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**FEMWATER: A Finite-Element
Model of WATER Flow
Through Saturated-Unsaturated
Porous Media**

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ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1370

OPERATED BY
UNION CARBIDE CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ACKNOWLEDGMENT

The financial support of this study came from the Radionuclide Movement from Burial Grounds and Development of Technology for Land Burial programs of the Office of Waste Management, U. S. Department of Energy, under contract W-7405-eng-26 with Union Carbide Corporation.

Reeves and Duguid's original work provided the basis and stimulation for this study. Numerous constructive and valuable discussions with D. D. Huff led to the improvement in computing moisture-content rate change and in evaluating nonlinear terms.

ABSTRACT

YEH, G. T. and D. S. WARD. 1979. FEMWATER: A finite-element Model of water flow through saturated-unsaturated porous media. ORNL-5567. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 162 pp.

Upon examining the "Water Movement Through Saturated-Unsaturated Porous Media: A Finite-Element Galerkin Model," it was felt that the model should be modified and expanded. The modification is made in calculating the flow field in a manner consistent with the finite element approach, in evaluating the moisture-content increasing rate within the region of interest, and in numerically computing the nonlinear terms. With these modifications, the flow field is continuous everywhere in the flow regime, including element boundaries and nodal points, and the mass loss through boundaries is much reduced. Expansion is made to include four additional numerical schemes which would be more appropriate for many situations. Also, to save computer storage, all arrays pertaining to the boundary condition information are compressed to smaller dimension, and to ease the treatment of different problems, all arrays are variably dimensioned in all subroutines. This report is intended to document these efforts. In addition, in the derivation of finite-element equations, matrix component representation is used, which is believed more readable than the matrix representation in its entirety. Two identical sample problems are simulated to show the difference between the original and revised models.

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I. INTRODUCTION

To study the transport of dissolved constituents in a subsurface flow system, the velocity field therein must be determined first. A finite-element Galerkin model has been developed to obtain the flow field (Reeves and Duguid 1975). The continuity equation of water mass governing the distribution of pressure head is solved by the Galerkin finite-element method subject to appropriate boundary and initial conditions. The flow field is then computed with Darcy's law by taking the derivatives of the calculated pressure field. Inherent in that approach, however, is the resulting discontinuity in the velocity at element boundaries and nodal points, which unfortunately leads to a violation of the conservation of mass in a local sense. When the spatial distribution of the velocity is significant in the region, inputting this discontinuous flow field to the contaminant transport computation could conceivably produce a large error. This report describes a method to overcome this problem, this is, solving Darcy's law for the velocity field at nodal points by the finite-element method rather than by taking the derivatives of the pressure field. This approach is consistent with the spirit of finite-element methods, and yields, of course, continuous velocity over the whole region of interest, including element boundaries and nodal points. An alternative method is to evaluate the velocity at the Gaussian points of an element rather than at the nodal points from the pressure field with Darcy's law (Segol 1976, Huyakorn and Pinder 1977). Because only the velocity at Gaussian points are needed in the pollutant transport computations if

the Galerkin finite element is used therein, this method circumvents the need to calculate the velocity at nodal points. However, if the upstream weighting function is used in the pollutant transport formulation, continuous velocity field at nodal points is required to compute the optimum weighting factors. Under such circumstances, the alternative approach is not applicable, and the proposed method must be used.

In the development of the moisture transport model, the time-marching is dealt with by either the Crank-Nicolson central-difference or the backward-difference methods. The mass matrix (the matrix associated with the time derivative) as derived from the finite-element discretization in space is used without any modification. However, in many situations, the mid-difference in the time-marching would yield better results than either the central or backward-difference if the consistent mass matrix is used (Gureghian et al. 1978). The mid-difference option is, therefore, incorporated into the revised computer code.

Referring to the mass matrix, it appears as a unit matrix if the spatial discretization is done with the finite-difference method. By suitable scaling, the mass matrix may be reduced to a finite-difference equivalent if it is lumped (Clough 1971). The lumping of the mass matrix in many situations results in a better-behaved global matrix than that from no lumping, in particular, if it is used along with the central or backward-difference time-marching. Thus, the lumping option of the mass matrix is included in the revised code.

II. MATHEMATICAL STATEMENTS

The original work (Reeves and Duguid 1975) is followed very closely in the following statements of the problem. However, in the derivation of finite-element approximations, matrix component representation is used rather than the matrix itself. This component representation is believed more readable.

1. Governing Equations

The governing equations to describe the pressure field in a two-dimensional subsurface system are obtained from the principle of conservation of mass and Darcy's law. This can be written in the form:

$$L(h) = F \frac{\partial h}{\partial t} - \left[\frac{\partial}{\partial x} (K_{xx} \frac{\partial H}{\partial x} + K_{xz} \frac{\partial H}{\partial z}) + \frac{\partial}{\partial z} (K_{zx} \frac{\partial H}{\partial x} + K_{zz} \frac{\partial H}{\partial z}) \right] - Q = 0, \quad (1)$$

where

$$F = \frac{\theta}{n} \alpha' + \beta' \theta + \frac{d\theta}{dh}, \quad (1a)$$

and

$$H = h + z, \quad (1b)$$

in which h is the pressure head; θ is the moisture content; n is the effective porosity; α' and β' are the modified coefficients of compressibility of the medium and water, respectively; K_{xx} , K_{xz} , K_{zx} , and K_{zz} are the hydraulic conductivity tensor components; x and z are the horizontal and vertical coordinates, respectively; t is the time; Q is the artificial recharge or withdrawal; and L is an

operator. In general, Eq. (1) is nonlinear as both the soil properties, F , and hydraulic conductivity, K , are functions of the pressure head.

The initial condition of Eq. (1) is assumed to be known as:

$$h = h_0(x, z) \text{ in } R, \quad (2)$$

where h_0 is a known function of spatial coordinates, x and z . R is a region bounded by the curve $B(x, z)$ (Fig. 1). The function, h_0 , may be obtained by simulating the steady state version of Eq. (1) with time-invariant boundary conditions. Three types of boundary conditions are considered in the problem. In the first type (Dirichlet) boundary the pressure head is prescribed:

$$h = h_1(x, z, t) \text{ on } B_1, \quad (3)$$

where B_1 is a portion of B , and h_1 is a known function of time and (x, z) on B_1 . In the second type (Neumann) boundary the flux is prescribed as:

$$\begin{aligned} - \left[\left(K_{xx} \frac{\partial h}{\partial x} + K_{xz} \frac{\partial h}{\partial z} + K_{xz} \right) \cdot n_x + \left(K_{zx} \frac{\partial h}{\partial x} + K_{zz} \frac{\partial h}{\partial z} + K_{zz} \right) \cdot n_z \right] \\ = q_2 \text{ on } B_2, \end{aligned} \quad (4)$$

where n_x and n_z are the directional cosines of the outward unit vector normal to the B_2 portion of the curve B . The third type is the variable in the sense that either the Dirichlet or the Neumann conditions may prevail,

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Fig. 1. Spatial boundaries of flow region, R .

$$h = h_3(x, z, t) \text{ on } B_3, \quad (5)$$

or

$$-\left[(K_{xx} \frac{\partial h}{\partial x} + K_{xz} \frac{\partial h}{\partial z} + K_{xz}) \cdot n_x + (K_{zx} \frac{\partial h}{\partial x} + K_{zz} \frac{\partial h}{\partial z} + K_{zz}) \cdot n_z \right] = q_3, \quad (6)$$

where h_3 and q_3 are two known functions of time and (x, z) on the B_3 portion of B . The boundaries, B_1 , B_2 , B_3 , and the impervious boundary, B_I , constitute the entire boundary, $B(x, z) = 0$. Initially Eq. (5) is applied to the boundary B_3 when the exact boundary conditions cannot in general be predicted a priori. Such a case would arise at the ground surface where either ponding (Dirichlet) or infiltration (Neumann) conditions could prevail (Segol 1976). This can only be determined in the cyclic process of solving Eq. (1).

After Eq. (1) is solved for the pressure head, h [subject to initial and boundary conditions, Eqs. (2) through (6)], the velocity components are then obtained by,

$$\begin{aligned} v_x &= - (K_{xx} \frac{\partial h}{\partial x} + K_{xz} \frac{\partial h}{\partial z} + K_{xz}) , \\ \text{and} \quad v_z &= - (K_{zx} \frac{\partial h}{\partial x} + K_{zz} \frac{\partial h}{\partial z} + K_{zz}) . \end{aligned} \quad (7)$$

The important modification to the original work lies in the numerical treatment of Eq. (7). Expansion is made to provide optional numerical methods for solving Eqs. (1) through (6).

2. Finite Element Approximations

Equations (1) through (6) are solved by the Galerkin finite-element method. Numerical procedures for this method have been fully addressed (Reeves and Duguid 1975), thus the theoretical basis of the method will not be repeated, only the numerical procedures are summarized. The region of interest is subdivided into an assemblage of smaller subdomains called elements. The quadrilateral bilinear element is used. Following the standard procedure of the Galerkin finite-element method, approximate formulation of the pressure head h will be obtained. Thus, let the variable h be approximated in an element e by:

$$h \approx \hat{h} = \sum_{j=1}^4 h_j(t) N_j, \quad (8)$$

where N_j and h_j are the base function of element e and the amplitude of h , respectively, at nodal point j . Upon the substitution of Eq. (8) into Eq. (1) and application of the orthogonality theorem,

$$\int_{R_e} N_i L(h) dR = 0, \quad i = 1, 2, 3, 4, \quad (9)$$

one obtains the following element matrix equation for element e :

$$[M_{ij}] \{\dot{h}_j\} + [S_{ij}] \{h_j\} + \{D_i\} + \{Q_i\} = 0, \quad (10)$$

where R_e is the region of the element e , dR is the differential area, and the temporal derivative of the head, $\dot{h}_i$ is given below:

$$\dot{h}_i = \frac{dh_i}{dt}. \quad (11)$$

The matrix equation coefficients are defined as:

$$M_{ij} = \int_{R_e} N_i F N_j dR, \quad (12)$$

$$S_{ij} = \int_{R_e} \left\{ \frac{\partial N_i}{\partial x} \cdot \left(K_{xx} \frac{\partial N_j}{\partial x} + K_{xz} \frac{\partial N_j}{\partial z} \right) + \frac{\partial N_i}{\partial z} \cdot \left(K_{zx} \frac{\partial N_j}{\partial x} + K_{zz} \frac{\partial N_j}{\partial z} \right) \right\} dR, \quad (13)$$

$$D_i = \int_{R_e} \left\{ K_{xz} \frac{\partial N_i}{\partial x} + K_{zz} \frac{\partial N_i}{\partial z} - Q \right\} dR, \quad \text{and} \quad (14)$$

$$Q_i = \int_{B_{e2}} N_i q_2 dB + \int_{B_{e3}} N_i \cdot q_3 dB, \quad (15)$$

in which B_{e2} and B_{e3} are the boundaries of the element e , coinciding with the global boundaries B_2 and B_3 , respectively. The first term in Eq. (15) appears only for those elements having one or more sides on B_2 and the integration is carried only over B_2 . Similarly, the second term in that equation appears only for those elements having one or more sides on B_3 , and boundary condition Eq. (6) rather than (5) is prevailing.

In the original work (Reeves and Duguid 1975), the velocity components in Eq. (7) were approximated as

$$V_x = - \left(K_{xx} \frac{\partial N_j}{\partial x} + K_{xz} \frac{\partial N_j}{\partial z} \right) h_j - K_{xz},$$

and

$$V_z = - \left(K_{zx} \frac{\partial N_j}{\partial x} + K_{zz} \frac{\partial N_j}{\partial z} \right) h_j - K_{zz}. \quad (16)$$

This formulation results in a velocity field which is not continuous at element boundaries and nodal points if the variation of the pressure head is other than linear or constant. The alternative approach would be to apply the Galerkin technique to Eq. (7), thus one obtains

$$[S'_{ij}] \{v_{xj}\} = \{D_{xi}\} ,$$

and

(17)

$$[S'_{ij}] \{v_{zj}\} = \{D_{zi}\} ,$$

where

$$S'_{ij} = \int_{R_e} N_i N_j dR , \quad (18)$$

$$D_{xi} = - \int_{R_e} N_i \left\{ K_{xx} \frac{\partial N_j}{\partial x} h_j + K_{xz} \frac{\partial N_j}{\partial z} h_j + K_{xz} \right\} dR , \quad (19)$$

and

$$D_{zi} = - \int_{R_e} N_i \left\{ K_{zx} \frac{\partial N_j}{\partial x} h_j + K_{zz} \frac{\partial N_j}{\partial z} h_j + K_{zz} \right\} dR . \quad (20)$$

Referring to the element mass matrix (the matrix associated with the time-derivative term) in Eq. (10), one may recall that this is a unit matrix if the finite-difference formulation is adopted in spatial discretization. Hence, by proper scaling, the mass matrix can be reduced to the finite-difference equivalent by lumping (Clough 1971). In many occasions, the lumped mass matrix would result in better

solution, in particular, if it is used in conjunction with the central or backward-difference time marching (Gureghian et al. 1978). Under such circumstances, it is preferred to the consistent mass matrix (mass matrix without lumping). Therefore, an option is provided for the lumping of matrix M_{ij} . More explicitly, M_{ij} will be lumped according to

$$M_{ii} = \sum_{j=1}^4 \int_{R_e} F N_i N_j dR \text{ (no summation over } i) , \quad (21)$$

and

$$M_{ij} = 0 \text{ if } i \neq j . \quad (22)$$

3. Time-Marching Methods

An important advantage in finite-element approximation over the finite-difference approximation is the inherent ability to handle complex boundaries and obtain the normal derivatives therein. In the time dimension, such advantages are not evident. Thus, the finite-difference methods are typically used in the approximation of the time derivative. Three time-marching methods are adopted in the present water flow model. In the first one, the central or Crank-Nicolson formulation may be written as:

$$\begin{aligned} [M_{ij}] (\{h_j\}_{t+\Delta t} - \{h_j\}_t) / \Delta t + \frac{1}{2} [S_{ij}] (\{h_j\}_{t+\Delta t} + \{h_j\}_t) + \\ \{D_i\} + \{Q_i\} = 0 , \end{aligned} \quad (23)$$

where $\{M_{ij}\}$, $\{S_{ij}\}$, $\{D_i\}$, and $\{Q_i\}$ are evaluated at $(t + \Delta t/2)$.

In the second method the backward difference formulation may be written as:

$$[M_{ij}](\{h_j\}_{t+\Delta t} - \{h_j\}_t)/\Delta t + [S_{ij}]\{h_j\}_{t+\Delta t} + \{D_i\} + \{Q_i\} = 0 \quad (24)$$

where $[M_{ij}]$, $[S_{ij}]$, $\{D_i\}$, and $\{Q_i\}$ are evaluated at $t + \Delta t$. In the third optional method, the values of the unknown variables assumed to vary linearly with time during the time interval, Δt . In this mid-difference method, the recurrence formula is written as:

$$(2[M_{ij}]/\Delta t + [S_{ij}])\{h_j\}_{t+\Delta t/2} - \frac{2}{\Delta t}[M_{ij}]\{h_j\}_t + \{D_i\} + \{Q_i\} = 0 \quad (25)$$

and

$$\{h_j\}_{t+\Delta t} = 2\{h_j\}_{t+\Delta t/2} - \{h_j\}_t \quad (25a)$$

where $[M_{ij}]$, $[S_{ij}]$, $\{D_i\}$, and $\{Q_i\}$ are all evaluated at $t + \Delta t/2$.

This option has been shown superior to the central or backward-difference formulation, if the mass matrix is not lumped (Gureghian et al. 1978).

In summary, all element matrix equations presented in this section can be written as:

$$[C_{ij}]\{h_j\} = \{R_i\} - \{Q_i\} \quad (26)$$

where $[C_{ij}]$ is the element coefficient matrix, $\{h_j\}$ is the unknown vector to be found, and $\{R_i\}$ is the element load vector. Take, for example, Eq. (24). $[C_{ij}]$, $\{h_j\}$, and $\{R_i\}$ represent the following:

$$[C_{ij}] = [M_{ij}]/\Delta t + [S_{ij}] , \quad (24a)$$

$$\{h_j\} = \{h_j\}_t + \Delta t , \quad (24b)$$

and

$$\{R_j\} = ([M_{ij}]/\Delta t) \{h_j\}_t - \{D_i\} , \quad (24c)$$

respectively.

4. Numerical Integration

For a quadrilateral element with four corner nodes, a bilinear polynomial base function for the i -th node may be written in terms of local normalized coordinates as:

$$N_i = \frac{1}{4} (1 + \xi \xi_i) (1 + \eta \eta_i) \quad i = 1, 2, 3, 4 , \quad (27)$$

where ξ_i and η_i are the local coordinates of the corner nodes, which are numbered 1 to 4 progressing around the element in a counterclockwise direction as shown in Fig. 2. The element is square in the local coordinate system regardless of the shape of the quadrilateral in the global coordinates. The global coordinates at any point within the element e are given in terms of local coordinates by the relationships

$$x = \sum_{j=1}^4 x_j N_j$$

and

(28)

$$z = \sum_{j=1}^4 z_j N_j ,$$

Fig. 2. A typical finite element in global and local coordinates.

where x_j and z_j are the global coordinates of the nodes and N_j is the shape function evaluated at the local coordinates, ξ and η . The shape function, N_j , of the coordinate transformation is taken the same as the basis function; hence, this element formulation is termed isoparametric. The Jacobian for the transformation from global to the local coordinates is expressed as:

$$[J] = \begin{bmatrix} \frac{\partial x}{\partial \xi} & \frac{\partial z}{\partial \xi} \\ \frac{\partial x}{\partial \eta} & \frac{\partial z}{\partial \eta} \end{bmatrix}. \quad (29)$$

Substitution of Eq. (28) into the determinant of this expression yields:

$$J = \text{Det } [J] = (x_j \frac{\partial N_j}{\partial \xi}) \cdot (z_k \frac{\partial N_k}{\partial \eta}) - (z_j \frac{\partial N_j}{\partial \xi}) \cdot (x_k \frac{\partial N_k}{\partial \eta}). \quad (30)$$

The integrals of Eqs. (12-14) and (18-19) over the area of the e-th finite element may be written in local coordinates using the determinant of the Jacobian to transform the elemental area:

$$M_{ij} = \int_{-1}^1 \int_{-1}^1 N_i F N_j J d\eta d\xi, \quad (31)$$

$$S_{ij} = \int_{-1}^1 \int_{-1}^1 \left\{ \frac{\partial N_i}{\partial x} (K_{xx} \frac{\partial N_j}{\partial x} + K_{xz} \frac{\partial N_j}{\partial z}) + \frac{\partial N_i}{\partial z} (K_{zx} \frac{\partial N_j}{\partial x} + K_{zz} \frac{\partial N_j}{\partial z}) \right\} J d\xi d\eta, \quad (32)$$

and

$$D_i = \int_{-1}^1 \int_{-1}^1 \left\{ K_{xz} \frac{\partial N_i}{\partial x} + K_{zz} \frac{\partial N_i}{\partial z} - Q \right\} J d\xi d\eta, \quad (33)$$

$$S_{ij}' = \int_{-1}^1 \int_{-1}^1 N_i N_j J d\xi d\eta, \quad (34)$$

$$D_{xi} = - \int_{-1}^1 \int_{-1}^1 N_i \left\{ K_{xx} \frac{\partial N_j}{\partial x} h_j + K_{xz} \frac{\partial N_j}{\partial z} h_j + K_{xz} \right\} J d\xi d\eta, \quad (35)$$

and

$$D_{zi} = - \int_{-1}^1 \int_{-1}^1 N_i \left\{ K_{zx} \frac{\partial N_j}{\partial x} h_j + K_{zz} \frac{\partial N_j}{\partial z} h_j + K_{zz} \right\} J d\xi d\eta. \quad (36)$$

Integration of these equations is easily performed using 2 x 2 Gaussian integration. A linear algebraic equation, Eq. (26), results since $\{Q_j\}$ is a function of time only and the matrices, $[M_{ij}]$ and $[S_{ij}]$, and the vector $\{D_i\}$ are evaluated for the previous iteration and time step.

In order to evaluate $[S_{ij}]$, $\{D_i\}$, $\{R_{xi}\}$, and $\{R_{zi}\}$, expressions for the spatial derivative of the interpolation function and weighting function are necessary. The chain rule:

$$\begin{pmatrix} \frac{\partial}{\partial \xi} \\ \frac{\partial}{\partial \eta} \end{pmatrix} = [J] \begin{pmatrix} \frac{\partial}{\partial x} \\ \frac{\partial}{\partial z} \end{pmatrix}, \quad (37)$$

may be inverted to yield

$$\begin{pmatrix} \frac{\partial}{\partial x} \\ \frac{\partial}{\partial z} \end{pmatrix} = \frac{1}{J} \cdot \begin{bmatrix} \frac{\partial z}{\partial \eta} & - \frac{\partial z}{\partial \xi} \\ \frac{\partial x}{\partial \eta} & \frac{\partial x}{\partial \xi} \end{bmatrix} \begin{pmatrix} \frac{\partial}{\partial \xi} \\ \frac{\partial}{\partial \eta} \end{pmatrix}, \quad (38)$$

using the definition of $[J]$ in Eq. (29).

When the top row of Eq. (38) is applied to the base function, N_i , the following is obtained:

$$\frac{\partial N_i}{\partial x} = \frac{1}{J} \left[\left(z_j \frac{\partial N_j}{\partial \eta} \right) \cdot \frac{\partial N_i}{\partial \xi} - \left(z_j \frac{\partial N_j}{\partial \xi} \right) \cdot \frac{\partial N_i}{\partial \eta} \right]. \quad (39)$$

Similarly,

$$\frac{\partial N_i}{\partial z} = \frac{1}{J} \left[\left(x_j \frac{\partial N_j}{\partial \eta} \right) \cdot \frac{\partial N_i}{\partial \xi} + \left(x_j \frac{\partial N_j}{\partial \xi} \right) \cdot \frac{\partial N_i}{\partial \eta} \right]. \quad (40)$$

Equations (39) and (40) are in a form suitable for numerical integration. The derivatives of N_i with respect to ξ and η can be obtained by the partial derivation of Eq. (27).

5. Assembly of the Element Matrix

Equation (26) is evaluated for each element, and the direct stiff method is adopted to assemble the terms to form a system of algebraic equations as:

$$[T_{ij}] \{h_j\} = \{X_i\} - \{B_i\} = \{Y_i\}, \quad (41)$$

where $[T_{ij}]$ is the global coefficient matrix and $\{Y_i\}$ is the global load vector. The detailed discussion of the assembly of the element

matrix into a global matrix has been presented (Desai and Abel 1972, Reeves and Duguid 1975).

6. Application of Boundary Conditions

Surfaces on which the Neumann-type boundary conditions, Eqs. (4) or (6), are imposed yield pressure-independent entries in the element column matrix $\{Q_i\}$. These entries are evaluated by direct application of substituting Eqs. (4) or (6) into Eq. (15) to yield element normal fluxes. This is followed by assembling over all boundary elements having one or more sides on the boundaries B_2 or B_3 of B to yield a global column matrix $\{B_i\}$. The results are subtracted from the $\{X_i\}$ to form $\{Y_i\}$.

At nodes where Dirichlet boundary conditions are applied, an identity equation is generated for each node and included in the matrices of Eq. (41). The detailed method of applying this type of boundary conditions can be found elsewhere (Wang and Connor 1975). Computationally, this is done as shown in Fig. 3. If the k -th variable is prescribed, the k -th column in the coefficient matrix, $[T_{ij}]$, is stored. The k -th row and column in $[T_{ij}]$ are set to zero and the diagonal entry set equal to one. The stored column matrix is multiplied by the prescribed value of Y^* and subtracted from the right-hand side of Eq. (41). This procedure effectively replaces the k -th equation by the prescribed constraint.

7. Solution of the Assembled Equations

In solving the assembled equations expressed in Eq. (41), the matrix $[T_{ij}]$ is decomposed into the product of upper and lower

$$\begin{bmatrix}
 T_{11} & \dots & T_{1,k-1} & 0 & T_{1,k+1} & \dots & T_{1n} \\
 \cdot & & \cdot & \cdot & \cdot & & \cdot \\
 \cdot & & \cdot & \cdot & \cdot & & \cdot \\
 \cdot & & \cdot & \cdot & \cdot & & \cdot \\
 T_{k-1,1} & \dots & T_{k-1,k-1} & 0 & T_{k-1,k+1} & \dots & T_{k-1,n} \\
 0 & \dots & 0 & 1 & 0 & \dots & 0 \\
 T_{k+1,1} & \dots & T_{k+1,k-1} & 0 & T_{k+1,k+1} & \dots & T_{k+1,n} \\
 \cdot & & \cdot & \cdot & \cdot & & \cdot \\
 \cdot & & \cdot & \cdot & \cdot & & \cdot \\
 \cdot & & \cdot & \cdot & \cdot & & \cdot \\
 T_{n,1} & \dots & T_{n,k-1} & 0 & T_{n,k+1} & \dots & T_{nn}
 \end{bmatrix}
 \begin{Bmatrix}
 h_1 \\
 \cdot \\
 \cdot \\
 \cdot \\
 h_{k-1} \\
 h_k \\
 h_{k+1} \\
 \cdot \\
 \cdot \\
 \cdot \\
 h_n
 \end{Bmatrix}
 =
 \begin{Bmatrix}
 y_1 \\
 \cdot \\
 \cdot \\
 \cdot \\
 y_{k-1} \\
 0 \\
 y_{k+1} \\
 \cdot \\
 \cdot \\
 \cdot \\
 y_n
 \end{Bmatrix}$$

$$- \begin{bmatrix}
 0 & \dots & 0 & T_{1k} & 0 & \dots & 0 \\
 \cdot & & \cdot & \cdot & \cdot & & \cdot \\
 \cdot & & \cdot & \cdot & \cdot & & \cdot \\
 \cdot & & \cdot & \cdot & \cdot & & \cdot \\
 0 & \dots & 0 & T_{k-1,k} & 0 & \dots & 0 \\
 0 & \dots & 0 & -1 & 0 & \dots & 0 \\
 0 & \dots & 0 & T_{k+1,k} & 0 & \dots & 0 \\
 \cdot & & \cdot & \cdot & \cdot & & \cdot \\
 \cdot & & \cdot & \cdot & \cdot & & \cdot \\
 \cdot & & \cdot & \cdot & \cdot & & \cdot \\
 0 & \dots & 0 & T_{nk} & 0 & \dots & 0
 \end{bmatrix}
 \begin{Bmatrix}
 0 \\
 \cdot \\
 \cdot \\
 \cdot \\
 0 \\
 y^* \\
 0 \\
 \cdot \\
 \cdot \\
 \cdot \\
 0
 \end{Bmatrix}$$

Fig. 3. Application of Dirichlet boundary conditions.

triangular matrices using the Crout-Dolittle method. The lower triangular matrix is used to modify the right-hand side $\{Y_i\}$ for back-substitution into the upper triangular matrix to obtain a solution. If the matrix $[T_{ij}]$ and the time step, Δt , do not significantly change with time, the decomposition needs to be performed only once, and iteration is unnecessary. Typically in the unsaturated soil-moisture zone such a time-saving device cannot be used and decomposition is necessary for each time step and each iteration.

8. Mass Balance Computation

The mass balance over the whole region of interest is obtained by integrating Eq. (1):

$$\int_R F \frac{\partial h}{\partial t} dR = \int_B F_n dB, \quad (42)$$

where F_n is the normal flux through the global boundary $B(x,z) = 0$.

In fact, F_n denotes:

$$F_n = \left[(K_{xy} \frac{\partial h}{\partial x} + K_{xz} \frac{\partial h}{\partial z} + K_{xz}) \cdot n_x + (K_{zx} \frac{\partial h}{\partial x} + K_{zz} \frac{\partial h}{\partial z} + K_{zz}) \cdot n_z \right]. \quad (43)$$

Having obtained the pressure-head field, h , one could integrate the right- and left-hand sides of Eq. (42) independently. If the solution for h is free of error, one would expect the equality of two integrals. In the present report, the integral of the right-hand side is broken into several components:

$$F_D = \int_{B_1} F_n dB, \quad (44)$$

$$F_N = \int_{B_2} F_n dB, \quad (45)$$

$$F_S = \int_{B_{3S}} F_n dB, \quad (46)$$

$$F_R = \int_{B_{3R}} F_n dB, \text{ and} \quad (47)$$

$$F_I = \int_{B_I} F_n dB, \quad (48)$$

where F_D , F_N , F_S , F_R , and F_I represent the fluxes through the constant Dirichlet boundary, B_1 ; the constant Neumann boundary, B_2 ; the seepage boundary, B_{3S} ; the rainfall-infiltration boundary, B_{3R} ; and the impervious Neumann boundary, B_I ; respectively. On the other hand, the integral on the left-hand side of Eq. (42),

$$F_V = \int_R F \frac{\partial h}{\partial t} dR, \quad (49)$$

represents the volumetric increasing rate of the moisture content in the region. In the model developed earlier (Reeves and Duguid 1975), this term was evaluated by

$$F_V = \int_R \frac{\partial \theta}{\partial t} dR, \quad (50)$$

For exact solution, the net flux across the whole boundary, $B(x,z) = 0$, defined by

$$F_{\text{net}} = F_D + F_N + F_S + F_R + F_I \quad , \quad (51)$$

should satisfy the following equation

$$F_{\text{net}} = F_V \quad . \quad (52)$$

In addition, F_I should theoretically be equal to zero. However, in any practical numerical simulation, Eq. (52) will not be satisfied and F_I will be non-zero. Nevertheless, the mass balance computation should provide a means to check the numerical scheme and the consistence in computer code.

9. Numerical Treatment of Nonlinear Terms

In computing the element matrices, nonlinear terms as function of pressure head, h , are encountered. Take for example, the following equation:

$$M_{ij} = \int_{R_e} N_i F N_j \, dR \quad , \quad (53)$$

where F is, of course, a function of h , i.e., $F = F(h)$.

Reeves and Duguid (1975) adopted the following approximation for F as

$$F(x,y) \approx \sum_{i=1}^4 F_i N_i (\xi, \eta) \quad , \quad (54)$$

where F_i is the value of F at nodal point i and was evaluated by $F_i = F(h_i)$. This approach will yield large error when the variation of F with h is rapid unless the element size is set very small. A consistent approach should be:

$$F(x,y) \approx F \left(\sum_{i=1}^4 h_i N_i (\xi, \eta) \right) . \quad (55)$$

In our revised model we have employed the approach shown in Eq. (55) whenever nonlinear terms are encountered. It is worth noting that the nodal values of h should be used to interpolate for the field values of h . The field values of any other h -dependent variables may then be computed as a function of h . Nodal values of h -dependent variables, computed by the nodal values of h , cannot be used to interpolate for the field values of such variables without risk of significant error.

