

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

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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 <i>m</i> 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^0
j	= index to finite-difference grid in the horizontal (x or r) direction, L^0
k	= reference index to a face of grid block, L^0
\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}
\bar{K}	= linearized unsaturated hydraulic conductivity, LT^{-1}
K_r	= relative hydraulic conductivity to liquid, L^0
L	= length of horizontal column, L
M_w	= mass of a mole of water, $M \text{ Mol}^{-1}$
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^0
n	= general coordinate direction, L^0
\hat{P}	= water-vapor pressure in the soil atmosphere, $ML^{-1}T^{-2}$
\hat{P}_0	= 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
\bar{u}_n	= liquid flux normal to n , LT^{-1}
v	= volume of a grid block, L^3
w_k	= damping factor, computed for the k th 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°
 θ_r = residual moisture content, L°
 ϕ = porosity, L°

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:

<i>Multiply</i>	<i>By</i>	<i>To obtain</i>
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 ($^{\circ}C$) to degree Fahrenheit ($^{\circ}F$), use the following formula: $(^{\circ}C \times 9/5) + 32 = ^{\circ}F$. To convert Kelvin (K) to degree Rankin ($^{\circ}R$), use the following formula: $K \times 1.8 = ^{\circ}R$.

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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:

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

where: ρ = liquid density, ML^{-3} ;
 s = liquid saturation, L^0 ;
 ϕ = porosity, L^0 ;
 t = time, T ;
 \bar{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:

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

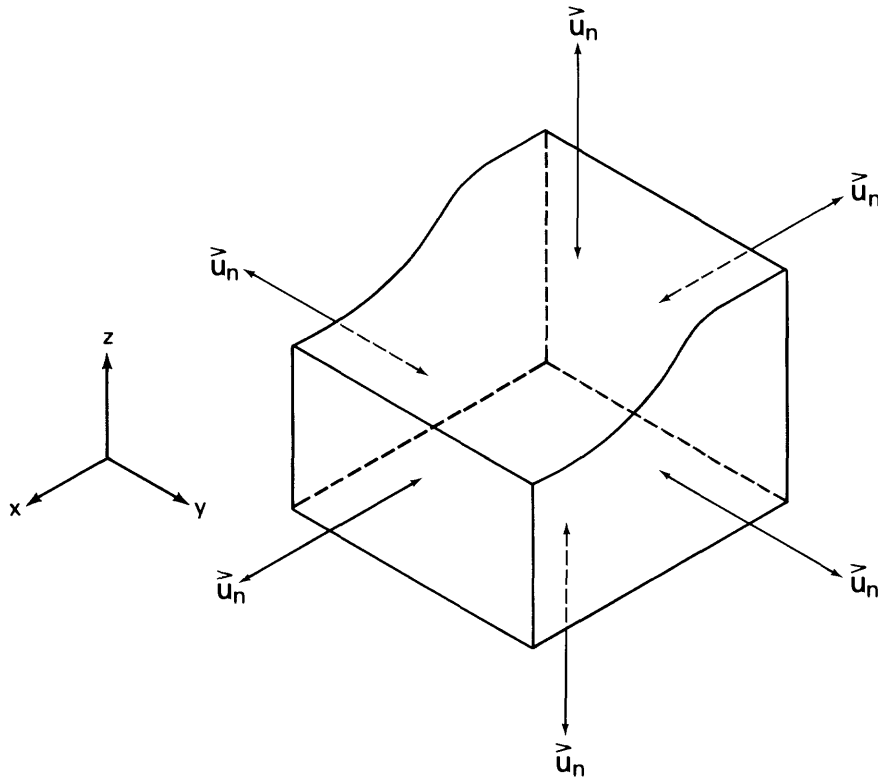


Figure 1.--General volume element, v , used for developing a fluid mass balance. (\bar{u} is liquid flux normal to face.)

Fluid-Flux Equation

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

$$\bar{u}_n^V = - \frac{\bar{K} K_r(h) \rho g}{\mu} \frac{\partial H}{\partial n}, \quad (3)$$

where: \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

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

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 $^{\circ}C$ 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:

$$H = h + h_z, \quad (4)$$

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):

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

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):

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

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

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):

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

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:

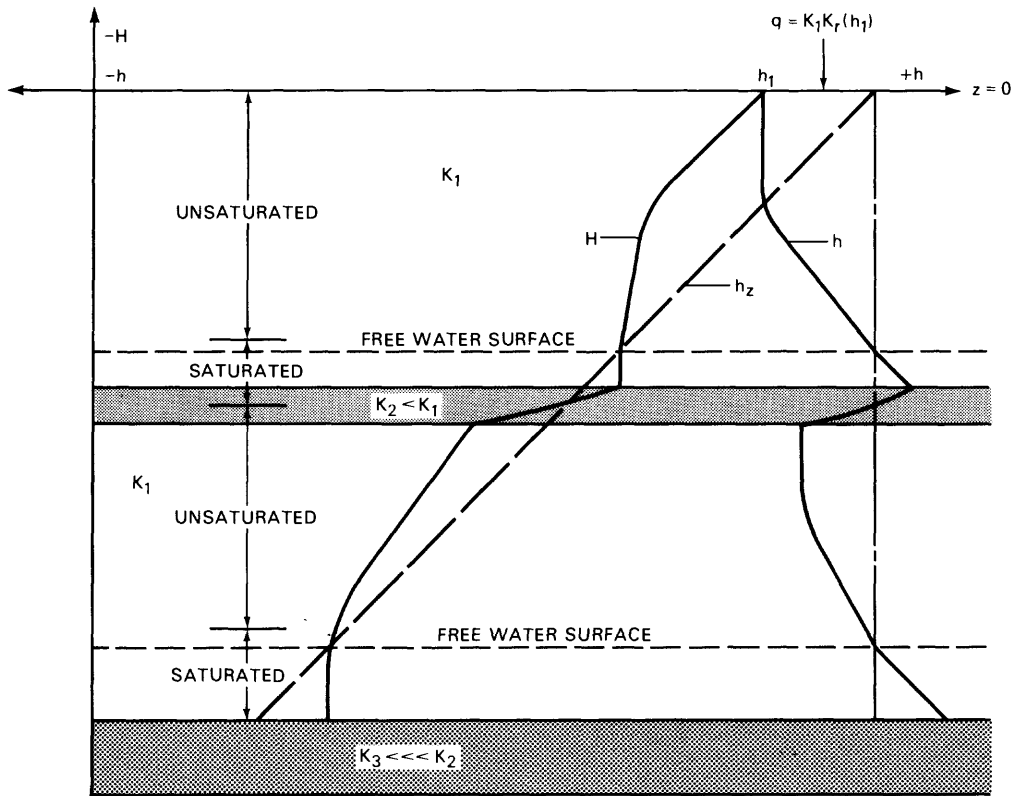
$$v \frac{\partial(\rho s \phi)}{\partial t} - \int_{\bar{s}} \rho K K_r(h) \frac{\partial H}{\partial n} d\bar{s} - \rho qv = 0 , \quad (8)$$

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:

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

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



EXPLANATION

- CONFINING LAYER 1
- CONFINING LAYER 2
- H TOTAL POTENTIAL, L
- h PRESSURE POTENTIAL, L
- h_z ELEVATION POTENTIAL, L
- K_1, K_2, K_3 SATURATED HYDRALIC CONDUCTIVITY OF MATERIALS 1, 2, AND 3, LT^{-1}
- $K_r(h_1)$ RELATIVE HYDRALIC CONDUCTIVITY OF LAYER 1 AT h_1 , DIMENSIONLESS
- q SURFACE VOLUME FLUX RATE PER UNIT AREA, LT^{-1}

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:

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

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:

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

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:

$$\begin{aligned} c_m &= \frac{\partial \theta}{\partial h} && = \text{specific moisture capacity, which is the slope} \\ &&& \text{of the moisture retention curve, } L^{-1}; \\ \alpha_c &= \frac{\partial \phi}{\partial \bar{P}} && = \text{matrix compressibility, } M^{-1}LT^2, \\ &&& \text{where } P = \text{average pressure, } ML^{-1}T^{-2}; \\ \beta_c &= \frac{1 \partial \rho}{\rho \partial \bar{P}} && = \text{fluid compressibility, } M^{-1}LT^2; \end{aligned}$$

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

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

$$v \{ \rho [c_m + s S_s] \} \frac{\partial H}{\partial t} - \rho \sum_{k=1}^{\hat{m}} A_k K K_r(h) \frac{\partial H}{\partial n_k} - \rho q v = 0. \quad (13)$$

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:

$$\rho_k \dot{u}_k = f_1(x, t, \nabla H, h)_k, \quad (14)$$

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:

$$H_k = f_2(x, t, \nabla H, h)_k, \quad (15)$$

where f_2 is a general time-dependent function.

Four phenomena can occur in flow through variably saturated media that may make a *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.

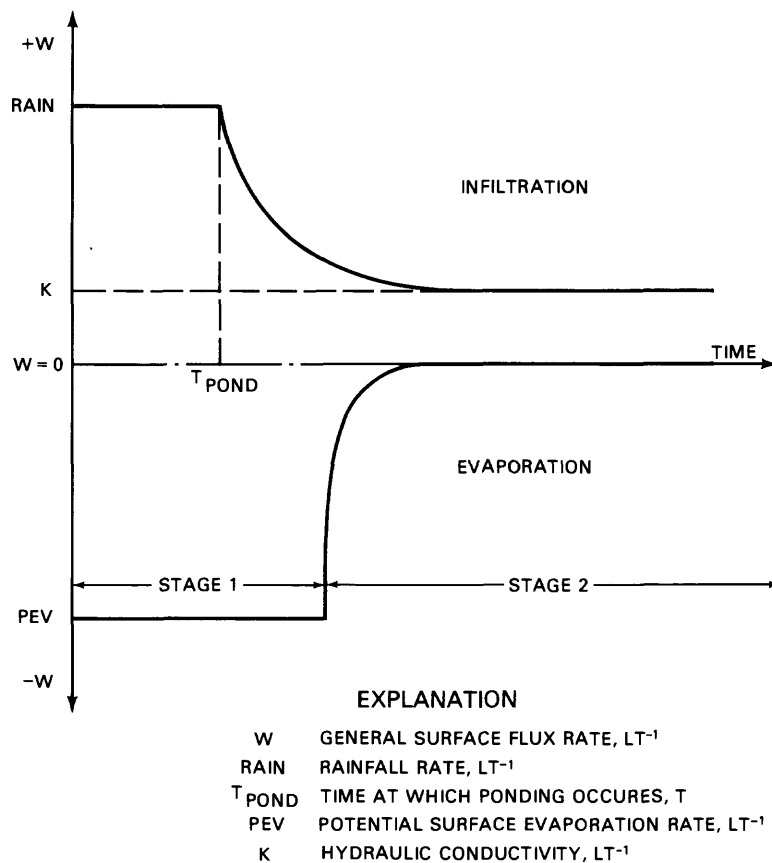


Figure 3.--Infiltration and evaporation as two-stage processes.

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:

$$\begin{aligned}
 (vpq)_m &= v \frac{\rho(h_{root} - h_m)}{R_m + R_{root_m}}, \quad \text{if } h_m > h_{root} \text{ and} \\
 (vpq)_m &= 0, \quad h_m \leq h_{root}; \quad (16)
 \end{aligned}$$

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:

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

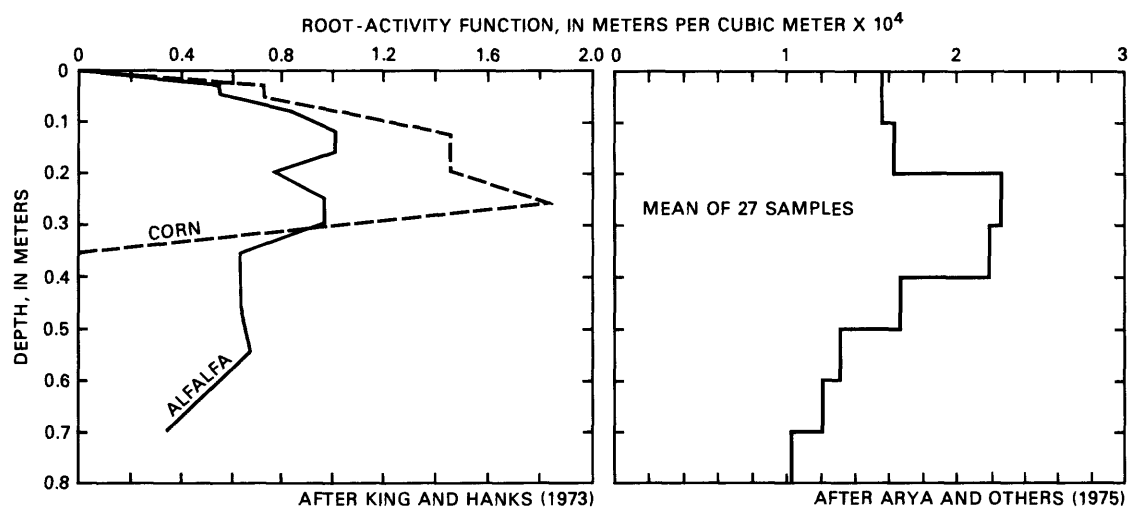


Figure 4.--Examples of root-activity functions.

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, ρq_v , 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.

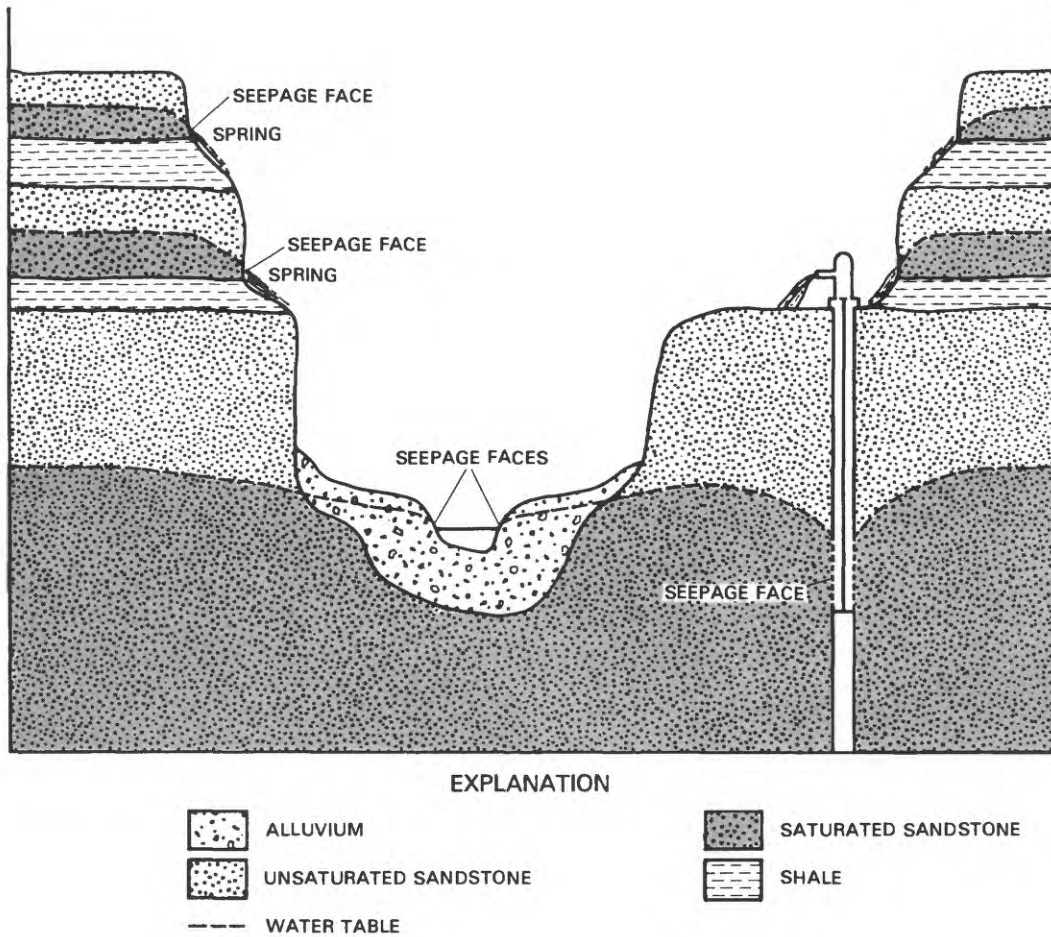


Figure 5.--Examples of seepage faces.

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, $c_m(h) = \phi \left(\frac{\partial s}{\partial h} \right) \cong \left(\frac{d\theta}{dh} \right)$, 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:

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

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

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^0 .

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.

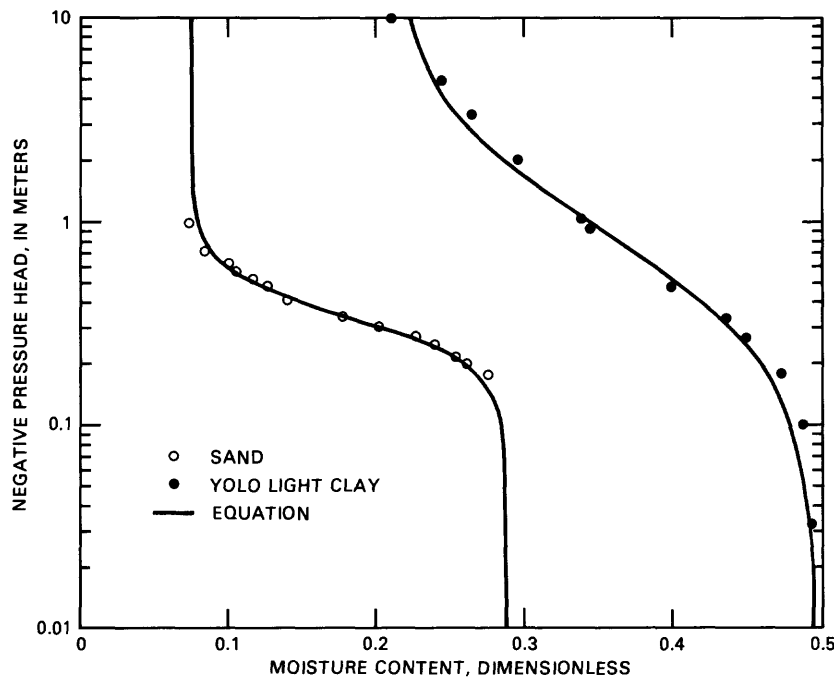


Figure 6.--Comparison of Haverkamp equation fit to experimental data of moisture content versus pressure head for a sand and for a light clay. Equation parameters are listed for soils 4 and 11 in table 1 (modified from Haverkamp and others, 1977).

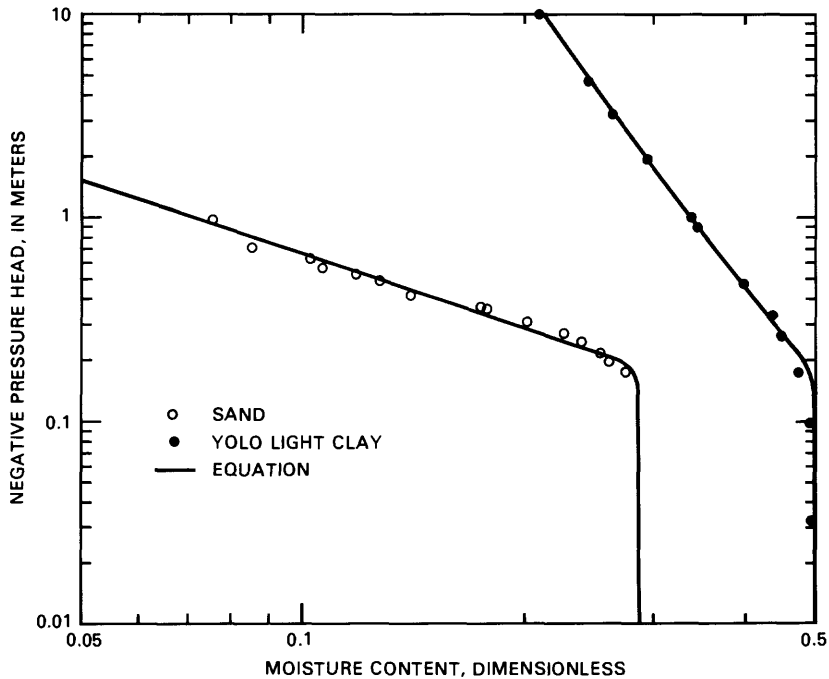


Figure 7.--Comparison of Brooks and Corey equation fit to experimental data of moisture content versus pressure head for a sand and for a light clay. Equation parameters are listed for soils 4 and 11 in table 1.

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:

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

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		Model 2		Model 3				
			θ_r	$-h_b$ (m)	λ	θ_r	$-\alpha$ (m)	β	θ_r	$-\alpha'$ (m)	β'
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
Fresno medium sand ²	4×10^2	.375	.000	.149	.84	.077	.273	3.0	.020	.232	3.1
Unconsolidated sand ³	8.5	.424	.090	.114	4.4	.046	.134	8.3	.051	.134	9.0
Sand ⁴	8.2	.435	.000	.196	.84	.076	.355	3.7	.069	.326	3.9
Fine sand (G.E. 13) ⁵	2.1	.377	.063	.82	3.7	.074	1.00	6.6	.072	.960	6.9
Columbia sandy loam ⁶	.70	.496	.11	.85	1.6	.16	1.26	4.6	.15	1.18	4.8
Touchet silt loam (G.E. 3) ⁵	0.22	0.430	0.095	1.45	1.7	0.17	2.05	6.6	0.17	1.98	7.0
Hygiene sandstone ⁷	.15	.25	.13	1.06	2.9	.15	1.28	10.3	.15	1.26	10.6

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--Continued

Soil or rock	Hydraulic conductivity (m/day)	Porosity	Model 1		Model 2		Model 3				
			θ_r	$-h_b$ (m)	λ	Brooks and Corey (1964)	Haverkamp (1977)	van Genuchten (1980)	θ_r	β	$-\alpha'$ (m)	$\beta'$
Adelanto loam ⁸	.039	.42	.13	1.41	.51	.18	4.32	1.8	.16	2.74	2.06
Limón 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

¹Data from Prill and others (1965), figure 23, column 1.

²Data from Prill and others (1965), figure 15, column 2.

³Data from Laliberte and others (1966), table C-8.

⁴Data from Haverkamp and others (1977), figure 1.

⁵Data from Brooks and Corey (1964), table 1.

⁶Data from Laliberte and others (1966), table C-5.

⁷Data from Brooks and Corey (1964), table 3.

⁸Data from Jackson and others (1965), figure 5. Values for $\psi_i \geq -100$ m only used.

⁹Data from Vachaud (1966), table 1.

¹⁰The 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.

The Haverkamp functions relating effective saturation to pressure potential 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:

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

where $\alpha' = \alpha / [(2^{1/\gamma} - 1)^{1-\gamma}]$, L;
 β' = exponent, L^0 ; and
 γ = exponent, = $1 - 1/\beta'$, L^0 .

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:

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

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:

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

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:

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

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

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

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:

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

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

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:

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

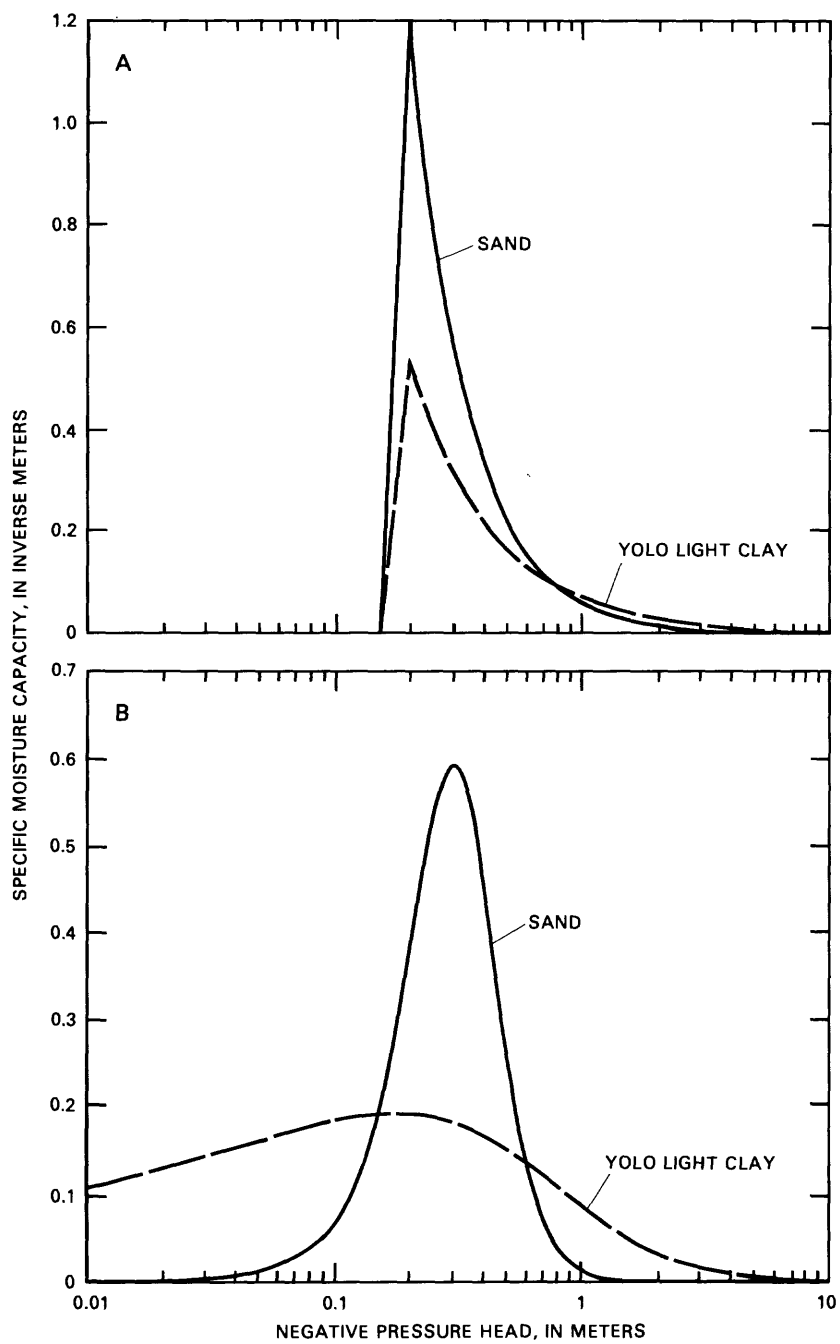


Figure 8.--Specific moisture capacity as a function of pressure head for a sand and a light clay:

- 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 9A for a sand, and for light clay by solid lines in figure 9B.

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:

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

and $K_r = 1.0, \quad h \geq h_b \quad (28)$

Relative hydraulic conductivities computed using equations 26 and 27 are compared to measured data for sand in figure 9A and for light clay in figure 9B. 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:

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

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 9A) is, as with the Brooks-Corey equation, quite good. Also similarly to the Brooks-Corey equation, the fit to the data for clay (fig. 9B) 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.

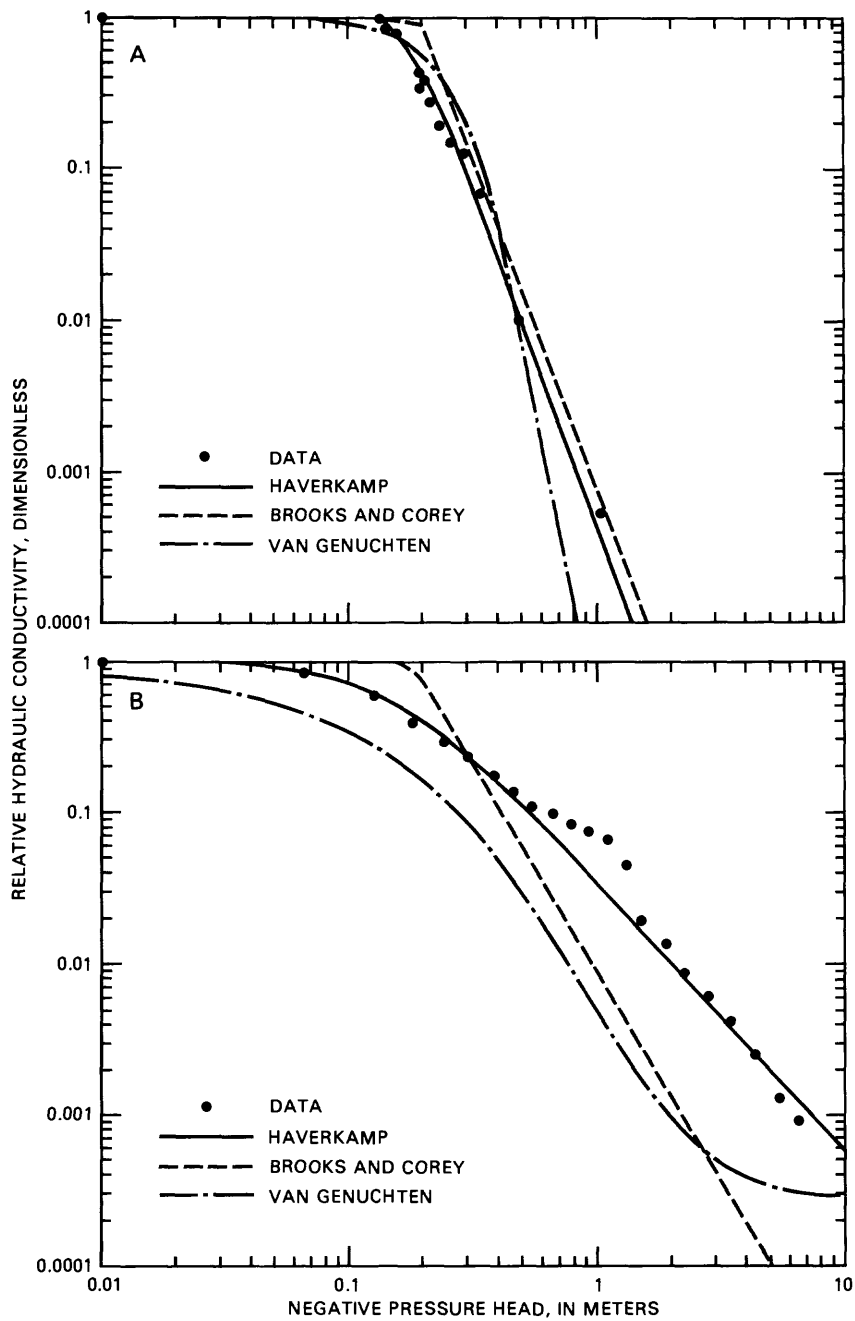


Figure 9.--Comparison of three functions to experimental data relating relative hydraulic conductivity to pressure potential for:
 A. A sand (soil no. 4, table 1);
 B. A light clay (soil no. 11, table 1).

