	1.000E+00
2.800E+00	5.000E-01	2.050E+01	-2.590E+01	-5.404E+00	5.199E-01	9.998E-01
2.800E+00	5.000E-01	2.850E+01	-3.400E+01	-5.496E+00	5.182E-01	9.965E-01
2.800E+00	5.000E-01	3.850E+01	-5.146E+01	-1.296E+01	4.365E-01	8.394E-01
2.900E+00	5.000E-01	3.500E+00	-8.900E+00	-5.400E+00	5.200E-01	1.000E+00
2.900E+00	5.000E-01	8.500E+00	-1.390E+01	-5.400E+00	5.200E-01	1.000E+00
2.900E+00	5.000E-01	1.450E+01	-1.990E+01	-5.400E+00	5.200E-01	1.000E+00
2.900E+00	5.000E-01	2.050E+01	-2.590E+01	-5.403E+00	5.199E-01	9.999E-01
2.900E+00	5.000E-01	2.850E+01	-3.396E+01	-5.459E+00	5.189E-01	9.978E-01
2.900E+00	5.000E-01	3.850E+01	-4.762E+01	-9.119E+00	4.683E-01	9.005E-01
3.000E+00	5.000E-01	3.500E+00	-8.900E+00	-5.400E+00	5.200E-01	1.000E+00
3.000E+00	5.000E-01	8.500E+00	-1.390E+01	-5.400E+00	5.200E-01	1.000E+00
3.000E+00	5.000E-01	1.450E+01	-1.990E+01	-5.400E+00	5.200E-01	1.000E+00
3.000E+00	5.000E-01	2.050E+01	-2.590E+01	-5.402E+00	5.200E-01	9.999E-01
3.000E+00	5.000E-01	2.850E+01	-3.394E+01	-5.436E+00	5.193E-01	9.987E-01
3.000E+00	5.000E-01	3.850E+01	-4.592E+01	-7.415E+00	4.880E-01	9.385E-01

Example Problem 2

Example 2 is a complex two-dimensional problem involving infiltration, evaporation, and evapotranspiration. The simulated section (fig. 25) consists of a 1.5-m thick clay layer which overlies a 0.6-m thick gravel layer. A discontinuous 0.3-m thick sand lens is embedded in the clay at a depth of 0.4 m. The width of the simulated section is 3.0 m. The sand lens extends from the left-hand side boundary for a distance of 1.5 m. During the simulation, the lens acts as a capillary barrier, affecting infiltration, evaporation, and plant-root extraction rates.

Four recharge periods, totaling 77 days, are simulated. For the first period, rainfall, at a rate of 75 mm/day, is allowed to infiltrate for 1 day. The second period consists of bare-soil evaporation (PEV = 2.0 mm/day) for 30 days. This is followed in the third period by another 1-day long rainfall at the rate of 75 mm/day. The final period lasts for 45 days and consists of both evaporation and evapotranspiration. The user-defined variables that control evaporation and evapotranspiration are assumed to remain constant throughout the simulation, with the exception of PET, RTDPTH, and HROOT. The length of the line segments over which these parameters vary is 30 days.

Input data for this problem are listed in table 10. The grid contains 672 nodes (29 rows and 24 columns variably spaced). Initial conditions consist of an equilibrium head profile specified above a fixed water table at a depth of 2.0 m. The minimum pressure head is set at -1.00 m. The hydraulic properties of the three different lithologies are represented by the Brooks-Corey functions.

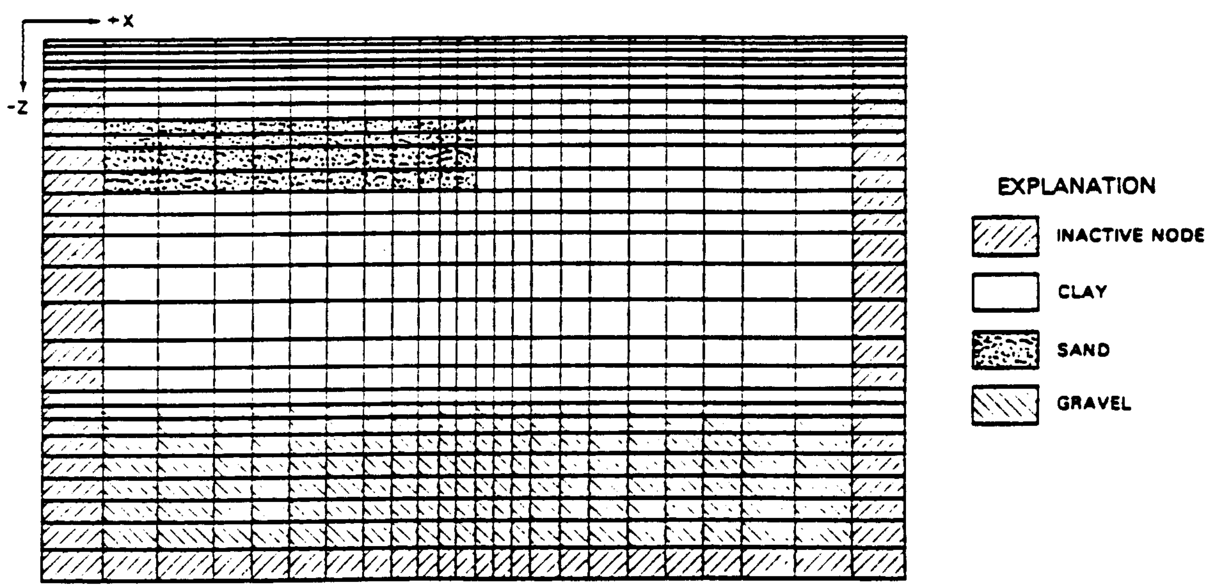

Figure 25.--Vertical section for example problem 1.

This problem illustrates some of the difficulties involved in simulation of highly nonlinear systems. During the second and fourth periods, when bare soil evaporation and transpiration are allowed, convergence was not achieved unless the initial time step for the period was about 10^{-5} day. Attempts were made to use a larger initial time step by first decreasing HMAX and then invoking upstream weighting. Neither approach was successful. Other simulation experiments have indicated that problems involving evaporation or evapotranspiration from fine-grained materials overlying coarse-grained materials that contain a water table are particularly difficult. Nonetheless, such problems generally can be solved by reducing the length of the initial time step and(or) by adjusting the value of HMAX.

Partial listings of output files 6, 7, 8, 9, and 11 are shown in tables 11, 12, 13, 14, and 15 respectively. The pressure-head profiles listed in table 11 show that by the end of the third recharge period, complicated flow patterns have developed in the vicinity of the right hand edge of the sand lens. This is further illustrated by figure 26, which shows the change in pressure head with respect to time at four of the observation nodes. These nodes are located at the same depth (0.33 m) and at horizontal distances of 0.11, 1.46, 1.54, and 2.89 m, respectively. The first two are in the sand lens and the last two are in the clay layer. After 60 days of simulated evapotranspiration the difference in pressure head between the node (at 0.11 m, 1.46 m) and the adjacent node (at 0.1 m, 1.54 m) is approximately 700 cm.

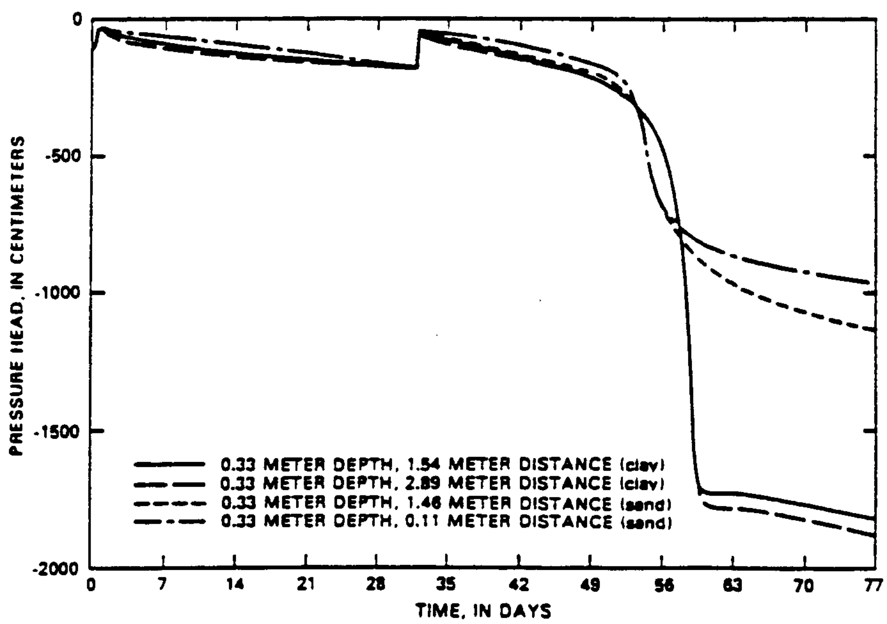

Figure 26.--Pressure-head profile at four locations for example problem 2.

Figure 27 shows evaporation and evapotranspiration rates at different times. During the second recharge period, evaporation occurs at the potential rate until about day 15, after which the rate is limited by the ability of the soil to conduct water to the surface. This same trend is shown in the fourth recharge period. The rate of evaporation is equal to the potential rate from day 32 to day 44, and decreases steadily thereafter. The evapotranspiration rate is equal to the potential rate from day 32 to day 54. The rate increases constantly during that time because PET was allowed to increase. After day 54 the evapotranspiration rate is limited by the ability of the soil to conduct water to the roots. At about day 57 there is a slight increase in this rate. This is somewhat of an anomaly and is related to the presence of the sand lens as well as the simplistic manner in which evapotranspiration is simulated.

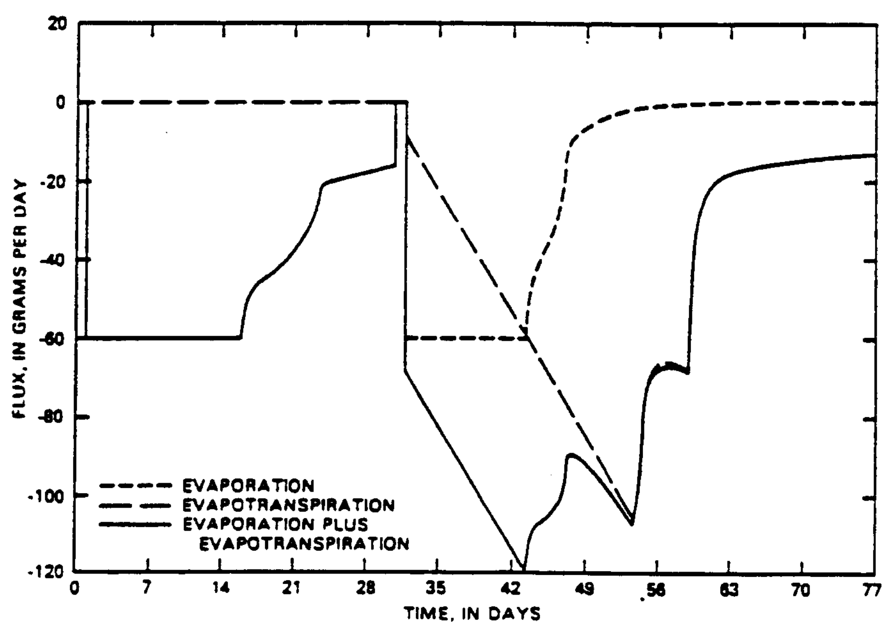

Figure 27.--Evaporation and evapotranspiration rates as functions of time for example problem 2.

Table 10.--*Input data for example problem 2*

```
EXAMPLE PROBLEM 2 -- 2D INFILTRATION AND EVAPOTRANSPIRATION
      77.    0.00                                             A2--TMAX, START TIME
  CMDAYSGRAM                                                  A3--UNITS
      24        28                                            A4--NO. OF COLUMNS, NO. OF ROWS
    4   1000                                                  A5-- NO. OF RECHARGE PERIODS, MAXIMUM NO. OF TIME STEPS
F T                                                           A6--RADIAL?    ITSTOP?
T T T T F                                                     A7--OUTPUT TO FILE 11? FILE 7? FILE 8? FILE 9? MASS BAL FILE 6?
T F T F                                                       A8--PRINT MOISTURE CONT.? SAT? PRESS HEAD? TOTAL HEAD?
0   7.5                                                       A9--IFAC,FACX
3.  3.  3.  2.  2.  2.  2.  1.5  1.5  1.  1.  1.              A10--HORIZONTAL SPACING
1.  1.  1.  1.5  1.5  2.  2.  2.  2.  3.  3.  3.              A10
         0      3.                                            A11--JFAC,FACZ
 1.  1.  1.  1.  1.5  1.5  2.0  2.0  2.0                      A12--VERTICAL SPACING
2.0  3.0  3.0  3.0  3.0  4.0  5.0  5.0  4.0  3.0              A12
2.0  2.0  2.0  3.0  3.0  3.0  3.0  4.0  5.0                   A12
     13                                                       A13--NO. OF TIMES TO PRINT PROFILES
0.5,1.0,2.0,5.0,16.,31.,31.5,32.,33.,40.,50.,60.,77.          A14--TIMES FOR PROFILES
     10                                                       A15--NO. OF NODES FOR TIME PLOTS
2 2   8 2  8 12  8 13  8 23  9 2  9 12  9 13  9 23  20 2      A16--ROW AND COLUMN FOR EACH NODE
.005 .750  0.0                                                B1--CLOSURE CRITERION, HMAX, WEIGHTING FOR KR
       1.0                                                    B2--FLUID DENSITY
         2       200                                          B3--MINIT,ITMAX
T                                                             B4--READ HEADS AS INITIAL CONDITIONS?
3  6                                                          B5--NO. OF TEXTURES, NO. OF PROPERTIES PER TEXTURE
1                                                             B6--TEXTURE CLASS 1
1  5.  1.0D-06  .45  -50.  .15  .6                            B7--ANIZ,KSAT,SS,POROSITY,HB,THETAR,LAMBDA BROOKS-COREY
2                                                             B6--TEXTURE CLASS 2
1  100.  1.0D-06  .40  -15.  .08  1.0                         B7--BROOKS-COREY PROPERTIES
3                                                             B6--TEXTURE CLASS 3
1.  300.  1.0D-06  .42  -8.  .05  1.2                         B7--BROOKS-COREY PROPERTIES
         1                                                    B8--TEXTURES READ BY BLOCK
1  24  8   1                                                  B10--LEFT COL., RIGHT COL., BOTTOM ROW, TEXTURAL CLASS
1  12  12  2                                                  B10
13  24  12   1                                                B10
1   24   20   1                                               B10
1  24  28  3                                                  B10--LAST OF B10 CARDS
2  1.0                                                        B11--EQUILIBRIUM HEAD PROFILE SPECIFIED
  200.       -100.                                            B12--WATER TABLE DEPTH, MIN. HEAD ALLOWED
T,T                                                           B14-- EVAP AND TRANSP TO BE SIMULATED ?
4     30.                                                     B15--NPV,ETCYC   NUMBER AND LENGTH OF ET PERIODS
0.2,0.2,0.2,0.2                                               B16--PEV
0.6,0.6,0.6,0.6                                               B17--SRES
-100000,-100000,-100000,-100000                               B18--HA
```

Table 10.--*Input data for example problem 2*--Continued

```
0.0,0.0,.45,.60                            B19--PET
0.0,35.,35.,35.                            B20--RTDPTH
0.2,0.2,0.2,0.2                            B21--RTBOT
0.9,0.9,0.9,0.9                            B22--RTTOP
-8000.,-8000.,-12000.,-15000.              B23--HROOT
     1.     .010                           C1--TPER,DELT
     1.1    .150     0.010     0.20        C2--TMULT,DLTMX,DLTMIN,TRED
100.    0.                                 C3--DSMAX,STERR
     0.                                    C4--POND
F                                          C5--HEADS PRINTED EACH TIME STEP?
F F F                                      C6--BCIT?  ETSIM? SEEP?
1                                          C10--BOUNDARY CONDITIONS READ BY LINE
2  2   2  23  2  7.5                       C12--TOP ROW, BOT ROW, LT COL., RT COL.,CODE, PFDUM
27  27  2  23  1  4.0                      C12--BOUNDARY CONDITIONS FOR BOTTOM ROW
999999 /                                   C13--END OF BOUNDARY CONDITION LIST FOR RECHARGE PERIOD 1.
     30.   .00001                          C1--TPER,DELT FOR PERIOD 2
     1.5      0.5   .00001   0.20          C2--TMULT,DLTMX,DLTMIN,TRED
100.     0.                                C3--DSMAX,  STERR
0.                                         C4--POND
F                                          C5--PRINT HEADS EVERY TIME STEP?
T F F                                      C6--BCIT? ETSIM? SEEP?
1                                          C10--BOUNDARY CONDITIONS BY LINE
2  2  2  23  5  /                          C12--EVAP BOUNDARY AT TOP OF MODEL
999999 /                                   C13--END OF BOUNDARY CONDITION LIST FOR RECHARGE PERIOD 2.
     1.      .010                          C1--TPER,DELT FOR PERIOD 3
     1.1     .100     0.010  0.20          C2--TMULT,DLTMX,DLTMIN,TRED
    100.        0.                         C3--DSMAX,STERR
0.0                                        C4--POND
F                                          C5--HEADS PRINTED?
F [illegible] F                            C6--BCIT?  BCIT?  SEEP?
1                                          C10--BOUNDARY CONDITIONS READ BY LINE
2  2  2  23    2  7.50                     C12--TOP ROW SPECIFIED FLUX
999999 /                                   C13--END OF BOUNDARY CONDITION LIST FOR RECHARGE PERIOD 3.
     45.     .00001                        C1--TPER,DELT FOR PER. 4
     1.5      0.5     .00001     0.20      C2--TMULT,DLTMX,DLTMIN,TRED
100.     0.                                C3--DSMAX,STERR
     0.                                    C4--POND
F                                          C5--HEADS PRINTED?
T T F                                      C6--BCIT?  ETSIM?  SEEP?
1                                          C10--BOUNDARY CONDITIONS BY LINE
2  2  2  23  5   /                         C12--EVAPORATION ALONG TOP BOUNDARY
999999 /                                   C13--END OF BOUNDARY CONDITION LIST FOR RECHARGE PERIOD 4.
9999999. /                                 C13--END OF FILE FOR SIMULATION
```

Table 11.--Partial listing of output to file 6, the main output file, for example problem 2

```
                 +++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                 +                        VS2D                           +
                 +    SIMULATION OF 2-DIMENSIONAL VARIABLY               +
                 +    SATURATED HEAD AND FLUID SATURATION                +
                 +    DISTRIBUTIONS. IMPLICIT FINITE DIFFERENCE          +
                 +    BODY-CENTERED CELLS USED                           +
                 +++++++++++++++++++++++++++++++++++++++++++++++++++++++++


*****************************************************************************************
   EXAMPLE PROBLEM 2 -- 2D INFILTRATION AND EVAPOTRANSPIRATION
*****************************************************************************************

       SPACE AND TIME CONSTANTS
       ------------------------
   MAXIMUM SIMULATION TIME =     77.0000 DAYS
   STARTING TIME =     0.0000
   NUMBER OF RECHARGE PERIODS =          4
   MAXIMUM NUMBER OF TIME STEPS =       1000
   NUMBER OF ROWS =     28
   NUMBER OF COLUMNS =     24
        SOLUTION OPTIONS
       ----------------
   WRITE ALL PRESSURE HEADS TO FILE 8 AT OBSERVATION TIMES? T
   STOP SOLUTION IF MAXIMUM NO. OF ITERATIONS EXCEEDED IN ANY TIME STEP?,T
   WRITE MAXIMUM CHANGE IN HEAD FOR EACH ITERATION TO FILE 7? T
   WRITE RESULTS AT SELECTED OBSERVATION POINTS TO FILE 11? T
   WRITE MASS BALANCE RATES TO FILE 9? T
   WRITE MASS BALANCE RATES TO FILE 6? F
   WRITE MOISTURE CONTENTS TO FILE 6? T
   WRITE SATURATIONS TO FILE 6? F
   WRITE PRESSURE HEADS TO FILE 6? T
   WRITE TOTAL HEADS TO FILE 6? F
                                              GRID SPACING IN VERTICAL DIRECTION, IN   CM
     3.000     3.000     3.000     3.000     4.500     4.500     6.000     6.000     6.000     6.000
     9.000     9.000     9.000     9.000    12.000    15.000    15.000    12.000     9.000     6.000
     6.000     6.000     9.000     9.000     9.000     9.000    12.000    15.000
                                              GRID SPACING IN HORIZONTAL OR RADIAL DIRECTION, IN   CM
    22.500    22.500    22.500    15.000    15.000    15.000    15.000    11.250    11.250     7.500
     7.500     7.500     7.500     7.500     7.500    11.250    11.250    15.000    15.000    15.000
    15.000    22.500    22.500    22.500
     TIMES AT WHICH H WILL BE WRITTEN TO FILE 08
```

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
  0.5000    1.0000    2.0000    5.0000   16.0000   31.0000   31.5000   32.0000   33.0000   40.0000
 50.0000   60.0000   77.0000
ROW AND COLUMN OF OBSERVATION POINTS:
 2  2    8  2    8 12    8 13    8 23    9  2    9 12    9 13    9 23   20  2
COORDINATE SYSTEM IS RECTANGULAR
MATRIX EQUATIONS TO BE SOLVED BY SIP
     INITIAL MOISTURE PARAMETERS
```

```
CONVERGENCE CRITERIA FOR SIP  =   5.000E-03   CM
DAMPING FACTOR, HMAX =    7.500E-01
FLUID DENSITY AT ZERO PRESSURE =   1.000E+00 GRAM/  CM**3
GEOMETRIC MEAN USED FOR INTERCELL CONDUCTIVITY
NUMBER OF SOIL TEXTURAL CLASSES =           3
NUMBER OF SOIL PARAMETERS FOR EACH CLASS =          6
MINIMUM PERMITTED NO. OF ITERATIONS/TIME STEP =         2
MAXIMUM PERMITTED NO. OF ITERATIONS/TIME STEP =       200
                                    CONSTANTS FOR SOIL TEXTURAL CLASSES

     ANISOTROPY       KSAT       SPECIFIC     POROSITY
                                 STORAGE
CLASS # 1
          1.0000D+00  5.0000D+00  1.0000D-06  4.5000D-01  -5.0000D+01  1.5000D-01  6.0000D-01
CLASS # 2
          1.0000D+00  1.0000D+02  1.0000D-06  4.0000D-01  -1.5000D+01  8.0000D-02  1.0000D+00
CLASS # 3
          1.0000D+00  3.0000D+02  1.0000D-06  4.2000D-01  -8.0000D+00  5.0000D-02  1.2000D+00
    TEXTURAL CLASS INDEX MAP


   TEXTURAL CLASSES READ IN BY BLOCK
        1  111111111111111111111111
        2  111111111111111111111111
        3  111111111111111111111111
        4  111111111111111111111111
        5  111111111111111111111111
        6  111111111111111111111111
        7  111111111111111111111111
        8  111111111111111111111111
        9  222222222222111111111111
       10  222222222222111111111111
       11  222222222222111111111111
       12  222222222222111111111111
       13  111111111111111111111111
```


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Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
   14 111111111111111111111111
   15 111111111111111111111111
   16 111111111111111111111111
   17 111111111111111111111111
   18 111111111111111111111111
   19 111111111111111111111111
   20 111111111111111111111111
   21 333333333333333333333333
   22 333333333333333333333333
   23 333333333333333333333333
   24 333333333333333333333333
   25 333333333333333333333333
   26 333333333333333333333333
   27 333333333333333333333333
   28 333333333333333333333333
                                  DEPTH FROM SURFACE
Z, IN
 CM                 X OR R DISTANCE, IN   CM
          11.25   33.75   52.50   67.50   82.50   97.50  110.62  121.87  131.25  138.75  146.25  153.75  161.25
         168.75  178.12  189.37  202.50  217.50  232.50  247.50  266.25  288.75
   1.50   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
          0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
   4.50   3.000   3.000   3.000   3.000   3.000   3.000   3.000   3.000   3.000   3.000   3.000   3.000   3.000
          3.000   3.000   3.000   3.000   3.000   3.000   3.000   3.000   3.000
   7.50   6.000   6.000   6.000   6.000   6.000   6.000   6.000   6.000   6.000   6.000   6.000   6.000   6.000
          6.000   6.000   6.000   6.000   6.000   6.000   6.000   6.000   6.000
  11.25   9.000   9.000   9.000   9.000   9.000   9.000   9.000   9.000   9.000   9.000   9.000   9.000   9.000
          9.000   9.000   9.000   9.000   9.000   9.000   9.000   9.000   9.000
  15.75  13.500  13.500  13.500  13.500  13.500  13.500  13.500  13.500  13.500  13.500  13.500  13.500  13.500
         13.500  13.500  13.500  13.500  13.500  13.500  13.500  13.500  13.500
  21.00  18.000  18.000  18.000  18.000  18.000  18.000  18.000  18.000  18.000  18.000  18.000  18.000  18.000
         18.000  18.000  18.000  18.000  18.000  18.000  18.000  18.000  18.000
  27.00  24.000  24.000  24.000  24.000  24.000  24.000  24.000  24.000  24.000  24.000  24.000  24.000  24.000
         24.000  24.000  24.000  24.000  24.000  24.000  24.000  24.000  24.000
  33.00  30.000  30.000  30.000  30.000  30.000  30.000  30.000  30.000  30.000  30.000  30.000  30.000  30.000
         30.000  30.000  30.000  30.000  30.000  30.000  30.000  30.000  30.000
  39.00  36.000  36.000  36.000  36.000  36.000  36.000  36.000  36.000  36.000  36.000  36.000  36.000  36.000
         36.000  36.000  36.000  36.000  36.000  36.000  36.000  36.000  36.000
  46.50  42.000  42.000  42.000  42.000  42.000  42.000  42.000  42.000  42.000  42.000  42.000  42.000  42.000
         42.000  42.000  42.000  42.000  42.000  42.000  42.000  42.000  42.000
  55.50  51.000  51.000  51.000  51.000  51.000  51.000  51.000  51.000  51.000  51.000  51.000  51.000  51.000
         51.000  51.000  51.000  51.000  51.000  51.000  51.000  51.000  51.000
  64.50  60.000  60.000  60.000  60.000  60.000  60.000  60.000  60.000  60.000  60.000  60.000  60.000  60.000
         60.000  60.000  60.000  60.000  60.000  60.000  60.000  60.000  60.000
```

Table 11.--Partial listing of output to file 6, the main output file, for example problem 2--Continued

73.50	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000
	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000				
84.00	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000
	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000				
97.50	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000
	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000	90.000				
112.50	105.000	105.000	105.000	105.000	105.000	105.000	105.000	105.000	105.000	105.000	105.000	105.000	105.000
	105.000	105.000	105.000	105.000	105.000	105.000	105.000	105.000	105.000				
126.00	120.000	120.000	120.000	120.000	120.000	120.000	120.000	120.000	120.000	120.000	120.000	120.000	120.000
	120.000	120.000	120.000	120.000	120.000	120.000	120.000	120.000	120.000				
136.50	132.000	132.000	132.000	132.000	132.000	132.000	132.000	132.000	132.000	132.000	132.000	132.000	132.000
	132.000	132.000	132.000	132.000	132.000	132.000	132.000	132.000	132.000				
144.00	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000
	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000				
150.00	147.000	147.000	147.000	147.000	147.000	147.000	147.000	147.000	147.000	147.000	147.000	147.000	147.000
	147.000	147.000	147.000	147.000	147.000	147.000	147.000	147.000	147.000				
156.00	153.000	153.000	153.000	153.000	153.000	153.000	153.000	153.000	153.000	153.000	153.000	153.000	153.000
	153.000	153.000	153.000	153.000	153.000	153.000	153.000	153.000	153.000				
163.50	159.000	159.000	159.000	159.000	159.000	159.000	159.000	159.000	159.000	159.000	159.000	159.000	159.000
	159.000	159.000	159.000	159.000	159.000	159.000	159.000	159.000	159.000				
172.50	168.000	168.000	168.000	168.000	168.000	168.000	168.000	168.000	168.000	168.000	168.000	168.000	168.000
	168.000	168.000	168.000	168.000	168.000	168.000	168.000	168.000	168.000				
181.50	177.000	177.000	177.000	177.000	177.000	177.000	177.000	177.000	177.000	177.000	177.000	177.000	177.000
	177.000	177.000	177.000	177.000	177.000	177.000	177.000	177.000	177.000				
190.50	186.000	186.000	186.000	186.000	186.000	186.000	186.000	186.000	186.000	186.000	186.000	186.000	186.000
	186.000	186.000	186.000	186.000	186.000	186.000	186.000	186.000	186.000				
201.00	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000
	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000	195.000				

EQUILLIBRIUM PROFILE USED TO INITIALIZE PRESSURE HEADS ABOVE WATER TABLE AT 200.00 CM BELOW ORIGIN
EQUILLIBRIUM PROFILE ONLY USED UNTIL PRESSURE HEADS EQUAL -100.00 CM
PRESSURE HEADS BELOW 200.00 CM ARE HYDROSTATIC

NUMBER OF EVAPORATION AND/OR EVAPOTRASPIRATION PERIODS = 4
LENGTH OF EACH PERIOD = 30.0000 DAYS

EVAPORATION PERIOD	POTENTIAL RATE CM/DAYS	SURFACE RESISTANCE CM**(-1)	ATMOSHERIC PRESSURE CM
1	0.20000E+00	0.60000E+00	-0.10000E+06
2	0.20000E+00	0.60000E+00	-0.10000E+06
3	0.20000E+00	0.60000E+00	-0.10000E+06

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
      4        0.20000E+00   0.60000E+00  -0.10000E+06


TRANSPIRATION   POTENTIAL          ROOT       ACTIVITY      ACTIVITY       ROOT
    PERIOD        RATE             DEPTH      AT BOTTOM      AT TOP      PRESSURE
                 CM/DAYS            CM        CM**(-2)      CM**(-2)        CM
----------------------------------------------------------------------------------
      1         0.00000E+00   0.00000E+00   0.20000E+00   0.90000E+00  -0.80000E+04
      2         0.00000E+00   0.35000E+02   0.20000E+00   0.90000E+00  -0.80000E+04
      3         0.45000E+00   0.35000E+02   0.20000E+00   0.90000E+00  -0.12000E+05
      4         0.60000E+00   0.35000E+02   0.20000E+00   0.90000E+00  -0.15000E+05

 5SIP ITERATION PARAMETERS:  0.14210850-13  0.80530700+00  0.96209460+00  0.99262010+00  0.99856320+00
  EXAMPLE PROBLEM 2 -- 2D INFILTRATION AND EVAPOTRANSPIRATION
 TOTAL ELAPSED TIME =    0.000E-01 DAYS
 TIME STEP      0


                                        PRESSURE HEAD
Z, IN
 CM                      X OR R DISTANCE, IN   CM
           11.25     33.75     52.50     67.50     82.50     97.50    110.62    121.87    131.25    138.75    146.25    153.75    161.25
          168.75    178.12    189.37    202.50    217.50    232.50    247.50    266.25    288.75
   1.50-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
       -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
   4.50-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
       -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
   7.50-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
       -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
  11.25-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
       -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
  15.75-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
       -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
  21.00-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
       -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
  27.00-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
       -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
  33.00-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
       -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
  39.00-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
       -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
  46.50-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
       -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
```

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
 55.50-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
      -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
 64.50-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
      -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
 73.50-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
      -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
 84.00-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
      -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
 97.50-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
      -1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02
112.50-8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01
      -8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01
126.00-7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01
      -7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01-7.40E+01
136.50-6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01
      -6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01-6.35E+01
144.00-5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01
      -5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01-5.60E+01
150.00-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01
      -5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01
156.00-4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01
      -4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01-4.40E+01
163.50-3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01
      -3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01-3.65E+01
172.50-2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01
      -2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01-2.75E+01
181.50-1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01
      -1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01-1.85E+01
190.50-9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00
      -9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00-9.50E+00
201.00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00
       1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00
                                               MOISTURE CONTENT
Z, IN
 CM                   X OR R DISTANCE, IN     CM
         11.25    33.75    52.50    67.50    82.50    97.50   110.62   121.87   131.25   138.75   146.25   153.75   161.25
        168.75   178.12   189.37   202.50   217.50   232.50   247.50   266.25   288.75
  1.50   0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348
         0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348
  4.50   0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348
         0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348
  7.50   0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348
         0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348
 11.25   0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348    0.348
```

Table 11.--Partial listing of output to file 6, the main output file, for example problem 2--Continued

	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348				
15.75	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348
	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348				
21.00	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348
	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348				
27.00	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348
	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348				
33.00	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.348	0.348
	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348				
39.00	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.348	0.348
	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348				
46.50	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.348	0.348
	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348				
55.50	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.348	0.348
	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348				
64.50	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348
	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348				
73.50	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348
	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348				
84.00	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348
	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348				
97.50	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348
	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348				
112.50	0.364	0.364	0.364	0.364	0.364	0.364	0.364	0.364	0.364	0.364	0.364	0.364	0.364
	0.364	0.364	0.364	0.364	0.364	0.364	0.364	0.364	0.364				
126.00	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387
	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387				
136.50	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410
	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410				
144.00	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430
	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430				
150.00	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091				
156.00	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098
	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098				
163.50	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110
	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110				
172.50	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134
	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134				
181.50	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185
	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185				
190.50	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351
	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351				
201.00	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
        0.420     0.420     0.420     0.420     0.420     0.420     0.420     0.420     0.420
 DATA FOR RECHARGE PERIOD     1

     LENGTH OF THIS PERIOD =    1.000E+00 DAYS
     LENGTH OF INITIAL TIME STEP FOR THIS PERIOD = 1.000E-02 DAYS
     MULTIPLIER FOR TIME STEP =  1.100E+00
     MAXIMUM TIME STEP SIZE =  1.500E-01 DAYS
     MINIMUM TIME STEP SIZE =  1.000E-02 DAYS
     TIME STEP REDUCTION FACTOR =  2.000E-01
          MAXIMUM PRESSURE HEAD CHANGE ALLOWED IN ONE TIME STEP = 100.000
          STEADY-STATE CLOSURE CRITERION =  0.000E-01
          MAXIMUM DEPTH OF PONDING =     0.000
          PRINT SOLUTION AFTER EVERY TIME STEP? F
          SIMULATE EVAPORATION? F
          SIMULATE EVAPOTRANSPIRATION? F
          SIMULATE SEEPAGE FACES? F

 NODE TYPE AND INITIAL BOUNDARY CONDITIONS FOR PERIOD     1
LEGEND:
          0 = INTERIOR CELL
          1 = SPECIFIED PRESSURE HEAD CELL
          2 = SPECIFIED FLUX CELL
          3 = POTENTIAL SEEPAGE FACE NODE
          5 = NODE FOR WHICH EVAPORATION IS PERMITTED