10. Alternative Numerical Schemes

To conclude this chapter, Table 1 lists six alternative numerical schemes used in this report. They are dependent on the method of time-marching and the treatment of mass matrix. For example, scheme 1 uses the central difference time-marching with no lumping on the mass matrix.

Table 1. Listing of alternative numerical schemes

	Time-marching			Mass matrix	
	Central	Backward	Mid-difference	No lumping	Lumping
1	X			X	
2		X		X	
3	X				X
4		X			X
5			X	X	
6			X		X

III. COMPUTER PROGRAM MODIFICATION AND EXPANSION

The overall program organization is shown in Fig. 4a and b. Except for the name of subroutines, the original computer code (Reeves and Duguid 1975) has been almost completely overhauled. The overhaul is necessary to accomplish: (1) the application of the finite-element method to the Darcy's law, (2) the provision of six alternative numerical schemes, (3) the modification of computing the volumetric integral of the moisture-content changing rate, (4) the computation of nonlinear terms, (5) the reduction of storage by compressing all arrays of the boundary variables, and (6) the adoption of variable array in all subroutines.

A short main program is written to dimensionalize and initialize all arrays and to specify the maximum dimension in each of the arrays. The program is then passed to the subroutine, GW2DXZ, which was the main program in the computer code developed earlier (Reeves and Duguid 1975).

Subroutine DATAIN has been substantially reduced by getting rid of the duplication of codes that serve to read the steady state and transient boundary conditions. The compression of the arrays, specifying seepage-rainfall, Dirichlet boundary, and surface source term (or Neumann boundary) conditions, has been carried out also in the subroutine DATAIN. The compression of boundary elements and nodes is performed in the subroutine SURF.

The subroutines VELT and Q4D have been rewritten. VELT in the revised model is used to sum over the element matrix $[S_{ij}]$, and

(a)

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(b)

ORNL-DWG 79-13048

ORNL-5567

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Fig. 4. (a) Subroutine chart of the computer code, (b) Nonlinearity and rainfall-seepage iteration loops in FEOWATER computer code.

element load vectors $\{D_{xi}\}$ and $\{D_{zi}\}$, to form a global system of algebraic equations governing the velocity components, V_x and V_z , respectively. The subroutine subsequently calls BANSOL to yield the solution. Q4D is called by VELT to evaluate the element matrix $[S'_{ij}]$ and element load vectors $\{D_{xi}\}$ and $\{D_{zi}\}$. The computed continuous velocity is then returned to the calling subroutine GW2DXZ through the argument. This velocity field is then passed to the subroutine BCPREP to evaluate the Darcy's flux across the seepage-rainfall surface to ascertain the changing boundary conditions. BCPREP and SFLOW no longer call Q4S to calculate the velocity at the Gaussian point on the element boundary for obtaining the flux across the boundary surfaces. Instead, the velocity at Gaussian points is computed from the velocity field at nodal points by interpolation according to the principle of the finite-element method.

The subroutine ASSEMBL was modified to incorporate the mid-difference options and a new subroutine BASE was programmed to evaluate the basis functions at Gaussian point. The subroutine BASE was called by the subroutines, Q4, Q4D, and Q4TH. The options of lumping or no-lumping were decided in the subroutine Q4. Subroutine BC is the one with least change. It is altered only to accommodate the variable arrays. The standard subroutine, BANSOL, remains intact.

Subroutines SFLOW and Q4TH were changed to compute the new way of evaluating the volumetric integral of moisture-content changing rate. It will be seen that the new method better preserves the conservation of mass. Subroutines PRINTT and STORE are modified for better display

on printout and selectively storing the dynamic variables and additional information of boundary elements and nodes on Disk Unit 2. To store the information of boundary elements and nodes eliminates the need for the subroutine SURF in the new waste transport model (Yeh and Ward 1979).

IV. RESULTS

Two sample problems are made to compare the results from the original model (Reeves and Duguid 1975) and the revised model. The first example is the seepage pond problem described in ORNL-4928 (Duguid and Reeves 1976). The second one is the Freeze's transient problem reported in ORNL-4927 (Reeves and Duguid 1975). In addition, results by all six alternative numerical schemes are compared in both examples.

1. Seepage Pond Problem

A seepage pond is assumed to situate entirely in the unsaturated zone above the water table. This pond provides a source of water which infiltrates into the subsurface aquifers. After the water reaches the water table, it flows toward a stream (Fig. 5). It is further assumed that the system is composed of a highly permeable sand with soil properties shown in Fig. 6. For the finite-element computation, the entire region is discretized by 595 nodal points and 528 elements (Fig. 5). Seven nodal points on the stream-soil interface are designated as Dirichlet nodes (Fig. 5). Seven nodal points on the bottom of the seepage pond, namely, nodal point nos. 152, 164, 172, 180, 188, 196, and 207, are considered as constant Neuman flux points and are assigned a constant infiltration rate of 4.0×10^{-4} cm/sec. The top sides of all elements on the sloping surface, except the two elements immediately to the right of the seepage pond, are considered the seepage-rainfall boundary surface. In other words, the nodal points

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Fig. 5. Spatial discretization of the seepage pond problem.

Fig. 6. Hydraulic conductivity and soil-moisture characteristics of a hypothetical sandy soil.

on this surface are either Dirichlet or Neumann points with the infiltration rate equal to the excess rainfall rate.

Figures 7a-d show the Darcy's velocity vector plot and the distribution of pressure head, total head, and moisture content as simulated by the original model (Reeves and Duguid 1975). Figures 8a-d depict those simulated by the present revised model. It is seen that two models yield almost identical results in pressure head, total head, and moisture content. However, the velocity field computed by the original code shows the discontinuity at every nodal point as can be seen from Fig. 7a, which illustrates the nonunique velocity vector at all nodal points. The severity of the discontinuity depends on the location ranging from several hundred percent to negligible. This discontinuity is completely eliminated with the revised model as can be seen from Fig. 8a. Figure 8a shows the unique velocity vector at all nodal points. Table 2 shows the comparison of the computed Darcy's velocity components simulated by the original and the revised models, respectively, for three selective nodal points. These three sample points are taken randomly from computer output to illustrate the difference when two codes are used. It is seen that at nodal point no. 2, the vertical velocity component as computed from element no. 2 is about 2.58 times that computed from element no. 1. The values of the horizontal component, V_x , at nodal point no. 179 as computed from element nos. 159 and 160 are about 1.41 times those computed from element nos. 152 and 153; while the values of the vertical component, V_z , at the same point as computed from element nos. 153 and 160 are about 4.69 times those computed from element nos. 152 and 159. At nodal

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(a) VELOCITY VECTOR PLOT

(b) DISTRIBUTION OF PRESSURE HEAD

(c) DISTRIBUTION OF TOTAL HEAD

Fig. 7. Flow variables of seepage pond as simulated by Reeves and Duguid model: (a) velocity vector plot, (b) distribution of pressure head, (c) distribution of total head, (d) distribution of moisture content.

ORNL-DWG 79-13060

(a) VELOCITY VECTOR PLOT

(b) DISTRIBUTION OF PRESSURE HEAD

Fig. 8. Flow variables of seepage pond as simulated by present model: (a) velocity vector plot, (b) distribution of pressure head, (c) distribution of total head, (d) distribution of moisture content.

Table 2. Comparison of velocity components simulated by the original and revised codes, respectively, at selected points

Node no.	Element no.	Original code		Revised code	
		V_x (cm s ⁻¹)	V_z (cm s ⁻¹)	V_x (cm s ⁻¹)	V_z (cm s ⁻¹)
2	1	2.33E-8	-2.53E-8	1.24E-8	-4.44E-8
	2	2.33E-8	-6.54E-8	1.24E-8	-4.44E-8
	152	2.26E-5	-9.15E-5	3.03E-5	-2.94E-4
179	153	2.26E-5	-4.31E-4	3.03E-5	-2.94E-4
	159	3.31E-5	-9.15E-5	3.03E-5	-2.94E-4
	160	3.31E-5	-4.31E-4	3.03E-5	-2.94E-4
587	521	6.28E-5	1.85E-4	1.23E-5	1.84E-4
	522	6.28E-5	2.36E-4	1.23E-5	1.84E-4
	528	7.89E-10	1.85E-4	1.23E-5	1.84E-4

point no. 587, the vertical velocity component, V_z , as computed from element no. 522 is about 1.27 times that computed from element nos. 521 and 528. On the other hand, results from the revised model show that the values of velocity components are identical at the same point, which is the case one should expect. Fig. 8 is the plot of computer output with numerical scheme no. 2. Since the steady state solution is sought, numerical scheme nos. 1, 3, 4, 5, and 6 yield identical results as expected.

2. Freeze Transient Problem

A very small laboratory-sized watershed measuring 6 x 3 m was presented by Freeze (1972) to test his finite-difference computer code. The same watershed was also used by Reeves and Duguid (1975) to debug and test their finite-element model. This watershed is again employed in the present report to compare our revised finite-element model with the Reeves and Duguid's original model (1975).

The flow system is shown in Fig. 9. It is composed of highly permeable sand, the unsaturated properties of which were shown in Fig. 6. To obtain initial conditions, pressure-head values were prescribed along the stream channel, part of the slope, and the upper plateau. Taking all other boundaries to be impermeable, a steady state solution was determined which was the initial condition for the transient calculation.

Using Freeze's transient boundary condition (Fig. 9b) and Reeves and Duguid's finite-element discretization #2 (Fig. 9c), selected results obtained by the original and revised models are presented in Figs. 10 and 11, respectively. Again, almost identical pressure head, total head, and moisture-content distributions are obtained. However, the original model again displays the discontinuity of velocity vector at all nodal points, while our revised model has completely eliminated this inconsistency. Furthermore, Table 3 shows that the mass balance has not been satisfied by the original model. At the end of about a 3-hr simulation time, the total net mass through all boundaries is only about 76.2% of the mass accumulated in the media as computed by numerical scheme 1 of the original code. In other words, a 23.8% of

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(a) STEADY STATE
BOUNDARY CONDITIONS (b) TRANSIENT BOUNDARY
CONDITIONS (c) SPATIAL MESH
DISCRETIZATION

Fig. 9. Configuration of water transport in Freeze's experimental watershed; (a) steady state boundary condition, (b) transient boundary condition, (c) spatial mesh discretization

(a) VELOCITY VECTOR PLOT

(b) DISTRIBUTION OF PRESSURE HEAD

(c) DISTRIBUTION OF TOTAL HEAD

Fig. 10. Flow variables at time equal to 2.96 hr of Freeze's transient problem as simulated by Reeves and Duguid model: (a) velocity vector plot, (b) distribution of pressure head, (c) distribution of total head, (d) distribution of moisture content

(a) VELOCITY VECTOR PLOT

(b) DISTRIBUTION OF PRESSURE HEAD

(c) DISTRIBUTION OF TOTAL HEAD

- 150 cm
- 200 cm
- ▲ 250 cm
- ♦ 290 cm

Fig. 11. Flow variables at time equal to 2.96 hr of Freeze's transient problem as simulated by Yeh and Ward model: (a) velocity vector plot, (b) distribution of pressure head, (c) distribution of total head, (d) distribution of moisture content.

Table 3. Comparison of percentage of mass loss of Freeze's transient problem as simulated by the original and revised model

Code/Schemes	1	2	3	4	5	6
Old	23.8	29.7	N/A ^a	N/A	N/A	N/A
Revised	2.2	-3.6	8.9	3.0	-3.2	-3.3

^aN/A = not available.

mass has not been accounted for, i.e., has been lost through boundaries. Reeves and Duguid (1975) speculated that this large loss of mass might be eliminated by adding the triangular elements. However, without using triangular elements, our revised model only yields 2.2% of mass loss by eliminating the discontinuity of the velocity and by using a new method to evaluate a moisture-increasing rate in the region. An even larger mass loss of 29.7% is obtained by numerical scheme 2 of the original model. The revised model on the other hand renders a 3.6% of mass gain. Thus, the error of mass balance (positive for loss, negative for gain) by the revised model is much smaller than that by the original model.

Table 3 also shows the percentage of mass loss by all alternative numerical schemes. It is noted that the central difference standard Galerkin scheme in the revised model yields the best results. This is not surprising since the water transport equation does not contain advection (convection) terms. Figures 12 through 14 show the plots of flow variables as simulated by numerical scheme 1 of the revised model at time equal to 0.00 hr, 0.46 hr, and 1.85 hr, respectively. They

Fig. 12. Flow variables of Freeze's transient problem at time equal to 0.00 hr: (a) velocity vector plot, (b) distribution of pressure head, (c) distribution of total head, (d) distribution of moisture content.

Fig. 13. Flow variables of Freeze's transient problem at time equal to 0.46 hr: (a) velocity vector plot, (b) distribution of pressure head, (c) distribution of total head, (d) distribution of moisture content.

Fig. 14. Flow variables of Freeze's transient problem at time equal to 1.85 hr: (a) velocity vector plot, (b) distribution of pressure head, (c) distribution of total head, (d) distribution of moisture content.

show that the experimental watershed has been first gradually drained and then progressively wetted by the rainfall. Computer outputs on flow variables by all other alternative schemes show that comparable values are obtained at long simulation times.

To conclude this chapter, we state that the revised model (1) yields a continuous velocity field, (2) reduces mass loss through boundaries to as small as possible, and (3) provides four additional alternative numerical schemes, all of which are operational and render comparable results.

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VI. GLOSSARY OF NOTATIONS

B	Boundary line
B_1, B_2, B_3	Segments of boundary line
$\{B_i\}$	Global column matrix, the assembly of element column matrix, $\{Q_i\}$
$[C_{ij}]$	Element matrix whose component C_{ij} is defined by Eq. (24a)
$\{D_i\}$	An element column matrix whose component D_i is defined by Eq. (14)
$\{D_{xi}\}$	An element column matrix, whose component D_{xi} is defined by Eq. (19)
$\{D_{zi}\}$	An element column matrix, whose component D_{zi} is defined by Eq. (20)
e	Reference to the e-th element
F	Generalized storage coefficient
h	Pressure head
$\hat{h}$	Approximate pressure head
$\{h_j\}$	Pressure head column matrix
$\{\dot{h}_j\}$	Time derivative of $\{h_j\}$
h_0	Initial pressure head
h_1	Prescribed pressure head at Dirichlet boundary nodes
h_3	Prescribed pressure head at the rainfall-seepage boundary nodes
H	Total head
J	Determinant of $[J]$
$[J]$	Jacobian matrix for the e-th element
$K_{xx}, K_{xz}, K_{zx}, K_{zz}$	Tensor components of the hydraulic conductivity
L	Differential operator

$[M_{ij}]$	Element mass matrix, whose component M_{ij} is defined by Eq. (12)
n	Porosity
n_x	Directional cosine with the x-axis of a boundary line
n_z	Directional cosine with the y-axis of a boundary line
N_i, N_j	Basis functions
q_2	Prescribed fluxes on the Newman boundary segment
q_3	Prescribed fluxes on the rainfall-seepage boundary segment
Q	Withdrawal rate
$\{Q_i\}$	An element column matrix, whose component Q_i is defined by Eq. (15)
R	A region
R_e	An element region
$\{R_i\}$	A column matrix defined by Eq. (24c)
$[S_{ij}]$	The element stiff matrix, whose component S_{ij} is defined by Eq. (13)
$[S'_{ij}]$	The element stiff matrix, whose component S'_{ij} is defined by Eq. (18)
t	Time
Δt	Time step
$[T_{ij}]$	Global coefficient matrix
V_x	Darcy velocity component in the x-direction
V_z	Darcy velocity component in the z-direction
x	Global coordinate in the horizontal direction
x_i, x_j	The global x-coordinate of nodal points, i and j
$\{Y_i\}$	Global column matrix

z	Global coordinate in the vertical direction
z_i, z_j	The global/z-coordinate of nodal points, i and j
α'	Modified coefficient of compressibility of the medium
β'	Modified coefficient of compressibility of water
θ	Moisture content
ξ	Local coordinate in the horizontal direction
ξ_i	Local ξ -coordinate of the point i
η	Local coordinate in the vertical coordinate
η_i	Local η -coordinate of the nodal point, i

APPENDIX A
DATA INPUT GUIDE

APPENDIX A:
DATA INPUT GUIDE

Data Set 1 - General Information Card.

This card is used to identify the job and to indicate if the diagnostic output is required. Only one card is required.

Card 1	Format (15, 9A2, 1X, 211)
NPROB	Problem Number
TITLE	Array for the title of the problems
IBUG	An integer indicating if the diagnostic information of iteration is to be line-printed, = 0 no, = 1 yes
ICHNG	An integer indicating if the boundary-condition-changing information is to be line-printed, = 0 no, = 1 yes

Data Set 2 - Basic Integer Parameters

Only two cards are required per problem.

Card 1	Format (16 I 5)
NNP	Number of nodal points
NEL	Number of elements
NMAT	Number of different materials
NCM	Number of elements with material properties to be corrected
NTI	Number of time increments
KSS	Steady state control; 0 = steady state solution, 1 = transient solution
KSP	Soil property control; 0 = analytical function, 1 = tabular data
NSPPM	Number of points in tabular soil property definition, or number of soil property parameters to describe the analytical function
NSTR	Auxiliary storage control; 0 = no storage, 1 = output stored (disk or tape)

KCP	Conductivity control; 0 = conductivity input, 1 = permeability input
KGRAV	Gravity control; 0 = gravity term included, 1 = omission of gravity term
NSTRT	Number of logical records to be read from auxiliary storage for restarting calculation; 0 = no restart
MAXIT	Maximum number of iterations per time step
MAXCY	Maximum number of cycles for rainfall - seepage boundary condition adjustments
NMPPM	Number of material parameter per material
Card 2	Format (16 Z 5)
ILUMP	Matrix lumping control; 0 = no lumping, 1 = matrix lumped
IMID	Mid-difference time derivative control; 0 = Crank-Nicolson or backward difference, 1 = mid-difference

Data Set 3 - Basic Real Parameters

Two cards are required for each problem

Card 1	Format (8 F 10.0)
DELT	Time increment
CHNG	Multiplier for increasing time increment
DELMAX	Maximum value of DELT
TMAX	Value of maximum simulation time
FE	Angle between coordinate axes and principal directions of conductivity tensor in degrees
TOLA	Steady-state convergence criteria
TOLB	Transient-state convergence criteria
RHO	Density of water
Card 2	Format (8 F 10.0)
GRAV	Acceleration of gravity

VISC Dynamic viscosity of water

W Time derivative weighting; 0.5 = Crank-Nicolson,
1.0 = backward

Data Set 4 - Output Control

Two group of cards are required. One group is for printer output control and the other for auxiliary storage output control. The number of cards in each group is determined by the number of time increments, NTI, i.e., No. of Cards, NGD = $(NTI + 1)/80 + 1$

Card Group 1 Format (80 I 1)

KPRO Printer control for steady-state and initial conditions; 0 = No printout, 1 = FLOW, FRATE, TFLOW only, 2 = above (0) plus H, 3 = above (2) plus HT, 4 = above (3) plus TH, 5 = above (4) plus VX, VZ

KPR(1) Printer control for transient selection similar to KPRO

KPR(NTI) as a function of time index ITM

Card Group 2 Format (80 I 1)

KDSKO Auxiliary storage control; 0 = no auxiliary storage, 1 = yes

KDSK(1)
KDSK(NTI) Auxiliary storage control for transient solution similar to KDSKO as a function of time index ITM

Data Set 5 - Material Properties

A total of NMAT groups of cards are required. One group for each material. The number of cards in each group depends on NMPPM, i.e., the No. of cards, NOCD = $(NMPPM)/8 + 1$

Card Group J

PROP(J,1) Modified coefficient of compressibility of media, J

PROP(J,2) Modified coefficient of compressibility of water

PROP(J,3) Porosity of porous media, J

PROP(J,4) Component of conductivity in the x-direction for media, J

PROP(J,5) Component of conductivity in the z-direction for media, J

Data Set 6 - Analytical Soil Parameters

Input cards for this data set are needed if and only if $KSP = 0$. Two sets of cards are required, one for the moisture-content parameters and the other for the conductivity (permeability) parameters. Each set of cards consist of NMAT groups of cards, one group for each material. The number of cards in each group is determined by the number of soil property parameters per material, NSPPM. $NOCD = (NSPPM/8) + 1$

Card Set 1 This set of cards is for THPROP(I,J)

Card Group 1 Format (8 F 10.0)

THPROP(1,1) Analytical moisture content parameter 1 of material 1

THPROP(1,2) Analytical moisture content parameter 2 of material 1

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· ·
· ·

THPROP(1,NSPPM) Analytical moisture content parameter NSPPM of material 1
NOCD cards are required for this Card Group

Card Group 2 Format (8 F 10.0)

THPROP (2,1) Analytical moisture content parameter of material 2

THPROP (2,2) Analytical moisture content parameter of material 2

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THPROP(2,NSPPM) Analytical moisture content parameter NSPPM of material 2

NOCD cards are required for this Card Group

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Card Group NMAT FORMAT (8F10.0)

Total number of cards = NMAT * NOCD

Card Set 2: This set of cards is for ARPROP(I,J)

Card Group 1 Format (9F10.0) = for material 1

AKPROP(1,1) Analytical conductivity parameter 1 of material 1

AKPROP(1,2) Analytical conductivity parameter 2 of material 1

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AKPROP(1,NSPPM) Analytical conductivity parameter NSPPM of material 1.
NOCD cards are required for this Card Group

Card Group 2 Format (8F10.0) = for material 2

AKPROP(2,1) Analytical conductivity parameter 1 of material 2

AKPROP(2,2) Analytical conductivity parameter 2 of material 2

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AKPROP(2,NSPPM) Analytical conductivity parameter NSPPM of material 2
NOCD cards are required for this Card Group

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Card Group NMAT Format (8F10.0) for material NMAT

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Total number of cards = NMAT * NOCD

Input cards for this data set are needed if and only if KSP $\neq$ 0. Four sets of cards are required, one for pressure, HPROP, one for water content, THPROP, one for conductivity (permeability), AKPROP, and one for water capacity, CAPROP. Each set of cards consist of NMAT groups of cards, one group for each material. The number of cards in each group is determined by the number of soil property data permit per material, NSPPM. $NOC = (NSPPM/8) + 1$

Card Group 1 Format (8F10.0)

HPROP(1,2) 2nd point of the tabular pressure for material 1

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Card Group 2 Format (8F10.0)

HPROP(2,2) 2nd point of the tabular pressure for material 2

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Total number of cards for this card set = NMAT ≠ NOCD

Card Set 2: This set of cards is for THPROP(I,J)

Card Group 1 Format (8F10.0)

THPROP(1,1) 1st point of the tabular moisture-content for material 1

THPROP(1,2) 2nd point of the tabular moisture-content for material 1

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THPROP(1,NSPPM) NSPPM-th point of the tabular moisture-content for material 1. NOCD cards are required for this Card Group

Card Group 2 Format (8F10.0)

THPROP(2,1) 1st point of the tabular moisture-content for material 2

THPROP(2,2) 2nd point of the tabular moisture-content for material 2

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THPROP(2,NSPPM) NSPPM-th point of the tabular moisture-content for material 2. NOCD cards are required for this Card Group

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Card Group NMAT Format (8F10.0)

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Total number of cards for this card set = NMAT * NOCD

Card Set 3: This set of cards is for AKPROP(I,J)

Card Group 1 Format (8F10.0)

AKPROP(1,1) 1st tabular value of conductivity for material 1

AKPROP(1,2) 2nd tabular value of conductivity for material 1

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AKPROP(1,NSPPM) NSPPM-th tabular value of conductivity for material 1.
NOCD cards are required for this Card Group

Card Group 2 Format (8F10.0)

AKPROP(2,1) 1st tabular value of conductivity for material 2

AKPROP(2,2) 2nd tabular value of conductivity for material 2

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AKPROP(2,NSPPM) NSPPM-th tabular value of conductivity for
material 2. NOCD cards are required for this Card
Group

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Card Group NMAT Format (8F10.0)

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Total number of cards for this card set = NMAT * NOCD

Card Set 4: This set of cards is for CAPROP(I,J)

Card Group 1 Format (8F10.0)

CAPROP(1,1) 1st tabular value of water capacity for material 1

CAPROP(1,2) 2nd tabular value of water capacity for material 1

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CAPROP(1,NSPPM) NSPPM-th tabular value of conductivity for material 1.
NOCD cards are required for this Card Group

Card Group 2 Format (8F10.0)

CAPROP(2,1) 1st tabular value of water capacity for material 2

CAPROP(2,2) 2nd tabular value of water capacity for material 2

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CAPROP(2,NSPPM) NSPPM-th tabular value of water capacity for
material 2. NOCD cards are required for this Card
Group

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Card Group NMAT Format (8F10.0)

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Total number of cards for this card set = NMAT * NOCD

Data Set 8 - Nodal Point Coordinates

Usually one card per node is needed, i.e., a total of NNP cards. However, if some nodes fall on a straight line and are equidistant, data for only the first and last points of this data set are needed. Intermediate nodal positions are automatically generated by linear interpolation.

Card 1 Format (I5, 2F10.3)

NJ Node number

X(NJ) X-coordinate of node NJ

Z(NJ) Z-coordinate of node NJ

Card 2 Format (I2, 2F10.3)

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Data Set 9 - Element incidences.

Usually one card per element is needed, i.e., a total of NEL cards. However, for a rectangular blocks of elements, it is only necessary to specify the first element, the width and length of the block. The subsequent elements to the first one in the block will be generated automatically.

Card 1 Format (16I5)

MI Element number

IE(MI,1)	{	Node numbers of element MI beginning with lower left and progressing around element in counter clockwise direction
IE(MI,2)		
IE(MI,3)		
IE(MI,4)		

IE(MI,5) Material type of element MI

MODL Number of elements in width of a block

NLAY Number of elements in length of a block

Card 2 Format (16I5)

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Data Set 10 - Material Corrections

Usually, one card is required per material change. However, in those cases where numbers of the affected elements range from a lower limit of MI to an upper limit of MK with an increment MINC, automatic correction may be used. Fields MK and MINC are left blank if the automatic-generation facility is not used.

Card 1 Format (16I5)

MI Material correction element number

MTYP Type of material correction element

MK Upper limit of automatic correction

MINC Element Increment of automatic correction (MK = 0,
MINC = 0 for no automatically generated correction)

Card 2 Format (16I5)

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Data Set 11 - Initial or heinatial Pressure Head

The data set is necessary only if NSTRT = 0. In the most general case, one card per node is required, i.e., a total of NNT cards. Frequently, however, groups of neighboring nodal points NJ have identical values H(NJ). All gaps will be filled with value at lower bound of the gap.

Card 1 Format (I5, 5X, F10.0)

NJ Node number

H(NJ) Initial head for node NJ

Card 2 Format (I5, 5X, F10.0)

NJ Node number

H(NJ) Initial head for node NJ

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Card NNP

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Data Set 12 - Steady State Integer Parameters

One card is required for one problem. It is needed if and only if $KSS = 0$.

Card 1	Format (16I5)
NBC	Number of constant Dirichlet nodes
NST	Number of element-sides with Neumann conditions
NRFPR	Number of rainfall profiles
NRFPAR	Number of parameters in each rainfall profile
NRSEL	Number of rainfall-seepage elements
NRSN	Number of rainfall-seepage nodes

Data Set 13 - Steady State Rainfall Profiles

These cards are necessary if and only if the number of rainfall-seepage nodes, $NRSN > 0$ and the number of rainfall profiles $NRFPR > 0$. If $NRSN > 0$ and $NRFPR = 0$, a rainfall rate of zero is assumed.

The number of cards required will depend on both $NRFPR$ and $NRFPAR$, the number of parameters within each profile. $NRFPR$ sets of cards are required. Each set consists of two groups of cards, one for the rainfall occurring time and the other for the rainfall rate. The number of cards in each group, $NOCD = NRFPAR/8 + 1$

Card Set 1: This set of cards is for rainfall profile 1

Card Group 1 Format (8F10.0)

TRF(1,1) 1st point of time-occurring value for rainfall profile 1

TRF(1,2) 2nd point of time-occurring value for rainfall profile 1

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TRF(1,NRFPAR) NRFPAR-th point of time-occurring value for rainfall profile 1. NOCD cards are required for this Card Group

Card Group 2 Format (8F10.0)

RF(1,1) 1st point of time-occurring value for rainfall profile 1

RF(1,2) 2nd point of time-occurring value for rainfall profile 1

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RF(1,NRFPAR) NRFPAR-th point of time-occurring value for rainfall profile 1. NOCD cards are required for this Card Group

Card Set 2: This set of cards is for rainfall-profile 2

Card Group 1 Format (8F10.0)

TRF(2,1) 1st point of time-occurring value for rainfall profile 2

TRF(2,2) 2nd point of time-occurring value for rainfall profile 2

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TRF(2,NRFPAR) NRFPAR-th point of time-occurring value for rainfall profile 2. NOCD cards are required for this Card Group

Card Group 2 Format (8F10.0)

RF(2,1) 1st point of time-occurring value for rainfall profile 2

RF(2,2) 2nd point of time-occurring value for rainfall profile 2

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RF(2,NRFPAR) NRFPAR-th point of time-occurring value for rainfall profile 2. NOCD cards are required for this Card Group

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Card Set NRFPR: This set of cards is for rainfall-profile NRFPR

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Total number of cards for this data set = NRFPR * (2 * NOCD)

Data Set 14 - Steady-State Rainfall types and Ponding Depth

Card input is required if and only if $NRSN > 0$. Typically, one card is required per rainfall - see page node.

Card I	Format (3I5, 5X, 2F10.0)
NI	Node number of rainfall-seepage node
IRFTYP(NII)	Rainfall-type parameter used to identify the rainfall profile to be used at node NI
NPINC(NII)	Automatic generation increment
HCON(NII)	Ponding depth at node NI

Note: NII is the compressed index for node number NI. If $NPINC \neq 0$, automatic generation mechanism will be made. If the card immediately preceeding is for node, NJ, then nodes $NJ + NPINC$, $NJ + 2 * NPINC$, ..., NK will be given rainfall type $IRFTYP(NJ)$ and ponding depth $HCON(NJ)$, where NK is the largest integer in the above sequence that is less than the current nodal value NI.

Data Set 15 - Steady-state Rainfall-seepage Surface Elements

As in the previous two data set, input is necessary if and only if $NRSN > 0$. Typically one card is required for each side of each element on which the rainfall-seepage boundary condition is applied. However, automatic generation may be made similar to data set 14.

Card MP	Format (16I5)
NRSE(MP)	Element number of MP-th side
IS(MP,1)	Global node number of the first node of MP-th side
IS(MP,2)	Global node number of the second node of MP-th side
KINC	Automatic generation increments for NRSE and IS

Data Set 16 - Steady-state Dirichlet Pressure-type Boundary conditions

Input cards are required for this data set if and only if $NBC > 0$. Normally, one card is required for each node with Dirichlet boundary condition. However, automatic generation may be made, if applicable, similar to data set 14.