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.

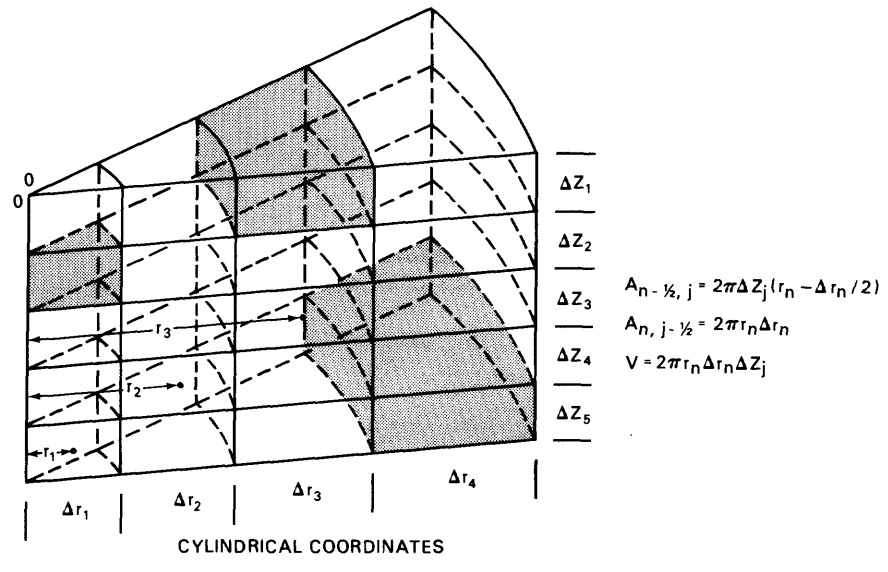
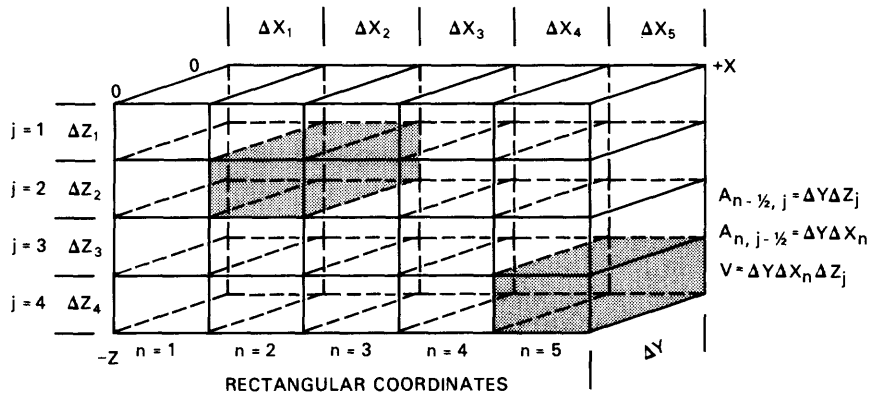
For a two-dimensional rectangular grid, the number of faces (\hat{m} in equation 13) of the volume subdivision is 6. However, two of the faces are not explicitly included, because the assumption used for two-dimensional problems to be simulated with this model is that no liquid flow can occur across 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:

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

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.



EXPLANATION

- $A_{n-1/2, j}$ SURFACE AREA BETWEEN CELLS $n-1, j$ AND n, j
- $A_{n, j-1/2}$ 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.

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:

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

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

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

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.

$$\begin{aligned} \text{Left side: } \left(\frac{K}{\Delta x}\right)_{n-1/2,j} &= \frac{2 K_{n-1,j} K_{n,j}}{K_{n-1,j} \Delta x_n + K_{n,j} \Delta x_{n-1}} \\ \text{Top side: } \left(\frac{K}{\Delta z}\right)_{n,j-1/2} &= \frac{2 K_{n,j-1} K_{n,j} (K_{zz}/K_{xx})}{K_{n,j-1} \Delta z_j + K_{n,j} \Delta z_{j-1}} \end{aligned} \quad (33)$$

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} .

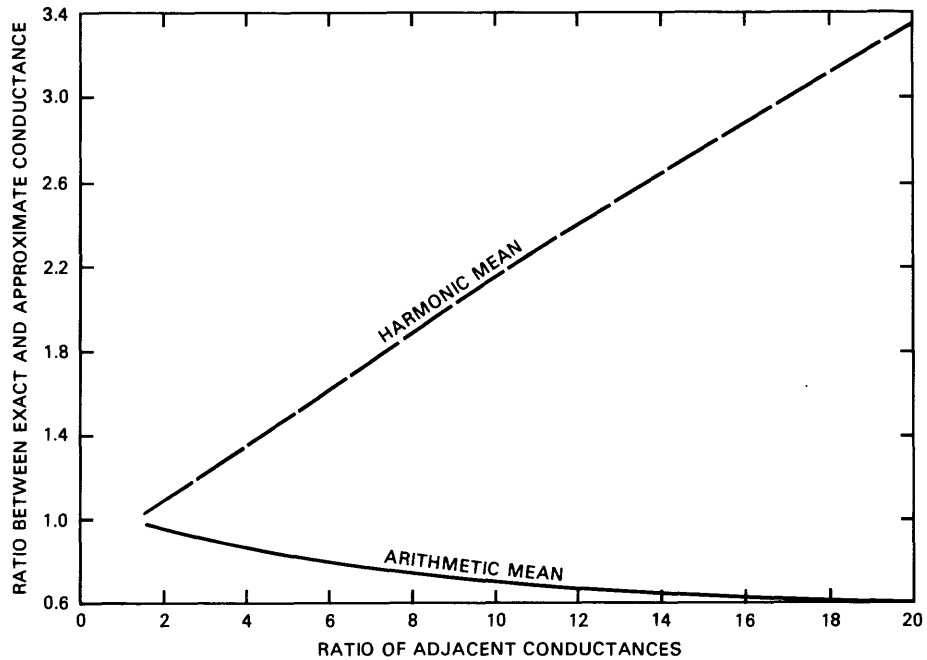


Figure 11.--Accuracy of arithmetic and harmonic means in estimating saturated intercell hydraulic conductivities for a linear spatial variation of conductivity and constant grid spacing (after Appel, 1976).

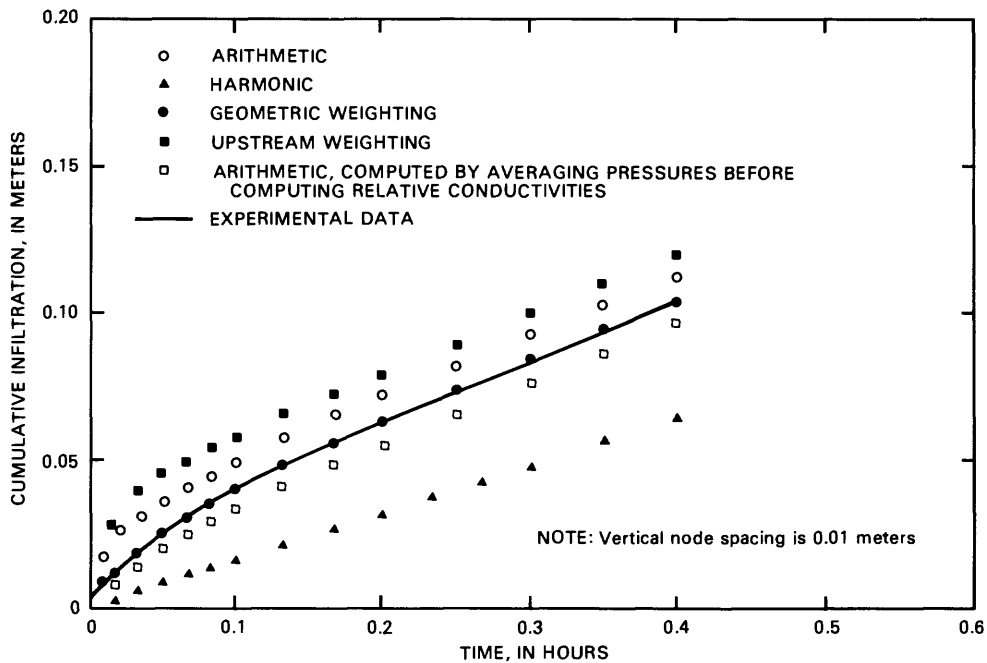


Figure 12.--Accuracy of several intercell weighting schemes for unsaturated hydraulic conductivity in estimating cumulative infiltration in a sand column with ponded upper boundary.

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

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

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

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:

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

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

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 preferentially weighting the relative hydraulic conductivity at the upstream node, is achieved by the following equations:

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

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

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

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

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:

$$\frac{dH}{dt} = k\Delta H, \quad (37)$$

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

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

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:

$$\begin{aligned} & \nu\rho[c_m + sS_s]^{i-1/2} \left(\frac{H_{n,j}^i - H_{n,j}^{i-1}}{t^i - t^{i-1}} \right) = \\ & + \hat{c}_{n-1/2,j}^{i-1/2} (H_{n-1,j}^i - H_{n,j}^i) + \hat{c}_{n,j-1/2}^{i-1/2} (H_{n,j-1}^i - H_{n,j}^i) \\ & + \hat{c}_{n+1/2,j}^{i-1/2} (H_{n+1,j}^i - H_{n,j}^i) + \hat{c}_{n,j+1/2}^{i-1/2} (H_{n,j+1}^i - H_{n,j}^i) \\ & + (\rho qv)_{n,j}^{i-1/2}. \end{aligned} \quad (39)$$

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:

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

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:

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

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

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

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:

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

where $\bar{C}_{k-1} = \nu \rho \{c_m + s S_s\}^{k-1}$. (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:

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

where:

$$\beta_s = \text{user-defined damping factor, HMAX.}$$

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:

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

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 straightforward, 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,

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

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 hydraulic 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:

$$EV = K K_r \text{ SRES } (H_A - h) . \quad (48)$$

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 $EV \times A \times \rho$, where A = surface area of the cell. (2) If $EV \leq PEV$, the sink term for the cell is set equal to $PEV \times A \times \rho$.

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)

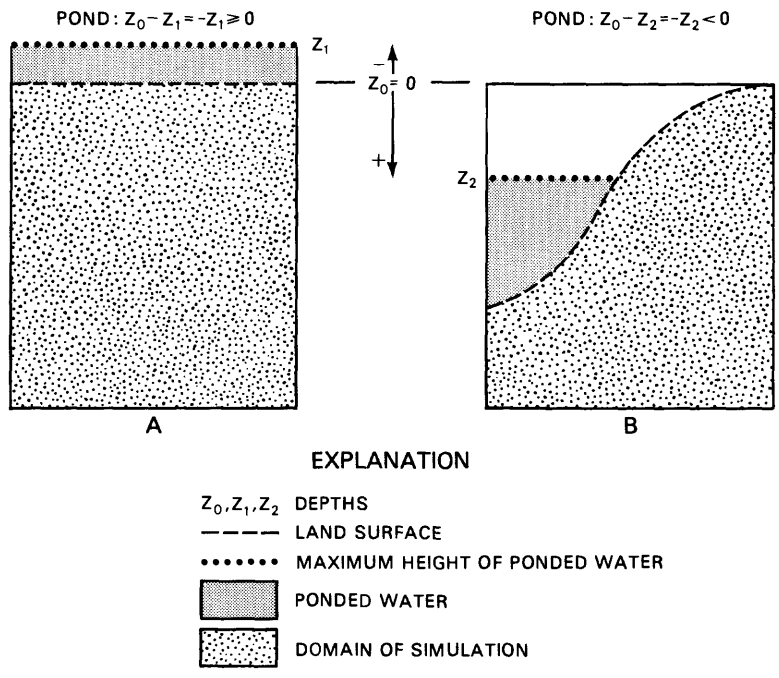


Figure 13.--The reference plane from which the depth of ponding, POND, is measured:
 A. For infiltration through a horizontal surface.
 B. For infiltration through a furrowed surface.

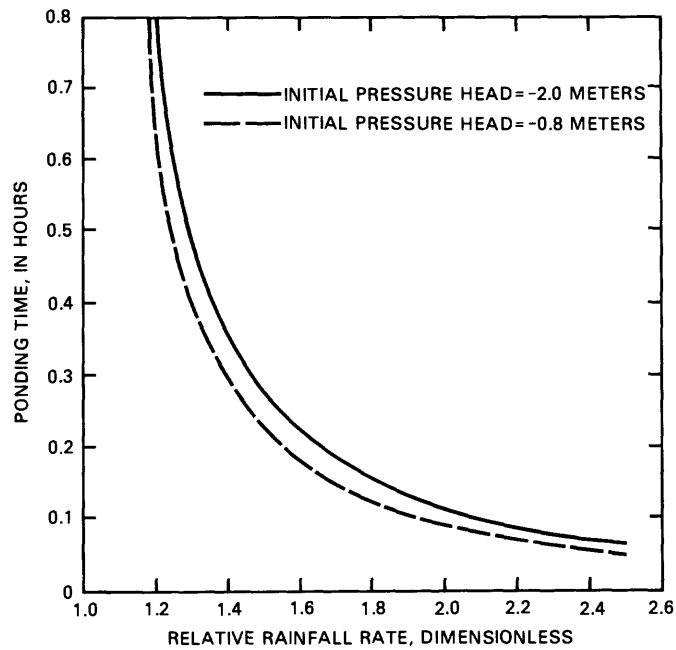


Figure 14.--Ponding time as a function of relative rainfall rate for a sand (soil no. 4, table 1) for two different initial conditions.

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 $R = 8.31 \text{ kg} \cdot \text{m}^2/\text{sec}^2 \cdot \text{K} \cdot \text{g} \cdot \text{mol}$, and $M_w = 0.018 \text{ kg/g-mol}$, $HA = -1,490 \text{ m}$. Moreover, at the same temperature and a relative humidity of 0.1, $HA = -32,500 \text{ m}$. 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 $-1 \times 10^3 \text{ m}$ 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 $-1,000 \text{ m}$ 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 $DELZ(2)/2.$,

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

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.

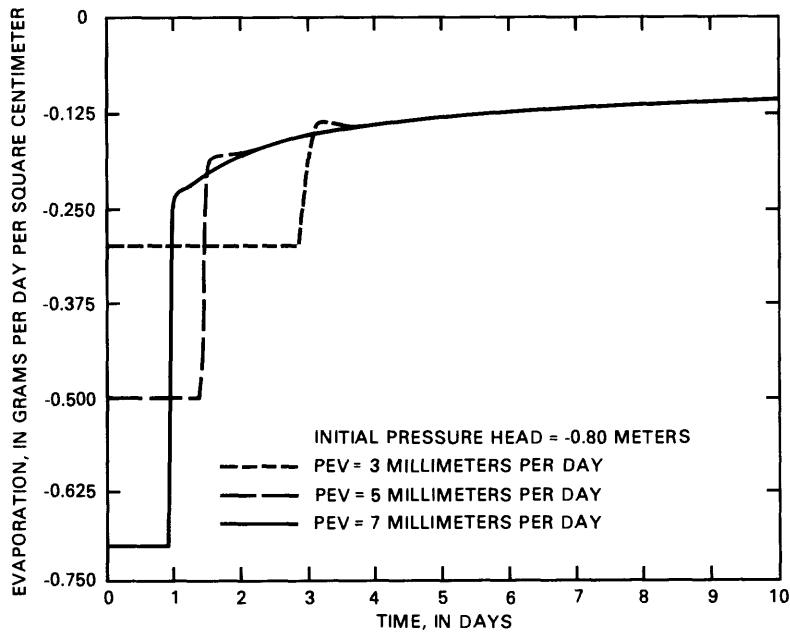


Figure 15.--Variation of evaporation rate from the surface of a column of sand (soil no. 4, table 1), 1-meter deep, for different potential evaporation rates.

Evapotranspiration

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

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

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:

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

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 $\text{PET} \times A \times \rho$, and if \hat{Q} is larger in magnitude than that value, all q_m are adjusted by

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

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 [$r(\text{RTDPTH}, t)$ 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 linearly 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:

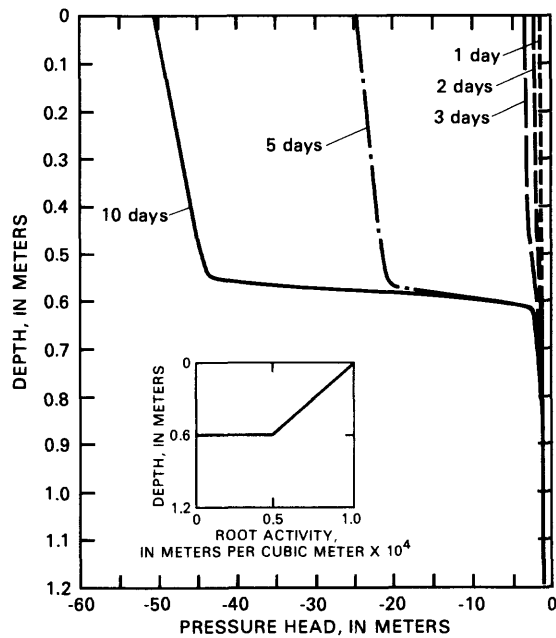


Figure 16.--Pressure-head profiles following transpiration from shallow-rooted plants in sand (soil no. 4, table 1) underlain by an impermeable bed at 1.8 meters. Potential evapotranspiration is 1 gram per square centimeter per day and the numbers on the curves represent elapsed days from the start of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

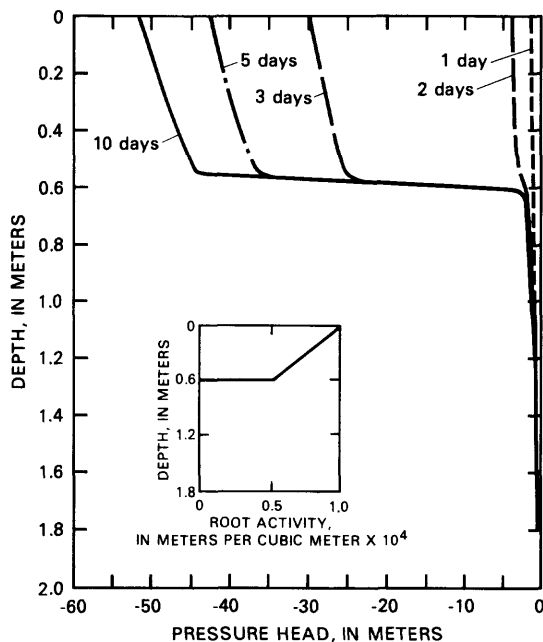


Figure 17.--Pressure-head profiles following transpiration from shallow-rooted plants in sand (soil no. 4, table 1) in the presence of a shallow water table at 1.2 meters. Potential evapotranspiration is 1.0 grams per square centimeter per day and the numbers on the curves represent elapsed days since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

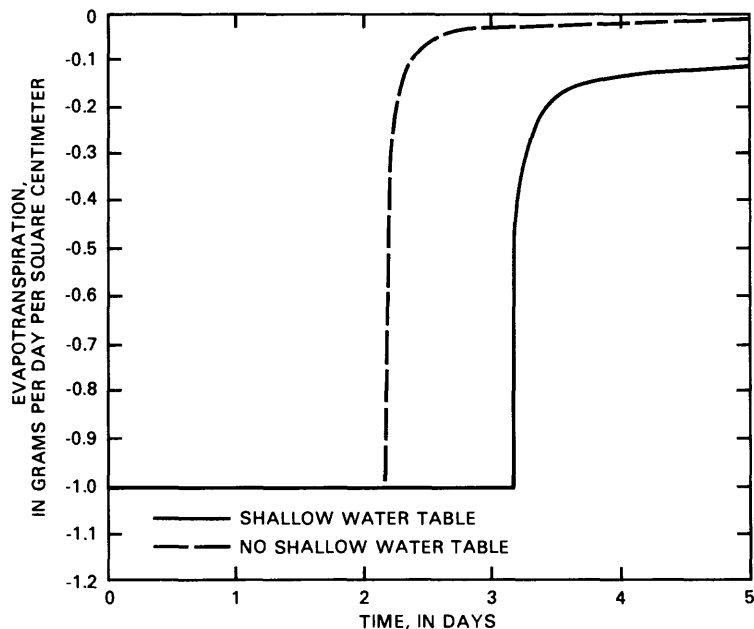


Figure 18.--Evapotranspiration rate as a function of time for transpiration by shallow-rooted plants in the presence and absence of a shallow water table. Potential evapotranspiration, soil properties and root-density profiles are the same as for figures 16 and 17.

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^0 .
THLST (NN)	Volumetric moisture content at previous time step. L^0 .
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^0 .
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 x π , 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.

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-13	NPLT	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		
<p>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).</p> <p>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.</p>		
HK(ITEK,4)	(1) h_p , 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(ITEK,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(ITEK,6)	(1) λ . (2) β' . (3) B' . (4) Third smallest pressure head in table.	
HK(ITEK,7)	(1) Not used. (2) Not used. (3) α , L. (must be less than 0.0). (4) Fourth smallest pressure head in table.	
HK(ITEK,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(ITE _X ,9)	Next largest pressure head in table.
	HK(ITE _X ,N1+3)	Maximum pressure head in table. (Here N1 = Number of pressure heads in table; NPROP = 3*(N1+1)+3).
	HK(ITE _X ,N1+4)	Always input a value of 99.
	HK(ITE _X ,N1+5)	Relative hydraulic conductivity corresponding to first pressure head.
	HK(ITE _X ,N1+6)	Relative hydraulic conductivity corresponding to second pressure head.
	.	
	.	
	.	
	HK(ITE _X ,2*N1+4)	Relative hydraulic conductivity corresponding to largest pressure head.
	HK(ITE _X ,2*N1+5)	Always input a value of 99.
	HK(ITE _X ,2*N1+6)	Moisture content corresponding to first pressure head.
	HK(ITE _X ,2*N1+7)	Moisture content corresponding to second pressure head.
	.	
	.	
	.	
	HK(ITE _X ,3*N1+5)	Moisture content corresponding to largest pressure head.
	HK(ITE _X ,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 (ITE _X) 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.

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 DELT	Length of this recharge period, T. Length of initial time step for this period, T.
C-2	TMLT DLTMX DLTMIN TRED	Multiplier for time step length. Maximum allowed length of time step, T. Minimum allowed length of time step, T. 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 STERR	Maximum allowed change in head per time step for this period, L. 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.

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 initial 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 /.

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. VSHKU 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:

$$\frac{\partial H}{\partial t} = D \frac{\partial^2 H}{\partial x^2} \quad (53)$$

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):

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

where erfc is the complementary error function.

The computer code was applied to a one-dimensional column for which $D = 0.3118 \text{ cm}^2/\text{min}$, with a grid spacing of $\Delta x = 0.05 \text{ cm}$. Results are shown in figure 19 for an elapsed time of 5 minutes. The boundary conditions used were $H_i = 0 \text{ m}$; $H_o = 3 \text{ m}$.

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:

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

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

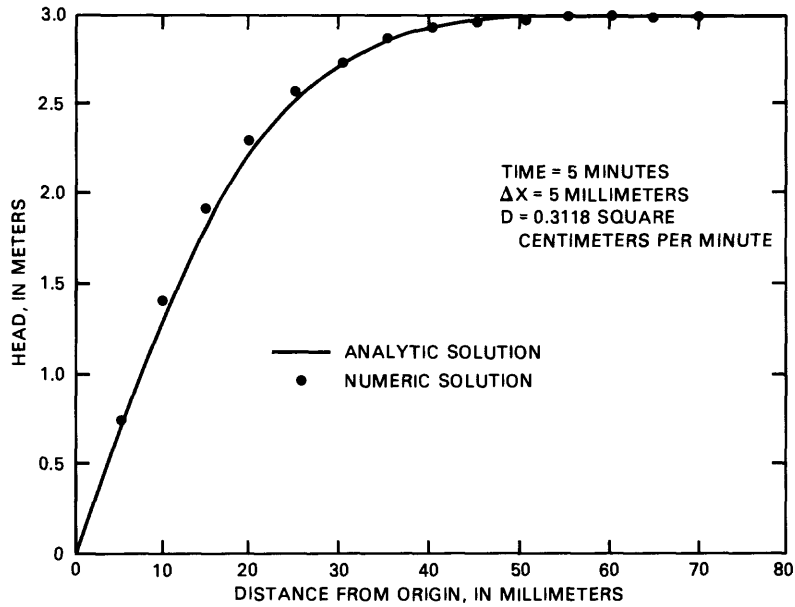


Figure 19.--Comparison of analytical and numerical solutions for one-dimensional linear diffusion.

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

where b is the thickness of the aquifer, L ; with the Dirichlet condition at $r = \infty$ of H_0 and the initial condition, $H = H_0$, the solution to this problem is (Theis, 1935):

$$H_0 - H = \frac{\hat{q}}{4\pi K b} \int_{\frac{r^2 S}{4K t}}^{\infty} \frac{e^{-u}}{u} du . \quad (57)$$

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:

$$H_0 = 100 \text{ meters};$$

$$K = 0.03472 \text{ meters per minute};$$

$$b = 10 \text{ meters.}$$

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

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

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.

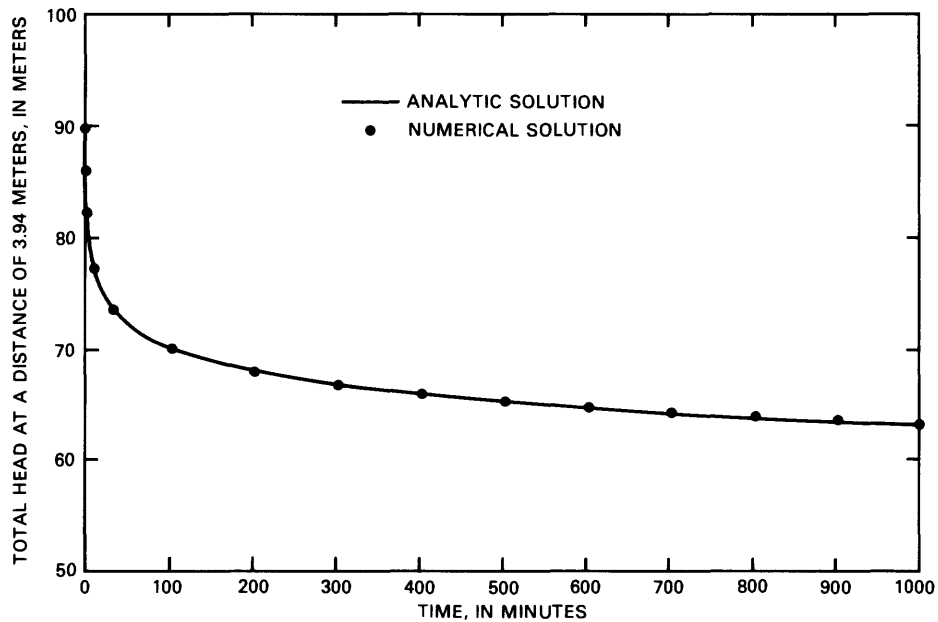


Figure 20.--Comparison of analytical and numerical solutions for one-dimensional radial flow to a well in a confined aquifer.

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

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

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 $E_{\infty} \ll K$.

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

$SRES = 2./\Delta Z$

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, $mm/day \times 10^{-1}$
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:

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

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.

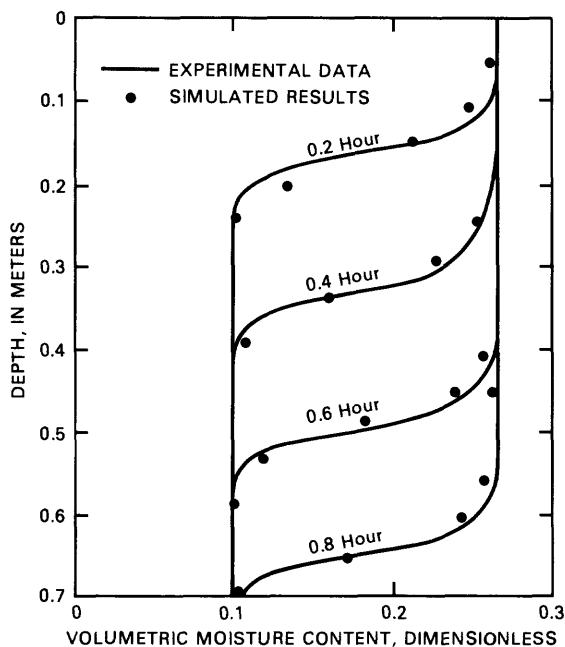


Figure 21.--Comparison of moisture content profiles with those measured by Haverkamp and others (1977, p. 285) for one-dimensional vertical infiltration.