  1     000000000000000000000000
  2     022222222222222222222220
  3     000000000000000000000000
  4     000000000000000000000000
  5     000000000000000000000000
  6     000000000000000000000000
  7     000000000000000000000000
  8     000000000000000000000000
  9     000000000000000000000000
 10     000000000000000000000000
 11     000000000000000000000000
 12     000000000000000000000000
 13     000000000000000000000000
 14     000000000000000000000000
 15     000000000000000000000000
 16     000000000000000000000000
 17     000000000000000000000000
 18     000000000000000000000000
```

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
19      0000000000000000000000000
20      0000000000000000000000000
21      0000000000000000000000000
22      0000000000000000000000000
23      0000000000000000000000000
24      0000000000000000000000000
25      0000000000000000000000000
26      0000000000000000000000000
27      0111111111111111111111110
28      0000000000000000000000000
 TIME STEP NUMBER =    1  RECHARGE PERIOD =    1 ELAPSED TIME =   1.100E-02 DAYS REQUIRED ITERATIONS =    8

 TIME STEP NUMBER =    2  RECHARGE PERIOD =    1 ELAPSED TIME =   2.310E-02 DAYS REQUIRED ITERATIONS =   23

 TIME STEP NUMBER =    3  RECHARGE PERIOD =    1 ELAPSED TIME =   3.641E-02 DAYS REQUIRED ITERATIONS =    8

 TIME STEP NUMBER =    4  RECHARGE PERIOD =    1 ELAPSED TIME =   5.105E-02 DAYS REQUIRED ITERATIONS =    8

 TIME STEP NUMBER =    5  RECHARGE PERIOD =    1 ELAPSED TIME =   6.716E-02 DAYS REQUIRED ITERATIONS =    8

 TIME STEP NUMBER =    6  RECHARGE PERIOD =    1 ELAPSED TIME =   8.487E-02 DAYS REQUIRED ITERATIONS =    8

 TIME STEP NUMBER =    7  RECHARGE PERIOD =    1 ELAPSED TIME =   1.044E-01 DAYS REQUIRED ITERATIONS =    9

 TIME STEP NUMBER =    8  RECHARGE PERIOD =    1 ELAPSED TIME =   1.258E-01 DAYS REQUIRED ITERATIONS =    8

 TIME STEP NUMBER =    9  RECHARGE PERIOD =    1 ELAPSED TIME =   1.494E-01 DAYS REQUIRED ITERATIONS =    9

 TIME STEP NUMBER =   10  RECHARGE PERIOD =    1 ELAPSED TIME =   1.753E-01 DAYS REQUIRED ITERATIONS =    9

 TIME STEP NUMBER =   11  RECHARGE PERIOD =    1 ELAPSED TIME =   2.038E-01 DAYS REQUIRED ITERATIONS =    9

 TIME STEP NUMBER =   12  RECHARGE PERIOD =    1 ELAPSED TIME =   2.352E-01 DAYS REQUIRED ITERATIONS =    9

 TIME STEP NUMBER =   13  RECHARGE PERIOD =    1 ELAPSED TIME =   2.697E-01 DAYS REQUIRED ITERATIONS =   10

 TIME STEP NUMBER =   14  RECHARGE PERIOD =    1 ELAPSED TIME =   3.077E-01 DAYS REQUIRED ITERATIONS =   10

 TIME STEP NUMBER =   15  RECHARGE PERIOD =    1 ELAPSED TIME =   3.495E-01 DAYS REQUIRED ITERATIONS =   12

 TIME STEP NUMBER =   16  RECHARGE PERIOD =    1 ELAPSED TIME =   3.954E-01 DAYS REQUIRED ITERATIONS =   14
```

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
 PONDING AT NODE    2   2 DURING TIME STEP  17


 PONDING AT NODE    2   3 DURING TIME STEP  17


 PONDING AT NODE    2   4 DURING TIME STEP  17


 PONDING AT NODE    2   5 DURING TIME STEP  17


 PONDING ENDED AT NODE    2   5 DURING TIME STEP   17
TIME STEP NUMBER =   17  RECHARGE PERIOD =    1 ELAPSED TIME =   4.460E-01 DAYS REQUIRED ITERATIONS =  123


 PONDING AT NODE    2   5 DURING TIME STEP  18


 PONDING AT NODE    2   6 DURING TIME STEP  18


 PONDING AT NODE    2   7 DURING TIME STEP  18


 PONDING AT NODE    2   8 DURING TIME STEP  18


 PONDING ENDED AT NODE    2   8 DURING TIME STEP   18
TIME STEP NUMBER =   18  RECHARGE PERIOD =    1 ELAPSED TIME =   5.000E-01 DAYS REQUIRED ITERATIONS =   77

EXAMPLE PROBLEM 2 -- 2D INFILTRATION AND EVAPOTRANSPIRATION
TOTAL ELAPSED TIME =   5.000E-01 DAYS
TIME STEP    18

                                        PRESSURE HEAD
Z, IN
 CM                    X OR R DISTANCE, IN   CM
         11.25     33.75     52.50     67.50     82.50     97.50    110.62    121.87    131.25    138.75    146.25    153.75    161.25
        168.75    178.12    189.37    202.50    217.50    232.50    247.50    266.25    288.75
 1.50 0.00E-01 0.00E-01 0.00E-01 0.00E-01 0.00E-01 0.00E-01-1.99E-01-3.27E+00-7.92E+00-1.27E+01-1.82E+01-2.39E+01-2.92E+01
     -3.36E+01-3.77E+01-4.05E+01-4.22E+01-4.30E+01-4.32E+01-4.33E+01-4.34E+01-4.34E+01
```

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
  4.50-6.81E-01-6.75E-01-6.64E-01-6.56E-01-6.70E-01-7.99E-01-1.49E+00-4.59E+00-9.26E+00-1.40E+01-1.96E+01-2.55E+01-3.09E+01
       -3.53E+01-3.93E+01-4.21E+01-4.38E+01-4.45E+01-4.47E+01-4.48E+01-4.49E+01-4.49E+01
  7.50-1.36E+00-1.35E+00-1.33E+00-1.31E+00-1.34E+00-1.57E+00-2.61E+00-5.73E+00-1.04E+01-1.53E+01-2.11E+01-2.72E+01-3.27E+01
       -3.71E+01-4.11E+01-4.38E+01-4.54E+01-4.60E+01-4.63E+01-4.63E+01-4.64E+01-4.64E+01
 11.25-2.21E+00-2.20E+00-2.16E+00-2.13E+00-2.16E+00-2.49E+00-3.80E+00-6.94E+00-1.17E+01-1.67E+01-2.28E+01-2.94E+01-3.52E+01
       -3.97E+01-4.36E+01-4.60E+01-4.75E+01-4.80E+01-4.81E+01-4.82E+01-4.82E+01-4.82E+01
 15.75-3.23E+00 3.21E+00-3.15E+00-3.10E+00-3.11E+00-3.48E+00-4.91E+00-7.98E+00-1.27E+01-1.79E+01-2.46E+01-3.23E+01-3.87E+01
       -4.32E+01-4.69E+01-4.89E+01-5.00E+01-5.04E+01-5.05E+01-5.06E+01-5.06E+01-5.06E+01
 21.00-4.43E+00-4.39E+00-4.32E+00-4.23E+00-4.19E+00-4.51E+00-5.86E+00-8.71E+00-1.33E+01-1.87E+01-2.64E+01-3.62E+01-4.35E+01
       -4.78E+01-5.09E+01-5.25E+01-5.33E+01-5.37E+01-5.38E+01-5.39E+01-5.39E+01-5.39E+01
 27.00-5.79E+00-5.75E+00-5.65E+00-5.51E+00-5.37E+00-5.48E+00-6.46E+00-8.77E+00-1.29E+01-1.83E+01-2.70E+01-4.22E+01-4.94E+01
       -5.32E+01-5.62E+01-5.78E+01-5.86E+01-5.89E+01-5.91E+01-5.91E+01-5.91E+01-5.91E+01
 33.00-3.72E+01 3.72E+01-3.73E+01-3.76E+01-3.82E+01-3.94E+01-4.13E+01-4.41E+01-4.80E+01-5.21E+01-5.63E+01-5.34E+01-5.69E+01
       -6.05E+01-6.35E+01-6.51E+01-6.59E+01-6.62E+01-6.63E+01-6.63E+01-6.63E+01-6.64E+01
 39.00-7.69E+01-7.70E+01-7.73E+01-7.79E+01-7.89E+01-8.06E+01-8.30E+01-8.59E+01-8.87E+01-9.09E+01-8.81E+01-6.41E+01-6.69E+01
       -7.00E+01-7.28E+01-7.43E+01-7.49E+01-7.52E+01-7.52E+01-7.52E+01-7.53E+01-7.53E+01
 46.50-9.93E+01-9.93E+01-9.93E+01-9.94E+01-9.94E+01-9.95E+01-9.96E+01-9.97E+01-9.98E+01-9.98E+01-9.79E+01-8.12E+01-8.26E+01
       -8.44E+01-8.60E+01-8.69E+01-8.73E+01-8.74E+01-8.75E+01-8.75E+01-8.75E+01-8.75E+01
 55.50-1.02E+02-1.02E+02-1.02E+02-1.02E+02-1.02E+02-1.02E+02-1.02E+02-1.02E+02-1.02E+02-1.02E+02-1.01E+02-9.42E+01-9.43E+01
       -9.47E+01-9.52E+01-9.55E+01-9.56E+01-9.56E+01-9.56E+01-9.56E+01-9.57E+01-9.57E+01
 64.50-1.09E+02-1.09E+02-1.09E+02-1.09E+02-1.09E+02-1.09E+02-1.09E+02-1.09E+02-1.08E+02-1.07E+02-1.05E+02-1.00E+02-9.91E+01
       -9.87E+01-9.86E+01-9.86E+01-9.87E+01-9.87E+01-9.87E+01-9.87E+01-9.87E+01-9.87E+01
 73.50-1.04E+02-1.04E+02-1.04E+02-1.04E+02-1.04E+02-1.04E+02-1.04E+02-1.04E+02-1.04E+02-1.03E+02-1.02E+02-1.01E+02-9.99E+01
       -9.96E+01-9.94E+01-9.94E+01-9.94E+01-9.94E+01-9.94E+01-9.94E+01-9.94E+01-9.94E+01
 84.00-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-9.98E+01-9.94E+01-9.91E+01
       -9.89E+01-9.88E+01-9.88E+01-9.88E+01-9.88E+01-9.88E+01-9.88E+01-9.88E+01-9.88E+01
 97.50-9.57E+01-9.57E+01-9.57E+01-9.57E+01-9.57E+01-9.57E+01-9.57E+01-9.57E+01-9.57E+01-9.56E+01-9.56E+01-9.55E+01-9.54E+01
       -9.54E+01-9.53E+01-9.53E+01-9.53E+01-9.53E+01-9.53E+01-9.53E+01-9.53E+01-9.53E+01
112.50-8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01
       -8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01-8.55E+01
126.00-7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01
       -7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01-7.34E+01
136.50-6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01
       -6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01-6.32E+01
144.00-5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01
       -5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01-5.58E+01
150.00-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01
       -5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01-5.00E+01
156.00-4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01
       -4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01-4.39E+01
163.50-3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01
       -3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01-3.58E+01
172.50-2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01
       -2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01-2.50E+01
```

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
181.50-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01
      -1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01
190.50-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00
      -6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00
201.00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00
       4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00
```

MOISTURE CONTENT

Z, IN CM	X OR R DISTANCE, IN CM												
	11.25	33.75	52.50	67.50	82.50	97.50	110.62	121.87	131.25	138.75	146.25	153.75	161.25
	168.75	178.12	189.37	202.50	217.50	232.50	247.50	266.25	288.75				
1.50	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
4.50	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
7.50	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
11.25	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
15.75	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.450	0.450	0.450	0.450	0.449	0.448	0.448	0.448	0.448				
21.00	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.450	0.447	0.441	0.439	0.437	0.437	0.437	0.437	0.437				
27.00	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.439	0.430	0.425	0.423	0.422	0.421	0.421	0.421	0.421				
33.00	0.209	0.209	0.209	0.208	0.206	0.202	0.196	0.189	0.180	0.172	0.165	0.439	0.428
	0.418	0.410	0.406	0.404	0.403	0.403	0.403	0.403	0.403				
39.00	0.142	0.142	0.142	0.142	0.141	0.140	0.138	0.136	0.134	0.133	0.135	0.408	0.402
	0.395	0.389	0.387	0.385	0.385	0.385	0.385	0.385	0.385				
46.50	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.129	0.374	0.372
	0.369	0.367	0.365	0.365	0.365	0.365	0.364	0.364	0.364				
55.50	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.355	0.355
	0.354	0.354	0.354	0.353	0.353	0.353	0.353	0.353	0.353				
64.50	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.339	0.340	0.342	0.347	0.349
	0.349	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350				
73.50	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.344	0.344	0.345	0.347	0.348
	0.348	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349				
84.00	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.348	0.348	0.348	0.349	0.349
	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349	0.349				
97.50	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.354
	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354				
112.50	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367
	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367				
126.00	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.388

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
         0.388  0.388  0.388  0.388  0.388  0.388  0.388  0.388  0.388
136.50   0.411  0.411  0.411  0.411  0.411  0.411  0.411  0.411  0.411  0.411  0.411  0.411  0.411
         0.411  0.411  0.411  0.411  0.411  0.411  0.411  0.411  0.411
144.00   0.431  0.431  0.431  0.431  0.431  0.431  0.431  0.431  0.431  0.431  0.431  0.431  0.431
         0.431  0.431  0.431  0.431  0.431  0.431  0.431  0.431  0.431
150.00   0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091
         0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091
156.00   0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098
         0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098
163.50   0.111  0.111  0.111  0.111  0.111  0.111  0.111  0.111  0.111  0.111  0.111  0.111  0.111
         0.111  0.111  0.111  0.111  0.111  0.111  0.111  0.111  0.111
172.50   0.144  0.144  0.144  0.144  0.144  0.144  0.144  0.144  0.144  0.144  0.144  0.144  0.144
         0.144  0.144  0.144  0.144  0.144  0.144  0.144  0.144  0.144
181.50   0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217
         0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217
190.50   0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420
         0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420
201.00   0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420
         0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420
                ---------- MASS BALANCE SUMMARY FOR TIME STEP  18 ----------
                    PUMPING PERIOD NUMBER      1
                    TOTAL ELAPSED SIMULATION TIME =  5.000E-01 DAYS

++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                                                        +
+                                                                          MASS  THIS     RATE FOR THIS  +
+                                                            TOTAL  MASS   TIME STEP       TIME STEP     +
+                                                               GRAM       GRAM            GRAM/DAYS     +
+   FLUX INTO DOMAIN ACROSS SPECIFIED PRESSURE HEAD BOUNDARIES --  3.59790E+02   3.67448E+01   6.80355E+02  +
+ FLUX OUT OF DOMAIN ACROSS SPECIFIED PRESSURE HEAD BOUNDARIES --  0.00000E-01   0.00000E-01   0.00000E-01  +
+          FLUX INTO DOMAIN ACROSS SPECIFIED FLUX BOUNDARIES --  1.05972E+03   7.89871E+01   1.46250E+03  +
+        FLUX OUT OF DOMAIN ACROSS SPECIFIED FLUX BOUNDARIES --  0.00000E-01   0.00000E-01   0.00000E-01  +
+                                     TOTAL FLUX INTO DOMAIN --  1.41951E+03   1.15732E+02   2.14286E+03  +
+                                   TOTAL FLUX OUT OF DOMAIN --  0.00000E-01   0.00000E-01   0.00000E-01  +
+                                                EVAPORATION --  0.00000E-01   0.00000E-01   0.00000E-01  +
+                                              TRANSPIRATION --  0.00000E-01   0.00000E-01   0.00000E-01  +
+                                   TOTAL EVAPOTRANSPIRATION --  0.00000E-01   0.00000E-01   0.00000E-01  +
+                              CHANGE IN FLUID STORED IN DOMAIN --  1.41874E+03   1.15732E+02   2.14285E+03  +
+                                         FLUID MASS BALANCE --  7.76598E-01   1.93121E-04   3.57578E-03  +
+                                                                                                        +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

PONDING ENDED AT NODE    2   7 DURING TIME STEP   19
```

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
 TIME STEP NUMBER =   19  RECHARGE PERIOD =     1 ELAPSED TIME =   5.594E-01 DAYS REQUIRED ITERATIONS =   45


  PONDING ENDED AT NODE      2   6 DURING TIME STEP   20
 TIME STEP NUMBER =   20  RECHARGE PERIOD =     1 ELAPSED TIME =   6.248E-01 DAYS REQUIRED ITERATIONS =   46


  PONDING ENDED AT NODE      2   3 DURING TIME STEP   21


  PONDING ENDED AT NODE      2   4 DURING TIME STEP   21


  PONDING ENDED AT NODE      2   5 DURING TIME STEP   21


  PONDING ENDED AT NODE      2   2 DURING TIME STEP   21
 TIME STEP NUMBER =   21  RECHARGE PERIOD =     1 ELAPSED TIME =   6.966E-01 DAYS REQUIRED ITERATIONS =   61

 TIME STEP NUMBER =   22  RECHARGE PERIOD =     1 ELAPSED TIME =   7.757E-01 DAYS REQUIRED ITERATIONS =   21

 TIME STEP NUMBER =   23  RECHARGE PERIOD =     1 ELAPSED TIME =   8.627E-01 DAYS REQUIRED ITERATIONS =   18

 TIME STEP NUMBER =   24  RECHARGE PERIOD =     1 ELAPSED TIME =   9.584E-01 DAYS REQUIRED ITERATIONS =   19

 TIME STEP NUMBER =   25  RECHARGE PERIOD =     1 ELAPSED TIME =   1.000E+00 DAYS REQUIRED ITERATIONS =   25

 EXAMPLE PROBLEM 2 -- 2D INFILTRATION AND EVAPOTRANSPIRATION
TOTAL ELAPSED TIME =   1.000E+00 DAYS
TIME STEP    25

                                          PRESSURE HEAD
Z, IN
  CM                    X OR R DISTANCE, IN   CM
          11.25     33.75     52.50     67.50     82.50     97.50    110.62    121.87    131.25    138.75    146.25    153.75    161.25
         168.75    178.12    189.37    202.50    217.50    232.50    247.50    266.25    288.75
  1.50-1.18E+00-1.21E+00-1.29E+00-1.41E+00-1.65E+00-2.11E+00-2.87E+00-3.92E+00-5.28E+00-6.67E+00-8.37E+00-1.03E+01-1.21E+01
       -1.39E+01-1.59E+01-1.78E+01-1.97E+01-2.13E+01-2.25E+01-2.34E+01-2.42E+01-2.47E+01
  4.50-2.68E+00-2.71E+00-2.79E+00-2.91E+00-3.14E+00-3.59E+00-4.34E+00-5.38E+00-6.73E+00-8.13E+00-9.84E+00-1.18E+01-1.37E+01
       -1.54E+01-1.74E+01-1.94E+01-2.12E+01-2.28E+01-2.40E+01-2.49E+01-2.57E+01-2.62E+01
  7.50-4.18E+00-4.21E+00-4.28E+00-4.40E+00-4.62E+00-5.06E+00-5.78E+00-6.80E+00-8.13E+00-9.53E+00-1.13E+01-1.33E+01-1.52E+01
```

Table 11.--Partial listing of output to file 6, the main output file, for example problem 2--Continued

```
-1.70E+01-1.90E+01-2.09E+01-2.28E+01-2.44E+01-2.55E+01-2.64E+01-2.72E+01-2.77E+01
11.25-6.05E+00-6.08E+00-6.15E+00-6.26E+00-6.46E+00-6.87E+00-7.55E+00-8.51E+00-9.81E+00-1.12E+01-1.30E+01-1.51E+01-1.72E+01
-1.90E+01-2.10E+01-2.29E+01-2.47E+01-2.63E+01-2.75E+01-2.83E+01-2.91E+01-2.96E+01
15.75-8.30E+00-8.32E+00-8.38E+00-8.48E+00-8.66E+00-9.01E+00-9.62E+00-1.05E+01-1.17E+01-1.31E+01-1.50E+01-1.74E+01-1.96E+01
-2.14E+01-2.34E+01-2.53E+01-2.71E+01-2.86E+01-2.98E+01-3.07E+01-3.15E+01-3.19E+01
21.00-1.09E+01-1.09E+01-1.10E+01-1.11E+01-1.12E+01-1.15E+01-1.20E+01-1.27E+01-1.37E+01-1.51E+01-1.71E+01-2.02E+01-2.26E+01
-2.44E+01-2.64E+01-2.82E+01-3.00E+01-3.14E+01-3.25E+01-3.34E+01-3.42E+01-3.46E+01
27.00-1.39E+01-1.39E+01-1.40E+01-1.40E+01-1.41E+01-1.43E+01-1.45E+01-1.50E+01-1.57E+01-1.68E+01-1.89E+01-2.38E+01-2.63E+01
-2.80E+01-2.99E+01-3.16E+01-3.33E+01-3.47E+01-3.57E+01-3.65E+01-3.73E+01-3.78E+01
33.00-2.52E+01-2.52E+01-2.52E+01-2.53E+01-2.53E+01-2.54E+01-2.56E+01-2.59E+01-2.64E+01-2.70E+01-2.80E+01-2.89E+01-3.04E+01
-3.19E+01-3.35E+01-3.51E+01-3.67E+01-3.80E+01-3.89E+01-3.97E+01-4.05E+01-4.09E+01
39.00-2.53E+01-2.53E+01-2.53E+01-2.53E+01-2.54E+01-2.55E+01-2.58E+01-2.62E+01-2.69E+01-2.78E+01-2.93E+01-3.34E+01-3.46E+01
-3.58E+01-3.72E+01-3.87E+01-4.02E+01-4.13E+01-4.22E+01-4.29E+01-4.37E+01-4.41E+01
46.50-2.53E+01-2.53E+01-2.54E+01-2.54E+01-2.55E+01-2.57E+01-2.61E+01-2.69E+01-2.84E+01-3.05E+01-3.40E+01-3.91E+01-3.99E+01
-4.07E+01-4.19E+01-4.33E+01-4.47E+01-4.56E+01-4.63E+01-4.69E+01-4.77E+01-4.82E+01
55.50-3.27E+01-3.28E+01-3.30E+01-3.34E+01-3.42E+01-3.59E+01-3.93E+01-4.53E+01-5.44E+01-6.26E+01-5.74E+01-4.65E+01-4.63E+01
-4.66E+01-4.74E+01-4.89E+01-5.06E+01-5.18E+01-5.26E+01-5.32E+01-5.38E+01-5.41E+01
64.50-8.67E+01-8.68E+01-8.74E+01-8.83E+01-9.01E+01-9.33E+01-9.77E+01-1.01E+02-9.97E+01-9.09E+01-7.50E+01-5.88E+01-5.52E+01
-5.43E+01-5.45E+01-5.57E+01-5.74E+01-5.91E+01-6.04E+01-6.13E+01-6.20E+01-6.24E+01
73.50-9.88E+01-9.89E+01-9.91E+01-9.96E+01-1.00E+02-1.02E+02-1.03E+02-1.03E+02-1.00E+02-9.30E+01-8.18E+01-7.06E+01-6.58E+01
-6.41E+01-6.39E+01-6.52E+01-6.74E+01-6.96E+01-7.12E+01-7.22E+01-7.29E+01-7.33E+01
84.00-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.00E+02-1.01E+02-1.01E+02-1.00E+02-9.86E+01-9.55E+01-9.03E+01-8.46E+01-8.08E+01
-7.91E+01-7.86E+01-7.97E+01-8.15E+01-8.33E+01-8.44E+01-8.51E+01-8.56E+01-8.58E+01
97.50-9.45E+01-9.45E+01-9.45E+01-9.45E+01-9.45E+01-9.45E+01-9.45E+01-9.43E+01-9.37E+01-9.29E+01-9.17E+01-9.02E+01-8.90E+01
-8.83E+01-8.80E+01-8.83E+01-8.89E+01-8.95E+01-8.98E+01-9.00E+01-9.01E+01-9.02E+01
112.50-8.42E+01-8.42E+01-8.42E+01-8.42E+01-8.42E+01-8.42E+01-8.42E+01-8.41E+01-8.40E+01-8.38E+01-8.36E+01-8.33E+01-8.31E+01
-8.29E+01-8.29E+01-8.29E+01-8.30E+01-8.31E+01-8.31E+01-8.32E+01-8.32E+01-8.32E+01
126.00-7.24E+01-7.24E+01-7.24E+01-7.24E+01-7.24E+01-7.24E+01-7.24E+01-7.24E+01-7.24E+01-7.23E+01-7.23E+01-7.22E+01-7.22E+01
-7.21E+01-7.21E+01-7.21E+01-7.21E+01-7.21E+01-7.22E+01-7.22E+01-7.22E+01-7.22E+01
136.50-6.24E+01-6.24E+01-6.24E+01-6.24E+01-6.24E+01-6.24E+01-6.24E+01-6.24E+01-6.24E+01-6.24E+01-6.24E+01-6.23E+01-6.23E+01
-6.23E+01-6.23E+01-6.23E+01-6.23E+01-6.23E+01-6.23E+01-6.23E+01-6.23E+01-6.23E+01
144.00-5.50E+01-5.50E+01-5.50E+01-5.50E+01-5.50E+01-5.50E+01-5.50E+01-5.50E+01-5.50E+01-5.50E+01-5.50E+01-5.50E+01-5.49E+01
-5.49E+01-5.49E+01-5.49E+01-5.49E+01-5.49E+01-5.49E+01-5.49E+01-5.49E+01-5.49E+01
150.00-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01
-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01-4.96E+01
156.00-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01
-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01-4.36E+01
163.50-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01
-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01-3.51E+01
172.50-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01
-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01-2.47E+01
181.50-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01
-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01
190.50-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00
```

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00
201.00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00
4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00

MOISTURE CONTENT

Z, IN CM	X OR R DISTANCE, IN CM												
	11.25	33.75	52.50	67.50	82.50	97.50	110.62	121.87	131.25	138.75	146.25	153.75	161.25
	168.75	178.12	189.37	202.50	217.50	232.50	247.50	266.25	288.75				
1.50	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
4.50	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
7.50	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
11.25	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
15.75	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
21.00	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
27.00	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
33.00	0.270	0.270	0.270	0.270	0.270	0.269	0.267	0.265	0.262	0.257	0.252	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
39.00	0.270	0.270	0.270	0.269	0.269	0.268	0.266	0.263	0.258	0.253	0.244	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
46.50	0.269	0.269	0.269	0.269	0.268	0.267	0.264	0.259	0.249	0.237	0.221	0.450	0.450
	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450				
55.50	0.227	0.226	0.225	0.224	0.221	0.214	0.202	0.186	0.168	0.157	0.164	0.450	0.450
	0.450	0.450	0.450	0.448	0.444	0.441	0.439	0.437	0.436				
64.50	0.366	0.365	0.365	0.363	0.361	0.356	0.351	0.346	0.348	0.360	0.385	0.422	0.433
	0.435	0.435	0.431	0.426	0.421	0.418	0.416	0.414	0.413				
73.50	0.349	0.349	0.349	0.348	0.347	0.346	0.344	0.344	0.348	0.357	0.373	0.394	0.404
	0.409	0.409	0.406	0.401	0.396	0.393	0.391	0.389	0.389				
84.00	0.348	0.348	0.348	0.348	0.347	0.347	0.347	0.347	0.350	0.354	0.360	0.369	0.375
	0.378	0.379	0.377	0.374	0.371	0.369	0.368	0.367	0.367				
97.50	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.356	0.357	0.359	0.361	0.362
	0.363	0.364	0.363	0.362	0.362	0.361	0.361	0.361	0.361				
112.50	0.369	0.369	0.369	0.369	0.369	0.369	0.370	0.370	0.370	0.370	0.370	0.371	0.371
	0.371	0.372	0.372	0.371	0.371	0.371	0.371	0.371	0.371				
126.00	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.390	0.391	0.391
	0.391	0.391	0.391	0.391	0.391	0.391	0.391	0.391	0.391				
136.50	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413
	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413				

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
144.00   0.433  0.433  0.433  0.433  0.433  0.433  0.433  0.433  0.433  0.433  0.433  0.433  0.434
         0.434  0.434  0.434  0.434  0.434  0.434  0.434  0.434  0.434
150.00   0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091
         0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091  0.091
156.00   0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098
         0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098  0.098
163.50   0.113  0.113  0.113  0.113  0.113  0.113  0.113  0.113  0.113  0.113  0.113  0.113  0.113
         0.113  0.113  0.113  0.113  0.113  0.113  0.113  0.113  0.113
172.50   0.146  0.146  0.146  0.146  0.146  0.146  0.146  0.146  0.146  0.146  0.146  0.146  0.146
         0.146  0.146  0.146  0.146  0.146  0.146  0.146  0.146  0.146
181.50   0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217
         0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217  0.217
190.50   0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420
         0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420
201.00   0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420
         0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420  0.420
          ---------- MASS BALANCE SUMMARY FOR TIME STEP  25 ----------
              PUMPING PERIOD NUMBER      1
              TOTAL ELAPSED SIMULATION TIME =  1.000E+00 DAYS

++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                                                +
+                                                             MASS  THIS      RATE FOR THIS      +
+                                               TOTAL  MASS   TIME STEP       TIME STEP          +
+                                                  GRAM         GRAM          GRAM/DAYS          +
+  FLUX INTO DOMAIN ACROSS SPECIFIED PRESSURE HEAD BOUNDARIES --  4.44260E+02  5.48043E-01  1.31670E+01  +
+ FLUX OUT OF DOMAIN ACROSS SPECIFIED PRESSURE HEAD BOUNDARIES --  0.00000E-01  0.00000E-01  0.00000E-01  +
+         FLUX INTO DOMAIN ACROSS SPECIFIED FLUX BOUNDARIES --  2.10786E+03  9.36508E+01  2.25000E+03  +
+       FLUX OUT OF DOMAIN ACROSS SPECIFIED FLUX BOUNDARIES --  0.00000E-01  0.00000E-01  0.00000E-01  +
+                                    TOTAL FLUX INTO DOMAIN --  2.55212E+03  9.41989E+01  2.26317E+03  +
+                                  TOTAL FLUX OUT OF DOMAIN --  0.00000E-01  0.00000E-01  0.00000E-01  +
+                                               EVAPORATION --  0.00000E-01  0.00000E-01  0.00000E-01  +
+                                             TRANSPIRATION --  0.00000E-01  0.00000E-01  0.00000E-01  +
+                                  TOTAL EVAPOTRANSPIRATION --  0.00000E-01  0.00000E-01  0.00000E-01  +
+                              CHANGE IN FLUID STORED IN DOMAIN --  2.55135E+03  9.41974E+01  2.26313E+03  +
+                                        FLUID MASS BALANCE --  7.77542E-01  1.50603E-03  3.61830E-02  +
+                                                                                                +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
          .
          .
          .
TIME STEP NUMBER =  703  RECHARGE PERIOD =    4 ELAPSED TIME =   7.441E+01 DAYS REQUIRED ITERATIONS =    8

TIME STEP NUMBER =  704  RECHARGE PERIOD =    4 ELAPSED TIME =   7.491E+01 DAYS REQUIRED ITERATIONS =    8
```

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
TIME STEP NUMBER =  705  RECHARGE PERIOD =    4 ELAPSED TIME =   7.541E+01 DAYS REQUIRED ITERATIONS =    8