Card NPP	Format (2I5, 2F10.0)
NN(NPP)	Global node number of NPP-th Dirichlet node
NPINC	Automatic generation increment
BB(NPP)	Specified pressure head at NPP-th Dirichlet node

Data Set 17 - Steady-state Neumann flux-type Boundary Condition

Input cards for this set of data are required if and only if $NST > 0$. Usually a number of cards equal to NST must be used. However, automatic generation may be made, if applicable, similar to Data Set 15

Card MPP	Format (3I5, 5X, 2F10.0)
NI	First global node number of MPP-th element-side with Neumann flux-type Boundary condition
NJ	Second global node number of MPP-th element-side with Neumann flux-type Boundary condition
KINC	Automatic generation increment for NI and NJ
EI	Dot product of flux at NI with outwardly directed unit vector normal to the element side MPP
EJ	Dot product of flux at NJ with outwardly directed unit vector normal to the element side MPP

Data Set 18, Data Set 19, Data Set 20, Data Set 21, Data Set 22, and Data Set 23 are for transient simulation and are identical to Data Sets 12-17. Those data inputs are necessary only if $NTI > 0$. If $NTI = 0$, there will be no transient calculation, and transient-state boundary conditions are not necessary

Note: If $KSS = 0$ and $NTI = 0$, only steady-state solution is desired. If $KSS = 0$ and $NTI > 0$, both steady-state solution and transient-state simulation are desired and the steady-state solution is used as the initial condition of transient simulation. If $KSS = 1$ and $NTI > 0$, only transient solution is desired and the initial condition for the transient simulation must be inputted. The case of $KSS = 1$ and $NTI = 0$ is physically not possible and should be avoided.

APPENDIX B
SAMPLE INPUT OF SEEPAGE POND PROBLEM

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C
C ----- CARD GROUP 1  TITLE CARD
C 1273  WATER FLOW IN SATURATED-UNSATURATED AQUIFER FROM SEEPAGE POND      CARD 001
C
C ----- CARD GROUP 2  BASIC INTEGER PARAMETERS
C 595  528  1  0  0  0  1  15  1  1  0  0  20  15  5      CARD 002
C   0    0                                     CARD 003
C
C ----- CARD GROUP 3  BASIC REAL PARAMETERS
C 300.      .5      86400.  0.      0.      .31      .1      1.      CARD 004
C 980.6     .013     1.                                     CARD 005
C
C ----- CARD GROUP 4  PRINTER OUTPUT AND DISK STORE CONTROL
C 35
C 11
C                                     CARD 006
C                                     CARD 007
C
C ----- CARD GROUP 5  MATERIAL PROPERTIES
C 0.      0.      .3      .58E-7  .58E-7      CARD 008
C
C ----- CARD GROUP 6  ANALYTICAL SOIL PARAMETERS ARE NOT REQUIRED
C ----- SINCE KSP IS NOT EQUAL TO 0
C
C ----- CARD GROUP 7  SOIL PROPERTIES IN TABULAR FORM
C ----- PRESSURE HEAD DATA POINT
C -800.0  -400.  -200.  -175.  -150.  -125.  -100.  -62.5      CARD 009
C -50.0   -37.5  -25.   -12.5  0.    50.   100.   200.      CARD 010
C
C ----- MOISTURE-CONTENT DATA POINT
C .024    .032    .0425  .045    .050    .0525  .09    .21      CARD 011
C .25     .275    .285    .290    .2925  .2975  .2995  .3      CARD 012
C
C ----- RELATIVE HYDRAULIC CONDUCTIVITY DATA POINT
C .10057E-5 .11886E-5 .14857E-5 .16000E-5 .18286E-5 .21715E-5 .36555E-5 .91430E-5      CARD 013

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Appendix B (continued)

C	.10972E-4	.12114E-4	.12572E-4	.12800E-4	.13029E-4	.13237E-4	.13257E-4	CARD	014
C	-----	WATER CAPACITY (DTH/DH) DATA POINT							
C	0.20E-2	.52E-4	.10E-3	.20E-3	.50E-3	.12E-2	.32E-2	CARD	015
C		.80E-3	.40E-3	.20E-3	.10E-3	.15E-6	0.	CARD	016
C	-----	CARD GROUP 8 NODAL POINTS POSITION							
C	1	0.0	0.0	0.0	0.0	0.0	0.0	CARD	017
C	2	0.0	500.000	1000.000	1500.000	2000.000	2500.000	CARD	018
C	3	0.0	1000.000	1500.000	2000.000	2500.000	3000.000	CARD	019
C	4	0.0	1500.000	2000.000	2500.000	3000.000	3500.000	CARD	020
C	5	0.0	2000.000	2500.000	3000.000	3500.000	4000.000	CARD	021
C	6	0.0	2500.000	3000.000	3500.000	4000.000	4500.000	CARD	022
C	7	0.0	3000.000	3500.000	4000.000	4500.000	5000.000	CARD	023
C	8	0.0	3500.000	4000.000	4500.000	5000.000	5500.000	CARD	024
C	9	0.0	4000.000	4500.000	5000.000	5500.000	6000.000	CARD	025
C	10	0.0	4500.000	5000.000	5500.000	6000.000	6500.000	CARD	026
C	11	0.0	5000.000	5500.000	6000.000	6500.000	7000.000	CARD	027
C	12	0.0	5500.000	6000.000	6500.000	7000.000	7500.000	CARD	028
C	13	0.0	6000.000	6500.000	7000.000	7500.000	8000.000	CARD	029
C	14	0.0	6500.000	7000.000	7500.000	8000.000	8500.000	CARD	030
C	15	0.0	7000.000	7500.000	8000.000	8500.000	9000.000	CARD	031
C	16	0.0	7500.000	8000.000	8500.000	9000.000	9500.000	CARD	032
C	17	0.0	8000.000	8500.000	9000.000	9500.000	10000.000	CARD	033
C	18	0.0	8500.000	9000.000	9500.000	10000.000	10500.000	CARD	034
C	19	0.0	9000.000	9500.000	10000.000	10500.000	11000.000	CARD	035
C	20	0.0	9500.000	10000.000	10500.000	11000.000	11500.000	CARD	036
C	21	0.0	10000.000	10500.000	11000.000	11500.000	12000.000	CARD	037
C	22	0.0	10500.000	11000.000	11500.000	12000.000	12500.000	CARD	038
C	23	0.0	11000.000	11500.000	12000.000	12500.000	13000.000	CARD	039
C	24	0.0	11500.000	12000.000	12500.000	13000.000	13500.000	CARD	040
C	25	0.0	12000.000	12500.000	13000.000	13500.000	14000.000	CARD	041
C	26	0.0	12500.000	13000.000	13500.000	14000.000	14500.000	CARD	042
C	27	0.0	13000.000	13500.000	14000.000	14500.000	15000.000	CARD	043
C	28	0.0	13500.000	14000.000	14500.000	15000.000	15500.000	CARD	044
C	29	0.0	14000.000	14500.000	15000.000	15500.000	16000.000	CARD	045
C	30	0.0	14500.000	15000.000	15500.000	16000.000	16500.000	CARD	046
C	31	0.0	15000.000	15500.000	16000.000	16500.000	17000.000	CARD	047
C	32	0.0	15500.000	16000.000	16500.000	17000.000	17500.000	CARD	048
C	33	0.0	16000.000	16500.000	17000.000	17500.000	18000.000	CARD	049
C	34	0.0	16500.000	17000.000	17500.000	18000.000	18500.000	CARD	050
C	35	0.0	17000.000	17500.000	18000.000	18500.000	19000.000	CARD	051
C	36	0.0	17500.000	18000.000	18500.000	19000.000	19500.000	CARD	052
C	37	0.0	18000.000	18500.000	19000.000	19500.000	20000.000	CARD	053
C	38	0.0	18500.000	19000.000	19500.000	20000.000	20500.000	CARD	054
C	39	0.0	19000.000	19500.000	20000.000	20500.000	21000.000	CARD	055
C	40	0.0	19500.000	20000.000	20500.000	21000.000	21500.000	CARD	056

Appendix B (continued)

41	1500.000	2000.000	2000.000	CARD 057
42	1500.000	2000.000	2000.000	CARD 058
43	1500.000	2000.000	2000.000	CARD 059
44	1500.000	2000.000	2000.000	CARD 060
45	1500.000	2000.000	2000.000	CARD 061
46	1500.000	2000.000	2000.000	CARD 062
47	1500.000	2000.000	2000.000	CARD 063
48	1500.000	2000.000	2000.000	CARD 064
49	2000.000	2000.000	2000.000	CARD 065
50	2000.000	2000.000	2000.000	CARD 066
51	2000.000	2000.000	2000.000	CARD 067
52	2000.000	2000.000	2000.000	CARD 068
53	2000.000	2000.000	2000.000	CARD 069
54	2000.000	2000.000	2000.000	CARD 070
55	2000.000	2000.000	2000.000	CARD 071
56	2000.000	2000.000	2000.000	CARD 072
57	2000.000	2000.000	2000.000	CARD 073
58	2000.000	2000.000	2000.000	CARD 074
59	2000.000	2000.000	2000.000	CARD 075
60	2000.000	2000.000	2000.000	CARD 076
61	2500.000	2000.000	2000.000	CARD 077
62	2500.000	2000.000	2000.000	CARD 078
63	2500.000	2000.000	2000.000	CARD 079
64	2500.000	2000.000	2000.000	CARD 080
65	2500.000	2000.000	2000.000	CARD 081
66	2500.000	2000.000	2000.000	CARD 082
67	2500.000	2000.000	2000.000	CARD 083
68	2500.000	2000.000	2000.000	CARD 084
69	2500.000	2000.000	2000.000	CARD 085
70	2500.000	2000.000	2000.000	CARD 086
71	2500.000	2000.000	2000.000	CARD 087
72	2500.000	2000.000	2000.000	CARD 088
73	2500.000	2000.000	2000.000	CARD 089
74	2500.000	2000.000	2000.000	CARD 090
75	2500.000	2000.000	2000.000	CARD 091
76	2500.000	2000.000	2000.000	CARD 092
77	2500.000	2000.000	2000.000	CARD 093
78	2500.000	2000.000	2000.000	CARD 094
79	2500.000	2000.000	2000.000	CARD 095
80	2500.000	2000.000	2000.000	CARD 096
81	2500.000	2000.000	2000.000	CARD 097
82	2500.000	2000.000	2000.000	CARD 098
83	2500.000	2000.000	2000.000	CARD 099
84	2500.000	2000.000	2000.000	CARD 100
85	2500.000	2000.000	2000.000	CARD 101
86	2500.000	2000.000	2000.000	CARD 102
87	2500.000	2000.000	2000.000	CARD 103
88	2500.000	2000.000	2000.000	CARD 104
89	2500.000	2000.000	2000.000	CARD 105
90	2500.000	2000.000	2000.000	CARD 106

51	3500	000	2400	000
92	3500	000	2600	000
93	3500	000	2750	000
94	3500	000	2350	000
95	3500	000	2550	000
96	4000	000	000	000
97	4000	000	000	000
98	4000	000	500	000
99	4000	000	1000	000
100	4000	000	1500	000
101	4000	000	2000	000
102	4000	000	2200	000
103	4000	000	2400	000
104	4000	000	2600	000
105	4000	000	2750	000
106	4000	000	2900	000
107	4000	000	3500	000
108	4500	000	350	000
109	4500	000	000	000
110	4500	000	500	000
111	4500	000	1000	000
112	4500	000	1500	000
113	4500	000	2000	000
114	4500	000	2200	000
115	4500	000	2400	000
116	4500	000	2600	000
117	4500	000	2750	000
118	4500	000	2900	000
119	4500	000	3500	000
120	5000	000	350	000
121	5000	000	000	000
122	5000	000	500	000
123	5000	000	1000	000
124	5000	000	1500	000
125	5000	000	2000	000
126	5000	000	2200	000
127	5000	000	2400	000
128	5000	000	2600	000
129	5000	000	2750	000
130	5000	000	2900	000
131	5000	000	3500	000
132	5000	000	350	000
133	5000	000	000	000
134	5000	000	500	000
135	5000	000	1000	000
136	5000	000	1500	000
137	5000	000	2000	000
138	5000	000	2200	000
139	5000	000	2400	000
140	5000	000	2600	000

CARD	107
CARD	108
CARD	109
CARD	110
CARD	111
CARD	112
CARD	113
CARD	114
CARD	115
CARD	116
CARD	117
CARD	118
CARD	119
CARD	120
CARD	121
CARD	122
CARD	123
CARD	124
CARD	125
CARD	126
CARD	127
CARD	128
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CARD	134
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CARD	136
CARD	137
CARD	138
CARD	139
CARD	140
CARD	141
CARD	142
CARD	143
CARD	144
CARD	145
CARD	146
CARD	147
CARD	148
CARD	149
CARD	150
CARD	151
CARD	152
CARD	153
CARD	154
CARD	155
CARD	156

Appendix B (continued)

141	5500.000	2750.000	CARD	157
142	5500.000	2900.000	CARD	158
143	5500.000	2950.000	CARD	159
144	5500.000	3000.000	CARD	160
145	6000.000	500.000	CARD	161
146	6000.000	500.000	CARD	162
147	6000.000	1000.000	CARD	163
148	6000.000	1500.000	CARD	164
149	6000.000	2000.000	CARD	165
150	6000.000	2200.000	CARD	166
151	6000.000	2400.000	CARD	167
152	6000.000	2600.000	CARD	168
153	6000.000	2750.000	CARD	169
154	6000.000	2900.000	CARD	170
155	6000.000	2950.000	CARD	171
156	6000.000	3000.000	CARD	172
157	6500.000	500.000	CARD	173
158	6500.000	500.000	CARD	174
159	6500.000	1000.000	CARD	175
160	6500.000	1500.000	CARD	176
161	6500.000	2000.000	CARD	177
162	6500.000	2200.000	CARD	178
163	6500.000	2400.000	CARD	179
164	6500.000	2600.000	CARD	180
165	7000.000	500.000	CARD	181
166	7000.000	500.000	CARD	182
167	7000.000	1000.000	CARD	183
168	7000.000	1500.000	CARD	184
169	7000.000	2000.000	CARD	185
170	7000.000	2200.000	CARD	186
171	7000.000	2400.000	CARD	187
172	7000.000	2600.000	CARD	188
173	7500.000	500.000	CARD	189
174	7500.000	500.000	CARD	190
175	7500.000	1000.000	CARD	191
176	7500.000	1500.000	CARD	192
177	7500.000	2000.000	CARD	193
178	7500.000	2200.000	CARD	194
179	7500.000	2400.000	CARD	195
180	7500.000	2600.000	CARD	196
181	8000.000	500.000	CARD	197
182	8000.000	500.000	CARD	198
183	8000.000	1000.000	CARD	199
184	8000.000	1500.000	CARD	200
185	8000.000	2000.000	CARD	201
186	8000.000	2200.000	CARD	202
187	8000.000	2400.000	CARD	203
188	8000.000	2600.000	CARD	204
189	8500.000	500.000	CARD	205
190	8500.000	500.000	CARD	206

Appendix B (continued)

Appendix B (continued)

241	10500.000	2700.000	CARD	257
242	10500.000	2850.000	CARD	258
243	10500.000	2900.000	CARD	259
244	10500.000	2950.000	CARD	260
245	11000.000	0.0	CARD	261
246	11000.000	450.000	CARD	262
247	11000.000	910.000	CARD	263
248	11000.000	1380.000	CARD	264
249	11000.000	1805.559	CARD	265
250	11000.000	2020.000	CARD	266
251	11000.000	2200.000	CARD	267
252	11000.000	2389.559	CARD	268
253	11000.000	2570.000	CARD	269
254	11000.000	2750.000	CARD	270
255	11000.000	2800.000	CARD	271
256	11000.000	2850.000	CARD	272
257	11500.000	0.0	CARD	273
258	11500.000	400.000	CARD	274
259	11500.000	850.000	CARD	275
260	11500.000	1250.000	CARD	276
261	11500.000	1655.559	CARD	277
262	11500.000	1855.559	CARD	278
263	11500.000	2055.559	CARD	279
264	11500.000	2250.000	CARD	280
265	11500.000	2439.559	CARD	281
266	11500.000	2585.559	CARD	282
267	11500.000	2635.559	CARD	283
268	11500.000	2685.559	CARD	284
269	12000.000	0.0	CARD	285
270	12000.000	360.000	CARD	286
271	12000.000	750.000	CARD	287
272	12000.000	1100.000	CARD	288
273	12000.000	1500.000	CARD	289
274	12000.000	1700.000	CARD	290
275	12000.000	1855.559	CARD	291
276	12000.000	2020.000	CARD	292
277	12000.000	2200.000	CARD	293
278	12000.000	2370.000	CARD	294
279	12000.000	2420.000	CARD	295
280	12000.000	2470.000	CARD	296
281	12500.000	0.0	CARD	297
282	12500.000	300.000	CARD	298
283	12500.000	650.000	CARD	299
284	12500.000	950.000	CARD	300
285	12500.000	1330.000	CARD	301
286	12500.000	1450.000	CARD	302
287	12500.000	1635.559	CARD	303
288	12500.000	1755.559	CARD	304
289	12500.000	1875.559	CARD	305
290	12500.000	2000.000	CARD	306

Appendix B (continued)

291	12500.000	2050.660
292	12500.000	2100.000
293	13000.000	0.0
294	13000.000	270.000
295	13000.000	570.000
296	13000.000	850.660
297	13000.000	1140.000
298	13000.000	1210.000
299	13000.000	1300.000
300	13000.000	1400.000
301	13000.000	1510.660
302	13000.000	1620.000
303	13000.000	1670.000
304	13000.000	1720.000
305	13250.000	0.0
306	13250.000	250.000
307	13250.000	530.000
308	13250.000	770.000
309	13250.000	1030.000
310	13250.000	1120.000
311	13250.000	1200.000
312	13250.000	1300.000
313	13250.000	1370.000
314	13250.000	1450.000
315	13250.000	1500.000
316	13250.000	1550.660
317	13500.000	0.0
318	13500.000	220.000
319	13500.000	460.000
320	13500.000	700.000
321	13500.000	920.000
322	13500.000	1010.000
323	13500.000	1100.000
324	13500.000	1180.000
325	13500.000	1250.000
326	13500.000	1300.000
327	13500.000	1350.000
328	13500.000	1400.000
329	13750.000	0.0
330	13750.000	200.000
331	13750.000	440.000
332	13750.000	650.000
333	13750.000	830.000
334	13750.000	910.000
335	13750.000	1000.000
336	13750.000	1080.000
337	13750.000	1140.000
338	13750.000	1200.000
339	13750.000	1250.660
340	13750.000	1300.000

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CARD	355
CARD	356

Appendix B (continued)

341	14000.000	0.0	CARD	357
342	14000.000	190.000	CARD	358
343	14000.000	400.000	CARD	359
344	14000.000	550.000	CARD	360
345	14000.000	750.000	CARD	361
346	14000.000	830.000	CARD	362
347	14000.000	900.000	CARD	363
348	14000.000	980.000	CARD	364
349	14000.000	1050.000	CARD	365
350	14000.000	1120.000	CARD	366
351	14000.000	1170.000	CARD	367
352	14000.000	1220.000	CARD	368
353	14250.000	0.0	CARD	369
354	14250.000	170.000	CARD	370
355	14250.000	350.000	CARD	371
356	14250.000	540.000	CARD	372
357	14250.000	670.000	CARD	373
358	14250.000	750.000	CARD	374
359	14250.000	820.000	CARD	375
360	14250.000	900.000	CARD	376
361	14250.000	950.000	CARD	377
362	14250.000	1050.000	CARD	378
363	14250.000	1100.000	CARD	379
364	14250.000	1150.000	CARD	380
365	14500.000	0.0	CARD	381
366	14500.000	150.000	CARD	382
367	14500.000	320.000	CARD	383
368	14500.000	470.000	CARD	384
369	14500.000	610.000	CARD	385
370	14500.000	650.000	CARD	386
371	14500.000	760.000	CARD	387
372	14500.000	830.000	CARD	388
373	14500.000	900.000	CARD	389
374	14500.000	980.000	CARD	390
375	14500.000	1030.000	CARD	391
376	14500.000	1080.000	CARD	392
377	14750.000	0.0	CARD	393
378	14750.000	140.000	CARD	394
379	14750.000	270.000	CARD	395
380	14750.000	430.000	CARD	396
381	14750.000	560.000	CARD	397
382	14750.000	630.000	CARD	398
383	14750.000	700.000	CARD	399
384	14750.000	760.000	CARD	400
385	14750.000	840.000	CARD	401
386	14750.000	910.000	CARD	402
387	14750.000	960.000	CARD	403
388	14750.000	1010.000	CARD	404
389	15000.000	0.0	CARD	405
390	15000.000	120.000	CARD	406

Appendix B (continued)

Appendix B (continued)

441	16000.000	50.000	452	CARD	471	CARD	501	CARD
442	16000.000	50.000	453	CARD	472	CARD	502	CARD
443	16000.000	510.000	454	CARD	473	CARD	503	CARD
444	16000.000	550.000	455	CARD	474	CARD	504	CARD
445	16000.000	600.000	456	CARD	475	CARD	505	CARD
446	16000.000	730.000	457	CARD	476	CARD		
447	16000.000	780.000	458	CARD	477	CARD		
448	16000.000	830.000	459	CARD	478	CARD		
449	16250.000	0.0	460	CARD	479	CARD		
450	16250.000	50.000	461	CARD	480	CARD		
451	16250.000	190.000	462	CARD	481	CARD		
452	16250.000	380.000	463	CARD	482	CARD		
453	16250.000	560.000	464	CARD	483	CARD		
454	16250.000	440.000	465	CARD	484	CARD		
455	16250.000	490.000	466	CARD	485	CARD		
456	16250.000	560.000	467	CARD	486	CARD		
457	16250.000	630.000	468	CARD	487	CARD		
458	16250.000	700.000	469	CARD	488	CARD		
459	16250.000	750.000	470	CARD	489	CARD		
460	16250.000	800.000	471	CARD				
461	16500.000	0.0	472	CARD				
462	16500.000	50.000	473	CARD				
463	16500.000	180.000	474	CARD				
464	16500.000	370.000	475	CARD				
465	16500.000	550.000	476	CARD				
466	16500.000	410.000	477	CARD				
467	16500.000	480.000	478	CARD				
468	16500.000	540.000	479	CARD				
469	16500.000	600.000	480	CARD				
470	16500.000	660.000	481	CARD				
471	16500.000	710.000	482	CARD				
472	16500.000	760.000	483	CARD				
473	16600.000	0.0	484	CARD				
474	16600.000	90.000	485	CARD				
475	16600.000	180.000	486	CARD				
476	16600.000	270.000	487	CARD				
477	16600.000	350.000	488	CARD				
478	16600.000	400.000	489	CARD				
479	16600.000	460.000						
480	16600.000	520.000						
481	16600.000	550.000						
482	16600.000	650.000						
483	16600.000	700.000						
484	16600.000	750.000						
485	16700.000	0.0						
486	16700.000	90.000						
487	16700.000	180.000						
488	16700.000	260.000						
489	16700.000	340.000						
490	16700.000	400.000						

Appendix B (continued)

491	16700.000	460.000
492	16700.000	510.000
493	16700.000	570.000
494	16700.000	640.000
495	16700.000	690.000
496	16700.000	740.000
497	16800.000	0.0
498	16800.000	90.000
499	16800.000	180.000
500	16800.000	260.000
501	16800.000	340.000
502	16800.000	400.000
503	16800.000	450.000
504	16800.000	500.000
505	16800.000	560.000
506	16800.000	620.000
507	16800.000	670.000
508	16800.000	720.000
509	16900.000	0.0
510	16900.000	90.000
511	16900.000	180.000
512	16900.000	260.000
513	16900.000	340.000
514	16900.000	390.000
515	16900.000	450.000
516	16900.000	500.000
517	16900.000	550.000
518	16900.000	610.000
519	16900.000	660.000
520	16900.000	710.000
521	17000.000	0.0
522	17000.000	90.000
523	17000.000	180.000
524	17000.000	260.000
525	17000.000	340.000
526	17000.000	390.000
527	17000.000	450.000
528	17000.000	500.000
529	17000.000	550.000
530	17000.000	600.000
531	17000.000	650.000
532	17000.000	700.000
533	17100.000	0.0
534	17100.000	90.000
535	17100.000	180.000
536	17100.000	260.000
537	17100.000	340.000
538	17100.000	390.000
539	17100.000	450.000
540	17100.000	500.000

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CARD	556

Appendix B (continued)

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84

591 18000.000 180.000
592 18000.000 260.000
593 18000.000 340.000
594 18000.000 350.000
595 18000.000 450.000

CARD 607
CARD 608
CARD 609
CARD 610
CARD 611

----- CARD GROUP 9 ELEMENT INCIDENCE DEFINITION

1 1 13 14 2 1 11 12
133 145 157 158 146 1
139 151 163 164 152 1
140 157 165 166 158 1 7 5
175 197 209 210 198 1 11 31
516 569 581 582 570 1
522 575 587 588 576 1
523 581 585 590 582 1
528 586 594 595 587 1

CARD 612
CARD 613
CARD 614
CARD 615
CARD 616
CARD 617
CARD 618
CARD 619
CARD 620

----- CARD GROUP 10 MATERIAL CORRECTIONS ARE NOT REQUIRED ----- SINCE NCM = 0

----- CARD GROUP 11 CARD INPUT FOR INITIAL CONDITIONS

1 0.
595 0.

CARD 621
CARD 622

----- CARD GROUP 12 STEADY STATE INTEGER PARAMETERS

7 6 0 0 29 29

CARD 623

----- CARD GROUP 13 STEADY STATE RAINFALL PROFILES ARE NOT REQUIRED ----- SINCE NRPFR = 0

----- CARD GROUP 14 STEADY STATE RAINFALL TYPES AND PONDING DEPTH

244 0.
580 12 0.

CARD 624
CARD 625

----- CARD GROUP 15 STEADY STATE RAINFALL-SEEPAGE SURFACE ELEMENT-SIDES

218 244 256 0

CARD 626

Appendix B (continued)

CARD 627
CARD 628

CARD 629
CARD 630
CARD 631
CARD 632
CARD 633
CARD 634
CARD 635

CARD 636
CARD 637

CARD 638

85

ORNL-5567

APPENDIX C
LISTING OF FORTRAN IV SOURCE PROGRAM

APPENDIX C LISTING OF FORTRAN IV SOURCE PROGRAM

THIS COMPUTER CODE IS CONTAINED IN THE FOLLOWING REPORT:
YEH, G. T. AND D. S. WAPD, 1979. "FEMWATER: A FINITE-ELEMENT MODEL OF WATER FLOW THROUGH SATURATED-UNSATURATED POROUS MEDIA", ORNL-5567, OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TN 37930
A SLIGHTLY UPDATED VERSION IS CONTAINED IN FEMWATER (ORNL/T4----)
FOR ANY QUESTION, PLEASE CONTACT DR. G. T. YEH AT (615) 574-7285
ADDITIONAL REFERENCES IS:
REEVES, M. AND J. DUGUID, 1975. "WATER MOVEMENT THROUGH SATURATED-UNSATURATED POROUS MEDIA: A GALERKIN FINITE ELEMENT MODEL", ORNL 4927, OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENNESSEE 37930
----- MAIN PROGRAM
IMPLICIT REAL*8(A-H,O-Z)
REAL*4 PMAT,THPAR,AKPAR,SUBHD
DIMENSION X(595),Z(595),IE(528,5)
DIMENSION C(595,16),R(595),H(595),HP(595),HW(595),HT(595),
> TH(528,4),DTH(528,4),VX(595),VZ(595),
> AKX(528,4),AKZ(528,4),NPCNV(595)
DIMENSION DLB(195),DCOSXB(199),DCOSZB(199),BFLX(200),BFLXP(200),
> NBE(195),ISB(195,4),NPB(200)
DIMENSION DL(99),DCOSX(99),DCOSZ(99),DCYFLX(100),FLX(100),
> RSFLX(100),HCCN(100),NRSE(99),IS(99,4),NPRS(100),NPCON(100),
> NPFLX(100),IRFTYP(100),TRF(3,20),RF(3,20),RFALL(3)
DIMENSION RP(30),NPST(30),BB(40),NN(40)
DIMENSION PROP(3,5),THPROP(3,52),AKPROP(3,52),HPROP(3,52),
> CAPROP(3,52)
DIMENSION PMAT(3,5),AKPAR(3,8),THPAR(3,8)
DIMENSION KPR(500),KDSK(500)
DIMENSION SUBHD(8,3),FRATE(10),FLOW(10),TFLOW(10)
COMMON /GEOM/ SNFE,CSFE,NNP,NEL,IBAND

MAIN 005
MAIN 010
MAIN 015
MAIN 020
MAIN 025
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MAIN 035
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MAIN 235
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MAIN 245
MAIN 250

Appendix C (continued)

COMMON /CNTRL/ NTI,MAXCY,MAXIT,NSTRT,KSTR,KPRO,KDSK,KSS,<5	MAIN 255
COMMON /TOTLNS/ TCLA,TOLB	MAIN 260
COMMON /PARAM/ DELT,CHNG,DELMAX,TMAX	MAIN 265
COMMON /BRSD/ NBEL,NBN,NRSEL,NRSN,NRFPR,NRFPAR	MAIN 270
COMMON /BCST/ NBC,NST,NSTN	MAIN 275
COMMON /MTL/ NMAT,NMPPM,NSPPM	MAIN 280
COMMON /OPT/ ILUMF,IMID	MAIN 285
C DATA MAXEL,MAXNP,MAXHBP /528,595,16/	MAIN 290
DATA MAXBEL,MAXBAF /199,200/	MAIN 295
DATA MXRSEL,MXRSNP,MXRFP,MRPAR /99,100,3,20/	MAIN 300
DATA MXSTEL,MXSTNF,MAXBCN /29,30,40/	MAIN 305
DATA MAXMAT,MXSPPM,MXMPPM, NTHPPM,NAKPPM/ 3,52,5,8,3/	MAIN 310
DATA MAXNTI /500/	MAIN 315
C DATA PMAT/4H .4H ALP,4H .4H B,4HETAP,4H .4H .	MAIN 320
> 4H POR,4H .4H .4H KX .4H .4H .4H KZ .4H /	MAIN 325
DATA THPAR/4H .4H TH1,4H .4H .4H TH2,4H .4H .	MAIN 330
> 4H H0,4H .4H .4H A1,4H .4H .4H A2,4H .4H .	MAIN 335
> 4H R1,4H .4H .4H R2,4H .4H .4H C,4H /	MAIN 340
C DATA AKPAR/4H .4H B1,4H .4H .4H B2,4H .18*4H /	MAIN 345
C DATA SUBHD/4HINPL,4HT IN,4HTIA,4HL CO,4HNDIT,4HION3,2*4H .	MAIN 350
> 4HSTEA,4HDY-S,4HTATE,4H INI,4HTIAL,4H CON,4HDITI,4HONS , 8*	MAIN 355
> 4H /	MAIN 360
C C	MAIN 365
C C	MAIN 370
C C	MAIN 375
C C	MAIN 380
C C	MAIN 385
C C	MAIN 390
C C	MAIN 395
C C	MAIN 400
C C	MAIN 405
C C	MAIN 410
C C	MAIN 415
C C	MAIN 420
C C	MAIN 425
C C	MAIN 430
C C	MAIN 435
C C	MAIN 440
C C	MAIN 445
C C	MAIN 450
C C	MAIN 455
C C	MAIN 460
C C	MAIN 465
C C	MAIN 470
C C	MAIN 475
C C	MAIN 480
C C	MAIN 485
C C	MAIN 490
C C	MAIN 495
C C	MAIN 500