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:

- $\theta_s = 0.348;$
- $h_b = -.19 \text{ m};$
- $\lambda = 1.6;$
- $\theta_r = 0;$
- $K = 5.564 \text{ m/d};$

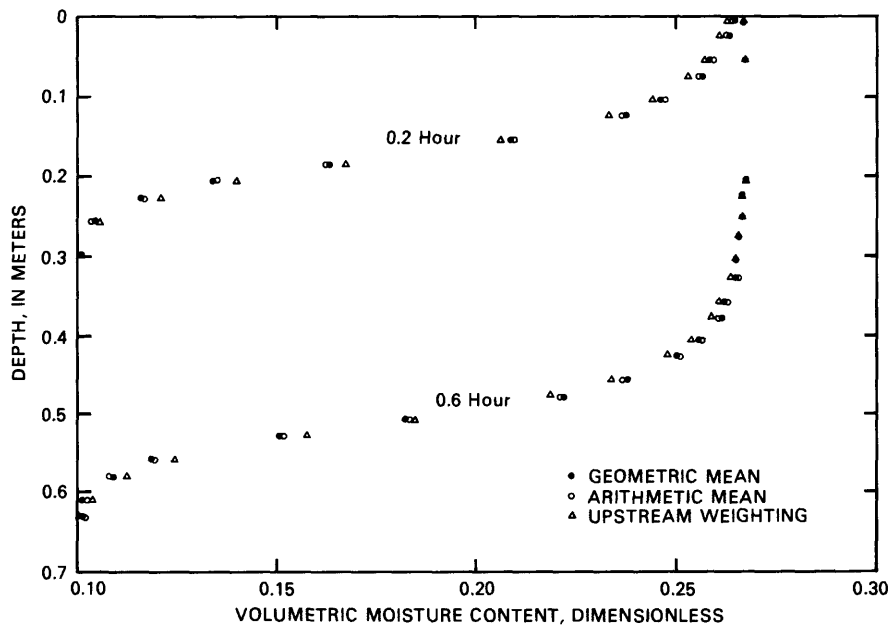


Figure 22.--Comparison of effects of using different methods for determining interblock relative hydraulic conductivity in vertical infiltration problems.

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.

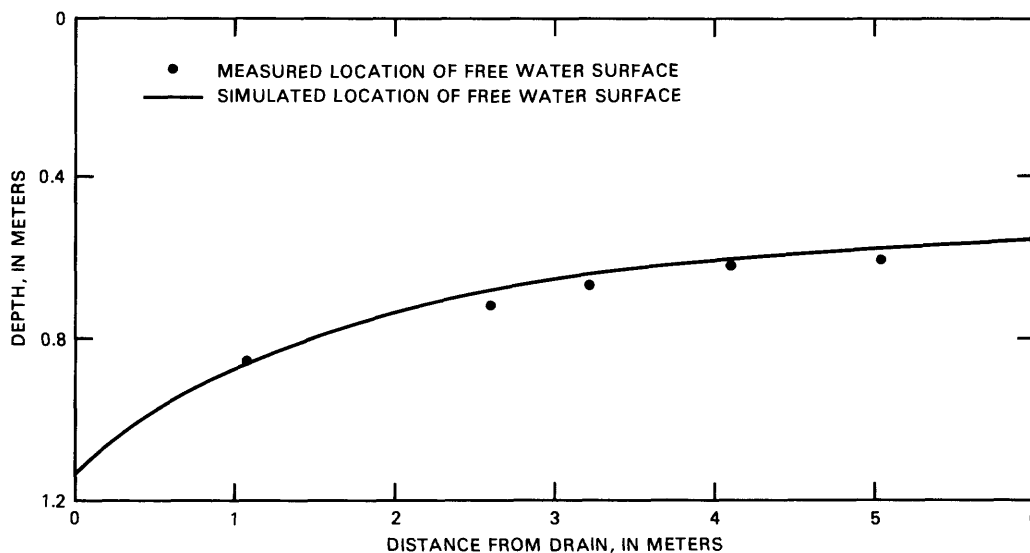


Figure 23.--Comparison of simulated and measured location of the free-water surface for the drainage problem of Duke (1973).

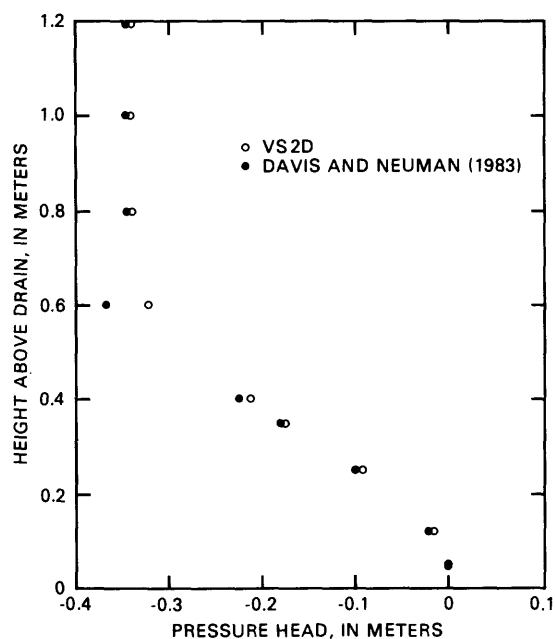


Figure 24.--Comparison of pressure head profiles at the left hand boundary as computed by VS2D and Davis and Neuman (1983) for the drainage problem of Duke (1973).

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:

$$\begin{aligned}
 h_b &= -0.054 \text{ m;} \\
 \lambda &= 0.2; \\
 \theta_s &= 0.52; \\
 \theta_r &= 0.0; \text{ and} \\
 K &= 0.0375 \text{ m/h.}
 \end{aligned}$$

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:

<u>Heading</u>	<u>Description</u>
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 Prime¹ 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.

¹Use 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--DSMAX,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--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

CLASS # 1 ANISOTROPY KSAT SPECIFIC POROSITY
TEXTURAL CLASS INDEX MAP 0.000D-01 5.200D-01 -5.400D+00 0.000D-01 2.000D-01

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

Z, IN	X OR R DISTANCE, IN	DEPTH FROM SURFACE	SATURATION
CM	CM		
56	0.50	0.50	
57	1.50	1.500	
58	2.50	2.500	
59	3.50	3.500	
60	4.50	4.500	
61	5.50	5.500	
62	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
SSIP 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

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	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	X OR R DISTANCE, IN	CM		
	0.50			
	1.000			
0.50	0.998			
1.50	0.994			
2.50	0.988			
3.50	0.978			
4.50	0.964			
5.50	0.943			
6.50	0.912			
7.50	0.866			
8.50	0.799			
9.50	0.707			
10.50	0.606			
11.50	0.548			
12.50	0.532			
13.50	0.530			
14.50	0.529			
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

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

	TOTAL MASS GRAM	MASS THIS TIME STEP GRAM	RATE FOR THIS TIME STEP 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

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-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+02-1.300E+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

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-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
-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+02-1.300E+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												
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	THETA	SAT	
0.000E-01	5.000E-01	3.500E+00	-1.335E+02	-1.300E+02	2.752E-01	5.293E-01	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	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	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	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	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	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	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	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	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	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	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	2.752E-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	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	2.787E-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	2.752E-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	2.752E-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	2.752E-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	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	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	3.192E-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	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	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	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	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	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	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	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	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	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	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	5.136E-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	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	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	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	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	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	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	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	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	1.000E+00
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.

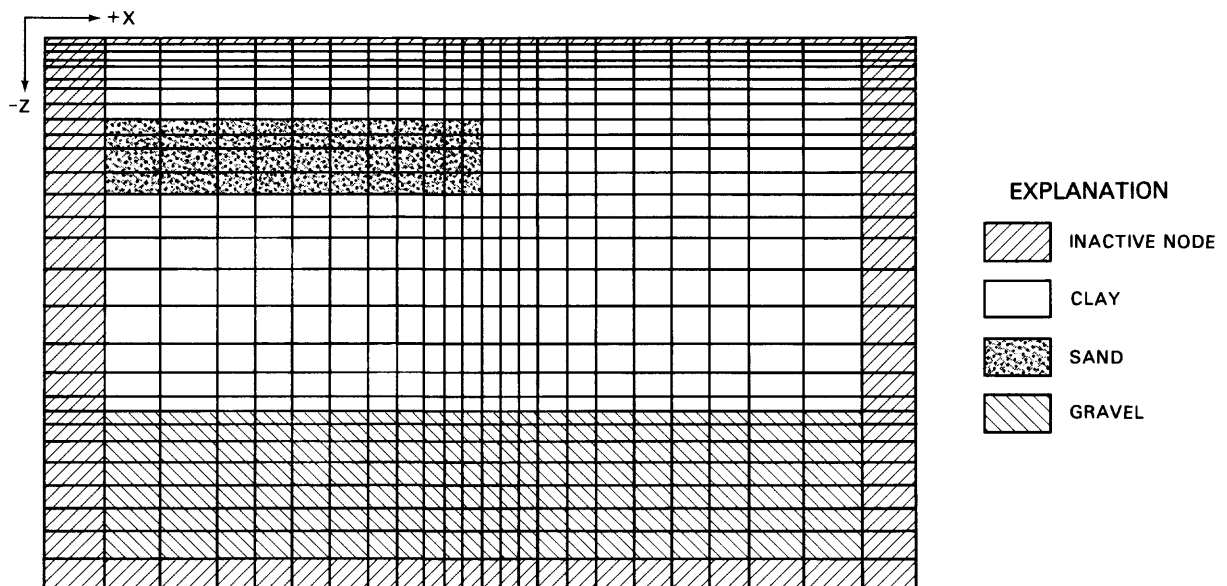


Figure 25.--Vertical section for example problem 1.

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.

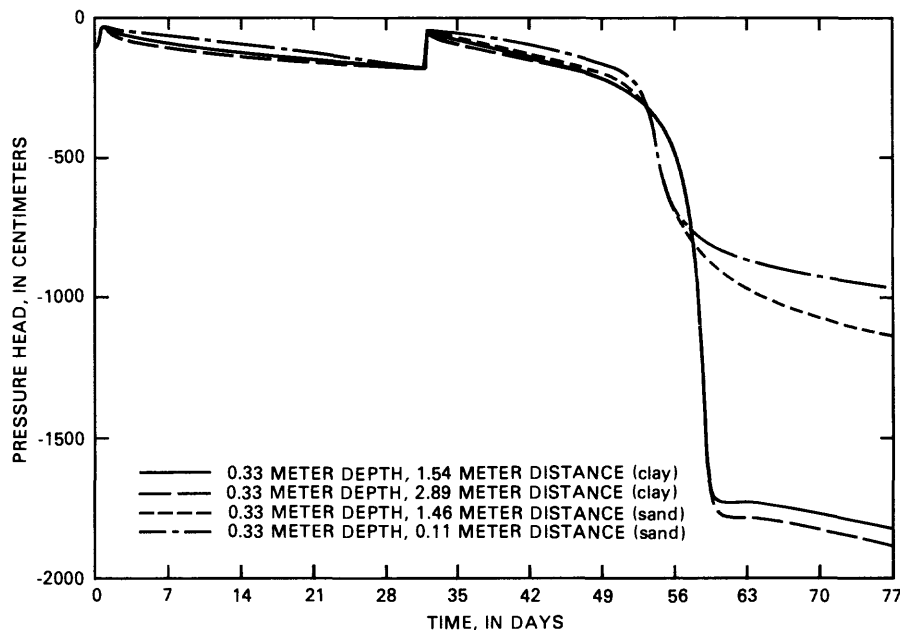


Figure 26.--Pressure-head profile at four locations for example problem 2.

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.

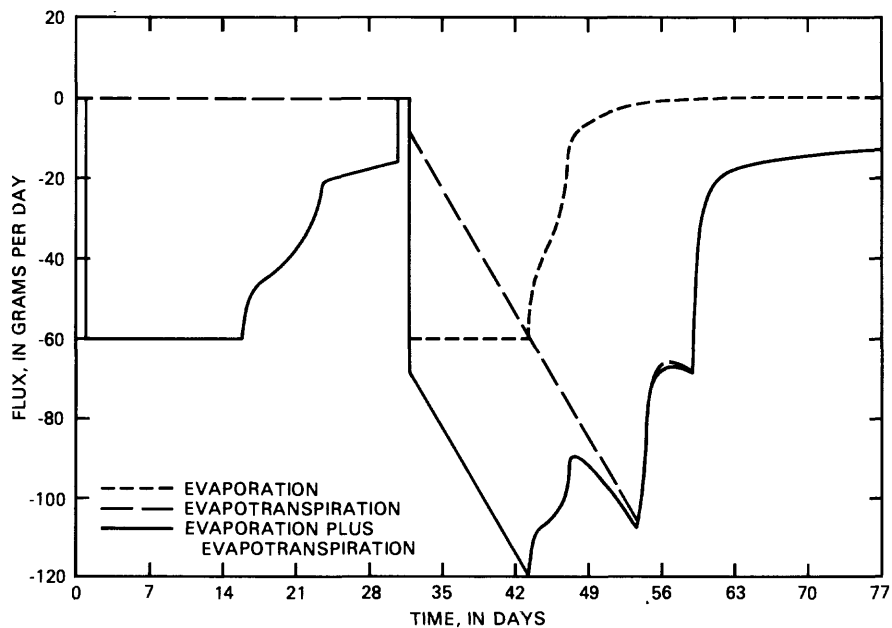


Figure 27.--Evaporation and evapotranspiration rates as functions of time for example problem 2.

Table 10.--Input data for example problem 2

```

EXAMPLE PROBLEM 2 -- 2D INFILTRATION AND EVAPOTRANSPIRATION
77. 0.00
CMDAYSGRAM 24 28
4 1000
F T T T F
T T T F
T F T F
0 7.5
3. 3. 3. 2. 2. 2. 1.5 1.5 1. 1. 1.
1. 1. 1. 1.5 1.5 2. 2. 2. 3. 3. 3.
0
1. 1. 1. 1. 1.5 2.0 2.0 2.0
2.0 3.0 3.0 3.0 4.0 5.0 5.0 4.0 3.0
2.0 2.0 2.0 3.0 3.0 3.0 4.0 5.0
13
0.5,1.0,2.0,5.0,16.,31.,31.5,32.,33.,40.,50.,60.,77.
10
2 2 8 2 8 12 8 13 8 23 9 2 9 12 9 13 9 23 20 2
.005 .750 0.0
1.0
2 200
T 3 6
1 1
1 5. 1.0D-06 .45 -50. .15 .6
2
1 100. 1.0D-06 .40 -15. .08 1.0
3
1. 300. 1.0D-06 .42 -8. .05 1.2
1 24 8 1
1 12 12 2
13 24 12 1
1 24 20 1
1 24 28 3
2 1.0 -100.
T,T
4 30.
0.2,0.2,0.2,0.2
0.6,0.6,0.6,0.6
-100000,-100000,-100000,-100000,-100000
A2--TMAX, START TIME
A3--UNITS
A4--NO. OF COLUMNS, NO. OF ROWS
A5-- NO. OF RECHARGE PERIODS, MAXIMUM NO. OF TIME STEPS
A6--RADIAL? ITSTOP?
A7--OUTPUT TO FILE 11? FILE 7? FILE 8? FILE 9? MASS BAL FILE 6?
A8--PRINT MOISTURE CONT.? SAT? PRESS HEAD? TOTAL HEAD?
A9--IFAC,FACZ
A10--HORIZONTAL SPACING
A11--JFAC,FACZ
A12--VERTICAL SPACING
A12
A12
A13--NO. OF TIMES TO PRINT PROFILES
A14--TIMES FOR PROFILES
A15--NO. OF NODES FOR TIME PLOTS
A16--ROW AND COLUMN FOR EACH NODE
B1--CLOSURE CRITERION, HMAX, WEIGHTING FOR KR
B2--FLUID DENSITY
B3--MINIT,ITMAX
B4--READ HEADS AS INITIAL CONDITIONS?
B5--NO. OF TEXTURES, NO. OF PROPERTIES PER TEXTURE
B6--TEXTURE CLASS 1
B7--ANIZ,KSAT,SS,POROSITY,HB,THETAR,LAMBDA BROOKS-COREY
B6--TEXTURE CLASS 2
B7--BROOKS-COREY PROPERTIES
B6--TEXTURE CLASS 3
B7--BROOKS-COREY PROPERTIES
B8--TEXTURES READ BY BLOCK
B10--LEFT COL., RIGHT COL., BOTTOM ROW, TEXTURAL CLASS
B10
B10
B10
B10--LAST OF B10 CARDS
B11--EQUILIBRIUM HEAD PROFILE SPECIFIED
B12--WATER TABLE DEPTH, MIN. HEAD ALLOWED
B14-- EVAP AND TRANSP TO BE SIMULATED ?
B15--NPV,ETCYC NUMBER AND LENGTH OF ET PERIODS
B16--PEV
B17--SRES
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--RTDPH
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.	C1--TPER, DELT
1.1	C2--TMULT,DLTMX,DLTMIN,TRED
0.	C3--DSMAX,STERR
100.	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.	C3--DSMAX, STERR
0.	C4--POND
F	C5--PRINT HEADS EVERY TIME STEP?
F 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.	C3--DSMAX,STERR
0.0	C4--POND
F	C5--HEADS PRINTED?
F F 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.	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			GRID SPACING IN HORIZONTAL OR RADIAL DIRECTION, IN CM		
3.000	3.000	3.000	4.500	6.000	6.000	6.000
9.000	9.000	9.000	12.000	15.000	12.000	9.000
6.000	6.000	9.000	9.000	12.000	15.000	
22.500	22.500	22.500	15.000	15.000	11.250	11.250
7.500	7.500	7.500	7.500	11.250	15.000	15.000
15.000	22.500	22.500	22.500	11.250	15.000	15.000

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	23	9	12
2	2	8	2	8	13	8	23	9	13
2	2	8	2	8	13	8	23	9	23
2	2	8	2	8	13	8	23	9	23
2	2	8	2	8	13	8	23	9	23
2	2	8	2	8	13	8	23	9	23
2	2	8	2	8	13	8	23	9	23

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 STORAGE	POROSITY
CLASS # 1	1.000D+00	5.000D+00	1.000D-06	4.500D-01
CLASS # 2	1.000D+00	1.000D+02	1.000D-06	4.000D-01
CLASS # 3	1.000D+00	3.000D+02	1.000D-06	4.200D-01
TEXTURAL CLASS INDEX MAP				

TEXTURAL CLASSES READ IN BY BLOCK

1	1111111111111111111111
2	1111111111111111111111
3	1111111111111111111111
4	1111111111111111111111
5	1111111111111111111111
6	1111111111111111111111
7	1111111111111111111111
8	1111111111111111111111
9	2222222222221111111111
10	2222222222221111111111
11	2222222222221111111111
12	2222222222221111111111
13	1111111111111111111111

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

Z, IN CM	DEPTH FROM SURFACE															
	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							
	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
1.50	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
4.50	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
7.50	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
11.25	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
15.75	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
21.00	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
27.00	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
33.00	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
39.00	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
46.50	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
55.50	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
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
14	11111111111111111111111111111111															
15	11111111111111111111111111111111															
16	11111111111111111111111111111111															
17	11111111111111111111111111111111															
18	11111111111111111111111111111111															
19	11111111111111111111111111111111															
20	11111111111111111111111111111111															
21	33333333333333333333333333333333															
22	33333333333333333333333333333333															
23	33333333333333333333333333333333															
24	33333333333333333333333333333333															
25	33333333333333333333333333333333															
26	33333333333333333333333333333333															
27	33333333333333333333333333333333															
28	33333333333333333333333333333333															

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	
84.00	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
97.50	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
112.50	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
126.00	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
136.50	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
144.00	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
150.00	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
156.00	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
163.50	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
172.50	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
181.50	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
190.50	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
201.00	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
	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	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 EVAPOTRANSPIRATION PERIODS = 4
 LENGTH OF EACH PERIOD = 30.0000 DAYS

EVAPORATION PERIOD	POTENTIAL RATE CM/DAYS	SURFACE RESISTANCE CM**(-1)	ATMOSPHERIC 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 PERIOD	POTENTIAL RATE CM/DAYS	ROOT DEPTH CM	ACTIVITY AT BOTTOM CM**(-2)	ACTIVITY AT TOP CM**(-2)	ROOT PRESSURE 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: 0.1421085D-13 0.8053070D+00 0.9620946D+00 0.9926201D+00 0.9985632D+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
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
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
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
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
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
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
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
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
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

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 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 00000000000000000000000000000000
 2 02222222222222222222222222222220
 3 00000000000000000000000000000000
 4 00000000000000000000000000000000
 5 00000000000000000000000000000000
 6 00000000000000000000000000000000
 7 00000000000000000000000000000000
 8 00000000000000000000000000000000
 9 00000000000000000000000000000000
 10 00000000000000000000000000000000
 11 00000000000000000000000000000000
 12 00000000000000000000000000000000
 13 00000000000000000000000000000000
 14 00000000000000000000000000000000
 15 00000000000000000000000000000000
 16 00000000000000000000000000000000
 17 00000000000000000000000000000000
 18 00000000000000000000000000000000

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

```

19 00000000000000000000000000000000
20 00000000000000000000000000000000
21 00000000000000000000000000000000
22 00000000000000000000000000000000
23 00000000000000000000000000000000
24 00000000000000000000000000000000
25 00000000000000000000000000000000
26 01111111111111111111111111111110
27 00000000000000000000000000000000
28 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