TIME STEP NUMBER =  706  RECHARGE PERIOD =    4 ELAPSED TIME =   7.591E+01 DAYS REQUIRED ITERATIONS =    8

TIME STEP NUMBER =  707  RECHARGE PERIOD =    4 ELAPSED TIME =   7.641E+01 DAYS REQUIRED ITERATIONS =    8

TIME STEP NUMBER =  708  RECHARGE PERIOD =    4 ELAPSED TIME =   7.691E+01 DAYS REQUIRED ITERATIONS =    8

TIME STEP NUMBER =  709  RECHARGE PERIOD =    4 ELAPSED TIME =   7.700E+01 DAYS REQUIRED ITERATIONS =    7

EXAMPLE PROBLEM 2 -- 2D INFILTRATION AND EVAPOTRANSPIRATION
TOTAL ELAPSED TIME =   7.700E+01 DAYS
TIME STEP   709

                                  PRESSURE HEAD
Z, IN
 CM                   X OR R DISTANCE, IN   CM
          11.25     33.75     52.50     67.50     82.50     97.50    110.62    121.87    131.25    138.75    146.25    153.75    161.25
         168.75    178.12    189.37    202.50    217.50    232.50    247.50    266.25    288.75
  1.50-1.08E+04-1.08E+04-1.08E+04-1.08E+04-1.08E+04-1.08E+04-1.09E+04-1.09E+04-1.09E+04-1.09E+04-1.08E+04-1.04E+04-1.04E+04
      -1.03E+04-1.03E+04-1.03E+04-1.03E+04-1.03E+04-1.03E+04-1.04E+04-1.04E+04-1.04E+04
  4.50-7.50E+03-7.50E+03-7.51E+03-7.52E+03-7.52E+03-7.53E+03-7.54E+03-7.55E+03-7.55E+03-7.54E+03-7.48E+03-7.19E+03-7.16E+03
      -7.15E+03-7.15E+03-7.15E+03-7.16E+03-7.16E+03-7.17E+03-7.17E+03-7.17E+03-7.17E+03
  7.50-7.33E+03-7.33E+03-7.34E+03-7.34E+03-7.35E+03-7.36E+03-7.37E+03-7.38E+03-7.38E+03-7.37E+03-7.30E+03-7.02E+03-6.99E+03
      -6.98E+03-6.98E+03-6.98E+03-6.99E+03-6.99E+03-7.00E+03-7.00E+03-7.00E+03-7.00E+03
 11.25-7.15E+03-7.15E+03-7.16E+03-7.16E+03-7.17E+03-7.18E+03-7.19E+03-7.20E+03-7.20E+03-7.19E+03-7.13E+03-6.84E+03-6.82E+03
      -6.81E+03-6.81E+03-6.81E+03-6.82E+03-6.82E+03-6.82E+03-6.83E+03-6.83E+03-6.83E+03
 15.75-6.91E+03-6.92E+03-6.92E+03-6.93E+03-6.94E+03-6.95E+03-6.95E+03-6.96E+03-6.96E+03-6.96E+03-6.89E+03-6.61E+03-6.59E+03
      -6.58E+03-6.58E+03-6.58E+03-6.59E+03-6.59E+03-6.59E+03-6.60E+03-6.60E+03-6.60E+03
 21.00-6.60E+03-6.60E+03-6.60E+03-6.61E+03-6.61E+03-6.62E+03-6.63E+03-6.64E+03-6.64E+03-6.65E+03-6.64E+03-6.57E+03-6.30E+03-6.28E+03
      -6.27E+03-6.26E+03-6.27E+03-6.27E+03-6.28E+03-6.28E+03-6.28E+03-6.29E+03-6.29E+03
 27.00-6.13E+03-6.13E+03-6.14E+03-6.14E+03-6.15E+03-6.16E+03-6.17E+03-6.17E+03-6.18E+03-6.17E+03-6.10E+03-5.59E+03-5.57E+03
      -5.57E+03-5.57E+03-5.58E+03-5.58E+03-5.59E+03-5.59E+03-5.60E+03-5.60E+03-5.60E+03
 33.00-9.65E+02-9.65E+02-9.66E+02-9.67E+02-9.68E+02-9.70E+02-9.75E+02-9.84E+02-1.00E+03-1.04E+03-1.14E+03-1.82E+03-1.83E+03
      -1.83E+03-1.84E+03-1.85E+03-1.86E+03-1.87E+03-1.87E+03-1.88E+03-1.88E+03-1.88E+03
 39.00-1.49E+02-1.49E+02-1.49E+02-1.50E+02-1.50E+02-1.51E+02-1.52E+02-1.54E+02-1.60E+02-1.70E+02-1.99E+02-2.19E+02-2.20E+02
      -2.22E+02-2.24E+02-2.25E+02-2.27E+02-2.28E+02-2.29E+02-2.30E+02-2.31E+02-2.31E+02
 46.50-1.38E+02-1.39E+02-1.39E+02-1.39E+02-1.39E+02-1.40E+02-1.41E+02-1.43E+02-1.47E+02-1.55E+02-1.75E+02-1.86E+02-1.87E+02
      -1.88E+02-1.90E+02-1.91E+02-1.93E+02-1.94E+02-1.95E+02-1.95E+02-1.96E+02-1.96E+02
 55.50-1.33E+02-1.33E+02-1.33E+02-1.34E+02-1.34E+02-1.35E+02-1.36E+02-1.37E+02-1.39E+02-1.42E+02-1.51E+02-1.59E+02-1.61E+02
      -1.62E+02-1.64E+02-1.65E+02-1.66E+02-1.67E+02-1.68E+02-1.68E+02-1.69E+02-1.69E+02
 64.50-1.26E+02-1.26E+02-1.26E+02-1.27E+02-1.27E+02-1.28E+02-1.29E+02-1.30E+02-1.31E+02-1.33E+02-1.35E+02-1.40E+02-1.42E+02
```

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
      -1.44E+02-1.45E+02-1.46E+02-1.47E+02-1.48E+02-1.49E+02-1.49E+02-1.50E+02-1.50E+02
 73.50-1.17E+02-1.17E+02-1.18E+02-1.18E+02-1.18E+02-1.19E+02-1.20E+02-1.21E+02-1.22E+02-1.23E+02-1.25E+02-1.26E+02-1.28E+02
      -1.29E+02-1.30E+02-1.31E+02-1.32E+02-1.33E+02-1.33E+02-1.34E+02-1.34E+02-1.34E+02
 84.00-1.07E+02-1.07E+02-1.07E+02-1.08E+02-1.08E+02-1.09E+02-1.09E+02-1.10E+02-1.11E+02-1.11E+02-1.12E+02-1.13E+02-1.14E+02
      -1.15E+02-1.16E+02-1.17E+02-1.17E+02-1.18E+02-1.18E+02-1.19E+02-1.19E+02-1.19E+02
 97.50-9.37E+01-9.38E+01-9.41E+01-9.43E+01-9.47E+01-9.51E+01-9.56E+01-9.62E+01-9.67E+01-9.72E+01-9.77E+01-9.82E+01-9.87E+01
      -9.91E+01-9.97E+01-1.00E+02-1.01E+02-1.01E+02-1.02E+02-1.02E+02-1.02E+02-1.02E+02
112.50-7.90E+01-7.91E+01-7.93E+01-7.96E+01-7.99E+01-8.03E+01-8.07E+01-8.11E+01-8.14E+01-8.17E+01-8.21E+01-8.24E+01-8.27E+01
      -8.30E+01-8.34E+01-8.38E+01-8.42E+01-8.46E+01-8.50E+01-8.53E+01-8.55E+01-8.57E+01
126.00-6.57E+01-6.58E+01-6.60E+01-6.62E+01-6.65E+01-6.69E+01-6.72E+01-6.76E+01-6.79E+01-6.81E+01-6.84E+01-6.86E+01-6.89E+01
      -6.91E+01-6.95E+01-6.98E+01-7.02E+01-7.06E+01-7.09E+01-7.12E+01-7.14E+01-7.16E+01
136.50-5.52E+01-5.54E+01-5.56E+01-5.58E+01-5.61E+01-5.64E+01-5.68E+01-5.71E+01-5.74E+01-5.76E+01-5.78E+01-5.81E+01-5.83E+01
      -5.85E+01-5.88E+01-5.92E+01-5.95E+01-5.99E+01-6.02E+01-6.05E+01-6.07E+01-6.09E+01
144.00-4.78E+01-4.79E+01-4.81E+01-4.83E+01-4.86E+01-4.90E+01-4.93E+01-4.96E+01-4.99E+01-5.01E+01-5.03E+01-5.06E+01-5.08E+01
      -5.10E+01-5.13E+01-5.17E+01-5.20E+01-5.24E+01-5.27E+01-5.30E+01-5.32E+01-5.33E+01
150.00-4.25E+01-4.26E+01-4.28E+01-4.30E+01-4.32E+01-4.35E+01-4.38E+01-4.40E+01-4.42E+01-4.44E+01-4.46E+01-4.48E+01-4.50E+01
      -4.52E+01-4.54E+01-4.57E+01-4.60E+01-4.63E+01-4.66E+01-4.68E+01-4.70E+01-4.71E+01
156.00-3.88E+01-3.89E+01-3.90E+01-3.91E+01-3.92E+01-3.93E+01-3.95E+01-3.96E+01-3.97E+01-3.98E+01-3.99E+01-4.00E+01-4.01E+01
      -4.01E+01-4.02E+01-4.04E+01-4.05E+01-4.06E+01-4.07E+01-4.08E+01-4.09E+01-4.09E+01
163.50-3.29E+01-3.29E+01-3.29E+01-3.30E+01-3.30E+01-3.30E+01-3.31E+01-3.31E+01-3.31E+01-3.32E+01-3.32E+01-3.32E+01-3.32E+01
      -3.33E+01-3.33E+01-3.33E+01-3.34E+01-3.34E+01-3.34E+01-3.34E+01-3.34E+01-3.35E+01
172.50-2.44E+01-2.44E+01-2.44E+01-2.44E+01-2.44E+01-2.44E+01-2.45E+01-2.45E+01-2.45E+01-2.45E+01-2.45E+01-2.45E+01 2.45E+01
      -2.45E+01-2.45E+01-2.45E+01-2.45E+01-2.45E+01-2.45E+01-2.45E+01-2.45E+01-2.45E+01
181.50-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01
      -1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01-1.55E+01
190.50-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00
      -6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00-6.50E+00
201.00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00
       4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00 4.00E+00
                                                   MOISTURE CONTENT
Z, IN
 CM                  X OR R DISTANCE, IN    CM
        11.25    33.75    52.50    67.50    82.50    97.50   110.62   121.87   131.25   138.75   146.25   153.75   161.25
       168.75   178.12   189.37   202.50   217.50   232.50   247.50   266.25   288.75
  1.50  0.162    0.162    0.162    0.162    0.162    0.162    0.162    0.162    0.162    0.162    0.162    0.162    0.162
        0.162    0.162    0.162    0.162    0.162    0.162    0.162    0.162    0.162
  4.50  0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165
        0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165
  7.50  0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165
        0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165
 11.25  0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.165    0.166    0.166
        0.166    0.166    0.166    0.166    0.166    0.166    0.166    0.166    0.166
 15.75  0.166    0.166    0.166    0.166    0.166    0.166    0.166    0.166    0.166    0.166    0.166    0.166    0.166
        0.166    0.166    0.166    0.166    0.166    0.166    0.166    0.166    0.166
```

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

21.00	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.167
	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.166				
27.00	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.168	0.168
	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168				
33.00	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.084	0.185	0.185
	0.185	0.184	0.184	0.184	0.184	0.184	0.184	0.184	0.184				
39.00	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.111	0.110	0.108	0.104	0.274	0.273
	0.273	0.272	0.272	0.271	0.271	0.270	0.270	0.270	0.270				
46.50	0.115	0.115	0.115	0.115	0.114	0.114	0.114	0.114	0.113	0.111	0.107	0.287	0.286
	0.285	0.285	0.284	0.284	0.283	0.283	0.283	0.282	0.282				
55.50	0.116	0.116	0.116	0.116	0.116	0.116	0.115	0.115	0.115	0.114	0.112	0.300	0.299
	0.298	0.297	0.297	0.296	0.295	0.295	0.295	0.295	0.294				
64.50	0.322	0.322	0.322	0.322	0.321	0.321	0.320	0.319	0.318	0.317	0.315	0.312	0.310
	0.309	0.308	0.308	0.307	0.306	0.306	0.306	0.305	0.305				
73.50	0.330	0.330	0.330	0.329	0.329	0.328	0.328	0.327	0.326	0.325	0.324	0.322	0.321
	0.320	0.319	0.318	0.317	0.317	0.316	0.316	0.316	0.316				
84.00	0.340	0.340	0.340	0.339	0.339	0.338	0.338	0.337	0.336	0.335	0.335	0.334	0.333
	0.332	0.331	0.331	0.330	0.329	0.329	0.329	0.328	0.328				
97.50	0.356	0.356	0.355	0.355	0.355	0.354	0.353	0.353	0.352	0.351	0.351	0.350	0.350
	0.349	0.348	0.348	0.347	0.346	0.346	0.346	0.345	0.345				
112.50	0.378	0.378	0.377	0.377	0.376	0.376	0.375	0.374	0.374	0.373	0.373	0.372	0.372
	0.371	0.371	0.370	0.369	0.369	0.368	0.368	0.367	0.367				
126.00	0.405	0.404	0.404	0.403	0.403	0.402	0.401	0.400	0.400	0.399	0.399	0.398	0.398
	0.397	0.396	0.396	0.395	0.394	0.393	0.393	0.392	0.392				
136.50	0.433	0.432	0.432	0.431	0.430	0.429	0.428	0.427	0.426	0.426	0.425	0.424	0.424
	0.423	0.422	0.421	0.420	0.419	0.418	0.418	0.417	0.417				
144.00	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.449	0.448	0.447
	0.446	0.445	0.444	0.443	0.442	0.441	0.440	0.439	0.439				
150.00	0.100	0.100	0.099	0.099	0.099	0.099	0.098	0.098	0.098	0.097	0.097	0.097	0.097
	0.096	0.096	0.096	0.095	0.095	0.095	0.094	0.094	0.094				
156.00	0.106	0.105	0.105	0.105	0.105	0.105	0.105	0.104	0.104	0.104	0.104	0.104	0.104
	0.103	0.103	0.103	0.103	0.103	0.103	0.102	0.102	0.102				
163.50	0.118	0.118	0.118	0.118	0.118	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117
	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.116	0.116				
172.50	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147
	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147				
181.50	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217
	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217				
190.50	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420
	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420				
201.00	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420
	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420				

---------- MASS BALANCE SUMMARY FOR TIME STEP 709 ----------

PUMPING PERIOD NUMBER 4

Table 11.--*Partial listing of output to file 6, the main output file, for example problem 2*--Continued

```
                         TOTAL ELAPSED SIMULATION TIME =  7.700E+01 DAYS

+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                          MASS  THIS    RATE FOR THIS  +
+                                                          TOTAL  MASS    TIME STEP      TIME STEP      +
+                                                            GRAM          GRAM          GRAM/DAYS      +
+     FLUX INTO DOMAIN ACROSS SPECIFIED PRESSURE HEAD BOUNDARIES --   5.73912E+02   0.00000E-01    0.00000E-01  +
+   FLUX OUT OF DOMAIN ACROSS SPECIFIED PRESSURE HEAD BOUNDARIES --  -2.43402E+03  -2.19147E-01   -2.33124E+00  +
+              FLUX INTO DOMAIN ACROSS SPECIFIED FLUX BOUNDARIES --   4.18279E+03   0.00000E-01    0.00000E-01  +
+            FLUX OUT OF DOMAIN ACROSS SPECIFIED FLUX BOUNDARIES --   0.00000E-01   0.00000E-01    0.00000E-01  +
+                                        TOTAL FLUX INTO DOMAIN --   4.75671E+03   0.00000E-01    0.00000E-01  +
+                                      TOTAL FLUX OUT OF DOMAIN --  -2.43402E+03  -2.19147E-01   -2.33124E+00  +
+                                                   EVAPORATION --  -2.19970E+03  -1.10371E-02   -1.17411E-01  +
+                                                 TRANSPIRATION --  -1.95950E+03  -1.26451E+00   -1.3[illegible]516E+01  +
+                                    TOTAL EVAPOTRANSPIRATION --  -4.15920E+03  -1.27555E+00   -1.35690E+01  +
+                               CHANGE IN FLUID STORED IN DOMAIN --  -1.83604E+03  -1.49420E+00   -1.58951E+01  +
+                                            FLUID MASS BALANCE --  -4.72101E-01  -4.88980E-04   -5.20168E-03  +
+                                                                                                          +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
    *******************************************************************************
    END OF SIMULATION
    *******************************************************************************
TOTAL NUMBER OF ITERATIONS =   7418
```

Table 12.--*Partial listing of output to file 7 for example problem 2*

```
 MAXIMUM HEAD CHANGE DURING EACH  ITERATION FOR TIME STEP    1     ,AFTER   1.100E-02 DAYS OF SIMULATION TIME

1.284E+01   1.125E+00   4.284E-01   1.512E-01   6.210E-02   2.177E-02   8.824E-03   3.573E-03
 MAXIMUM HEAD CHANGE DURING EACH  ITERATION FOR TIME STEP    2     ,AFTER   2.310E-02 DAYS OF SIMULATION TIME

8.534E+00   4.098E+02   7.459E+01   7.252E+03   3.089E+03   2.892E+01   8.886E+00   3.759E+00   2.731E+00   1.130E+01
1.594E+01   5.663E+00   1.253E+00   1.101E+00   3.284E+00   1.906E+00   6.309E-01   4.758E-01   9.839E-02   8.113E-02
2.260E-02   9.268E-03   2.163E-03
 MAXIMUM HEAD CHANGE DURING EACH  ITERATION FOR TIME STEP    3     ,AFTER   3.641E-02 DAYS OF SIMULATION TIME

6.085E+00   1.884E+00   5.746E-01   2.386E-01   8.449E-02   3.571E-02   1.152E-02   4.307E-03
 MAXIMUM HEAD CHANGE DURING EACH  ITERATION FOR TIME STEP    4     ,AFTER   5.105E-02 DAYS OF SIMULATION TIME

4.633E+00   1.664E+00   6.158E-01   2.623E-01   8.547E-02   3.327E-02   1.007E-02   4.064E-03
 MAXIMUM HEAD CHANGE DURING EACH  ITERATION FOR TIME STEP    5     ,AFTER   6.716E-02 DAYS OF SIMULATION TIME

4.061E+00   1.639E+00   5.917E-01   2.334E-01   8.244E-02   3.657E-02   1.235E-02   4.718E-03
 MAXIMUM HEAD CHANGE DURING EACH  ITERATION FOR TIME STEP    6     ,AFTER   8.487E-02 DAYS OF SIMULATION TIME

3.722E+00   1.523E+00   5.576E-01   2.542E-01   9.051E-02   3.813E-02   1.170E-02   4.372E-03
 MAXIMUM HEAD CHANGE DURING EACH  ITERATION FOR TIME STEP    7     ,AFTER   1.044E-01 DAYS OF SIMULATION TIME

3.421E+00   1.476E+00   5.821E-01   2.531E-01   8.266E-02   3.839E-02   1.382E-02   5.537E-03   1.691E-03
 MAXIMUM HEAD CHANGE DURING EACH  ITERATION FOR TIME STEP    8     ,AFTER   1.258E-01 DAYS OF SIMULATION TIME

3.478E+00   1.261E+00   5.558E-01   2.227E-01   9.783E-02   3.817E-02   1.559E-02   4.737E-03
 MAXIMUM HEAD CHANGE DURING EACH  ITERATION FOR TIME STEP    9     ,AFTER   1.494E-01 DAYS OF SIMULATION TIME

3.342E+00   1.253E+00   5.982E-01   2.375E-01   9.932E-02   3.642E-02   1.487E-02   5.283E-03   2.110E-03
 MAXIMUM HEAD CHANGE DURING EACH  ITERATION FOR TIME STEP   10     ,AFTER   1.753E-01 DAYS OF SIMULATION TIME

3.404E+00   1.483E+00   5.904E-01   2.602E-01   9.735E-02   4.752E-02   1.751E-02   7.131E-03   2.182E-03
 MAXIMUM HEAD CHANGE DURING EACH  ITERATION FOR TIME STEP   11     ,AFTER   2.038E-01 DAYS OF SIMULATION TIME

3.376E+00   1.240E+00   6.036E-01   2.531E-01   1.115E-01   4.569E-02   1.932E-02   7.465E-03   3.215E-03
 MAXIMUM HEAD CHANGE DURING EACH  ITERATION FOR TIME STEP   12     ,AFTER   2.352E-01 DAYS OF SIMULATION TIME

3.614E+00   1.563E+00   6.419E-01   3.049E-01   1.260E-01   6.555E-02   2.659E-02   1.205E-02   4.344E-03
```

Table 13.--*Partial listing of output to file 8 for example problem 2*

```
TIME =      0.5000E+00 DAYS

-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00
-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00
-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00
 1.500E+00 0.000E-01 0.000E-01 0.000E-01 0.000E-01 0.000E-01 0.000E-01-1.992E-01
-3.271E+00-7.922E+00-1.267E+01-1.818E+01-2.395E+01-2.925E+01-3.360E+01-3.770E+01
-4.052E+01-4.225E+01-4.298E+01-4.323E+01-4.332E+01-4.335E+01-4.336E+01 1.500E+00
 4.500E+00-6.807E-01-6.753E-01-6.642E-01-6.559E-01-6.702E-01-7.986E-01-1.492E+00
-4.592E+00-9.258E+00-1.404E+01-1.964E+01-2.552E+01-3.090E+01-3.527E+01-3.935E+01
-4.211E+01-4.380E+01-4.450E+01-4.474E+01-4.482E+01-4.485E+01-4.486E+01 4.500E+00
 7.500E+00-1.361E+00-1.351E+00-1.328E+00-1.311E+00-1.336E+00-1.570E+00-2.607E+00
-5.734E+00-1.042E+01-1.529E+01-2.106E+01-2.718E+01-3.271E+01-3.712E+01-4.115E+01
-4.380E+01-4.540E+01-4.603E+01-4.625E+01-4.633E+01-4.635E+01-4.636E+01 7.500E+00
 1.125E+01-2.213E+00-2.195E+00-2.158E+00-2.127E+00-2.157E+00-2.487E+00-3.801E+00
-6.939E+00-1.166E+01-1.666E+01-2.276E+01-2.936E+01-3.519E+01-3.967E+01-4.359E+01
-4.602E+01-4.746E+01-4.797E+01-4.815E+01-4.821E+01-4.823E+01-4.824E+01 1.125E+01
 1.575E+01-3.235E+00-3.210E+00-3.154E+00-3.101E+00-3.115E+00-3.481E+00-4.911E+00
-7.980E+00-1.270E+01-1.791E+01-2.461E+01-3.227E+01-3.866E+01-4.322E+01-4.688E+01
-4.889E+01-5.002E+01-5.041E+01-5.054E+01-5.058E+01-5.060E+01-5.060E+01 1.575E+01
 2.100E+01-4.428E+00-4.395E+00-4.317E+00-4.230E+00-4.195E+00-4.507E+00-5.860E+00
-8.707E+00-1.332E+01-1.874E+01-2.637E+01-3.618E+01-4.347E+01-4.776E+01-5.092E+01
-5.250E+01-5.334E+01-5.370E+01-5.382E+01-5.386E+01-5.387E+01-5.387E+01 2.100E+01
 2.700E+01-5.794E+00-5.753E+00-5.649E+00-5.512E+00-5.372E+00-5.480E+00-6.463E+00
-8.772E+00-1.291E+01-1.827E+01-2.698E+01-4.218E+01-4.940E+01-5.323E+01-5.615E+01
-5.779E+01-5.862E+01-5.895E+01-5.905E+01-5.909E+01-5.910E+01-5.910E+01 2.700E+01
 3.300E+01-3.716E+01-3.720E+01-3.735E+01-3.764E+01-3.823E+01-3.936E+01-4.130E+01
-4.413E+01-4.795E+01-5.210E+01-5.628E+01-5.336E+01-5.692E+01-6.046E+01-6.350E+01
-6.515E+01-6.593E+01-6.622E+01-6.631E+01-6.634E+01-6.635E+01-6.635E+01 3.300E+01
 3.900E+01-7.694E+01-7.702E+01-7.731E+01-7.785E+01-7.887E+01-8.060E+01-8.304E+01
-8.585E+01-8.869E+01-9.085E+01-8.807E+01-6.414E+01-6.689E+01-7.000E+01-7.278E+01
-7.425E+01-7.492E+01-7.515E+01-7.523E+01-7.525E+01-7.526E+01-7.526E+01 3.900E+01
 4.650E+01-9.932E+01-9.932E+01-9.934E+01-9.936E+01-9.941E+01-9.949E+01-9.959E+01
-9.968E+01-9.977E+01-9.978E+01-9.788E+01-8.118E+01-8.260E+01-8.439E+01-8.605E+01
-8.691E+01-8.729E+01-8.741E+01-8.745E+01-8.746E+01-8.747E+01-8.747E+01 4.650E+01
 5.550E+01-1.024E+02-1.024E+02-1.024E+02-1.024E+02-1.024E+02-1.024E+02-1.024E+02
-1.024E+02-1.023E+02-1.022E+02-1.014E+02-9.418E+01-9.433E+01-9.475E+01-9.521E+01
-9.547E+01-9.559E+01-9.563E+01-9.565E+01-9.565E+01-9.565E+01-9.565E+01 5.550E+01
 6.450E+01-1.087E+02-1.087E+02-1.087E+02-1.087E+02-1.087E+02-1.086E+02-1.086E+02
-1.085E+02-1.082E+02-1.074E+02-1.054E+02-1.005E+02-9.909E+01-9.872E+01-9.863E+01
-9.864E+01-9.866E+01-9.867E+01-9.867E+01-9.867E+01-9.867E+01-9.867E+01 6.450E+01
 7.350E+01-1.040E+02-1.040E+02-1.040E+02-1.040E+02-1.040E+02-1.040E+02-1.040E+02
-1.039E+02-1.037E+02-1.032E+02-1.023E+02-1.008E+02-9.993E+01-9.956E+01-9.940E+01
-9.936E+01-9.935E+01-9.935E+01-9.935E+01-9.935E+01-9.935E+01-9.935E+01 7.350E+01
 8.400E+01-1.005E+02-1.005E+02-1.005E+02-1.005E+02-1.005E+02-1.005E+02-1.004E+02
-1.004E+02-1.003E+02-1.001E+02-9.981E+01-9.939E+01-9.909E+01-9.892E+01-9.883E+01
-9.879E+01-9.879E+01-9.879E+01-9.879E+01-9.879E+01-9.879E+01-9.879E+01 8.400E+01
 9.750E+01-9.572E+01-9.572E+01-9.572E+01-9.572E+01-9.572E+01-9.572E+01-9.572E+01
-9.571E+01-9.568E+01-9.563E+01-9.556E+01-9.548E+01-9.541E+01-9.537E+01-9.534E+01
-9.533E+01-9.533E+01-9.533E+01-9.533E+01-9.533E+01-9.533E+01-9.533E+01 9.750E+01
 1.125E+02-8.553E+01-8.553E+01-8.553E+01-8.553E+01-8.553E+01-8.553E+01-8.553E+01
```

Table 13.--*Partial listing of output to file 8 for example problem 2*--Continued

```
-8.553E+01-8.552E+01-8.551E+01-8.550E+01-8.549E+01-8.548E+01-8.547E+01-8.546E+01
-8.546E+01-8.546E+01-8.546E+01-8.546E+01-8.546E+01-8.546E+01-8.546E+01 1.125E+02
 1.260E+02-7.339E+01-7.339E+01-7.339E+01-7.339E+01-7.339E+01-7.339E+01-7.339E+01
-7.339E+01-7.339E+01-7.339E+01-7.338E+01-7.338E+01-7.338E+01-7.338E+01-7.338E+01
-7.338E+01-7.338E+01-7.338E+01-7.338E+01-7.338E+01-7.338E+01-7.338E+01 1.260E+02
 1.365E+02-6.320E+01-6.320E+01-6.320E+01-6.320E+01-6.320E+01-6.320E+01-6.320E+01
-6.320E+01-6.320E+01-6.320E+01-6.320E+01-6.320E+01-6.320E+01-6.320E+01-6.320E+01
-6.320E+01-6.320E+01-6.320E+01-6.320E+01-6.320E+01-6.320E+01-6.320E+01 1.365E+02
 1.440E+02-5.576E+01-5.576E+01-5.576E+01-5.576E+01-5.576E+01-5.576E+01-5.576E+01
-5.576E+01-5.576E+01-5.576E+01-5.576E+01-5.576E+01-5.576E+01-5.576E+01-5.576E+01
-5.576E+01-5.576E+01-5.576E+01-5.576E+01-5.576E+01-5.576E+01-5.576E+01 1.440E+02
 1.500E+02-4.995E+01-4.995E+01-4.995E+01-4.995E+01-4.995E+01-4.995E+01-4.995E+01
-4.995E+01-4.995E+01-4.995E+01-4.995E+01-4.995E+01-4.995E+01-4.995E+01-4.995E+01
-4.995E+01-4.995E+01-4.995E+01-4.995E+01-4.995E+01-4.995E+01-4.995E+01 1.500E+02
 1.560E+02-4.392E+01-4.392E+01-4.392E+01-4.392E+01-4.392E+01-4.392E+01-4.392E+01
-4.392E+01-4.392E+01-4.392E+01-4.392E+01-4.392E+01-4.392E+01-4.392E+01-4.392E+01
-4.392E+01-4.392E+01-4.392E+01-4.392E+01-4.392E+01-4.392E+01-4.392E+01 1.560E+02
 1.635E+02-3.583E+01-3.583E+01-3.583E+01-3.583E+01-3.583E+01-3.583E+01-3.583E+01
-3.583E+01-3.583E+01-3.583E+01-3.583E+01-3.583E+01-3.583E+01-3.583E+01-3.583E+01
-3.583E+01-3.583E+01-3.583E+01-3.583E+01-3.583E+01-3.583E+01-3.583E+01 1.635E+02
 1.725E+02-2.502E+01-2.502E+01-2.502E+01-2.502E+01-2.502E+01-2.502E+01-2.502E+01
-2.502E+01-2.502E+01-2.502E+01-2.502E+01-2.502E+01-2.502E+01-2.502E+01-2.502E+01
-2.502E+01-2.502E+01-2.502E+01-2.502E+01-2.502E+01-2.502E+01-2.502E+01 1.725E+02
 1.815E+02-1.553E+01-1.553E+01-1.553E+01-1.553E+01-1.553E+01-1.553E+01-1.553E+01
-1.553E+01-1.553E+01-1.553E+01-1.553E+01-1.553E+01-1.553E+01-1.553E+01-1.553E+01
-1.553E+01-1.553E+01-1.553E+01-1.553E+01-1.553E+01-1.553E+01-1.553E+01 1.815E+02
 1.905E+02-6.504E+00-6.504E+00-6.504E+00-6.504E+00-6.504E+00-6.504E+00-6.504E+00
-6.504E+00-6.504E+00-6.504E+00-6.504E+00-6.504E+00-6.504E+00-6.504E+00-6.504E+00
-6.504E+00-6.504E+00-6.504E+00-6.504E+00-6.504E+00-6.504E+00-6.504E+00 1.905E+02
 2.010E+02 4.000E+00 4.000E+00 4.000E+00 4.000E+00 4.000E+00 4.000E+00 4.000E+00
 4.000E+00 4.000E+00 4.000E+00 4.000E+00 4.000E+00 4.000E+00 4.000E+00 4.000E+00
 4.000E+00 4.000E+00 4.000E+00 4.000E+00 4.000E+00 4.000E+00 4.000E+00 2.010E+02
 2.145E+02 2.145E+02 2.145E+02 2.145E+02 2.145E+02 2.145E+02 2.145E+02 2.145E+02
 2.145E+02 2.145E+02 2.145E+02 2.145E+02 2.145E+02 2.145E+02 2.145E+02 2.145E+02
 2.145E+02 2.145E+02 2.145E+02 2.145E+02 2.145E+02 2.145E+02 2.145E+02 2.145E+02

 TIME =      0.1000E+01 DAYS

-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00
-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00
-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00-1.500E+00
 1.500E+00-1.182E+00-1.213E+00-1.289E+00-1.411E+00-1.648E+00-2.105E+00-2.868E+00
-3.919E+00-5.279E+00-6.675E+00-8.367E+00-1.025E+01-1.214E+01-1.390E+01-1.588E+01
-1.784E+01-1.970E+01-2.130E+01-2.250E+01-2.340E+01-2.421E+01-2.469E+01 1.500E+00
 4.500E+00-2.681E+00-2.711E+00-2.786E+00-2.906E+00-3.140E+00-3.589E+00-4.339E+00
-5.378E+00-6.730E+00-8.127E+00-9.837E+00-1.175E+01-1.366E+01-1.542E+01-1.740E+01
-1.936E+01-2.122E+01-2.282E+01-2.402E+01-2.491E+01-2.572E+01-2.620E+01 4.500E+00
 7.500E+00-4.180E+00-4.209E+00-4.282E+00-4.397E+00-4.622E+00-5.056E+00-5.783E+00
-6.796E+00-8.129E+00-9.530E+00-1.127E+01-1.325E+01-1.520E+01-1.698E+01-1.896E+01
-2.091E+01-2.276E+01-2.435E+01-2.554E+01-2.643E+01-2.724E+01-2.772E+01 7.500E+00
 1.125E+01-6.053E+00-6.080E+00-6.148E+00-6.255E+00-6.465E+00-6.870E+00-7.553E+00
-8.515E+00-9.813E+00-1.121E+01-1.302E+01-1.513E+01-1.716E+01-1.897E+01-2.095E+01
-2.289E+01-2.472E+01-2.629E+01-2.746E+01-2.834E+01-2.915E+01-2.962E+01 1.125E+01
 1.575E+01-8.300E+00-8.323E+00-8.382E+00-8.476E+00-8.659E+00-9.013E+00-9.616E+00
```

Table 14.--*Partial listing of output to file 9 for example problem 2*

EXAMPLE PROBLEM 2 -- 2D INFILTRATION AND EVAPOTRANSPIRATION
MASS BALANCE RATE COMPONENTS

TIME, DAYS	FLXIN1	FLXOUT1	FLXIN2	FLXOUT2	TOTAL ET	TRANSP	EVAP	DELS	ERROR	%ERROR
1.1000E-02	1.3903E+04	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	1.6086E+04	6.7183E+01	4.1765E-01
2.3100E-02	5.0474E+03	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	7.2973E+03	9.5385E-02	1.3071E-03
3.6410E-02	1.4246E+03	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.6739E+03	6.3628E-01	1.7319E-02
5.1051E-02	1.0009E+03	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	3.2505E+03	3.4934E-01	1.0747E-02
6.7156E-02	6.8259E+02	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.9323E+03	2.8760E-01	9.8081E-03
8.4072E-02	4.5972E+02	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.7095E+03	2.6311E-01	9.7107E-03
1.0436E-01	3.1224E+02	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.5622E+03	8.3544E-02	3.2607E-03
1.2579E-01	2.1870E+02	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.4684E+03	2.5068E-01	1.0155E-02
1.4937E-01	1.6078E+02	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.4107E+03	6.4883E-02	2.6914E-03
1.7531E-01	1.2486E+02	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.3748E+03	8.9743E-02	3.7790E-03
2.0384E-01	1.0177E+02	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.3517E+03	8.2061E-02	3.4895E-03
2.3523E-01	8.5788E+01	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.3357E+03	1.2406E-01	5.3116E-03
2.6975E-01	7.3656E+01	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.3236E+03	5.7585E-02	2.4783E-03
3.0772E-01	6.3654E+01	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.3136E+03	6.1632E-02	2.6639E-03
3.4950E-01	5.4967E+01	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.3050E+03	7.7483E-03	3.3616E-04
3.9545E-01	4.7260E+01	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.2972E+03	1.9091E-02	8.3103E-04
4.4599E-01	4.6413E+02	0.0000E-01	1.8000E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.2643E+03	-1.8322E-01	-8.0918E-03
5.0000E-01	6.8036E+02	0.0000E-01	1.4625E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.1429E+03	3.5758E-03	1.6687E-04
5.5941E-01	6.7289E+02	0.0000E-01	1.5750E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.2479E+03	-4.3071E-02	-1.9160E-03
6.2476E-01	5.8482E+02	0.0000E-01	1.6875E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.2723E+03	2.4223E-02	1.0660E-03
6.9664E-01	2.1480E+01	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.2716E+03	-8.5520E-02	-3.7648E-03
7.7572E-01	1.8461E+01	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.2685E+03	1.6925E-03	7.4610E-05
8.6270E-01	1.5980E+01	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.2659E+03	3.8591E-02	1.7031E-03
9.5838E-01	1.3944E+01	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.2639E+03	3.2101E-02	1.4180E-03
1.0000E+00	1.3167E+01	0.0000E-01	2.2500E+03	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	2.2631E+03	3.6183E-02	1.5988E-03
1.0000E+00	1.3167E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.6620E+01	-2.1303E-01	4.5695E-01
1.0000E+00	1.3166E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.6593E+01	-2.4028E-01	5.1569E-01
1.0001E+00	1.3166E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.6431E+01	-4.0298E-01	8.6791E-01
1.0001E+00	1.3165E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.7094E+01	2.5890E-01	-5.4974E-01
1.0002E+00	1.3163E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.7906E+01	1.0691E+00	-2.2316E+00
1.0003E+00	1.3161E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.8549E+01	1.7099E+00	-3.5220E+00
1.0005E+00	1.3158E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.6790E+01	-5.2290E-02	1.1175E-01
1.0007E+00	1.3153E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.8348E+01	1.5017E+00	-3.1060E+00
1.0011E+00	1.3146E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.6949E+01	9.5216E-02	-2.0281E-01
1.0017E+00	1.3135E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.6989E+01	1.2423E-01	-2.6438E-01
1.0026E+00	1.3119E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.6933E+01	5.2529E-02	-1.1192E-01
1.0039E+00	1.3096E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.6807E+01	-9.7264E-02	2.0780E-01
1.0058E+00	1.3060E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.6786E+01	-1.5391E-01	3.2897E-01
1.0087E+00	1.3007E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.7006E+01	1.2613E-02	-2.6834E-02
1.0131E+00	1.2929E+01	0.0000E-01	0.0000E-01	0.0000E-01	-6.0000E+01	0.0000E-01	-6.0000E+01	-4.7051E+01	-2.0127E-02	4.2778E-02