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C
C
C ----- INITIATE ARRAYS FOR NODAL POINTS
C
DO 100 NP=1,MAXNP
  X(NP)=0.0
  Z(NP)=0.0
  R(NP)=0.0
  H(NP)=0.0
  HP(NP)=0.0
  HW(NP)=0.0
  HT(NP)=0.0
  VX(NP)=0.0
  VZ(NP)=0.0
DO 100 I=1,MAXHBP
  C(NP,I)=0.0
100
C
C
C ----- INITIATE ARRAYS FOR ELEMENTS
C
DO 150 MP=1,MAXEL
  DO 120 IF=1,5
    IF(MF,IF)=0
120
C

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Appendix C (continued)

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      DO 140 IQ=1,4
        TH(MP,IQ)=0.0
        DTH(MP,IQ)=0.0
140
C
C 150 CONTINUE
C
C
C ----- INITIATE ARRAYS FOR BOUNDARY ELEMENTS
C
      DO 200 MP=1,MAXBEL
        DLB(MP)=0.0
        DCOSXB(MP)=0.0
        DCOSZB(MP)=0.0
        NBE(MP)=0
        DO 200 IQ=1,4
          ISB(MP,IQ)=0
200 CONTINUE
C
C
C ----- INITIATE ARRAYS FOR BOUNDARY NODAL POINTS
C
      DO 250 NP=1,MAXBNP
        BFLX(NP)=0.0
        BFLXP(NP)=0.0
        NPB(NP)=0
250
C
      DO 300 MP=1,MAXRSEL
        DL(MP)=0.0
        DCOSX(MP)=0.0
        DCOSZ(MP)=0.0
        NRSE(MP)=0
        DO 300 IQ=1,4
          IS(MP,IQ)=0
300 CONTINUE
C
C
C ----- INITIATE ARRAYS FOR RAINFALL-SEEPAGE BOUNDARY NODAL POINTS
C
      DO 350 NP=1,MAXRSNP
        DCYFLX(NP)=0.0
        FLX(NP)=0.0
        RSFLX(NP)=0.0
        HCON(NP)=0.0
        NPRS(NP)=0
        NPCON(NP)=0
        NPFLX(NP)=0
        IRFTYP(NP)=0
350
C
C

```

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MAIN 505
MAIN 510
MAIN 515
MAIN 520
MAIN 525
MAIN 530
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MAIN 555
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MAIN 605
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MAIN 635
MAIN 640
MAIN 645
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MAIN 655
MAIN 660
MAIN 665
MAIN 670
MAIN 675
MAIN 680
MAIN 685
MAIN 690
MAIN 695
MAIN 700
MAIN 705
MAIN 710
MAIN 715
MAIN 720
MAIN 725
MAIN 730
MAIN 735
MAIN 740
MAIN 745
MAIN 750

```


Appendix C (continued)

```

C ----- INITIATE ARRAYS FOR RAINFALL INFORMATION
C
C      DO 360 I=1,MXRFPF
C        RFALL(I)=0.0
C      DO 360 J=1,MXRPAR
C        TRF(I,J)=0.0
C      360      RF(I,J)=0.0
C
C ----- INITIATE ARRAYS FOR SURFACE TERM POINT FLJX
C
C      DO 500 NP=1,MXSTAF
C        NPST(NP)=0
C      500      RP(NP)=0.0
C
C ----- INITIATE ARRAYS FOR DIRICHLET BOUNDARY CONDITIONS
C
C      DO 510 NP=1,MAXBCA
C        BB(NP)=0.0
C      510      NN(NP)=0
C
C ----- INITIATE ARRAYS FOR MATERIAL PROPERTIES
C
C      DO 610 I=1,MAXMAT
C        DO 610 J=1,MXMFPM
C          PROP(I,J)=0.0
C      610
C      DO 630 J=1,MXSFPF
C        THPROP(I,J)=0.0
C        AKPROP(I,J)=0.0
C        HPROP(I,J)=0.0
C      630      CAPROP(I,J)=0.0
C
C      650      CONTINUE
C
C ----- INITIATE ARRAYS FOR FLOW THROUGH VARIOUS TYPES OF BOUNDARIES
C
C      DO 700 I=1,10
C        FRATE(I)=0.0
C        FLOW(I)=0.0
C      700      IFLOW(I)=0.0
C
C ----- PASS THE PROGRAM TO GW2DXZ
C
C      CALL GW2DXZ(X,Z,IE, C,R,H,HP,HV,HT,TH,DTH,VX, /Z,AKX,AKZ,VPCV,
C      > DLB,DCOSXB,DCCSZB,BFLX,BFLXP,NBE,ISB,NPB, DL,DCOSX,DCOSZ,

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MAIN 755
MAIN 760
MAIN 765
MAIN 770
MAIN 775
MAIN 780
MAIN 785
MAIN 790
MAIN 795
MAIN 800
MAIN 805
MAIN 810
MAIN 815
MAIN 820
MAIN 825
MAIN 830
MAIN 835
MAIN 840
MAIN 845
MAIN 850
MAIN 855
MAIN 860
MAIN 865
MAIN 870
MAIN 875
MAIN 880
MAIN 885
MAIN 890
MAIN 895
MAIN 900
MAIN 905
MAIN 910
MAIN 915
MAIN 920
MAIN 925
MAIN 930
MAIN 935
MAIN 940
MAIN 945
MAIN 950
MAIN 955
MAIN 960
MAIN 965
MAIN 970
MAIN 975
MAIN 980
MAIN 985
MAIN 990
MAIN 995
MAIN1000

```

Appendix C (continued)

```

> DCYFLX,FLX,RSFLX,HCON,NRSE,IS,NPRS,NPCCN,NPFLX,IRFTYP,TZF,RF,
> RFALL,RP,NPST,BB,NN,PROP,THP33P,
> AKPROP,HPROP,CAPROP,MAXEL,MAXNP,MAXHBP,MAXBEL,MAXBNP,MAXSE,
> MXR SNP,MXRFP,MXRPAR,MXSTEL,MXSTNP,MAXBCV,
> MAXMAT,MXNPPM,MXSPPM,NTHPPM,NAKPPM,MAXNTI,FRATE,FLOW,TF,DW,
> PMAT,AKPAR,THPAR,SUBHD,KPR,KDSK)

```

C

```

STOP
END

```

```

MAIN1005
MAIN1010
MAIN1015
MAIN1020
MAIN1025
MAIN1030
MAIN1035
MAIN1040
MAIN1045

```

Appendix C (continued)

	SUBROUTINE GW2DXZ(X,Z,IE, C,R,H,HP,HV,HT,TH,DTH,VX,VZ,AKX,AKZ,	GW2D 005
	> NPCNV, DLB,DCOSXB,DCOSZB,BFLX,BFLXP,NBE,ISB,NPB, DL,DCOSX,	GW2D 010
	> DCOSZ,DCYFLX,FLX,RSFLX,HCON,NRSE,IS,NPRS,NPCON,NPFLX,IRFTYP,TRF,	GW2D 015
	> RF,RFALL, RP,NPST, BB,NV, PRJP,THPRJP,	GW2D 020
	> AKPROP,HPROP,CAPROP, MAXEL,MAXNP,MAXHBP, MAXBEL,MAXBNP, MXRSEL,	GW2D 025
	> MXR SNP,MXRFPF,MXRPAR, MXSTEL,MXSTNP, MAXBCN,	GW2D 030
	> MAXMAT,MXNPPM,MXSPPM,NTHPPM,NAKPPM, MAXNTI, FRATE,FL3B,TF,DW,	GW2D 035
	> PMAT,AKPAR,THPAR,SUBHD,KPR,KDSK)	GW2D 040
C	IMPLICIT REAL*8(A-H,O-Z)	GW2D 045
	REAL*4 PMAT,THPAR,AKPAR,SUBHD	GW2D 050
C	DIMENSION TITLE(5)	GW2D 055
	DIMENSION X(MAXNP),Z(MAXNP),IE(MAXEL,5)	GW2D 060
C	DIMENSION C(MAXNP,MAXHBP),R(MAXNP),H(MAXNP),HP(MAXNP),HV(MAXNP),	GW2D 065
	> HT(MAXNP),TH(MAXEL,4),DTH(MAXEL,4),VX(MAXNP),VZ(MAXNP),	GW2D 070
	> AKX(MAXEL,4),AKZ(MAXEL,4),NPCNV(MAXNP)	GW2D 075
C	DIMENSION DLB(MAXBEL),DCOSXB(MAXBEL),DCOSZB(MAXBEL),RFLX(MAXBNP),	GW2D 080
	> BFLXP(MAXBNP),NBE(MAXBEL),ISB(MAXBEL,4),NPB(MAXBNP)	GW2D 085
C	DIMENSION DL(MXRSEL),DCOSX(MXRSEL),DCOSZ(MXRSEL),DCYFLX(MXRSEL),	GW2D 090
	> FLX(MXR SNP),RSFLX(MXR SNP),HCCN(MXR SNP),NRSE(MXRSEL),IS(MXRSEL,4),	GW2D 095
	> NPRS(MXR SNP),NPCON(MXR SNP),NPFLX(MXR SNP),IRFTYP(MXR SNP),	GW2D 100
	> TRF(MXRFPF,MXRPAR),RF(MXRFPF,MXRPAR),RFALL(MXRFPF)	GW2D 105
C	DIMENSION RP(MXSTNP),NPST(MXSTNP),BB(MAXBCN),NN(MAXBCN)	GW2D 110
C	DIMENSION PROP(MAXMAT,MXNPPM),THPROP(MAXMAT,MXSPPM),	GW2D 115
	> AKPROP(MAXMAT,MXSPPM),HPROP(MAXMAT,MXSPPM),CAPROP(MAXMAT,MXSPPM)	GW2D 120
C	DIMENSION FRATE(10),FLOW(10),TFLOW(10)	GW2D 125
	DIMENSION PMAT(3,MXNPPM),AKPAR(3,NAKPPM),THPAR(3,NTHPPM)	GW2D 130
	DIMENSION SUBHD(8,3)	GW2D 135
	DIMENSION KPR(MAXNTI),KDSK(MAXNTI)	GW2D 140
C	COMMON /GEOM/ SNFE,CSFE,NNP,NEL,IBAND	GW2D 145
	COMMON /CNTRL/ NTI,MAXCY,MAXIT,NSTRT,KSTR,KPRO,KDSK,KSS,(S)	GW2D 150
	COMMON /TOTLNS/ TCLA,TOLB	GW2D 155
	COMMON /PARAM/ DELT,CHNG,DELMAX,TMAX	GW2D 160
	COMMON /BRND/ NBEL,NBN,NRSEL,NRSN,NRFPF,NRFPAR	GW2D 165
	COMMON /BCST/ NBC,NST,NSTN	GW2D 170
	COMMON /MTL/ PMAT,MXNPPM,MXSPPM	GW2D 175
	COMMON /OPT/ ILLMF,IMID	GW2D 180
C		GW2D 185
C		GW2D 190
C	PROBLEM IDENTIFICATION AND DESCRIPTION	GW2D 195
	10 READ 10J60,NPROB,(TITLE(I),I=1,9),IBUG,ICHNG	GW2D 200
		GW2D 205
		GW2D 210
		GW2D 215
		GW2D 220
		GW2D 225
		GW2D 230
		GW2D 235
		GW2D 240
		GW2D 245
		GW2D 250

Appendix C (continued)

	IF (NPROB.LE.0) GC TO 270	GW2D 255
	PRINT 10100,NPROB,(TITLE(I),I=1,9)	GW2D 260
C		GW2D 265
C	READ AND PRINT INPLT DATA	GW2D 270
C		GW2D 275
	KOUT=0	GW2D 280
	KSS=1	GW2D 285
C		GW2D 290
C		GW2D 295
	CALL DATAIN(X,Z,IE, H,HT,TH,VX,VZ, DLB,DCOSXB,DCOSZB,NBE,	GW2D 300
	> ISB,NPB, DL,DCCSX,DCOSZ,HCON,NRSE,IS,NPRS,NPCON,NPFLX,IRFTY,	GW2D 305
	> TRF,RF, RP,NPST,BB,NV,	GW2D 310
	> PROP,THPROP,AKPRCP,HPROP,CAPROP, MAXEL,MAXNP,MAXHBP,	GW2D 315
	> MAXBEL,MAXBNP, MXRSEL,MXRSNP,MXRFPR,MXRPAR,	GW2D 320
	> MXSTEL,MXSTNP, MAXECN, MAXMAT,MXNPPM,MXSPPM,NTHPPM,MAXPPM,	GW2D 325
	> MAXNTI, PMAT,AKPAR,THPAR, KPR,KDSK, ISTOP,MAXDIF,W.TIME,	GW2D 330
	> TITLE,NPROB)	GW2D 335
C		GW2D 340
	KDIG=NSTRT	GW2D 345
	IF (ISTOP.GT.0) GC TO 270	GW2D 350
C		GW2D 355
C	COMPUTE BAND-WIDTH VARIABLES	GW2D 360
C		GW2D 365
	IHALFB=MAXDIF	GW2D 370
	IBAND=2*IHALFB+1	GW2D 375
	IHBP=IHALFB+1	GW2D 380
	IF (IHBP.GT.MAXHBP) GO TO 260	GW2D 385
C		GW2D 390
C	PREPARE INITIAL VARIABLES	GW2D 395
C		GW2D 400
	CALL SPROP(IE, H,TH,DTH,AKX,AKZ,PROP,THPROP,AKPROP,HPROP,	GW2D 405
	> CAPROP, MAXEL,MAXNP, MAXMAT,MXNPPM,MXSPPM, NEL,(S))	GW2D 410
C		GW2D 415
	CALL VELT(X,Z,IE, C,H,HT,VX,VZ,AKX,AKZ, MAXEL,MAXNP,MAXHBP)	GW2D 420
C		GW2D 425
	KFLOW=-1	GW2D 430
C		GW2D 435
	CALL SFLOW(X,Z,IE, H,VX,VZ, DLB,DCOSXB,DCOSZB,BFLX,BFLXP,ISD,	GW2D 440
	> NDE,NPB, NPRS, NPST,NN, FRATE,FLOW,TFLOW, MAXNP,MAXEL,	GW2D 445
	> MAXBEL,MAXBNP, MXRSNP, MXSTNP,MAXBCN,KFLOW,DELT,DTH,d,HP,	GW2D 450
	> PROP,MAXMAT,MXNPPM)	GW2D 455
C		GW2D 460
C		GW2D 465
C	PRINT INITIAL VARIABLES	GW2D 470
C		GW2D 475
	KDIAG=0	GW2D 480
C		GW2D 485
	CALL PRINTT(VX,VZ,H,HT,TH, NPB,BFLX, NPRS,RSFLX,NPCON,NPFLX,	GW2D 490
	> FRATE,FLOW,TFLOW, MAXNP,MAXEL, MAXBNP,MXRSNP, NNP,NEL, VBN,VRSN,	GW2D 495
	> TIME,DELT,SUBHD(1,1),IBAND,KPRO,KOUT,KDIAG,-1)	GW2D 500

Appendix C (continued)

```

C      IF(KSTR.EQ.1 .AND. KSS.EQ.1 .AND. NSTRT.EQ.1 .AND. <DS<0.E2.1)
C      > CALL STORE(X,Z,IE, H,HT,TH,VX,VZ,DLB,DCOSXB,DCOSZB,NBE,ISB,IPB,
C      > TITLE,TIME,MAXNP,MAXEL,MAXBNP,MAXBEL,NPROB,NNP,NEL,NBN,VBE,NTI,
C      > NPCON,NPFLX,MXRSNP,NRSN, NSTRT)
C
C      IF (KSS.NE.0) GO TO 130
C
C      PERFORM STEADY-STATE CALCULATION
C
C      IF (NRSN.EQ.0) GO TO 30
C
C      DO 20 NPP=1,NRSN
C      NPCON(NPP)=NPRS(NPP)
C      20 NPFLX(N,P)=0
C
C      NCHG=-1
C      CALL BCPREP(IE, H,VX,VZ, DL,DCOSX,DCOSZ,DCYFLX,FLX,RSF,X,
C      > HCON,NRSE,IS,NPRS,NPCON,NPFLX,IRFTYP,TRF,RF,RFall, MAXEL,MAXVP,
C      > MXRSEL,MXRSNP,MXRFP, MXRPAR, TIME,NCHG)
C
C      30 DO 40 NP=1,NNP
C      40 HP(NP)=H(NP)
C
C      NIT=0
C      KDIG=KDIG+1
C      IF(BUG.NE.0) PRINT 10400,KDIG,TIME,DELT
C
C      ITERATION LOOP ON THE SEEPAGE-RAINFALL BOUNDARY CONDITIONS BEGINS
C
C      DO 100 ICY=1,MAXCY
C      DO 50 NP=1,NNP
C      50 H(NP)=HP(NP)
C
C      ITERATION LOOP ON THE NON-LINEAR EQUATION BEGINS
C
C      IF(BUG.NE.0) PRINT 10401
C      DO 80 IT=1,MAXIT
C      NIT=NIT+1
C
C      EVALUATE SOIL PROPERTIES FOR PREVIOUS ITERATE
C
C      > CALL SPROP(IE, H,TH,DTH,AKX,AKZ, PROP,THPROP,AKPROP,HPRDP,
C      CAPROP, MAXEL,MAXNP, MAXMAT,MXMPPM, MXSPPM, NE,<3>)
C
C      ASSEMBLE STEADY-STATE COEFFICIENT MATRICES A, B, AND C, AND CONSTRUCT
C      LOAD VECTOR R
C
C      CALL ASEMBL(X,Z,IE, C,R,H,HP,TH,DTH,AKX,AKZ, PROP,

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GW2J 505
GW2D 510
GW2D 513
GW2D 520
GW2D 525
GW2J 530
GW2D 535
GW2D 540
GW2D 545
GW2D 550
GW2D 555
GW2D 560
GW2D 565
GW2D 570
GW2D 575
GW2D 580
GW2D 585
GW2D 590
GW2D 595
GW2D 600
GW2D 605
GW2D 610
GW2D 615
GW2D 620
GW2D 625
GW2D 630
GW2D 635
GW2D 640
GW2D 645
GW2D 650
GW2D 655
GW2D 660
GW2J 665
GW2D 670
GW2D 675
GW2D 680
GW2D 685
GW2D 690
GW2D 695
GW2J 700
GW2D 705
GW2J 710
GW2D 715
GW2D 720
GW2D 725
GW2D 730
GW2D 735
GW2D 740
GW2J 745
GW2D 750

```

Appendix C (continued)

```

      >      MAXNP,MAXEL,MAXHBP, MAXMAT,MAXMPFM, KSS, #, DELT)
C
C  APPLY STEADY-STATE BOUNDARY CONDITIONS
C
      CALL BC(C,R, FLX,HCON,NPCON,NPFLX, RP,NPST,BB,YN,
      >      MAXNP,MAXHBP, MXRSNP,MAXSTNP,MAXBCN, KSS)
C
C  TRIANGULARIZE STEADY-STATE C MATRIX
C
      CALL BANSOL(1,C,R,NNP,IHBP,MAXNP,MAXHBP)
C
C  BACK-SUBSTITUTE FOR STEADY-STATE SOLUTION
C
      CALL BANSOL(2,C,R,NNP,IHBP,MAXNP,MAXHBP)
C
C  OBTAIN MAXIMUM RELATIVE DEVIATION FROM PREVIOUS ITERATE
C
      NPP=0
      RD=-1.
      RES=-1.
      DO 60 NP=1,NNP
        RESNP=DABS(R(NP)-H(NP))
        RES=DMAX1(RES,RESNP)
        IF (H(NP).NE.0.00) RD=DMAX1(RD,DABS(RESNP/H(NP)))
        IF (RESNP.LE.TOLA) GO TO 60
        NPP=NPP+1
        NPCNV(NPF)=NP
      60  CONTINUE
C
C  UPDATE PRESSURE WITH CURRENT ITERATE
C
      NNCVN=NPP
      DO 70 NP=1,NNP
        H(NP)=R(NP)
      70
C
C  ESCAPE FROM ITERATION LOOP IF THE MAXIMUM RESIDUAL IS
C  SUFFICIENTLY SMALL
C
      IF (IBUG.NE.0) PRINT 10200,NIT,RES,RD,NNCVN
      IF (NIT.EQ.1) GO TO 80
      IF (RES.LT.TOLA) GO TO 90
      80  CONTINUE
C
C  END OF ITERATION LOOP ON THE NONO-LINEAR EQUATION
C
C  PRINT NONCONVERGING NODES
C
      IF (IBUG.EQ.0) GO TO 90
      PRINT 10500

```

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GW2D 755
GW2D 760
GW2D 765
GW2D 770
GW2D 775
GW2D 780
GW2D 785
GW2D 790
GW2D 795
GW2D 800
GW2D 805
GW2D 810
GW2D 815
GW2D 820
GW2D 825
GW2D 830
GW2D 835
GW2D 840
GW2D 845
GW2D 850
GW2D 855
GW2D 860
GW2D 865
GW2D 870
GW2D 875
GW2D 880
GW2D 885
GW2D 890
GW2D 895
GW2D 900
GW2D 905
GW2D 910
GW2D 915
GW2D 920
GW2D 925
GW2D 930
GW2D 935
GW2D 940
GW2D 945
GW2D 950
GW2D 955
GW2D 960
GW2D 965
GW2D 970
GW2D 975
GW2D 980
GW2D 985
GW2D 990
GW2D 995
GW2D 1000

```

Appendix C (continued)

```

C      PRINT 10600,(NPCNV(NPP),NPP=1,NNCVN)
C
C      PRINT RAINFALL-SEEPAGE B. C. CHANGL INFORMATION
C
C      90      IF(ICHNG.EQ.0) GO TO 95
C              IF(NRSN.EQ.0) GO TO 95
C              PRINT 10402
C              DO 94 IRSN=1,NRSN
C                  NP=NPRS(IRSN)
C                  PRINT 10403,IRSN,NP,NPCCN(IRSN),HCON(IRSN),NPF_X(IRSN),
C              >              FLX(IRSN),DCYFLX(IRSN)
C      94      CONTINUE
C
C      CALCULATE FLOW RATES
C
C      95      CALL SPROP(IE,H,TH,DTH,AKX,AKZ,PRCP,THPROP,AKPROP,HPRJ,
C      >              CAPROP,MAXEL,MAXNP,MAXMAT,MXNPPM,MXSPPM,VEL,KSP)
C
C              CALL VELT(X,Z,IE,C,H,HT,VX,VZ,AKX,AKZ,MAXEL,MAXNP,MAXHJ)
C
C              IF (NRSN.EQ.0) GO TO 110
C
C              CALL BCPREP(IE,H,VX,VZ,DL,DCOSX,DCOSZ,DCYFLX,F_X,RSFLX,
C      >              HCON,NRSE,IS,NPRS,NPCCN,NPFLX,IRFTYP,TRF,RF,RFALL,MAXE,
C      >              MAXNP,MXRSEL,MXRSNP,MXRFP,MRPAR,TIME,NCHG)
C              IF (NCHG.EQ.0) GO TO 110
C      100      CONTINUE
C
C      END OF ITERATION LCCF ON THE SEEPAGE-RAINFALL BOUNDARY CONDITIONS
C
C      110 KFLOW=-1
C          CALL SFLOW(X,Z,IE,TH,VX,VZ,DLB,DCOSXB,DCOSZB,BFLX,BFLXP,1,3,
C      >          NBE,NPB,NPRS,NPST,NN,FRATE,FLOW,TFLOW,MAXNP,MAXEL,
C      >          MAXBEL,MAXBNP,MXRSNP,MXSTNP,MAXBCN,KFLOW,DELT,DTH,d,H)
C
C          DO 120 I=1,6
C              FLOW(I)=0.
C      120      TFLOW(I)=0.
C              FRATE(7)=0.
C              FLOW(7)=0.
C
C      PRINT STEADY-STATE VARIABLES
C
C          CALL PRINTT(VX,VZ,H,HT,TH,NPB,BFLX,NPRS,RSFLX,NPCCN,NPF_X,
C      >          FRATE,FLOW,TFLOW,MAXNP,MAXEL,MAXBNP,MXRSNP,NNP,NEL,VRN,VRN,
C      >          TIME,DELT,SUBHD(1,2),IBAND,KPRO,KOUT,KDIAG,0)

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GW201005
 GW201010
 GW201015
 GW201020
 GW201025
 GW201030
 GW201035
 GW201040
 GW201045
 GW201050
 GW201055
 GW201060
 GW201065
 GW201070
 GW201075
 GW201080
 GW201085
 GW201090
 GW201095
 GW201100
 GW201105
 GW201110
 GW201115
 GW201120
 GW201125
 GW201130
 GW201135
 GW201140
 GW201145
 GW201150
 GW201155
 GW201160
 GW201165
 GW201170
 GW201175
 GW201180
 GW201185
 GW201190
 GW201195
 GW201200
 GW201205
 GW201210
 GW201215
 GW201220
 GW201225
 GW201230
 GW201235
 GW201240
 GW201245
 GW201250

Appendix C (continued)

```

C      IF (KSTR.EQ.1 .AND. KDSKO.EQ.1) CALL STORE(X,Z,IE,
> H,HT,TH,VX,VZ,DLB,DCOSXB,DCOSZB,NBE,ISB,NPB,TIF,E,TIME,MAXV,
> MAXEL,MAXBNP,MAXBEL,NPROB,NRP,NEL,NBN,NBEL,NTI, NPCON,NPFLX,
> MXRSP,NRSP, NSTRT)
> IF (NTI.EQ.0) GO TO 10
C      READ TRANSIENT BCLNDARY CONDITIONS
C      CALL DATIN(X,Z,IE, H,HT,TH,VX,VZ, DLB,DCOSXB,DCOSZB,NBE,
> ISB,NPB, DL,DCCSX,DCOSZ,HCCN,NRSE,IS,NPRS,NPCON,NPFLX,IRFTYP,
> TRF,RF, RP,NPST, BB,NN,
> PROP,THPROP,AKPRCP,HPRCP,CAPROP, MAXEL,MAXNP,MAXHBP,
> MAXDEL,MAXBNP, MXRSEL,MXRSP,MXRFP,MYRPAR,
> MXSTEL,MXSTNP, MAXBCN, MAXMAT,MXMPPM,MXSPPM,NTHPPM,NAKPM,
> MAXNTI, PMAT,AKPAR,THPAR, KPR,KOSK, ISTOP,MAXDIF,E,TIME,
> TITLE,NPROB)
C      KSS=1
C      PERFORM TRANSIENT-STATE CALCULATION
C      130 IF (NRSP.EQ.0) GO TO 160
> IF (NSTRT.GT.0) GO TO 150
C      DO 140 NPP=1,NRSP
> NPCON(NPP)=NPRS(NPP)
> NPFLX(NPP)=0
C      140 NCHG=-1
C      CALL BCPREP(IE, H,VX,VZ, DL,DCOSX,DCOSZ,DCYFLX,FLX,RSFLX,
> HCON,NRSE,IS,NPRS,NPCCN,NPFLX,IRFTYP,TRF,RF,RFALL, MAXE,MAXV,
> MXRSEL,MXRSP,MXRFP,MYRPAR, TIME,NCHG)
C      160 TIME=TIME+DELT
> W1=W
> W2=1.-W
> KFLOW=1
C      BEGIN THE TIME-MARCHING LOOP
C      DO 250 ITN=1,NTI
C      DO 170 NP=1,NRP
> HP(NP)=H(NP)
C      170
> NIT=0
> KDIG=KDIG+1

```

GW2D1255
GW2D1260
GW2D1265
GW2D1270
GW2D1275
GW2D1280
GW2D1285
GW2D1290
GW2D1295
GW2D1300
GW2D1305
GW2D1310
GW2D1315
GW2D1320
GW2D1325
GW2D1330
GW2D1335
GW2D1340
GW2D1345
GW2D1350
GW2D1355
GW2D1360
GW2D1365
GW2D1370
GW2D1375
GW2D1380
GW2D1385
GW2D1390
GW2D1395
GW2D1400
GW2D1405
GW2D1410
GW2D1415
GW2D1420
GW2D1425
GW2D1430
GW2D1435
GW2D1440
GW2D1445
GW2D1450
GW2D1455
GW2D1460
GW2D1465
GW2D1470
GW2D1475
GW2D1480
GW2D1485
GW2D1490
GW2D1495
GW2D1500


```

C      IF (IBUG.NE.0) PRINT 10400,KDIG,TIME,DELT
C      BEGIN THE ITERATION LOOP ON THE SEEPAGE-RAINFALL BOUNDARY CONDITIONS
C      DO 230 ICY=1,MAXCY
C          IF (IBUG.NE.0) PRINT 10401
C          DO 180 NP=1,NNP
C              HW(NP)=HP(NP)
C          BEGIN THE ITERATION LOOP ON THE NON-LINEAR EQUATION
C          DO 210 IT=1,MAXIT
C              NIT=NIT+1
C          EVALUATE SOIL PROPERTIES FOR PREVIOUS ITERATE
C          CALL SPROP(IE,HW,TH,DTH,AKX,AKZ, PROP,THPRJP,AKPRJP,
C              >      CALL SPRCP(IE,H, TH,DTH,AKX,AKZ, PROP,THPRJP,AKPRJP,
C              >      HPROF,CAPROP,MAXEL,MAXNP,MAXMAT,MXNPPM,MXSPPM,VEL,(SS))
C          ASSEMBLE COEFFICIENT MATRICES A, B, AND C, AND CONSTRUCT LOAD
C          VECTOR R
C          CALL ASEMBL(X,2,IE, C,R,H,HP,TH,DTH,AKX,AKZ, PRJP,
C              >      MAXNP,MAXEL,MAXHBP, MAXMAT,MXNPPM, KSS,W,DELT)
C          APPLY BOUNDARY CONDITIONS
C          CALL BC(C,R, FLX,HCCN,NPCON,NPFLX, RP,NPST, BB,VN,
C              >      MAXNP,MAXHBP, MXRSNP,MXSTNP,MAXBCN, (SS))
C          TRIANGULARIZE C MATRIX
C          CALL BANSOL(1,C,R,NNP,IHBP,MAXNP,MAXHBP)
C          BACK-SUBSTITUTE
C          CALL BANSOL(2,C,R,NNP,IHBP,MAXNP,MAXHBP)
C          OBTAIN MAXIMUM RELATIVE DEVIATION FROM PREVIOUS ITERATE
C          NPP=0
C          RD=-1.
C          RES=-1.
C          DO 190 NP=1,NNP
C              RESNP=DABS(R(NP)-H(NP))
C              RES=DMAX1(RES,RESNP)
C              IF (H(NP).NE.0.D0) RD=DMAX1(RD,DABS(RESNP/H(NP)))
C              IF (RESNP.LE.TOLB) GO TO 190