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 -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
PRESSURE HEAD

```

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+00-1.31E+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+01-4.63E+01-4.63E+01-4.63E+01-4.64E+01-4.64E+01
 11.25-2.21E+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+01-6.17E+01-6.69E+01
 -6.05E+01-6.35E+01-6.51E+01-6.59E+01-6.62E+01-6.63E+01-6.63E+01-6.63E+01-6.63E+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+01-9.81E+01-10.61E+01-11.49E+01
 -7.00E+01-7.28E+01-7.43E+01-7.49E+01-7.52E+01-7.52E+01-7.52E+01-7.52E+01-7.53E+01
 46.50-9.93E+01-9.93E+01-9.94E+01-9.94E+01-9.94E+01-9.95E+01-9.95E+01-9.96E+01-9.97E+01-9.98E+01-9.98E+01-9.98E+01-9.98E+01
 -8.44E+01-8.69E+01-8.73E+01-8.74E+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+02-1.02E+02-1.02E+02-1.02E+02
 -9.47E+01-9.52E+01-9.55E+01-9.56E+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+02-1.09E+02-1.09E+02-1.09E+02-1.09E+02-1.09E+02
 -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+02-1.04E+02-1.04E+02-1.04E+02-1.04E+02
 -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+02-1.00E+02-1.00E+02-1.00E+02
 -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+01-9.57E+01-9.57E+01-9.57E+01-9.57E+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

Z, 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
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
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
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
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
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
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
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
33.00	0.439	0.430	0.425	0.423	0.422	0.421	0.421	0.421	0.421	0.172	0.165	0.439	0.428
39.00	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	0.133	0.135	0.408	0.402
	0.142	0.142	0.142	0.142	0.141	0.140	0.138	0.136	0.134	0.128	0.129	0.374	0.372
	0.395	0.389	0.387	0.385	0.385	0.385	0.385	0.385	0.385	0.127	0.127	0.355	0.355
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	0.127	0.127	0.355	0.355
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	0.340	0.342	0.347	0.349
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	0.344	0.345	0.347	0.348
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	0.348	0.348	0.349	0.349
84.00	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.349	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	0.353	0.353	0.353	0.354
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	0.367	0.367	0.367	0.367
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	0.388	0.388	0.388	0.388
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

MOISTURE CONTENT

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

Z, IN
 CM

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
-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
-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
-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	-1.41E+01	-1.43E+01	-1.45E+01	-1.50E+01	-1.57E+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	-2.54E+01	-2.56E+01	-2.59E+01	-2.64E+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	-2.54E+01	-2.55E+01	-2.58E+01	-2.62E+01	-2.69E+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
-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
-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
-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	-1.00E+02
-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	-1.01E+02	-1.01E+02	-1.00E+02	-9.86E+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	-9.43E+01	-9.37E+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	-8.41E+01	-8.40E+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
-7.21E+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
-6.23E+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
-5.49E+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
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
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
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
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
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

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

Z, IN	MOISTURE CONTENT														
CM	11.25	168.75	33.75	178.12	52.50	67.50	82.50	97.50	110.62	121.87	131.25	138.75	146.25	153.75	161.25
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
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
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
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
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
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
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
33.00	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
39.00	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
46.50	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
55.50	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
64.50	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
73.50	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
84.00	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
97.50	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
112.50	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
126.00	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
136.50	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

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

Z, IN CM	PRESSURE HEAD											
	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+04-1.09E+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+04-1.04E+04-1.04E+04-1.04E+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+03-7.17E+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+03-7.38E+03-7.37E+03-7.30E+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+03-7.00E+03-7.00E+03												
11.25-7.15E+03-7.15E+03-7.16E+03-7.16E+03-7.17E+03-7.17E+03-7.18E+03-7.19E+03-7.20E+03-7.20E+03-7.20E+03-7.19E+03-6.84E+03-6.82E+03												
-6.81E+03-6.81E+03-6.81E+03-6.82E+03-6.82E+03-6.82E+03-6.82E+03-6.82E+03-6.82E+03-6.82E+03-6.82E+03-6.83E+03-6.83E+03												
15.75-6.91E+03-6.92E+03-6.92E+03-6.93E+03-6.94E+03-6.94E+03-6.95E+03-6.95E+03-6.95E+03-6.96E+03-6.96E+03-6.96E+03-6.96E+03-6.96E+03												
-6.58E+03-6.58E+03-6.58E+03-6.59E+03-6.59E+03-6.59E+03-6.59E+03-6.59E+03-6.59E+03-6.59E+03-6.59E+03-6.60E+03-6.60E+03												
21.00-6.60E+03-6.60E+03-6.60E+03-6.61E+03-6.62E+03-6.62E+03-6.63E+03-6.64E+03-6.64E+03-6.64E+03-6.65E+03-6.65E+03-6.65E+03												
-6.27E+03-6.27E+03-6.27E+03-6.27E+03-6.27E+03-6.28E+03-6.28E+03-6.28E+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+03-6.16E+03-6.16E+03-6.17E+03-6.17E+03-6.17E+03-6.18E+03-6.18E+03												
-5.57E+03-5.57E+03-5.58E+03-5.58E+03-5.58E+03-5.59E+03-5.59E+03-5.59E+03-5.60E+03-5.60E+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+02-9.68E+02-9.70E+02-9.70E+02-9.70E+02-9.75E+02-9.75E+02-9.84E+02-9.84E+02-9.84E+02												
-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+03-1.88E+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+02-1.52E+02-1.54E+02-1.54E+02-1.54E+02-1.60E+02-1.60E+02												
-2.22E+02-2.24E+02-2.25E+02-2.27E+02-2.27E+02-2.28E+02-2.29E+02-2.29E+02-2.30E+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+02-1.39E+02-1.40E+02-1.40E+02-1.41E+02-1.41E+02-1.41E+02-1.47E+02-1.47E+02												
-1.88E+02-1.90E+02-1.91E+02-1.93E+02-1.94E+02-1.94E+02-1.95E+02-1.95E+02-1.95E+02-1.95E+02-1.96E+02-1.96E+02-1.96E+02												
55.50-1.33E+02-1.33E+02-1.33E+02-1.34E+02-1.34E+02-1.34E+02-1.35E+02-1.35E+02-1.35E+02-1.36E+02-1.36E+02-1.39E+02-1.39E+02												
-1.62E+02-1.64E+02-1.65E+02-1.66E+02-1.67E+02-1.67E+02-1.68E+02-1.68E+02-1.68E+02-1.68E+02-1.69E+02-1.69E+02-1.69E+02												
64.50-1.26E+02-1.26E+02-1.27E+02-1.27E+02-1.27E+02-1.27E+02-1.28E+02-1.28E+02-1.28E+02-1.29E+02-1.29E+02-1.31E+02-1.31E+02												
-1.40E+02-1.42E+02-1.42E+02-1.42E+02-1.42E+02-1.42E+02-1.42E+02-1.42E+02-1.42E+02-1.42E+02-1.42E+02-1.42E+02-1.42E+02												

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
MAXIMUM HEAD CHANGE DURING EACH ITERATION FOR TIME STEP	2	, AFTER	2.177E-02	8.824E-03
			2.310E-02	3.573E-03
8.534E+00	4.098E+02	7.459E+01	7.252E+03	3.089E+03
1.594E+01	5.663E+00	1.253E+00	1.101E+00	3.284E+00
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
			2.892E+01	8.886E+00
			1.906E+00	6.309E-01
			3.759E+00	2.731E+00
			4.758E-01	9.839E-02
			8.113E-02	1.130E+01
6.085E+00	1.884E+00	5.746E-01	2.386E-01	8.449E-02
MAXIMUM HEAD CHANGE DURING EACH ITERATION FOR TIME STEP	4	, AFTER	5.105E-02	DAYS OF SIMULATION TIME
			3.571E-02	1.152E-02
			4.307E-03	
4.633E+00	1.664E+00	6.158E-01	2.623E-01	8.547E-02
MAXIMUM HEAD CHANGE DURING EACH ITERATION FOR TIME STEP	5	, AFTER	6.716E-02	DAYS OF SIMULATION TIME
			3.327E-02	1.007E-02
			4.064E-03	
4.061E+00	1.639E+00	5.917E-01	2.334E-01	8.244E-02
MAXIMUM HEAD CHANGE DURING EACH ITERATION FOR TIME STEP	6	, AFTER	8.487E-02	DAYS OF SIMULATION TIME
			3.657E-02	1.235E-02
			4.718E-03	
3.722E+00	1.523E+00	5.576E-01	2.542E-01	9.051E-02
MAXIMUM HEAD CHANGE DURING EACH ITERATION FOR TIME STEP	7	, AFTER	1.044E-01	DAYS OF SIMULATION TIME
			3.813E-02	1.170E-02
			4.372E-03	
3.421E+00	1.476E+00	5.821E-01	2.531E-01	8.266E-02
MAXIMUM HEAD CHANGE DURING EACH ITERATION FOR TIME STEP	8	, AFTER	1.258E-01	DAYS OF SIMULATION TIME
			3.839E-02	1.382E-02
			5.537E-03	1.691E-03
3.478E+00	1.261E+00	5.558E-01	2.272E-01	9.783E-02
MAXIMUM HEAD CHANGE DURING EACH ITERATION FOR TIME STEP	9	, AFTER	1.494E-01	DAYS OF SIMULATION TIME
			3.817E-02	1.559E-02
			4.737E-03	
3.342E+00	1.253E+00	5.982E-01	2.375E-01	9.932E-02
MAXIMUM HEAD CHANGE DURING EACH ITERATION FOR TIME STEP	10	, AFTER	1.753E-01	DAYS OF SIMULATION TIME
			3.642E-02	1.487E-02
			5.283E-03	2.110E-03
3.404E+00	1.483E+00	5.904E-01	2.602E-01	9.735E-02
MAXIMUM HEAD CHANGE DURING EACH ITERATION FOR TIME STEP	11	, AFTER	2.038E-01	DAYS OF SIMULATION TIME
			4.752E-02	1.751E-02
			7.131E-03	2.182E-03
3.376E+00	1.240E+00	6.036E-01	2.531E-01	1.115E-01
MAXIMUM HEAD CHANGE DURING EACH ITERATION FOR TIME STEP	12	, AFTER	2.352E-01	DAYS OF SIMULATION TIME
			4.569E-02	1.932E-02
			7.465E-03	3.215E-03
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

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-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 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+02-1.087E+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

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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		
8.4872E-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-02	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	0.0000E+01	0.0000E-01	0.0000E-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	0.0000E+01	0.0000E-01	0.0000E-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	0.0000E+01	0.0000E-01	0.0000E-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	0.0000E+01	0.0000E-01	0.0000E-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	0.0000E+01	0.0000E-01	0.0000E-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	0.0000E+01	0.0000E-01	0.0000E-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	0.0000E+01	0.0000E-01	0.0000E-01	4.6790E+01	5.2290E-01	1.1175E-01		
1.0007E+00	1.3153E+01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E+01	0.0000E-01	0.0000E-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	0.0000E+01	0.0000E-01	0.0000E-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	0.0000E+01	0.0000E-01	0.0000E-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	0.0000E+01	0.0000E-01	0.0000E-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	0.0000E+01	0.0000E-01	0.0000E-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	0.0000E+01	0.0000E-01	0.0000E-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	0.0000E+01	0.0000E-01	0.0000E-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	0.0000E+01	0.0000E-01	0.0000E-01	4.7051E+01	2.0127E-02	4.2778E-02		

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

3.1587E+01	0.0000E-01	-1.3945E+01	2.2500E+03	0.0000E-01	0.0000E-01	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	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	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	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	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	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	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	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	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	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	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	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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	1.790E-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	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-01	0.0000E-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	THETA	SAT	THETA	SAT	THETA	SAT
0.000E-01	1.125E+01	1.500E+00	-1.015E+02	-1.000E+02	3.479E-01	7.732E-01	3.479E-01	7.732E-01	3.479E-01	7.732E-01	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	3.479E-01	7.732E-01	3.479E-01	7.732E-01	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	3.479E-01	7.732E-01	3.479E-01	7.732E-01	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	3.479E-01	7.732E-01	3.479E-01	7.732E-01	3.479E-01	7.732E-01
0.000E-01	2.887E+02	3.300E+01	-1.330E+02	-1.000E+02	1.280E-01	3.200E-01	1.280E-01	3.200E-01	1.280E-01	3.200E-01	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	1.280E-01	3.200E-01	1.280E-01	3.200E-01	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	3.479E-01	7.732E-01	3.479E-01	7.732E-01	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	3.479E-01	7.732E-01	3.479E-01	7.732E-01	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	4.303E-01	9.562E-01	4.303E-01	9.562E-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	3.671E-01	8.158E-01	3.671E-01	8.158E-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	3.485E-01	7.744E-01	3.485E-01	7.744E-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	3.485E-01	7.744E-01	3.485E-01	7.744E-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	3.480E-01	7.732E-01	3.480E-01	7.732E-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	3.479E-01	7.732E-01	3.479E-01	7.732E-01	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	1.280E-01	3.201E-01	1.280E-01	3.201E-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	1.280E-01	3.201E-01	1.280E-01	3.201E-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	3.479E-01	7.732E-01	3.479E-01	7.732E-01	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	3.479E-01	7.732E-01	3.479E-01	7.732E-01	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	4.303E-01	9.562E-01	4.303E-01	9.562E-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	3.820E-01	8.490E-01	3.820E-01	8.490E-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	3.491E-01	7.757E-01	3.491E-01	7.757E-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	3.490E-01	7.756E-01	3.490E-01	7.756E-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	3.480E-01	7.733E-01	3.480E-01	7.733E-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	3.479E-01	7.732E-01	3.479E-01	7.732E-01	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	1.281E-01	3.202E-01	1.281E-01	3.202E-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	1.281E-01	3.202E-01	1.281E-01	3.202E-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	3.479E-01	7.732E-01	3.479E-01	7.732E-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	3.479E-01	7.732E-01	3.479E-01	7.732E-01	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	4.303E-01	9.562E-01	4.303E-01	9.562E-01	4.303E-01	9.562E-01
1.705E+01	1.125E+01	1.500E+00	-2.051E+02	-2.036E+02	2.792E-01	6.204E-01	2.792E-01	6.204E-01	2.792E-01	6.204E-01	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	3.217E-01	7.149E-01	3.217E-01	7.149E-01	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	3.015E-01	6.701E-01	3.015E-01	6.701E-01	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	3.018E-01	6.706E-01	3.018E-01	6.706E-01	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	2.967E-01	6.594E-01	2.967E-01	6.594E-01	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	1.234E-01	3.085E-01	1.234E-01	3.085E-01	1.234E-01	3.085E-01

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	2.887E+02	2.700E+01	-1.829E+02	-1.559E+02	3.016E-01	6.703E-01
1.710E+01	1.125E+01	3.300E+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
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	-1.078E+04	1.619E-01	3.599E-01
7.691E+01	1.125E+01	2.700E+01	-6.147E+03	-6.147E+03	-6.120E+03	1.668E-01	3.706E-01
7.691E+01	1.462E+02	2.700E+01	-6.116E+03	-6.116E+03	-6.089E+03	1.668E-01	3.707E-01
7.691E+01	1.537E+02	2.700E+01	-5.610E+03	-5.610E+03	-5.583E+03	1.677E-01	3.727E-01
7.691E+01	2.887E+02	2.700E+01	-5.619E+03	-5.619E+03	-5.592E+03	1.677E-01	3.727E-01
7.691E+01	1.125E+01	3.300E+01	-9.976E+02	-9.976E+02	-9.646E+02	8.498E-02	2.124E-01
7.691E+01	1.462E+02	3.300E+01	-1.168E+03	-1.168E+03	-1.135E+03	8.423E-02	2.106E-01
7.691E+01	1.537E+02	3.300E+01	-1.852E+03	-1.852E+03	-1.819E+03	1.847E-01	4.105E-01
7.691E+01	2.887E+02	3.300E+01	-1.913E+03	-1.913E+03	-1.880E+03	1.840E-01	4.090E-01
7.691E+01	1.125E+01	1.440E+02	-1.918E+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	-1.079E+04	1.619E-01	3.599E-01
7.700E+01	1.125E+01	2.700E+01	-6.155E+03	-6.155E+03	-6.128E+03	1.668E-01	3.706E-01
7.700E+01	1.462E+02	2.700E+01	-6.124E+03	-6.124E+03	-6.097E+03	1.668E-01	3.707E-01
7.700E+01	1.537E+02	2.700E+01	-5.617E+03	-5.617E+03	-5.590E+03	1.677E-01	3.727E-01
7.700E+01	2.887E+02	2.700E+01	-5.626E+03	-5.626E+03	-5.599E+03	1.677E-01	3.726E-01
7.700E+01	1.125E+01	3.300E+01	-9.981E+02	-9.981E+02	-9.651E+02	8.497E-02	2.124E-01
7.700E+01	1.462E+02	3.300E+01	-1.168E+03	-1.168E+03	-1.135E+03	8.423E-02	2.106E-01
7.700E+01	1.537E+02	3.300E+01	-1.853E+03	-1.853E+03	-1.820E+03	1.847E-01	4.105E-01
7.700E+01	2.887E+02	3.300E+01	-1.914E+03	-1.914E+03	-1.881E+03	1.840E-01	4.090E-01
7.700E+01	1.125E+01	1.440E+02	-1.918E+02	-1.918E+02	-4.778E+01	4.500E-01	1.000E+00

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ATTACHMENT 1. PROGRAM LISTING

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SUBROUTINE VSEXEC	100
C	200
C*****	300
CVSEXEC	400
C*****	500
C-----	600
C ***** PROGRAM VS2D *****	700
C	800
C PROGRAM TO SOLVE FOR:	900
C TWO DIMENSIONAL VERTICAL SECTION OR CYLINDRICAL THREE	1000
C DIMENSIONAL FLUID FLOW UNDER VARIABLY SATURATED	1100
C CONDITIONS	1200
C	1300
C FLUID FLOW IS SOLVED FOR BY AN IMPLICIT FINITE DIFFERENCE	1400
C FORMULATION OF THE COMBINED RICHARDS AND COOPER-JACOB	1500
C EQUATIONS FOR FLUID CONTINUITY.	1600
C	1700
C ----- VERSION AS OF OCTOBER 23,1986 -----	1800
C 	1900
C	2000
C DEFINITION OF FUNCTIONAL RELATIONSHIPS REQUIRED	2100
C VSHKU = RELATIVE HYDRAULIC CONDUCTIVITY AS A FUNCTION OF	2200
C PRESSURE HEAD	2300
C VSTHU = VOLUMETRIC MOISTURE CONTENT AS A FUNCTION OF PRESSURE HEAD	2400
C VSDTHU = FIRST DERIVATIVE OF MOISTURE CONTENT WITH RESPECT	2500
C TO PRESSURE HEAD	2600
C VSTHNV = PRESSURE HEAD AS A FUNCTION OF VOLUMETRIC MOISTURE	2700
C CONTENT	2800
C VSRDF = ROOT ACTIVITY AS A FUNCTION OF TIME AND DEPTH.	2900
C	3000
C-----	3100
C	3200
C SPECIFICATIONS FOR ARRAYS AND SCALARS	3300
C	3400
C IMPLICIT DOUBLE PRECISION (A-H,P-Z)	3500
C COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2	3600
C COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES	3700
C COMMON/KCON/HX(0900),NTYP(0900)	3800
C COMMON/RPROP/HK(10,100),ANIZ(10)	3900
C COMMON/MPROP/THETA(0900),THLST(0900)	4000
C COMMON/PRESS/P(0900),PXXX(0900)	4100
C COMMON/DISCH/Q(0900),QQ(0900),ETOUT,ETOUT1,RHOZ	4200
C COMMON/HCON/HCND(0900),HKLL(0900),HKTT(0900)	4300
C COMMON/EQUAT/A(0900),B(0900),C(0900),D(0900),E(0900),RHS(0900),	4400
C &XI(0900)	4500
C COMMON/JTXX/JTEX(0900)	4600
C COMMON/DUMM/DUM(0900)	4700
C COMMON/SPFC/JSPX(3,25,4),NFC(4),JLAST(4),NFCS	4800
C COMMON/PTET/DEPTH(0900),RT(0900),RDC(6,25),ETCYC,	4900
C &PEVAL(25),PTVAL(25),PET,PEV,HROOT,HA,SRES,RTDPH,	5000
C &RTBOT,RTTOP,NPV	5100
C COMMON/PND/POND	5200

COMMON/PLOTT/PLTIM(50), IJOBS(50), JPLT, NPLT, NOBS	5300
COMMON/WGT/WUS, WDS	5400
COMMON/SCON/DHMX(200), DELT, HMAX, TMAX, EPS, NUMT, ITMAX, MINIT, ITEST	5500
COMMON/SCN1/TMPX, TMLT, DLTMX, DLTMIN, TRED	5600
COMMON/TCON/STIM, DSMAX, KTIM, NIT, KP	5700
COMMON/JCON/JSTOP, JFLAG	5800
LOGICAL RAD, BCIT, ETSIM, SEEP, ITSTOP	5900
LOGICAL F7P, F11P, F8P, F9P, F6P, PRNT	6000
LOGICAL THPT, SPNT, PPNT, HPNT	6100
COMMON/LOG1/RAD, BCIT, ETSIM, SEEP, ITSTOP	6200
COMMON/LOG2/F7P, F11P, F8P, F9P, F6P, PRNT	6300
COMMON/LOG4/THPT, SPNT, PPNT, HPNT	6400
CHARACTER*80 TITL	6500
CHARACTER*4 ZUNIT, TUNIT, CUNX	6600
COMMON/SCHAR/TITL, ZUNIT, TUNIT, CUNX	6700
SAVE IFET, IFET1, NITT	6800
DIMENSION KDUM(50,2)	6900
C	7000
C-----	7100
C	7200
C ---- READ AND WRITE PROBLEM TITLE AND SPACE AND TIME CONSTANTS	7300
C	7400
READ (05,4000) TITL	7500
READ (5,*) TMAX,STIM	7600
READ (05,4020) ZUNIT,TUNIT,CUNX	7700
READ (05,*) NXR,NLY	7800
READ (05,*) NRECH,NUMT	7900
WRITE (06,4070)	8000
WRITE (06,4080) TITL,TMAX,TUNIT,STIM,NRECH,NUMT,NLY,NXR	8100
READ (05,*) RAD,ITSTOP	8200
READ (05,*) F11P,F7P,F8P,F9P,F6P	8300
READ (05,*) THPT,SPNT,PPNT,HPNT	8400
WRITE (06,4090) F8P,ITSTOP,F7P,F11P,F9P,F6P	8500
WRITE (06,4100) THPT,SPNT,PPNT,HPNT	8600
NLYY=NLY-1	8700
NXRR=NXR-1	8800
NNODES=NLY*NXR	8900
C	9000
C IF NUMBER OF NODES IS GREATER THAN ARRAY DIMENSIONS THEN	9100
C TERMINATE SIMULATION	9200
C	9300
IF(NNODES.GT.0900.OR.NXR.GT.100.OR.NLY.GT.100) GO TO 10	9400
GO TO 20	9500
10 WRITE (06,4030) NLY,NXR	9600
STOP	9700
C	9800
C ESTABLISH HORIZONTAL OR RADIAL SPACING	9900
C	10000
20 READ (05,*) IFAC,FACX	10100
IF(IFAC.GT.0) GO TO 40	10200
C	10300
C READ IN SPACING FOR EACH COLUMN	10400
C	10500
READ (05,*) (DXR(K),K=1,NXR)	10600

	DO 30 K=1,NXR	10700
	30 DXR(K)=DXR(K)*FACX	10800
	GO TO 80	10900
	40 IF(IFAC.EQ.2) GO TO 60	11000
	DO 50 K=1,NXR	11100
	50 DXR(K)=FACX	11200
	GO TO 80	11300
C		11400
C	IF IFAC=2, HORIZONTAL NODE SPACING IS INCREMENTED BY A CONSTANT	11500
C	MULTIPLIER UNTIL A USER-SPECIFIED MAXIMUM IS REACHED, WHERE-	11600