Table 14.--*Partial listing of output to file 9 for example problem 2*--Continued

```
1.0197E+00 1.2814E+01 0.0000E-01 0.0000E-01 0.0000E-01-6.0000E+01 0.0000E-01-6.0000E+01-4.7173E+01-1.3590E-02 2.8809E-02
1.0295E+00 1.2647E+01 0.0000E-01 0.0000E-01 0.0000E-01-6.0000E+01 0.0000E-01-6.0000E+01-4.7357E+01 4.2330E-03-8.9384E-03
1.0443E+00 1.2407E+01 0.0000E-01 0.0000E-01 0.0000E-01-6.0000E+01 0.0000E-01-6.0000E+01-4.7587E+01-5.7051E-03 1.1989E-02
1.0665E+00 1.2071E+01 0.0000E-01 0.0000E-01 0.0000E-01-6.0000E+01 0.0000E-01-6.0000E+01-4.7879E+01-5.0190E-02 1.0483E-01
1.0997E+00 1.1611E+01 0.0000E-01 0.0000E-01 0.0000E-01-6.0000E+01 0.0000E-01-6.0000E+01-4.8343E+01-4.6056E-02 9.5269E-02
1.1496E+00 1.1002E+01 0.0000E-01 0.0000E-01 0.0000E-01-6.0000E+01 0.0000E-01-6.0000E+01-4.8943E+01-5.5432E-02 1.1326E-01
                  .
                  .
                  .
2.8246E+01 0.0000E-01-1.7558E+01 0.0000E-01 0.0000E-01-1.7875E+01 0.0000E-01-1.7875E+01-3.5403E+01-2.9613E-02 8.3643E-02
2.8746E+01 0.0000E-01-1.6950E+01 0.0000E-01 0.0000E-01-1.7566E+01 0.0000E-01-1.7566E+01-3.4484E+01-3.2543E-02 9.4370E-02
2.9246E+01 0.0000E-01-1.6370E+01 0.0000E-01 0.0000E-01-1.7268E+01 0.0000E-01-1.7268E+01-3.3609E+01-2.8775E-02 8.5619E-02
2.9746E+01 0.0000E-01-1.5813E+01 0.0000E-01 0.0000E-01-1.6981E+01 0.0000E-01-1.6981E+01-3.2762E+01-3.1675E-02 9.6681E-02
3.0246E+01 0.0000E-01-1.5280E+01 0.0000E-01 0.0000E-01-1.6704E+01 0.0000E-01-1.6704E+01-3.1957E+01-2.7990E-02 8.7586E-02
3.0746E+01 0.0000E-01-1.4769E+01 0.0000E-01 0.0000E-01-1.6439E+01 0.0000E-01-1.6439E+01-3.1177E+01-3.0858E-02 9.8975E-02
3.1000E+01 0.0000E-01-1.4515E+01 0.0000E-01 0.0000E-01-1.6307E+01 0.0000E-01-1.6307E+01-3.0784E+01-3.7853E-02 1.2296E-01
3.1011E+01 0.0000E-01-1.4504E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2354E+03 4.8211E-02 2.1566E-03
3.1021E+01 0.0000E-01-1.4494E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2354E+03 7.1540E-02 3.2003E-03
3.1031E+01 0.0000E-01-1.4484E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2354E+03 1.0317E-01 4.6151E-03
3.1041E+01 0.0000E-01-1.4474E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2354E+03 1.4520E-01 6.4956E-03
3.1052E+01 0.0000E-01-1.4463E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2356E+03-5.6936E-02-2.5468E-03
3.1064E+01 0.0000E-01-1.4451E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2356E+03-8.6310E-02-3.8607E-03
3.1077E+01 0.0000E-01-1.4438E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2356E+03-9.2300E-05-4.1287E-06
3.1092E+01 0.0000E-01-1.4424E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2355E+03 4.1446E-02 1.85[illegible]E-03
3.1108E+01 0.0000E-01-1.4408E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2356E+03 1.0324E-02 4.6182E-04
3.1126E+01 0.0000E-01-1.4390E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2356E+03-3.8791E-02-1.7351E-03
3.1145E+01 0.0000E-01-1.4371E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2356E+03 3.4394E-03 1.5384E-04
3.1167E+01 0.0000E-01-1.4350E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2357E+03-1.7020E-02-7.6130E-04
3.1190E+01 0.0000E-01-1.4327E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2357E+03-5.8710E-02-2.6260E-03
3.1216E+01 0.0000E-01-1.4301E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2357E+03 1.4275E-02 6.3851E-04
3.1245E+01 0.0000E-01-1.4273E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2357E+03-5.7894E-03-2.5895E-04
3.1276E+01 0.0000E-01-1.4243E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2358E+03-3.2987E-02-1.4754E-03
3.1311E+01 0.0000E-01-1.4209E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2358E+03-4.9635E-03-2.2200E-04
3.1349E+01 0.0000E-01-1.4173E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2358E+03-1.5580E-02-6.9684E-04
3.1390E+01 0.0000E-01-1.4132E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2359E+03-2.9114E-02-1.3021E-03
3.1436E+01 0.0000E-01-1.4088E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2359E+03-5.5781E-03-2.4948E-04
3.1487E+01 0.0000E-01-1.4040E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2360E+03-1.3782E-02-6.1636E-04
3.1500E+01 0.0000E-01-1.4028E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2359E+03 7.8742E-02 3.5217E-03
3.1514E+01 0.0000E-01-1.4014E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2359E+03 1.0762E-01 4.8135E-03
3.1530E+01 0.0000E-01-1.3999E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2360E+03 3.5720E-02 1.5975E-03
3.1547E+01 0.0000E-01-1.3983E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2360E+03 4.3349E-02 1.9387E-03
3.1566E+01 0.0000E-01-1.3964E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2360E+03 6.3500E-02 2.8399E-03
```

Table 14.--Partial listing of output to file 9 for example problem 2--Continued

```
3.1587E+01 0.0000E-01-1.3945E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2360E+03 3.1372E-02 1.4030E-03
3.1610E+01 0.0000E-01-1.3923E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2360E+03 5.4956E-02 2.4578E-03
3.1636E+01 0.0000E-01-1.3899E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2360E+03 1.0403E-01 4.6524E-03
3.1664E+01 0.0000E-01-1.3873E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2361E+03 6.1882E-02 2.7675E-03
3.1694E+01 0.0000E-01-1.3844E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2361E+03 6.6665E-02 2.9813E-03
3.1728E+01 0.0000E-01-1.3813E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2361E+03 5.1629E-02 2.3088E-03
3.1765E+01 0.0000E-01-1.3778E+01 2.2500E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2361E+03 7.2315E-02 3.2339E-03
3.1806E+01 1.6447E+02-1.3741E+01 2.0812E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2321E+03-8.3598E-02-3.7454E-03
3.1851E+01 3.5150E+02-1.3699E+01 1.2937E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 1.6316E+03-1.6521E-02-1.0126E-03
3.1900E+01 5.5488E+02-1.3654E+01 1.2937E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 1.8348E+03 1.4695E-01 8.0089E-03
3.1955E+01 7.4038E+02-1.3605E+01 1.3781E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.1050E+03-8.7142E-02-4.1398E-03
3.2000E+01 6.4926E+02-1.3564E+01 1.5750E+03 0.0000E-01 0.0000E-01 0.0000E-01 0.0000E-01 2.2107E+03 3.8475E-02 1.7404E-03
3.2000E+01 0.0000E-01-1.3564E+01 0.0000E-01 0.0000E-01-6.9000E+01-9.0001E+00-6.0000E+01-9.7408E+02 8.9152E+02-9.1524E+01
3.2000E+01 0.0000E-01-1.3564E+01 0.0000E-01 0.0000E-01-6.9000E+01-9.0002E+00-6.0000E+01-8.2593E+01 2.8560E-02-3.4579E-02
3.2000E+01 0.0000E-01-1.3564E+01 0.0000E-01 0.0000E-01-6.9000E+01-9.0003E+00-6.0000E+01-8.3017E+01 4.5249E-01-5.4506E-01
3.2000E+01 0.0000E-01-1.3564E+01 0.0000E-01 0.0000E-01-6.9001E+01-9.0005E+00-6.0000E+01-8.2815E+01 2.5112E-01-3.0322E-01
3.2000E+01 0.0000E-01-1.3564E+01 0.0000E-01 0.0000E-01-6.9001E+01-9.0009E+00-6.0000E+01-8.3030E+01 4.6587E-01-5.6109E-01
3.2000E+01 0.0000E-01-1.3564E+01 0.0000E-01 0.0000E-01-6.9001E+01-9.0014E+00-6.0000E+01-8.3043E+01 4.7752E-01-5.7503E-01
3.2000E+01 0.0000E-01-1.3563E+01 0.0000E-01 0.0000E-01-6.9002E+01-9.0022E+00-6.0000E+01-8.2547E+01-1.8726E-02 2.2686E-02
      .
      .
      .
4.7028E+01 0.0000E-01-3.1708E+01 0.0000E-01 0.0000E-01-9.2154E+01-7.6626E+01-1.5528E+01-1.2384E+02-2.5257E-02 2.0395E-02
4.7053E+01 0.0000E-01-3.1640E+01 0.0000E-01 0.0000E-01-9.1482E+01-7.6739E+01-1.4743E+01-1.2310E+02-2.0783E-02 1.6883E-02
4.7082E+01 0.0000E-01-3.1562E+01 0.0000E-01 0.0000E-01-9.0911E+01-7.6869E+01-1.4041E+01-1.2245E+02-2.7239E-02 2.2246E-02
4.7115E+01 0.0000E-01-3.1471E+01 0.0000E-01 0.0000E-01-9.0429E+01-7.7020E+01-1.3409E+01-1.2188E+02-2.3058E-02 1.8919E-02
4.7154E+01 0.0000E-01-3.1367E+01 0.0000E-01 0.0000E-01-9.0027E+01-7.7194E+01-1.2833E+01-1.2136E+02-3.0411E-02 2.5058E-02
4.7200E+01 0.0000E-01-3.1245E+01 0.0000E-01 0.0000E-01-8.9701E+01-7.7398E+01-1.2303E+01-1.2094E+02-9.1717E-03 7.5839E-03
4.7253E+01 0.0000E-01-3.1102E+01 0.0000E-01 0.0000E-01-8.9445E+01-7.7637E+01-1.1808E+01-1.2054E+02-1.0223E-02 8.4810E-03
4.7316E+01 0.0000E-01-3.0933E+01 0.0000E-01 0.0000E-01-8.9261E+01-7.7922E+01-1.1339E+01-1.2018E+02-1.1669E-02 9.7092E-03
4.7392E+01 0.0000E-01-3.0732E+01 0.0000E-01 0.0000E-01-8.9150E+01-7.8263E+01-1.0887E+01-1.1987E+02-1.3684E-02 1.1416E-02
4.7484E+01 0.0000E-01-3.0488E+01 0.0000E-01 0.0000E-01-8.9118E+01-7.8677E+01-1.0441E+01-1.1959E+02-1.6547E-02 1.3836E-02
      .
      .
      .
7.6906E+01 0.0000E-01-2.3541E+00 0.0000E-01 0.0000E-01-1.3585E+01-1.3467E+01-1.1790E-01-1.5918E+01-2.1308E-02 1.3386E-01
7.7000E+01 0.0000E-01-2.3312E+00 0.0000E-01 0.0000E-01-1.3569E+01-1.3452E+01-1.1741E-01-1.5895E+01-5.2017E-03 3.2725E-02
```