```

```

GW2D1505
GW2D1510
GW2D1515
GW2D1520
GW2D1525
GW2D1530
GW2D1535
GW2D1540
GW2D1545
GW2D1550
GW2D1555
GW2D1560
GW2D1565
GW2D1570
GW2D1575
GW2D1580
GW2D1585
GW2D1590
GW2D1595
GW2D1600
GW2D1605
GW2D1610
GW2D1615
GW2D1620
GW2D1625
GW2D1630
GW2D1635
GW2D1640
GW2D1645
GW2D1650
GW2D1655
GW2D1660
GW2D1665
GW2D1670
GW2D1675
GW2D1680
GW2D1685
GW2D1690
GW2D1695
GW2D1700
GW2D1705
GW2D1710
GW2D1715
GW2D1720
GW2D1725
GW2D1730
GW2D1735
GW2D1740
GW2D1745
GW2D1750

```

Appendix C (continued)

```

      NPP=NPP+1
      NPCNV(NPP)=NP
      CCONTINUE
190
C      ANCVN=NPF
C
C      UPDATE PRESSURE WITH CURRENT ITERATE
C
      DO 200 NP=1,NNP
      H(NP)=R(NP)
200      H(NP)=W1*H(NP)+W2*HP(NP)
C
C      ESCAPE FROM ITERATION LOOP IF THE MAXIMUM RESIDUAL IS
C      SUFFICIENTLY SMALL
C
      IF (IBUG.NE.0) PRINT 10200,NIT,RES,RO,NNCVN
      IF (IT.EQ.1.AND.ITM.EQ.1) GO TO 210
      IF (RES.LT.TOLB) GO TO 220
210      CONTINUE
C
C      END THE ITERATION LOOP ON THE NON-LINEAR EQUATION
C
      IF (IBUG.EQ.0) GO TO 220
C
C      PRINT NONCONVERGING NODES
C
      PRINT 10500
      PRINT 10600,(NPCNV(NPP),NPP=1,NNCVN)
C
C      PRINT RAINFALL-SEEPAGE BOUNDARY CONDITION CHANGE INFORMATION
C
220      IF (ICHNG.EQ.0) GO TO 225
      IF (NRSN.EQ.0) GO TO 225
      PRINT 10402
      DO 224 IRSN=1,NRSN
      NP=NPRS(IRSN)
      PRINT 10403,IRSN,NP,NPCON(IRSN),HCON(IRSN),NPFLX(IRSN),
      FLX(IRSN),DCYFLX(IRSN)
224      CONTINUE
C
C      CALCULATE FLOW RATES
C
225      CALL SPROP(IE, H,TH,DTH,AKX,AKZ, PROP,THPRDP,AKPROD,H2POD,
      CAPROP,MAXEL,MAXNP,MAXMAT,MXNPPM,MXSPPM,NEL,K5)
C
      CALL VELT(X,Z,IE, C,H,HT,VX,VZ,AKX,AKZ, MAXEL,MAXNP,MAXHSD)
C
      IF (NRSN.EQ.0) GO TO 240
C
      CALL BCPREP(IE, H,VX,VZ, DL,DCOSX,DCOSZ,DCYFLX,FLX,R5FLX,

```

GW2D1755
 GW2D1760
 GW2D1765
 GW2D1770
 GW2D1775
 GW2D1780
 GW2D1785
 GW2D1790
 GW2D1795
 GW2D1800
 GW2D1805
 GW2D1810
 GW2D1815
 GW2D1820
 GW2D1825
 GW2D1830
 GW2D1835
 GW2D1840
 GW2D1845
 GW2D1850
 GW2D1855
 GW2D1860
 GW2D1865
 GW2D1870
 GW2D1875
 GW2D1880
 GW2D1885
 GW2D1890
 GW2D1895
 GW2D1900
 GW2D1905
 GW2D1910
 GW2D1915
 GW2D1920
 GW2D1925
 GW2D1930
 GW2D1935
 GW2D1940
 GW2D1945
 GW2D1950
 GW2D1955
 GW2D1960
 GW2D1965
 GW2D1970
 GW2D1975
 GW2D1980
 GW2D1985
 GW2D1990
 GW2D1995
 GW2D2000

Appendix C (continued)

>	HCCN,NRSE,IS,NPRS,NPCCN,NPFLX,IRFTYP,TRF,RF,RFALL,MAXEL,	GW202005
>	MAXNP, MXRSEL, MXRSNP, MXRFR, MXRPAR, TIME, NCHG)	GW202010
	IF (NCHG.EQ.0) GO TO 240	GW202015
230	CONTINUE	GW202020
C	END THE ITERATION LCCP ON THE SEEPAGE-RAINFALL BOUNDARY CONDITIONS	GW202025
C		GW202030
C		GW202035
240	IF(IMID.EQ.0) GO TO 245	GW202040
	DO 243 I=1,NNP	GW202045
243	H(I)=2.0004H(I) - HP(I)	GW202050
C		GW202055
	DO 244 I=1,NBC	GW202060
	NI=NN(I)	GW202065
244	H(NI)=BB(I)	GW202070
C		GW202075
245	CALL SFLOW(X,Z,IE,TH,VX,VZ,DLB,DCOSXB,DCOSZB,BFLX,BFLX,ISB,	GW202080
>	NBE,NPB,NPRS,NPST,NN,FRATE,FLOW,TFLOW,MAXNP,MAXEL,	GW202085
>	MAXBEL,MAXBNP, MXRSNP, MXSTNP,MAXBCN,KFLD,DELT,OTH,HP,	GW202090
>	PROP,MAXMAT,MAXPPM)	GW202095
C		GW202100
C	PRINT VARIABLES AT EACH TIME STEP	GW202105
C		GW202110
	CALL PRINTT(VX,VZ,H,HT,TH,NPB,BFLX,NPRS,RSFLX,NPCCN,NPF,X,	GW202115
>	FRATE,FLOW,TFLOW,MAXNP,MAXEL,MAXBNP,MXRSNP,NNP,NEL,NBY,NRS,	GW202120
>	TIME,DELT,SUBMD(1,3),IBAND,KPR(ITM),KOUT,KDIAG,ITM)	GW202125
C		GW202130
	IF(KSTR.EQ.1 .AND. KDSK(ITM).EQ.1) CALL STORE(X,Z,IE,H,HT,TH,X,VZ,	GW202135
>	DLB,DCOSXB,DCOSZB,NBE,ISB,NPB,TITLE,TIME,MAXNP,MAXEL,MAXBNP,	GW202140
>	MAXBEL,NPROB,NNP,NEL,NBN,NOEL,NTI,NPCCN,NPF,X,MXRSNP,NISN,	GW202145
>	NSTR)	GW202150
C		GW202155
C	PREPARE FOR NEXT TIME STEP	GW202160
C		GW202165
	IF (TIME.GT.TMAX) GO TO 10	GW202170
	DELT=DELT*(1.+CHNG)	GW202175
	DELT=DMIN1(DELT,DELMAX)	GW202180
	TIME=TIME+DELT	GW202185
250	CONTINUE	GW202190
C		GW202195
C	END OF TIME-MARCHING LOOP	GW202200
C		GW202205
C		GW202210
	GO TO 10	GW202215
260	PRINT 10300,IMBP,MAXHBP	GW202220
C		GW202225
270	RETURN	GW202230
C		GW202235
10000	FORMAT(15,9A8,1X,211)	GW202240
10100	FORMAT(/8H1PROBLEM,15,3H..,9A8/)	GW202245
		GW202250

Appendix C (continued)

10200	FORMAT(5X,I10,3X,E12.4,3X,E12.4,15X,I10)	GW2D2255
10300	FORMAT(///26H HALF-BANDWIDTH-PLUS-ONE =.I4,	GW2D2260
	> 25H EXCEEDS MAX. ALLOWABLE =.I4)	GW2D2265
10400	FORMAT(1H1,52H*****	GW2D2270
	> 62H*****	GW2D2275
	> 5H*****//17H DIAGNOSTIC TABLE,I4,I2H.. AT TIME =.1PD12.4,	GW2D2280
	> 9H .(DELT = 1PD12.4,1H))	GW2D2285
10401	FORMAT(///30H TABLE OF ITERATIVE PARAMETERS// 5X,	GW2D2290
	> 9H ITERATION,7X,8HRESIDUAL,6X,9HDEVIATION,6X,	GW2D2295
	> 19HNO. NCN-CONV. NODES)	GW2D2300
10402	FORMAT(//44H TABLE OF RAINFALL-SEEPAGE B. C. INFORMATION, / 5X,	GW2D2305
	> 87HIRSN NPRS(IRSN) NPCON(IRSN) HCON(NPRS) NPF_X(12SV)	GW2D2310
	> FLX(NPRS) DCYFLX(NPRS))	GW2D2315
10403	FORMAT(1H ,I10,I13,I15,E13.4,I15,E13.3,E15.3)	GW2D2320
10500	FORMAT(//30H TABLE OF NCN-CONVERGING NODES)	GW2D2325
10600	FORMAT(/(5X,20I5))	GW2D2330
	END	GW2D2335

Appendix C (continued)

```

SUBROUTINE DATAIN(X,Z,IE, H,HT,TH,VX,VZ, DLB,DCOSXB,DCOSZB,V3E,
> ISB,NPB, DL,DCCSX,DCOSZ,HCON,NRSE,IS,NPRS,NPCON,NPFLX,IRFTYP,
> TRF,RF, RP,NPST, BB,NN,
> PROP,THPROP,AKPRCP,HPROP,CAPROP, MAXEL,MAXNP,MAXHBP,
> MAXBEL,MAXBNP, MXRSEL,MXRSNP,MXRFP,MRPAR,
> MXSTEL,MXSTNP, MAXBCN, MAXMAT,MXMPPM,MXSPPM,NTHPPM,NAKPPM,
> MAXNTI, PMAT,AKPAR,THPAR, KPR,KDSK, ISTOP,MAXDIF,W,TIME,
> TITLE,NPROB)

```

FUNCTION OF SUBROUTINE--TO READ, PRINT, AND CHECK VARIABLES
PERTAINING TO SIMULATION TIME, GEOMETRY OF THE SYSTEM, ITS SOIL
PROPERTIES, BOUNDARY-INITIAL CONDITIONS FOR BOTH STEADY-STATE AND
TRANSIENT CASES, AND NUMERICAL CONVERGENCE CRITERIA.

```

IMPLICIT REAL*8(A-H,O-Z)
REAL*4 PMAT,THPAR,AKPAR

```

```

DIMENSION TITLE(5)
DIMENSION X(MAXNF),Z(MAXNP),IE(MAXEL,5)

```

```

DIMENSION H(MAXNP),HT(MAXNP),TH(MAXEL,4),VX(MAXNP),VZ(MAXNP)

```

```

DIMENSION DLB(MAXBEL),DCOSXB(MAXBEL),DCOSZB(MAXBEL),NBE(MAXBEL),
> ISB(MAXBEL,4),NPB(MAXBNP)

```

```

DIMENSION DL(MXRSEL),DCOSX(MXRSEL),DCOSZ(MXRSEL),HCON(MXRSEL),
> NRSE(MXRSEL),IS(MXRSEL,4),NPRS(MXRSEL),NPCON(MXRSEL),
> NPFLX(MXRSEL),IRFTYP(MXRSEL),TRF(MXRFP,MRPAR),
> RF(MXRFP,MRPAR)

```

```

DIMENSION RP(MXSTNP),NPST(MXSTNP),BB(MAXBCN),NN(MAXBCN)
DIMENSION PROP(MAXMAT,MXMPPM),THPROP(MAXMAT,MXSPPM),
> AKPROP(MAXMAT,MXSPPM),HPROP(MAXMAT,MXSPPM),CAPROP(MAXMAT,MXSPPM)

```

```

DIMENSION PMAT(3,MXNPPM),AKPAR(3,NAKPPM),THPAR(3,NTHPPM)
DIMENSION KPR(MAXNTI),KDSK(MAXNTI)

```

```

COMMON /GEOM/ SNFE,CSFE,ANP,NEL,IBAND
COMMON /CNTRL/ NTI,MAXCY,MAXIT,NSTRT,KSTR,KPRO,KDSK,KSS,(5)
COMMON /TOTLNS/ TCLA,TOLE
COMMON /PARAM/ DELT,CHNG,DELMAX,TMAX
COMMON /BRND/ NBEL,NBN,NRSEL,NRSN,NRFP,MRPAR
COMMON /BCST/ NBC,NST,NSTN
COMMON /NTL/ NMAT,MNPPM,NSPPM
COMMON /CPT/ ILUMP,IMID

```

```

IF (KSS.EQ.0) GO TO 505

```

```

DATA 005
DATA 010
DATA 015
DATA 020
DATA 025
DATA 030
DATA 035
DATA 040
DATA 045
DATA 050
DATA 055
DATA 060
DATA 065
DATA 070
DATA 075
DATA 080
DATA 085
DATA 090
DATA 095
DATA 100
DATA 105
DATA 110
DATA 115
DATA 120
DATA 125
DATA 130
DATA 135
DATA 140
DATA 145
DATA 150
DATA 155
DATA 160
DATA 165
DATA 170
DATA 175
DATA 180
DATA 185
DATA 190
DATA 195
DATA 200
DATA 205
DATA 210
DATA 215
DATA 220
DATA 225
DATA 230
DATA 235
DATA 240
DATA 245
DATA 250

```

Appendix C (continued)

```

C      ISTOP=0
      READ 12000,NNP,NEL,NMAT,NCM,NTI,KSS,KSP,NSPPM,<STR,<CP,KGRAV,
>      NSTRT,MAXIT,MAXCY,NMPPM
      READ 12000,ILLMP,IMID
      READ 12300,DELT,CHNG,DELMAX,TMAX,FE,TOLA,TOLB,RHO,GRAV,/ISC,W
      READ 12100,KPRO,(KPR(ITM),ITM=1,NTI)
      READ 12100,KDSK0,(KDSK(ITM),ITM=1,NTI)
C
      IF(TMAX.LE.0.0) TMAX=1.0E50
C
      PRINT 10000,NNP,NEL,NMAT,NCM,NTI,KSS,KSP,NSPPM,KSTR,KCP,<GRAV,
>      NSTRT,MAXIT,MAXCY
      PRINT 10001,ILLMP,IMID
      PRINT 10100,DELT,CHNG,DELMAX,TMAX,FE,TOLA,TOLB,RHO,GRAV,/ISC,W
      PRINT 10200
      PRINT 12200,KPRO,(KPR(ITM),ITM=1,NTI)
      PRINT 10201
      PRINT 12200,KDSK0,(KDSK(ITM),ITM=1,NTI)
C
      PI=3.14159265
      FE=FE*PI/180.
      SNFE=DSIN(FE)
      CSFE=DCOS(FE)
      IF (KGRAV.EQ.1) SNFE=0.
      IF (KGRAV.EQ.1) CSFE=0.
C
C      READ AND PRINT MATERIAL PROPERTIES
C
      70 IF (NMPPM.LE.J) GO TO 90
      IF (NMAT.LE.0) GO TO 90
      PRINT 10300,((PMAT(I,J),I=1,3),J=1,NMPPM)
      DO 80 I=1,NMAT
      READ 12300,(PRCP(I,J),J=1,NMPPM)
      80 PRINT 12500,I,(PROP(I,J),J=1,NMPPM)
      90 IF (KSP.EQ.1) GO TO 120
C
C      SOIL PROPERTIES ARE TO BE REPRESENTED BY ANALYTIC FUNCTIONS
C
C      READ AND PRINT MOISTURE-CONTENT PARAMETERS
C
      IF (NSPPM.EQ.0) GO TO 200
      PRINT 10500,((THPAR(I,J),I=1,3),J=1,NSPPM)
      DO 100 I=1,NMAT
      READ 12300,(THPROP(I,J),J=1,NSPPM)
      PRINT 12700,I,(THPROP(I,J),J=1,NSPPM)
100 CONTINUE

```

```

DATA 255
DATA 260
DATA 265
DATA 270
DATA 275
DATA 280
DATA 285
DATA 290
DATA 295
DATA 300
DATA 305
DATA 310
DATA 315
DATA 320
DATA 325
DATA 330
DATA 335
DATA 340
DATA 345
DATA 350
DATA 355
DATA 360
DATA 365
DATA 370
DATA 375
DATA 380
DATA 385
DATA 390
DATA 395
DATA 400
DATA 405
DATA 410
DATA 415
DATA 420
DATA 425
DATA 430
DATA 435
DATA 440
DATA 445
DATA 450
DATA 455
DATA 460
DATA 465
DATA 470
DATA 475
DATA 480
DATA 485
DATA 490
DATA 495
DATA 500

```

Appendix C (continued)

```

C READ AND PRINT CONDUCTIVITY PARAMETERS
C
  PRINT 10600,((AKFAR(I,J),I=1,3),J=1,NSFFM)
  DO 110 I=1,NMAT
    READ 12300, (AKPROP(I,J),J=1,NSPPM)
    PRINT 12700, I,(AKPROP(I,J),J=1,NSPPM)
  110 CONTINUE
  GO TO 200
  120 IF (NSPPM.EQ.0) GC TO 200
C SOIL PROPERTIES ARE TO BE GIVEN IN TABULAR FORM
C
C READ PRESSURES
C
  DO 130 I=1,NMAT
    READ 12300, (HPROP(I,J),J=1,NSPPM)
  130 CONTINUE
C READ WATER CONTENTS
C
  DO 140 I=1,NMAT
    READ 12300, (THPROP(I,J),J=1,NSPPM)
  140 CONTINUE
C READ CONDUCTIVITIES OR PERMEABILITIES
C
  DO 150 I=1,NMAT
    READ 12300, (AKPROP(I,J),J=1,NSPPM)
  150 CONTINUE
C READ WATER CAPACITIES
C
  DO 160 I=1,NMAT
    READ 12300, (CAPROP(I,J),J=1,NSPPM)
  160 CONTINUE
  PRINT 10400
  DO 170 I=1,NMAT
    PRINT 12600,I,(HPROP(I,J),THPROP(I,J),AKPROP(I,J),CAPROP(I,J),
    > J=1,NSPPM)
  170 CONTINUE
  IF (KCP.EQ.0) GO TO 200
C CONVERT FROM PERMEABILITY TO CONDUCTIVITY IF NECESSARY
C
  DO 190 I=1,NMAT
    PKCF=RHO*GRAV/VISC
    PROP(I,4)=PROP(I,4)*PKCF
    PROP(I,5)=PROP(I,5)*PKCF

```

```

DATA 505
DATA 510
DATA 515
DATA 520
DATA 525
DATA 530
DATA 535
DATA 540
DATA 545
DATA 550
DATA 555
DATA 560
DATA 565
DATA 570
DATA 575
DATA 580
DATA 585
DATA 590
DATA 595
DATA 600
DATA 605
DATA 610
DATA 615
DATA 620
DATA 625
DATA 630
DATA 635
DATA 640
DATA 645
DATA 650
DATA 655
DATA 660
DATA 665
DATA 670
DATA 675
DATA 680
DATA 685
DATA 690
DATA 695
DATA 700
DATA 705
DATA 710
DATA 715
DATA 720
DATA 725
DATA 730
DATA 735
DATA 740
DATA 745
DATA 750

```

Appendix C (continued)

```

      DO 180 J=1,NSPPM
180      AKPROP(I,J)=AKPRCP(I,J)*PKCF
190      CONTINUE
C
C      READ AND PRINT NODAL-PCINT DATA
C
200      NI=1
210      READ 12800, NJ,X(NJ),Z(NJ)
      IF (NJ-NI) 220,250,230
220      PRINT 15100, NJ
      PRINT 12500, NJ,X(NJ),Z(NJ)
      ISTOP=ISTCP+1
      GO TO 210
230      DF=NJ+1-NI
      DX=(X(NJ)-X(NI-1))/DF
      DZ=(Z(NJ)-Z(NI-1))/DF
240      CONTINUE
      X(NI)=X(NI-1)+DX
      Z(NI)=Z(NI-1)+DZ
250      NI=NI+1
      IF (NJ-NI) 260,250,240
260      IF (NI.LE.NNP) GO TO 210
      PRINT 10700
      KLINE=0
C
      DO 265 NI=1,NNP,4
      NJMN=NI
      NJMX=MIN0(NI+3,NNP)
      PRINT 12900,(NJ,X(NJ),Z(NJ),NJ=NJMN,NJMX)
      KLINE=KLINE+1
265      IF (MOD(KLINE,50).EQ.0) PRINT 10700
C
C      READ AND PRINT ELEMENT DATA
C
C      ALSO COMPUTE MAXIMUM NODAL DIFFERENCE FOR EACH ELEMENT
C
      PRINT 10800
      KLINE=0
      MAXDIF = 0
      MJ = 0
270      READ 12000, MI,(IE(MI,I),I=1,5),MODL,NLAY
      MTP=IE(MI,5)
      MND = 0
      DO 280 IQ=1,3
      IQ1 = IQ + 1
      DO 280 JQ=IQ1,4
      ND = IABS(IE(MI,IQ)-IE(MI,JQ))
      MND = MAX0(ND,MND)
280      MAXDIF = MAX0(ND,MAXDIF)

```

```

DATA 750
DATA 760
DATA 765
DATA 770
DATA 775
DATA 780
DATA 785
DATA 790
DATA 795
DATA 800
DATA 805
DATA 810
DATA 815
DATA 820
DATA 825
DATA 830
DATA 835
DATA 840
DATA 845
DATA 850
DATA 855
DATA 860
DATA 865
DATA 870
DATA 875
DATA 880
DATA 885
DATA 890
DATA 895
DATA 900
DATA 905
DATA 910
DATA 915
DATA 920
DATA 925
DATA 930
DATA 935
DATA 940
DATA 945
DATA 950
DATA 955
DATA 960
DATA 965
DATA 970
DATA 975
DATA 980
DATA 985
DATA 990
DATA 995
DATA 1000

```



```

250 MJ = MJ + 1
300 IF (MI-MJ) 300,330,310
300 PRINT 15200, MI
300 PRINT 13000, MI, (IE(MI,1),I=1.5).MND
310 ISTOP = ISTOP + 1
310 DO 320 I=1,4
320 IE(MJ,10) = IE(MJ-1,10) + 1
320 IE(MJ,5) = IE(MJ-1,5)
330 PRINT 13000, MJ, (IE(MJ,1),I=1.5).MND
330 IF (MJ-LT.MI) GO TO 290
330 IF (MJ-EQ.NEL) GC TO 370
330 IF (MODL.LE.0) GC TO 270
330 DO 360 I=1,NLAY
330 LL=2
330 DO 360 J=1,MODL
330 IF (MJ.EQ.MI) G' TO 350
330 DO 340 K=1,4
330 IE(MJ,KQ) = IE(MJ-1,KQ) + LL
330 IE(MJ,5) = IE(MJ-1,5)
330 PRINT 13000, MJ, (IE(MJ,K),K=1.5).MND
330 KLINE=KLINE+1
330 IF (MOD(KLINE,50).EQ.0) PRINT 10800
330 LL = 1
330 MJ = MJ + 1
330 MJ = MJ - 1
330 IF (MJ.LT.NEL) GC TO 270
330 CONTINUE
C
C C MODIFY MATERIAL TYPES FOR SELECTED ELEMENTS IF NECESSARY
C
330 IF (NCH.LE.0) GO TO 410
330 PRINT 10900
330 L=0
330 READ 12000, MI,MTYP,MK,MINC
330 IE(MI,5) = MTYP
330 PRINT 13100, MI,IE(MI,5)
330 L = L + 1
330 IF (MK.LE.MI) GO TO 400
330 IF (MINC.LE.0) MINC = 1
330 MI = MI + MINC
330 DO 390 MJ=MI,MK,MINC
330 IE(MJ,5) = MTYP
330 PRINT 13100, MJ,IE(MJ,5)
330 L = L + 1
330 IF (L.LT.NCH) GO TO 380
330 CONTINUE
390 DO 420 M=1,NEL
390 MTYP=IE(M,5)
390 IF (MTYP.GT.0.AND.MTYP.LE.NMAT) GO TO .
390 PRINT 15900,M

```

DATA1005
DATA1010
DATA1015
DATA1020
DATA1025
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DATA1035
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DATA1045
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DATA1055
DATA1060
DATA1065
DATA1070
DATA1075
DATA1080
DATA1085
DATA1090
DATA1095
DATA1100
DATA1105
DATA1110
DATA1115
DATA1120
DATA1125
DATA1130
DATA1135
DATA1140
DATA1145
DATA1150
DATA1155
DATA1160
DATA1165
DATA1170
DATA1175
DATA1180
DATA1185
DATA1190
DATA1195
DATA1200
DATA1205
DATA1210
DATA1215
DATA1220
DATA1225
DATA1230
DATA1235
DATA1240
DATA1245
DATA1250

Appendix C (continued)

```

      ISTOP=ISTOP+1
420  CONTINUE
      IF(ISTOP.EQ.0) GC TO 430
      PRINT 15000, ISTOP
      STOP
C
C  READ INITIAL CONDITIONS
C
430  TIME=0.000
      IF (NSTRY.EQ.0) GC TO 450
      REWIND 1
      REWIND 2
      READ(2) (DUM,I=1,6),IDUM,NPT,NET,NBN,NBEL,IDJM,NRSN
      IF (KSTR.EQ.1) WRITE(1) (TITLE(I),I=1,9),NPROB,NNP,NEL,NBN,NBE,
> NTL,NRSN
      READ(2) (X(NP),NP=1,NPT),(Z(NP),NP=1,NPT),((IE(M,IQ),M=1,NEL),IQ=
> 1,4),(DLB(M),M=1,NBEL),(DCOSXB(M),M=1,NBEL),
> (DCOSZB(M),M=1,NBEL),(NBE(M),M=1,NBEL),((ISB(M,IQ),M=1,NBE),IQ=
> 1,4),(NPB(NP),NP=1,NBN)
      IF (KSTR.EQ.1) WRITE(1) (X(NP),NP=1,NNP),(Z(NP),NP=1,NNP),((IE(M,
> IQ),M=1,NEL),IQ=1,4),(DLB(M),M=1,NBEL),(DCOSXB(M),M=1,NBE),
> (DCOSZB(M),M=1,NBEL),(NBE(M),M=1,NBEL),((ISB(M,IQ),M=1,NBE),IQ=
> 1,4),(NPB(NP),NP=1,NBN)
      DO 440 ITH=1,NSTRY
        READ(2) TIME,(H(NP),NP=1,NPT),(HT(NP),NP=1,NPT),((TH(M,I),M=1,
> NET),IQ=1,4),(VX(NP),NP=1,NPT),(VZ(NP),NP=1,NPT),
> (NPCCN(NP),NP=1,NRSN),(NPFLX(NP),NP=1,NRSN)
        IF (KSTR.EQ.0) GO TO 440
        WRITE(1) TIME,(H(NP),NP=1,NNP),(HT(NP),NP=1,NNP),((TH(M,I),M=
> 1,NEL),IQ=1,4),(VX(NP),NP=1,NNP),(VZ(NP),NP=1,NNP),
> (NPCCN(NP),NP=1,NRSN),(NPFLX(NP),NP=1,NRSN)
440  CONTINUE
      GO TO 500
450  NI = 0
      NJ = 0
460  IF (NJ.EQ.NNP) GC TO 500
      READ 13600,NJ,H(NJ)
470  NI = NI + 1
      IF (NI.GT.1) GO TO 480
      IF (NJ.EQ.1) GO TO 480
      PRINT 15300,NJ
      ISTOP=ISTOP+1
      GO TO 500
480  IF (NJ.EQ.NI) GO TO 460
      IF (NJ.GT.NI) GO TO 490
      PRINT 15300,NJ
      ISTOP=ISTOP+1
      GO TO 500
490  H(NI)=H(NI-1)
      GO TO 470

```

DATA1255
 DATA1260
 DATA1265
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 DATA1300
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 DATA1375
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 DATA1385
 DATA1390
 DATA1395
 DATA1400
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 DATA1425
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 DATA1435
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 DATA1445
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 DATA1455
 DATA1460
 DATA1465
 DATA1470
 DATA1475
 DATA1480
 DATA1485
 DATA1490
 DATA1495
 DATA1500

Appendix C (continued)

```

C IDENTIFY BOUNDARY ELEMENTS AND COMPUTE DIRECTION COSINES OF
C BOUNDARY SIDES
C
500 CALL SURF(X,Z,IE,DLB,DCOSXB,DCOSZB,NBE,ISB,NPB,
> MAXNP,MAXEL,MAXBEL,MAXBNP)
IF(KSS.EQ.1) GO TO 505
NRSN=0
C
C READ STEADY STATE OR TRANSIENT PARAMETERS
C
505 READ 12000,NBC,NST,NRFPR,NRFPAR,NRSEL,NRSN
C
PRINT 11000,NBC,NST,NRFPR,NRFPAR,NRSEL,NRSN
C
C READ AND PRINT STEADY STATE OR TRANSIENT RAINFALL-SEEPAGE INFO AT.
C
570 IF (NRSN.EQ.0) GO TO 800
C
C STEADY STATE OR TRANSIENT RAINFALL PROFILES
C
IF (NRFPR.EQ.0) GO TO 590
PRINT 11400
DO 580 I=1,NRFPR
READ 12300,(TRF(I,J),J=1,NRFPAR)
READ 12300,(RF(I,J),J=1,NRFPAR)
PRINT 11500,I
DO 580 J=1,NRFPAR
580 PRINT 12400,(TRF(I,J),RF(I,J))
C
C STEADY STATE OR TRANSIENT RAINFALL TYPES AND PONDING DEPTH
C
590 CONTINUE
NPP=0
610 IF (NPP.EQ.NRSN) GO TO 670
IF (NPP.LT.NRSN) GO TO 620
PRINT 14800,NRSN
ISTOP=ISTOP+1
GO TO 670
620 READ 13400,NI,ITYP,NPINC,HCCNI
IF (NPINC.GT.0) GO TO 640
630 NPP=NPP+1
NPRS(NPP)=NI
IRFTYP(NPP)=ITYP
HCON(NPP)=HCCNI
GO TO 610
640 IF (NPP.GT.0) GO TO 650
ISTOP=ISTOP+1
PRINT 15500