C	UPON THE SPACING BECOMES CONSTANT	11700
C		11800
	60 READ (05,*) XMULT,XMAX	11900
	DXR(1)=FACX	12000
	DXR(2)=FACX	12100
	DO 70 K=3,NXRR	12200
	DXR(K)=DXR(K-1)*XMULT	12300
	IF(DXR(K) .GT. XMAX)DXR(K)=XMAX	12400
	70 CONTINUE	12500
	DXR(NXR)=DXR(NXRR)	12600
C		12700
C	ESTABLISH VERTICAL SPACING	12800
C		12900
	80 READ (05,*) JFAC,FACZ	13000
	IF(JFAC.GT.0) GO TO 100	13100
C		13200
C	READ IN VERTICAL SPACINGS INDIVIDUALLY	13300
C		13400
	READ (05,*) (DELZ(K),K=1,NLY)	13500
	DO 90 K=1,NLY	13600
	90 DELZ(K)=DELZ(K)*FACZ	13700
	GO TO 140	13800
	100 IF(JFAC.EQ.2) GO TO 120	13900
	DO 110 K=1,NLY	14000
	110 DELZ(K)=FACZ	14100
	GO TO 140	14200
C		14300
C	ESTABLISH VERTICAL SPACING BY PROGRESSION, AS ABOVE FOR HORIZ.	14400
C		14500
	120 READ (05,*) ZMULT,ZMAX	14600
	DELZ(1)=FACZ	14700
	DELZ(2)=FACZ	14800
	DO 130 K=3,NLYY	14900
	DELZ(K)=DELZ(K-1)*ZMULT	15000
	IF(DELZ(K) .GT. ZMAX)DELZ(K)=ZMAX	15100
	130 CONTINUE	15200
	DELZ(NLY)=DELZ(NLYY)	15300
	140 CONTINUE	15400
C		15500
C	DETERMINE HORIZONTAL AND VERTICAL COORDINATES	15600
C		15700
	RX(1)=-0.5 *DXR(1)	15800
	DO 150 N=2,NXR	15900
	RX(N)=RX(N-1)+0.5 *(DXR(N-1)+DXR(N))	16000

150	CONTINUE	16100
	DZZ(1)=-0.5 *DELZ(1)	16200
	DO 160 J=2,NLY	16300
160	DZZ(J)=DZZ(J-1)+0.5 *(DELZ(J-1)+DELZ(J))	16400
	WRITE (06,4110) ZUNIT,(DELZ(K),K=1,NLY)	16500
	WRITE (06,4120) ZUNIT,(DXR(K),K=1,NXR)	16600
	DELY=1.	16700
C		16800
C	READ DATA FOR MONITORING TIMES AND POINTS	16900
C		17000
	NPLT=0	17100
	IF(.NOT.F8P) GO TO 170	17200
	READ (05,*) NPLT	17300
	IF(NPLT.GT.50)NPLT=50	17400
	IF(NPLT.EQ.0)NPLT=1	17500
	READ (05,*) (PLTIM(K),K=1,NPLT)	17600
	WRITE (06,4130) (PLTIM(K),K=1,NPLT)	17700
170	IF(.NOT.F11P) GO TO 190	17800
	READ (05,*) NOBS	17900
	READ (05,*) ((KDUM(K,J),J=1,2),K=1,NOBS)	18000
	WRITE (06,4140) ((KDUM(K,J),J=1,2),K=1,NOBS)	18100
	DO 180 K=1,NOBS	18200
	N=NLY*(KDUM(K,2)-1)+KDUM(K,1)	18300
180	IJOBS(K)=N	18400
190	CONTINUE	18500
	PLTIM(NPLT+1)=TMAX+TMAX	18600
	IF(RAD) GO TO 200	18700
	WRITE (06,4050)	18800
	GO TO 210	18900
200	WRITE (06,4060)	19000
210	CONTINUE	19100
	IF(F11P) WRITE (11,4040) TITL,TUNIT,ZUNIT,ZUNIT,ZUNIT,ZUNIT	19200
C		19300
C	INITIALIZE CONSTANTS	19400
C		19500
	PI=3.14159265	19600
	PI2=PI+PI	19700
	ITEST=0	19800
	KTIM=0	19900
	NITT=0	20000
	JFLAG=1	20100
	KP=0	20200
	WRITE (06,4150)	20300
C		20400
C		20500
C	READ AND WRITE INITIAL VALUES OF PRESSURE HEAD, TOTAL HEAD,	20600
C	THETA, AND SATURATION	20700
C	-----	20800
C		20900
	CALL VSREAD	21000
	CALL VSSIP	21100
	IFET=0	21200
	IFET2=0	21300
	CALL VSOUTP	21400

C		21500
C	-----	21600
C	START OF TIME LOOP	21700
C	-----	21800
C		21900
	220 IF(JFLAG.EQ.1)IFET1=1	22000
	CALL VSTMER	22100
C		22200
C	SET UP AND SOLVE MATRIX EQUATIONS	22300
C		22400
	230 CALL VSMGEN	22500
C		22600
C	CHECK FOR PONDING DURING THIS TIME STEP	22700
C		22800
	CALL VSPOND(IFET,IFET1,IFET2)	22900
C		23000
C	IF PONDING HAS OCCURRED, EQUATIONS NEED TO BE SOLVED AGAIN	23100
C		23200
	IF(IFET.NE.0) GO TO 230	23300
C		23400
C	REEVALUATE NONLINEAR COEFFICIENTS AND PRINT RESULTS	23500
C	FOR CURRENT TIME STEP	23600
C		23700
	CALL VSCOEF	23800
	CALL VSOUTP	23900
C		24000
C	COMPUTE MASS BALANCE COMPONENTS	24100
C		24200
	CALL VSFLUX	24300
	NITT=NITT+NIT	24400
	IF(JSTOP.EQ.1) GO TO 240	24500
	GO TO 220	24600
C		24700
C	-----	24800
C	END OF TIME LOOP	24900
C	-----	25000
C		25100
	240 WRITE (06,4160)	25200
	WRITE (6,4170) NITT	25300
	RETURN	25400
4000	FORMAT(A80)	25500
4020	FORMAT(4A4)	25600
4030	FORMAT(5X,20(1H*),1X,31HDIMENSIONS TOO LARGE FOR ARRAYS,	25700
	&1X,20(1H*)/5X,6HNLY = ,I5,2X,6H,NXR = ,I5)	25800
4040	FORMAT(A80/21HMONITORING POINT FILE/2X,6HTIME, ,A4,2X,	25900
	& 6H XR, ,A4,2X,6H Z, ,A4,2X,6H H, ,A4,2X,6H P, ,A4,	26000
	& 2X,6H THETA,4X,8H SAT)	26100
4050	FORMAT(5X,32HCOORDINATE SYSTEM IS RECTANGULAR)	26200
4060	FORMAT(5X,27HCOORDINATE SYSTEM IS RADIAL)	26300
4070	FORMAT(35X,60(1H+)/35X,1H+,26X,6H VS2D ,28X,1H+/35X,	26400
	&1H+,4X,36HSIMULATION OF 2-DIMENSIONAL VARIABLY,20X,1H+/	26500
	&35X,1H+,4X,35HSATURATED HEAD AND FLUID SATURATION,21X,1H+	26600
	&/35X,1H+,4X,41HDISTRIBUTIONS. IMPLICIT FINITE DIFFERENCE,15X,1H+	26700
	&/35X,1H+,4X,24HBODY-CENTERED CELLS USED,32X,1H+	26800

& /36X,60(1H+)//)	26900
4080 FORMAT(//,1X,100(1H*)/5X,A80/1X,100(1H*)//10X,	27000
&24HSPACE AND TIME CONSTANTS/10X,23(1H-)/	27100
& 5X,26HMAXIMUM SIMULATION TIME = ,F10.4,1X,A4/	27200
&5X,'STARTING TIME = ',F10.4,/	27300
&5X,28HNUMBER OF RECHARGE PERIODS =,I10/	27400
&4X,32H-MAXIMUM NUMBER OF TIME STEPS = ,I10/	27500
&5X,17HNUMBER OF ROWS = ,I5/5X,20HNUMBER OF COLUMNS = ,I5)	27600
4090 FORMAT(10X,16HSOLUTION OPTIONS/10X,16(1H-)/	27700
&5X,'WRITE ALL PRESSURE HEADS TO FILE 8',	27800
&23H AT OBSERVATION TIMES? ,L1,/	27900
&5X,28HSTOP SOLUTION IF MAXIMUM NO.,	28000
&42H OF ITERATIONS EXCEEDED IN ANY TIME STEP?,L1/5X,	28100
&'WRITE MAXIMUM CHANGE IN HEAD FOR EACH ITERATION TO FILE 7? ',	28200
&L1/5X,'WRITE RESULTS AT SELECTED OBSERVATION POINTS TO ',	28300
&9HFILE 11? , L1/,5X,36HWRITE MASS BALANCE RATES TO FILE 9? L1/	28400
&5X,36HWRITE MASS BALANCE RATES TO FILE 6? ,L1)	28500
4100 FORMAT(1H ,4X,35HWRITE MOISTURE CONTENTS TO FILE 6? ,L1/	28600
& 5X,29HWRITE SATURATIONS TO FILE 6? ,L1/	28700
& 5X,32HWRITE PRESSURE HEADS TO FILE 6? ,L1/	28800
& 5X,29HWRITE TOTAL HEADS TO FILE 6? ,L1)	28900
4110 FORMAT(50X,39HGRID SPACING IN VERTICAL DIRECTION, IN ,A4/	29000
& (10(F10.3)))	29100
4120 FORMAT(50X,47HGRID SPACING IN HORIZONTAL OR RADIAL DIRECTION,	29200
& ,3H IN,1X,A4/(10F10.3))	29300
4130 FORMAT(5X,43HTIMES AT WHICH H WILL BE WRITTEN TO FILE 08	29400
&/(5X,10F10.4))	29500
4140 FORMAT(5X,37HROW AND COLUMN OF OBSERVATION POINTS:/	29600
& 3X,10(2X,2I4))	29700
4150 FORMAT(5X,36HMATRIX EQUATIONS TO BE SOLVED BY SIP)	29800
4160 FORMAT(5X,100(1H*)/5X,17HEND OF SIMULATION/	29900
& 5X,100(1H*))	30000
4170 FORMAT(1H ,'TOTAL NUMBER OF ITERATIONS = ',I6)	30100
END	30200
BLOCK DATA DAT1	30300
IMPLICIT DOUBLE PRECISION (A-H,P-Z)	30400
COMMON/PRESS/P(0900),PXXX(0900)	30500
COMMON/KCON/HX(0900),NTYP(0900)	30600
COMMON/MPROP/THETA(0900),THLST(0900)	30700
COMMON/HCON/HCND(0900),HKLL(0900),HKTT(0900)	30800
COMMON/PTET/DPTH(0900),RT(0900),RDC(6,25),ETCYC,	30900
&PEVAL(25),PTVAL(25),PET,PEV,HROOT,HA,SRES,RTDPTH,	31000
&RTBOT,RTTOP,NPV	31100
COMMON/DISCH/Q(0900),QQ(0900),ETOUT,ETOUT1,RHOZ	31200
DATA P/0900*0.0/,PXXX/0900*0.0/,HX/0900*0.0/,THETA/0900*0.0/,	31300
&THLST/0900*0.0/	31400
DATA HCND/0900*0.0/,HKLL/0900*0.0/,HKTT/0900*0.0/,DPTH/0900*0.0/,	31500
&RT/0900*0.0/,PTVAL/25*0.0/,PEVAL/25*0.0/	31600
DATA Q/0900*0.0/,QQ/0900*0.0/	31700
END	31800
SUBROUTINE VSREAD	31900
C*****	32000
CVSREAD	32100
C*****	32200

C		32300
C	PURPOSE: TO READ INITIAL HEAD AND SATURATION DATA	32400
C		32500
C	-----	32600
C		32700
C	SPECIFICATIONS FOR ARRAYS AND SCALARS	32800
C		32900
	IMPLICIT DOUBLE PRECISION (A-H,P-Z)	33000
	COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2	33100
	COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES	33200
	COMMON/KCON/HX(0900),NTYP(0900)	33300
	COMMON/RPROP/HK(10,100),ANIZ(10)	33400
	COMMON/MPROP/THETA(0900),THLST(0900)	33500
	COMMON/PRESS/P(0900),PXXX(0900)	33600
	COMMON/DISCH/Q(0900),QQ(0900),ETOUT,ETOUT1,RHOZ	33700
	COMMON/HCON/HCND(0900),HKLL(0900),HKT(0900)	33800
	COMMON/JTXX/JTEX(0900)	33900
	COMMON/DUMM/DUM(0900)	34000
	COMMON/PTET/DPTH(0900),RT(0900),RDC(6,25),ETCYC,	34100
	&PEVAL(25),PTVAL(25),PET,PEV,HROOT,HA,SRES,RTDPTH,	34200
	&RTBOT,RTTOP,NPV	34300
	COMMON/WGT/WUS,WDS	34400
	COMMON/SCON/DHMX(200),DELT,HMAX,TMAX,EPS,NUMT,ITMAX,MINIT,ITEST	34500
	COMMON/SCN1/TMPX,TMLT,DLTMX,DLTMIN,TRED	34600
	COMMON/TCON/STIM,DSMAX,KTIM,NIT,KP	34700
	LOGICAL PHRD	34800
	LOGICAL RAD,BCIT,ETSIM,SEEP,ITSTOP	34900
	COMMON/LOG1/RAD,BCIT,ETSIM,SEEP,ITSTOP	35000
	CHARACTER*80 TITL	35100
	CHARACTER*36 IFMT	35200
	CHARACTER*4 ZUNIT,TUNIT,CUNX	35300
	COMMON/SCHAR/TITL,ZUNIT,TUNIT,CUNX	35400
	DIMENSION IDUM(0100)	35500
C	-----	35600
C		35700
C	READ AND WRITE INITIAL DATA FOR SIMULATION	35800
C		35900
	READ (5,*) EPS,HMAX,WUS	36000
	READ (05,*) RHOZ	36100
	READ (5,*) MINIT,ITMAX	36200
	READ (05,*) PHRD	36300
	READ (05,*) NTEX,NPROP	36400
C		36500
C	CHECK THAT SUM OF WEIGHTING FACTORS IS EQUAL TO ONE	36600
C		36700
	WRITE (6,4010) EPS,ZUNIT,HMAX	36800
	WRITE (6,4020) RHOZ,CUNX,ZUNIT	36900
	IF(WUS.EQ.1) GO TO 10	37000
	IF(WUS.EQ.0.5) GO TO 20	37100
	WUS=0.	37200
	WRITE (6,4030)	37300
	GO TO 30	37400
10	WDS=0.	37500
	WRITE (6,4040)	37600

	GO TO 30	37700
20	WDS=0.5	37800
	WRITE (6,4090)	37900
30	CONTINUE	38000
	WRITE (6,4100) NTEX,NPROP,MINIT,ITMAX	38100
	IF(ITMAX.GT.300) GO TO 330	38200
	WRITE (06,4120)	38300
C		38400
C	READ AND WRITE MATERIAL PROPERTIES FOR EACH TEXTURAL CLASS	38500
C		38600
	DO 40 J22=1,NTEX	38700
	READ (5,*) J	38800
	READ (5,*) ANIZ(J),(HK(J,I),I=1,NPROP)	38900
	WRITE (6,4130) J,ANIZ(J),(HK(J,I),I=1,NPROP)	39000
40	CONTINUE	39100
	WRITE (06,4150)	39200
C		39300
C	READ TEXTURAL CLASS INDEX MAP	39400
C		39500
	READ (05,*) IROW	39600
	IF(IROW.EQ.0) WRITE (6,4110)	39700
	IF(IROW.EQ.1) GO TO 70	39800
	DO 60 J=1,NLY	39900
	READ (05,*) (IDUM(N),N=1,NXR)	40000
	WRITE (06,4160) J,(IDUM(N),N=1,NXR)	40100
	DO 50 N=1,NXR	40200
	IN=NLY*(N-1)+J	40300
	J22=IDUM(N)	40400
	HX(IN)=HK(J22,1)	40500
50	JTEX(IN)=J22	40600
60	CONTINUE	40700
	GO TO 120	40800
C		40900
C	READ TEXTURE CLASSES BY BLOCK--EITHER CONTINUOUS LAYERS OR	41000
C	LAYERS BOUNDED BY VERTICAL DISCONTINUITIES.	41100
C		41200
70	WRITE (06,4060)	41300
	JTP=1	41400
80	READ (05,*) IL,IR,JBT,JRD	41500
	DO 90 N=IL,IR	41600
	IDUM(N)=JRD	41700
90	CONTINUE	41800
	IF(IR.LT.NXR) GO TO 80	41900
	DO 100 J=JTP,JBT	42000
100	WRITE (06,4160) J,(IDUM(N),N=1,NXR)	42100
	DO 110 J=JTP,JBT	42200
	DO 110 N=1,NXR	42300
	IN=NLY*(N-1)+J	42400
	J22=IDUM(N)	42500
	HX(IN)=HK(J22,1)	42600
	JTEX(IN)=J22	42700
110	CONTINUE	42800
	IF(JBT.EQ.NLY) GO TO 120	42900
	JTP=JBT+1	43000

	GO TO 80	43100
	120 CONTINUE	43200
C		43300
C	BORDERS OF DOMAIN ARE ALL SET TO NO FLOW BOUNDARIES	43400
C		43500
	DO 130 I=1,NLY	43600
	I1=NNODES-I+1	43700
	HX(I)=0	43800
	130 HX(I1)=0	43900
	DO 140 I=2,NXR	44000
	I1=(I-1)*NLY	44100
	HX(I1)=0	44200
	140 HX(I1+1)=0	44300
		44400
C		44500
C	COMPUTE DEPTHS FOR ET CALCULATIONS	44600
C		44700
	DPTH(1)=-.5 *DELZ(1)	44800
	DO 170 J=2,NLYY	44900
	DO 170 N=2,NXRR	45000
	IN=NLY*(N-1)+J	45100
	JM1=IN-1	45200
	IF(HX(IN).EQ.0.) GO TO 170	45300
	IF(HX(JM1).EQ.0.) GO TO 150	45400
	GO TO 160	45500
	150 DPTH(IN)=0.0	45600
	GO TO 170	45700
	160 DPTH(IN)=DPTH(JM1)+DELZ(J-1)	45800
	170 CONTINUE	45900
	WRITE (6,4240)	46000
	CALL VSOUT(2,DPTH)	46100
C		46200
C	READ INITIAL HEADS OR MOISTURE CONTENTS	46300
C		46400
	READ (05,*) IREAD,FACTOR	46500
	IF(IREAD.NE.2) GO TO 190	46600
	READ (05,*) DWTX,HMIN	46700
	WRITE (06,4220) DWTX,ZUNIT,HMIN,ZUNIT,DWTX,ZUNIT	46800
C		46900
C	CALCULATE EQUILIBRIUM INITIAL HEAD PROFILE	47000
C		47100
	DO 180 J=2,NLYY	47200
	DO 180 N=2,NXRR	47300
	IN=NLY*(N-1)+J	47400
	IF(HX(IN).EQ.0.) GO TO 180	47500
	P(IN)=DZZ(J)-DWTX	47600
	IF(P(IN).LT.HMIN)P(IN)=HMIN	47700
	P(IN)=P(IN)-DZZ(J)	47800
	PXXX(IN)=P(IN)	47900
	180 CONTINUE	48000
	GO TO 290	48100
	190 IF(IREAD.EQ.1) GO TO 200	48200
	WRITE (6,4190) FACTOR	48300
	GO TO 210	48400
	200 READ (05,*) IU,IFMT	

	WRITE (06,4200) IU,FACTOR	48500
210	DO 280 J=1,NLY	48600
	IF(IREAD.EQ.0) GO TO 220	48700
C		48800
C	READ INITIAL CONDITIONS FROM FILE IU	48900
C		49000
	READ (IU,FMT=IFMT) (DUM(N),N=1,NXR)	49100
	GO TO 240	49200
220	DO 230 N=1,NXR	49300
230	DUM(N)=FACTOR	49400
240	DO 270 N=1,NXR	49500
	IN=NLY*(N-1)+J	49600
	IF(IREAD.EQ.1)DUM(N)=DUM(N)*FACTOR	49700
	IF(PHRD) GO TO 260	49800
	IF(DUM(N).LE.0.) GO TO 250	49900
	IF(HX(IN).EQ.0) GO TO 250	50000
C		50100
C	CONVERT INITIAL MOISTURE CONTENTS TO HEADS	50200
C		50300
	P(IN)=VSTHNV(DUM(N),JTEX(IN),HK)-DZZ(J)	50400
250	CONTINUE	50500
	THETA(IN)=DUM(N)	50600
	PXXX(IN)=P(IN)	50700
	GO TO 270	50800
260	P(IN)=DUM(N)-DZZ(J)	50900
	PXXX(IN)=P(IN)	51000
270	CONTINUE	51100
280	CONTINUE	51200
C		51300
C	COMPUTE INITIAL NONLINEAR COEFFICIENT VALUES	51400
C		51500
290	CALL VSCOEF	51600
C		51700
C	IF ET IS TO BE SIMULATED, ALL VARIABLES MUST BE ENTERED HERE.	51800
C		51900
	READ(05,*) BCIT,ETSIM	52000
	IF(.NOT.BCIT .AND. .NOT. ETSIM) GO TO 310	52100
C		52200
C	READ EVAPORATION VARIABLES	52300
C		52400
	READ(05,*)NPV,ETCYC	52500
	WRITE(6,4050) NPV,ETCYC,TUNIT	52600
	IF(.NOT.BCIT) GO TO 300	52700
	READ (05,*)(PEVAL(I),I=1,NPV)	52800
	READ(05,*) (RDC(1,I),I=1,NPV)	52900
	READ(05,*) (RDC(2,I),I=1,NPV)	53000
	WRITE (06,4070)ZUNIT,TUNIT,ZUNIT,ZUNIT,(I,PEVAL(I),RDC(1,I),RDC(2,	53100
	*I),I=1,NPV)	53200
300	IF (.NOT. ETSIM)GO TO 310	53300
C		53400
C	READ TRANSPIRATION VARIABLES	53500
C		53600
	READ(05,*)(PTVAL(I),I=1,NPV)	53700
	READ(05,*) (RDC(3,I),I=1,NPV)	53800

	READ(05,*) (RDC(4,I),I=1,NPV)	53900
	READ(05,*) (RDC(5,I),I=1,NPV)	54000
	READ(05,*) (RDC(6,I),I=1,NPV)	54100
	WRITE(06,4080)ZUNIT,TUNIT,ZUNIT,ZUNIT,ZUNIT,ZUNIT,(I,PTVAL(I),	54200
	*(RDC(J,I),J=3,6),I=1,NPV)	54300
310	CONTINUE	54400
	DO 320-IN=1,NNODES	54500
	NTYP(IN)=0	54600
	IF(HX(IN).EQ.0) GO TO 320	54700
	THLST(IN)=THETA(IN)	54800
320	CONTINUE	54900
C		55000
C	COMPUTE INTERCELL CONDUCTANCES	55100
C		55200
	CALL VSHCMP	55300
	RETURN	55400
330	WRITE (06,4180) ITMAX	55500
	STOP	55600
4010	FORMAT(10X,27HINITIAL MOISTURE PARAMETERS/10X,27(1H_)//	55700
	&5X,31HCONVERGENCE CRITERIA FOR SIP =,1PE12.3,1X,A4/	55800
	&5X,23HDAMPING FACTOR, HMAX = ,1PE12.3)	55900
4020	FORMAT(1H ,4X,32HFLUID DENSITY AT ZERO PRESSURE =,1PE12.3,1X,A4,	56000
	&1H/,A4,3H**3)	56100
4030	FORMAT(5X,46HGEOMETRIC MEAN USED FOR INTERCELL CONDUCTIVITY)	56200
4040	FORMAT(5X,45HUPSTREAM WEIGHTING USED FOR INTERCELL CONDUCT	56300
	1,5HIVITY)	56400
4050	FORMAT(//15X,'NUMBER OF EVAPORATION AND/OR EVAPOTRANSPIRATION PER'	56500
	&,'IODS = ',I4,/,15X,'LENGTH OF EACH PERIOD = ',F10.4,2X,A4)	56600
4060	FORMAT(5X,'TEXTURAL CLASSES READ IN BY BLOCK')	56700
4070	FORMAT(//5X,'EVAPORATION POTENTIAL SURFACE ATMOSHERIC',	56800
	&/' PERIOD RATE RESISTANCE PRESSURE',	56900
	&/19X,A4,'/',A4,3X,A4,'**(-1)',5X,A4,/,1X,90('-'),	57000
	&25(/,5X,I6,4X,3E14.5))	57100
4080	FORMAT(//,3X,'TRANSPIRATION POTENTIAL ROOT ACTIVIT	57200
	&Y ACTIVITY ROOT',	57300
	&/' PERIOD RATE DEPTH AT BOTTOM A	57400
	&T TOP PRESSURE',/,19X,A4,'/',A4,9X,A4,5X,A4,'**(-2)',4X,A4,	57500
	&'**(-2)',8X,A4,/,1X,90('-'),25(/,5X,I6,4X,5E14.5))	57600
4090	FORMAT(5X,47HARITHEMTIC MEAN USED FOR INTERCELL CONDUCTIVITY)	57700
4100	FORMAT(5X,34HNUMBER OF SOIL TEXTURAL CLASSES = ,I10/	57800
	&5X,43HNUMBER OF SOIL PARAMETERS FOR EACH CLASS = ,I10/	57900
	&5X,47HMINIMUM PERMITTED NO. OF ITERATIONS/TIME STEP =,I10/	58000
	&5X,47HMAXIMUM PERMITTED NO. OF ITERATIONS/TIME STEP =,I10)	58100
4110	FORMAT(5X,41HTEXTURAL CLASS TO BE READ IN FOR EACH ROW)	58200
4120	FORMAT(41X,35HCONSTANTS FOR SOIL TEXTURAL CLASSES//	58300
	210X,10HANISOTROPY,7X,4HKSAT,5X,8HSPECIFIC,4X,8HPOROSITY,/,	58400
	236X,7HSTORAGE)	58500
4130	FORMAT(1X,7HCLASS #,I2,/9X,3(1PD12.3),14(7(1PD12.3),/))	58600
4150	FORMAT(6X,24HTEXTURAL CLASS INDEX MAP//)	58700
4160	FORMAT(1H ,5X,I4,2X,100I1)	58800
4180	FORMAT(5X,24H ***** VALUE OF ITMAX =,I5,8HEXCEEDS ,	58900
	&44HDIMENSION OF DHMX, PROGRAM TERMINATED *****)	59000
4190	FORMAT(5X,48HINITIAL PRESSURE HEAD OR MOISTURE CONTENT WAS SE,	59100
	& 24HT TO A CONSTANT VALUE OF,1PE12.3)	59200

4200	FORMAT(5X,48HINITIAL PRESSURE HEAD OR MOISTURE CONTENT WAS RE,	59300
	& 12HAD FROM UNIT,I5,	59400
	& 20H A SCALING FACTOR OF,1PE12.3,9H WAS USED)	59500
4220	FORMAT(5X,'EQUILLIBRIUM PROFILE USED TO INITIALIZE PRESSURE',	59600
	& 27H HEADS ABOVE WATER TABLE AT,F10.2,1X,A4,1X,	59700
	& 12HBELOW ORIGIN/5X,	59800
	& 57HEQUILLIBRIUM PROFILE ONLY USED UNTIL PRESSURE HEADS EQUAL,	59900
	& F10.2,1X,A4/5X,	60000
	& 20HPRESSURE HEADS BELOW,F10.2,1X,A4,16H ARE HYDROSTATIC)	60100
4240	FORMAT(1H ,50X,18HDEPTH FROM SURFACE)	60200
	END	60300
	SUBROUTINE VSTMER	60400
C*****		60500
CVSTMER		60600
C*****		60700
C		60800
C	PURPOSE: TO CONTROL THE TIME SEQUENCE OF SIMULATION	60900
C	AND TO READ NEW BOUNDARY CONDITION DATA	61000
C		61100
C	-----	61200
C		61300
C	SPECIFICATIONS FOR ARRAYS AND SCALARS	61400
C		61500
	IMPLICIT DOUBLE PRECISION (A-H,P-Z)	61600
	COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2	61700
	COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES	61800
	COMMON/KCON/HX(0900),NTYP(0900)	61900
	COMMON/MPROP/THETA(0900),THLST(0900)	62000
	COMMON/PRESS/P(0900),PXXX(0900)	62100
	COMMON/DISCH/Q(0900),QQ(0900),ETOUT,ETOUT1,RHOZ	62200
	COMMON/HCON/HCND(0900),HKLL(0900),HKTT(0900)	62300
	COMMON/DUMM/DUM(0900)	62400
	COMMON/SPFC/JSPX(3,25,4),NFC(4),JLAST(4),NFCS	62500
	COMMON/PTET/DPTH(0900),RT(0900),RDC(6,25),ETCYC,	62600
	&PEVAL(25),PTVAL(25),PET,PEV,HROOT,HA,SRES,RTDPTH,	62700
	&RTBOT,RTTOP,NPV	62800
	COMMON/PND/POND	62900
	COMMON/PLOTT/PLTIM(50),IJOBS(50),JPLT,NPLT,NOBS	63000
	COMMON/SCON/DHMX(200),DELT,HMAX,TMAX,EPS,NUMT,ITMAX,MINIT,ITEST	63100
	COMMON/SCN1/TMPX,TMLT,DLTMX,DLTMIN,TRED	63200
	COMMON/TCON/STIM,DSMAX,KTIM,NIT,KP	63300
	COMMON/JCON/JSTOP,JFLAG	63400
	LOGICAL RAD,BCIT,ETSIM,SEEP,ITSTOP	63500
	LOGICAL F7P,F11P,F8P,F9P,F6P,PRNT	63600
	COMMON/LOG1/RAD,BCIT,ETSIM,SEEP,ITSTOP	63700
	COMMON/LOG2/F7P,F11P,F8P,F9P,F6P,PRNT	63800
	CHARACTER*80 TITL	63900
	CHARACTER*4 ZUNIT,TUNIT,CUNX	64000
	COMMON/SCHAR/TITL,ZUNIT,TUNIT,CUNX	64100
	DIMENSION IDUM(0100)	64200
	SAVE STERR,KPLT,DHMAX,STIMI	64300
C	-----	64400
C		64500
C	ADVANCE TO NEXT TIME STEP	64600

C		64700
	KTIM=KTIM+1	64800
	IF (KTIM.NE.1.AND.JSTOP.EQ.1) RETURN	64900
	JSTOP=0	65000
	JPLT=0	65100
	NIT=0	65200
	IF(KTIM.EQ.1) KPLT=1	65300
	IF(JFLAG.EQ.1) GO TO 10	65400
	GO TO 160	65500
C		65600
C	.....	65700
C		65800
C	READ DATA FOR NEW RECHARGE PERIOD	65900
C	.....	66000
C		66100
	10 READ (05,*) TPER,DELT	66200
C		66300
C	CHECK FOR END OF SIMULATION	66400
C		66500
	IF(TPER.LT.999998.) GO TO 20	66600
	WRITE (06,4100) TMAX,STIM	66700
	STOP	66800
	20 READ (05,*) TMLT,DLTMX,DLTMIN,TRED	66900
	KP=KP+1	67000
	WRITE (06,4010) KP,TPER,TUNIT,DELT,TUNIT,TMLT,DLTMX,TUNIT,DLTMIN,	67100
	*TUNIT,TRED	67200
	READ (05,*) DSMAX,STERR	67300
	READ (05,*) POND	67400
	WRITE (06,4030) DSMAX,STERR,POND	67500
	READ (05,*) PRNT	67600
	READ (05,*) BCIT,ETSIM,SEEP	67700
	WRITE (06,4020) PRNT,BCIT,ETSIM,SEEP	67800
	DSMAX=ABS(DSMAX)	67900
	ETOUT=0	68000
	ETOUT1=0	68100
C		68200
C	READ SEEPAGE FACE DATA	68300
C		68400
	IF(.NOT.SEEP) GO TO 60	68500
	READ (05,*) NFCS	68600
	DO 50 K=1,NFCS	68700
	READ (05,*) JJ,JLAST(K)	68800
	NFC(K)=JJ	68900
	READ (05,*) ((JSPX(L,J,K),L=2,3),J=1,JJ)	69000
	DO 40 J=1,JJ	69100
	J1=JSPX(2,J,K)	69200
	N1=JSPX(3,J,K)	69300
	N2=NLY*(N1-1)+J1	69400
	JSPX(1,J,K)=N2	69500
	Q(N2)=0.	69600
	QQ(N2)=0.	69700
	IF(J.LE.JLAST(K)) GO TO 30	69800
	NTYP(N2)=3	69900
	GO TO 40	70000

30	NTYP(N2)=1	70100
	P(N2)=-DZZ(J1)	70200
40	CONTINUE	70300
50	CONTINUE	70400
C		70500
C	READ IN NEW BOUNDARY CONDITIONS FOR RECHARGE PERIOD	70600
C	IF IBC=0, POINT BOUNDARY CONDITIONS ARE READ IN.	70700
C	IF IBC=1, LINE BOUNDARY CONDITIONS ARE READ IN, AND IT IS NECESSARY	70800
C	TO SPECIFY FOUR POINTS ON THE LINE--THIS ALLOWS VERTICAL OR HORI-	70900
C	ZONTAL LINES TO BE READ IN INDISCRIMINATELY. THE SEQUENCE IS:	71000
C	TOP ROW, BOTTOM ROW, LEFT COLUMN, RIGHT COLUMN, CODE, AND FLUX OR	71100
C	PRESSURE HEAD FOR BOUNDARY CONDITION.	71200
C		71300
60	READ (05,*) IBC	71400
	IF(IBC.GT.0) GO TO 80	71500
70	READ (05,*) JJ,NN,NTX,PFDUM	71600
	IF(JJ.GE.999998) GO TO 130	71700
	JJT=JJ	71800
	JJB=JJ	71900
	NNL=NN	72000
	NNR=NN	72100
	GO TO 90	72200
80	READ (05,*) JJT,JJB,NNL,NNR,NTX,PFDUM	72300
	IF(JJT.GE.999) GO TO 130	72400
90	CONTINUE	72500
	DO 120 JJ=JJT,JJB	72600
	DO 120 NN=NNL,NNR	72700
	IN=NLY*(NN-1)+JJ	72800
	IF(NTX.NE.6) GO TO 100	72900
	NTYP(IN)=2	73000
	QQ(IN)=PFDUM	73100
	GO TO 120	73200
100	NTYP(IN)=NTX	73300
	IF(NTX.EQ.4)NTYP(IN)=1	73400
	IF(NTX.EQ.0) WRITE (06,4040) JJ,NN	73500
	IF(NTX.EQ.1) P(IN)=PFDUM-DZZ(JJ)	73600
	IF(NTX.EQ.4) P(IN)=PFDUM	73700
	IF(NTX.EQ.2) GO TO 110	73800
	QQ(IN)=0	73900
	GO TO 120	74000
110	CONTINUE	74100
C		74200
C	SET QQ TO RAINFALL RATE	74300
C		74400
	AREA=DELY*DXR(NN)	74500
	IF(RAD)AREA=PI2*RX(NN)*DXR(NN)	74600
	QQ(IN)=PFDUM*AREA	74700
120	CONTINUE	74800
	IF(IBC.EQ.0) GO TO 70	74900
	GO TO 80	75000
130	CONTINUE	75100
C		75200
C	WRITE INITIAL BOUNDARY CONDITIONS FOR THIS PERIOD	75300
C		75400

	WRITE (06,4060) KP	75500
	DO 150 J=1,NLY	75600
	DO 140 N=1,NXR	75700
	IN=NLY*(N-1)+J	75800
	Q(IN)=0.	75900
140	IDUM(N)=NTYP(IN)	76000
150	WRITE (06,4080) J,(IDUM(I),I=1,NXR)	76100
	TMPX=STIM+TPER	76200
	IF(TMPX+0.5*DLTMIN.GT.TMAX) TMPX=TMAX	76300
C		76400
C	CALCULATE NEW COEFFICIENTS	76500
C		76600
	IF(KTIM.NE.1)CALL VSCOEF	76700
160	CONTINUE	76800
C		76900
C	INITIALIZE REQUIRED ARRAYS FOR NEW BOUNDARY CONDITION, UPDATE	77000
C	PXXX,THLST. COMPUTE MAXIMUM HEAD CHANGE DURING LAST TIME STEP	77100
C		77200
	IF(KTIM.EQ.1) GO TO 210	77300
	DHMAX=0.	77400
	PDIF=0.	77500
	DO 170 J=2,NLYY	77600
	DO 170 N=2,NXRR	77700
	IN=NLY*(N-1)+J	77800
	IF(HX(IN).EQ.0.) GO TO 170	77900
	P12=P(IN)-PXXX(IN)	78000
	PTMP=ABS(P12)	78100
	IF(PTMP.GT.PDIF)PDIF=PTMP	78200
	PXXX(IN)=P(IN)	78300
	IF(PDIF.GT.DHMAX)DHMAX=PDIF	78400
	THLST(IN)=THETA(IN)	78500
170	CONTINUE	78600
C		78700
C	CHECK FOR STEADY STATE	78800
C		78900
	IF(PDIF.LE.STERR.AND.JFLAG.EQ.0) GO TO 180	79000
	GO TO 210	79100
180	WRITE (06,4090)	79200
C		79300
C	IF STEADY STATE IS REACHED, ONE MORE TIME STEP IS RUN FOR	79400
C	THIS PERIOD WITH DELT SET TO THE TIME REMAINING IN THE PERIOD	79500
C		79600
	DELT=TMPX-STIM	79700
	STIM=TMPX	79800
190	IF(KPLT.GT.NPLT) GO TO 200	79900
	IF(TMPX.LE.PLTIM(KPLT)) GO TO 200	80000
	KPLT=KPLT+1	80100
	GO TO 190	80200
200	JFLAG=1	80300
	JPLT=1	80400
	RETURN	80500
210	JFLAG=0	80600
C		80700
C	INITIALIZE DHMX	80800

C		80900
	DO 220 K=1,200	81000
	220 DHMX(K)=0.	81100
C		81200
C	ADVANCE DELT AND RESET TO PROPER LENGTH IF NECESSARY	81300
C		81400
	DLTOLD=DELT	81500
	DELT= TMLT*DELT	81600
C		81700
C	MAXIMUM PERMISSABLE HEAD CHANGE CHECK	81800
C		81900
	IF(KTIM.LT.2) GO TO 230	82000
	IF((DHMAX*DELT/DLTOLD).GT.DSMAX)DELT=DLTOLD*DSMAX*.98/DHMAX	82100
230	IF(ABS(TMPX-PLTIM(KPLT)).LT.DLTMIN) PLTIM(KPLT)=TMPX	82200
	T1=DMIN1(TMPX,PLTIM(KPLT))	82300
	T2=T1-STIM	82400
	IF(DELT.GT.(T2-DLTMIN)) DELT=T2	82500
	IF(DELT.LT.DLTMIN)DELT=DLTMIN	82600
	IF(DELT.GT.DLTMX)DELT=DLTMX	82700
	IF(T1.NE.PLTIM(KPLT).OR.T2-DELT.GT.0.5*DLTMIN) GO TO 240	82800
	KPLT=KPLT+1	82900
	JPLT=1	83000
240	IF(DELT.LT.DLTMIN)DELT=DLTMIN	83100
	STIM=STIM+DELT	83200
	IF (TMPX-STIM.LT.0.5*DLTMIN) JFLAG=1	83300
	IF(TMAX-STIM.LT.0.5*DLTMIN.OR.KTIM.GT.NUMT) GO TO 250	83400
	RETURN	83500
250	JSTOP=1	83600
	JPLT=1	83700
	RETURN	83800
4010	FORMAT(6X,'DATA FOR RECHARGE PERIOD ',I5//10X,	83900