Table 15.--*Partial listing of output to file 11 for example problem 2*

```
EXAMPLE PROBLEM 2 -- 2D INFILTRATION AND EVAPOTRANSPIRATION
MONITORING POINT FILE
  TIME, DAYS   XR,    CM    Z,     CM    H,      CM     P,     CM    THETA       SAT
  0.000E-01   1.125E+01   1.500E+00  -1.015E+02  -1.000E+02   3.479E-01   7.732E-01
  0.000E-01   1.125E+01   2.700E+01  -1.270E+02  -1.000E+02   3.479E-01   7.732E-01
  0.000E-01   1.462E+02   2.700E+01  -1.270E+02  -1.000E+02   3.479E-01   7.732E-01
  0.000E-01   1.537E+02   2.700E+01  -1.270E+02  -1.000E+02   3.479E-01   7.732E-01
  0.000E-01   2.887E+02   2.700E+01  -1.270E+02  -1.000E+02   3.479E-01   7.732E-01
  0.000E-01   1.125E+01   3.300E+01  -1.330E+02  -1.000E+02   1.280E-01   3.200E-01
  0.000E-01   1.462E+02   3.300E+01  -1.330E+02  -1.000E+02   1.280E-01   3.200E-01
  0.000E-01   1.537E+02   3.300E+01  -1.330E+02  -1.000E+02   3.479E-01   7.732E-01
  0.000E-01   2.887E+02   3.300E+01  -1.330E+02  -1.000E+02   3.479E-01   7.732E-01
  0.000E-01   1.125E+01   1.440E+02  -2.000E+02  -5.600E+01   4.303E-01   9.562E-01
  1.100E-02   1.125E+01   1.500E+00  -8.721E+01  -8.571E+01   3.671E-01   8.158E-01
  1.100E-02   1.125E+01   2.700E+01  -1.265E+02  -9.952E+01   3.485E-01   7.744E-01
  1.100E-02   1.462E+02   2.700E+01  -1.265E+02  -9.954E+01   3.485E-01   7.744E-01
  1.100E-02   1.537E+02   2.700E+01  -1.270E+02  -9.998E+01   3.480E-01   7.732E-01
  1.100E-02   2.887E+02   2.700E+01  -1.270E+02  -1.000E+02   3.479E-01   7.732E-01
  1.100E-02   1.125E+01   3.300E+01  -1.329E+02  -9.994E+01   1.280E-01   3.201E-01
  1.100E-02   1.462E+02   3.300E+01  -1.329E+02  -9.994E+01   1.280E-01   3.201E-01
  1.100E-02   1.537E+02   3.300E+01  -1.330E+02  -1.000E+02   3.479E-01   7.732E-01
  1.100E-02   2.887E+02   3.300E+01  -1.330E+02  -1.000E+02   3.479E-01   7.732E-01
  1.100E-02   1.125E+01   1.440E+02  -2.000E+02  -5.600E+01   4.303E-01   9.562E-01
  2.310E-02   1.125E+01   1.500E+00  -7.822E+01  -7.672E+01   3.820E-01   8.490E-01
  2.310E-02   1.125E+01   2.700E+01  -1.260E+02  -9.904E+01   3.491E-01   7.757E-01
  2.310E-02   1.462E+02   2.700E+01  -1.261E+02  -9.910E+01   3.490E-01   7.756E-01
  2.310E-02   1.537E+02   2.700E+01  -1.269E+02  -9.994E+01   3.480E-01   7.733E-01
  2.310E-02   2.887E+02   2.700E+01  -1.270E+02  -1.000E+02   3.479E-01   7.732E-01
  2.310E-02   1.125E+01   3.300E+01  -1.329E+02  -9.986E+01   1.281E-01   3.202E-01
  2.310E-02   1.462E+02   3.300E+01  -1.329E+02  -9.987E+01   1.281E-01   3.202E-01
  2.310E-02   1.537E+02   3.300E+01  -1.330E+02  -9.999E+01   3.479E-01   7.732E-01
  2.310E-02   2.887E+02   3.300E+01  -1.330E+02  -1.000E+02   3.479E-01   7.732E-01
  2.310E-02   1.125E+01   1.440E+02  -2.000E+02  -5.600E+01   4.303E-01   9.562E-01
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                  .
  1.705E+01   1.125E+01   1.500E+00  -2.051E+02  -2.036E+02   2.792E-01   6.204E-01
  1.705E+01   1.125E+01   2.700E+01  -1.537E+02  -1.267E+02   3.217E-01   7.149E-01
  1.705E+01   1.462E+02   2.700E+01  -1.831E+02  -1.561E+02   3.015E-01   6.701E-01
  1.705E+01   1.537E+02   2.700E+01  -1.827E+02  -1.557E+02   3.018E-01   6.706E-01
  1.705E+01   2.887E+02   2.700E+01  -1.917E+02  -1.647E+02   2.967E-01   6.594E-01
  1.705E+01   1.125E+01   3.300E+01  -1.436E+02  -1.106E+02   1.234E-01   3.085E-01
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Table 15.--Partial listing of output to file 11 for example problem 2--Continued

1.705E+01	1.462E+02	3.300E+01	-1.721E+02	-1.391E+02	1.145E-01	2.863E-01
1.705E+01	1.537E+02	3.300E+01	-1.783E+02	-1.453E+02	3.082E-01	6.849E-01
1.705E+01	2.887E+02	3.300E+01	-1.855E+02	-1.525E+02	3.037E-01	6.748E-01
1.705E+01	1.125E+01	1.440E+02	-1.783E+02	-3.433E+01	4.500E-01	1.000E+00
1.710E+01	1.125E+01	1.500E+00	-2.062E+02	-2.047E+02	2.788E-01	6.195E-01
1.710E+01	1.125E+01	2.700E+01	-1.541E+02	-1.271E+02	3.214E-01	7.142E-01
1.710E+01	1.462E+02	2.700E+01	-1.834E+02	-1.564E+02	3.013E-01	6.696E-01
1.710E+01	1.537E+02	2.700E+01	-1.829E+02	-1.559E+02	3.016E-01	6.703E-01
1.710E+01	2.887E+02	2.700E+01	-1.918E+02	-1.648E+02	2.967E-01	6.593E-01
1.710E+01	1.125E+01	3.300E+01	-1.439E+02	-1.109E+02	1.233E-01	3.083E-01
1.710E+01	1.462E+02	3.300E+01	-1.723E+02	-1.393E+02	1.144E-01	2.861E-01
1.710E+01	1.537E+02	3.300E+01	-1.785E+02	-1.455E+02	3.081E-01	6.846E-01
1.710E+01	2.887E+02	3.300E+01	-1.856E+02	-1.526E+02	3.036E-01	6.747E-01
1.710E+01	1.125E+01	1.440E+02	-1.784E+02	-3.435E+01	4.500E-01	1.000E+00
	. . .					
3.111E+01	1.125E+01	1.500E+00	-8.497E+01	-8.347E+01	3.706E-01	8.235E-01
3.111E+01	1.125E+01	2.700E+01	-2.537E+02	-2.267E+02	2.711E-01	6.025E-01
3.111E+01	1.462E+02	2.700E+01	-2.370E+02	-2.100E+02	2.768E-01	6.151E-01
3.111E+01	1.537E+02	2.700E+01	-2.222E+02	-1.952E+02	2.825E-01	6.277E-01
3.111E+01	2.887E+02	2.700E+01	-2.137E+02	-1.867E+02	2.861E-01	6.357E-01
3.111E+01	1.125E+01	3.300E+01	-2.106E+02	-1.776E+02	1.070E-01	2.676E-01
3.111E+01	1.462E+02	3.300E+01	-2.154E+02	-1.824E+02	1.063E-01	2.658E-01
3.111E+01	1.537E+02	3.300E+01	-2.093E+02	-1.763E+02	2.908E-01	6.463E-01
3.111E+01	2.887E+02	3.300E+01	-2.060E+02	-1.730E+02	2.925E-01	6.499E-01
3.111E+01	1.125E+01	1.440E+02	-1.850E+02	-4.100E+01	4.500E-01	1.000E+00
3.113E+01	1.125E+01	1.500E+00	-7.946E+01	-7.796E+01	3.798E-01	8.440E-01
3.113E+01	1.125E+01	2.700E+01	-2.537E+02	-2.267E+02	2.711E-01	6.025E-01
3.113E+01	1.462E+02	2.700E+01	-2.371E+02	-2.101E+02	2.768E-01	6.151E-01
3.113E+01	1.537E+02	2.700E+01	-2.223E+02	-1.953E+02	2.825E-01	6.277E-01
3.113E+01	2.887E+02	2.700E+01	-2.138E+02	-1.868E+02	2.861E-01	6.357E-01
3.113E+01	1.125E+01	3.300E+01	-2.106E+02	-1.776E+02	1.070E-01	2.676E-01
3.113E+01	1.462E+02	3.300E+01	-2.154E+02	-1.824E+02	1.063E-01	2.658E-01
3.113E+01	1.537E+02	3.300E+01	-2.094E+02	-1.764E+02	2.908E-01	6.463E-01
3.113E+01	2.887E+02	3.300E+01	-2.060E+02	-1.730E+02	2.925E-01	6.499E-01
3.113E+01	1.125E+01	1.440E+02	-1.850E+02	-4.100E+01	4.500E-01	1.000E+00
	. . .					
4.405E+01	1.125E+01	1.500E+00	-2.549E+02	-2.534E+02	2.633E-01	5.851E-01
4.405E+01	1.125E+01	2.700E+01	-1.747E+02	-1.477E+02	3.066E-01	6.814E-01

Table 15.--*Partial listing of output to file 11 for example problem 2--Continued*

4.405E+01	1.462E+02	2.700E+01	-2.133E+02	-1.863E+02	2.862E-01	6.361E-01
4.405E+01	1.537E+02	2.700E+01	-2.058E+02	-1.788E+02	2.897E-01	6.437E-01
4.405E+01	2.887E+02	2.700E+01	-2.169E+02	-1.899E+02	2.847E-01	6.326E-01
4.405E+01	1.125E+01	3.300E+01	-1.488E+02	-1.158E+02	1.215E-01	3.036E-01
4.405E+01	1.462E+02	3.300E+01	-1.812E+02	-1.482E+02	1.124E-01	2.810E-01
4.405E+01	1.537E+02	3.300E+01	-1.929E+02	-1.599E+02	2.993E-01	6.652E-01
4.405E+01	2.887E+02	3.300E+01	-2.021E+02	-1.691E+02	2.944E-01	6.542E-01
4.405E+01	1.125E+01	1.440E+02	-1.794E+02	-3.545E+01	4.500E-01	1.000E+00
4.408E+01	1.125E+01	1.500E+00	-2.574E+02	-2.559E+02	2.626E-01	5.836E-01
4.408E+01	1.125E+01	2.700E+01	-1.754E+02	-1.484E+02	3.062E-01	6.804E-01
4.408E+01	1.462E+02	2.700E+01	-2.142E+02	-1.872E+02	2.859E-01	6.353E-01
4.408E+01	1.537E+02	2.700E+01	-2.064E+02	-1.794E+02	2.894E-01	6.431E-01
4.408E+01	2.887E+02	2.700E+01	-2.174E+02	-1.904E+02	2.845E-01	6.322E-01
4.408E+01	1.125E+01	3.300E+01	-1.491E+02	-1.161E+02	1.213E-01	3.033E-01
4.408E+01	1.462E+02	3.300E+01	-1.816E+02	-1.486E+02	1.123E-01	2.808E-01
4.408E+01	1.537E+02	3.300E+01	-1.934E+02	-1.604E+02	2.991E-01	6.647E-01
4.408E+01	2.887E+02	3.300E+01	-2.025E+02	-1.695E+02	2.942E-01	6.538E-01
4.408E+01	1.125E+01	1.440E+02	-1.795E+02	-3.546E+01	4.500E-01	1.000E+00
	.					
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5.878E+01	1.125E+01	1.500E+00	-7.729E+03	-7.727E+03	1.646E-01	3.657E-01
5.878E+01	1.125E+01	2.700E+01	-3.995E+03	-3.968E+03	1.717E-01	3.817E-01
5.878E+01	1.462E+02	2.700E+01	-3.865E+03	-3.838E+03	1.722E-01	3.826E-01
5.878E+01	1.537E+02	2.700E+01	-2.199E+03	-2.172E+03	1.812E-01	4.027E-01
5.878E+01	2.887E+02	2.700E+01	-2.043E+03	-2.016E+03	1.826E-01	4.059E-01
5.878E+01	1.125E+01	3.300E+01	-8.303E+02	-7.973E+02	8.602E-02	2.151E-01
5.878E+01	1.462E+02	3.300E+01	-8.891E+02	-8.561E+02	8.561E-02	2.140E-01
5.878E+01	1.537E+02	3.300E+01	-1.478E+03	-1.445E+03	1.899E-01	4.219E-01
5.878E+01	2.887E+02	3.300E+01	-1.396E+03	-1.363E+03	1.913E-01	4.251E-01
5.878E+01	1.125E+01	1.440E+02	-1.860E+02	-4.201E+01	4.500E-01	1.000E+00
5.885E+01	1.125E+01	1.500E+00	-7.750E+03	-7.748E+03	1.646E-01	3.657E-01
5.885E+01	1.125E+01	2.700E+01	-4.012E+03	-3.985E+03	1.717E-01	3.815E-01
5.885E+01	1.462E+02	2.700E+01	-3.884E+03	-3.857E+03	1.721E-01	3.825E-01
5.885E+01	1.537E+02	2.700E+01	-2.275E+03	-2.248E+03	1.806E-01	4.013E-01
5.885E+01	2.887E+02	2.700E+01	-2.124E+03	-2.097E+03	1.819E-01	4.042E-01
5.885E+01	1.125E+01	3.300E+01	-8.322E+02	-7.992E+02	8.601E-02	2.150E-01
5.885E+01	1.462E+02	3.300E+01	-8.919E+02	-8.589E+02	8.559E-02	2.140E-01
5.885E+01	1.537E+02	3.300E+01	-1.528E+03	-1.495E+03	1.891E-01	4.201E-01
5.885E+01	2.887E+02	3.300E+01	-1.456E+03	-1.423E+03	1.902E-01	4.227E-01
5.885E+01	1.125E+01	1.440E+02	-1.860E+02	-4.204E+01	4.500E-01	1.000E+00
	.					

Table 15.--*Partial listing of output to file 11 for example problem 2--Continued*

7.691E+01	1.125E+01	1.500E+00	-1.078E+04	-1.078E+04	1.619E-01	3.599E-01
7.691E+01	1.125E+01	2.700E+01	-6.147E+03	-6.120E+03	1.668E-01	3.706E-01
7.691E+01	1.462E+02	2.700E+01	-6.116E+03	-6.089E+03	1.668E-01	3.707E-01
7.691E+01	1.537E+02	2.700E+01	-5.610E+03	-5.583E+03	1.677E-01	3.727E-01
7.691E+01	2.887E+02	2.700E+01	-5.619E+03	-5.592E+03	1.677E-01	3.727E-01
7.691E+01	1.125E+01	3.300E+01	-9.976E+02	-9.646E+02	8.498E-02	2.124E-01
7.691E+01	1.462E+02	3.300E+01	-1.168E+03	-1.135E+03	8.423E-02	2.106E-01
7.691E+01	1.537E+02	3.300E+01	-1.852E+03	-1.819E+03	1.847E-01	4.105E-01
7.691E+01	2.887E+02	3.300E+01	-1.913E+03	-1.880E+03	1.840E-01	4.090E-01
7.691E+01	1.125E+01	1.440E+02	-1.918E+02	-4.775E+01	4.500E-01	1.000E+00
7.700E+01	1.125E+01	1.500E+00	-1.079E+04	-1.079E+04	1.619E-01	3.599E-01
7.700E+01	1.125E+01	2.700E+01	-6.155E+03	-6.128E+03	1.668E-01	3.706E-01
7.700E+01	1.462E+02	2.700E+01	-6.124E+03	-6.097E+03	1.668E-01	3.707E-01
7.700E+01	1.537E+02	2.700E+01	-5.617E+03	-5.590E+03	1.677E-01	3.727E-01
7.700E+01	2.887E+02	2.700E+01	-5.626E+03	-5.599E+03	1.677E-01	3.726E-01
7.700E+01	1.125E+01	3.300E+01	-9.981E+02	-9.651E+02	8.497E-02	2.124E-01
7.700E+01	1.462E+02	3.300E+01	-1.168E+03	-1.135E+03	8.423E-02	2.106E-01
7.700E+01	1.537E+02	3.300E+01	-1.853E+03	-1.820E+03	1.847E-01	4.105E-01
7.700E+01	2.887E+02	3.300E+01	-1.914E+03	-1.881E+03	1.840E-01	4.090E-01
7.700E+01	1.125E+01	1.440E+02	-1.918E+02	-4.778E+01	4.500E-01	1.000E+00

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DOCUMENTATION OF COMPUTER PROGRAM VS2D TO SOLVE THE EQUATIONS OF FLUID FLOW IN VARIABLY SATURATED POROUS MEDIA

By E. G. Lappala, R. W. Healy, and E. P. Weeks

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LIST OF SYMBOLS

A = area of grid-block face, L^2

A' = scaling length in Haverkamp relative hydraulic conductivity function, L

$[A]$ = coefficient matrix

$[\bar{A}]$ = linear equivalent of $[A]$

B' = exponent in Haverkamp relative hydraulic conductivity function, L^0

$[B]$ = matrix containing all conductance terms of $[\bar{A}]$

c_m = specific moisture capacity, L^{-1}

C = mass concentration of solutes in liquid in Van't Hoff Law, ML^{-3}

$\hat{C}$ = conductance to liquid across a grid-block face, $ML^{-1}T^{-1}$

$\bar{C}$ = volumetric lumped storage term for a given cell, ML^{-1}

D = ratio between hydraulic conductivity and specific storage, or hydraulic diffusivity, for saturated systems, L^2T^{-1}

E_∞ = evaporation rate from bare soil overlying shallow water table, LT^{-1}

EV = evaporation rate, LT^{-1}

f_1 = specified-liquid-flux function, MT^{-1}

f_2 = specified-total-potential function, L

g = gravitational acceleration, LT^{-2}

G = arbitrary function

$[G_s]$ = diagonal matrix of storage terms, used in Newton-Raphson linearization

h = relative humidity of soil gas, L^0

h_a = relative humidity of air, L^0

h = pressure potential expressed as the height of a column of water, L

h_b = bubbling or air-entry pressure potential, L

h_m = pressure potential of water in soil in block m surrounding a root, L

h_o = osmotic pressure potential, L

h_{pond} = pressure potential corresponding to depth of ponding, L

h_{root} = pressure potential in plant root, L

h_z = elevation or position potential, L

H = total potential, L

H_A = water pressure potential of the atmosphere, L

H^{*k} = residual vector at kth iteration

HKLL = lumped harmonic mean saturated hydraulic conductivity term for left side of finite-difference cell, L^2T^{-1}

HKTT = lumped harmonic mean saturated conductivity term for top side of finite-difference cell, L^2T^{-1}

i = index to time steps, L^o

j = index to finite-difference grid in the horizontal (x or r) direction, L^o

k = reference index to a face of grid block, L^o

$\bar{\bar{K}}$ = intrinsic permeability, L^2

K = saturated hydraulic conductivity, LT^{-1}

K_{xx}, K_{zz} = saturated hydraulic conductivity in the x and z directions, LT^{-1}

$\tilde{K}$ = linearized unsaturaturated hydraulic conductivity, LT^{-1}

K_r = relative hydraulic conductivity to liquid, L^o

L = length of horizontal column, L

M_w = mass of a mole of water, M Mol^{-1}

m = reference index to an arbitrary grid block, L

m = dimension of coefficient matrix equal to the number of rows times the number of columns

$\hat{m}$ = number of faces in arbitrary grid block

$\bar{m}$ = number of volume subdivisions in column

n = index to finite-difference grid in the vertical (z) direction, L^o

n = general coordinate direction, L^o

$\hat{p}$ = water-vapor pressure in the soil atmosphere, $ML^{-1}T^{-2}$

$\hat{p}_o$ = saturated water-vapor pressure over a flat surface of pure water, $ML^{-1}T^{-2}$

$\bar{P}$ = average water pressure, $ML^{-1}T^{-2}$.

PEV = potential evaporation rate, LT^{-1}

PET = potential evapotranspiration rate, LT^{-1}

$\hat{Q}$ = evapotranspiration flux from a surface area, MT^{-1}

q = volumetric flux per unit volume, T^{-1}

$\hat{q}$ = volumetric discharge, L^3T^{-1}

q_m = liquid flux to roots in block m, MT^{-1}

r = radial coordinate, L

r_c = radius of a capillary tube, L

$r(z,t)$	= root activity factor, L^{-2}
R	= ideal gas constant, $ML^2T^{-2}K^{-1}$ Mol^{-1}
R_m	= resistance of soil in block m, TL
R_{root}	= resistance of root system, TL
RHS	= vector containing all known quantities in flow equation
S_s	= specific storage, L^{-1}
s	= liquid saturation, L^0
$\bar{s}$	= surface of an arbitrary volume, L^2
s_e	= effective saturation, L^0
t	= time, T
t_{pond}	= ponding time, T
T	= absolute temperature, K
$\vec{u}_n$	= liquid flux normal to n, LT^{-1}
v	= volume of a grid block, L^3
w_k	= damping factor, computed for the kth iteration, used in SIP, L^0
W	= surface flux rate, LT^{-1}
x	= horizontal coordinate, L
y	= horizontal coordinate direction orthogonal to x and z, L
z	= vertical coordinate, positive downward, L
α	= scaling length in Haverkamp equation relating saturation to pressure, L
α_c	= matrix compressibility, LT^2M^{-1}
α'	= scaling length in van Genuchten equation relating saturation to pressure, L
$\hat{\alpha}$	= contact angle between liquid and solid
$\bar{\alpha},\bar{\beta}$	= weighting coefficients for upstream weighting for hydraulic conductivity, L^0
β	= exponent in Haverkamp equation relating saturation to pressure, L
β'	= exponent in van Genuchten equation relating saturation to pressure, L^0
β_c	= liquid compressibility, LT^2M^{-1}
β_s	= damping factor used in SIP algorithm, L^0
γ	= second exponent in van Genuchten equation, L^0
λ	= pore size distribution index in Brooks-Corey equation, L^0
ρ	= liquid mass density, ML^{-3}
$\bar{\sigma}$	= surface tension of liquid against air, MT^{-2}

μ = dynamic viscosity of liquid, $ML^{-1}T^{-1}$

θ = volumetric moisture content, L^{o}

θ_r = residual moisture content, L^{o}

ϕ = porosity, L^{o}

METRIC CONVERSION FACTORS

The International System of Units (SI) used in this report may be converted to inch-pound units by the following conversion factors:

Multiply	*By*	*To obtain*
centimeter (cm)	.03281	foot
centimeter (cm)	.3937	inch
gram (gm)	.002205	pound
kilopascal (kPa)	.01450	pound per square inch
meter (m)	3.281	foot
millimeter (mm)	.03937	inch

To convert degree Celsius (°C) to degree Fahrenheit (°F), use the following formula: (°Cx9/5)+32=°F. To convert Kelvin (K) to degree Rankin (°R), use the following formula: Kx1.8=°R.

DOCUMENTATION OF COMPUTER PROGRAM VS2D TO SOLVE THE EQUATIONS

OF FLUID FLOW IN VARIABLY SATURATED POROUS MEDIA

By E. G. Lappala, R. W. Healy, and E. P. Weeks

ABSTRACT

This report documents a computer code for solving problems of variably saturated, single-phase flow in porous media. The mathematical model of this physical process is developed by combining the law of conservation of fluid mass with a nonlinear form of Darcy's law. The resultant mathematical model, or flow equation, is written with total hydraulic potential as the dependent variable. This allows straightforward treatment of both saturated and unsaturated conditions. The spatial derivatives in the flow equation are approximated by central differences written about grid-block boundaries. Time derivatives are approximated by a fully implicit backward scheme. Nonlinear storage terms are linearized by an implicit Newton-Raphson method. Nonlinear conductance terms, boundary conditions, and sink terms are linearized implicitly. Relative hydraulic conductivity is evaluated at cell boundaries by using full upstream weighting, the arithmetic mean, or the geometric mean of values from adjacent cells. Saturated hydraulic conductivities are evaluated at cell boundaries by using distance-weighted harmonic means. The linearized matrix equations are solved using the strongly implicit procedure.

Nonlinear conductance and storage coefficients are assumed to be represented by one of three closed-form algebraic equations. Alternatively, these values may be interpolated from tabulated data. Nonlinear boundary conditions treated by the code include infiltration, evaporation, and seepage faces. Extraction by plant roots is included as a nonlinear sink term.

The code is written in standard ANSI Fortran. Extensive use of subroutines and function subprograms provides a modular code that is easily modified. A complete listing of data-input requirements and input and output for a one-dimensional infiltration problem and for a two-dimensional problem involving infiltration, evaporation, and evapotranspiration (plant-root extraction) are included.

INTRODUCTION

This report documents VS2D, a computer program for simulating isothermal, two-dimensional movement of liquid water in variably saturated porous media. Understanding the occurrence and movement of water in variably saturated systems is important for developing predictive tools for managing both quantity and quality of ground water within ground-water flow systems. Recharge to aquifer systems generally occurs through overlying materials that are variably saturated. Land-use activities may alter both quantity and quality of recharge. Prediction of the fate of pollutants applied to the land surface or buried above the zone of permanent saturation requires estimates of the rate of moisture movement. VS2D provides a user-oriented tool for examining such problems. Although an attempt has been made to make the model general enough to handle many field situations, its use should be accompanied by a thorough understanding of the theoretical and practical limitations described herein. Field applications exist for which the model is not appropriate; an example would be evapotranspiration in which significant anisothermal movement of water vapor as well as liquid water occurs. However, such problems can be analyzed by modifying the basic isothermal model. This model does not include solution of the equations for movement of solutes.

The code has been verified for two one-dimensional transient linear problems and one one-dimensional steady-state nonlinear problem for which analytical solutions exist, and against two nonlinear problems for which experimental data exist.

An extensive review (Lappala, 1981) of the literature on numerical modeling of variably saturated flow was conducted during the development of this program. Based on this review, the model was developed to include the following features:

1. Capability to handle problems in which part of the mathematical solution domain is saturated and part is unsaturated.

2. Capability to handle "difficult" nonlinear problems, such as those caused by infiltration into dry soils and by discontinuities in permeabilities and porosities. This capability is best met by using finite differences to discretize the spatial and temporal domains. Adequate solutions of nonlinear equations using finite-element discretization in space require such numerical tricks as lumping the capacity (storage) term over each element. The upstream weighting of relative hydraulic conductivities that may be required to prevent numerical oscillations is more difficult with finite elements than with finite differences. Finally, the algebraic equations resulting from a finite-element spatial-discretization scheme generally require more computer core storage and time to solve than those resulting from a finite-difference scheme (Lappala, 1981).

3. Capability to analyze problems in one and two dimensions with planar or cylindrical geometries.

4. A modular structure to simplify program modification.

These features are described more completely below.

THEORETICAL DEVELOPMENT

The equation that describes the movement of liquid water under isothermal and isohaline conditions is developed by combining the equation for conservation of mass for water with auxiliary equations for fluid flux and storage.

Conservation of Mass

Given a volume of porous medium, v, bounded by a surface $\bar{s}$ as shown in figure 1, conservation of mass for liquid water requires that the following equation be satisfied:

$$\int_v \frac{\partial(\rho s \phi)}{\partial t} dv + \int_{\bar{s}} \rho \vec{u}_n d\bar{s} - \int_v \rho q dv = 0 , \qquad (1)$$

where:
- ρ = liquid density, ML^{-3};
- s = liquid saturation, L°;
- ϕ = porosity, L°;
- t = time, T;
- $\vec{u}_n$ = liquid flux per unit area in the direction n, which is normal to $\bar{s}$, LT^{-1}; and
- q = volumetric source-sink term accounting for liquid added to (+q) or taken away from (-q) the volume v, per unit volume per unit time, T^{-1}.

Equation 1 states that the rate of change of mass stored in v must be balanced by the sum of liquid flux across the surface boundary of v and of liquid added by sources or removed at sinks.

It is assumed that the volume v is small enough that within v, the liquid density (ρ), saturation (s), and porosity (ϕ) can be considered constant "representative" values, so that the first term of equation 1 can be expressed as:

$$\int_v \frac{\partial(\rho s \phi)}{\partial t} dv = v \frac{\partial(\rho s \phi)}{\partial t} ,$$

and the third term as:

$$\int_v \rho q dv = \rho q v .$$

Equation 1 becomes:

$$v \frac{\partial(\rho s \phi)}{\partial t} + \int_{\bar{s}} \rho \vec{u}_n d\bar{s} - \rho q v = 0 . \qquad (2)$$

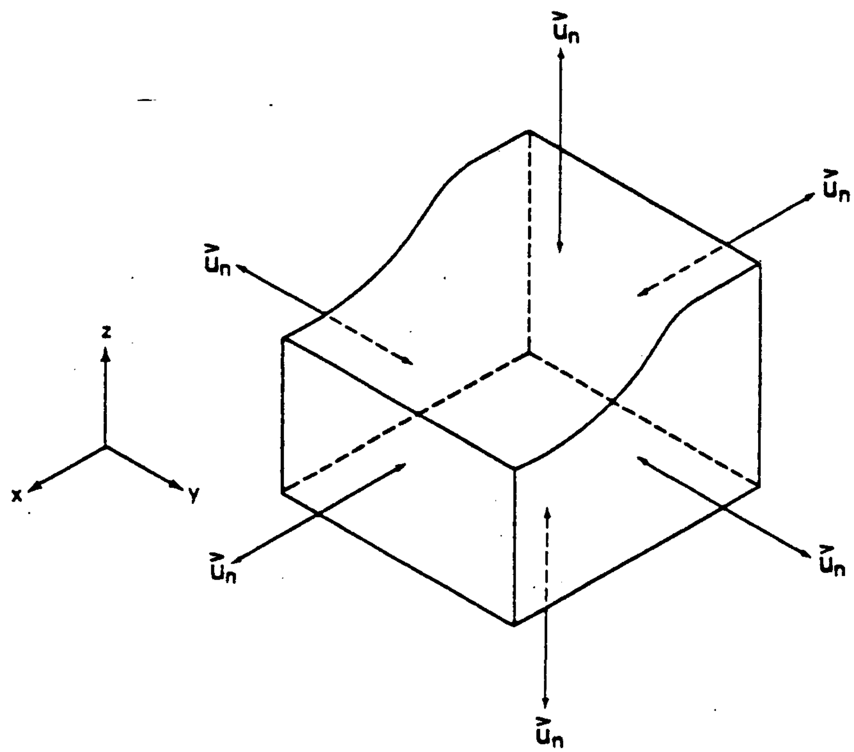


Figure 1.--General volume element, v, used for developing a fluid mass balance. ($\vec{u}$ is liquid flux normal to face.)

<u>Fluid-Flux Equation</u>

The fluid flux normal to the surface $\bar{s}$ bounding v is described by Darcy's law extended to variably saturated conditions:

$$\vec{u}_n = - \frac{\bar{\bar{k}} K_r(h) \rho g}{\mu} \frac{\partial H}{\partial n} , \tag{3}$$

where: $\bar{\bar{K}}$ = intrinsic permeability of the medium, L^2;

$K_r(h)$ = relative hydraulic conductivity to liquid as a function of pressure head, L^0;

h = pressure head, L;

g = gravitational acceleration, LT^{-2};

μ = dynamic viscosity of the liquid, $ML^{-1}T^{-1}$; and

H = total potential of the liquid, expressed as the height of a column of the liquid, L.

The saturated hydraulic conductivity, K, commonly used as a lumped term in hydrology is

$$K = \frac{\bar{\bar{K}}\rho g}{\mu}, \quad LT^{-1} .$$

Because density and viscosity are assumed to be constant in the program, saturated hydraulic conductivity is used as a medium property in the remainder of this report, rather than intrinsic permeability. However, dynamic viscosity, μ, for water is strongly temperature dependent, changing by about 3 percent per °C in the common ambient temperature range. The program user should take this temperature dependence into account when formulating his simulation problem.

The effective hydraulic conductivity defined as $KK_r(h)$,LT^{-1}, is sometimes used as the lumped conductivity term; however, in this program K_r is determined by a function call, so the two terms (K and K_r) are maintained as separate entities.

Under variably saturated conditions, total hydraulic potential, H, is comprised of two components:

$$H = h + h_z , \tag{4}$$

where: h_z = elevation potential, L.

Below the water table, the pressure potential is proportional to the weight of the overlying water and increases with depth. Above the water table, water is held in porous media by adsorptive and capillary forces. Flow under unsaturated conditions generally occurs only when water is held by capillary forces, which can be illustrated by the capillary-rise equation (Stallman, 1964):

$$h = \frac{2\,\bar{\sigma}\cos\hat{\alpha}}{r_c \rho g} , \tag{5}$$

where: $\bar{\sigma}$ = surface tension of water against the gas phase, MT^{-2};

$\hat{\alpha}$ = contact angle between liquid and solid measured through the liquid (taken to be 0 degrees for water in contact with most media); and

r_c = radius of the capillary, L.

The capillary-rise principle embodied in equation 5 adequately describes the occurrence and movement of water in relatively coarse-grained materials, such as silt, sand, and gravel. However, if the media contain a large fraction of clay-size material, adsorption forces may be dominant in controlling the occurrence and movement of water.

Pressure head below the water table is often measured in piezometers or wells. Above the water table, small negative pressure heads (less than about 100 kPa) can be measured by using tensiometers, which couple the measuring fluid in a manometer, vacuum gage, or pressure transducer to water in the partially saturated medium through a porous membrane. The operation of tensiometers is described in various soil physics texts, including Hillel (1971), Baver and others (1972), and Kirkham and Powers (1972).

The pressure status of water held under large negative pressure (greater than 100 kPa) may be measured using thermocouple psychrometers (Wiebe and others, 1971), which measure the relative humidity of the gas phase within the medium. Determination of pressure head from a thermocouple psychrometer measurement is made using the thermodynamic relation, commonly called the Kelvin equation, developed by Edelfson and Anderson (1943, p. 145):

$$h = \frac{RT}{M_w g} \ln \frac{\hat{p}}{\hat{p}_o} = \frac{RT}{M_w g} \ln (\mathit{h}) \quad (6)$$

where: R = ideal gas constant, $ML^2T^{-2}{}^{\circ}K^{-1}\ Mol^{-1}$;

T = absolute temperature, °K;

M_w = mass of water, $M\ Mol^{-1}$;

$\hat{p}$ = water-vapor pressure in the soil atmosphere, $ML^{-1}T^{-2}$;

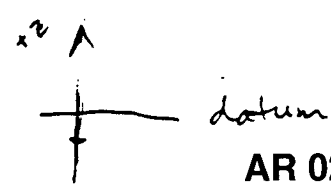
$\hat{p}_o$ = vapor pressure over a flat surface of pure water; and

h = relative humidity, L^0.

Other symbols were defined previously.

Thermocouple psychrometers measure the combined hydraulic and osmotic potential (described hereafter), and thus may result in measured potentials at variance with those measured by tensiometers.

Elevation potential, h_z, is a measure of the gravitational potential resulting from position relative to a selected reference datum. The convention used in this report is taken as z being positive upward, with the datum at or above the land surface; thus, elevation potential is always negative.



The model solves for the total hydraulic potential, H, as the principal dependent variable. As such, the individual components of H are not solved for explicitly. However, model applications to field situations should be made using equations 4 through 7 to gain an adequate understanding of the relation between field measurements of components of H and the simulated values.

If osmotic membranes and chemical gradients are present, water may move in response to osmotic potential, as well as to hydraulic potential. The magnitude of the osmotic potential across a perfect membrane is given by the Van't Hoff law (Campbell, 1977, p. 26):

$$h_o \cong \frac{CRT}{g} , \qquad (7)$$

where: h_o = osmotic potential, L; and

C = molal solute concentration, Mol M^{-1}.

Osmotic potential affects movement in the liquid phase only when an osmotic membrane is present. However, the liquid-water surface acts as such a membrane to the vapor phase, and relative humidity will be affected by the concentration of solutes in the liquid phase. Modeling of water movement due to osmotic-potential gradients would require the inclusion of solute concentrations within the liquid, membrane properties of the medium, and possibly movement in the vapor phase. Although this program does not include provision for such modeling, the effects of osmotic potential on water movement in the prototype system should be considered when formulating the simulation model.

Total hydraulic potential, H, was chosen as the principal independent variable because it allows a simple unified treatment of both saturated and unsaturated conditions. Interfaces between saturated and unsaturated regions are surfaces where the pressure potential is equal to the atmospheric pressure potential, or zero. Along these interfaces, the total potential equals the elevation potential (fig. 2).

When equation 3 is substituted into equation 2, the following results:

$$v \frac{\partial(\rho s \phi)}{\partial t} - \int_{\bar{s}} \rho K K_r(h) \frac{\partial H}{\partial n} d\bar{s} - \rho q v = 0 , \qquad (8)$$

where all terms are reducible to units of mass per unit time (MT^{-1}).

If all the quantities under the surface integral can be considered constant over each of $\hat{m}$ faces of a general curvilinear polygonal volume, v, such as a cube or cylinder, equation 8 can be approximated by:

$$v \frac{\partial(\rho s \phi)}{\partial t} - \sum_{k=1}^{\hat{m}} \rho K K_r(h) A_k \frac{\partial H}{\partial n_k} - \rho q v = 0 , \qquad (9)$$

where A_k is the area of the kth face to which n_k is orthogonal.

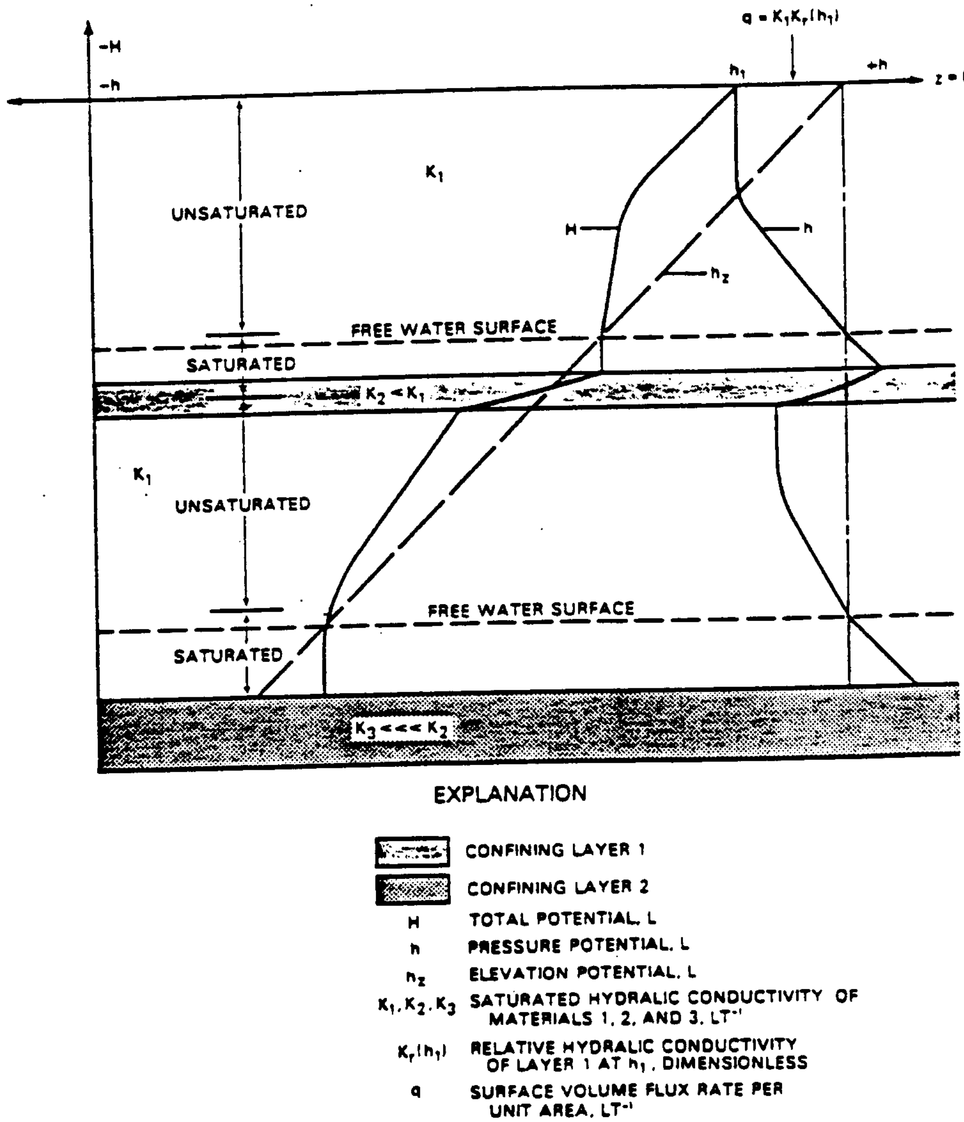


Figure 2.--Relations among capillary, elevation, and total potentials for downward flux through layered media with a perched water table and a deep water table.

Storage Term

Liquid water held in storage is expressed by the first term in equation 8 and can be expanded as follows using the product rule:

$$v \frac{\partial(\rho s \phi)}{\partial t} = v \left[\rho\phi \left(\frac{\partial s}{\partial t}\right) + \rho s \left(\frac{\partial \phi}{\partial t}\right) + s\phi \left(\frac{\partial \rho}{\partial t}\right) \right] . \qquad (10)$$

The three terms in parentheses on the right-hand side of equation 10 account for changes in liquid stored in v owing to: (1) Changes in liquid saturation, (2) compression or expansion of pore space of the porous medium; and (3) compression or expansion of the liquid.

Because the principal dependent variable used in the model is total hydraulic potential, H, the storage terms are written in terms of H by using the chain rule of calculus to yield:

$$v \frac{\partial(\rho s \phi)}{\partial t} = v \left[\rho\phi \left(\frac{\partial s}{\partial H}\right) + \rho s \left(\frac{\partial \phi}{\partial H}\right) + s\phi \left(\frac{\partial \rho}{\partial H}\right) \right] \frac{\partial H}{\partial t} . \qquad (11)$$

The functional dependence of s, ϕ, and ρ on H is taken to be independent of all components of H except the pressure potential, h. The following expressions can be defined:

$c_m = \frac{\partial \theta}{\partial h}$ = specific moisture capacity, which is the slope of the moisture retention curve, L^{-1};

$\alpha_c = \frac{\partial \phi}{\partial \bar{P}}$ = matrix compressibility, $M^{-1}LT^2$, where P = average pressure, $ML^{-1}T^{-2}$;

$\beta_c = \frac{1}{\rho}\frac{\partial \rho}{\partial \bar{P}}$ = fluid compressibility, $M^{-1}LT^2$;

and $S_s = \rho g(\phi\beta_c + \alpha_c)$ = specific storage, L^{-1}. (12)