```

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DATA1505
DATA1510
DATA1515
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DATA1525
DATA1530
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DATA1570
DATA1575
DATA1580
DATA1585
DATA1590
DATA1595
DATA1600
DATA1605
DATA1610
DATA1615
DATA1620
DATA1625
DATA1630
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DATA1640
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DATA1655
DATA1660
DATA1665
DATA1670
DATA1675
DATA1680
DATA1685
DATA1690
DATA1695
DATA1700
DATA1705
DATA1710
DATA1715
DATA1720
DATA1725
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DATA1735
DATA1740
DATA1745
DATA1750

```

Appendix C (continued)

```

650 NJ=NPRS(NPP)
    JTYP=IRFTYP(NPP)
    HCONJ=HCON(NPP)
    NJ=NJ+NPINC
    NK=NI-1
    DO 660 NP=NJ,NK,NFINC
        NPP=NPP+1
        NPRS(NPP)=NP
        IRFTYP(NPP)=JTYP
660    HCON(NPP)=HCONJ
        GO TO 630
670 PRINT 11600
    DO 680 NPP=1,NRSH
        NP=NPRS(NPP)
680    PRINT 13500,NP,IRFTYP(NPP),HCON(NPP)
C
C    STEADY STATE OR TRANSIENT RAINFALL-SEEPAGE ELEMENT SURFACE INFORMAT.
C
    MPI=0
690 IF (MPI.EQ.NRSEL) GO TO 740
    READ 12000,MI,IS1,IS2,KINC
    IF (KINC.GT.0) GO TO 710
700 MPI=MPI+1
    NRSE(MPI)=MI
    IS(MPI,1)=IS1
    IS(MPI,2)=IS2
    GO TO 690
710 IF (MPI.GT.0) GO TO 720
    ISTOP=ISTOP+1
    PRINT 15600
720 NPINC=IS(MPI,2)-IS(MPI,1)
    MINC=ABS(NPINC)-1
    MINC=MAX0(MINC,1)
    MJ=NRSE(MPI)+MINC
    NK=MI-1
    DO 730 N=MJ,NK,MINC
        MPJ=MPI
        MPI=MPI+1
        NRSE(MPI)=N
        IS(MPI,1)=IS(MPJ,1)+NPINC
730    IS(MPI,2)=IS(MPJ,2)+NPINC
        GO TO 700
740 PRINT 11700
    DO 750 MP=1,NRSEL
        N=NRSE(MP)
750    PRINT 13000,M,IS(MP,1),IS(MP,2)
C
C    DETERMINE DIRECTION COSINES FOR STEADY STATE OR TRANSIENT
C    RAINFALL-SEEPAGE SURFACES
C

```

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DATA1755
DATA1760
DATA1765
DATA1770
DATA1775
DATA1780
DATA1785
DATA1790
DATA1795
DATA1800
DATA1805
DATA1810
DATA1815
DATA1820
DATA1825
DATA1830
DATA1835
DATA1840
DATA1845
DATA1850
DATA1855
DATA1860
DATA1865
DATA1870
DATA1875
DATA1880
DATA1885
DATA1890
DATA1895
DATA1900
DATA1905
DATA1910
DATA1915
DATA1920
DATA1925
DATA1930
DATA1935
DATA1940
DATA1945
DATA1950
DATA1955
DATA1960
DATA1965
DATA1970
DATA1975
DATA1980
DATA1985
DATA1990
DATA1995
DATA2000

```

Appendix C (continued)

```

DO 790 MPI=1,NRSEL
  MI=NRSE(MPI)
  DO 780 MPJ=1,NBEL
    MJ=NBE(MPJ)
    IF (MJ.NE.MI) GO TO 780
    IF (ISB(MPJ,1).EQ.IS(MPI,1).AND.ISB(MPJ,2).EQ.IS(MPI,2)) GJ
  >    TO 760
  >    IF (ISB(MPJ,1).EQ.IS(MPI,2).AND.ISB(MPJ,2).EQ.IS(MPI,1)) GJ
    TO 760
    GO TO 780
  DO 770 J=1,4
  760    IS(MPI,J)=ISB(MPJ,J)
  770    DL(MPI)=DLB(MPJ)
    DCOSX(MPI)=DCOSXB(MPJ)
    DCOSZ(MPI)=DCOSZB(MPJ)
    GO TO 790
  780    CONTINUE
    ISTOP=ISTOP+1
    PRINT 14900,MI
  790    CONTINUE
  800 DO 810 NP=1,MAXBCN
  810    RP(NP)=0.
    IF (NBC.EQ.0) GC TO 900
C C C
  READ STEADY STATE OR TRANSIENT BOUNDARY CONDITIONS OF THE FJRM H=83
  NPP=0
  820 IF (NPP.EQ.NBC) GC TO 880
    IF (NPP.LT.NBC) GC TO 830
    PRINT 14300,NBC
    ISTOP=ISTOP+1
    GO TO 880
  830 READ 13300,NI,NPINC,88I
    IF (NPINC.GT.0) GC TO 850
  840 NPP=NPP+1
    NN(NPP)=NI
    BB(NPP)=88I
    GO TO 820
  850 IF (NPP.GT.0) GO TO 860
    ISTOP=ISTOP+1
    PRINT 15400
  860 NJ=NN(NPP)+NPINC
    BBJ=BB(NPP)
    NK=NI-1
    DO 870 NP=NJ,NK,NFINC
      NPP=NPP+1
      NN(NPP)=NP
      BB(NPP)=BBJ
  870    GO TO 840
  880 PRINT 11100

```

DATA2005
 DATA2010
 DATA2015
 DATA2020
 DATA2025
 DATA2030
 DATA2035
 DATA2040
 DATA2045
 DATA2050
 DATA2055
 DATA2060
 DATA2065
 DATA2070
 DATA2075
 DATA2080
 DATA2085
 DATA2090
 DATA2095
 DATA2100
 DATA2105
 DATA2110
 DATA2115
 DATA2120
 DATA2125
 DATA2130
 DATA2135
 DATA2140
 DATA2145
 DATA2150
 DATA2155
 DATA2160
 DATA2165
 DATA2170
 DATA2175
 DATA2180
 DATA2185
 DATA2190
 DATA2195
 DATA2200
 DATA2205
 DATA2210
 DATA2215
 DATA2220
 DATA2225
 DATA2230
 DATA2235
 DATA2240
 DATA2245
 DATA2250

Appendix C (continued)

```

      DO 890 NPP=1,NBC
890   PRINT 13200,NK(NPP),BB(NPP)
900   IF (NST.LE.0) GO TO 1000
C
C   READ STEADY STATE OR TRANSIENT SURFACE-TERM POINT FLUXES
C
      NPP=0
      NP=0
      PRINT 11200
910   IF (NP.EQ.NST) GC TO 960
      READ 13400,NI,NJ,KINC,EI,EJ
      IF (KINC.GT.0) GC TO 930
920   NP=NP+1
      DX=X(NI)-X(NJ)
      DZ=Z(NI)-Z(NJ)
      EL=DSORT(DX*DX+DZ*DZ)
      PRINT 13500,NI,NJ,EI,EJ
      IF (NP.GT.1) GC TC 921
      NPP=NPP+1
      NPST(NPP)=NI
      NII=NPP
      NPP=NPP+1
      NPST(NPP)=NJ
      NJJ=NPP
      GO TO 920
921   DO 922 I=1,NPP
      IJ=NPST(I)
      IF (IJ.EQ.NI) GC TO 923
922   CONTINUE
      NPP=NPP+1
      NPST(NPP)=NI
      NII=NPP
      GO TO 924
923   NII=I
924   DO 925 J=1,NPP
      IJ=NPST(J)
      IF (IJ.EQ.NJ) GC TO 926
925   CONTINUE
      NPP=NPP+1
      NPST(NPP)=NJ
      NJJ=NPP
      GO TO 922
926   NJJ=J
928   RP(NII)=RP(NII)+EI*EL/3.0+EJ*EL/6.0
      RP(NJJ)=RP(NJJ)+EI*EL/6.0+EJ*EL/3.0
      EK=EJ
      GO TO 910
930   IF (NP.GT.0) GC TC 940
      ISTOP=ISTOP+1
      PRINT 15700

```

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DATA2255
DATA2260
DATA2265
DATA2270
DATA2275
DATA2280
DATA2285
DATA2290
DATA2295
DATA2300
DATA2305
DATA2310
DATA2315
DATA2320
DATA2325
DATA2330
DATA2335
DATA2340
DATA2345
DATA2350
DATA2355
DATA2360
DATA2365
DATA2370
DATA2375
DATA2380
DATA2385
DATA2390
DATA2395
DATA2400
DATA2405
DATA2410
DATA2415
DATA2420
DATA2425
DATA2430
DATA2435
DATA2440
DATA2445
DATA2450
DATA2455
DATA2460
DATA2465
DATA2470
DATA2475
DATA2480
DATA2485
DATA2490
DATA2495
DATA2500

```

Appendix C (continued)

```

940 NPINC=IABS(NJ-NI)
    NPMIN=MAX0(NPST(NPP),NPST(NPP-1))
    NPMAX=MIN0(NI,NJ)-1
    DO 950 NK=NPMIN,NFMAX,NPINC
        NL=NK+NPINC
        MP=MP+1
        DX=X(NK)-X(NL)
        DZ=Z(NK)-Z(NL)
        EL=OSORT(DX*DX+DZ*DZ)
        PRINT 13500,NK,NL,EK,EK
        IF(MP.GT.1) GC TO 941
        NPP=NPP+1
        NPST(NPP)=NK
        NKK=NPP
        NPP=NPP+1
        NPST(NPP)=NL
        NLL=NPP
        GO TO 948
941 DO 942 K=1,NPP
        KL=NPST(K)
        IF(KL.EQ.NK) GO TO 943
942 CONTINUE
        NPP=NPP+1
        NPST(NPP)=NK
        NKK=NPP
        GO TO 944
943 NKK=K
944 DO 945 L=1,NPP
        KL=NPST(L)
        IF(KL.EQ.NL) GO TO 946
945 CONTINUE
        NPP=NPP+1
        NPST(NPP)=NL
        NLL=NPP
        GO TO 948
946 NLL=L
948 RP(NKK)=RP(NKK)+EK*EL/2.0
        RP(NLL)=RP(NLL)+EK*EL/2.0
950 CONTINUE
        GO TO 920
960 NSTN=NPP
C
C APPLY STEADY STATE OR TRANSIENT DIRICHLET BOUNDARY CONDITIONS ( )
C INITIAL CONDITIONS
C
1000 IF (NBC.EQ.0) GO TO 1020
    DO 1010 NPP=1,NBC
        NP=NN(NPP)
        H(NP)=BB(NPP)
1010 H(NP)=BB(NPP)
1020 IF (ISTOP.EQ.0) GC TO 1030

```

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DATA2505
DATA2510
DATA2515
DATA2520
DATA2525
DATA2530
DATA2535
DATA2540
DATA2545
DATA2550
DATA2555
DATA2560
DATA2565
DATA2570
DATA2575
DATA2580
DATA2585
DATA2590
DATA2595
DATA2600
DATA2605
DATA2610
DATA2615
DATA2620
DATA2625
DATA2630
DATA2635
DATA2640
DATA2645
DATA2650
DATA2655
DATA2660
DATA2665
DATA2670
DATA2675
DATA2680
DATA2685
DATA2690
DATA2695
DATA2700
DATA2705
DATA2710
DATA2715
DATA2720
DATA2725
DATA2730
DATA2735
DATA2740
DATA2745
DATA2750

```

Appendix C (continued)

```

      PRINT 15000, 1STCP
C
C   REAL STEADY STATE OR TRANSIENT NATURAL-DRAINAGE ELEMENT
C   SURFACE INFORMATION
C
1030 CONTINUE
C
      PRINT 20000, NBN,(NPB(I),I=1,NBN)
      PRINT 21000, NBEL,(NBE(I),I=1,NBEL)
      IF(NRSN.NE.0) PRINT 22000, NRSN,(NPRS(I),I=1,NRSN)
      IF(NRSEL.NE.0) PRINT 23000, NRSEL,(NRSE(I),I=1,NRSEL)
      IF(NST.NE.0) PRINT 26000, NST,NSTN,(NPST(I),I=1,NSTN)
      IF(NBC.NE.0) PRINT 27000, NBC,(NN(I),I=1,NBC)
C
      RETURN
C
C
10000 FORMAT(35H0INPUT TABLE 1.. BASIC PARAMETERS // 5X,
> 40H NUMBER OF NODAL POINTS. . . . .15/ 5X,
> 40H NUMBER OF ELEMENTS. . . . .15/ 5X,
> 40H NUMBER OF DIFFERENT MATERIALS. . . . .15/ 5X,
> 40H NUMBER OF CORRECTION MATERIALS. . . . .15/ 5X,
> 40H NUMBER OF TIME INCREMENTS. . . . .15/ 5X,
> 40H STEADY-STATE I.C. CONTROL. . . . .15/ 5X,
> 40H SOIL-PROPERTY CONTROL. . . . .15/ 5X,
> 40H NUMBER OF SOIL PARAMETERS. . . . .15/ 5X,
> 40H AUXILIARY STORAGE CONTROL. . . . .15/ 5X,
> 40H CONDUCTIVITY-PERMEABILITY CONTROL. . . . .15/ 5X,
> 40H GRAVITY CONTROL. . . . .15/ 5X,
> 40H RESTART PARAMETER. . . . .15/ 5X,
> 40H MAXIMUM ITERATIONS PER CYCLE. . . . .15/ 5X,
> 40H MAXIMUM CYCLES PER TIME STEP. . . . .15)
10001 FORMAT(1H ,4X,
> 40H LUMPING INDICATOR, ILUMP. . . . .15/ 5X,
> 40H TIME-DIFFERENCE INDICATOR, IMID. . . . .15)
10100 FORMAT(5X,40H TIME INCREMENT. . . . .F10.6/ 5X,
> 40H MULTIPLIER FOR INCREASING DELT. . . . .F10.6/ 5X,
> 40H MAXIMUM VALUE OF DELT. . . . .D10.4/ 5X,
> 40H MAXIMUM VALUE OF TIME. . . . .D10.4/ 5X,
> 40H DEGREES OF PRIN-AXIS INCLINATION. . . . .F10.6/ 5X,
> 40H STEADY-STATE TOLERANCE. . . . .F10.6/ 5X,
> 40H TRANSIENT STATE TOLERANCE. . . . .F10.6/ 5X,
> 40H DENSITY OF WATER. . . . .F10.6/ 5X,
> 40H ACCELERATION OF GRAVITY. . . . .F10.3/ 5X,
> 40H VISCOSITY OF WATER. . . . .F10.6/ 5X,
> 40H TIME-INTEGRATION PARAMETER. . . . .F10.6)
10200 FORMAT(/6X,14HOUTPUT CONTROL)
10201 FORMAT(/6X,15HDISK OUTPUT CONTROL)
10300 FORMAT(35H1INPUT TABLE 2.. MATERIAL PROPERTIES// 9H MAT. V)..  

> 3A4))

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DATA2755
DATA2760
DATA2765
DATA2770
DATA2775
DATA2780
DATA2785
DATA2790
DATA2795
DATA2800
DATA2805
DATA2810
DATA2815
DATA2820
DATA2825
DATA2830
DATA2835
DATA2840
DATA2845
DATA2850
DATA2855
DATA2860
DATA2865
DATA2870
DATA2875
DATA2880
DATA2885
DATA2890
DATA2895
DATA2900
DATA2905
DATA2910
DATA2915
DATA2920
DATA2925
DATA2930
DATA2935
DATA2940
DATA2945
DATA2950
DATA2955
DATA2960
DATA2965
DATA2970
DATA2975
DATA2980
DATA2985
DATA2990
DATA2995
DATA3000

```


Appendix C (continued)

```

10400 FORMAT(53HINPUT TABLE 3.. SOIL-PROPERTIES INTERPOLATION VALUES//
> 9H MAT. NO.,9X,2HMPRESSURE,13X,16HMOISTURE CONTENT,4X,
> 25HCONDUCTIVITY/PERMEABILITY,6X,14HWATER CAPACITY)
10500 FORMAT(44HINPUT TABLE 3.. MOISTURE-CONTENT PARAMETERS//
> 9H MAT. NO.,8(3A4))
10600 FORMAT(40HINPUT TABLE 4.. CONDUCTIVITY PARAMETERS// 9H MAT. NO.,
> 2(3A4))
10700 FORMAT(32HINPUT TABLE 5.. NODAL POINT DATA//2X,
> 4HNODE,10X,1HX,10X,1HZ,4X,4HNODE,10X,1HX,10X,1HZ,4X,4HNODE,
> 10X,1HX,10X,1HZ,4X,4HNODE,10X,1HX,10X,1HZ/
> 27H*****3X,27H*****
> 3X,27H*****3X,27H*****
> 6/)
10800 FORMAT(29HINPUT TABLE 6.. ELEMENT DATA// 11X,
> 31HGLOBAL INDICES OF ELEMENT NODES/7X,7HELEMENT,3X,1H1,7X,1H2,
> 7X,1H3,7X,1H4,6X,8HMATERIAL,4X,9HNODE DIFF.)
10900 FORMAT(64H CORRECTIONS TO MATERIAL TYPES AND CLASSES FOR SELECTED
> ELEMENTS)
11000 FORMAT(45HINPUT TABLE 7.. STEADY-STATE B.C. PARAMETERS// 5X,
> 40H NUMBER OF BOUNDARY CONDITIONS . . . . .15/ 5X,
> 40H NUMBER OF SURFACE TERMS . . . . .15/ 5X,
> 40H NUMBER OF RAINFALL PROFILES . . . . .15/ 5X,
> 40H NUMBER OF RAINFALL PARAMETERS . . . . .15/ 5X,
> 40H NUMBER OF RAINFALL-SEEPAGE ELEMENTS . . .15/ 5X,
> 40H NUMBER OF RAINFALL-SEEPAGE NODES. . . .15)
11100 FORMAT(53HINPUT TABLE 8.. STEADY-STATE BOUNDARY CONDITIONS OF ,
> 9HFORM H=BB//6H NODE,7X,2HBB)
11200 FORMAT(43HINPUT TABLE 9.. STEADY-STATE SURFACE TERMS,
> 33H E=E1 AT NODE NI, E=EJ AT NODE NJ//8X,2HNI,8X,2HNJ,10X,2HEI,
> 13X,2HEJ/)
11300 FORMAT(43HINPUT TABLE 10.. TRANSIENT B.C. PARAMETERS// 5X,
> 40H NUMBER OF BOUNDARY CONDITIONS . . . . .15/ 5X,
> 40H NUMBER OF SURFACE TERMS . . . . .15/ 5X,
> 40H NUMBER OF RAINFALL PROFILES . . . . .15/ 5X,
> 40H NUMBER OF RAINFALL PARAMETERS . . . . .15/ 5X,
> 40H NUMBER OF RAINFALL-SEEPAGE ELEMENTS . . .15/ 5X,
> 40H NUMBER OF RAINFALL-SEEPAGE NODES. . . .15)
11400 FORMAT(31HINPUT TABLE 11.. RAINFALL DATA)
11500 FORMAT(/8H PROFILE,15/8X,4HTIME,11X,4HRATE)
11600 FORMAT(51HINPUT TABLE 12.. RAINFALL DISTRIBUTION AND PONDING//
> 6X,4HNODE,6X,4HTYPE,5X,5HDEPTH)
11700 FORMAT(54HINPUT TABLE 13.. RAINFALL-SEEPAGE SURFACE INFORMATION//
> 5X,7HELEMENT,2X,6HNODE 1,2X,6HNODE 2)
11701 FORMAT(54HINPUT TABLE 13A. NATURAL DRAINAGE SURFACE INFORMATION//
> 5X,7HELEMENT,2X,6HNODE 1,2X,6HNODE 2)
11800 FORMAT(50HINPUT TABLE 14.. BOUNDARY CONDITIONS OF FORM H=BB//
> 6H NODE,7X,2HBB)
11900 FORMAT(31HINPUT TABLE 15.. SURFACE TERMS,
> 33H E=E1 AT NODE NI, E=EJ AT NODE NJ// 5H NI,5H NJ,6X,2HEI,
> 12X,2HEJ/)

```

```

DATA3005
DATA3010
DATA3015
DATA3020
DATA3025
DATA3030
DATA3035
DATA3040
DATA3045
DATA3050
DATA3055
DATA3060
DATA3065
DATA3070
DATA3075
DATA3080
DATA3085
DATA3090
DATA3095
DATA3100
DATA3105
DATA3110
DATA3115
DATA3120
DATA3125
DATA3130
DATA3135
DATA3140
DATA3145
DATA3150
DATA3155
DATA3160
DATA3165
DATA3170
DATA3175
DATA3180
DATA3185
DATA3190
DATA3195
DATA3200
DATA3205
DATA3210
DATA3215
DATA3220
DATA3225
DATA3230
DATA3235
DATA3240
DATA3245
DATA3250

```

Appendix C (continued)

```

12000 FORMAT(16I5)
12100 FORMAT(80I1)
12200 FORMAT(10X,10I1)
12300 FORMAT(8F10.0)
12400 FORMAT(2(1PD15.4))
12500 FORMAT(1E,5D12.4)
12600 FORMAT(1E,019.4,3D25.4/(2X,4D25.4))
12700 FORMAT(1E,9D12.4/(8X,9D12.4))
12800 FORMAT(15,2F10.3)
12900 FORMAT(1H,1E,2D11.3,3X,15,2D11.3,3X,15,2D11.3,3X,15,2D11.3)
13000 FORMAT(110,4I8,110,113)
13100 FORMAT(110,32X,110,32X,110)
13200 FORMAT(15,D15.4)
13300 FORMAT(21E,2F10.0)
13400 FORMAT(31E,5X,2F10.0)
13500 FORMAT(2110,2(1PD15.4))
13600 FORMAT(15,5X,F10.0)
14300 FORMAT(////37H CHECK BOUNDARY CONDITIONS, MAXIMUM =,15//)
14800 FORMAT(////43H TOO MANY RAINFALL-SEEPAGE NODES, MAXIMUM =,15//)
14900 FORMAT(////34H ERROR IN SURFACE CARD FOR ELEMENT,15//)
15000 FORMAT(////28H EXECUTION HALTED BECAUSE OF,15,13H FATAL ERRORS//)
15100 FORMAT(////30H ERROR IN NODAL-POINT CARD NO.,15//)
15200 FORMAT(////26H ERROR IN ELEMENT CARD NO.,15//)
15300 FORMAT(////36H ERROR IN INITIAL-CONDITION CARD NO.,15//)
15400 FORMAT(////49H ERROR IN FIRST H-BB TYPE BOUNDARY-CONDITION CARD //
> //)
15500 FORMAT(////48H ERROR IN FIRST RAINFALL-TYPE-PONDING-DEPTH CARD//)
15600 FORMAT(////45H ERROR IN FIRST RAINFALL-SEEPAGE ELEMENT CARD//)
15700 FORMAT(////33H ERROR IN FIRST SURFACE-TERM CARD//)
15800 FORMAT(////45H ASSEMBLY AND SOLUTION WILL NOT BE PERFORMED.,15.
> 15H FATAL CARD ERRORS//)
15900 FORMAT(////40H ERROR IN MATERIAL TYPE CODE FOR ELEMENT,15//)
20000 FORMAT(1H1,5X,'CHECK ALL BOUNDARY NODAL AND ELEMENT INFORMATION'//
> /5X,'TOTAL NUMBER OF BOUNDARY NODES ='',15/5X,
> 'THEY ARE LISTED BELOW:'/(5X,10I5))
21000 FORMAT(1H0,4X,'TOTAL NUMBER OF BOUNDARY ELEMENTS ='',15/5X,
> 'THEY ARE LISTED BELOW:'/(5X,10I5))
22000 FORMAT(1H0,4X,'TOTAL NUMBER OF RAINFALL-SEEPAGE BOUNDARY NODES ='',
> 15/5X,'THEY ARE LISTED BELOW:'/(5X,10I5))
23000 FORMAT(1H0,4X,'TOTAL NUMBER OF RAINFALL-SEEPAGE BOUNDARY ELEMENTS ='',
> 15/5X,'THEY ARE LISTED BELOW:'/(5X,10I5))
26000 FORMAT(1H0,4X,'TOTAL NUMBER OF SURFACE TERM BOUNDARY ELEMENTS ='',
> 15/5X,'TOTAL NUMBER OF SURFACE TERM BOUNDARY NODES ='',15/5X,
> 'THEY ARE LISTED BELOW:'/(5X,10I5))
27000 FORMAT(1H0,4X,'TOTAL NUMBER OF DIRICHLET NODES ='',15/5X,
> 'THEY ARE LISTED BELOW:'/(5X,10I5))
END

```

```

DATA3255
DATA3260
DATA3265
DATA3270
DATA3275
DATA3280
DATA3285
DATA3290
DATA3295
DATA3300
DATA3305
DATA3310
DATA3315
DATA3320
DATA3325
DATA3330
DATA3335
DATA3340
DATA3345
DATA3350
DATA3355
DATA3360
DATA3365
DATA3370
DATA3375
DATA3380
DATA3385
DATA3390
DATA3395
DATA3400
DATA3405
DATA3410
DATA3415
DATA3420
DATA3425
DATA3430
DATA3435
DATA3440
DATA3445
DATA3450
DATA3455
DATA3460
DATA3465
DATA3470
DATA3475
DATA3480
DATA3485

```


Appendix C (continued)

```

      NBN=NBN+1
      NPB(NBN)=NJ
25      DO 26 I=1,NBN
          IJ=NPB(I)
          IF(IJ.EQ.NI) GC TO 27
26      CONTINUE
      NBN=NBN+1
      NPB(NBN)=NI
27      DO 28 J=1,NBN
          IJ=NPB(J)
          IF(IJ.EQ.NJ) GC TC 29
28      CONTINUE
      NBN=NBN+1
      NPB(NBN)=NJ
29      CONTINUE
30      CONTINUE
40      CONTINUE
C
C      CALCULATE SIDE LENGTHS AND DIRECTION COSINES
C
      DO 70 MP=1,NBEL
          M=NBE(MP)
          NI=ISB(MP,1)
          NJ=ISB(MP,2)
          DX=X(NI)-X(NJ)
          DZ=Z(NI)-Z(NJ)
          DX=X(NJ)-X(NI)
          DZ=Z(NJ)-Z(NI)
          DLB(MP)=DSQRT(DX*DX+DZ*DZ)
C
          BETA=DATAN2(DZ,DX)
          DCOSXB(MP)=DSIN(BETA)
          DCOSZB(MP)=-DCOS(BETA)
70      CONTINUE
      RETURN
      END

```

```

SURF 255
SURF 260
SURF 265
SURF 270
SURF 275
SURF 280
SURF 285
SURF 290
SURF 295
SURF 300
SURF 305
SURF 310
SURF 315
SURF 320
SURF 325
SURF 330
SURF 335
SURF 340
SURF 345
SURF 350
SURF 355
SURF 360
SURF 365
SURF 370
SURF 375
SURF 380
SURF 385
SURF 390
SURF 395
SURF 400
SURF 405
SURF 410
SURF 415
SURF 420
SURF 425
SURF 430

```

Appendix C (continued)

```

C      SUBROUTINE VELT(X,Z,IE, C,H,HT,VX,VZ,AKX,AKZ, MAXEL,MAXNP,MAXHBP)
C      FUNCTION OF SUBROUTINE TO COMPUTE DARCY VELOCITY VX AND VZ
C      IMPLICIT REAL*8(A-H,O-Z)
C      DIMENSION X(MAXNP),Z(MAXNP),IE(MAXEL,5)
C      DIMENSION C(MAXNP,MAXHBP),H(MAXNP),HT(MAXNP),VX(MAXNP),VZ(MAXNP),
C      > AKX(MAXEL,4),AKZ(MAXEL,4)
C      DIMENSION QQ(4,4),RQ(4),XQ(4),ZQ(4),HTQ(4),AKXQ(4),AKZQ(4)
C      COMMON /GEOM/ SNFE,CSFE,INP,NEL,IBAND
C      IHALFB=(IBAND-1)/2
C      IHBP=IHALFB+1
C      INITIAZE THE DARCY VELOCITY VX(NP) AND VZ(NP)
C      DO 100 NP=1,INP
C      VX(NP)=0.0
C      100 VZ(NP)=0.0
C      CALCULATE THE TOTAL HEAD HT(NP)
C      DO 105 NP=1,INP
C      105 HT(NP)=H(NP)-X(NP)*SNFE+Z(NP)*CSFE
C      COMPUTE DARCY VELOCITIES BY APPLYING FINITE ELEMENT METHOD TO DARCY
C      EQUATIONS. IXZ=1 FOR COMPUTING VX, IXZ=2 FOR COMPUTING VZ.
C      DO 300 IXZ=1,2
C      INITIALIZE MATRIX C(NP,IB)
C      DO 110 NP=1,INP
C      DO 110 IB=1,IHBP
C      110 C(NP,IB)=0.0
C      COMPUTE THE ELEMENT MATRIX QQ(IQ,JQ) AND RQ(IQ)
C      DO 120 N=1,NEL
C      DO 120 IQ=1,4
C      NP=IE(N,IQ)
C      XQ(IQ)=X(NP)
C      ZQ(IQ)=Z(NP)
C      HTQ(IQ)=HT(NP)
C      AKXQ(IQ)=AKX(N,IQ)

```

```

VELT 005
VELT 010
VELT 015
VELT 020
VELT 025
VELT 030
VELT 035
VELT 040
VELT 045
VELT 050
VELT 055
VELT 060
VELT 065
VELT 070
VELT 075
VELT 080
VELT 085
VELT 090
VELT 095
VELT 100
VELT 105
VELT 110
VELT 115
VELT 120
VELT 125
VELT 130
VELT 135
VELT 140
VELT 145
VELT 150
VELT 155
VELT 160
VELT 165
VELT 170
VELT 175
VELT 180
VELT 185
VELT 190
VELT 195
VELT 200
VELT 205
VELT 210
VELT 215
VELT 220
VELT 225
VELT 230
VELT 235
VELT 240
VELT 245
VELT 250