	&23HLENGTH OF THIS PERIOD =,1PE12.3,1X,A4/10X,	84000
	&45HLENGTH OF INITIAL TIME STEP FOR THIS PERIOD =,1PE10.3,1X,A4/	84100
	&10X,27HMULTIPLIER FOR TIME STEP = ,1PE10.3,/10X,	84200
	&25HMAXIMUM TIME STEP SIZE = ,1PE10.3,1X,A4/10X,	84300
	&25HMINIMUM TIME STEP SIZE = ,1PE10.3,1X,A4,	84400
	&/10X,'TIME STEP REDUCTION FACTOR = ',1PE10.3)	84500
4020	FORMAT(15X,37HPRINT SOLUTION AFTER EVERY TIME STEP?,1X,L1/	84600
	&15X,'SIMULATE EVAPORATION? ',L1/	84700
	&15X,29HSIMULATE EVAPOTRANSPIRATION? ,L1/	84800
	&15X,24HSIMULATE SEEPAGE FACES? ,L1/)	84900
4030	FORMAT(	85000
	&15X,55HMAXIMUM PRESSURE HEAD CHANGE ALLOWED IN ONE TIME STEP =,	85100
	&F8.3/15X,'STEADY-STATE CLOSURE CRITERION = ',1PE10.3/	85200
	&15X,27HMAXIMUM DEPTH OF PONDING = ,F8.3)	85300
4040	FORMAT(1H ,1X,10(1H*),41HWARNING --- NODE TYPE OF 0 ASSIGNED TO BO	85400
	&12HUNDARY NODE ,2I4,43H SPECIFIED FLUX OR PRESSURE HEAD NOT ASSIGN	85500
	&2HED)	85600
4060	FORMAT(6X,41HNODE TYPE AND INITIAL BOUNDARY CONDITIONS,	85700
	&12H FOR PERIOD ,I4/6X,8HLEGEND: /15X,17H0 = INTERIOR CELL/	85800
	&15X,32H1 = SPECIFIED PRESSURE HEAD CELL/15X,	85900
	&23H2 = SPECIFIED FLUX CELL/	86000
	& 15X,31H3 = POTENTIAL SEEPAGE FACE NODE/	86100
	& 15X,43H5 = NODE FOR WHICH EVAPORATION IS PERMITTED//)	86200

4080	FORMAT(1H ,I5,5X,80I1)	86300
4090	FORMAT(6X,100(1H*)/5X,	86400
	&44HSTEADY STATE REACHED, ADVANCE TO NEXT PERIOD//)	86500
4100	FORMAT(6X,100(1H*),/,5X,17HEND OF SIMULATION/,	86600
	&5X,33HMAXIMUM SIMULATION TIME (TMAX) = ,E15.4/,	86700
	&5X,33HELAPSED SIMULATION TIME (STIM) = ,E15.4/,	86800
	&6X,100(1H*))	86900
	END	87000
	SUBROUTINE VSMGEN	87100
C*****		87200
CVSMGEN		87300
C*****		87400
C		87500
C	PURPOSE: TO SET UP COEFFICIENT MATRICES AND CALL	87600
C	SOLUTION ALGORITHM	87700
C		87800
C	-----	87900
C		88000
C	SPECIFICATIONS FOR ARRAYS AND SCALARS	88100
C		88200
	IMPLICIT DOUBLE PRECISION (A-H,P-Z)	88300
	COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2	88400
	COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES	88500
	COMMON/KCON/HX(0900),NTYP(0900)	88600
	COMMON/RPROP/HK(10,100),ANIZ(10)	88700
	COMMON/MPROP/THETA(0900),THLST(0900)	88800
	COMMON/PRESS/P(0900),PXXX(0900)	88900
	COMMON/DISCH/Q(0900),QQ(0900),ETOUT,ETOUT1,RHOZ	89000
	COMMON/HCON/HCND(0900),HKLL(0900),HKTT(0900)	89100
	COMMON/EQUAT/A(0900),B(0900),C(0900),D(0900),E(0900),RHS(0900),	89200
	&XI(0900)	89300
	COMMON/JTXX/JTEX(0900)	89400
	COMMON/PTET/DPTH(0900),RT(0900),RDC(6,25),ETCYC,	89500
	&PEVAL(25),PTVAL(25),PET,PEV,HROOT,HA,SRES,RTDPTH,	89600
	&RTBOT,RTTOP,NPV	89700
	COMMON/WGT/WUS,WDS	89800
	COMMON/SCON/DHMX(200),DELT,HMAX,TMAX,EPS,NUMT,ITMAX,MINIT,ITEST	89900
	COMMON/SCN1/TMPX,TMLT,DLTMX,DLTMIN,TRED	90000
	COMMON/TCON/STIM,DSMAX,KTIM,NIT,KP	90100
	COMMON/JCON/JSTOP,JFLAG	90200
	LOGICAL RAD,BCIT,ETSIM,SEEP,ITSTOP	90300
	COMMON/LOG1/RAD,BCIT,ETSIM,SEEP,ITSTOP	90400
	CHARACTER*80 TITL	90500
	CHARACTER*4 ZUNIT,TUNIT,CUNX	90600
	COMMON/SCHAR/TITL,ZUNIT,TUNIT,CUNX	90700
	DIMENSION PITT(0900)	90800
	SAVE PITT	90900
C		91000
C	.....	91100
C	START OF LINEARIZATION ITERATION LOOP	91200
C	.....	91300
C		91400
C	UPDATE COEFFICIENTS	91500
C		91600

I13=0	91700
C	91800
C ESTABLISH TIME-DEPENDENT PARAMETERS GOVERNING EVAPORATION AND	91900
C TRANSPIRATION. DETERMINE ROOT ACTIVITY.	92000
C	92100
10 IF (.NOT. BCIT.AND. .NOT.ETSIM)GO TO 30	92200
CALL VSPET	92300
DO 20 J=2,NLYY	92400
DO 20 I=2,NXRR	92500
N=NLY*(I-1)+J	92600
IF(HX(N).EQ.0) GO TO 20	92700
RT(N)=VSRDF(DPTH(N),DELZ(J))	92800
Q(N)=0.0	92900
20 CONTINUE	93000
30 CONTINUE	93100
40 IF (NIT.NE.0) CALL VSCOEF	93200
C	93300
C ----- UPDATE BOUNDARY AND FLUX CONDITIONS -----	93400
C	93500
IF(BCIT)CALL VSEVAP	93600
IF (ETSIM)CALL VSPLNT	93700
IF(SEEP) CALL VSSFAC	93800
C	93900
C	94000
C	94100
C LOOP TO CALCULATE COEFFICIENT MATRIX	94200
C	94300
C	94400
DO 110 J=2,NLYY	94500
DO 110 I=2,NXRR	94600
N=NLY*(I-1)+J	94700
IF(HX(N).EQ.0.) GO TO 110	94800
JM1=N-1	94900
JP1=N+1	95000
IM1=N-NLY	95100
IP1=N+NLY	95200
VOL=DELY*DXR(I)*DELZ(J)	95300
IF(RAD)VOL=PI2*RX(I)*DXR(I)*DELZ(J)	95400
JJ=JTEX(N)	95500
C	95600
C CALCULATE STORAGE TERMS	95700
C	95800
PTMP=P(N)+DZZ(J)	95900
SCAP=VSDTHU(PTMP,JJ,HK)	96000
GSF=VOL*SCAP	96100
SS=HK(JJ,2)/HK(JJ,3)	96200
GSS=VOL*THETA(N)*SS	96300
G1=0	96400
C	96500
C APPLY NEWTON-RAPHSON LINEARIZATION TO STORAGE TERM.	96600
C PITT HOLDS STORAGE TERMS FROM PREVIOUS ITERATION.	96700
C	96800
IF(NIT.GT.0.AND.XI(N).NE.0)G1=(P(N)-PXXX(N))*(GSF+GSS-PITT(N))/	96900
&XI(N)	97000

	PITT(N)=GSF+GSS	97100
	G1=-G1/DELT	97200
	GSF=-GSF/DELT	97300
	GSS=-GSS/DELT	97400
	IF(WUS.NE.0.) GO TO 50	97500
C		97600
C	USE GEOMETRIC MEAN OR WEIGHTS FOR INTERCELL K	97700
C		97800
	A(N)=HKLL(N)*DSQRT(HCND(IM1)*HCND(N))	97900
	B(N)=HKTT(N)*DSQRT(HCND(JM1)*HCND(N))	98000
	C(N)=HKLL(IP1)*DSQRT(HCND(IP1)*HCND(N))	98100
	D(N)=HKTT(JP1)*DSQRT(HCND(JP1)*HCND(N))	98200
	GO TO 100	98300
C		98400
C	CHOOSE UPSTREAM WEIGHTING COEFFICIENTS	98500
C		98600
	50 ALA=WDS	98700
	BTA=WUS	98800
	IF(P(IM1).LE.P(N).OR.HX(IM1).EQ.0.) GO TO 60	98900
	ALA=WUS	99000
	BTA=WDS	99100
	60 ALB=WDS	99200
	BTB=WUS	99300
	IF(P(JM1).LE.P(N).OR.HX(JM1).EQ.0.) GO TO 70	99400
	ALB=WUS	99500
	BTB=WDS	99600
	70 ALC=WDS	99700
	BTC=WUS	99800
	IF(P(IP1).LE.P(N).OR.HX(IP1).EQ.0.) GO TO 80	99900
	ALC=WUS	100000
	BTC=WDS	100100
	80 ALD=WDS	100200
	BTD=WUS	100300
	IF(P(JP1).LE.P(N).OR.HX(JP1).EQ.0.) GO TO 90	100400
	ALD=WUS	100500
	BTD=WDS	100600
	90 CONTINUE	100700
C		100800
C	SET THE PENTA-DIAGNOL COEFFICIENT MATRIX (E IS MAIN DIAGNOL)	100900
C	AND RIGHT HAND SIDE	101000
C		101100
	A(N)=(ALA*HCND(IM1)+BTA*HCND(N))*HKLL(N)	101200
	B(N)=(ALB*HCND(JM1)+BTB*HCND(N))*HKTT(N)	101300
	C(N)=(ALC*HCND(IP1)+BTC*HCND(N))*HKLL(IP1)	101400
	D(N)=(ALD*HCND(JP1)+BTD*HCND(N))*HKTT(JP1)	101500
	100 E(N)=-A(N)-B(N)-C(N)-D(N)	101600
	RHS(N)=VOL*(THETA(N)-THLST(N))/DELT-(Q(N)+QQ(N))-(A(N)*P(IM1)+B(N)	101700
	&*P(JM1)+C(N)*P(IP1)+D(N)*P(JP1)+(E(N)+GSS)*P(N))+GSS*PXXX(N)	101800
	E(N)=E(N)+GSF+GSS+G1	101900
	110 CONTINUE	102000
C		102100
C	CALL SOLUTION ALGORITHM	102200
C		102300
	NIT=NIT+1	102400

	CALL SLVSIP	102500
	IF(NIT.LT.MINIT) GO TO 40	102600
C		102700
C	IF SOLUTION HAS BEEN FOUND THEN RETURN	102800
C		102900
	IF(ITEST.NE.0) GO TO 120	103000
	RETURN	103100
	120 IF(NIT.LE.ITMAX) GO TO 40	103200
C		103300
C	MAXIMUM NUMBER OF ITERATIONS EXCEEDED	103400
C		103500
	WRITE (6,4000) NIT,KTIM,STIM,TUNIT	103600
C		103700
C	AUTOMATICALLY REDUCE TIME STEP SIZE, BUT NOT MORE	103800
C	THAN TWICE.	103900
C		104000
	IF(DELT.LE.DLTMIN.OR.I13.GT.2.OR.TRED.LE.0) GO TO 140	104100
	I13=I13+1	104200
	DELTT=DELT*TRED	104300
	IF(DELTT.LT.DLTMIN) DELTT=DLTMIN	104400
	WRITE(6,4010) DELTT	104500
	STIM=STIM-DELT+DELTT	104600
	DELT=DELTT	104700
C		104800
C	RESET HEADS TO VALUES AT END OF PREVIOUS TIME STEP.	104900
C		105000
	DO 130 II=1,NNODES	105100
	IF(NTYP(II).EQ.1.OR.HX(II).EQ.0) GO TO 130	105200
	?(II)=PXXX(II)	105300
	130 CONTINUE	105400
	NIT=1	105500
	GO TO 10	105600
	140 IF(.NOT.ITSTOP)RETURN	105700
C		105800
C	TERMINATE SIMULATION.	105900
C		106000
	JSTOP=1	106100
	JFLAG=1	106200
	RETURN	106300
	4000 FORMAT(5X,100(1H*)/5X,'EXCEEDED PERMITTED NUMBER OF ITERATIONS',	106400
	&' (=',I4,')'	106500
	& /5X,'TIME STEP NUMBER',I4/5X,'ELAPSED TIME = ',	106600
	& 1PE12.3,1X,A4 /5X,100(1H*))	106700
	4010 FORMAT(5X,'TIME STEP SIZE REDUCED TO ',E12.4)	106800
	END	106900
	SUBROUTINE VSSIP	107000
C		107100
C	*****	107200
C	CVSSIP	107300
C	*****	107400
C		107500
C	PURPOSE: TO SOLVE THE MATRIX EQUATIONS USING THE	107600
C	STRONGLY IMPLICIT METHOD	107700
C		107800

C	-----	107900
C		108000
C	SPECIFICATIONS FOR ARRAYS AND SCALARS	108100
C		108200
	IMPLICIT DOUBLE PRECISION (A-H,P-Z)	108300
	COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2	108400
	COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES	108500
	COMMON/KCON/HX(0900),NTYP(0900)	108600
	COMMON/RPROP/HK(10,100),ANIZ(10)	108700
	COMMON/PRESS/P(0900),PXXX(0900)	108800
	COMMON/EQUAT/A(0900),B(0900),C(0900),D(0900),E(0900),RHS(0900),	108900
	&XI(0900)	109000
	COMMON/JTXX/JTEX(0900)	109100
	COMMON/SCON/DHMX(200),DELT,HMAX,TMAX,EPS,NUMT,ITMAX,MINIT,ITEST	109200
	COMMON/SCN1/TMPX,TMLT,DLTMX,DLTMIN,TRED	109300
	COMMON/TCON/STIM,DSMAX,KTIM,NIT,KP	109400
	DIMENSION IORDER(21)	109500
	DIMENSION DEL(0900),ETA(0900),V(0900),TEMP(100),HM(30)	109600
	SAVE HM,W1,W9,L2	109700
C		109800
C	-----	109900
C		110000
	DATA IORDER/1,2,3,4,5,1,2,3,4,5,11*1/	110100
C		110200
C	COMPUTE ITERATION PARAMETERS	110300
C		110400
	J2=NXR-2	110500
	I2=NLY-2	110600
	L2=5	110700
	PL2=L2-1	110800
	W=0.	110900
	PIE=0.	111000
	W9=100.	111100
C		111200
C	COMPUTE MAXIMUM PARAMETER	111300
C		111400
	DO 10 I=2,NLYY	111500
	DO 10 J=2,NXRR	111600
	N=NLY*(J-1)+I	111700
	IF(HX(N).EQ.0.) GO TO 10	111800
	IM1=JTEX(N)	111900
	PIE=PIE+1.	112000
	DX=DXR(J)/RX(NXR)	112100
	DY=DELZ(I)/DZZ(NLY)	112200
	DX2=DX*DX	112300
	DY2=DY*DY	112400
	W=W+1-DMIN1((DX2+DX2)/(1.+ANIZ(IM1)*DX2/DY2),(DY2+DY2)/(1+DY2/	112500
	1(ANIZ(IM1)*DX2)))	112600
	10 CONTINUE	112700
	W=W/PIE	112800
C		112900
C	COMPUTE PARAMETERS IN GEOMETRIC SEQUENCE	113000
C		113100
	PJ=-1.	113200

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DO 20 I=1,L2                                113300
  PJ=PJ+1.                                    113400
20 TEMP(I)=1. -(1. -W)**(PJ/PL2)            113500
C                                              113600
C ORDER SEQUENCE OF PARAMETERS                113700
C                                              113800
  DO 30 J=1,L2                                113900
  30 HM(J)=TEMP(IORDER(J))                    114000
  WRITE (06,4000) L2,(HM(J),J=1,L2)          114100
4000 FORMAT(1X,I5,25HSIP ITERATION PARAMETERS: ,6D15.7/(28X,6D15.7/)) 114200
  RETURN                                       114300
C                                              114400
C STRONGLY IMPLICIT ALGORITHM                 114500
C                                              114600
  ENTRY SLVSIP                                114700
  I2=NLY-2                                    114800
  J2=NXR-2                                    114900
C                                              115000
C SELECT ITERATION PARAMETER. INITIALIZE ARRAYS 115100
C                                              115200
  IF(MOD(NIT,L2).EQ.0.OR.NIT.EQ.1)NTH=0      115300
  NTH=NTH+1                                   115400
  W=HM(NTH)                                   115500
  ITEST=0                                     115600
  DO 40 I=1,NNODES                            115700
  DEL(I)=0.                                   115800
  ETA(I)=0.                                   115900
  V(I)=0.                                     116000
40 XI(I)=0.                                   116100
  BIGI=0.                                     116200
C                                              116300
C CHOOSE SIP NORMAL OR REVERSE ALGORITHM      116400
C                                              116500
  IF(MOD(NIT,2)) 50,80,50                    116600
C ..... 116700
C ORDER EQUATIONS WITH ROW 1 FIRST - 3X3 EXAMPLE: 116800
C 1 2 3                                       116900
C 4 5 6                                       117000
C 7 8 9                                       117100
C ..... 117200
  50 DO 60 I=2,NLYY                            117300
  DO 60 J=2,NXRR                                117400
  N=I+NLY*(J-1)                                117500
C                                              117600
C ---- SKIP COMPUTATIONS OF NODE IS OUTSIDE OF SOLUTION DOMAIN 117700
C                                              117800
  IF(HX(N).EQ.0..OR.NTYP(N).EQ.1) GO TO 60    117900
  NL=N-NLY                                     118000
  NR=N+NLY                                     118100
  NA=N-1                                       118200
  NB=N+1                                       118300
C                                              118400
C --- SIP "NORMAL" ALGORITHM----- 118500
C --- FORWARD SUBSTITUTE, COMPUTING INTERMEDIATE VECTOR V -- 118600

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C		118700
	CH=DEL(NA)*B(N)/(1.+W*DEL(NA))	118800
	GH=ETA(NL)*A(N)/(1.+W*ETA(NL))	118900
	BH=B(N)-W*CH	119000
	DH=A(N)-W*GH	119100
	EH=E(N)+W*CH+W*GH	119200
	FH=C(N)-W*CH	119300
	HH=D(N)-W*GH	119400
	ALFA=BH	119500
	BETA=DH	119600
	GAMA=EH-ALFA*ETA(NA)-BETA*DEL(NL)	119700
	DEL(N)=FH/GAMA	119800
	ETA(N)=HH/GAMA	119900
	RES=RHS(N)	120000
	V(N)=(HMAX*RES-ALFA*V(NA)-BETA*V(NL))/GAMA	120100
	60 CONTINUE	120200
C		120300
C	---BACK SUBSTITUTE FOR VECTOR XI	120400
C		120500
	DO 70 I=1,I2	120600
	I3=NLY-I	120700
	DO 70 J=1,J2	120800
	J3=NXR-J	120900
	N=I3+NLY*(J3-1)	121000
	IF(HX(N).EQ.0..OR.NTYP(N).EQ.1) GO TO 70	121100
	XI(N)=V(N)-DEL(N)*XI(N+NLY)-ETA(N)*XI(N+1)	121200
C		121300
C	FIND MAXIMUM HEAD CHANGE	121400
C		121500
	TCHK=ABS(XI(N))	121600
	IF(TCHK.LT.BIGI) GO TO 70	121700
	BIGI=TCHK	121800
	BIGI1=XI(N)	121900
	70 CONTINUE	122000
	GO TO 110	122100
C		122200
C	.....	122300
C	---ORDER EQUATIONS WITH THE LAST ROW FIRST - 3X3 EXAMPLE	122400
C	7 8 9	122500
C	4 5 6	122600
C	1 2 3	122700
C	.....	122800
C		122900
	80 DO 90 II=1,I2	123000
	I=NLY-II	123100
	DO 90 J=2,NXRR	123200
	N=I+NLY*(J-1)	123300
	NL=N-NLY	123400
	NR=N+NLY	123500
	NA=N-1	123600
	NB=N+1	123700
C		123800
C	-- SKIP COMPUTATIONS IF NODE IS OUTSIDE OF SOLUTION DOMAIN	123900
C		124000

IF(HX(N).EQ.0..OR.NTYP(N).EQ.1) GO TO 90	124100
C	124200
C ----- SIP "REVERSE" ALGORITHM	124300
C --- FORWARD SUBSTITUTE, COMPUTING INTERMEDIATE VECTOR V	124400
C	124500
CH=DEL(NB)*D(N)/(1. +W*DEL(NB))	124600
GH=ETA(NL)*A(N)/(1. +W*ETA(NL))	124700
BH=D(N)-W*CH	124800
DH=A(N)-W*GH	124900
EH=E(N)+W*CH+W*GH	125000
FH=C(N)-W*CH	125100
HH=B(N)-W*GH	125200
ALFA=BH	125300
BETA=DH	125400
GAMA=EH-ALFA*ETA(NB)-BETA*DEL(NL)	125500
DEL(N)=FH/GAMA	125600
ETA(N)=HH/GAMA	125700
RES=RHS(N)	125800
V(N)=(HMAX*RES-ALFA*V(NB)-BETA*V(NL))/GAMA	125900
90 CONTINUE	126000
C	126100
C --- BACK SUBSTITUTE FOR VECTOR XI	126200
C	126300
DO 100 I3=2,NLYY	126400
DO 100 J=1,J2	126500
J3=NXR-J	126600
N=I3+NLY*(J3-1)	126700
IF(HX(N).EQ.0..OR.NTYP(N).EQ.1) GO TO 100	126800
XI(N)=V(N)-DEL(N)*XI(N+NLY)-ETA(N)*XI(N-1)	126900
C	127000
C FIND MAXIMUM HEAD CHANGE	127100
C	127200
TCHK=ABS(XI(N))	127300
IF(TCHK.LT.BIGI) GO TO 100	127400
BIGI=TCHK	127500
BIGI1=XI(N)	127600
100 CONTINUE	127700
C	127800
C COMPUTE RELAXATION PARAMETER W FOR HEAD CHANGES. ALGORITHM	127900
C IS FROM COOLEY (1983)	128000
C	128100
110 S=1.	128200
IF(NIT.GT.1) S=BIGI1/W1	128300
S1=ABS(S)	128400
IF(S.LT.-1.) GO TO 120	128500
W=(3+S)/(3+S1)	128600
GO TO 130	128700
120 W=1/(S1+S1)	128800
130 IF(W.EQ.W9) W=.9*W	128900
W1=W*BIGI	129000
IF(W1.GT.DSMAX) W=DSMAX/BIGI	129100
IF(BIGI1.LT.0.) W1=-W1	129200
C	129300
C ADD CHANGES TO HEAD MATRIX.	129400

C		129500
	W9=W	129600
	DO 140 N=NLY+1,NNODES	129700
	IF(HX(N).EQ.0.OR.NTYP(N).EQ.1) GO TO 140	129800
	P(N)=P(N)+W*XI(N)	129900
	140 CONTINUE	130000
C		130100
C	COMPARE MAXIMUM HEAD CHANGE TO CLOSURE CRITERION.	130200
C		130300
	IF(BIGI.GT.EPS) ITEST=1	130400
	DHMX(NIT)=BIGI	130500
	RETURN	130600
	END	130700
	SUBROUTINE VSCOEF	130800
C*****		130900
CVSCOEF		131000
C*****		131100
C	PURPOSE: TO COMPUTE ALL VALUES OF NONLINEAR COEFFICIENTS	131200
C	USING THE MOST RECENT VALUES OF PRESSURE HEAD	131300
C	-----	131400
C		131500
C	SPECIFICATIONS FOR ARRAYS AND SCALARS	131600
C		131700
	IMPLICIT DOUBLE PRECISION (A-H,P-Z)	131800
	COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2	131900
	COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES	132000
	COMMON/KCON/HX(0900),NTYP(0900)	132100
	COMMON/RPROP/HK(10,100),ANIZ(10)	132200
	COMMON/MPROP/THETA(0900),THLST(0900)	132300
	COMMON/PRESS/P(0900),PXXX(0900)	132400
	COMMON/HCON/HCND(0900),HKLL(0900),HKTT(0900)	132500
	COMMON/JTXX/JTEX(0900)	132600
C		132700
C	-----	132800
	DO 10 J=2,NLYY	132900
	DO 10 N=2,NXRR	133000
	IN=NLY*(N-1)+J	133100
	IF(HX(IN).EQ.0.) GO TO 10	133200
	J1=JTEX(IN)	133300
	HCND(IN)=0.D0	133400
C		133500
C	COMPUTE PRESSURE HEADS TO USE IN FUNCTIONS	133600
C		133700
	PTMP=P(IN)+DZZ(J)	133800
	HCND(IN)=VSHKU(PTMP,J1,HK)	133900
	THETA(IN)=VSTHU(PTMP,J1,HK)	134000
	10 CONTINUE	134100
	RETURN	134200
	END	134300
	SUBROUTINE VSHCMP	134400
C*****		134500
CVSHCMP		134600
C*****		134700
C		134800

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C   PURPOSE: TO COMPUTE INTERCELL CONDUCTANCES                                134900
C                                                                                   135000
C -----                                                                    135100
C                                                                                   135200
C   SPECIFICATIONS FOR ARRAYS AND SCALARS                                       135300
C                                                                                   135400
C     IMPLICIT DOUBLE PRECISION (A-H,P-Z)                                       135500
C     COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2                 135600
C     COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES                                     135700
C     COMMON/KCON/HX(0900),NTYP(0900)                                           135800
C     COMMON/RPROP/HK(10,100),ANIZ(10)                                          135900
C     COMMON/HCON/HCND(0900),HKLL(0900),HKTT(0900)                             136000
C     COMMON/JTXX/JTEX(0900)                                                    136100
C     LOGICAL RAD,BCIT,ETSIM,SEEP,ITSTOP                                         136200
C     COMMON/LOG1/RAD,BCIT,ETSIM,SEEP,ITSTOP                                     136300
C                                                                                   136400
C -----                                                                    136500
C                                                                                   136600
C   COMPUTE HARMONIC MEANS OF KSAT AND GRID SPACING                             136700
C                                                                                   136800
C     DO 10 J=2,NLY                                                             136900
C     DO 10 N=2,NXR                                                             137000
C     IN=NLY*(N-1)+J                                                            137100
C     JM1=IN-1                                                                    137200
C     NM1=IN-NLY                                                                  137300
C     A1=ANIZ(JTEX(IN))                                                           137400
C     A2=ANIZ(JTEX(JM1))                                                           137500
C     IF(HX(IN).EQ.0.) GO TO 10                                                  137600
C     AREA=DELY*DXR(N)                                                            137700
C     IF(RAD)AREA=PI2*RX(N)*DXR(N)                                               137800
C                                                                                   137900
C   VERTICAL CONDUCTANCE                                                         138000
C   THROUGH TOP                                                                  138100
C                                                                                   138200
C     HKTT(IN)=2.0*A1*A2*AREA*HX(IN)*HX(JM1)/(A2*HX(JM1)*DELZ(J)+            138300
C     &A1*HX(IN)*DELZ(J-1))                                                       138400
C     AREA=DELY*DELZ(J)                                                           138500
C     IF(RAD)AREA=PI2*DELZ(J)*(RX(N)-.5 *DXR(N))                               138600
C                                                                                   138700
C   HORIZONTAL OR RADIAL CONDUCTANCE                                             138800
C   THROUGH LEFT-HAND SIDE                                                       138900
C                                                                                   139000
C     HKLL(IN)=2.0*AREA*HX(IN)*HX(NM1)/(HX(NM1)*DXR(N)+HX(IN)*DXR(N-1))      139100
C   10 CONTINUE                                                                    139200
C     RETURN                                                                        139300
C     END                                                                            139400
C     SUBROUTINE VSFLUX                                                            139500
C *****                                                                        139600
C   CVSFLUX                                                                        139700
C *****                                                                        139800
C                                                                                   139900
C   PURPOSE: TO COMPUTE FLUXES AND MASS BALANCE                                140000
C                                                                                   140100
C -----                                                                    140200

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C		140300
C	SPECIFICATIONS FOR ARRAYS AND SCALARS	140400
C		140500
	IMPLICIT DOUBLE PRECISION (A-H,P-Z)	140600
	COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2	140700
	COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES	140800
	COMMON/KCON/HX(0900),NTYP(0900)	140900
	COMMON/RPROP/HK(10,100),ANIZ(10)	141000
	COMMON/MPROP/THETA(0900),THLST(0900)	141100
	COMMON/PLOTT/PLTIM(50),IJOBS(50),JPLT,NPLT,NOBS	141200
	COMMON/PRESS/P(0900),PXXX(0900)	141300
	COMMON/DISCH/Q(0900),QQ(0900),ETOUT,ETOUT1,RHOZ	141400
	COMMON/JTXX/JTEX(0900)	141500
	COMMON/SCON/DHMX(200),DELT,HMAX,TMAX,EPS,NUMT,ITMAX,MINIT,ITEST	141600
	COMMON/SCN1/TMPX,TMLT,DLTMX,DLTMIN,TRED	141700
	COMMON/TCON/STIM,DSMAX,KTIM,NIT,KP	141800
	COMMON/JCON/JSTOP,JFLAG	141900
	LOGICAL RAD,BCIT,ETSIM,SEEP,ITSTOP	142000
	LOGICAL F7P,F11P,F8P,F9P,F6P,PRNT	142100
	COMMON/LOG1/RAD,BCIT,ETSIM,SEEP,ITSTOP	142200
	COMMON/LOG2/F7P,F11P,F8P,F9P,F6P,PRNT	142300
	CHARACTER*80 TITL	142400
	CHARACTER*4 ZUNIT,TUNIT,CUNX	142500
	COMMON/SCHAR/TITL,ZUNIT,TUNIT,CUNX	142600
	SAVE FINT,FIN1T,FIN2T,FOTT,FOT1T,FOT2T,QTOT,DELST,REST,QTOTE,QTOTT	142700
C-----		142800
C		142900
C	INITIALIZE MASS BALANCE VARIABLES USED FOR	143000
C	ENTIRE SIMULATION.	143100
C		143200
	IF(KTIM.GT.1) GO TO 10	143300
	FIN1T=0.	143400
	FOT1T=0.	143500
	FIN2T=0.	143600
	FOT2T=0.	143700
	QTOT=0.	143800
	QTOTE=0	143900
	QTOTT=0	144000
	DELST=0.	144100