Substituting equations 11 and 12 into equation 9 yields the following equation, which is written for each volume subdivision within the solution domain:

$$v \{\rho[c_m + sS_s]\} \frac{\partial H}{\partial t} - \rho \sum_{k=1}^{\hat{m}} A_k KK_r(h) \frac{\partial H}{\partial n_k} - \rho q v = 0 . \qquad (13)$$

This is the form of the nonlinear flow equation that is solved by the computer code.

Initial Conditions

The solution to equation 13 requires that initial values of H be specified everywhere in the solution domain. These initial conditions usually represent some type of steady state or equilibrium. If initial conditions are used that do not represent steady state, any simulation results will include transient effects from the difference between specified initial conditions and equilibrium conditions. Since equation 13 is nonlinear, it is not permissible to use the principle of superposition to subtract out the effects of transient initial conditions, as is often done in simulating fully saturated ground-water systems, in which the aquifer properties are not a function of total potential.

Boundary Conditions

Solutions to equation 13 require boundary conditions that specify either the flux of liquid across the boundary, the total potential along the boundary, or some combination of specified head and specified flux. The specified flux boundary can be expressed as:

$$\rho \vec{u}_k = f_1(x,t,\nabla H,h)_k \ , \tag{14}$$

where

$f_1\ (x,t,\nabla H,h)_k$ = a general function that depends upon position, time, the gradient in total hydraulic potential across the face, and the pressure head at the face.

Boundary conditions that specify only the total potential are defined as:

$$H_k = f_2(x,t,\nabla H,h)_k \ , \tag{15}$$

where f_2 is a general time-dependent function.

Four phenomena can occur in flow through variably saturated media that may make a *priori* specification of the boundary condition type impossible: infiltration, evaporation, plant-root extraction, and discharge through seepage faces. These processes are described immediately below, and their implementation into the computer code is described later.

Infiltration and Ponding

Infiltration of water into a thick uniform medium from rainfall or sprinkler irrigation is a two-stage process. During the first stage, water enters the system at the applied rate as long as the conductive and sorptive capacities of the medium are not exceeded. If these capacities are exceeded, water ponds on the surface and infiltration decreases asymptotically to a rate equal to the saturated hydraulic conductivity of the medium.

Rubin and Steinhardt (1964), Rubin (1966), and Smith (1972) present extensive discussions of the ponding process. This is an important concept in rainfall-runoff analysis, because surface runoff cannot occur until ponding has begun. The ponding process is illustrated in figure 3 and is summarized as follows for a uniform medium with a deep water table. At land surface, two boundary conditions are possible:

1. Vertical flux of liquid specified by equation 14, equal to the application rate prior to the time ponding occurs, t_{pond}; and

2. Specified pressure potential (eq. 15) equal to the maximum height of ponding after ponding occurs.

The point in time that the boundary type changes, t_{pond}, must, therefore, be determined during simulation.

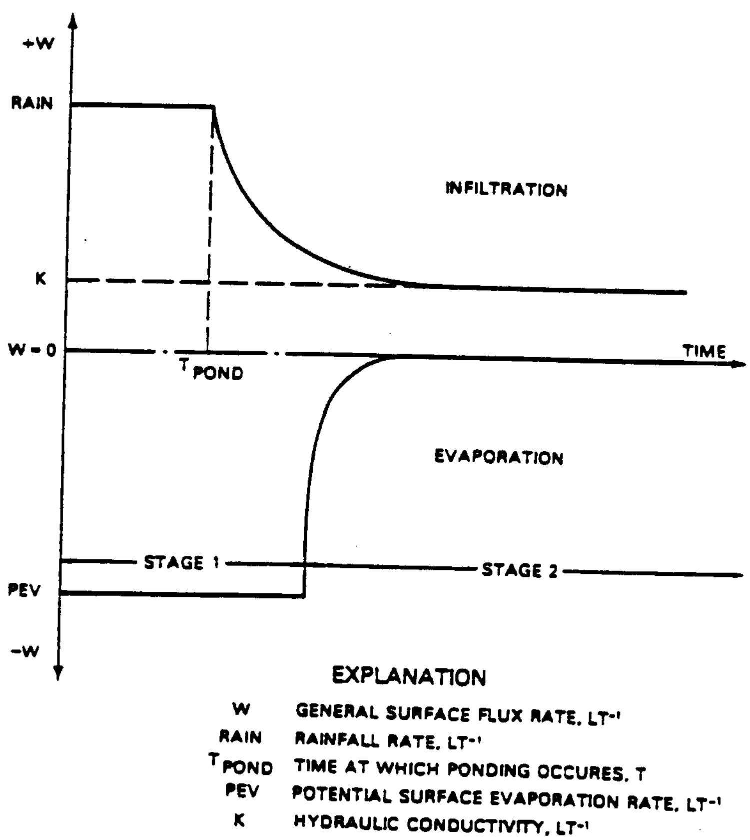


Figure 3.--Infiltration and evaporation as two-stage processes.

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Infiltration into a layered medium is a more complicated process. If a thin surface layer of fine-grained materials overlies a coarser layer, infiltrated water will initially be retained above the interface between the layers. This phenomenon occurs because the water at the wetting front is under too low a pressure head to enter the larger openings constituting the pore space of the coarse layer, resulting in a head and saturation buildup above the interface before breakthrough occurs. As head builds up at the interface, the potential gradient may become too small to maintain infiltration at the applied rate, and ponding may occur. Once flow commences into the coarse layer, however, the pressure head above the interface declines, and the infiltration rate again increases. Thus, the ponding process is still governed by either a specified flux or a specified pressure potential, but it is possible for the specified pressure-potential boundary condition to revert to one of specified flux.

Evaporation

The applicable boundary condition at land surface where evaporation can occur is determined by both the potential evaporative demand of the atmosphere and the ability of the porous medium to conduct water to the surface. Thus, it is a two-stage process analogous to infiltration (Hillel, 1971, p. 191). During the first stage of evaporation, occurring when the soil surface is wet, liquid leaves the system at a rate equal to the evaporative demand of the atmosphere, referred to here as potential evaporation rate (PEV). This rate will continue as long as the medium can conduct water to the surface at a rate equal to this demand. In the absence of sources of liquid in the system, such as a shallow water table, this conductive capability will be reduced by drying of the surface layer, and the rate of discharge by evaporation will be reduced. This process is illustrated in figure 3.

The two-stage evaporation process thus is expressed by two possible boundary conditions at land surface:

1. Specified liquid flux equal to the potential evaporative demand, until liquid cannot be conducted fast enough to meet this demand.

2. Specified flux driven by the gradient in pressure potential between the soil and the atmosphere.

The point in time that the boundary condition type changes must be determined during simulation; details of the numerical implementation of this determination are given later in this report.

Caution should be exercised in using VS2D to simulate bare-soil evaporation. The potential evaporation rate depends on a number of factors, including the energy and radiation balance, air temperature and humidity, soil-surface temperature, aerodynamic roughness, pressure potential, wind speed, and atmospheric stability. Most of these factors show great diurnal variation and would require a sophisticated simulation, such as that used by Bristow (1983) to be accurately simulated. Instead, potential evaporation is treated simplistically in VS2D as an empirically determined value that is allowed to vary in time in a user-defined manner. This degree of detail probably is all that is warranted in an isothermal model. Nonetheless, the user should be well aware that much empiricism is involved in the representation of potential evaporation in VS2D.

Evapotranspiration

Evapotranspiration occurs when the soil surface supports vegetative cover, and is similar to evaporation except that soil moisture can be removed by plant-root extraction throughout the depth of rooting. As with evaporation, evapotranspiration is a two-step process. The rate at which water is extracted from a soil column containing roots is limited by the amount of available energy to the potential evapotranspiration rate, PET. However, the rate of extraction is also limited by the rate at which the soil can transmit water to the roots and may, therefore, be less than PET.

Plant-root extraction is apportioned among the cells in a vertical column containing roots through the use of a depth- and time-dependent root activity function (Molz, 1981), defined as the length of roots per unit volume of soil. Examples of root-activity functions are shown in figure 4. The root-activity function $r(z,t)$ is used to compute the bulk resistance to flow in the root system, and using a development similar to Hillel (1971), root extraction is expressed as the quotient of the pressure-potential difference divided by the combined resistance to flow imposed by the soil and the roots:

$$(v\rho q)_m = v \frac{\rho(h_{root} - h_m)}{R_m + R_{root_m}} , \quad \text{if } h_m > h_{root} \text{ and}$$

$$(v\rho q)_m = 0 , \quad h_m \leq h_{root} ; \qquad (16)$$

where
- h_m = pressure potential in the soil in volume m, L;
- h_{root} = pressure potential in the plant roots, L;
- R_m = resistance to flow in the soil towards the roots, in volume m, TL; and
- R_{root_m} = resistance to flow in the roots occurring in volume m, TL;

The resistance term, $(R_m + R_{root_m})$ is expressed as $1/[KK_r(h)r(z,t)]$ in the program.

Transpiration from the soil column is the sum of the fluxes computed by equation 16 over all cells containing roots in that column:

$$\hat{Q} = \rho \sum_{m=1}^{\bar{m}} (vq)_m \qquad (17)$$

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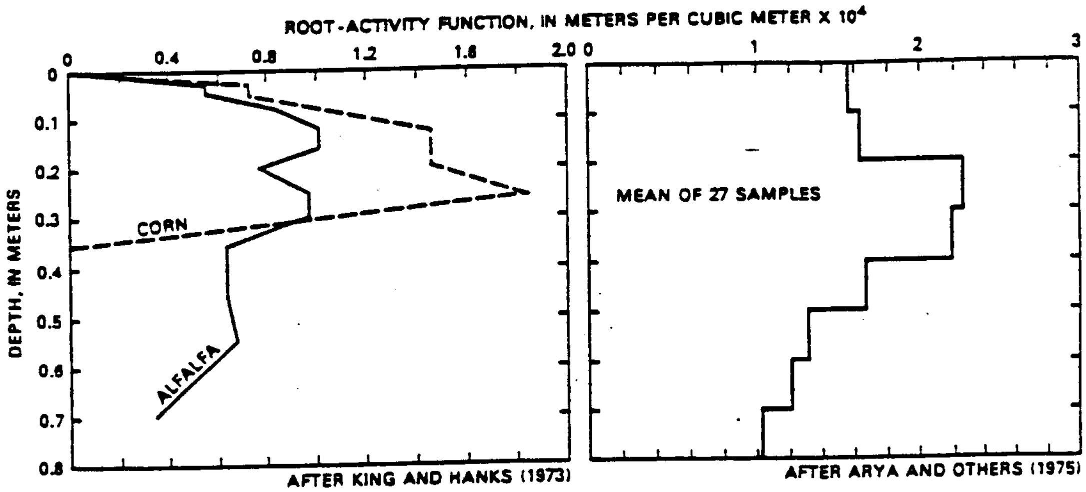

Figure 4.--Examples of root-activity functions.

where $\bar{m}$ is the number of volume subdivisions in the column. If $\hat{Q}/(\rho x A)$, where A is the top surface area of cells in the column, is greater in magnitude than PET, q_m for each node is reduced by a uniform factor so that the two terms are equal. If the magnitude of $\hat{Q}/(\rho x A)$ is less than PET, q_m remains as originally computed. Finally, if h_m becomes less than h_{root}, q_m is set to 0. In each case, q_m becomes a specified flux for that node, dependent on the above conditions. Because q_m is dependent on pressure potential in the soil and on $K_r(h)$, its value must be evaluated iteratively.

Further details of the numerical implementation of this procedure are given in following sections of this report.

As with potential evaporation, potential evapotranspiration is dependent on many variables, except that additional variables related to the plant cover, including vertical and horizontal density of leaf cover, canopy height, leaf cover per unit surface area, plant-water potential, resistance and plant phenology of leaf stomata to vapor transport are involved (Sudar and others, 1981; Norman and Campbell, 1983).

Potential evapotranspiration is treated simplistically in VS2D as an empirically determined value that can vary in time in a manner similar to that of potential evaporation. Potential evapotranspiration for a freely transpiring perennial crop such as alfalfa may be computed using the Penman equation (Campbell, 1977; Jensen, 1973) the Jensen-Haise equation, or one of several other equations listed by Jensen (1973). Crop factors, empirical factors by which the above potential evapotranspiration values are adjusted for different crops or vegetation types and for vegetation growth stage, are also given by Jensen (1973).

Most equations estimating potential evapotranspiration provide daily average values. However, when water is not limiting, evapotranspiration varies dramatically during the day, from near zero during the nighttime hours to a peak slightly lagging the solar radiation peak at solar noon. On clear days, in fact, potential evapotranspiration can be represented by a rectified sine function with reasonable accuracy, thus resulting in peak demand being about π times the mean daily rate. This peak use rate will be attenuated much earlier during the drying phase than would be the case for an average evaporative demand over the entire day.

Seepage Faces

Seepage faces are boundaries along which liquid leaves the system and along which the total potential is equal to the elevation potential, $H = h_z$. Seepage faces exist along interfaces between the surface of the solution domain and the atmosphere, such as along stream banks, spring discharge zones, and well bores that tap unconfined aquifers. Examples of these types of boundaries are shown in figure 5.

The boundary condition along a seepage face is one of specified potential with the requirement that liquid leave the system. These boundaries are nonlinear, in the sense that the top of a seepage face is not known a *priori* and must be determined as part of the solution (Narasimhan and Witherspoon, 1977).

Source-Sink Terms

The general source-sink term, ρqv, included in equation 13, accounts for liquid introduced into or removed from the system at points that do not lie along boundaries. An important class of sink term, plant-root extraction, has been discussed above under "Evapotranspiration". Other source-sink terms would be those specified in time and space, such as withdrawal or injection by wells, suction lysimeters, or drip-irrigation devices. Such specified fluxes may result in problems when applied to the unsaturated zone, either because the specified withdrawal may exceed the capacity of the unsaturated soil to transmit water, or because unrealistically high pressure potential may be required to achieve the injection rate. On the other hand, use of specific source-sink terms in a saturated portion of the cross section to simulate, say, well withdrawal, well injection, or deep basin leakage is straightforward.

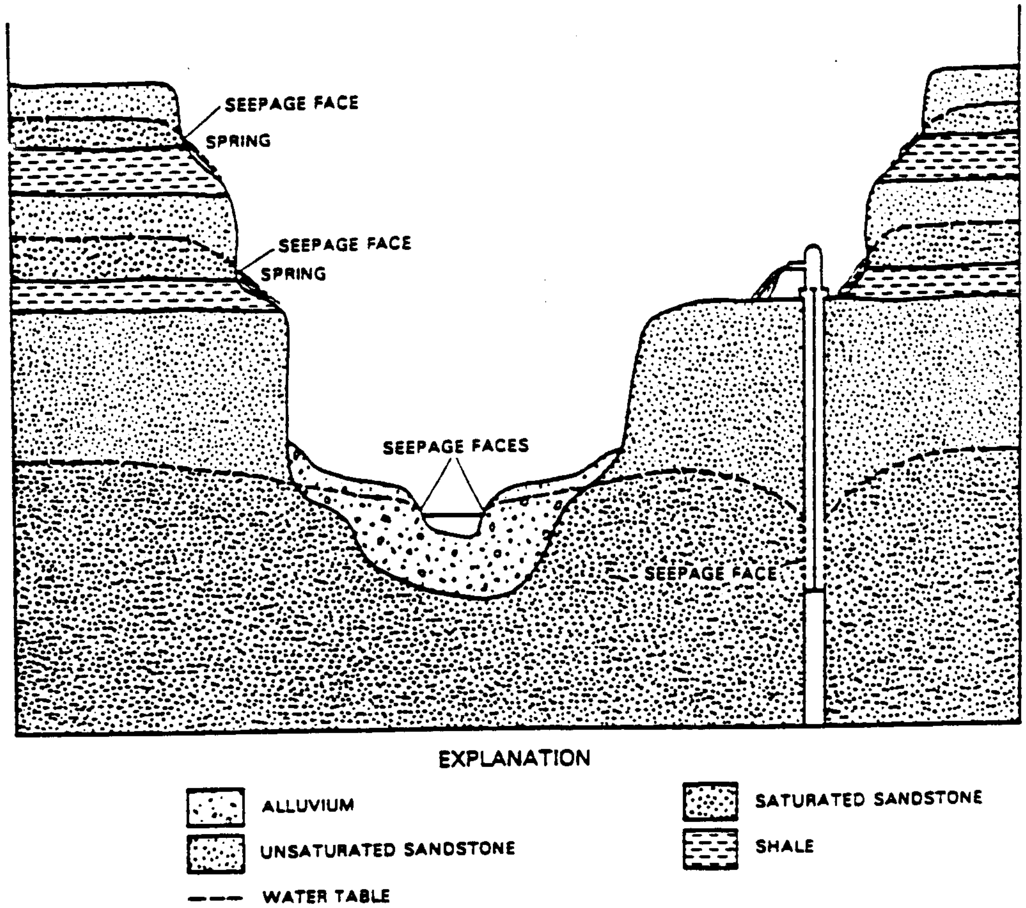

Figure 5.--Examples of seepage faces.

Nonlinear Coefficient Functions

The coefficients in equation 13 that appear in the storage and fluid flux terms are, in general, nonlinear functions of the pressure potential. Several general functional relations for porous media have been developed and tabulated in the literature. Although a given medium may exhibit behavior not described by the general models, a brief description of those that fit a wide range of media is useful. The functional relations required by the program described in this report are:

1. Volumetric moisture content ($\theta = \phi s$) as a function of pressure potential, $\theta(h)$ and the inverse function, $h(\theta)$.

2. Specific moisture capacity as a function of pressure potential, $c_m(h) = \phi(\frac{\partial s}{\partial h}) \cong (\frac{d\theta}{dh})$, assuming changes in ϕ are small compared to changes in θ.

3. Relative hydraulic conductivity as a function of pressure potential, $K_r(h)$.

When experimental data cannot be fit adequately by analytical expressions such as those that follow, tabulations of the dependence of saturation and relative hydraulic conductivity on pressure potential can be used. Use of these tabulations is described more fully in the section on numerical implementation.

The functional relations between volumetric moisture content or relative hydraulic conductivity versus pressure potential demonstrate hysteresis; that is, different functions apply during drainage than during uptake. This hysteretic relation is quite complicated and consists of main wetting and drying curves and a family of scanning curves that represent the functional relation when a partially drained medium is rewetted, or when drainage follows incomplete wetting. The phenomenon is described in various soil physics texts (Hillel, 1971; Kirkham and Powers, 1972; Baver and others, 1972). The program does not treat hysteresis among the head-related functional parameters and must be modified by the user if such considerations are significant to the problem being analyzed.

Liquid Saturation

For partly saturated media, liquid saturation decreases as pressure potential becomes increasingly negative. The curve relating the saturation of a given soil to pressure potential is commonly termed the moisture-characteristic curve, and generally is empirically determined (Hillel, 1971, p. 61). Examples of moisture-characteristic curves for a sand and a light clay are shown by the symbols in figure 6. The slope of the moisture-characteristic curve defines the specific moisture capacity and the curve can be integrated to define the relation between relative hydraulic conductivity and pressure potential. Hence, it is desirable, if possible, to fit the moisture-characteristic curve by an algebraic expression.

Three different algebraic equations to represent the moisture-characteristic curve are available for use in program VS2D, including one by Brooks and Corey (1964), one by Gardner (1958), as used by Haverkamp and others (1977), and one by van Genuchten (1980).

The Brooks and Corey (1964) equation is:

$$s_e = \frac{\theta-\theta_r}{\phi-\theta_r} = \left(\frac{h_b}{h}\right)^{\lambda}, \quad h < h_b ; \qquad (18)$$

$\theta = \theta_r + (\phi - \theta_r)\left(\frac{h_b}{h}\right)^{\lambda}$

$$s_e = 1.0, \quad h \geq h_b ;$$

where:
- s_e = effective saturation, L^0;
- θ = volumetric moisture content, L^0;
- θ_r = residual moisture content, L^0;
- ϕ = porosity, L^0;

h_b = bubbling or air-entry pressure potential, equal to the pressure potential required to desaturate the largest pores in the medium, L (actually this is a curve-fitting parameter that may not equal the actual bubbling pressure, but must be less than 0); and

λ = a pore size distribution index that is a function of soil texture, L°.

Parameters for the Brooks-Corey equation may be determined from the best-fit straight line through the data points on a log-log plot of pressure potential versus effective saturation, as shown in figure 7 for a sand and a light clay. The slope of the straight line represents λ, and its intercept at full saturation represents h_b. The residual moisture content may be varied to improve the straight line fit, as described by Brooks and Corey (1964, p. 24). Alternatively, the three parameters (λ, h_b, and θ_r) may be identified by a computer-aided search procedure. Mualem (1976) tabulates the results of fitting the Brooks-Corey equation to experimentally determined moisture-characteristic curves for 46 soils. Brooks-Corey parameters for 11 soils are listed in table 1. These parameters were determined by the authors using a search procedure that minimized the least-squares residual between the equation and all the experimental data. However, the residual moisture content was not allowed to have a negative value.

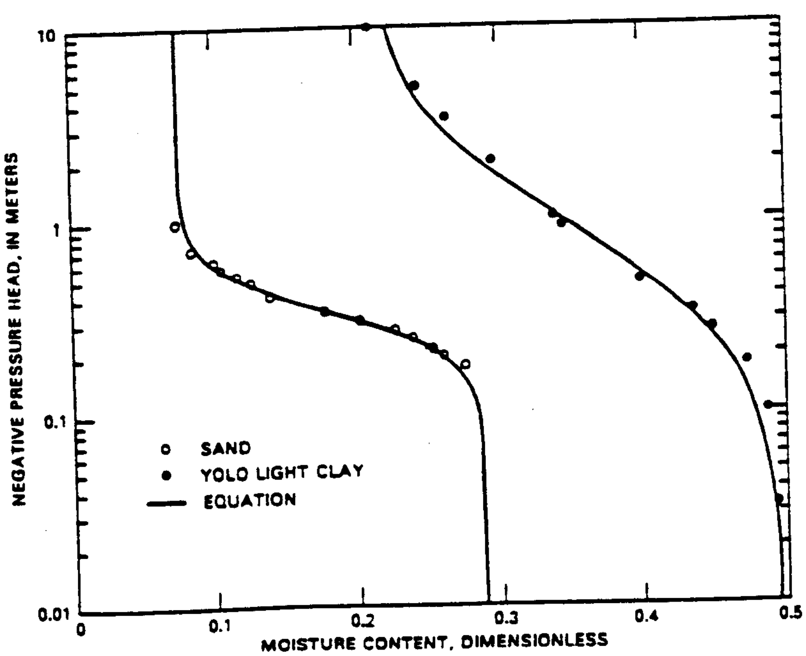

Figure 6.--Comparison of Haverkamp equation fit to experimental data of moisture content versus pressure head for a sand and for a light clay. Equation parameters are listed for soils 4 and 11 in table 1 (modified from Haverkamp and others, 1977).

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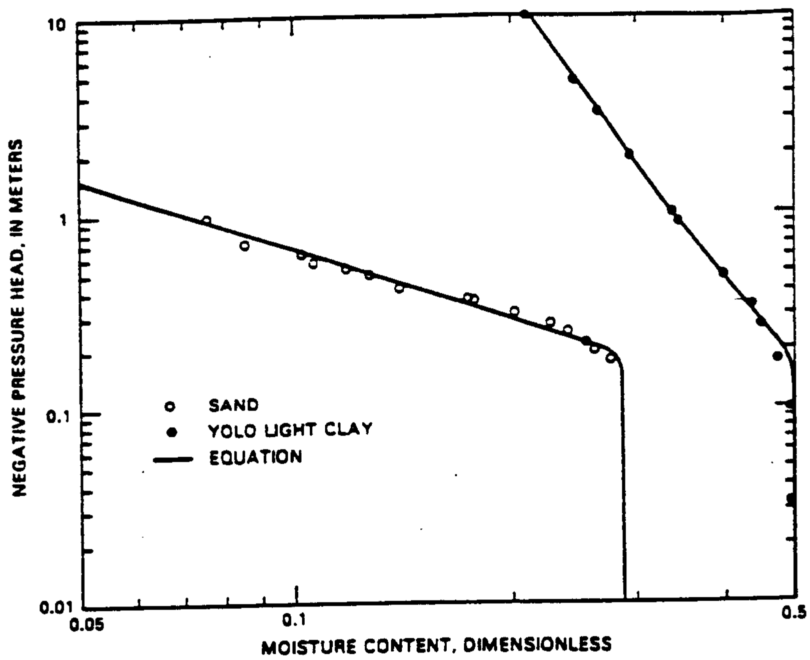


Figure 7.--Comparison of Brooks and Corey equation fit to experimental data of moisture content versus pressure head for a sand and for a light clay. Equation parameters are listed for soils 4 and 11 in table 1.

When the wet end of the plot shows too much curvature to be adequately fit by two straight-line segments on the log-log plot, a function of the type used by Haverkamp and others (1977) may fit the data reasonably well:

$$s_e = \frac{1}{1+(\frac{h}{\alpha})^{\beta}}, \qquad (19)$$

where α = pressure potential at which $s_e = 0.5$, L; and

β = slope of the log-log plot of $(1/s_e - 1)$ versus h, L°.

As with the Brooks-Corey equation, use of the Haverkamp function requires the identification of three fitting parameters (assuming porosity is known from other data): θ_r, α, and β, as may be seen from the above definitions; α and β may be determined graphically if θ_r is known or can be estimated. Alternatively, all three parameters may be determined using a computer-aided search procedure. The best-fit Haverkamp equation parameters for 11 soils are listed in table 1, and the fit of the Haverkamp equation to data for a sand and a light clay (soils 4 and 11 in table 1) are shown in figure 6.

Table 1.--*Values for 11 soils of residual moisture content, scaling length, and pore-size distribution parameter that best fit three different models to measured moisture content versus pressure head*

[m, meters; θ_r, residual moisture content; h_b, bubbling head, or scaling length; λ, pore-size distribution parameter for model 1; α, scaling length, and β, pore-size distribution parameter for model 2; α', scaling length, and β', pore-size distribution parameter for model 3]

Soil or rock	Hydraulic conductivity (m/day)	Porosity	Model 1 Brooks and Corey (1964) θ_r	Model 1 $-h_b$ (m)	Model 1 λ	Model 2 Haverkamp (1977) θ_r	Model 2 -α (m)	Model 2 β	Model 3 van Genuchten (1980) θ_r	Model 3 -α' (m)	Model 3 β'	$\alpha\left(\frac{1}{m}\right)$
Del Monte Sand (20 mesh)	7×10^3	0.36	0.011	0.112	2.5	0.039	0.147	6.0	0.036	0.142	6.3	7.0
Fresno medium sand[2]	4×10^2	.375	.000	.149	.84	.077	.273	3.0	.020	.232	3.1	4.3
Unconsolidated sand[3]	8.5	.424	.090	.114	4.4	.046	.134	8.3	.051	.134	9.0	7.5
Sand[4]	8.2	.435	.000	.196	.84	.076	.355	3.7	.069	.326	3.9	3.1
Fine sand (G.E. 13)[5 10]	2.1	.377	.063	.82	3.7	.074	1.00	6.6	.072	.960	6.9	1.0
Columbia sandy loam[6 10]	.70	.496	.11	.85	1.6	.16	1.26	4.6	.15	1.18	4.8	0.85
Touchet silt loam (G.E. 3)[5 10]	0.22	0.430	0.095	1.45	1.7	0.17	2.05	6.6	0.17	1.98	7.0	0.50
Hygiene sandstone[7 10]	.15	.25	.13	1.06	2.9	.15	1.28	10.3	.15	1.26	10.6	0.79

Table 1.--*Values for 11 soils of residual moisture content, scaling length, and pore-size distribution parameter that best fit three different models to measured moisture content versus pressure head*--Continued

Soil or rock	Hydraulic conductivity (m/day)	Porosity	Model 1 Brooks and Corey (1964) θ_r	$-h_b$ (m)	λ	Model 2 Haverkamp (1977) θ_r	$-\alpha$ (m)	β	Model 3 van Genuchten (1980) θ_r	$-\alpha'$ (m)	β'
Adelanto loam[8]	.039	.42	.13	1.41	.51	.18	4.32	1.8	.16	2.74	2.06
Limon silt (imbibition data)[9]	.013	.449	.000	.338	.22	.012	5.84	.73	.001	.651	1.3
Yolo light clay[4]	.011	.495	.055	.181	.25	.215	.883	1.3	.175	.401	1.6

[1]Data from Prill and others (1965), figure 23, column 1.
[2]Data from Prill and others (1965), figure 15, column 2.
[3]Data from Laliberte and others (1966), table C-8.
[4]Data from Haverkamp and others (1977), figure 1.
[5]Data from Brooks and Corey (1964), table 1.
[6]Data from Laliberte and others (1966), table C-5.
[7]Data from Brooks and Corey (1964), table 3.
[8]Data from Jackson and others (1965), figure 5. Values for psi ≥ -100 m only used.
[9]Data from Vachaud (1966), table 1.
[10]The data for these samples were obtained using an oil as the wetting fluid (Soltrol "C" core test fluid). This fluid has a surface tension of 22.9 dynes per centimeter and a density of 0.758 grams per cubic centimeter. Brooks and Corey (1964, p. 9) experimentally determined that the pressure potential for water at a given saturation is equal to twice that for the oil. Consequently, the pressure potentials tabulated for these samples have been multiplied by 2.0.

0.36
1.5
2.5

The Haverkamp functions relating effective saturation to pressure potenial cannot be directly integrated using Mualem's (1976) procedure to provide a functional relation between K_r and pressure potential. To overcome this problem, van Genuchten (1980) has cast equation 18 in slightly different form:

$$s_e = \left[\frac{1}{1+(\frac{h}{\alpha'})^{\beta'}}\right]^{\gamma}, \qquad (20)$$

where $\alpha' = \alpha/[(2^{1/\gamma} - 1)^{1-\gamma}]$, L;

β' = exponent, L°; and

γ = exponent, $= 1-1/\beta'$, L°.

Note that α' is the negative of the reciprocal of α defined by van Genuchten (1980). It is defined in this form here to enhance the concept that the parameter represents a characteristic length for the porous medium.

Van Genuchten describes a graphical technique to determine γ if θ_r is known. The value of γ may be used with that for the pressure potential at which $s_e = 0.5$ (Haverkamp's α) to find α', and β' is found from the formula:

$$\beta' = 1/(1 - \gamma) . \qquad (21)$$

Alternatively, the three parameters can be determined by a search procedure. Van Genuchten equation parameters for 11 soils are listed in table 1. Note that, for soils for which β' is large, the results are nearly identical to those for the Haverkamp equation, but the deviations become substantial as β' becomes small. Also, the van Genuchten fit to most sets of data is almost indistinguishable from the best Haverkamp fit. Consequently, no separate fit of the van Genuchten equation is shown here.

Specific Moisture Capacity

Specific moisture capacity, defined as the slope of the moisture-characteristic curve, describes the change in saturation due to a change in pressure potential under partly saturated conditions. Hence, the term represents the dominant component of the storage coefficient under such conditions. Specific moisture capacity is given by the equation:

$$c_m(h) = \phi(\frac{\partial s}{\partial h}) = (\frac{\partial \theta}{\partial h}) , \qquad (22)$$

where $c_m(h)$ = specific moisture capacity, L^{-1}.

If the Brooks-Corey equation is used to represent the moisture-characteristic curve, specific moisture capacity is defined as follows:

$$c_m(h) = - (\phi - \theta_r)(\lambda/h_b)(h/h_b)^{-(\lambda+1)}, \ h \le h_b \qquad (23)$$

and $c_m(h) = 0, \ h > h_b$,

where all terms are as defined above. Examples of curves of specific moisture capacity versus negative pressure head, as computed from equation 23 for a sand and for Yolo light clay (entries 4 and 11, table 1) are shown in figure 8A. Note that the specific moisture capacity is discontinuous at h_b, and that it is extremely nonlinear with respect to the negative pressure head at smaller values.

If the moisture-characteristic curve is represented by the Haverkamp equation, specific moisture capacity is defined by the equation

$$c_m(h) = -(\phi - \theta_r)(\beta/\alpha)(h/\alpha)^{\beta-1}/[1 + (h/\alpha)^{\beta}]^2 \qquad (24)$$

for pressure head less than 0. Specific moisture capacity as a function of pressure potential computed from the Haverkamp functions for the same sand and light clay as for figure 8A are shown in figure 8B. Note that the Haverkamp specific moisture-capacity function differs substantially from the Brooks-Corey function, particularly for pressure heads near the bubbling pressure head.

For moisture-characteristic curves represented by the van Genuchten equation:

$$c_m(h) = \frac{-\gamma\beta'(\phi-\theta_r)(\frac{h}{\alpha'})^{\beta'-1}}{\alpha'[1 + (\frac{h}{\alpha'})^{\beta'}]^{\gamma+1}} \quad , \leq 0 \qquad (25)$$

$$c_m(h) = 0 \; , \; h > 0 \; .$$

The specific moisture capacity curves for the van Genuchten formulation are essentially undistinguishable from those for the Haverkamp formulation and are not shown separately.

When tabular data are used to describe the moisture-characteristic curve, specific moisture capacity can be determined by taking the slope of the line segment between data points adjacent to the h value of interest.

Relative Hydraulic Conductivity

Relative hydraulic conductivity, defined as the ratio of unsaturated to saturated hydraulic conductivity also decreases with increasingly negative pressure potential. Relative hydraulic conductivity may be determined experimentally or may be estimated by numerically or analytically integrating the moisture characteristic curve.

Experimentally determined data frequently may be fit to a Haverkamp and others (1977) type equation:

$$K_r = \frac{1}{1 + (\frac{h}{A'})^{B'}} \quad , \qquad (26)$$

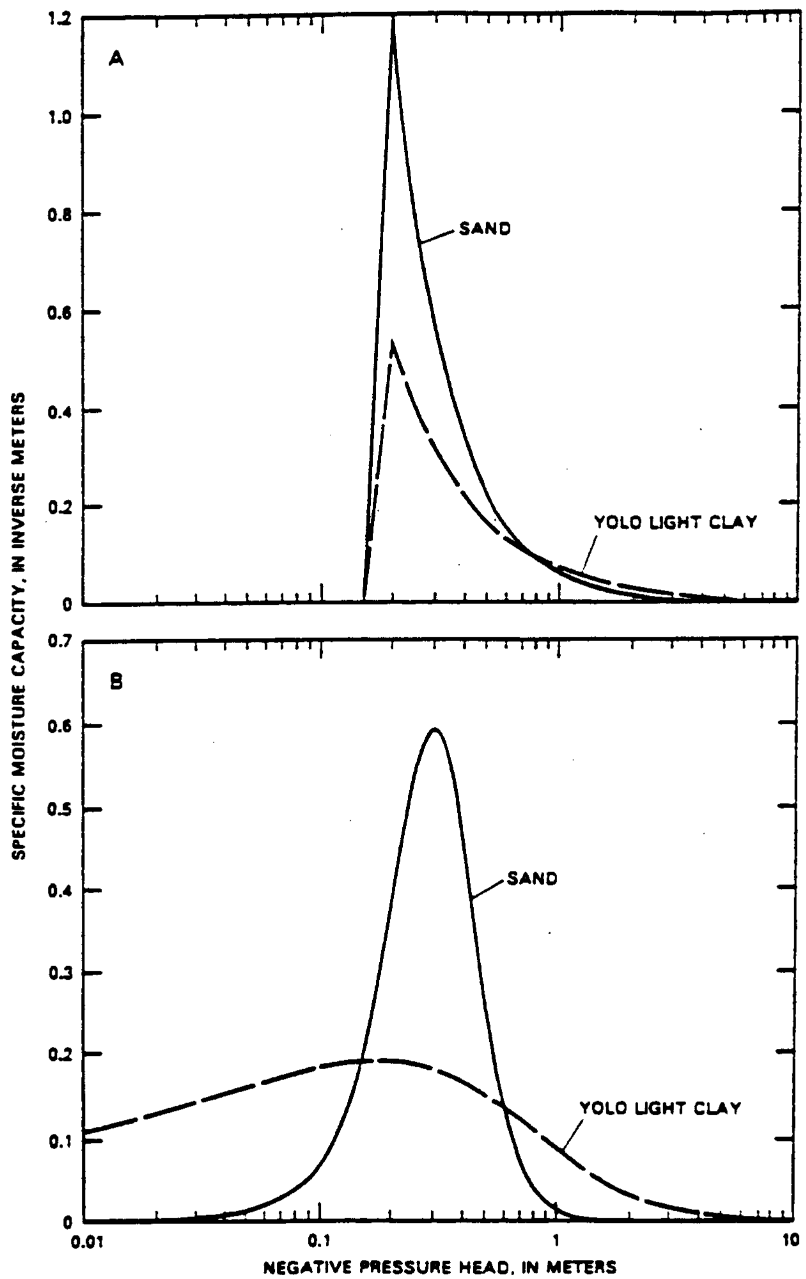


Figure 8.--Specific moisture capacity as a function of pressure head for a sand and a light clay:
A. As computed using the Brooks-Corey formulation.
B. As computed using the Haverkamp formulation.

where A' = pressure potential at which $K_r = 0.5$, L; and

B' = dimensionless constant, equal to the slope of the log-log plot of $(1/K_r - 1)$ versus the pressure potential.

The best-fit Haverkamp function to experimentally determined values of relative hydraulic conductivity versus pressure head are shown in figure 9*A* for a sand, and for light clay by solid lines in figure 9*B*.

If the moisture-characteristic curve is represented by the Brooks-Corey equation, Brooks and Corey (1964) show that the relative hydraulic conductivity commonly is well represented by the equations:

$$K_r = \left(\frac{h}{h_b}\right)^{-2-3\lambda}, \quad h < h_b \tag{27}$$

and

$$K_r = 1.0, \quad h \geq h_b . \tag{28}$$

Relative hydraulic conductivities computed using equations 26 and 27 are compared to measured data for sand in figure 9*A* and for light clay in figure 9*B*. The Brooks-Corey equations fit the data for sand very well, but poorly represent the data for the clay. This phenomenon has been frequently observed, suggesting that care should be exercised using the Brooks-Corey equations to represent the relative hydraulic conductivity of clays.

For the van Genuchten (1980) equation, relative hydraulic conductivity is given by the equation:

$$K_r = \frac{\left\{1 - \left(\frac{h}{\alpha'}\right)^{\beta'-1} \left[1 + \left(\frac{h}{\alpha'}\right)^{\beta'}\right]^{-\gamma}\right\}^2}{\left[1 + \left(\frac{h}{\alpha'}\right)^{\beta'}\right]^{\gamma/2}} . \tag{29}$$

Relative hydraulic conductivities computed using equation 29 are also compared to measured data in figure 9. The fit of the equation to data for sand (figure 9*A*) is, as with the Brooks-Corey equation, quite good. Also similarly to the Brooks-Corey equation, the fit to the data for clay (fig. 9*B*) is poor.

If the moisture-characteristic curve cannot be adequately fit by an integrable algebraic function, relative hydraulic conductivity can be estimated by dividing the curve into segments of equal $\Delta\theta$ or Δs and integrating numerically, using the method of Marshall (1958) or Millington and Quirk (1961). The data thus generated can then be used in tabular form in the program.

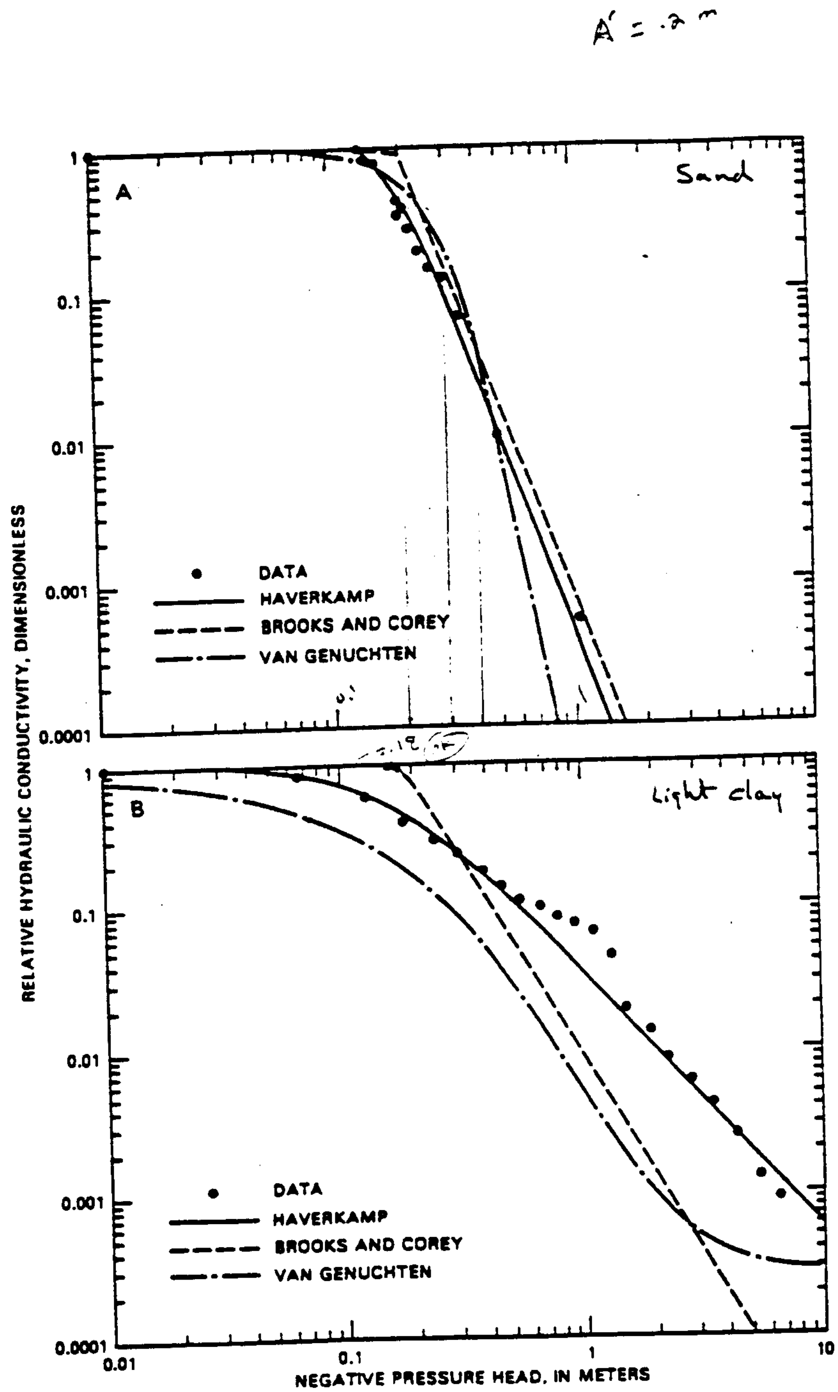


Figure 9.--Comparison of three functions to experimental data relating relative hydraulic conductivity to pressure potential for:

A. A sand (soil no. 4, table 1);

B. A light clay (soil no. 11, table 1).

NUMERICAL SOLUTION

Equation 13, subject to the boundary conditions described by equations 14 and 15, is a nonlinear partial differential equation that has no general closed-form or analytic solution. Consequently, numerical approximations to the spatial and temporal derivatives in equations 13, 14, and 15 must be made. These approximations result in a set of simultaneous nonlinear algebraic equations that must be first linearized, then solved.

Spatial Discretization

The spatial derivatives in equation 13 are approximated by a block-centered regular finite-difference scheme. This scheme is illustrated in figure 10 for a rectangular (x,z) and a cylindrical (r,z) grid. The nodes in each volume subdivision or grid block are located at the center of each block.

For a two-dimensional rectangular grid, the number of faces ($\bar{m}$ in equation 13) of the volume subdivision is 6. However, two of the faces are not explicitly included, because the assumption used for two-dimensional problems to be simulated with this model is that no liquid flow can occur across them. When vertical section problems are analyzed, these no-flow faces are on the front and back of each grid block.

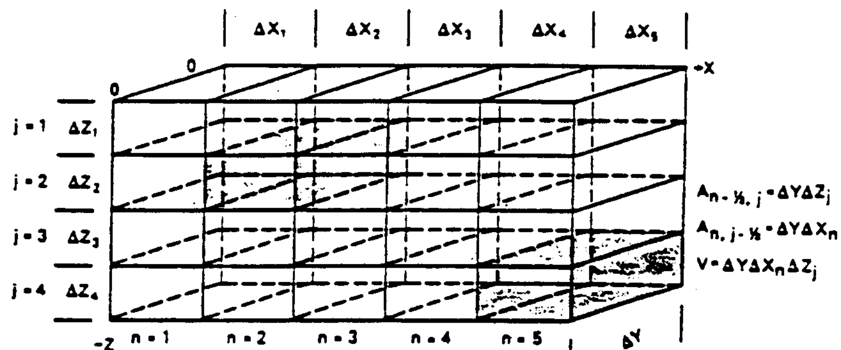
By retaining the volume and area terms in equation 13, it is a simple matter to use either rectangular or cylindrical coordinate systems. The computer program calculates the proper areas and volumes using the equations given in figure 10.

The spatial derivatives of total potential in equation 13 are approximated at the block boundaries, using the following space-centered finite-difference scheme:

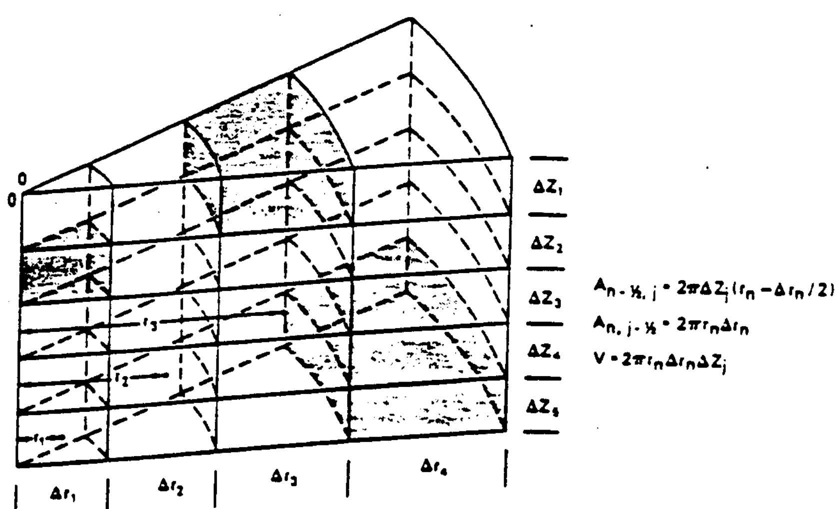
$$\begin{aligned}
\text{Left side} &= \left(\frac{\partial H}{\partial x}\right)_{n-1/2,j} = \frac{H_{n-1,j} - H_{n,j}}{\Delta x_{n-1/2}}\ ; \\
\text{Top side} &= \left(\frac{\partial H}{\partial z}\right)_{n,j-1/2} = \frac{H_{n,j-1} - H_{n,j}}{\Delta z_{j-1/2}}\ ; \\
\text{Right side} &= \left(\frac{\partial H}{\partial x}\right)_{n+1/2,j} = \frac{H_{n+1,j} - H_{n,j}}{\Delta x_{n+1/2}}\ ; \\
\text{Bottom side} &= \left(\frac{\partial H}{\partial z}\right)_{n,j+1/2} = \frac{H_{n,j+1} - H_{n,j}}{\Delta z_{j+1/2}}\ ;
\end{aligned} \qquad (30)$$

where $\Delta x_{n-1/2}$ = horizontal distance between nodes n-1,j and n,j

$\Delta z_{j-1/2}$ = vertical distance between nodes n,j-1 and n,j.



RECTANGULAR COORDINATES



CYLINDRICAL COORDINATES

EXPLANATION

$A_{n-½, j}$	SURFACE AREA BETWEEN CELLS $n-1, j$ AND n, j
$A_{n, j-½}$	SURFACE AREA BETWEEN CELLS $n, j-1$ AND n, j
V	VOLUME OF CELL n, j

Figure 10.--Rectangular and cylindrical coordinates and grid-block systems.

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The sign convention used is such that flow out of each cell is positive. Equation 30 is defined for a rectangular grid; however, equations for a cylindrical grid are analogous with r replacing x as the horizontal coordinate. For simplicity, x will be used for the horizontal coordinate for the remainder of this report. Taylor series expansion about the points n-1/2, j; n, j-1/2; n+1/2, j; and n, j+1/2 shows equation 30 to be second-order correct in approximating the spatial derivatives (von Rosenberg, 1969, p. 5).