```

Appendix C (continued)

```

120 AKZQ(IQ)=AKZ(M,IQ)
C
CALL Q4D(QQ,RQ,XQ,ZQ,AKXQ,AKZQ,HTQ,SNFE,CSFE,IXZ)
C
C
C ASSEMBLE QQ(IQ,JQ) INTO THE GLOBAL MATRIX C(NP,IB) AND
C FORM THE LOAD VECTOR VX(NP) OR VZ(NP)
C
DO 140 IQ=1,4
NI=IE(M,IQ)
DO 130 JQ=1,4
NJ=IE(M,JQ)
IF(NJ.LT.NI) GO TC 130
IB=NJ-NI+1
C(NI,IB)=C(NI,IB)+QQ(IQ,JQ)
130 CONTINUE
C
IF(IXZ.EQ.2) GO TC 135
VX(NI)=VX(NI)+RQ(IQ)
GO TO 140
135 VZ(NI)=VZ(NI)+RQ(IQ)
140 CONTINUE
C
160 CONTINUE
C
C SOLVE THE MATRIX EQUATION CX=B
C
IF(IXZ.EQ.2) GO TC 200
CALL BANSCL(1,C,VX,NNP,IHBP,MAXNP,MAXHBP)
CALL BANSCL(2,C,VX,NNP,IHBP,MAXNP,MAXHBP)
GO TO 300
200 CALL BANSOL(1,C,VZ,NNP,IHBP,MAXNP,MAXHBP)
CALL BANSOL(2,C,VZ,NNP,IHBP,MAXNP,MAXHBP)
300 CONTINUE
C
RETURN
END

```

```

VELT 255
VELT 260
VELT 265
VELT 270
VELT 275
VELT 280
VELT 285
VELT 290
VELT 295
VELT 300
VELT 305
VELT 310
VELT 315
VELT 320
VELT 325
VELT 330
VELT 335
VELT 340
VELT 345
VELT 350
VELT 355
VELT 360
VELT 365
VELT 370
VELT 375
VELT 380
VELT 385
VELT 390
VELT 395
VELT 400
VELT 405
VELT 410
VELT 415
VELT 420
VELT 425
VELT 430
VELT 435

```

Appendix C (continued)

```

C      SUBROUTINE Q4D(QQ,RQ,XQ,ZQ,AKXQ,AKZQ,HTQ,SNFE,CSFE,IND)
C
C      FUNCTION OF SUBROUTINE-TO EVALUATE THE MATRIX QUADRATURE OVER THE
C      AREA OF ONE ELEMENT. THESE INTEGRALS ARISE THROUGH THE
C      APPLICATION OF THE GALERKIN INTEGRATION SCHEME
C
C      IMPLICIT REAL*8 (A-H,O-Z)
C      REAL*8 N(4)
C
C      DIMENSION QQ(4,4),RQ(4),XQ(4),ZQ(4),HTQ(4),AKXQ(4),AKZQ(4)
C      DIMENSION S(4),T(4),DNX(4),DNZ(4)
C      DIMENSION PJAB(2,2),DNSS(4),DNNT(4)
C
C      DATA P / 577350269189626 /, S / -1.0D+00, 1.0D+00, 1.0D+00, -
C      > 1.0D+00 /, T / -1.0D+00, -1.0D+00, 1.0D+00, 1.0D+00 /
C
C      INITIALIZE MATRICES QQ(IQ,JQ) AND RQ(IQ)
C
C      DO 100 IQ=1,4
C      RQ(IQ)=0.0
C      DO 100 JQ=1,4
100  QQ(IQ,JQ)=0.0
C
C      SUMMATION OF THE INTEGRAND OVER THE GAUSSIAN POINTS
C
C      DO 400 KG=1,4
C
C      DETERMINE LOCAL COORDINATE (SS,TT) OF
C      GAUSS-INTEGRATION POINT KG
C
C      SS=P*S(KG)
C      TT=P*T(KG)
C
C      CALCULATE VALUES OF THE BASIS FUNCTIONS N(IQ) AND THEIR DERIVATIVES
C      DNX(IQ) AND DNZ(IQ) WITH RESPECT TO X AND Z, RESPECTIVELY, AT
C      THE GAUSS POINT KG
C
C      CALL BASE(N,DNSS,DNNT,SS,TT)
C
C      DO 11 I=1,2
C      DO 11 J=1,2
11  PJAB(I,J)=0.0
C      DO 12 I=1,4
C      PJAB(1,1)=PJAB(1,1)+ZQ(I)*DNNT(I)
C      PJAB(1,2)=PJAB(1,2)-ZQ(I)*DNSS(I)
C      PJAB(2,1)=PJAB(2,1)-XQ(I)*DNNT(I)

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040 005
040 010
040 015
040 020
040 025
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040 035
040 040
040 045
040 050
040 055
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040 070
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040 245
040 250

```

Appendix C (continued)

12	PJAB(2,2)=PJAB(2,2)+XQ(I)*DNSS(I)	Q40	255
	DJAC=PJAB(2,2)*PJAB(1,1)-PJAB(1,2)*PJAB(2,1)	Q40	260
	DJACI=1.0/DJAC	Q40	265
	DO 13 I=1,2	Q40	270
	DO 13 J=1,2	Q40	275
13	PJAB(I,J)=PJAB(I,J)*DJACI	Q40	280
	DO 14 I=1,4	Q40	285
	DNX(I)=DNSS(I)*PJAB(1,1)+DNTT(I)*PJAB(1,2)	Q40	290
14	DNZ(I)=DNSS(I)*PJAB(2,1)+DNTT(I)*PJAB(2,2)	Q40	295
C	AKXK=0.0	Q40	300
	AKZK=0.0	Q40	305
C		Q40	310
C	ACCUMULATE THE SLMS TO OBTAIN THE MATRIX INTEGRALS QQ(IQ,JQ)	Q40	315
C	AND RQ(IQ)	Q40	320
	DO 150 IQ=1,4	Q40	325
	AKXK=AKXK+AKXQ(IQ)*N(IQ)	Q40	330
150	AKZK=AKZK+AKZQ(IQ)*N(IQ)	Q40	335
	DO 300 IQ=1,4	Q40	340
	DO 300 JQ=1,4	Q40	345
	QQ(IQ,JQ)=QQ(IQ,JQ)+ N(IQ)*N(JQ)*DJAC	Q40	350
	IF(IND.EQ.2) GO TC 200	Q40	355
	RQ(IQ)=RQ(IQ)-AKXK*N(IQ)*(HTQ(JQ)*DNX(JQ))*DJAC	Q40	360
	GO TO 330	Q40	370
200	RQ(IQ)=RQ(IQ)-AKZK*N(IQ)*(HTC(JQ)*DNZ(JQ))*DJAC	Q40	375
300	CONTINUE	Q40	380
400	CONTINUE	Q40	385
	RETURN	Q40	390
	END	Q40	395
		Q40	400

Appendix C (continued)

```

SUBROUTINE SPRCP(IE, H, TH, DTH, AKX, AKZ, PROP, THPROP, A(CPROP, HSP),
> CAPROP, MAXEL, MAXNP, MAXMAT, MXMPPM, MXSPPM, NEL, KSP)

FUNCTION OF SUBROUTINE--TO CALCULATE SOIL PROPERTIES. I.E. THE
WATER CONTENTS TH(M,IQ), WATER CAPACITIES DTH(M,IQ), AND
PRINCIPAL VALUES OF THE CONDUCTIVITY TENSOR AKX(M,IQ) AND AKZ(4,IQ).

      IMPLICIT REAL*8(A-H,O-Z)

      DIMENSION IE(MAXEL,5), H(MAXNP), TH(MAXEL,4), DTH(MAXEL,4),
> AKX(MAXEL,4), AKZ(MAXEL,4)

      DIMENSION PROP(MAXMAT, MXMPPM), THPROP(MAXMAT, MXSPPM),
> AKPROP(MAXMAT, MXSPPM), HPROP(MAXMAT, MXSPPM),
> CAPROP(MAXMAT, MXSPPM)

      COMMON /MTL/ NMAT, NMPPM, NSPPM

----- TH, DTH/DH, AKX, AND AKZ ARE OBTAINED BY TABLE

      IF(KSP.EQ.0) GO TO 80
      DO 70 M=1, NEL
        MTP=IE(M,5)
        SATKX=PROP(MTYP,4)
        SATKZ=PROP(MTYP,5)
        DO 60 IQ=1,4
          NP=IE(M,IQ)
          HNP=H(NP)
          IF (HNP.GT.HPROP(MTYP,1)) GO TO 10
          JL=1
          JU=2
          A=0.
          GO TO 50
10         IF (HNP.LT.HPROP(MTYP,NSPPM)) GO TO 20
          JL=NSPPM
          JU=1
          A=C.
          GO TO 50
20         DO 30 J=2, NSPPM
          JU=J
          IF (HPROP(MTYP,J).GT.HNP) GO TO 40
          CONTINUE
30         JL=JU-1
40         A=(HNP-HPROP(MTYP,JL))/(HPROP(MTYP,JU)-HPROP(MTYP,JL))
50         TH(M,IQ)=THPROP(MTYP,JL)+A*(THPROP(MTYP,JJ)-THPROP(MTYP,JL))
          DTH(M,IQ)=CAPROP(MTYP,JL)+A*(CAPROP(MTYP,JJ)-CAPROP(MTYP,JL))

```

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SPRO 005
SPRO 010
SPRO 015
SPRO 020
SPRO 025
SPRO 030
SPRO 035
SPRO 040
SPRO 045
SPRO 050
SPRO 055
SPRO 060
SPRO 065
SPRO 070
SPRO 075
SPRO 080
SPRO 085
SPRO 090
SPRO 095
SPRO 100
SPRO 105
SPRO 110
SPRO 115
SPRO 120
SPRO 125
SPRO 130
SPRO 135
SPRO 140
SPRO 145
SPRO 150
SPRO 155
SPRO 160
SPRO 165
SPRO 170
SPRO 175
SPRO 180
SPRO 185
SPRO 190
SPRO 195
SPRO 200
SPRO 205
SPRO 210
SPRO 215
SPRO 220
SPRO 225
SPRO 230
SPRO 235
SPRO 240
SPRO 245
SPRO 250

```

Appendix C (continued)

```

>      )
      USKFCT=AKPROP(MTYP,JL)+A*(AKPROP(MTYP,JJ)-AKPROP(MTYP,JL))
      AKX(M,IQ)=SATKX*USKFCT
      AKZ(M,IQ)=SATKZ*USKFCT
60      CONTINUE
70      CONTINUE
      RETURN

C ----- TH, DTH/DH, AKX, AND AKZ ARE OBTAINED BY ANALYTICAL FORM
C ----- THE READER MUST SUPPLY THE FUNCTIONAL FORM OF FKX, FCZ, AND
C ----- FTH BELOW

C      80 DO 95 N=1,NEL
C      MTYP=IE(M,5)
C      SATKX=PROP(MTYP,4)
C      SATKZ=PROP(MTYP,5)

C ----- WCR=THPROP(MTYP,1)=0.065, 0.050 FOR TWO SAMPLE MATERIALS
C ----- WCS=THPRGF(MTYP,2)=0.364, 0.341 FOR TWO SAMPLE MATERIALS
C ----- RN=THPROP(MTYP,3)=1.092217, 1.546937 FOR TWO SAMPLE MATERIALS
C ----- ALPH=THPRGF(MTYP,4)=0.109, 0.002166 FOR TWO SAMPLE MATERIALS

      WCR=THPROP(MTYP,1)
      WCS=THPROP(MTYP,2)
      RN=THPROP(MTYP,3)
      ALPH=THPRGF(MTYP,4)
      RM=1.000-1.000/RN
      DO 90 IQ=1,4
        NP=IE(M,IQ)
        HNP=H(NP)
        HNP=-HNP

C ----- SATURATED CONDITION

      IF(HNP.GT.0.0) GO TO 85
      TH(M,IQ)=WCS
      DTH(M,IQ)=0.000
      AKX(M,IQ)=SATKX
      AKZ(M,IQ)=SATKZ
      GO TO 90

C ----- UNSATURATED CASE

      85      THMIQ=WCR+(WCS-WCR)/(1.000+(ALPH*HNP)**RN)**RM
      TH(M,IQ)=THMIQ
      RWC=(THMIQ-WCR)/(WCS-WCR)
      TERM=(1.0-RWC**((1.0/RN)**RM))
      RK=DSORT(RWC)*((1.0-TERM)**(1.-TERM))
      AKX(M,IQ)=SATKX*RK

```

SPRO 255
 SPRO 260
 SPRO 265
 SPRO 270
 SPRO 275
 SPRO 280
 SPRO 285
 SPRO 290
 SPRO 295
 SPRO 300
 SPRO 305
 SPRO 310
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 SPRO 320
 SPRO 325
 SPRO 330
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 SPRO 345
 SPRO 350
 SPRO 355
 SPRO 360
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 SPRO 370
 SPRO 375
 SPRO 380
 SPRO 385
 SPRO 390
 SPRO 395
 SPRO 400
 SPRO 405
 SPRO 410
 SPRO 415
 SPRO 420
 SPRO 425
 SPRO 430
 SPRO 435
 SPRO 440
 SPRO 445
 SPRO 450
 SPRO 455
 SPRO 460
 SPRO 465
 SPRO 470
 SPRO 475
 SPRO 480
 SPRO 485
 SPRO 490
 SPRO 495
 SPRO 500

Appendix C (continued)

```

C      AKZ(M,IG)=SATKZ*RK
      DTH(M,IQ)=ALPH*(RN-1.0)*TERM*RWCM*(1.0/RM)
      50  CONTINUE
      55  CONTINUE
      RETURN
      END

```

```

SPRD 505
SPRD 510
SPRD 515
SPRD 520
SPRD 525
SPRD 530
SPRD 535

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ORNL-5567

127

ORNL-5567

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BCPR	005
BCPR	010
BCPR	015
BCPR	020
BCPR	025
BCPR	030
BCPR	035
BCPR	040
BCPR	045
BCPR	050
BCPR	055
BCPR	060
BCPR	065
BCPR	070
BCPR	075
BCPR	080
BCPR	085
BCPR	090
BCPR	095
BCPR	100
BCPR	105
BCPR	110
BCPR	115
BCPR	120
BCPR	125
BCPR	130
BCPR	135
BCPR	140
BCPR	145
BCPR	150
BCPR	155
BCPR	160
BCPR	165
BCPR	170
BCPR	175
BCPR	180
BCPR	185
BCPR	190
BCPR	195
BCPR	200
BCPR	205
BCPR	210
BCPR	215
BCPR	220
BCPR	225
BCPR	230
BCPR	235
BCPR	240
BCPR	245
BCPR	250

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BCPR	255
BCPR	260
BCPR	265
BCPR	270
BCPR	275
BCPR	280
BCPR	285
BCPR	290
BCPR	295
BCPR	300
BCPR	305
BCPR	310
BCPR	315
BCPR	320
BCPR	325
BCPR	330
BCPR	335
BCPR	340
BCPR	345
BCPR	350
BCPR	355
BCPR	360
BCPR	365
BCPR	370
BCPR	375
BCPR	380
BCPR	385
BCPR	390
BCPR	395
BCPR	400
BCPR	405
BCPR	410
BCPR	415
BCPR	420
BCPR	425
BCPR	430
BCPR	435
BCPR	440
BCPR	445
BCPR	450
BCPR	455
BCPR	460
BCPR	465
BCPR	470
BCPR	475
BCPR	480
BCPR	485
BCPR	490
BCPR	495
BCPR	500

Appendix C (continued)

```

70    CONTINUE
C
C    CHANGE TO FLUX OR CONSTANT-HEAD CONDITIONS, AS NECESSARY, AND 3)
C    INDICATE IN THE ARRAYS NPFLX(NPP) AND NPCCN(NPP)
C
      IF (NCHG.NE.(-1)) GO TO 80
      NCHG=0
      RETURN
80    NCHG=0
      DO 100 NPP=1,NRSH
C
C    CHECK IF THE CHANGING FROM RAINFALL-FLUX (NEUMANN) CONDITION TO
C    PONDING (DIRICHLET) CONDITION IS NECESSARY
C
      NP=NPFLX(NPP)
      IF (NP.EQ.0) GO TO 90
      IF (HCCN(NPP).GE.H(NP)) GO TO 100
      NPCCN(NPP)=NPFLX(NPP)
      NPFLX(NPP)=0
      NCHG=NCHG+1
      GO TO 100
C
C    CHECK IF THE CHANGING FROM PONDING (DIRICHLET) CONDITION TO
C    RAINFALL-FLUX (NEUMANN) CONDITION IS NECESSARY
C
80    NP=NPCCN(NPP)
      IF (FLX(NPP).LE.DCYFLX(NPP)) GO TO 100
      NPFLX(NPP)=NPCCN(NPP)
      NPCCN(NPP)=0
      NCHG=NCHG+1
100   CONTINUE
      RETURN
      END

```

```

BCPR 505
BCPR 510
BCPR 515
BCPR 520
BCPR 525
BCPR 530
BCPR 535
BCPR 540
BCPR 545
BCPR 550
BCPR 555
BCPR 560
BCPR 565
BCPR 570
BCPR 575
BCPR 580
BCPR 585
BCPR 590
BCPR 595
BCPR 600
BCPR 605
BCPR 610
BCPR 615
BCPR 620
BCPR 625
BCPR 630
BCPR 635
BCPR 640
BCPR 645
BCPR 650
BCPR 655
BCPR 660
BCPR 665

```

Appendix C (continued)

```

C      SUBROUTINE ASEMBL(X,Z,IE, C,R,H,HP,TH,DTH,AKX,AKZ, PROP,
C      > MAXNP,MAXEL,MAXHBP, MAXMAT,MXMPPM, KSS,W,DELT)
C
C      FUNCTION OF SUBROUTINE--TO ASSEMBLE THE TOTAL COEFFICIENT MATRIX
C      C(NP,IB) AND LOAD VECTOR R(NP) FROM THE ELEMENT MATRICES QA(IQ,JQ),
C      QB(IQ,JQ), AND RQ(IQ).
C
C      IMPLICIT REAL*8(A-H,O-Z)
C
C      DIMENSION X(MAXNP),Z(MAXNP),IE(MAXEL,5)
C      DIMENSION C(MAXNP,MAXHBP),R(MAXNP),H(MAXNP),HP(MAXNP),
C      > TH(MAXEL,4),DTH(MAXEL,4),AKX(MAXEL,4),AKZ(MAXEL,4)
C      DIMENSION PROP(MAXMAT,MXMPPM)
C
C      DIMENSION QA(4,4),QB(4,4),RQ(4),THQ(4),DTHQ(4),AKXQ(4),AKZ(4),
C      > XQ(4),ZQ(4),IEM(4)
C
C      COMMON /GEOM/ SINFE,CSFE,NNP,NEL,IBAND
C      COMMON /G4PAR/ ALF,BETAP,POR,SINFE,COSFE
C      COMMON /OPT/ ILUMP,IMID
C
C      SINFE=SINFE
C      COSFE=COSFE
C      IHALFB=(IBAND-1)/2
C      IHBP=IHALFB+1
C
C      DELTI=1./DELT
C      W1=W
C      W2=1.-W
C      IF (KSS.GT.0) GO TO 10
C      DELTI=0.
C      W1=1.
C      W2=0.
C
C      INITIALIZE MATRICES C(NP,IB) AND R(NP)
C
C      10 DO 20 NP=1,NAP
C          R(NP)=0.0
C          DO 20 IB=1,IHBP
C              C(NP,IB)=0.0
C
C      START TO ASSEMBLE OVER ALL ELEMENTS
C
C      DO 60 M=1,NEL
C
C      COMPUTE MATRICES QA(IQ,JQ), QB(IQ,JQ), AND RQ(IQ) FOR ELEMENT M
C
C      MTYP=IE(M,5)

```

```

ASEM 005
ASEM 010
ASEM 015
ASEM 020
ASEM 025
ASEM 030
ASEM 035
ASEM 040
ASEM 045
ASEM 050
ASEM 055
ASEM 060
ASEM 065
ASEM 070
ASEM 075
ASEM 080
ASEM 085
ASEM 090
ASEM 095
ASEM 100
ASEM 105
ASEM 110
ASEM 115
ASEM 120
ASEM 125
ASEM 130
ASEM 135
ASEM 140
ASEM 145
ASEM 150
ASEM 155
ASEM 160
ASEM 165
ASEM 170
ASEM 175
ASEM 180
ASEM 185
ASEM 190
ASEM 195
ASEM 200
ASEM 205
ASEM 210
ASEM 215
ASEM 220
ASEM 225
ASEM 230
ASEM 235
ASEM 240
ASEM 245
ASEM 250

```


Appendix C (continued)

```

C      SUBROUTINE Q4(QA,QB,RQ,THQ,DTHQ,AKXQ,AKZQ,XQ,ZQ)
C
C      FUNCTION OF SUBROUTINE--TO EVALUATE THE MATRIX QUADRATJRES OVER THE
C      AREA OF ONE ELEMENT OF WATER CONTENT AND COMPRESSIBILITY QA(IQ,JQ)
C      AND OF CONDUCTIVITY QB(IQ,JQ) AND RQ(IQ), THE LATTER ARISING FROM THE
C      GRAVITY TERM IN THE MOISTURE-FLOW EQUATION. THESE INTEGRALS ARISE
C      THROUGH APPLICATION OF THE GALERKIN INTEGRATION SCHEME.
C
C      IMPLICIT REAL*8 (A-H,O-Z)
C      REAL*8 N(4)
C
C      COMMON /Q4PAR/ ALF,BETAP,POR,SMFE,CSFE
C      COMMON /OPT/ ILLMF,IMID
C
C      DIMENSION QA(4,4),QB(4,4),RQ(4),THQ(4),DTHQ(4),AKXQ(4),AKZQ(4),
C      > XQ(4),ZQ(4)
C      DIMENSION S(4),T(4),DNX(4),DNZ(4)
C      DIMENSION PJAB(2,2),DNSS(4),DNNT(4)
C
C      DATA P / 0.577350269189626 /, S / -1.0D+00, 1.0D+00, 1.0D+00, -
C      > 1.0D+00 /, T / -1.0D+00,-1.0D+00, 1.0D+00, 1.0D+00 /
C
C      INITIALIZE MATRICES QA, QB, AND RQ
C
C      DO 10 IQ=1,4
C        RQ(IQ)=0.
C        DO 10 JQ=1,4
C          QB(IQ,JQ)=0.0
C10      QA(IQ,JQ)=0.0
C
C      DO 40 KG=1,4
C
C      DETERMINE LOCAL COORDINATES (SS,TT) OF GAUSS-INTEGRATION POINT KG
C
C      SS = P*S(KG)
C      TT = P*T(KG)
C
C      CALCULATE VALUES OF THE BASIS FUNCTIONS N(IQ) AND THEIR DERIVATIVES
C      DNX AND DNZ W.R.T X AND Z, RESPECTIVELY, AT THE GAUSS POINT KG
C
C      CALL BASE(N,DNDS,DNNT,SS,TT)
C
C      DO 11 I=1,2
C        DO 11 J=1,2
C          PJAB(I,J)=0.0
C11
C      DO 12 I=1,4
C        PJAB(1,1)=PJAB(1,1)+ZQ(I)*DNNT(I)

```

```

04      005
04      010
04      015
04      020
04      025
04      030
04      035
04      040
04      045
04      050
04      055
04      060
04      065
04      070
04      075
04      080
04      085
04      090
04      095
04      100
04      105
04      110
04      115
04      120
04      125
04      130
04      135
04      140
04      145
04      150
04      155
04      160
04      165
04      170
04      175
04      180
04      185
04      190
04      195
04      200
04      205
04      210
04      215
04      220
04      225
04      230
04      235
04      240
04      245
04      250

```

Appendix C (continued)

```

      PJAB(1,2)=PJAB(1,2)-ZQ(I)*DNSS(I)
      PJAB(2,1)=PJAB(2,1)-XQ(I)*DNNT(I)
12     PJAB(2,2)=PJAB(2,2)+XQ(I)*DNSS(I)
      DJAC=PJAB(2,2)*PJAB(1,1)-PJAB(1,2)*PJAB(2,1)
      DJACI=1.0/DJAC
      DO 13 I=1,2
        DO 13 J=1,2
          PJAB(I,J)=PJAB(I,J)*DJACI
13     DO 14 I=1,4
        DNx(I)=DNSS(I)*PJAB(1,1)+DNNT(I)*PJAB(1,2)
14     DNz(I)=DNSS(I)*PJAB(2,1)+DNNT(I)*PJAB(2,2)
C
      AKXQP=0.
      AKZQP=0.
      THQP=C.
      DTHQP=0.
C
C  ACCUMULATE THE SUMS TO EVALUATE THE MATRIX INTEGRALS QA(IQ,JQ),
C  QB(IQ,JQ), AND RC(IG)
C
      DO 20 IQ=1,4
        AKXQP=AKXQP+AKXQ(IQ)*N(IQ)
        AKZQP=AKZQP+AKZQ(IQ)*N(IQ)
        THQP=THQP+THQ(IQ)*N(IQ)
20     DTHQP=DTHQP+DTHQ(IQ)*N(IQ)
      FHP=ALP*THQP/PCR+BETAP*THQP+DTHQP
      AKXQP=AKXQP+DJAC
      AKZQP=AKZQP+DJAC
      FHP=FHP+DJAC
      DO 30 IQ=1,4
        RQ(IQ)=RQ(IQ)-DNx(IQ)*AKXQP*SNFE+DNz(IQ)*AKZQP*CSFE
      DO 30 JQ=1,4
        QA(IQ,JQ)=QA(IQ,JQ)+FHP*N(IQ)*N(JQ)
        QB(IQ,JQ)=QB(IQ,JQ)+DNx(IQ)*AKXQP*DNx(JQ) +
          DNz(IQ)*AKZQP*DNz(JQ)
30     CONTINUE
40     CONTINUE
      IF(ILUMP.NE.0) GO TO 50
C
      RETURN
50 CONTINUE
      DO 52 I=1,4
        SUM=0.0
        DO 52 J=1,4
          SUM=SUM+QA(I,J)
51     QA(I,J)=0.0
52     QA(I,I)=SUM
      RETURN
      END

```

04	255
04	260
04	265
04	270
04	275
04	280
04	285
04	290
04	295
04	300
04	305
04	310
04	315
04	320
04	325
04	330
04	335
04	340
04	345
04	350
04	355
04	360
04	365
04	370
04	375
04	380
04	385
04	390
04	395
04	400
04	405
04	410
04	415
04	420
04	425
04	430
04	435
04	440
04	445
04	450
04	455
04	460
04	465
04	470
04	475
04	480
04	485
04	490
04	495
04	500

Appendix C (continued)

```

C      SUBROUTINE BASE(A,DNSS,DNTT,SS,TT)
C      FUNCTION OF THE SUBROUTINE-TO COMPUTE THE VALUES OF BASIS FUNCTIONS
C
C      IMPLICIT REAL*8 (A-H,O-Z)
C      REAL*8 N(4)
C      DIMENSION DNSS(4),DNTT(4)
C
C      SM=1.0-SS
C      SP=1.0+SS
C      TM=1.0-TT
C      TP=1.0+TT
C      N(1)=0.25*SM*TM
C      N(2)=0.25*SP*TM
C      N(3)=0.25*SP*TP
C      N(4)=0.25*SM*TP
C      DNSS(1)=-0.25*TM
C      DNSS(2)=0.25*TM
C      DNSS(3)=0.25*TP
C      DNSS(4)=-0.25*TP
C      DNTT(1)=-0.25*SM
C      DNTT(2)=0.25*SP
C      DNTT(3)=0.25*SP
C      DNTT(4)=0.25*SM
C      RETURN
C      END

```

```

BASE 005
BASE 010
BASE 015
BASE 020
BASE 025
BASE 030
BASE 035
BASE 040
BASE 045
BASE 050
BASE 055
BASE 060
BASE 065
BASE 070
BASE 075
BASE 080
BASE 085
BASE 090
BASE 095
BASE 100
BASE 105
BASE 110
BASE 115
BASE 120
BASE 125
BASE 130
BASE 135
BASE 140

```

Appendix C (continued)

C	SUBROUTINE BC(C,R,FLX,HCON,NPCON,NPFLX,RP,NPST,BB,NN,	BC	005
C	> MAXNP,MAXHBP,MXRSNP,MXSTNP,MAXBCN,KSS)	BC	010
C		BC	015
C	FUNCTION OF SUBROUTINE--TO APPLY BOTH CONSTANT AND TIME-VARYING	BC	020
C	(RAINFALL-SEEPAGE) FLUX-TYPE NEUMANN AND PRESSURE-TYPE DIRICHLET	BC	025
C	BOUNDARY CONDITIONS.	BC	030
C		BC	035
C		BC	040
C	IMPLICIT REAL*8(A-H,O-Z)	BC	045
C		BC	050
C	DIMENSION C(MAXNP,MAXHBP),R(MAXNP)	BC	055
C	DIMENSION FLX(MXRSNP),HCON(MXRSNP),NPCON(MXRSNP),NPFLX(MXRSNP)	BC	060
C	DIMENSION RP(MXSTNP),NPST(MXSTNP),BB(MAXBCN),NN(MAXBCN)	BC	065
C		BC	070
C	COMMON /GEOM/ SNFE,CSFE,NNP,NEL,IBAND	BC	075
C	COMMON /BRND/ NBEL,NBN,NRSEL,NRSN,NRFPR,NRFPR	BC	080
C	COMMON /BCST/ NBC,NST,NSTN	BC	085
C		BC	090
C	IHALFB=(IBAND-1)/2	BC	095
C	IHBP=IHALFB+1	BC	100
C	IF (NBC.EQ.0) GO TO 90	BC	105
C		BC	110
C	APPLY CONSTANT DIRICHLET BOUNDARY CONDITIONS	BC	115
C		BC	120
C	DO 80 NPP=1,NBC	BC	125
C		BC	130
C	MODIFY LOAD VECTOR FOR NON-ZERO BB	BC	135
C		BC	140
C	NI=NN(NPP)	BC	145
C	IF (BB(NPP).EQ.0.0) GO TO 40	BC	150
C	DO 10 IB=1,IHALFB	BC	155
C	NJ=NI-IB	BC	160
C	IF (NJ.LT.1) GO TO 20	BC	165
C	JB=IB+1	BC	170
C	10 R(NJ)=R(NJ)-BB(NPP)*C(NJ,JB)	BC	175
C	20 DO 30 IB=1,IHALFB	BC	180
C	NJ=NI+IB	BC	185
C	IF (NJ.GT.NNP) GO TO 40	BC	190
C	JB=IB+1	BC	195
C	30 R(NJ)=R(NJ)-BB(NPP)*C(NJ,JB)	BC	200
C	40 R(NI)=BB(NPP)	BC	205
C		BC	210
C	ZERO COLUMN NN	BC	215
C		BC	220
C	DO 50 IB=1,IHALFB	BC	225
C	NJ=NI-IB	BC	230
C	IF (NJ.LT.1) GO TO 60	BC	235
C	JB=IB+1	BC	240
C	50 C(NJ,JB)=0.0	BC	245
C		BC	250