	REST=0.	144200
	FINT=0.	144300
	FOTT=0.	144400
	IF(.NOT.F9P) GO TO 10	144500
	WRITE (09,4000) TITL,TUNIT	144600
C		144700
C	INITIALIZE MASS BALANCE VARIABLES USED FOR CURRENT	144800
C	TIME STEP	144900
C		145000
10	FIN1R=0.	145100
	FOT1R=0.	145200
	FIN2R=0.	145300
	FOT2R=0.	145400
	QTR=0.	145500
	DELSX=0.D0	145600

	DO 100 J=2,NLYY	145700
	DO 100 N=2,NXRR	145800
	IN=NLY*(N-1)+J	145900
	IF(HX(IN).EQ.0.) GO TO 100	146000
	JM1=IN-1	146100
	JP1=IN+1	146200
	NM1=IN-NLY	146300
	NP1=IN+NLY	146400
	VOL=DXR(N)*DELZ(J)*DELY	146500
	IF(RAD)VOL=PI2*RX(N)*DXR(N)*DELZ(J)	146600
C		146700
C	SUM CHANGE IN STORAGE	146800
C		146900
	GSF=VOL*(THETA(IN)-THLST(IN))	147000
	JJ=JTEX(IN)	147100
	SS=HK(JJ,2)/HK(JJ,3)	147200
	GSS=VOL*THETA(IN)*SS	147300
	DELSI=(GSF+GSS*(P(IN)-PXXX(IN)))*RHOZ	147400
	DELSX=DELSI+DELSI	147500
20	CONTINUE	147600
	IF(NTYP(IN).EQ.1) GO TO 60	147700
	IF(NTYP(IN).EQ.2) GO TO 30	147800
	GO TO 90	147900
C		148000
C	CALCULATE FLUX RATES ACROSS DOMAIN BOUNDARIES	148100
C		148200
C	FLUX FOR NEUMAN CELLS	148300
C		148400
30	IF(QQ(IN)) 40,40,50	148500
40	FOT2R=FOT2R+QQ(IN)*RHOZ	148600
	GO TO 100	148700
50	FIN2R=FIN2R+QQ(IN)*RHOZ	148800
	GO TO 100	148900
C		149000
C	FLUX FOR DIRICHLET CELLS	149100
C		149200
60	CONTINUE	149300
	QX=RHOZ*VSFLX1(IN)	149400
	IF(QX) 80,80,70	149500
70	FOT1R=FOT1R-QX	149600
	GO TO 100	149700
80	FIN1R=FIN1R-QX	149800
	GO TO 100	149900
C		150000
C	SUM SOURCES AND SINKS	150100
C		150200
90	QTR=QTR+Q(IN)*RHOZ	150300
100	CONTINUE	150400
C		150500
C	ACCUMULATE VALUES FOR TOTAL ELAPSED SIMULATION TIME	150600
C		150700
	DELS=DELSX	150800
	ETOUT=ETOUT*RHOZ	150900
	ETOUT1=ETOUT1*RHOZ	151000

DELSR=DELSX/DELT	151100
QQQ=QTR*DELT	151200
QQQE=DELT*ETOUT1	151300
QQQT=DELT*ETOUT	151400
QTOTE=QTOTE+QQQE	151500
QTOTT=QTOTT+QQQT	151600
FINR=FIN1R+FIN2R	151700
FOTR=FOT1R+FOT2R	151800
FOT1=FOT1R*DELT	151900
FIN1=FIN1R*DELT	152000
FOT2=FOT2R*DELT	152100
FIN2=FIN2R*DELT	152200
FIN=FINR*DELT	152300
FOT=FOTR*DELT	152400
FIN1T=FIN1T+FIN1	152500
FOT1T=FOT1T+FOT1	152600
FOT2T=FOT2T+FOT2	152700
FINT=FINT+FIN	152800
FIN2T=FIN2T+FIN2	152900
FOTT=FOTT+FOT	153000
QTOT=QTOT+QQQ	153100
DELST=DELST+DELS	153200
RES=FIN+FOT+QQQ-DELS	153300
RESR=RES/DELT	153400
IF(DELS.NE.0.) PERCER=(RES/DELS)*100	153500
REST=REST+RES	153600
IF(.NOT.F9P) GO TO 110	153700
C	153800
C WRITE RESULTS TO FILE 9	153900
C	154000
FINXX=-FIN1R	154100
WRITE (09,4010) STIM,FIN1R,FOT1R,FIN2R,FOT2R,QTR,ETOUT,ETOUT1,	154200
*DELSR,RESR,PERCER	154300
110 CONTINUE	154400
IF(.NOT.F6P.AND.JPLT.NE.1.AND.JSTOP.NE.1.AND.JFLAG.NE.1) GO TO 120	154500
C	154600
C WRITE RESULTS OF MASS BALANCE TO FILE 6	154700
C	154800
WRITE (06,4020) KTIM,KP,STIM,TUNIT,CUNX,CUNX,CUNX,TUNIT,FIN1T,	154900
*FIN1,FIN1R,FOT1T,FOT1,FOT1R,FIN2T,FIN2,FIN2R,FOT2T,FOT2,FOT2R	155000
WRITE (06,4030) FINT,FIN,FINR,FOTT,FOT,FOTR,QTOTE,QQQE,ETOUT1,	155100
*QTOTT,QQQT,ETOUT,QTOT,QQQ,QTR,DELST,DELS,DELSR,REST,RES,RESR	155200
120 CONTINUE	155300
RETURN	155400
4000 FORMAT(A80/28HMASS BALANCE RATE COMPONENTS/6HTIME, ,A4,	155500
&11H FLXIN1 ,11H FLXOUT1 ,11H FLXIN2 ,	155600
&11H FLXOUT2 ,11H TOTAL ET ,	155700
&11H TRANSP ,11H EVAP ,	155800
&11H DELS ,11H ERROR ,11H %ERROR)	155900
4010 FORMAT(11(1PE11.4))	156000
4020 FORMAT(21X,10(1H-),1X,'MASS BALANCE SUMMARY FOR TIME STEP',	156100
& I4,1X,10(1H-)/25X,'PUMPING PERIOD NUMBER ',I4/25X,	156200
&'TOTAL ELAPSED SIMULATION TIME = ',1PE10.3,1X,A4//2X,128(1H+)/	156300
& 2X,'+',126X,'+'//	156400

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&2X,'+',89X,' MASS THIS',8X,'RATE FOR THIS',5X,'+' /2X,'+',      156500
&68X,'TOTAL MASS ',9X,'TIME STEP',11X,'TIME STEP',8X,'+' /      156600
&2X,'+',71X,A4,15X,A4,15X,A4,'/' ,A4,8X,'+' /                    156700
&2X,'+',4X,'FLUX INTO DOMAIN ACROSS SPECIFIED PRESSURE HEAD',    156800
&1X,'BOUNDARIES -- ',2(1PE15.5,5X),1PE15.5,4X,'+' /            156900
&2X,'+',2X,'FLUX OUT OF DOMAIN ACROSS SPECIFIED PRESSURE HEAD',  157000
&1X,'BOUNDARIES -- ',2(1PE15.5,5X),1PE15.5,4X,'+' /            157100
&2X,'+',13X,'FLUX INTO DOMAIN ACROSS SPECIFIED FLUX BOUNDARIES', 157200
&1X,'-- ',2(1PE15.5,5X),1PE15.5,4X,'+' /                        157300
&2X,'+',11X,'FLUX OUT OF DOMAIN ACROSS SPECIFIED FLUX',          157400
&1X,'BOUNDARIES -- ',2(1PE15.5,5X),1PE15.5,4X,'+' )            157500
4030 FORMAT(1H ,1X,'+',40X,'TOTAL FLUX INTO DOMAIN -- ',2(1PE15.5,5X), 157600
& 1PE15.5,4X,'+' /2X,'+',38X,'TOTAL FLUX OUT OF DOMAIN -- ',    157700
&2(1PE15.5,5X),1PE15.5,4X,'+' /                                  157800
&2X,'+',51X,'EVAPORATION -- ',2(1PE15.5,5X),1PE15.5,4X,'+' /   157900
&2X,'+',49X,'TRANSPIRATION -- ',2(1PE15.5,5X),1PE15.5,4X,'+' /  158000
&2X,'+',38X,'TOTAL EVAPOTRANSPIRATION',                          158100
&1X,'-- ',2(1PE15.5,5X),1PE15.5,4X,'+' /                        158200
&2X,'+',30X,'CHANGE IN FLUID STORED IN DOMAIN -- ',              158300
&2(1PE15.5,5X),1PE15.5,4X,'+' /2X,'+',44X,'FLUID MASS BALANCE' 158400
& ,1X,'-- ',2(1PE15.5,5X),1PE15.5,4X,'+' /2X,'+',126X,'+' /    158500
& 2X,128(1H+))                                                    158600
END                                                                    158700
DOUBLE PRECISION FUNCTION VSFLX1(IN)                                158800
C*****                                                                158900
CVSFLX1                                                                159000
C*****                                                                159100
C  PURPOSE: TO COMPUTE INTERCELL MASS FLUX RATES FOR DIRICHLET    159200
C  BOUNDARY NODES                                                  159300
C -----                                                            159400
C                                                                    159500
C  SPECIFICATIONS FOR ARRAYS AND SCALARS                            159600
C                                                                    159700
  IMPLICIT DOUBLE PRECISION (A-H,P-Z)                               159800
  COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2      159900
  COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES                            160000
  COMMON/KCON/HX(0900),NTYP(0900)                                  160100
  COMMON/PRESS/P(0900),PXXX(0900)                                  160200
  COMMON/DISCH/Q(0900),QQ(0900),ETOUT,ETOUT1,RHOZ                 160300
  COMMON/HCON/HCND(0900),HKLL(0900),HKTT(0900)                   160400
  COMMON/EQUAT/A(0900),B(0900),C(0900),D(0900),E(0900),RHS(0900), 160500
  &XI(0900)                                                         160600
  COMMON/WGT/WUS,WDS                                               160700
  LOGICAL RAD,BCIT,ETSIM,SEEP,ITSTOP                               160800
  COMMON/LOG1/RAD,BCIT,ETSIM,SEEP,ITSTOP                           160900
C -----                                                            161000
C                                                                    161100
C                                                                    161200
C  COMPUTE FLUXES ON ALL FOUR SIDES OF EACH CONSTANT HEAD NODE    161300
C                                                                    161400
  JM1=IN-1                                                         161500
  JP1=IN+1                                                         161600
  NP1=IN+NLY                                                       161700
  NM1=IN-NLY                                                       161800

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C		161900
C	COMPUTE A,B,C,D	162000
C		162100
	IF(WUS.NE.0.) GO TO 10	162200
	A(IN)=HKLL(IN)*DSQRT(HCND(NM1)*HCND(IN))	162300
	B(IN)=HKTT(IN)*DSQRT(HCND(JM1)*HCND(IN))	162400
	C(IN)=HKLL(NP1)*DSQRT(HCND(NP1)*HCND(IN))	162500
	D(IN)=HKTT(JP1)*DSQRT(HCND(JP1)*HCND(IN))	162600
	GO TO 100	162700
10	ALA=WDS	162800
	BTA=WUS	162900
	IF(P(NM1).GT.P(IN).AND.HX(NM1).NE.0.) GO TO 20	163000
	GO TO 30	163100
20	ALA=WUS	163200
	BTA=WDS	163300
30	ALB=WDS	163400
	BTB=WUS	163500
	IF(P(JM1).GT.P(IN).AND.HX(JM1).NE.0.) GO TO 40	163600
	GO TO 50	163700
40	ALB=WUS	163800
	BTB=WDS	163900
50	ALC=WDS	164000
	BTC=WUS	164100
	IF(P(NP1).GT.P(IN).AND.HX(NP1).NE.0.) GO TO 60	164200
	GO TO 70	164300
60	ALC=WUS	164400
	BTC=WDS	164500
70	ALD=WDS	164600
	BTD=WUS	164700
	IF(P(JP1).GT.P(IN).AND.HX(JP1).NE.0.) GO TO 80	164800
	GO TO 90	164900
80	ALD=WUS	165000
	BTD=WDS	165100
90	CONTINUE	165200
C		165300
C	DETERMINE FLUXES	165400
C		165500
	A(IN)=(ALA*HCND(NM1)+BTA*HCND(IN))*HKLL(IN)	165600
	B(IN)=(ALB*HCND(JM1)+BTB*HCND(IN))*HKTT(IN)	165700
	C(IN)=(ALC*HCND(NP1)+BTC*HCND(IN))*HKLL(NP1)	165800
	D(IN)=(ALD*HCND(JP1)+BTD*HCND(IN))*HKTT(JP1)	165900
100	QL=-A(IN)*(P(IN)-P(NM1))	166000
	QT=-B(IN)*(P(IN)-P(JM1))	166100
	QR=-C(IN)*(P(IN)-P(NP1))	166200
	QB=-D(IN)*(P(IN)-P(JP1))	166300
C		166400
C	COMPUTE NET FLUX IN (+) OR OUT (-)	166500
C		166600
	VSFLX1=QL+QR+QT+QB	166700
	RETURN	166800
	END	166900
	SUBROUTINE VSOUTP	167000
C*****		167100
CVSOUTP		167200

C*****	167300
C	167400
C PURPOSE: TO OUTPUT RESULTS AFTER EACH TIME STEP.	167500
C	167600
C-----	167700
C	167800
C SPECIFICATIONS FOR ARRAYS AND SCALARS	167900
C	168000
IMPLICIT DOUBLE PRECISION(A-H,P-Z)	168100
COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2	168200
COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES	168300
COMMON/KCON/HX(0900),NTYP(0900)	168400
COMMON/RPROP/HK(10,100),ANIZ(10)	168500
COMMON/MPROP/THETA(0900),THLST(0900)	168600
COMMON/PRESS/P(0900),PXXX(0900)	168700
COMMON/DISCH/Q(0900),QQ(0900),ETOUT,ETOUT1,RHOZ	168800
COMMON/JTXX/JTEX(0900)	168900
COMMON/DUMM/DUM(0900)	169000
COMMON/PLOTT/PLTIM(50),IJOBS(50),JPLT,NPLT,NOBS	169100
COMMON/SCON/DHMX(200),DELT,HMAX,TMAX,EPS,NUMT,ITMAX,MINIT,ITEST	169200
COMMON/SCN1/TMPX,TMLT,DLTMX,DLTMIN,TRED	169300
COMMON/TCON/STIM,DSMAX,KTIM,NIT,KP	169400
COMMON/JCON/JSTOP,JFLAG	169500
LOGICAL F7P,F11P,F8P,F9P,F6P,PRNT	169600
LOGICAL THPT,SPNT,PPNT,HPNT	169700
COMMON/LOG2/F7P,F11P,F8P,F9P,F6P,PRNT	169800
COMMON/LOG4/THPT,SPNT,PPNT,HPNT	169900
CHARACTER*80 TITL	170000
CHARACTER*4 ZUNIT,TUNIT,CUNX	170100
COMMON/SCHAR/TITL,ZUNIT,TUNIT,CUNX	170200
C	170300
C-----	170400
C	170500
C OUTPUT RESULTS TO FILE 11 AT EACH TIME STEP	170600
C	170700
IF(.NOT.F11P) GO TO 20	170800
DO 10 J=1,NOBS	170900
N=IJOBS(J)	171000
I=N/NLY+1	171100
J1=MOD(N,NLY)	171200
IF(HX(N).EQ.0.) GO TO 10	171300
PPR=HK(JTEX(N),3)	171400
IF(PPR.EQ.0.)PPR=1.	171500
SAT=THETA(N)/PPR	171600
PHD=P(N)+DZZ(J1)	171700
WRITE (11,4030) STIM,RX(I),DZZ(J1),P(N),PHD,THETA(N),SAT	171800
10 CONTINUE	171900
20 IF(KTIM.EQ.0) GO TO 30	172000
C	172100
C WRITE TIME STEP HEADER TO FILE 6	172200
C	172300
C WRITE MAXIMUM HEAD CHANGE EACH TIME STEP TO FILE 7	172400
C	172500
IF(F7P) WRITE (07,4050) KTIM,STIM,TUNIT,(DHMX(K),K=1,NIT)	172600

	WRITE (06,4060) KTIM,KP,STIM,TUNIT,NIT	172700
	IF(JSTOP.EQ.1.OR.JPLT.EQ.1) GO TO 30	172800
	IF(.NOT.PRNT.AND.JFLAG.EQ.0) RETURN	172900
C		173000
C	PRINT SOLUTION FOR CURRENT TIME STEP	173100
C		173200
C	PRINT TOTAL HEADS	173300
C		173400
	30 WRITE (6,4080) TITL,STIM,TUNIT,KTIM	173500
	IF(.NOT.HPNT) GO TO 40	173600
	WRITE (6,4090)	173700
	CALL VSOUT(1,P)	173800
C		173900
C	PRINT PRESSURE HEADS	174000
C		174100
	40 IF(.NOT.PPNT) GO TO 60	174200
	DO 50 J=2,NLYY	174300
	DO 50 N=2,NXRR	174400
	IN=NLY*(N-1)+J	174500
	DUM(IN)=P(IN)+DZZ(J)	174600
	IF(HX(IN).EQ.0.)DUM(IN)=0.	174700
	50 CONTINUE	174800
	WRITE (6,4100)	174900
	CALL VSOUT(1,DUM)	175000
C		175100
C	PRINT SATURATIONS	175200
C		175300
	60 IF(.NOT.SPNT) GO TO 90	175400
	DO 80 J=2,NLYY	175500
	DO 80 N=2,NXRR	175600
	IN=NLY*(N-1)+J	175700
	TTX=HK(JTEX(IN),3)	175800
	IF(TTX.EQ.0.) GO TO 70	175900
	DUM(IN)=THETA(IN)/TTX	176000
	GO TO 80	176100
	70 DUM(IN)=0.	176200
	80 CONTINUE	176300
	WRITE (6,4110)	176400
	CALL VSOUT(2,DUM)	176500
C		176600
C	PRINT MOISTURE CONTENTS	176700
C		176800
	90 IF(.NOT.THPT) GO TO 100	176900
	WRITE (6,4120)	177000
	CALL VSOUT(2,THETA)	177100
	100 CONTINUE	177200
	IF(JPLT.NE.1) GO TO 130	177300
C		177400
C	WRITE PRESSURE HEADS TO FILE 8 AT OBSERVATION TIMES.	177500
C		177600
	WRITE (8,4010) STIM,TUNIT	177700
	DO 120 J=1,NLY	177800
	DO 110 N=1,NXR	177900
	IN=NLY*(N-1)+J	178000

110 DUM(N)=P(IN)+DZZ(J)	178100
120 WRITE (8,4020) (DUM(N),N=1,NXR)	178200
130 CONTINUE	178300
RETURN	178400
4010 FORMAT(/,8H TIME = ,E14.4,1X,A4/)	178500
4020 FORMAT(8(1PE10.3))	178600
4030 FORMAT(7(1PE12.3))	178700
4050 FORMAT(6X,'MAXIMUM HEAD CHANGE DURING EACH '	178800
&,' ITERATION FOR TIME STEP ',I4,5X,',AFTER',	178900
&1PE12.3,1X,A4,' OF SIMULATION TIME',//,	179000
&(1X,10(1PE12.3)))	179100
4060 FORMAT(6X,'TIME STEP NUMBER = ',I4,' RECHARGE PERIOD = ',	179200
&I4,' ELAPSED TIME = ',1PE11.3,1X,A4,' REQUIRED ITERATIONS = ',I4/)	179300
4080 FORMAT(6X,A80/5X,20HTOTAL ELAPSED TIME =,1PE12.3,1X,A4/5X,	179400
110HTIME STEP ,I5,//)	179500
4090 FORMAT(1H ,50X,10HTOTAL HEAD)	179600
4100 FORMAT(1H ,50X,13HPRESSURE HEAD)	179700
4110 FORMAT(1H ,50X,10HSATURATION)	179800
4120 FORMAT(1H ,50X,16HMOISTURE CONTENT)	179900
END	180000
SUBROUTINE VSOUT(IV,VPRNT)	180100
C*****	180200
CVSOUT	180300
C*****	180400
C	180500
C PURPOSE: TO PRINT TWO DIMENSIONAL ARRAYS	180600
C	180700
C	180800
C-----	180900
C	181000
C SPECIFICATIONS FOR ARRAYS AND SCALARS	181100
C	181200
C	181300
IMPLICIT DOUBLE PRECISION (A-H,P-Z)	181400
COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2	181500
COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES	181600
COMMON/KCON/HX(0900),NTYP(0900)	181700
COMMON/DUMM/DUM(0900)	181800
COMMON/PLOTT/PLTIM(50),IJOBS(50),JPLT,NPLT,NOBS	181900
LOGICAL F7P,F11P,F8P,F9P,F6P,PRNT	182000
COMMON/LOG2/F7P,F11P,F8P,F9P,F6P,PRNT	182100
CHARACTER*80 TITL	182200
CHARACTER*4 ZUNIT,TUNIT,CUNX	182300
COMMON/SCHAR/TITL,ZUNIT,TUNIT,CUNX	182400
DIMENSION VPRNT(1),DUM1(100)	182500
C	182600
C-----	182700
C	182800
WRITE (06,4000) ZUNIT,ZUNIT	182900
WRITE (06,4010) (RX(K),K=2,NXRR)	183000
DO 30 J=2,NLYY	183100
DO 10 N=2,NXRR	183200
IN=NLY*(N-1)+J	183300
DUM1(N)=VPRNT(IN)	183400

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      IF(HX(IN).EQ.0. ) DUM1(N)=0.                                183500
10  CONTINUE                                                    183600
      IF(IV.GT.1) GO TO 20                                       183700
      WRITE (06,4020) DZZ(J),(DUM1(N),N=2,NXRR)                 183800
      GO TO 30                                                    183900
20  WRITE (06,4030) DZZ(J),(DUM1(N),N=2,NXRR)                 184000
30  CONTINUE                                                    184100
      RETURN                                                      184200
4000 FORMAT(1H ,1X,5HZ, IN/2X,A4,20X,20HX OR R DISTANCE, IN ,A4) 184300
4010 FORMAT(1H ,8X,13(F9.2)/(9X,13(F9.2)))                     184400
4020 FORMAT(1X,F8.2,13(1PE9.2)/(9X,13(1PE9.2)))               184500
4030 FORMAT(1X,F8.2,13F9.3/(9X,13F9.3))                       184600
      END                                                         184700
      SUBROUTINE VSEVAP                                         184800
C*****                                                         184900
CVSEVAP                                                         185000
C*****                                                         185100
C                                                               185200
C  PURPOSE: TO COMPUTE SURFACE EVAPORATION RATES              185300
C                                                               185400
C                                                               185500
C-----                                                       185600
C                                                               185700
C  SPECIFICATIONS FOR ARRAYS AND SCALARS                       185800
C                                                               185900
      IMPLICIT DOUBLE PRECISION (A-H,P-Z)                       186000
      COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2 186100
      COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES                    186200
      COMMON/KCON/HX(0900),NTYP(0900)                          186300
      COMMON/HCON/HCND(0900),HKLL(0900),HKTT(0900)            186400
      COMMON/PRESS/P(0900),PXXX(0900)                          186500
      COMMON/DISCH/Q(0900),QQ(0900),ETOUT,ETOUT1,RHOZ         186600
      COMMON/PTET/DPTH(0900),RT(0900),RDC(6,25),ETCYC,        186700
      &PEVAL(25),PTVAL(25),PET,PEV,HROOT,HA,SRES,RTDPTH,       186800
      &RTBOT,RTTOP,NPV                                          186900
      LOGICAL RAD,BCIT,ETSIM,SEEP,ITSTOP                       187000
      COMMON/LOG1/RAD,BCIT,ETSIM,SEEP,ITSTOP                   187100
C                                                               187200
C-----                                                       187300
C                                                               187400
      ETOUT1=0                                                  187500
      IF(SRES.EQ.0) RETURN                                       187600
      DO 30 J=2,NLYY                                           187700
      DO 30 N=2,NXRR                                           187800
      IN=NLY*(N-1)+J                                           187900
      IF(HX(IN).EQ.0.) GO TO 30                                  188000
      IF(NTYP(IN).NE.5) GO TO 30                                188100
C                                                               188200
C  COMPUTE TEMPORARY EVAP RATE, CHECK AGAINST MAX AND         188300
C  CORRECT IF NECESSARY                                       188400
C                                                               188500
      AREA=DELY*DXR(N)                                          188600
      IF(RAD)AREA=PI2*RX(N)*DXR(N)                              188700
      PETT=PEV*AREA                                             188800

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PTMP=P(IN)+DZZ(J)	188900
HKX=HCND(IN)*HX(IN)	189000
EV=HKX*SRES*(HA-PTMP)*AREA	189100
IF(EV.GT.0.) EV=0.	189200
IF(EV.GT.PETT) GO TO 10	189300
Q(IN)=PETT	189400
GO TO Z0	189500
10 Q(IN)=EV	189600
20 ETOUT1=ETOUT1+Q(IN)	189700
30 CONTINUE	189800
RETURN	189900
END	190000
SUBROUTINE VSPLNT	190100
C*****	190200
CVSPLNT	190300
C*****	190400
C	190500
C THIS SUBROUTINE COMPUTES ACTUAL ET AS A FUNCTION OF A ROOT	190600
C ACTIVITY FUNCTION, HYDRAULIC CONDUCTIVITY OF THE SOIL,	190700
C AND THE DIFFERENCE IN PRESSURE HEAD BETWEEN THE ROOTS AND	190800
C THE SOIL	190900
C	191000
C -----	191100
C	191200
C SPECIFICATIONS FOR ARRAYS AND SCALARS	191300
C	191400
IMPLICIT DOUBLE PRECISION (A-H,P-Z)	191500
COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2	191600
COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES	191700
COMMON/KCON/HX(0900),NTYP(0900)	191800
COMMON/PRESS/P(0900),PXXX(0900)	191900
COMMON/DISCH/Q(0900),QQ(0900),ETOUT,ETOUT1,RHOZ	192000
COMMON/HCON/HCND(0900),HKLL(0900),HKTT(0900)	192100
COMMON/PTET/DPTH(0900),RT(0900),RDC(6,25),ETCYC,	192200
&PEVAL(25),PTVAL(25),PET,PEV,HROOT,HA,SRES,RTDPTH,	192300
&RTBOT,RTTOP,NPV	192400
COMMON/TCON/STIM,DSMAX,KTIM,NIT,KP	192500
LOGICAL RAD,BCIT,ETSIM,SEEP,ITSTOP	192600
COMMON/LOG1/RAD,BCIT,ETSIM,SEEP,ITSTOP	192700
C	192800
C SUM TRANSPIRATION FOR EACH COLUMN	192900
C	193000
ETOUT=0	193100
IF(PET.GE. 0)RETURN	193200
DO 70 I=2,NXRR	193300
ETR=0	193400
AREA=DELY*DXR(I)	193500
IF (RAD) AREA=PI2*RX(I)*DXR(I)	193600
PETT=AREA*PET	193700
DO 20 J=2,NLYY	193800
C	193900
C COMPUTE TRANSPIRATION FOR EACH NODE IN COLUMN	194000
C	194100
IN=NLY*(I-1)+J	194200

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        IF(HX(IN).EQ.0) GO TO 20                                194300
        VOL=AREA*DELZ(J)                                       194400
        IF(NTYP(IN).NE.0) GO TO 20                             194500
        IF(DPTH(IN).GT.RTDPH) GO TO 30                         194600
C                                                                 194700
C  TRANSPARATION IS ZERO IF NTYP IS NOT 0, NODE IS DEEPER    194800
C  THAN RTDPH, OR PRESSURE IS LESS THAN HROOT                194900
C                                                                 195000
        PTMP=P(IN)+DZZ(J)                                       195100
        IF(PTMP.GT.HROOT) GO TO 10                             195200
        Q(IN)=0                                                 195300
        GO TO 20                                               195400
10  HXX=HCND(IN)*HX(IN)*RT(IN)*VOL                             195500
C                                                                 195600
C  Q IS TRANSPARATION FOR EACH NODE.  ETR IS TOTAL FOR COLUMN 195700
C                                                                 195800
        Q(IN)=(HROOT-PTMP)*HXX                                   195900
        ETR=ETR+Q(IN)                                          196000
20  CONTINUE                                                  196100
30  IF(ETR.GT.PETT) GO TO 60                                   196200
C                                                                 196300
C  IF TOTAL TRANSPARATION FOR COLUMN IS GREATER              196400
C  THAN POTENTIAL THEN ADJUST TRANSPARATION VALUES         196500
C                                                                 196600
        R1=PETT/ETR                                           196700
        ETR=PETT                                              196800
        DO 40 K=2,J                                           196900
        IN=NLY*(I-1)+K                                         197000
        IF(HX(IN).EQ.0.OR.NTYP(IN).GT.0) GO TO 40             197100
        IF(DPTH(IN).GT.RTDPH) GO TO 50                         197200
        Q(IN)=Q(IN)*R1                                         197300
40  CONTINUE                                                  197400
50  CONTINUE                                                  197500
60  ETOUT=ETOUT+ETR                                          197600
70  CONTINUE                                                  197700
        RETURN                                               197800
        END                                                  197900
        SUBROUTINE VSPOND(IFET,IFET1,IFET2)                   198000
C*****                                                       198100
CVSPOND                                                       198200
C*****                                                       198300