Substituting equation 30 into equation 13 gives the difference form of the balance equation for each grid block:

$$
\begin{aligned}
&v\rho(c_m+sS_s)\frac{\partial H}{\partial t} \\
&- \hat{C}_{n-1/2,j}\ (H_{n-1,j} - H_{n,j}) - \hat{C}_{n,j-1/2}\ (H_{n,j-1} - H_{n,j}) \\
&- \hat{C}_{n+1/2,j}\ (H_{n+1,j} - H_{n,j}) - \hat{C}_{n,j+1/2}\ (H_{n,j+1} - H_{n,j}) - \rho q v = 0
\end{aligned}
\tag{31}
$$

Where the conductances, $\hat{C}$, are defined as

$$
\begin{aligned}
\hat{C}_{n-1/2,j} &= \left(\frac{\rho\ KK_r A}{\Delta x}\right)_{n-1/2,j} ; \\
\hat{C}_{n,j-1/2} &= \left(\frac{\rho\ KK_r A}{\Delta z}\right)_{n,j-1/2} ; \\
\hat{C}_{n+1/2,j} &= \left(\frac{\rho\ KK_r A}{\Delta x}\right)_{n+1/2,j} ; \\
\hat{C}_{n,j+1/2} &= \left(\frac{\rho\ KK_r A}{\Delta z}\right)_{n,j+1/2}
\end{aligned}
\tag{32}
$$

where A represents block face area.

Intercell Averaging of Conductance Terms

When block-centered finite-difference discretization schemes are used, as in this program, it is necessary to average the conductance terms for adjacent blocks to develop intercell conductances. Several authors have evaluated methods for determining these intercell-conductance terms. Appel (1976) compared the accuracy of arithmetic and harmonic means for saturated systems (K_r=1.0). He concluded that the actual functional variation in space of the conductance should be incorporated into a scheme for determining the interblock values. For a constant grid spacing with linear spatial variation in conductance, an arithmetic mean gives the most accurate estimate (fig. 11). When smooth changes in conductance are present, the geometric mean should be used, owing to the observed log-normal distribution of this parameter (Freeze, 1975). For the case where conductance varies as a step function, as for layered soil, the harmonic mean gives the exact value of the interblock conductance (Appel, 1976). Haverkamp and Vauclin (1979) analyzed unsaturated conductances (K_r<1.0) and concluded that the geometric mean provided the most accurate representation of interblock conductances (fig. 12), although they did not evaluate the accuracy of separate methods of averaging each parameter composing conductances. Separate methods are used in this report and are described hereafter for the parameters K and K_r.

Saturated Hydraulic Conductivity

Saturated hydraulic conductivity, K, is used to represent the conductance of the medium in this program. The distance-weighted harmonic mean of the saturated hydraulic conductivity of the adjacent cells is computed within the program to represent the intercell hydraulic conductivity. Appel (1976) shows that this method accurately represents interblock hydraulic conductivity when that parameter changes abruptly at node boundaries, and thus is best suited for layered systems. To simulate flow through a medium in which hydraulic conductivity varies gradually, node spacing should be adjusted such that the saturated hydraulic conductivity between adjacent blocks varies no more than 50 percent, based on figure 11.

Anisotropy in the saturated hydraulic conductivity is included in the model to reflect directional orientation in the resistance to liquid movement. It is assumed that coordinate axes used for a given problem are collinear with the principal directions of the intrinsic permeability tensor. This is a reasonable assumption for many vertical cross-section problems; however, steeply dipping beds cannot be adequately simulated with this code.

The distance-weighted, harmonic-mean saturated hydraulic conductivities accounting for anisotropy are given by the following equations. Since the left face of one block is the right face of the block on its left, and similarly for top and bottom faces, only two equations are needed for each block. The convention used in this report is to use the left and top sides.

$$\text{Left side:}\quad \left(\frac{K}{\Delta x}\right)_{n-1/2,j} = \frac{2\,K_{n-1,j}\,K_{n,j}}{K_{n-1,j}\,\Delta x_n + K_{n,j}\,\Delta x_{n-1}}$$

$$\text{Top side:}\quad \left(\frac{K}{\Delta z}\right)_{n,j-1/2} = \frac{2\,K_{n,j-1}\,K_{n,j}\,(K_{zz}/K_{xx})}{K_{n,j-1}\,\Delta z_j + K_{n,j}\,\Delta z_{j-1}} \qquad (33)$$

where:

$K_{n,j} = K_{xx}$ = saturated hydraulic conductivity in horizontal direction, LT^{-1}; and

K_{zz} = saturated hydraulic conductivity in vertical direction, LT^{-1}.

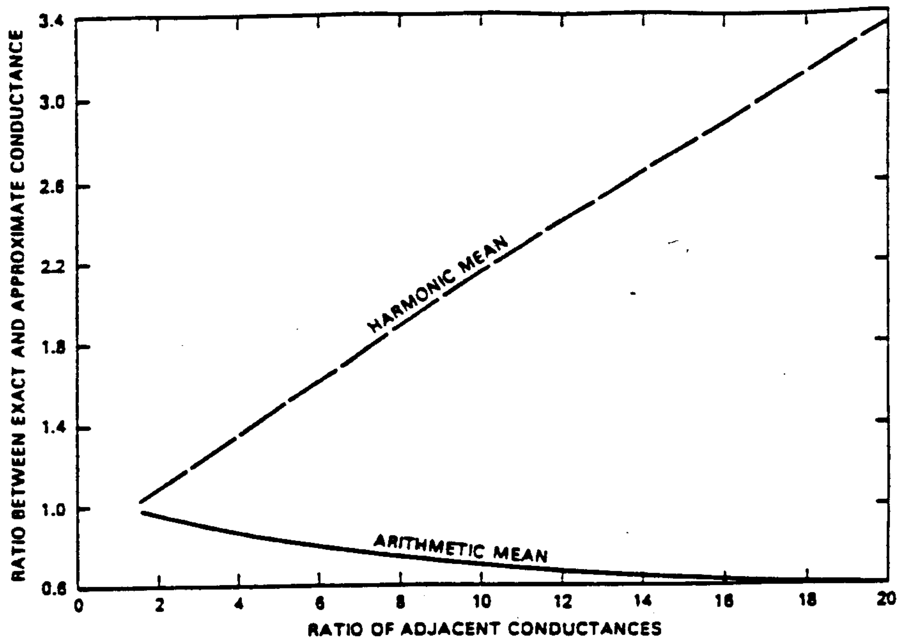

Figure 11.--Accuracy of arithmetic and harmonic means in estimating saturated intercell hydraulic conductivities for a linear spatial variation of conductivity and constant grid spacing (after Appel, 1976).

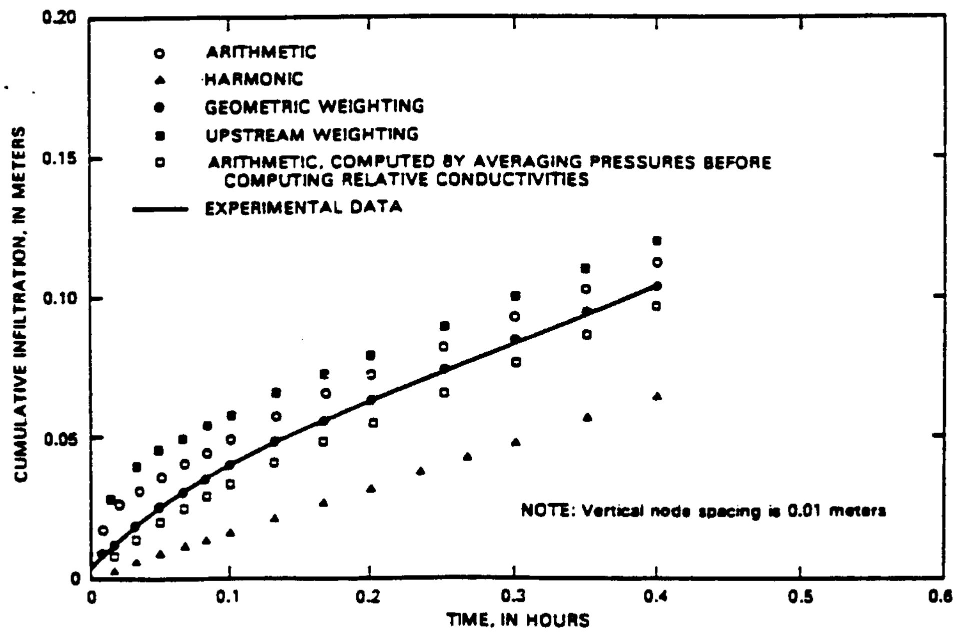

Figure 12.--Accuracy of several intercell weighting schemes for unsaturated hydraulic conductivity in estimating cumulative infiltration in a sand column with ponded upper boundary.

In the computer program, intercell saturated hydraulic conductivities are lumped with the block face area in the arrays HKLL and HKTT, as follows:

$$(HKLL)_{n,j} = \left(\frac{K}{\Delta x}\right)_{n-1/2,j} A_{n-1/2}$$

$$(HKTT)_{n,j} = \left(\frac{K}{\Delta z}\right)_{n,j-1/2} A_{j-1/2} \quad (34)$$

Relative Hydraulic Conductivity

Intercell averages of relative hydraulic conductivity, $K_r(h)$, are computed using either a geometric mean or a weighted arithmetic mean. Geometric mean averages provide the most accurate simulations, as discussed in the section on "Model Verification", and should be used whenever possible, their use being occasionally precluded by their generation of numerical oscillations. The geometric mean relative hydraulic conductivities are defined by the equations:

$$[K_r]_{n-1/2,j} = [K_r(h)_{n,j} \cdot K_r(h)_{n-1,j}]^{1/2}$$

$$[K_r]_{n,j-1/2} = [K_r(h)_{n,j} \cdot K_r(h)_{n,j-1}]^{1/2} . \quad (35)$$

This option is invoked by specifying the user-defined weighting coefficient $\bar{\alpha}$ as 0.

Arithmetic weighting, either based upon the mean weighting of the relative hydraulic conductivity between adjacent nodes or upon preferrentially weighting the relative hydraulic conductivity at the upstream node, is achieved by the following equations:

Left side, fluid moving to right $[K_r]_{n-1/2,j} = \bar{\alpha}K_r\,(h)_{n-1,j} + \bar{\beta}K_r\,(h)_{n,j}$;

Left side, fluid moving to left $[K_r]_{n-1/2,j} = \bar{\beta}K_r\,(h)_{n-1,j} + \bar{\alpha}K_r(h)_{n,j}$; (36)

Top side, fluid moving downward $[K_r]_{n,j-1/2} = \bar{\alpha}K_r\,(h)_{n,j-1} + \bar{\beta}K_r\,(h)_{n,j}$;

Top side, fluid moving upward $[K_r]_{n,j-1/2} = \bar{\beta}K_r\,(h)_{n,j-1} + \bar{\alpha}K_r\,(h)_{n,j}$;

where $\bar{\alpha}$ is a user-defined weighting coefficient from which $\bar{\beta}$ is computed using the relations:

$\bar{\alpha} + \bar{\beta} = 1.0$;

$0.5 \leq \bar{\alpha} \leq 1.0$;

$0 \leq \bar{\beta} \leq 0.5$;

if $\bar{\alpha} = 1.0$ and $\bar{\beta} = 0$, full upstream weighting results; and

if $\bar{\alpha} = \bar{\beta} = 0.5$, the usual arithmetic average results.

Although the weighted arithmetic mean method generally is less accurate than others (see fig. 12), its use is necessary to obtain realistic results in a few cases. Brutsaert (1971) has shown that in the case of an advancing sharp wetting front into a dry uniform medium, it is necessary to use the value of $K_r(h)$ for the cell from which liquid is flowing to obtain physically reasonable results and to prevent numerical oscillations that may prevent a solution. The need for upstream weighting arises because the relative hydraulic conductivity function (fig. 9) is very steep, and the difference in its value across a wetting front may be several orders of magnitude. If harmonic or geometric means are used for intercell relative hydraulic conductivity, the medium may not be able to conduct liquid fast enough at the front to maintain continuity. Consequently, some higher value of hydraulic conductivity should be used, based on upstream weighting.

Temporal Discretization

The numerical solution of equation 31 requires an approximation to the time derivative $\frac{\partial H}{\partial t}$ and evaluation of the differenced form of the spatial derivatives at a given point in time. Equation 31 can be written in the form of an ordinary differential equation:

$$\frac{dH}{dt} = k\Delta H \;, \tag{37}$$

where ΔH is the differenced form of the spatial derivatives. The first-order correct approximation to this equation (von Rosenberg, 1969, p.19) is:

$$\left(\frac{dH}{dt}\right)^{i-1/2} \cong \frac{H^{i} - H^{i-1}}{t^{i} - t^{i-1}} \;. \tag{38}$$

where i is an index to discrete points in the time domain. Equation 38 is referred to as a fully implicit or backward difference scheme. Its substitution into equation 31 results in the following equations:

$$v\rho[c_m + sS_s]^{i-1/2}\left(\frac{H^{i}_{n,j} - H^{i-1}_{n,j}}{t^{i} - t^{i-1}}\right) =$$

$$+\hat{C}^{i-1/2}_{n-1/2,j}(H^{i}_{n-1,j} - H^{i}_{n,j}) + \hat{C}^{i-1/2}_{n,j-1/2}(H^{i}_{n,j-1} - H^{i}_{n,j}) \tag{39}$$

$$+\hat{C}^{i-1/2}_{n+1/2,j}(H^{i}_{n+1,j} - H^{i}_{n,j}) + \hat{C}^{i-1/2}_{n,j+1/2}(H^{i}_{n,j+1} - H^{i}_{n,j})$$

$$+(\rho q v)^{i-1/2}_{n,j} \;.$$

Equation 39 may be written for each n from 1 to NLY (the number of nodes in each column of the finite-difference mesh) and for each j from 1 to NXR (the number of nodes in each row), resulting in a set of m simultaneous nonlinear algebraic equations that can be written in matrix form as:

$$[A^{i-1/2}]\ \{H^{i}\} = \{RHS\}\ , \qquad (40)$$

where: [A] is a square m by m (where m equals the number of rows times the number of columns) coefficient matrix that includes all implicit or unknown parts of conductance, storage, and source-sink terms; and RHS is a vector of all explicit or known parts of conductance, storage, and source-sink terms.

In equations 39 and 40, the implicit parts of all the conductance terms, the storage term, and the source-sink terms are evaluated at some approximation to the midpoint in time between t^{i} and t^{i-1}. It is the dependence of the parameters on H in these terms that makes equation 40 nonlinear. The next section discusses linearization of these terms to enable solution of equation 40.

Linearization

Evaluation of the nonlinear parameters in conductance and source-sink terms, as well as those that may occur in boundary condition equations, is accomplished by implicit linearization within the program. This means that these terms are evaluated at the current time level. Experience has shown, and it is evident from figure 8, that specific moisture capacity, the dominant component of the storage term, is more nonlinear than other terms composing elements of [A].

Hence the storage terms of [A] are linearized by a modified Newton-Raphson technique. Although this method requires additional computational effort for each iteration, it can significantly increase the rate of convergence (Finlayson, 1980).

The iterative method used in the program is developed as follows. By defining a residual vector $\{H^{*}\}^{k} = H^{i} - H^{k}$, where k is an iteration index, equation 40, can be written as:

$$[A]^{k-1}\{H^{*}\}^{k} \cong [\bar{A}]^{k-1}\{H^{*}\}^{k} = \{RHS\} - [\bar{A}]^{k-1}\{H\}^{k-1}\ , \qquad (41)$$

where $[\bar{A}]$ is the linear equivalent of [A]. $[\bar{A}]^{k-1}$ can be written as:

$$[\bar{A}]^{k-1} = [B]^{k-1} + [G_s]^{k-1}\ , \qquad (42)$$

where both B and G_s are m x m matrices, $[B]^{k-1}$ containing all conductance terms of $[\bar{A}]^{k-1}$, and $[G_s]^{k-1}$ containing all storage terms of $[\bar{A}]^{k-1}$. Following Cooley (1983, p. 1274) $[G_s]^{k-1}$ is a diagonal matrix with:

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$$[G_s]_{jj}^{k-1} = \left[\frac{\partial \bar{C}(H_{jj} - H_{jj}^{i-1})}{\partial H}\right]_{k-1} = C_{k-1} + (H_{jj}^{k-1} - H_{jj}^{i-1})\frac{\bar{C}_{k-1} - \bar{C}_{k-2}}{H_{jj}^{*\,k-1}} \tag{43}$$

$$\text{where} \qquad \bar{C}_{k-1} = v\rho\{c_m + sS_s\}^{k-1} \ . \tag{44}$$

Equation 41 is solved for the residual potential $\{H^*\}$ as a correction to values of $\{H\}^{k-1}$ obtained during the previous iteration. The use of residuals as the solution variable in iterative methods has been shown to minimize roundoff errors in algorithms to solve matrix equations such as equation 41 (Nobel, 1969). Elements of the coefficient matrix $[A]^{k-1}$ are updated after every iteration, using the most recent values of $\{H\}^{k-1}$.

Time-Step Limitation

An implicit time-discretization scheme is used in the computer code. For linear systems of parabolic equations, this scheme is unconditionally stable for all values of time step and grid spacing. For linear equations that may be a mixture of parabolic and hyperbolic, or nonlinear parabolic equations, such stability is not unconditional (Finlayson, 1980). The descriptive flow equation (equation 13) is nonlinear, and may exhibit hyperbolic behavior when the gradients in the gravitational potential dominate. The computer code includes provision for increasing the time-step length by a user-specified factor (TMLT). Consequently, a time-step limitation procedure is included in the computer code to give the user control over such stability problems. The code estimates the maximum change in head for the next time step (BIGI) by linearly extrapolating the maximum change from the previous time step. If BIGI is greater than DSMAX, the time-step length is decreased by a factor of (DSMAX/BIGI). Similarly if the time-step length is greater than DLTMX, it is set equal to DLTMX. The method is somewhat *ad hoc* in that the user specifies both a maximum time-step length (DLTMX) and a maximum change in pressure head permitted in any grid cell from one time step to the next (DSMAX). Finally, if convergence is not achieved in the specified number of iterations, the time step is reduced by the user-supplied factor, TRED, as described below.

Matrix Solution

The computer code uses the strongly implicit procedure (Stone, 1968) to solve the set of linear algebraic equations formed by equation 40 iteratively. At each iteration, the system of equations can be represented by:

$$[\bar{A}]^{k-1}\{H^*\}^{k} = \beta_s\{RHS\}^{k} - [\bar{A}]^{k-1}\{H\}^{k-1} \ , \tag{45}$$

where:

β_s = user-defined damping factor, HMAX.

Convergence of the nonlinear problem commonly simulated using VS2D is highly dependent on the value of HMAX. A value of 0.7 often works well, but values as low as 0.3 are sometimes needed to obtain convergence.

The iteration required to solve equation 44 is often separated from the iteration used to linearize the nonlinear equations (Brutsaert, 1971; Freeze, 1971; Cooley, 1971). However, these authors have found that it is efficient to use the same iterative loop for both linearization and matrix solution. This is accomplished as follows:

1. All nonlinear coefficients are evaluated using the latest value of H, and the elements of the $[\bar{A}]$ matrix and {RHS} vector are determined.

2. Equation 45 is solved for the residuals, $\{H^*\}$, using the strongly implicit procedure.

3. New potentials are computed using the following equation:

$$H^k = H^{k-1} + w_k H^* , \qquad (46)$$

where w_k is a damping factor ($0 < w_k \leq 1$) that is designed to dampen numerical oscillations. It is calculated by the computer code according to the formula given by Cooley (1983, p. 1274).

4. Convergence is tested for by requiring that all H^* be less in magnitude than a user-specified tolerance (EPS in table 3).

5. If convergence is achieved, the program proceeds to the next time step. If convergence is not achieved, steps 1 through 4 are repeated a maximum of ITMAX times, where ITMAX is a user-specified variable. If convergence is still not achieved, the length of the current time step is reduced by the user-specified factor of TRED and heads computed at the end of the previous time step are re-established as initial conditions for the shortened time step. Steps 1 through 4 are again repeated a maximum of ITMAX times. The length of the time step can be reduced 3 times within an individual time step. If convergence is still not obtained either the program proceeds to the next time step (if ITSTOP = FALSE) or the program terminates after writing an error message and results from the last iteration (if ITSTOP = TRUE).

In some cases, the iterative process may not converge within a specified tolerance. In these cases, the solution does not diverge, but oscillates about the true solution. These oscillations commonly occur in systems in which quasi-equilibrium or steady-state conditions are approached. No panacea exists for eliminating these oscillations, but convergence can often be achieved by changing the value of HMAX that multiplies the {RHS} term in equation 46. An approximate range of values for HMAX is 0.2 to 1.1. Trescott and others (1976, p. 26) give more detail on this parameter.

Care must be exercised when specifying the ITSTOP option (table 3) to FALSE. Errors may increase without bound with simulation time if convergence is not achieved in several sequential time steps, resulting in totally nonsensical results. Output generated using this option should be thoroughly scrutinized to ensure that the results are indeed meaningful.

Initial Conditions

Initial conditions required for solution of the fluid-flow equation are specified by reading either the initial volumetric-moisture content, (θ) or the initial pressure head, h. The program computes the pressure head or the volumetric-moisture content using the appropriate moisture content-pressure head function or its inverse from the supplied data. Boundary conditions at the start of simulation are read after initial conditions are set, so that they override initial conditions for boundary cells.

One commonly found initial condition is one in which the pressure potential is in equilibrium with the elevation potential above a free-water surface or water table. This condition is referred to in soil physics literature as an equilibrium profile. Automatic computation of pressure heads to provide such a profile as an initial condition is an option in the program. The user also may specify a constant minimum pressure head to replace the upper part of an equilibrium profile.

Boundary Conditions

Numerical approximations to the boundary conditions required to solve the fluid flow equation are described in this section.

Specified Flux and Potential

The specified flux boundary condition, which is described by equation 14, is also called a Neumann boundary condition. The specified potential, or Dirichlet boundary condition, is given by equation 15. The use of a block-centered finite difference grid in this model results in the following dilemma: The Neumann boundary condition (specified ∇H) can be specified properly, but the Dirichlet condition (specified H) cannot. With a face-centered grid, the Dirichlet boundary condition specification is straight-forward, because the nodes are located on the boundary; however, flux boundary conditions require special formulation of the equations for each face across which the flux occurs. Difficulty in numerical implementation of these formulations in two dimensions was one of the reasons for choosing a block-centered grid.

The specified flux boundary condition is implemented in the code by the use of source or sink terms at the boundary nodes. Each term in the summation in equation 13 represents a flux across a cell face. Consequently, when such a face is on a boundary, its conductance is set to zero, and a source or sink term approximates the boundary flux.

To accurately represent a specified potential on the boundary, these cells should be as small (as possible) in the dimension perpendicular to the boundary. However, making this dimension small may require smaller time steps to prevent oscillation (Finlayson and others, 1978) and to preserve accuracy. Nodes with a specified potential are actually removed from the model domain. Because of this, the user should be aware that errors may occur in the computed mass balance if specified potentials are changed between successive simulation periods.

Infiltration

As discussed previously, infiltration may be a multistage process in which the boundary condition initially is one of specified flux, followed by a specified potential, and possibly, a reversion to one of specified flux. The boundary condition changes at the time ponding occurs or ceases. Infiltration is implemented in the code by:

1. Specifying the application or rainfall rate as a source term at boundary cells on the land surface. A new simulation period must be used to change rainfall rates.

2. Solving for all heads at the current time step.

3. Checking values of pressure potential (h) at each rainfall boundary node. If h is less than the maximum height of ponding (h_{pond}), as specified by the user, the simulation proceeds to the next time step. If h is greater than h_{pond}, h is set equal to h_{pond}, the boundary condition at that node is set to a specified potential, and step 2 is repeated. At the same time, a flag (IFET2) is set to indicate that at least one node has been converted from specified flux to specified head.

4. Once ponding has occurred, the flux through each node subject to ponding is computed and compared to the specified flux. If the computed flux exceeds that specified by 1 percent or more, the node is respecified as a constant flux node, and step 2 is repeated. The 1-percent tolerance is incorporated to minimize flip-flopping between specified boundary conditions.

The value of h_{pond} is determined by the user-defined variable POND. The appropriate value for POND depends on the topography of the cross section being simulated. If the land surface is flat or uniformly sloping, the depth of ponding should be uniform. Under these conditions, POND should be a zero or positive value corresponding to the anticipated height of ponded water above land surface. If the cross section includes a furrow or depression, on the other hand, as shown in figure 13, water would drain by overland runoff into the depression, where it might accumulate to some significant depth. This situation may be simulated by establishing a horizontal zero reference line that coincides with the highest point on the land surface. POND is defined as the algebraic height of anticipated ponding in the depression above the reference line, and is thus negative. Under these conditions,

$$h_{pond} = \text{maximum of } (0, DZZ + POND) \ , \qquad (47)$$

where DZZ = depth of each boundary node subject to infiltration below the reference point (positive downward).

The maximum height of ponding for each node will thus be equal to the greater of the elevation equal to POND or the elevation of land surface.

The manner in which VS2D may be used to determine the duration of a given rainfall rate, relative to the saturated hydraulic conductivity, needed to produce surface ponding and overland runoff for a given soil and specified initial conditions, is illustrated in figure 14. This figure shows the time required to produce ponding on a thick (4 m) bed of sand having the hydaulic properties of soil 4 in table 1, based on Brooks-Corey parameters. The effect on ponding time of two different initial conditions is shown by the separate curves. Ponding occurs significantly sooner when the soil column is relatively wet (pressure head = -80 cm) than when it is well drained (pressure head = -200 cm).

Evaporation

Evaporation across a boundary cell face is simulated as a two-stage process, as described above. Bare-soil evaporation is computed as the upward flux driven by the pressure-potential gradient between the soil and the atmosphere by the equation:

$$EV = KK_r \ SRES \ (HA - h) \ . \qquad (48)$$

The actual value of the evaporation flux is established by the value of EV. (1) if EV > PEV, the sink term for the cell is set equal to EV x A x ρ, where A = surface area of the cell. (2) If EV $\leq$ PEV, the sink term for the cell is set equal to PEV x A x ρ.

When simulating evaporation, the user must specify three variables, as described below:

1. PEV, evaporative demand of the atmosphere, or potential evaporation, as a function of elapsed simulation time, LT^{-1}. Values for potential evaporation may be estimated using, say, the Penman equation (Campbell, 1977, p. 120) with an appropriate wind function. PEV is determined in the program by a subroutine VSPET (which can be provided by the user)

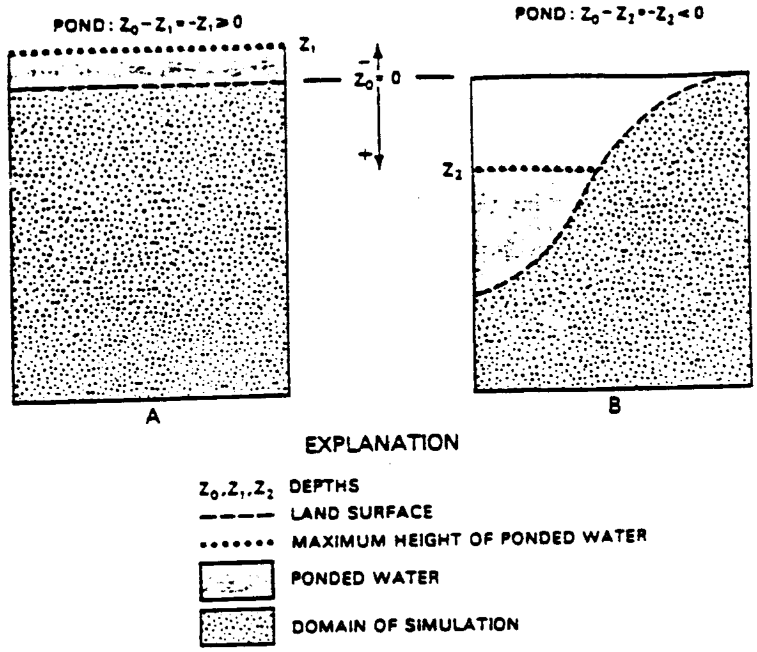

Figure 13.--The reference plane from which the depth of ponding, POND, is measured:
A. For infiltration through a horizontal surface.
B. For infiltration through a furrowed surface.

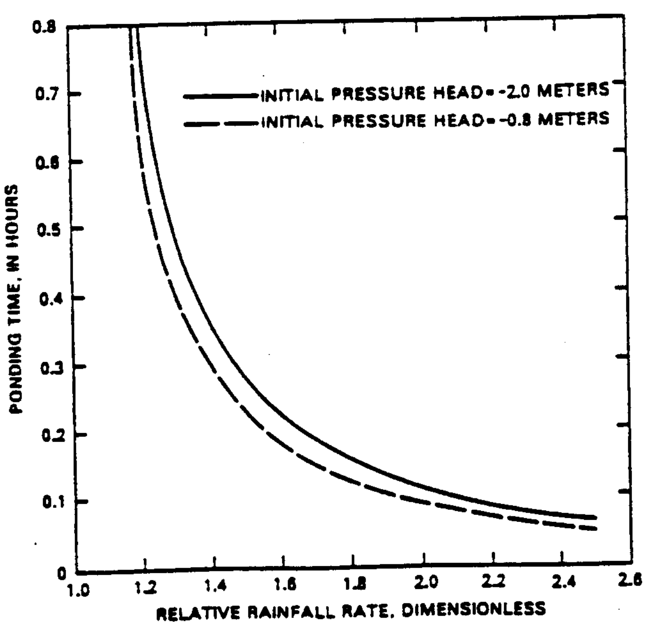

Figure 14.--Ponding time as a function of relative rainfall rate for a sand (soil no. 4, table 1) for two different initial conditions.

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based on the variation of potential evaporation with elapsed simulation time. The programmed subroutine assumes a recurring cycle of potential evaporation. Thus, several days of evapotranspiration may be simulated using a repeating daily sequence of hourly potential evapotranspiration values, or a few years of evapotranspiration could be simulated using a repeated annual sequence of, say, monthly values. The variation in PEV throughout a cycle is represented by a user-defined number (NPV) of line segments (ET periods) of equal length in time (ETCYC). Values of PEV for the beginning of each line segment must be entered by the user at the beginning of the simulation as a single set of values for that simulation. The program selects the proper line segment, based on elapsed simulation time, and then determines the value of PEV by linearly interpolating between values at the beginning and end of that segment.

2. HA, pressure potential of the atmosphere, L. This may be computed using the Kelvin equation (equation 6):

$$HA = \frac{RT}{M_w g} \ ln\ h_a \ ,$$

where h_a = relative humidity of the atmosphere.

As an example, assume that air temperature is 27 °C (300 K) and that relative humidity is 0.9. Since $R = 8.31\ kg \cdot m^2/sec^2 \cdot K \cdot g \cdot mol$, and M_w = 0.018 kg/g-mol, HA = -1,490 m. Moreover, at the same temperature and a relative humidity of 0.1, HA = -32,500 m. However, a pressure potential smaller than minus a few thousand meters of water can cause numerical instability in the simulation code. Thus, the user may want to arbitrarily specify HA as -1×10^3 m or so. Numerical experiments, described below, indicate that the computed evaporative flux is changed by only a few percent when HA is changed from -500 m to -1,000 m in a problem involving typical soil properties. Thus, little error should be introduced by using a value of HA of relatively small absolute magnitude.

3. SRES, surface resistance, L^{-1}. The total pressure potential in the atmosphere is assumed to apply at land surface. The surface resistance would be just the reciprocal of the distance from the node to land surface, or 2./DELZ(2). However, the user may want to simulate the effect of a less permeable surface crust. Under these conditions, SRES would be equal to the reciprocal of the thickness of designated soil that has the same hydraulic resistance as the crust. Thus, if the crust were assumed to have a thickness of DELZ(2)/2.,

$$SRES = [2./DELZ(2)] \times K_c/K_{i,2}, \qquad (49)$$

where $K_{i,2}$ = designated saturated hydraulic conductivity of boundary node, and

K_c = saturated hydraulic conductivity of the crust material.

For this approach, it is implicitly assumed that the unsaturated hydraulic conductivity function for the crust is the same as that for the surface soil.

SRES and HA are treated as cyclically varying parameters in the same manner as potential evaporation. Thus, it is necessary for the user to specify NPV values of both HA and SRES at the beginning of the simulation.

Some results obtained using Program VS2D to compute evaporation from a sand are shown in figure 15. For the simulations, the sand was assumed to have the hydraulic properties listed for entry 4 in table 1, based on the Brooks-Corey model. The sand was assumed to contain water throughout a deep profile underlain by impermeable materials at a pressure head of -80 cm. The pressure potential of the atmosphere was assumed to be -1,000 m. Simulations were made for three assumed potential evaporation rates, resulting in the graphed rates of evaporation. Note that once the evaporation rate becomes soil limited, it is essentially the same, regardless of the potential rate. The small humps in the curves likely arise from numerical problems in the code during the transition from climate-limited to soil-limited evaporation.

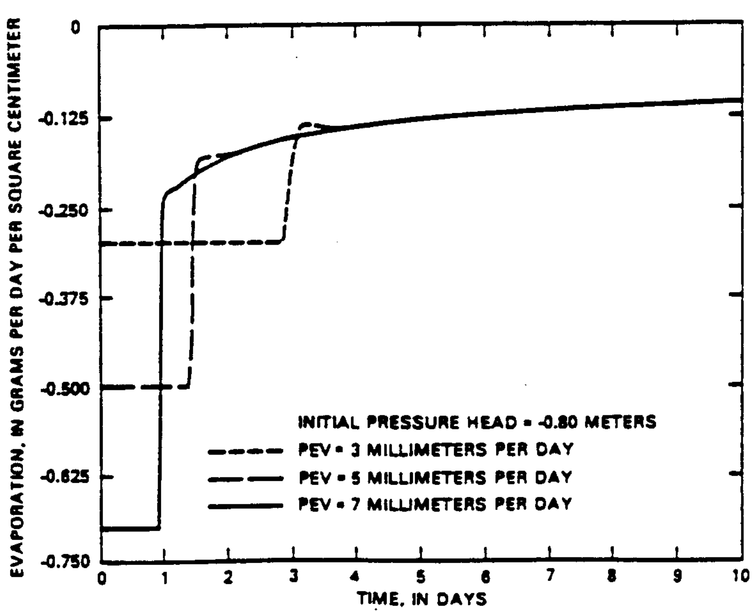

Figure 15.--Variation of evaporation rate from the surface of a column of sand (soil no. 4, table 1), 1-meter deep, for different potential evaporation rates.

Evapotranspiration

Evapotranspiration by vegetation results in plant-root extraction, which in turn is computed based on the following equation:

$$q_m = KK_r(h)r(z,t)(h_{root}-h) \tag{50}$$

where $r(z,t)$ is a root activity function of depth and time, L^{-2}; and

h_{root} = pressure head in the root for the entire system, L.

Total extraction by roots in a given column of cells is:

$$\hat{Q} = \rho \sum_{m=1}^{\bar{m}} (vq)_m \tag{51}$$

where $\bar{m}$ = number of cells in the column with roots present.

If water is freely available to the plants, equations 50 and 51 may compute a flux from the soil (thus negative in sign) that is larger in magnitude than the potential evapotranspiration rate (PET). Consequently, for each iteration, the value of $\hat{Q}$ computed by equation 51 is compared to PET x A x ρ, and if $\hat{Q}$ is larger in magnitude than that value, all q_m are adjusted by

$$q_m = \left(\frac{PET \times A \times \rho}{\hat{Q}}\right) q_m \tag{52}$$

Otherwise, all q_m remain as the values computed by equation 50. The flow equation is then solved using the specified values for q_m.

To simulate of evapotranspiration, the logical variable ETSIM must be set to TRUE, and values for five variables must be specified, including PET (potential evapotranspiration), HROOT (minimum pressure in the roots, RTDPTH (the depth of rooting), RTBOT (the root activity at the bottom of the root zone), and RTTOP (the root activity at land surface). All of these variables are assumed to vary cyclically, and NPV values of each variable must be specified at the beginning of the simulation. The variables used to simulate evapotranspiration are discussed in greater detail below.

1. PET, Potential evapotranspiration, LT^{-1}. Typically, potential evapotranspiration would be computed from climatic data, using an equation such as the Penman or Jensen-Haise equations (Jensen, 1973) times an appropriate empirically determined crop factor.

2. HROOT, the pressure potential within the plant roots, L. Ordinarily HROOT would be set equal to the permanent wilting point for the plants in question. The permanent wilting point is defined as the pressure

potential in the soil at which the plant wilts and dies. For most agricultural crops, the permanent wilting point is equivalent to about -150 m of water.

3. RTDPTH, depth of rooting, L. This is the maximum depth below land surface in which root extraction is allowed. As programmed, the roots could grow throughout the season, then die back at the end of the season to start over.

4. RTBOT, root activity at bottom of the root zone [r(RTDPTH,t) in equation 50], L^{-2}. This term is defined as the length of roots in a given volume of soil divided by that volume. The function routine VSRDF calculates the root activity for each depth within the root zone by linearily interpolating between the activity at the bottom of the root zone and that at land surface (RTTOP). Root activities range from 0 up to about 3.0 cm^{-2}, depending on the plant community and its stage of development.

5. RTTOP, root activity at land surface [r(0,t)], L^{-2}. This parameter is similar to RTBOT, and the comments above regarding RTBOT apply.

Several more comprehensive root-resistance functions have been presented in the literature (Molz, 1981). The user may want to supply his own root-activity function, which would replace VSRDF in the program.

Examples of the use of program VS2D to simulate the effects of evapotranspiration are shown in figures 16 through 18. Figures 16 and 17 show the effects of plant-root extraction on the pressure-head profile with time in a 1.8-m thick sandy soil having the hydraulic properties listed for soil 4 in table 1, based on the Brooks-Corey model. Figure 16 shows the pressure head profiles that would develop with time in the sand if it were underlain by an impermeable bed at a depth of 1.8 m, starting with an initial pressure head of -100 cm. Figure 17 shows the pressure-head profiles that would develop in the same sand underlain by a fixed water table at 1.8-m depth, with an equilibrium profile from the water table to a depth of 0.8 m and a uniform pressure head of -100 cm above that depth. Root depth was 0.6 m, and root activities varied from 1.0 cm^{-2} at land surface to 0.5 cm^{-2} at the base of the root zone.

The actual evapotranspiration rates for the two cases during the 10-day simulation are shown in figure 18. Note that, in the case involving a shallow water table, the plant-root extraction induces upward flow from the water table, but the plants are not able to obtain enough water to meet the atmospheric demand. On the other hand, the plants growing in the absence of a shallow water table are nearly unable to extract water after about 5 days. Note that these large differences in evapotranspiration rates arise even though the pressure-head profiles for the two situations are quite similar.

Seepage Faces

Seepage faces produce nonlinear boundary conditions because the position of the top of the face is not known a *priori*. The code simulates this boundary condition in a manner similar to that described by Neuman (1975). This is accomplished as follows:

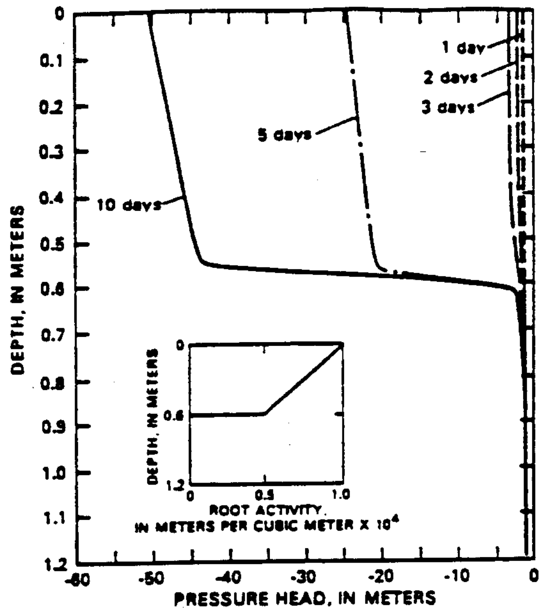

Figure 16.--Pressure-head profiles following transpiration from shallow-rooted plants in sand (soil no. 4, table 1) underlain by an impermeable bed at 1.8 meters. Potential evapotranspiration is 1 gram per square centimeter per day and the numbers on the curves represent elapsed days from the start of the simulation.

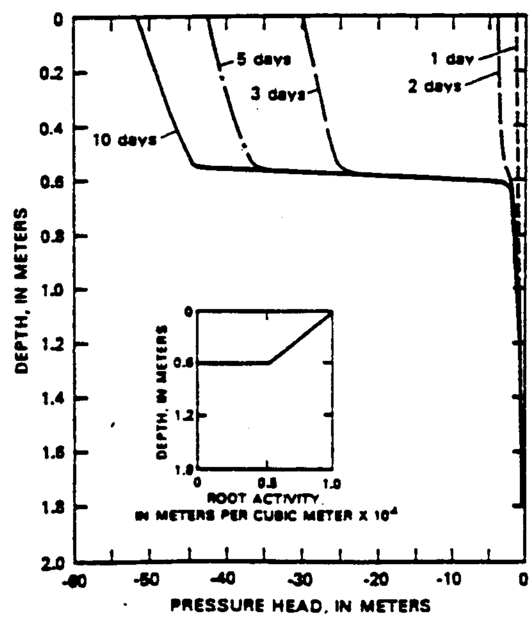

Figure 17.--Pressure-head profiles following transpiration from shallow-rooted plants in sand (soil no. 4, table 1) in the presence of a shallow water table at 1.2 meters. Potential evapotranspiration is 1.0 grams per square centimeter per day and the numbers on the curves represent elapsed days since the start of the simulation.

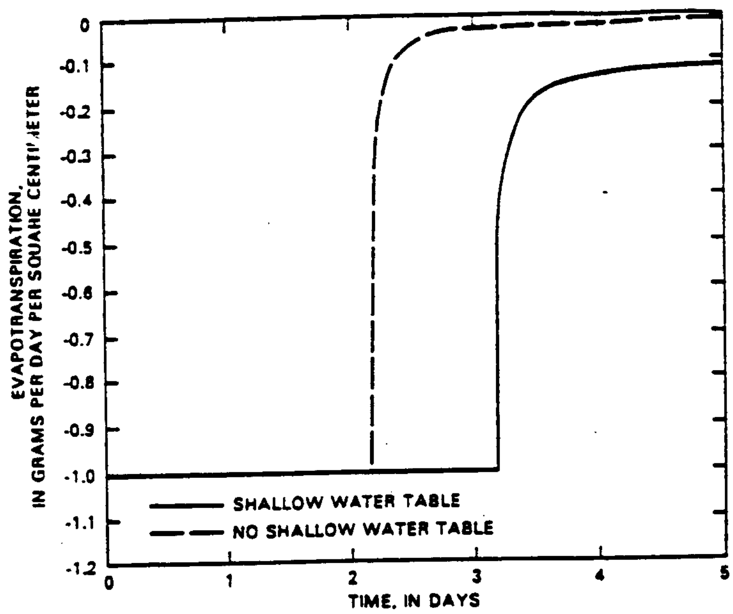

Figure 18.--Evapotranspiration rate as a function of time for transpiration by shallow-rooted plants in the presence and absence of a shallow water table. Potential evapotranspiration, soil properties and root-density profiles are the same as for figures 16 and 17.

1. The user specifies the nodes that fall on potential seepage face boundaries, as well as initial estimates of the seepage face heights.

2. For each seepage face, pressure potentials are set equal to zero from above the free-water surface to a height equal to the initial estimate of the seepage face height. Along the remainder of the potential seepage face, the boundary condition is considered to be one of specified zero flux.

3. Potentials are solved for in the entire system, and fluxes along the seepage face are computed. If these fluxes are all either zero or out of the system, simulation proceeds. If any point along the seepage face exists where h is specified as zero, and the computed flux is into the system, this cell is set to a prescribed zero flux boundary. For a specified zero flux cell, if the computed pressure head is positive, h is set to zero and the boundary condition is set to be one of specified potential.

4. Step 3 is repeated until all fluxes are out of the system along boundary segments at which h has been set to zero and all pressure potentials are less than or equal to 0 along the boundary.

Source-Sink Terms

Internal source-sink terms, other than plant-root extraction, must be treated either as constant-head or constant-flux nodes, the value of which may be changed with time. Fluxes must be in terms of volume per time (L^3/T) or of volume per time per unit of top surface area of the nodal cell (L/T). The former option is convenient for simulating pumping wells, while the latter option would be used to simulate infiltration. Constant-head nodes may be set in terms of pressure or total head. If the source-sink terms are made up of more than one node, the user must determine beforehand how the specified flux (or specified head) should be apportioned among all the nodes.

As was mentioned under "Theoretical Background", source-sink terms present in an unsaturated medium can possibly produce unrealistic results, due to the inability of the medium to conduct fluid at a fast enough rate. VS2D has no provision to check the validity of the computed results when this option is selected. Therefore the user is cautioned to scrutinize the calculated output to ensure that it is reasonable.

Nonlinear Coefficient Evaluation

Function subprograms have been written and tested to define θ from specified h, h from specified θ, $K_r(h)$, and $c_m(h)$, based on one of the following algebraic equations:

1. Brooks and Corey (1964).
2. van Genuchten (1980).
3. Haverkamp (1977).

The various expressions based on these equations are presented in the section "Nonlinear Coefficients". For all three equations, the variables used to evaluate the coefficients are stored in array HK (input line B-7 in table 3). The first four entries for each texture class must be the ratio of vertical to horizontal conductivity, horizontal saturated hydraulic conductivity, specific storage, and porosity. The fifth entry is the bubbling pressure for the Brooks and Corey equation, α' (as defined in this report) for the van Genuchten equation, or A' for the Haverkamp relative hydraulic conductivity equation. The sixth entry is residual moisture content for all three equations. The seventh entry is Brooks-Corey λ, van Genuchten β', or B' for the Haverkamp relative hydraulic conductivity equation. These seven values are adequate to evaluate all nonlinear coefficients using the Brooks-Corey and van Genuchten equations, but two additional values are needed to evaluate the coefficients for the Haverkamp equation. These are read as Haverkamp α for the eighth variable and Haverkamp β for the ninth.

Alternatively, different function subroutines may be used to interpolate the coefficient values from tabular data of h, θ, and K_r. For the included function routines, the first four values are the ratio of vertical to horizontal conductivity, saturated hydraulic conductivity, specific storage, and porosity, as above. All pressure heads are then input in increasing order from the smallest to the largest. Next all values of relative hydraulic conductivity are entered in the same order. Finally, all values of moisture content are input in the same order. There must be an equal number of heads, relative conductivities, and moisture contents. The last values of head, relative hydraulic conductivity, and moisture content should all be 99 to indicate the end of data. For this option, initial conditions must be specified in terms of pressure potential. It should be recognized that the use of tabular data and an interpolation scheme may add considerable time to the execution of the program.

As listed in Attachment 1, the program is set up to use the van Genuchten equations to define θ, h, K_r, and c_m. The functions using the Brooks and Corey or Haverkamp equations or linear interpolation are included as comment cards at the end of the program. To use these subroutines, they should be unloaded from the file, stripped of comment designation, compiled, and loaded with a compiled version of VS2D that does not include the functions for the Brooks-Corey model.

Liquid-Flux and Mass-Balance Computations

For many applications of this model, the quantities of most interest are fluxes in and out of the system. These fluxes are computed and printed separately for the following:

1. Specified potential boundaries;
2. Specified flux boundaries;
3. Evaporation;
4. Transpiration by plants; and
5. Specified source-sink cells.

These fluxes are balanced against changes in storage in the system being modeled. Integration of storage changes over the solution domain and over time uses differenced forms of the storage term in equation 13. The error in the balance is computed as a cumulative volume and as mass flux rates.

COMPUTER PROGRAM

Program Structure

The following pages list the functions of each of the subroutines, the required data inputs, and the content of the output files. A complete source-code listing is given in Attachment 1 and a flow chart for the program is given in Attachment 2. Definitions of variables are given in table 2. Table 3 lists the input data, including temporary designations not listed in table 2, and describes the read formats.

Communication among subroutines is achieved through the use of common blocks with minimal use of variables passed through calling sequences.

Table 2.--*Definitions of variables*

[NN, number of nodes; KT, number of time steps; NTEX, number of textural classes; NLY, number of rows; NXR, number of columns; NIT, number of iterations; NPLTIM, number of times to print to file 11; NFCS, number of seepage faces]

Variable	Definition
HX(NN)	Horizontal saturated hydraulic conductivity, LT^{-1}.
HKTT(NN)	Conductance at left side of cell, L^2T^{-1}.
HKLL (NN)	Conductance at left side of cell, L^2T^{-1}.
PXXX(NN)	Total head from previous time step, L.
Q(NN)	Evapotranspiration rate, L^3T^{-1}.
RT(NN)	Root activity function, L^{-2}.
THETA(NN)	Volumetric moisture content at current time step, L^o.
THLST (NN)	Volumetric moisture content at previous time step. L^o.
QQ(NN)	Array of constant fluxes into or out of each cell, L^3T^{-1}.
DUM(NN)	Temporary array used for input and output.
A(NN)	Coefficient in flow equation for left side of each cell, L^2T^{-1}.
B(NN)	Coefficient in flow equation for top side of each cell, L^2T^{-1}.
C(NN)	Coefficient in flow equation for right side of each cell, L^2T^{-1}.
D(NN)	Coefficient in flow equation for bottom of each cell, L^2T^{-1}.
E(NN)	Coefficient for center of each cell, L^2T^{-1}.
RHS(NN)	Right-hand side of the flow equation for each cell, L^3T^{-1}.
P(NN)	Total head at current time step, L.
PITT(NN)	Static array used in VSMGEN to allow Newton-Raphson treatment of capacitance terms.
HCND(NN)	Relative hydraulic conductivity at each cell, L^o.
DEL(NN)	Temporary array used in SIP.
ETA(NN)	Temporary array used in SIP.
V(NN)	Temporary array used in SIP.
XI(NN)	Residual of total head between iterations, L.
ETOUT	Total transpiration from system for each time step, MT^{-1}.
ETOUT1	Total evaporation from system for each time step, MT^{-1}.
TITL	80 character title.
DELZ(NLY)	Grid spacing in vertical direction, L.
DXR(NXR)	Grid spacing in horizontal direction, L.
RX(NXR)	Radial or horizontal distance from left side of domain to center of each column, L.
DELY	Thickness of vertical section, L.
DSMAX	Maximum allowed change in head per time step, L.
JTEX(NN)	Textural class code for each cell.
JSPX(3,25,4)	Integer map of seepage face nodes; first dimension contains cell number, row number, and column number for each cell on a possible seepage face; second dimension is the position on the seepage face from lowest to highest dimension; third dimension is the seepage face number.

Table 2.--*Definitions of variables*--Continued

Variable	Definition
NTYP(NN)	Boundary condition or cell type indicator: 0 = internal node; 1 = specified pressure head; 2 = specified flux per unit top surface area of cell; 3 = cell on which seepage face is permitted; 4 = specified total head; 5 = cell from which evaporation is permitted; and 6 = specified volumetric flow rate.
IDUM(NN)	Temporary array for input and output of texture class codes.
IJOBS(NOBS)	Array of observation points; head and saturation for each cell contained in IJOBS will be written to file 11 each time step.
KDUM(NN)	Temporary array to read in observation points for which data are to be written to file 11.
NFC(4)	Number of cells permitted in each seepage face.
EPS	Convergence criterion for all iterations, L.
STERR	Steady-state convergence criterion for all recharge periods, L.
STIM	Current value of elapsed simulation time, T.
TPER	Length of current recharge period, T.
PET	Potential plant transpiration per unit area, LT^{-1}, as computed by function VSPET.
PEV	Potential evaporation per unit area, LT^{-1}, as computed by function VSPET.
PETT	Potential evaporation or potential evapotranspiration from column area, L^3T^{-1}.
ANIZ(10)	Ratio of vertical-to-horizontal saturated hydraulic conductivity or anisotropy factor, L^0.
WUS	Upstream weighting factor for relative hydraulic conductivity, L^0.
WDS	Downstream weighting factor for relative hydraulic conductivity, L^0.
HROOT	Pressure head in roots at which plants permanently wilt, L.
HA	Pressure head in the atmosphere, used to compute evaporation, L.
NPV	Number of potential evaporation or potential evapotranspiration values to be read in during simulation.
PEVAL(25)	Potential evaporation at beginning of simulation and at end of each user-specified interval thereafter, LT^{-1}.
PTVAL(25)	Potential evapotranspiration at beginning of simulation and at end of each user-specified interval thereafter, LT^{-1}.
RDC(6,25)	Constants used to determine pressure potential of the atmosphere, surface resistance of the soil, rooting depth, root activity functions, and root pressure potential.
DHMX(NIT)	Maximum change in total head over entire solution domain for each iteration within each time step, L.
DPTH(NN)	Depth from land surface to center of each cell, L.
TEMP(NLY)	Temporary array.

Table 2.--*Definitions of variables*--Continued

Variable	Definition
DZZ(NLY)	Vertical distance from origin at top of domain to center of each layer, L.
PLTIM(NPLT)	Times at which heads are written to files 6 and 8 for all cells, T.
HM(30)	Iteration parameters for SIP algorithm, L^{0}.
HK(10,100)	Array of textural properties for each different class. First dimension refers to textural class. Second dimension refers to saturated hydraulic conductivity, specific storage, porosity, and other parameters required for determining moisture and conductivity functions.
DLTMIN	Minimum allowed time step, T.
SRES	Surface-resistance factor for evaporation, L^{-1}.
DELT	Current time-step length, T.
DLTMX	Maximum allowed time step, T.
HMAX	Relaxation or damping factor, L^{0}.
POND	Maximum allowed depth of ponded water, L.
CUNX	Descriptor for units of mass.
RTDPTH	Root depth, L.
TMLT	Multiplier for time-step length, L^{0}.
TRED	Factor for time-step length reduction, L^{0}.
TMAX	Maximum simulation time, T.
TUNIT	Descriptor for units of time.
RHOZ	Liquid density, ML^{-3}.
ZUNIT	Descriptor of units used for length.
PI2	$2 \times \pi$, L^{0}.
IFET	Counter that is set to 1 when ponding has occurred or ceased; allows rerunning of the time step with new boundary conditions.
IFET1	Counter to determine whether all nodes for which ponding can occur have been tested.
IFET2	Counter to determine whether any nodes that were initially specified as constant flux are now specified as constant-head nodes.
ITMAX	Maximum permitted number of iterations per time step.
JFLAG	Flag used to initiate print to file 6, when set to 1.
JSTOP	Flag used to stop simulation, if set to 1.
ITEST	Switch to indicate convergence (=0) or nonconvergence of iteration (=1).
NUMT	Maximum permitted number of time steps.
NRECH	Number of periods for which different boundary-condition data are to be read.
NLY	Number of rows in domain.
NXR	Number of columns in domain.
NLYY	NLY-1.
NXRR	NXR-1.
KP	Counter on number of periods with different boundary conditions (recharge periods).

Table 2.--*Definitions of variables*--Continued

Variable	Definition
KTIM	Time-step counter.
NIT	Iteration counter.
NITT	Total number of iterations for simulation.
MINIT	Minimum number of iterations for each time step.
JPLT	Switch to write all heads to file 8 (=1), or bypass writing these (=0).
NPLT	Number of times for which all heads are written to file 8.
NOBS	Number of cells for which head and saturation are written to file 11 each time step.
NFCS	Number of seepage faces.
JLAST(NFCS)	Number of node which represents current height of each seepage face.
NNODES	Total number of nodes in simulation.
NTEX	Number of textural classes.
THPT	If = T, moisture contents are written to file 6.
SPNT	If = T, saturations are written to file 6.
PPNT	If = T, pressure heads are written to file 6.
BCIT	If = T, flux boundary condition involving evaporation is permitted.
PRNT	If = T, heads and saturations are written to file 6 every time step; if = F, heads and saturation are written at designated times and at end of recharge period.
RAD	If = T, cylindrical coordinate system is used; if = F, rectangular system is used.
PHRD	If = T, initial values of pressure head are read; if = F, initial volumetric moisture contents are read for entire solution domain.
ITSTOP	If = T, simulation is terminated if MAXIT iterations are exceeded during a time step.
SEEP	If = T, seepage faces are permitted.
HPNT	If = T, total heads are written to site 6.
F6P	If = T, mass balance summary is written to file 6 each time step. If false, mass balance summary is written to file 6 at designated times and at end of recharge period.
ETSIM	If = T, flux boundary condition involving plant transpiration is permitted.
F7P	If = T, the maximum head change for each iteration is written to file 7 after every time step.
F8P	If = T, the mass-balance summary and pressure heads, total heads, saturations, and/or moisture contents, as designated are written to file 6 at specified times; pressure heads are written to file 8 for the same times.
F9P	If = T, mass-balance components, including evaporation and evapotranspiration are written to file 9 for each time step.
F11P	If = T, heads and saturations are written to file 11 for specified observation points each time step.

Input Data

Data are read, mainly as free-formatted or list-directed input, from file 5. However, the title and the units are read in VS2D in A-format to avoid the need to enclose the character strings in quotation marks. The use of free format, which is supported by Fortran-77 and some extended versions of Fortran-66 facilitates terminal input. Data for a given READ statement can occur anywhere on the line, or may occur on several lines, each entry being separated by a comma or by one or more blanks. Every item in the input list requires an entry (blanks do not represent zeros), but data may be read using a repeat count. Entry of data using the form n*d results in n values of d being read into the program. For repeated data entries, such as those read in at the start of a new recharge period, the user may wish to retain some previously read values. This may be accomplished for entries within the read list by the use of two commas surrounding the position of the the previous entry to be retained. If the entries to be retained are at the end of the list, the new entries may be followed by a / for some systems, or blank /, which terminates the record.

Users wishing to use this program on a computer with a Fortran compiler that does not support free format must add format statement numbers to the read statements, using formats of their choice (compatible with the data type of the variables).

Table 3 lists the data input entries by line. The usual Fortran convention is used to designate real numbers and integers.

Subroutine Descriptions

An attempt was made to make the computer code as modular as possible to facilitate updating of subroutines. As given in this report, the computer code comprises 22 subroutine and function subprograms. The main program to execute the code must be supplied by the user. This allows the inclusion of file attachment statements (if any) that may be required for a particular machine installation.

This section gives the purpose of each subroutine and function subprograms included in the computer code.

VS2D

1. VSEXEC — Executive control of simulation:
   a. Reads solution domain dimensions, program options and location and times for output to monitoring files.
   b. Calls routines to: (1) read material properties, boundary and initial conditions; (2) echo input data; (3) control time sequence of simulation; (4) compute coefficients in matrix equations and solve them; and (5) output results of simulation.

2. BLOCK DATA — Initializes values for common blocks used in the program.

3. VSREAD — Inputs initial conditions:
   a. Reads material properties, initial heads or moisture contents, and initial source/sink strengths from file 5.
   b. Computes depths for evapotranspiration calculations.

Table 3.--*Input data formats*

Card	Variable	Description
		[Line group A read by VSEXEC]
A-1	TITL	80-character problem description (formatted read, 20A4).
A-2	TMAX	Maximum simulation time, T.
	STIM	Initial time (usually set to 0), T.
A-3	ZUNIT	Units used for length (A4).
	TUNIT	Units used for time (A4).
	CUNX	Units used for mass (A4).
Note: Line A-3 is read in 3A4 format, so the unit designations must occur in columns 1-4, 5-8, 9-12, respectively.		
A-4	NXR	Number of cells in horizontal or radial direction.
	NLY	Number of cells in vertical direction.
A-5	NRECH	Number of recharge periods.
	NUMT	Maximum number of time steps.
A-6	RAD	Logical variable = T if radial coordinates are used; otherwise = F.
	ITSTOP	Logical variable = T if simulation is to terminate after ITMAX iterations in one time step; otherwise = F.
A-7	F11P	Logical variable = T if head, moisture content, and saturation at selected observation points are to be written to file 11 at end of each time step; otherwise = F.
	F7P	Logical variable = T if head changes for each iteration in every time step are to be written in file 7; otherwise = F.
	F8P	Logical variable = T if output of pressure heads to file 8 is desired at selected observation times; otherwise = F.
	F9P	Logical variable = T if one-line mass balance summary for each time step is to be written to file 9; otherwise = F.
	F6P	Logical variable = T if mass balance is to be written to file 6 for each time step; = F if mass balance is to be written to file 6 only at observation times and ends of recharge periods.

Table 3.--*Input data formats*--Continued

Card	Variable	Description
A-8	THPT	Logical variable = T if volumetric moisture contents are to be written to file 6; otherwise = F.
	SPNT	Logical variable = T if saturations are to be written to file 6; otherwise = F.
	PPNT	Logical variable = T if pressure heads are to be written to file 6; otherwise = F.
	HPNT	Logical variable = T if total heads are to be written to file 6; otherwise = F.
A-9	IFAC	= 0 if grid spacing in horizontal (or radial) direction is to be read in for each column and multiplied by FACX. = 1 if all horizontal grid spacing is to be constant and equal to FACX. = 2 if horizontal grid spacing is variable, with spacing for the first two columns equal to FACX and the spacing for each subsequent column equal to XMULT times the spacing of the previous column, until the spacing equals XMAX, whereupon spacing becomes constant at XMAX.
	FACX	Constant grid spacing in horizontal (or radial) direction (if IFAC=1); constant multiplier for all spacing (if IFAC=0); or initial spacing (if IFAC=2), L.
Line set A-10 is present if IFAC = 0 or 2.		
If IFAC = 0, A-10	DXR	Grid spacing in horizontal or radial direction. Number of entries must equal NXR, L.
If IFAC = 2, A-10	XMULT	Multiplier by which the width of each node is increased from that of the previous node.
	XMAX	Maximum allowed horizontal or radial spacing, L.
A-11	JFAC	= 0 if grid spacing in vertical direction is to be read in for each row and multiplied by FACZ. = 1 if all vertical grid spacing is to be constant and equal to FACZ.

Table 3.--*Input data formats*--Continued

Card	Variable	Description
A-11--JFAC--Continued		
		= 2 if vertical grid spacing is variable, with spacing for the first two rows equal to FACZ and the spacing for each subsequent row equal to ZMULT times the spacing at the previous row, until spacing equals ZMAX, whereupon spacing becomes constant at ZMAX.
	FACZ	Constant grid spacing in vertical direction (if JFAC=1); constant multiplier for all spacing (if JFAC =0); or initial vertical spacing (if JFAC=2), L.
Line set A-12 is present only if JFAC = 0 or 2.		
If JFAC = 0,		
A-12	DELZ	Grid spacing in vertical direction; number of entries must equal NLY, L.
If JFAC = 2,		
A-12	ZMULT	Multiplier by which each node is increased from that of previous node.
	ZMAX	Maximum allowed vertical spacing, L.
Line sets A-13 to A-14 are present only if F8P = T, (A-7)		
A-13	NPLT If NPLT < 0 write every step to unformatted file	Number of time steps to write heads to file 8 and heads, saturations and/or moisture contents to file 6.
A-14	PLTIM	Elapsed times at which pressure heads are to be written to file 8, and heads, saturations and/or moisture contents to file 6, T.
Line sets A-15 to A-16 are present only if F11P = T,		
A-15	NOBS	Number of observation points for which heads, moisture contents, and saturations are to be written to file 11.
A-16	J,N	Row and column of observation points. A double entry is required for each observation point, resulting in 2xNOBS values.
	[Line group B read by subroutine VSREAD]	
B-1	EPS	Closure criteria for iterative solution, units used for head, L.
	HMAX	Relaxation parameter for iterative solution. See discussion in text for more detail. Value is generally in the range of 0.4 to 1.2.

Table 3.--*Input data formats*--Continued

Card	Variable	Description
B-1--Continued		
	WUS	Weighting option for intercell relative hydraulic conductivity: WUS = 1 for full upstream weighting. WUS = 0.5 for arithmetic mean. WUS = 0.0 for geometric mean.
B-2	RHOZ	Fluid density (M/L^3 in units designated in line A-3).
B-3	MINIT	Minimum number of iterations per time step.
	ITMAX	Maximum number of iterations per time step. Must be less than 201.
B-4	PHRD	Logical variable = T if initial conditions are read in as pressure heads; = F if initial conditions are read in as moisture contents.
B-5	NTEX	Number of textural classes or lithologies having different values of hydraulic conductivity, specific storage, and/or constants in the functional relations among pressure head, relative conductivity, and moisture content.
	NPROP	Number of material properties to be read in for each textural class. When using Brooks and Corey or van Genuchten functions, set NPROP = 6, and when using Haverkamp functions, set NPROP = 8. When using tabulated data, set NPROP = 6 plus number of data points in table. [For example, if the number of pressure heads in the table is equal to N1, then set NPROP =3*(N1+1)+3]
Line sets B-6 and B-7 must be repeated NTEX times		
B-6	ITEX	Index to textural class.
B-7	ANIZ(ITEX)	Ratio of vertical-to-horizontal or radial conductivity for textural class ITEX.
	HK(ITEX,1)	Horizontal saturated hydraulic conductivity (K) for class ITEX, LT^{-1}.
	HK(ITEX,2)	Specific storage (S_s) for class ITEX, LT^{-1}.
	HK(ITEX,3)	Porosity for class ITEX.

Table 3.--*Input data formats*--Continued

Card	Variable	Description

B-7--Continued

Definitions for the remaining sequential values on this line are dependent upon which functional relation is selected to represent the nonlinear coefficients. Four different functional relations are allowed: (1) Brooks and Corey, (2) van Genuchten, (3) Haverkamp, and (4) tabular data. The choice of which of these to use is made when the computer program is compiled, by including only the function subroutine which pertains to the desired relation (see discussion in text for more detail).

In the following descriptions, definitions for the different functional relations are indexed by the above numbers. For tabular data, all pressure heads are input first (in increasing order from the smallest to the largest), all relative hydraulic conductivities are then input in the same order, followed by all moisture contents.

Card	Variable	Description
	HK(ITEX,4)	(1) h_b, L. (must be less than 0.0).
		(2) α', L. (must be less than 0.0).
		(3) A', L. (must be less than 0.0).
		(4) Smallest pressure head in table.
	HK(ITEX,5)	(1) Residual moisture content (θ_r).
		(2) Residual moisture content (θ_r).
		(3) Residual moisture content (θ_r).
		(4) Second smallest pressure head in table.
	HK(ITEX,6)	(1) λ.
		(2) β'.
		(3) B'.
		(4) Third smallest pressure head in table.
	HK(ITEX,7)	(1) Not used.
		(2) Not used.
		(3) α, L. (must be less than 0.0).
		(4) Fourth smallest pressure head in table.
	HK(ITEX,8)	(1) Not used.
		(2) Not used.
		(3) β.
		(4) Fifth smallest pressure head in table.

For functional relations (1), (2), and (3) no further values are required on this line for this textural class. For tabular data (4), data input continues as follows:

Table 3.--*Input data formats*--Continued

Card	Variable	Description
B-7--Continued		
	HK(ITEX,9)	Next largest pressure head in table.
	HK(ITEX,N1+3)	Maximum pressure head in table. (Here N1 = Number of pressure heads in table; NPROP = 3*(N1+1)+3).
	HK(ITEX,N1+4)	Always input a value of 99.
	HK(ITEX,N1+5)	Relative hydraulic conductivity corresponding to first pressure head.
	HK(ITEX,N1+6)	Relative hydraulic conductivity corresponding to second pressure head.
	. . .	
	HK(ITEX,2*N1+4)	Relative hydraulic conductivity corresponding to largest pressure head.
	HK(ITEX,2*N1+5)	Always input a value of 99.
	HK(ITEX,2*N1+6)	Moisture content corresponding to first pressure head.
	HK(ITEX,2*N1+7)	Moisture content corresponding to second pressure head.
	. . .	
	HK(ITEX,3*N1+5)	Moisture content corresponding to largest pressure head.
	HK(ITEX,3*N1+6)	Always input a value of 99.
Regardless of which functional relation is selected there must be NPROP+1 values on line B-7.		
B-8	IROW	If IROW = 0, textural classes are read for each row. This option is preferable if many rows differ from the others. IF IROW = 1, textural classes are read in by blocks of rows, each block consisting of all the rows in sequence consisting of uniform properties or uniform properties separated by a vertical interface.
Line set B-9 is present only if IROW = 0.		
B-9	JTEX	Indices (ITEX) for textural class for each node, read in row by row. There must be NLY*NXR entries.
Line set B-10 is present only if IROW = 1. As many groups of B-10 variables as are needed to completely cover the grid are required. The final group of variables for this set must have IR = NXR and JBT = NLY.		
B-10	IL	Left hand column for which texture class applies. Must equal 1 or [IR(from previous card)+1].

Table 3.--*Input data formats*--Continued

Card	Variable	Description
B-10--Continued		
	IR	Right hand column for which texture class applies. Final IR for sequence of rows must equal NXR.
	JBT	Bottom row of all rows for which the column designations apply. JBT must not be increased from its initial or previous value until IR = NXR.
	JRD	Texture class within block.
Note: As an example, for a column of uniform material; IL = 1, IR = NXR, JBT = NLY, and JRD = texture class designation for the column material. One line will represent the set for this example.		
B-11	IREAD	If IREAD = 0, all initial conditions in terms of pressure head or moisture content as determined by the value of PHRD are set equal to FACTOR. If IREAD = 1, all initial conditions are read from file IU in user-designated format and multiplied by FACTOR. If IREAD = 2 initial conditions are defined in terms of pressure head, and an equilibrium profile is specified above a free-water surface at a depth of DWTX until a pressure head of HMIN is reached. All pressure heads above this are set to HMIN.
	FACTOR	Multiplier or constant value, depending on value of IREAD, for initial conditions, L.
Line B-12 is present only if IREAD = 2,		
B-12	DWTX	Depth to free-water surface above which an equilibrium profile is computed, L.
	HMIN	Minimum pressure head to limit height of equilibrium profile; must be less than zero, L.
Line B-13 is read only if IREAD = 1,		
B-13	IU	Unit number from which initial head values are to be read.
	IFMT	Format to be used in reading initial head values from unit IU. Must be enclosed in quotation marks, for example '(10X,E10.3)'.
B-14	BCIT	Logical variable = T if evaporation is to be simulated at any time during the simulation; otherwise = F.