C                                                                 198400
C  PURPOSE:  TO DETERMINE IF PONDING OR UNPONDING HAS OCCURRED, AND 198500
C            IF SO TO CHANGE BOUNDARY CONDITIONS AT THOSE NODES FROM 198600
C            NEUMAN TO DIRICHLET OR VICE VERSA                198700
C                                                                 198800
C  -----                                                    198900
C                                                                 199000
C  SPECIFICATIONS FOR ARRAYS AND SCALARS                       199100
C                                                                 199200
        IMPLICIT DOUBLE PRECISION (A-H,P-Z)                   199300
        COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2 199400
        COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES                 199500
        COMMON/KCON/HX(0900),NTYP(0900)                       199600

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COMMON/PRESS/P(0900),PXXX(0900)	199700
COMMON/DISCH/Q(0900),QQ(0900),ETOUT,ETOUT1,RHOZ	199800
COMMON/EQUAT/A(0900),B(0900),C(0900),D(0900),E(0900),RHS(0900),	199900
&XI(0900)	200000
COMMON/PND/POND	200100
COMMON/TCON/STIM,DSMAX,KTIM,NIT,KP	200200
C	200300
C-----	200400
C	200500
C IFET1 INDICATES WHETHER THERE ARE ANY NEUMAN BOUNDARIES REMAINING	200600
C IFET2 INDICATES WHETHER ANY SPECIFIC FLUX NODES HAVE BEEN CONVERTED	200700
C TO SPECIFIED HEAD NODES. BECAUSE OF THE CAPILLARY BARRIER	200800
C EFFECT, THESE NODES MAY NEED TO REVERT TO SPECIFIED FLUX NODES.	200900
C IFET INDICATES WHETHER PONDING OCCURRED OR DISAPPEARED	201000
C	201100
IF(IFET1.EQ.0 .AND. IFET2 .EQ. 0) RETURN	201200
IFET=0	201300
IFET1=0	201400
IFET2=0	201500
DO 40 I=2,NLYY	201600
DZ1=DZZ(I)	201700
IF(POND.GE.0.) GO TO 10	201800
DZ2=-DMIN1(DZ1,-POND)	201900
C	202000
C DZ2 IS MAXIMUM ALLOWABLE TOTAL HEAD	202100
C	202200
GO TO 20	202300
10 DZ2=POND-DZ1	202400
20 DO 40 J=2,NXRR	202500
IN=(J-1)*NLY+I	202600
IF (HX(IN).EQ.0) GO TO 40	202700
IF (NTYP(IN).NE.2) GO TO 30	202800
IF(QQ(IN).LE.0) GO TO 30	202900
IFET1=1	203000
IF(P(IN).LE.DZ2) GO TO 30	203100
C	203200
C IF COMPUTED HEAD EXCEEDS MAXIMUM THEN SET P=DZ2	203300
C AND CHANGE BOUNDARY TYPE TO CONSTANT HEAD	203400
C	203500
P(IN)=DZ2	203600
NTYP(IN)=1	203700
IFET=1	203800
IFET2=1	203900
WRITE (6,4000) I,J,KTIM	204000
GO TO 40	204100
30 CONTINUE	204200
IF(NTYP(IN) .NE. 1 .OR. QQ(IN) .LE. 0.0)GO TO 40	204300
IFET2=1	204400
JP1=IN+1	204500
IM1=IN+NLY	204600
IP1=IN-NLY	204700
TEST=(DZ2-P(JP1))*D(IN)	204800
IF(HX(IM1).NE.0) TEST=TEST+(DZ2-P(IM1))*C(IN)	204900
IF(HX(IP1).NE.0)TEST=TEST+(DZ2-P(IP1))*A(IN)	205000

TEST=TEST/QQ(IN)	205100
IF (TEST .LT. 1.01)GO TO 40	205200
C	205300
C IF FLUX FROM THE CONVERTED NODE IS GREATER THAN THE SPECIFIED	205400
C FLUX RATE, THE NODE IS RECONVERTED TO A SPECIFIED FLUX NODE.	205500
C	205600
NTYP(IN)=2	205700
IFET=1	205800
IFET1=1	205900
WRITE(06,4010)I,J,KTIM	206000
40 CONTINUE	206100
IF (IFET.EQ.0)RETURN	206200
C	206300
C IF A BOUNDARY CHANGE OCCURRED RESET ALL HEADS TO HEAD AT	206400
C PREVIOUS TIME STEP, SO CURRENT STEP CAN BE REPEATED	206500
C	206600
DO 50 I=NLY,NNODES	206700
IF(NTYP(I).EQ.1.OR.HX(I).EQ.0) GO TO 50	206800
P(I)=PXXX(I)	206900
50 CONTINUE	207000
RETURN	207100
4000 FORMAT(//,6X,17H PONDING AT NODE ,2I4,17H DURING TIME STEP,	207200
1I4)	207300
4010 FORMAT(//,6X,' PONDING ENDED AT NODE ',2I4,	207400
&' DURING TIME STEP ',I4)	207500
END	207600
SUBROUTINE VSSFAC	207700
C*****	207800
CVSSFAC	207900
C*****	208000
C	208100
C PURPOSE: TO COMPUTE POSITION OF SEEPAGE FACE BOUNDARIES	208200
C	208300
C HEIGHT OF SEEPAGE FACE IS LOWERED IF THERE IS FLUX INTO SYSTEM	208400
C THRU FACE.	208500
C HEIGHT IS RAISED IF PRESSURE HEADS ARE POSITIVE ABOVE FACE.	208600
C	208700
C -----	208800
C	208900
C SPECIFICATIONS FOR ARRAYS AND SCALARS	209000
C	209100
IMPLICIT DOUBLE PRECISION (A-H,P-Z)	209200
COMMON/RSPAC/DELZ(100),DZZ(100),DXR(100),RX(100),DELY,PI2	209300
COMMON/ISPAC/NLY,NLYY,NXR,NXRR,NNODES	209400
COMMON/KCON/HX(0900),NTYP(0900)	209500
COMMON/PRESS/P(0900),PXXX(0900)	209600
COMMON/HCON/HCND(0900),HKLL(0900),HKTT(0900)	209700
COMMON/SPFC/JSPX(3,25,4),NFC(4),JLAST(4),NFCS	209800
COMMON/TCON/STIM,DSMAX,KTIM,NIT,KP	209900
C	210000
C -----	210100
C	210200
DO 100 K=1,NFCS	210300
NFX=NFC(K)	210400

	JFST=0	210500
	JLST=JLAST(K)	210600
C		210700
C	CHECK FOR POSITIVE PRESSURES ABOVE SEEPAGE FACE	210800
C		210900
	DO 10 J=NFX,1,-1	211000
	IN=JSPX(1,J,K)	211100
	JJ=JSPX(2,J,K)	211200
	PTMP=P(IN)+DZZ(JJ)	211300
	IF(PTMP.LT.0.) GO TO 10	211400
	JFST=J	211500
	GO TO 20	211600
	10 CONTINUE	211700
	20 CONTINUE	211800
C		211900
C	CHECK FOR FLOW INTO DOMAIN THROUGH SEEPAGE FACE	212000
C		212100
	DO 50 I=JLST,1,-1	212200
	IN=JSPX(1,I,K)	212300
	JJ=JSPX(2,I,K)	212400
	NM1=IN-NLY	212500
	IF(HX(NM1).EQ.0.0) GO TO 30	212600
	IF(P(NM1).GT.P(IN)) GO TO 60	212700
	GO TO 40	212800
	30 NP1=IN+NLY	212900
	IF(P(NP1).GT.P(IN)) GO TO 60	213000
	40 NTYP(IN)=3	213100
	50 CONTINUE	213200
	I=0	213300
	60 IF(I.EQ.JLST) GO TO 70	213400
C		213500
C	RESET SEEPAGE FACE HEIGHT AND BOUNDARIES	213600
C		213700
	JLAST(K)=I	213800
	GO TO 90	213900
	70 IF(JFST.EQ.JLST) GO TO 90	214000
	DO 80 I=1,JFST	214100
	IN=JSPX(1,I,K)	214200
	JJ=JSPX(2,I,K)	214300
	NTYP(IN)=1	214400
	P(IN)=-DZZ(JJ)	214500
	80 CONTINUE	214600
	JLAST(K)=JFST	214700
	90 CONTINUE	214800
	100 CONTINUE	214900
	END	215000
	SUBROUTINE VSPET	215100
C*****		215200
CVSPET		215300
C*****		215400
C		215500
C	PURPOSE: TO COMPUTE VALUES OF PEV,SRES,HA,PET,RTDPH,RTBOT,RTTOP,	215600
C	AND HROOT FOR EVAPORATION AND TRANSPIRATION CALCULATIONS.	215700
C	VALUES ARE DETERMINED BY LINEAR INTERPOLATION IN TIME	215800

C	BETWEEN EVAPOTRANSPIRATION PERIODS.	215900
C		216000
C	-----	216100
C		216200
C	SPECIFICATIONS FOR ARRAYS AND SCALARS	216300
C		216400
	IMPLICIT DOUBLE PRECISION (A-H,P-Z)	216500
	COMMON/PTET/DPTH(0900),RT(0900),RDC(6,25),ETCYC,	216600
	&PEVAL(25),PTVAL(25),PET,PEV,HROOT,HA,SRES,RTDPTH,	216700
	&RTBOT,RTTOP,NPV	216800
	COMMON/TCON/STIM,DSMAX,KTIM,NIT,KP	216900
	LOGICAL RAD,BCIT,ETSIM,SEEP,ITSTOP	217000
	COMMON/LOG1/RAD,BCIT,ETSIM,SEEP,ITSTOP	217100
C		217200
C	-----	217300
C		217400
	IF (NPV.EQ.1) THEN	217500
C		217600
C	IF ONLY 1 PERIOD THEN ALL VALUES ARE CONSTANT	217700
C		217800
	IF(BCIT) THEN	217900
	PEV=-PEVAL(1)	218000
	SRES=RDC(1,1)	218100
	HA=RDC(2,1)	218200
	END IF	218300
	IF(ETSIM) THEN	218400
	PET=-PTVAL(1)	218500
	RTDPTH=RDC(3,1)	218600
	RTBOT=RDC(4,1)	218700
	RTTOP=RDC(5,1)	218800
	HROOT=RDC(6,1)	218900
	END IF	219000
	ELSE	219100
C		219200
C	DETERMINE WHICH PERIOD TO USE	219300
C		219400
	ETCYC1=NPV*ETCYC	219500
	SITY=MOD(STIM,ETCYC1)	219600
	I=(SITY/ETCYC)+2	219700
	IF(I.EQ.1) THEN	219800
	K=NPV	219900
	ELSE	220000
	K=I-1	220100
	END IF	220200
C		220300
C	LINEARLY INTERPOLATE	220400
C		220500
	FRPER=(MOD(SITY,ETCYC))/ETCYC	220600
	IF (BCIT) THEN	220700
	PEV=-PEVAL(K)-(PEVAL(I)-PEVAL(K))*FRPER	220800
	SRES=RDC(1,K)+(RDC(1,I)-RDC(1,K))*FRPER	220900
	HA=RDC(2,K)+(RDC(2,I)-RDC(2,K))*FRPER	221000
	END IF	221100
	IF (ETSIM) THEN	221200

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PET=-PTVAL(K)-(PTVAL(I)-PTVAL(K))*FRPER                221300
RTDPATH=RDC(3,K)+(RDC(3,I)-RDC(3,K))*FRPER             221400
RTBOT=RDC(4,K)+(RDC(4,I)-RDC(4,K))*FRPER              221500
RTTOP=RDC(5,K)+(RDC(5,I)-RDC(5,K))*FRPER              221600
HROOT=RDC(6,K)+(RDC(6,I)-RDC(6,K))*FRPER              221700
END IF                                                  221800
END IF                                                  221900
RETURN                                                  222000
END                                                    222100
DOUBLE PRECISION FUNCTION VSRDF(Z1,Z2)                 222200
C*****                                               222300
CVSRDF                                               222400
C*****                                               222500
C                                                    222600
C      PURPOSE: TO DETERMINE THE ROOT ACTIVITY AT EACH NODE WITHIN 222700
C                THE ROOT ZONE FOR EACH TIME STEP      222800
C                                                    222900
C                                                    223000
C-----
C                                                    223100
C                                                    223200
C      IMPLICIT DOUBLE PRECISION (A-H,P-Z)             223300
C      COMMON/PTET/DPTH(0900),RT(0900),RDC(6,25),ETCYC, 223400
C      &PEVAL(25),PTVAL(25),PET,PEV,HROOT,HA,SRES,RTDPATH, 223500
C      &RTBOT,RTTOP,NPV                                223600
C                                                    223700
C-----
C                                                    223800
C                                                    223900
C                                                    224000
C      LINEARLY INTERPOLATE USING DEPTH OF NODE AND MAXIMUM ROOT DEPTH 224100
C                                                    224200
C      IF(RTDPATH.GT.Z1.AND.RTDPATH.GT.0)THEN          224300
C      IF(RTDPATH.GE.Z1+Z2)THEN                        224400
C      ZZ=Z1+0.5*Z2                                    224500
C      ZZ1=1.                                          224600
C      ELSE                                            224700
C      ZZ=(Z1+RTDPATH)*0.5                            224800
C      ZZ1=(RTDPATH-Z1)/Z2                            224900
C      END IF                                          225000
C      VSRDF=ZZ1*(ZZ*RTBOT+(RTDPATH-ZZ)*RTTOP)/RTDPATH 225100
C      ELSE                                           225200
C      VSRDF=0.0                                       225300
C      END IF                                          225400
C      RETURN                                          225500
C      END                                            225600
DOUBLE PRECISION FUNCTION VSDTHU(P,I,HK)              225700
C*****                                               225800
CVSDTHU                                               225900
C*****                                               226000
C                                                    226100
C      FIRST DERIVATIVE OF MOISTURE CONTENT AS A FUNCTION OF PRESSURE HEAD 226200
C                                                    226300
C      VAN GENUCHTEN FUNCTION                          226400
C                                                    226500
C      HK(I,1)=SATURATED HYDRAULIC CONDUCTIVITY      226600

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C	HK(I,2)=SPECIFIC STORAGE	226700
C	HK(I,3)=POROSITY	226800
C	HK(I,4)=ALPHA PRIME	226900
C	HK(I,5)=RESIDUAL MOISTURE CONTENT	227000
C	HK(I,6)=BETA PRIME	227100
C		227200
	IMPLICIT DOUBLE PRECISION (A-H,P-Z)	227300
	DIMENSION HK(10,100)	227400
	VSDTHU=0.D0	227500
	IF(P.GE.0.0)RETURN	227600
	SE=HK(I,3)-HK(I,5)	227700
	EN=HK(I,6)	227800
	EM=2.-1./EN	227900
	ALPH=HK(I,4)	228000
	A=P/ALPH	228100
	VSDTHU=- (EN-1)*SE*A** (EN-1)/(ALPH*(1+A**EN)**EM)	228200
	RETURN	228300
	END	228400
	DOUBLE PRECISION FUNCTION VSTHNV(V,I,HK)	228500
C*****		228600
CVSTHNV		228700
C*****		228800
C		228900
C	INITIAL UNSATURATED PRESSURE HEAD AS A FUNCTION OF VOLUMETRIC	229000
C	MOISTURE CONTENT	229100
C		229200
C	VAN GENUCHTEN FUNCTION	229300
C		229400
	IMPLICIT DOUBLE PRECISION (A-H,P-Z)	229500
	DIMENSION HK(10,100)	229600
	VSTHNV=0.0	229700
	IF(V.GE.HK(I,3)) RETURN	229800
	IF(V.GT.HK(I,5)) GO TO 10	229900
	WRITE(6,4000) V,I	230000
4000	FORMAT(/,28HINITIAL MOISTURE CONTENT OF ,F7.3,49HIS LESS THAN RES	230100
	LIDUAL MOISTURE CONTENT FOR CLASS ,I4,/,	230200
	214HPROGRAM HALTED)	230300
	STOP	230400
10	SE=(V-HK(I,5))/(HK(I,3)-HK(I,5))	230500
	EN=HK(I,6)	230600
	EM=1.-1./EN	230700
	ALPH=HK(I,4)	230800
	VSTHNV=ALPH*(1/SE**(1/EM)-1)**(1-EM)	230900
	RETURN	231000
	END	231100
	DOUBLE PRECISION FUNCTION VSTHU(P,I,HK)	231200
C*****		231300
CVSTHU		231400
C*****		231500
C		231600
C	MOISTURE CONTENT AS A FUNCTION OF PRESSURE HEAD	231700
C		231800
C	VAN GENUCHTEN FUNCTION	231900
C		232000


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      IMPLICIT DOUBLE PRECISION (A-H,P-Z)
      DIMENSION HK(10,100)
      VSTHU=HK(I,3)
      IF(P .GE. 0.0)RETURN
      EN=HK(I,6)
      EM=-(1.-1./EN)
      A=HK(I,3)-HK(I,5)
      ALPH=HK(I,4)
      VSTHU=HK(I,5)+A*(1+(P/ALPH)**EN)**EM
      RETURN
      END
      DOUBLE PRECISION FUNCTION VSHKU(P,I,HK)
C*****
CVSHKU
C*****
C
C   RELATIVE HYDRAULIC CONDUCTIVITY WITH RESPECT TO PRESSURE HEAD
C
C   VAN GENUCHTEN FUNCTION
C
C
      IMPLICIT DOUBLE PRECISION (A-H,P-Z)
      DIMENSION HK(10,100)
      VSHKU=1.00
      IF(P.GE.0.0)RETURN
      EN=HK(I,6)
      EM=1.-1./EN
      A=P/HK(I,4)
      TOP=A**EN
      DEN=(1+TOP)**(EM/2.)
      TOP=1-TOP/A*(1+TOP)**(-EM)
      VSHKU=TOP*TOP/DEN
      RETURN
      END
C
C
C
C   NOTE -- AS LISTED HERE THE PROGRAM USES THE FUNCTIONAL RELATIONS
C           OF THE VAN GENUCHTEN FORM.
C           FUNCTIONS FOR THE THREE ALTERNATIVE RELATIONS ARE LISTED
C           BELOW. TO USE ONE OF THESE: FIRST PLACE A 'C' (FOR COMMENT)
C           IN THE FIRST COLUMN OF EVERY LINE IN THE VAN GENUCHTEN
C           ROUTINES. NEXT REMOVE THE COMMENT DESIGNATIONS FOR THE
C           DESIRED SET OF ROUTINES -- 'C&' FOR BROOKS-COREY
C                                     'C$' FOR HAVERKAMP
C                                     'C+' FOR TABULAR DATA
C&   DOUBLE PRECISION FUNCTION VSDTHU(P,I,HK)
C*****
CVSDTHU
C*****
C
C   FIRST DERIVATIVE OF MOISTURE CONTENT AS A FUNCTION OF PRESSURE HEAD
C

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C      BROOKS AND COREY, CSU HYDROLOGY PAPER NO. 17 PP.3-4      237500
C      237600
C      HK(I,1)=SATURATED HYDRAULIC CONDUCTIVITY      237700
C      HK(I,2)=SPECIFIC STORAGE      237800
C      HK(I,3)=POROSITY      237900
C      HK(I,4)=BUBBLING PRESSURE      238000
C      HK(I,5)=RESIDUAL MOISTURE CONTENT      238100
C      HK(I,6)=LAMBDA      238200
C      238300
C&      IMPLICIT DOUBLE PRECISION (A-H,P-Z)      238400
C&      DIMENSION HK(10,100)      238500
C&      VSDTHU=0.D0      238600
C&      IF(P.GE.HK(I,4))RETURN      238700
C&      VSDTHU=-((HK(I,3)-HK(I,5))*HK(I,6)*(HK(I,4)/P)**HK(I,6))/P      238800
C&      IF(ABS(VSDTHU).LT.1.E-38)VSDTHU=0.D0      238900
C&      RETURN      239000
C&      END      239100
C&      DOUBLE PRECISION FUNCTION VSTHNV(V,I,HK)      239200
C*****      239300
CVSTHNV      239400
C*****      239500
C      239600
C      INITIAL UNSATURATED PRESSURE HEAD AS A FUNCTION OF VOLUMETRIC      239700
C      MOISTURE CONTENT      239800
C      239900
C      BROOKS AND COREY, CSU HYDROLOGY PAPER NO. 17 , PP.3-4      240000
C      240100
C&      IMPLICIT DOUBLE PRECISION (A-H,P-Z)      240200
C&      DIMENSION HK(10,100)      240300
C&      VSTHNV=HK(I,4)      240400
C&      IF(V.GE.HK(I,3)) RETURN      240500
C&      IF(V.GT.HK(I,5)) GO TO 1      240600
C&      WRITE(6,100) V,I      240700
C&100 FORMAT(/,28HINITIAL MOISTURE CONTENT OF ,F7.3,49HIS LESS THAN RES      240800
C&      IDUAL MOISTURE CONTENT FOR CLASS ,I4,/,      240900
C&      214HPROGRAM HALTED)      241000
C&      STOP      241100
C&1 SE=(V-HK(I,5))/(HK(I,3)-HK(I,5))      241200
C&      VSTHNV=HK(I,4)/(SE**(1.00/HK(I,6)))      241300
C&      RETURN      241400
C&      END      241500
C&      DOUBLE PRECISION FUNCTION VSTHU(P,I,HK)      241600
C*****      241700
CVSTHU      241800
C*****      241900
C      242000
C      MOISTURE CONTENT AS A FUNCTION OF PRESSURE HEAD BELOW BUBBLING      242100
C      PRESSURE: = POROSITY ELSEWHERE      242200
C      242300
C      BROOKS AND COREY, CSU HYDROLOGY PAPER NO.17, PP.3-4      242400
C      242500
C&      IMPLICIT DOUBLE PRECISION (A-H,P-Z)      242600
C&      DIMENSION HK(10,100)      242700
C&      VSTHU=HK(I,3)      242800

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C&	IF(P.GE.HK(I,4))RETURN	242900
C&	VSTHU=HK(I,5)+(HK(I,3)-HK(I,5))*(HK(I,4)/P)**HK(I,6)	243000
C&	RETURN	243100
C&	END	243200
C&	DOUBLE PRECISION FUNCTION VSHKU(P,I,HK)	243300
C*****		243400
CVSHKU		243500
C*****		243600
C		243700
C	RELATIVE HYDRAULIC CONDUCTIVITY WITH RESPECT TO PRESSURE HEAD	243800
C		243900
C	BROOKS AND COREY, CSU HYDROLOGY PAPER NO. 3	244000
C		244100
C		244200
C&	IMPLICIT DOUBLE PRECISION (A-H,P-Z)	244300
C&	DIMENSION HK(10,100)	244400
C&	VSHKU=1.00	244500
C&	IF(P.GE.HK(I,4))RETURN	244600
C&	VSHKU=(HK(I,4)/P)**(2.+3.*HK(I,6))	244700
C&	IF(VSHKU.LT.1.D-38)VSHKU=0.00	244800
C&	RETURN	244900
C&	END	245000
C\$	DOUBLE PRECISION FUNCTION VSDTHU(P,I,HK)	245100
C*****		245200
CVSDTHU		245300
C*****		245400
C		245500
C	FIRST DERIVATIVE OF MOISTURE CONTENT AS A FUNCTION OF PRESSURE HEAD	245600
C		245700
C	HAVERKAMP FUNCTION	245800
C		245900
C	HK(I,1)=SATURATED HYDRAULIC CONDUCTIVITY	246000
C	HK(I,2)=SPECIFIC STORAGE	246100
C	HK(I,3)=POROSITY	246200
C	HK(I,4)=A PRIME	246300
C	HK(I,5)=RESIDUAL MOISTURE CONTENT	246400
C	HK(I,6)=B PRIME	246500
C	HK(I,7)=ALPHA	246600
C	HK(I,8)=BETA	246700
C		246800
C\$	IMPLICIT DOUBLE PRECISION (A-H,P-Z)	246900
C\$	DIMENSION HK(10,100)	247000
C\$	VSDTHU=0.D0	247100
C\$	IF(P.GE.0.0)RETURN	247200
C\$	SE=HK(I,3)-HK(I,5)	247300
C\$	ALPH=HK(I,7)	247400
C\$	EM=HK(I,8)	247500
C\$	TOP=P/ALPH	247600
C\$	DEN=1+TOP**EM	247700
C\$	DEN=DEN*DEN	247800
C\$	VSDTHU=SE*EM*TOP**(EM-1)/(ALPH*DEN)	247900
C\$	RETURN	248000
C\$	END	248100
C\$	DOUBLE PRECISION FUNCTION VSTHNV(V,I,HK)	248200

C*****	248300
CVSTHNV	248400
C*****	248500
C	248600
C	248700
C	248800
C	248900
C	249000
C	249100
C\$	249200
C\$	249300
C\$	249400
C\$	249500
C\$	249600
C\$	249700
C\$100	249800
C\$	249900
C\$	250000
C\$	250100
C\$1	250200
C\$	250300
C\$	250400
C\$	250500
C\$	250600
C*****	250700
CVSTHU	250800
C*****	250900
C	251000
C	251100
C	251200
C	251300
C	251400
C\$	251500
C\$	251600
C\$	251700
C\$	251800
C\$	251900
C\$	252000
C\$	252100
C\$	252200
C*****	252300
CVSHKU	252400
C*****	252500
C	252600
C	252700
C	252800
C	252900
C	253000
C	253100
C\$	253200
C\$	253300
C\$	253400
C\$	253500
C\$	253600

C\$	RETURN	253700
C\$	END	253800
C	*****	253900
C	*****	254000
C		254100
C+	SUBROUTINE INTERP (P,I,HK)	254200
C	*****	254300
C	CINTERP	254400
C	*****	254500
C		254600
C	THIS SUBROUTINE PERFORMS LINEAR INTERPOLATION OF PRESSURE	254700
C	HEADS FOR RELATIVE HYDRAULIC CONDUCTIVITY (VSHKU), VOLUMETRIC	254800
C	MOISTURE CONTENT (VSTHU), AND MOISTURE CAPACITY (VSDTHU).	254900
C		255000
C		255100
C	TO USE THIS METHOD FOR EVALUATING THE NONLINEAR FUNCTIONS,	255200
C	THE USER MUST ENTER A TABLE OF PRESSURE HEADS	255300
C	AND VALUES OF RELATIVE	255400
C	CONDUCTIVITIES,AND MOISTURE CONTENTS	255500
C	WHICH CORRESPOND TO EACH PRESSURE HEAD INTO ARRAY HK ON	255600
C	B-7 CARDS FOR EACH TEXTURAL CLASS. SET NPROP (CARD B-5) EQUAL	255700
C	TO 3*(NUMBER OF PRESSURE HEADS IN TABLE + 1).	255800
C	BEGINNING WITH HK(ITEX,4), ENTER ALL PRESSURE HEADS IN DESCENDING	255900
C	ORDER STARTING WITH THE HIGHEST VALUE,	256000
C	NEXT ENTER THE NUMBER 99,	256100
C	NEXT ENTER THE RELATIVE HYDRAULIC	256200
C	CONDUCTIVITY FOR EACH PRESSURE HEAD,	256300
C	NEXT ENTER THE NUMBER 99,	256400
C	NEXT ENTER THE VOLUMETRIC MOISTURE CONTENT FOR EACH PRESSURE	256500
C	HEAD, FINALLY ENTER THE NUMBER 99.	256600
C		256700
C+	IMPLICIT DOUBLE PRECISION (A-H,P-Z)	256800
C+	DIMENSION HK(10,100)	256900
C+	COMMON I1,I2,I3,I4,I5,I6,DELP	257000
C+	IF (I2.GT.0) GO TO 1	257100
C+	I2=4	257200
C+	DO 2 J=I2,100	257300
C+	IF (HK(I,J).LT.99) GO TO 2	257400
C+	I3=J-I2+1	257500
C+	I1=I3+I3	257600
C+	GO TO 1	257700
C+ 2	CONTINUE	257800
C+ 1	IF(HK(I,I2).LE.P) THEN	257900
C+	DELP=0	258000
C+	I5=I2	258100
C+	I6=I2	258200
C+	ELSE	258300
C+	I4=I2+I3-2	258400
C+	IF(HK(I,I4).GE.P)THEN	258500
C+	I5=I4-1	258600
C+	I6=I4	258700
C+	DELP=0	258800
C+	ELSE	258900
C+	I4=I4-1	259000

C+ DO 3 J=I2+1,I4	259100
C+ IF(HK(I,J).GT.P) GO TO 3	259200
C+ I5=J-1	259300
C+ I6=J	259400
C+ DELP=(P-HK(I,I6))/(HK(I,I5)-HK(I,I6))	259500
C+ RETURN	259600
C+ 3 CONTINUE	259700
C+ END IF	259800
C+ END IF	259900
C+ RETURN	260000
C+ END	260100
C+ DOUBLE PRECISION FUNCTION VSHKU (P,I,HK)	260200
C*****	260300
CVSHKU	260400
C*****	260500
C	260600
C RELATIVE HYDRAULIC CONDUCTIVITY AS A FUNCTION OF PRESSURE HEAD	260700
C DETERMINED BY LINEAR INTERPOLATION OF KR VS HP TABLE WHICH IS	260800
C INPUT BY USER.	260900
C	261000
C+ IMPLICIT DOUBLE PRECISION (A-H,P-Z)	261100
C+ DIMENSION HK(10,100)	261200
C+ COMMON I1,I2,I3,I4,I5,I6,DELP	261300
C+ CALL INTERP (P,I,HK)	261400
C+ IF(I5.EQ.I6)THEN	261500
C+ VSHKU=HK(I,I3+I5)	261600
C+ RETURN	261700
C+ ELSE	261800
C+ VSHKU=HK(I,I3+I6)+(HK(I,I3+I5)-HK(I,I3+I6))*DELP	261900
C+ RETURN	262000
C+ END IF	262100
C+ END	262200
C+ DOUBLE PRECISION FUNCTION VSDTHU(P,I,HK)	262300
C*****	262400
CVSDTHU	262500
C*****	262600
C	262700
C MOISTURE CAPACITY AS A FUNCTION OF PRESSURE HEAD AS	262800
C DETERMINED FROM TABLE OF THETA VS HP WHICH IS INPUT	262900
C BY USER.	263000
C	263100
C+ IMPLICIT DOUBLE PRECISION (A-H,P-Z)	263200
C+ DIMENSION HK(10,100)	263300
C+ COMMON I1,I2,I3,I4,I5,I6,DELP	263400
C+ IF (I5.EQ.I6) THEN	263500
C+ VSDTHU=0.	263600
C+ RETURN	263700
C+ ELSE	263800
C+ VSDTHU=(HK(I,I1+I5)-HK(I,I1+I6))/(HK(I,I5)-HK(I,I6))	263900
C+ RETURN	264000
C+ END IF	264100
C+ END	264200
C+ DOUBLE PRECISION FUNCTION VSTHU (P,I,HK)	264300
C*****	264400

CVSTHU	264500
C*****	264600
C	264700
C VOLUMETRIC MOISTURE CONTENT AS A FUNCTION OF PRESSURE HEAD	264800
C AS DETERMINED BY LINEAR INTERPOLATION OF THETA VS HP TABLE	264900
C WHICH IS INPUT BY USER.	265000
C	265100
C+ IMPLICIT DOUBLE PRECISION (A-H,P-Z)	265200
C+ DIMENSION HK(10,100)	265300
C+ COMMON I1,I2,I3,I4,I5,I6,DELP	265400
C+ IF (DELP.EQ.0) THEN	265500
C+ VSTHU=HK(I,I1+I6)	265600
C+ ELSE	265700
C+ VSTHU=HK(I,I1+I6)+(HK(I,I1+I5)-HK(I,I1+I6))*DELP	265800
C+ END IF	265900
C+ RETURN	266000
C+ END	266100
C+ DOUBLE PRECISION FUNCTION VSTHNV(P,I,HK)	266200
C*****	266300
CVSTHNV	266400
C*****	266500
C	266600
C NOTE -- THIS FUNCTION IS NOT OPERATIVE WHEN USING INTERPOLATION	266700
C ROUTINES. INITIAL CONDITIONS MUST BE INPUT IN TERMS OF	266800
C PRESSURE HEADS NOT MOISTURE CONTENTS.	266900
C	267000
C+ IMPLICIT DOUBLE PRECISION (A-H,P-Z)	267100
C+ DIMENSION HK(10,100)	267200
C+ WRITE(6,100)	267300
C+ STOP	267400
C+100 FORMAT(5X,'INPUT OF MOISTURE CONTENT FOR INITIAL CONDITIONS IS ',	267500
C+ 1'NOT ALLOWED WHEN USING TABULAR DATA '/	267600
C+ 25X,'FOR MOISTURE RETENTION AND CONDUCTIVITY CURVES',/	267700
C+ 35X,'SIMULATION TERMINATED')	267800
C+ END	267900
C *****	268000

ATTACHMENT 2. PROGRAM FLOW CHART

ATTACHMENT 2. PROGRAM FLOW CHART