Appendix C (continued)

```

C
C  MODIFY ROW NN
C
  60  DO 70 KB=1,IHBP
  70    C(NI,KB)=0.0
      C(NI,1)=1.0
  80  CONTINUE
C
C  MODIFY LOAD VECTOR FOR CONSTANT SURFACE TERMS OF THE FORM DR/DI=C
C
  90  IF (NST.EQ.0) GO TO 110
      DO 100 NPP=1,NSTN
        NP=NPST(NPP)
  100    R(NP)=R(NP)-RF(NPP)
  110  IF (NRSN.EQ.0) GO TO 210
C
C  APPLY DIRICHLET TIME-VARIABLE (RAINFALL-SEEPAGE) CONDITIONS
C
      DO 190 NPP=1,NRSN
C
C  MODIFY LOAD VECTOR FOR NON-ZERO HCON
C
      NI=NPCON(NPP)
      IF (NI.EQ.0) GO TO 190
      IF (HCON(NI).EQ.0.0) GO TO 150
      DO 120 IB=1,IHALFB
        NJ=NI-IB
        IF (NJ.LT.1) GO TO 130
        JB=IB+1
  120    R(NJ)=R(NJ)-HCON(NPP)*C(NJ,JB)
  130    DO 140 IB=1,IHALFB
        NJ=NI+IB
        IF (NJ.GT.NNP) GO TO 150
        JB=IB+1
  140    R(NJ)=R(NJ)-HCON(NPP)*C(NI,JB)
  150    R(NI)=HCON(NPP)
C
C  ZERO COLUMN NPCON
C
      DO 160 IB=1,IHALFB
        NJ=NI-IB
        IF (NJ.LT.1) GO TO 170
        JB=IB+1
  160    C(NJ,JB)=0.0
C
C  MODIFY ROW NPCON
C
  170  DO 180 KB=1,IHBP
  180    C(NI,KB)=0.0
      C(NI,1)=1.0

```

BC	255
BC	260
BC	265
BC	270
BC	275
BC	280
BC	285
BC	290
BC	295
BC	300
BC	305
BC	310
BC	315
BC	320
BC	325
BC	330
BC	335
BC	340
BC	345
BC	350
BC	355
BC	360
BC	365
BC	370
BC	375
BC	380
BC	385
BC	390
BC	395
BC	400
BC	405
BC	410
BC	415
BC	420
BC	425
BC	430
BC	435
BC	440
BC	445
BC	450
BC	455
BC	460
BC	465
BC	470
BC	475
BC	480
BC	485
BC	490
BC	495
BC	500

Appendix C (continued)

```

190    CONTINUE
C
C    APPLY NEUMANN TIME-VARIABLE (RAINFALL-SEEPAGE) CONDITIONS
C
      DO 200 NPP=1,NRSH
        NP=NPFLX(NPP)
        IF (NP.EQ.0) GC TO 200
        R(NP)=R(NP)-FLX(NPP)
200    CONTINUE
210    RETURN
      END

```

```

BC    505
BC    510
BC    515
BC    520
BC    525
BC    530
BC    535
BC    540
BC    545
BC    550
BC    555

```

Appendix C (continued)

```

C      SUBROUTINE BANSCL(KKK,C,R,NNP,IHBP,MAXNP,MAXHBP)
C      FUNCTION OF SUBROUTINE--TO SOLVE THE MATRIX EQUATION CX = R,
C      RETURNING THE SOLUTION X IN R. IT IS ASSUMED THAT THE ARRAY
C      C(NP,IB) CONTAINS ONLY THE UPPER HALF BAND OF A SYMMETRIC MATRIX.
C
C      IMPLICIT REAL*8(A-H,O-Z)
C      DIMENSION C(MAXNP,MAXHBP),R(MAXNP)
C
C      IHALFB=IHBP-1
C      NNP1=NNP-1
C
C      IF KKK = 1. THEN TRIANGULARIZE THE BAND MATRIX C(NP,IB), BUT
C      IF KKK = 2. THEN SIMPLY SOLVE WITH THE NEW RIGHT-HAND SIDE R(NP).
C
C      IF (KKK.EQ.2) GO TO 50
C
C      TRIANGULARIZE MATRIX C
C
C      NU=NNP-IHALFB
C      DO 20 NI=1,NU
C        NJ=NI-1
C        PIVOTI=1./C(NI,1)
C        DO 20 LB=2,IHBP
C          A=C(NI,LB)*PIVOTI
C          NK=NJ+LB
C          JB=0
C          DO 10 KB=LB,IHBP
C            JB=JB+1
C            C(NK,JB)=C(NK,JB)-A*C(NI,KB)
C          10 C(NI,LB)=A
C        20 C(NI,LB)=A
C      NL=NU+1
C      DO 40 NI=NL,NNP1
C        NJ=NI-1
C        MB=NNP-NJ
C        PIVOTI=1./C(NI,1)
C        DO 40 LB=2,MB
C          A=C(NI,LB)*PIVOTI
C          NK=NJ+LB
C          JB=0
C          DO 30 KB=LB,MB
C            JB=JB+1
C            C(NK,JB)=C(NK,JB)-A*C(NI,KB)
C          30 C(NI,LB)=A
C        40 C(NI,LB)=A
C      RETURN
C
C      MODIFY LOAD VECTOR R
C
C      50 NU=NNP-IHALFB

```

```

BANS 005
BANS 010
BANS 015
BANS 020
BANS 025
BANS 030
BANS 035
BANS 040
BANS 045
BANS 050
BANS 055
BANS 060
BANS 065
BANS 070
BANS 075
BANS 080
BANS 085
BANS 090
BANS 095
BANS 100
BANS 105
BANS 110
BANS 115
BANS 120
BANS 125
BANS 130
BANS 135
BANS 140
BANS 145
BANS 150
BANS 155
BANS 160
BANS 165
BANS 170
BANS 175
BANS 180
BANS 185
BANS 190
BANS 195
BANS 200
BANS 205
BANS 210
BANS 215
BANS 220
BANS 225
BANS 230
BANS 235
BANS 240
BANS 245
BANS 250

```

Appendix C (continued)

```

DO 60 NI=1,NL
  NJ=NI-1
  A=R(NI)
  R(NI)=A/C(NI,1)
  DO 60 LB=2,IHBP
    NK=NJ+LB
    R(NK)=R(NK)-C(NI,LB)*A
60  NL=NL+1
  DO 70 NI=NL,NNP1
    NJ=NI-1
    MB=NNP-NJ
    A=R(NI)
    R(NI)=A/C(NI,1)
    DO 70 LB=2,MB
      NK=NJ+LB
      R(NK)=R(NK)-C(NI,LB)*A
70
C
C
C  BACK-SOLVE
  R(NNP)=R(NNP)/C(NNP,1)
  DO 80 IB=1,IHALFB
    NI=NNP-IB
    NJ=NI-1
    MB=IB+1
    DO 80 KB=2,MB
      NK=NJ+KB
      R(NI)=R(NI)-C(NI,KB)*R(NK)
80  DO 90 IB=IHBP,NNP1
    NI=NNP-IB
    NJ=NI-1
    DO 90 KB=2,IHBP
      NK=NJ+KB
      R(NI)=R(NI)-C(NI,KB)*R(NK)
90  RETURN
  END

```

```

BANS 255
BANS 260
BANS 265
BANS 270
BANS 275
BANS 280
BANS 285
BANS 290
BANS 295
BANS 300
BANS 305
BANS 310
BANS 315
BANS 320
BANS 325
BANS 330
BANS 335
BANS 340
BANS 345
BANS 350
BANS 355
BANS 360
BANS 365
BANS 370
BANS 375
BANS 380
BANS 385
BANS 390
BANS 395
BANS 400
BANS 405
BANS 410
BANS 415
BANS 420
BANS 425

```


Appendix C (continued)

```

SUBROUTINE SFLOW(X,Z,IE, TH,VX,VZ, DLB,DCOSXB,DCOSZB,BFLX,B2,X2,
> ISB,NBE,NPB,NPRS, NPST,NN, FRATE,FLOW,TFLOW, MAXNP,MAXEL,
> MAXBEL,MAXBNP, MXRSNP, MXSTNP,MAXBCN,KFLOW,DELT,DTH,4,H2,
> PROP,MAXMAT,MXMPM)

```

FUNCTION OF SUBROUTINE--TO COMPUTE BOUNDARY FLUXES, FLUX RATES,
INCREMENTAL FLOWS OCCURRING DURING TIME DELT, TOTAL FLOWS SINCE
TIME ZERO, AND THE CHANGE IN MOISTURE CONTENT FOR THE ENTIRE
SYSTEM DURING TIME DELT.

```

IMPLICIT REAL*8(A-H,O-Z)

```

```

DIMENSION X(MAXNP),Z(MAXNP),IE(MAXEL,5)
DIMENSION TH(MAXEL,4),VX(MAXNP),VZ(MAXNP)
DIMENSION DTH(MAXEL,4),H(MAXNP),HP(MAXNP)
DIMENSION DLB(MAXBEL),DCOSXB(MAXBEL),DCOSZB(MAXBEL),BF,X(MAXNP),
> BFLXP(MAXBNP),NBE(MAXBEL),ISB(MAXBEL,4),NPB(MAXBNP)
DIMENSION NPRS(MXRSNP), NPST(MXSTNP),NN(MAXBCN)
DIMENSION PROP(MAXMAT,MXMPM)
DIMENSION FRATE(10),FLOW(10),TFLOW(10)

```

```

DIMENSION XQ(4),ZQ(4),THQ(4)

```

```

COMMON /GEOM/ SNFE,CSFE,NNP,NEL,ISAND
COMMON /BRND/ NDEL,NBN,NRSEL,NRSN,NRFPR,NRFPR
COMMON /BCST/ NBC,NST,NSTN

```

```

KKFLOW=0

```

CALCULATE NODAL FLOW RATES

```

DO 10 NP=1,NBN
  BFLXP(NP)=BFLX(NP)
  BFLX(NP)=0.

```

```

DO 30 NP=1,NBEL
  N=NBE(NP)
  NI=ISB(NP,1)
  NJ=ISB(NP,2)
  DO 20 I=1,NBN
    IJ=NPB(I)
    IF(IJ.NE.NI) GO TO 20
    NI=I
    GO TO 22
  20 CONTINUE
  22 DO 25 J=1,NBN
    IJ=NPB(J)

```

```

SFLO 005
SFLO 010
SFLO 015
SFLO 020
SFLO 025
SFLO 030
SFLO 035
SFLO 040
SFLO 045
SFLO 050
SFLO 055
SFLO 060
SFLO 065
SFLO 070
SFLO 075
SFLO 080
SFLO 085
SFLO 090
SFLO 095
SFLO 100
SFLO 105
SFLO 110
SFLO 115
SFLO 120
SFLO 125
SFLO 130
SFLO 135
SFLO 140
SFLO 145
SFLO 150
SFLO 155
SFLO 160
SFLO 165
SFLO 170
SFLO 175
SFLO 180
SFLO 185
SFLO 190
SFLO 195
SFLO 200
SFLO 205
SFLO 210
SFLO 215
SFLO 220
SFLO 225
SFLO 230
SFLO 235
SFLO 240
SFLO 245
SFLO 250

```

Appendix C (continued)

```

                IF(IJ.NE.NJ) GO TO 25
                NJJ=J
                GO TO 27
25             CONTINUE
27             CONTINUE

C             COMPUTE THE FLUX THROUGH POINT NI USING THE WHOLE BOUNDARY LENGTH
C             AND THE FLUX THROUGH POINT NJ USING THE WHOLE BOUNDARY SIDE LENGTH
C
                FNI=(VX(NI)*DCCSX(B(MP))+VZ(NI)*DCOSZ(B(MP))*DLB(MP)
                FNJ=(VX(NJ)*DCCSX(B(MP))+VZ(NJ)*DCOSZ(B(MP))*DLB(MP)

C             DISTRIBUTE THE ABOVE FLUXES TO TWO END POINTS OF THE SIDE
C
                BFLX(NII)=BFLX(NII)+FNI/3.0+FNJ/6.0
                BFLX(NJJ)=BFLX(NJJ)+FNJ/3.0+FNI/6.0

C
30             CONTINUE
                IF (KFLOW.EQ.0) GO TO 60
                DO 40 NP=1,NBN
40             BFLXP(NP)=BFLX(NP)
                DO 50 I=1,6
50             TFLOW(I)=0.
                IF (KFLOW.EQ.(-1)) TFLOW(7)=0.
                IF (KFLOW.EQ.(-1)) GTH=0.
                IF(KFLOW.EQ.(-1)) KKFLOW=-1
                KFLOW=0

C             DETERMINE FLOWS AND FLOW RATES THROUGH THE VARIOUS
C             TYPES OF BOUNDARY NCDES. STARTING WITH THE
C             NET FLOWS THROUGH ALL BOUNDARY NCDES.
C
60             SUM=0.
                SUMP=0.
                DO 70 NP=1,NBN
                SUM=SLM+BFLX(NP)
70             SUMP=SLNP+BFLXP(NP)
                FRATE(6)=SUM
                FLOW(6)=.88*(SLM+SLNP)*DELT

C             CONSTANT DIRICHLET BOUNDARY NODES
C
                FRATE(1)=0.
                FLOW(1)=0.
                IF (NBC.LE.0) GO TO 90
                SUM=0.
                SUMP=0.
                DO 80 NPP=1,NBC
                NP=NN(NPP)
                DO 75 I=1,NBN

```

```

SFLO 255
SFLO 260
SFLO 265
SFLO 270
SFLO 275
SFLO 280
SFLO 285
SFLO 290
SFLO 295
SFLO 300
SFLO 305
SFLO 310
SFLO 315
SFLO 320
SFLO 325
SFLO 330
SFLO 335
SFLO 340
SFLO 345
SFLO 350
SFLO 355
SFLO 360
SFLO 365
SFLO 370
SFLO 375
SFLO 380
SFLO 385
SFLO 390
SFLO 395
SFLO 400
SFLO 405
SFLO 410
SFLO 415
SFLO 420
SFLO 425
SFLO 430
SFLO 435
SFLO 440
SFLO 445
SFLO 450
SFLO 455
SFLO 460
SFLO 465
SFLO 470
SFLO 475
SFLO 480
SFLO 485
SFLO 490
SFLO 495
SFLO 500

```

Appendix C (continued)

```

      IJ=NPB(I)
      IF(IJ.NE.NP) GO TC 75
      NII=I
      GO TO 76
75      CONTINUE
76      CONTINUE
      SUM=SLM+BFLX(NII)
80      SUMP=SLMP+BFLXP(NII)
      FRATE(1)=SUM
      FLOW(1)=.5*(SLM+SLMP)*DELT
C
C      CONSTANT NEUMANN BOUNDARY NODES
C
50      FRATE(2)=0.
      FLOW(2)=0.
      IF (NST.LE.0) GO TO 110
      SUM=0.
      SUMP=0.
      DO 100 NPP=1,NSTN
        NP=NPST(NPP)
        DO 95 I=1,NBN
          IJ=NPB(I)
          IF(IJ.NE.NP) GO TO 95
          NII=I
          GO TO 96
95      CONTINUE
96      CONTINUE
      SUM=SUM+BFLX(NII)
      SUMP=SUMP+BFLXP(NII)
100     FRATE(2)=SLM
      FLOW(2)=.5*(SLM+SLMP)*DELT
C
C      RAINFALL-SEEPAGE BOUNDARY NODES
C
110     FRATE(3)=0.
      FLOW(3)=0.
      FRATE(4)=0.
      FLOW(4)=0.
      SUMS=0.
      SUMSP=0.
      SUMR=0.
      SUMRP=0.
      IF (NRSN.LE.0) GO TO 140
      DO 130 NPP=1,NRSN
        NP=NPRS(NPP)
        DO 115 I=1,NBN
          IJ=NPB(I)
          IF(IJ.NE.NP) GO TC 115
          NII=I
          GO TO 116

```

```

SFLO 505
SFLO 510
SFLO 515
SFLO 520
SFLO 525
SFLO 530
SFLO 535
SFLO 540
SFLO 545
SFLO 550
SFLO 555
SFLO 560
SFLO 565
SFLO 570
SFLO 575
SFLO 580
SFLO 585
SFLO 590
SFLO 595
SFLO 600
SFLO 605
SFLO 610
SFLO 615
SFLO 620
SFLO 625
SFLO 630
SFLO 635
SFLO 640
SFLO 645
SFLO 650
SFLO 655
SFLO 660
SFLO 665
SFLO 670
SFLO 675
SFLO 680
SFLO 685
SFLO 690
SFLO 695
SFLO 700
SFLO 705
SFLO 710
SFLO 715
SFLO 720
SFLO 725
SFLO 730
SFLO 735
SFLO 740
SFLO 745
SFLO 750

```

Appendix C (continued)

```

115     CONTINUE
116     CONTINUE
      BFLXA=.5*(BFLX(NII)+BFLXP(NII))
      IF (BFLXA.LT.0.00) GC TO 120
      SUMS=SUMS+BFLX(NII)
      SUMSP=SUMSP+BFLXA
      GO TO 130
120     SUMR=SUMR+BFLX(NII)
      SUMRP=SUMRP+BFLXA
130     CONTINUE
      FRATE(3)=SUMS
      FLOW(3)=SUMSP*DELT
      FRATE(4)=SUMR
      FLOW(4)=SUMRP*DELT
C
C     NUMERICAL FLOW THROUGH UNSPECIFIED BOUNDARY NODES
C
140     SUM=0.
      SUMP=0.
      DO 150 I=1,4
        SUM=SUM+FRATE(I)
        SUMP=SUMP+FLOW(I)
150     FRATE(5)=FRATE(6)-SUM
      FLOW(5)=FLOW(6)-SUMP
C
C     FINALLY, CALCULATE THE INCREASE IN THE INTEGRATED WATER CONTENT
C
      QTHP=QTH
      QTH=0.
      DO 170 N=1,NEL
        MTYP=IE(N,5)
        ALP=PROP(MTYP,1)
        BETAP=PROP(MTYP,2)
        POR=PROP(MTYP,3)
C
        DO 160 IO=1,4
          NP=IE(N,IO)
          XQ(IO)=X(NP)
          ZQ(IO)=Z(NP)
          THQ(IO)=TH(N,IO)
          IF(KKFLOW.GE.0) THQ(IO)=(DTH(N,IO)+THQ(IO)*ALP/POR+BETAP)*
            (H(NP)-HP(NP))
160     CONTINUE
C
      CALL Q4TH(QTHM,THQ,XQ,ZQ)
C
      QTH=QTH+QTHM
170     CONTINUE
      FLOW(7)=QTH
      IF(KKFLOW.LT.0) FLOW(7)=0.0

```

```

SFLO 755
SFLO 760
SFLO 765
SFLO 770
SFLO 775
SFLO 780
SFLO 785
SFLO 790
SFLO 795
SFLO 800
SFLO 805
SFLO 810
SFLO 815
SFLO 820
SFLO 825
SFLO 830
SFLO 835
SFLO 840
SFLO 845
SFLO 850
SFLO 855
SFLO 860
SFLO 865
SFLO 870
SFLO 875
SFLO 880
SFLO 885
SFLO 890
SFLO 895
SFLO 900
SFLO 905
SFLO 910
SFLO 915
SFLO 920
SFLO 925
SFLO 930
SFLO 935
SFLO 940
SFLO 945
SFLO 950
SFLO 955
SFLO 960
SFLO 965
SFLO 970
SFLO 975
SFLO 980
SFLO 985
SFLO 990
SFLO 995
SFLO 1000

```

Appendix C (continued)

```
FRATE(7)=FLOW(7)/DELT  
DO 100 I=1,7  
  TFLOW(I)=TFLOW(I)+FLOW(I)  
100 RETURN  
END
```

```
SFL01005  
SFL01010  
SFL01015  
SFL01020  
SFL01025
```

Appendix C (continued)

```

C      SUBROUTINE Q4TH(QTHM,THQ,XQ,ZQ)
C      FUNCTION OF SUBROUTINE--TO EVALUATE THE WATER-CONTENT INTEGRAL
C      OVER THE AREA OF CNE ELEMENT.
C      IMPLICIT REAL*8 (A-H,O-Z)
C      REAL*8 N(4)
C      DIMENSION THQ(4),S(4),T(4),XQ(4),ZQ(4)
C      DIMENSION PJAB(2,2),DNSS(4),DNNT(4)
C      DATA P / 0.577350269189626 /, S / -1.00+00, 1.00+00, 1.00+00, -
C      > 1.00+00 /, T / -1.00+00,-1.00+00, 1.00+00, 1.00+00 /
C      QTHM=0.
C      DO 20 KG=1,4
C      DETERMINE LOCAL COORDINATES (SS,TT) OF GAUSS-INTEGRATION POINT (G
C      SS = P*S(KG)
C      TT = P*T(KG)
C      CALCULATE VALUES OF THE BASIS-INTERPOLATION FUNCTIONS V(IQ)
C      CALL BASE(N,DNSS,DNNT,SS,TT)
C      DO 11 I=1,2
C      DO 11 J=1,2
C      PJAB(I,J)=0.0
C      DO 12 I=1,4
C      PJAB(1,1)=PJAB(1,1)+ZQ(I)*DNNT(I)
C      PJAB(1,2)=PJAB(1,2)-ZQ(I)*DNSS(I)
C      PJAB(2,1)=PJAB(2,1)-XQ(I)*DNNT(I)
C      PJAB(2,2)=PJAB(2,2)+XQ(I)*DNSS(I)
C      DJAC=PJAB(2,2)*PJAB(1,1)-PJAB(1,2)*PJAB(2,1)
C      INTERPOLATE TO OBTAIN THE WATER CONTENT THQP AT THE GAUSS POINT (G
C      THQP=C.
C      DO 10 IQ=1,4
C      THQP=THQP+THQ(IQ)*N(IQ)
C      ACCUMULATE THE SUM TO EVALUATE THE INTEGRAL
C      QTHM=QTHM+THQP*DJAC
C      20 CONTINUE
C      RETURN
C      END

```

```

Q4TH 005
Q4TH 010
Q4TH 015
Q4TH 020
Q4TH 025
Q4TH 030
Q4TH 035
Q4TH 040
Q4TH 045
Q4TH 050
Q4TH 055
Q4TH 060
Q4TH 065
Q4TH 070
Q4TH 075
Q4TH 080
Q4TH 085
Q4TH 090
Q4TH 095
Q4TH 100
Q4TH 105
Q4TH 110
Q4TH 115
Q4TH 120
Q4TH 125
Q4TH 130
Q4TH 135
Q4TH 140
Q4TH 145
Q4TH 150
Q4TH 155
Q4TH 160
Q4TH 165
Q4TH 170
Q4TH 175
Q4TH 180
Q4TH 185
Q4TH 190
Q4TH 195
Q4TH 200
Q4TH 205
Q4TH 210
Q4TH 215
Q4TH 220
Q4TH 225
Q4TH 230
Q4TH 235
Q4TH 240

```

ORNL-5567

```
PRIN 005
PRIN 010
PRIN 015
PRIN 020
PRIN 025
PRIN 030
PRIN 035
PRIN 040
PRIN 045
PRIN 050
PRIN 055
PRIN 060
PRIN 065
PRIN 070
PRIN 075
PRIN 080
PRIN 085
PRIN 090
PRIN 095
PRIN 100
PRIN 105
PRIN 110
PRIN 115
PRIN 120
PRIN 125
PRIN 130
PRIN 135
PRIN 140
PRIN 145
PRIN 150
PRIN 155
PRIN 160
PRIN 165
PRIN 170
PRIN 175
PRIN 180
PRIN 185
PRIN 190
PRIN 195
PRIN 200
PRIN 205
PRIN 210
PRIN 215
PRIN 220
PRIN 225
PRIN 230
PRIN 235
PRIN 240
PRIN 245
PRIN 250
```

CCCCC

C

CCC

ccc

CCC

C

KOUT=KOUT+1

Appendix C (continued)

```

KLINE=-1
PRINT 10200,KOUT,TIME,DELT,IBAND,ITIM,(SUBHD(I),I=1,8)
DO 40 NI=1,NNP,8
  NJMN=NI
  NJMX=MINO(NI+7,NNP)
  KLINE=KLINE+1
  IF(MOD(KLINE,50).EQ.0.AND. KLINE.GE.1) PRINT 10200,KOUT,TIME,
>   DELT,IBAND,ITIM,(SUBHD(I),I=1,8)
40 PRINT 10000,NI,(H(NJ),NJ=NJMN,NJMX)
  IF (KPR.EQ.2) RETURN
C
C C
PRINT TOTAL HEADS
  KOUT=KOUT+1
  KLINE=-1
  PRINT 10300,KOUT,TIME,DELT,IBAND,ITIM,(SUBHD(I),I=1,8)
  DO 50 NI=1,NNP,8
    NJMN=NI
    NJMX=MINO(NI+7,NNP)
    KLINE=KLINE+1
    IF(MOD(KLINE,50).EQ.0.AND. KLINE.GE.1) PRINT 10300,KOUT,TIME,
>   DELT,IBAND,ITIM,(SUBHD(I),I=1,8)
50 PRINT 10000,NI,(HT(NJ),NJ=NJMN,NJMX)
  IF (KPR.EQ.3) RETURN
C
C C
PRINT WATER CONTENTS
  KOUT=KOUT+1
  KLINE=-1
  PRINT 10400,KOUT,TIME,DELT,IBAND,ITIM,(SUBHD(I),I=1,8)
  DO 60 M=1,NEL,2
    KLINE=KLINE+1
    IF(MOD(KLINE,50).EQ.0.AND. KLINE.GE.1) PRINT 10400,KOUT,TIME,
>   DELT,IBAND,ITIM,(SUBHD(I),I=1,8)
    NJMN=M
    NJMX=MINO(M+1,NEL)
60 PRINT 10103,(MJ,(TH(MJ,IQ),IQ=1,4),MJ=NJMN,NJMX)
  IF (KPR.EQ.4) RETURN
C
C C
PRINT DARCY VELOCITIES
  KOUT=KOUT+1
  KLINE=-1
  PRINT 10500,KOUT,TIME,DELT,IBAND,ITIM,(SUBHD(I),I=1,8)
  DO 70 NP=1,NNP,4
    KLINE=KLINE+1
    IF(MOD(KLINE,50).EQ.0.AND. KLINE.GE.1) PRINT 10500,KOUT,TIME,
>   DELT,IBAND,ITIM,(SUBHD(I),I=1,8)
    NJMN=NP
    NJMX=MINO(NP+3,NNP)

```

```

PRIN 255
PRIN 260
PRIN 265
PRIN 270
PRIN 275
PRIN 280
PRIN 285
PRIN 290
PRIN 295
PRIN 300
PRIN 305
PRIN 310
PRIN 315
PRIN 320
PRIN 325
PRIN 330
PRIN 335
PRIN 340
PRIN 345
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PRIN 355
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PRIN 430
PRIN 435
PRIN 440
PRIN 445
PRIN 450
PRIN 455
PRIN 460
PRIN 465
PRIN 470
PRIN 475
PRIN 480
PRIN 485
PRIN 490
PRIN 495
PRIN 500

```


Appendix C (continued)

```

70 PRINT 11000, (NJ,VX(NJ),VZ(NJ),NJ=NJMN,NJMX)
RETURN
C
10000 FORMAT(17,8(1PD15.4))
10100 FORMAT(8D15.4)
10101 FORMAT(1H0,'VALUES OF NFCON'/(8I15))
10102 FORMAT(1H0,'VALUES OF NPFLX'/(8I15))
10103 FORMAT(1H ,2(1X,17,2X,1PD12.4,1PD12.4,1PD12.4,1PD12.4,2X,))
10200 FORMAT(13H10LTPLT TABLE,14,27H.. PRESSURE HEADS AT TIME =,
> 1PD12.4,5H ,(DELT =,1PD12.4,15H),(BAND WIDTH =,14,1H),6H ,1T =,
> 15//1X,8A4/1X,7H NODE 1,5X,36HPRESSURE HEAD OF NODES 1,1+1,...,1+7
> /)
10300 FORMAT(13H10UTPUT TABLE,14,24H.. TOTAL HEADS AT TIME =, 1PD12.4,
> 9H ,(DELT =,1PD12.4,15H),(BAND WIDTH =,14,1H),6H ,1T =,15//1X,8A4
> /1X,7H NODE 1,5X,33HTOTAL HEAD OF NODES 1,1+1,...,1+7//)
10400 FORMAT(13H10LTPLT TABLE,14,27H.. WATER CONTENTS AT TIME =,
> 1PD12.4,5H ,(DELT =,1PD12.4,15H),(BAND WIDTH =,14,1H),6H ,1T =,
> 15//1X,8A4/3CX,5HNODES/2(17X,1H1,11X,1H2,11X,1H3,11X,1H4,6X)/
> 2(3X,7HELEMENT,2X,
> 46H*****2X)/)
10500 FORMAT(13H10UTPUT TABLE,14,29H.. DARCY VELOCITIES AT TIME =,
> 1PD12.4,5H ,(DELT =,1PD12.4,15H),(BAND WIDTH =,14,1H),6H ,1T =,
> 15//1X,8A4/2X,4HNODE,9X,2HVX,9X,2HVZ,4X,4HNODE,9X,2HVX,9X,2HVZ,
> 4X,4HNODE,9X,2HVX,9X,2HVZ,4X,4HNODE,9X,2HVX,9X,2HVZ/
> 27H*****3X,27H*****
> 3X,27H*****3X,27H*****
> *)
10600 FORMAT(1H1,32H TABLE OF SYSTEM-FLOW PARAMETERS,2X,7HTABLE: ,14,
> 12H.. AT TIME =,1PD12.4,9H ,(DELT = 1PD12.4,1H)//5X,,
> 13H TYPE OF FLOW,35X,4HHRATE,8X,9HINC. FLOW,7X,10HTOTAL FLOW/5X
> 40H CONSTANT-PRESSURE-NODE FLOW . . . . .3(E12.4,5X)/5X
> 40H CONSTANT-FLLX-NODE FLOW . . . . .3(E12.4,5X)/5X
> 40H SEEPAGE . . . . .3(E12.4,5X)/5X
> 40H RAINFALL . . . . .3(E12.4,5X)/5X
> 40H NUMERICAL LOSSES . . . . .3(E12.4,5X)/5X
> 40H NET FLOW . . . . .3(E12.4,5X)/5X
> 40H INCREASE IN VOLUMETRIC WATER CONTENT . .3(E12.4,5X))
10700 FORMAT(/29H RAINFALL-SEEPAGE NODAL FLOWS)
11000 FORMAT(1H ,15,2D11.3,3X,15,2D11.3,3X,15,2D11.3,3X,15,2D11.3)
END

```

```

PRIN 505
PRIN 510
PRIN 515
PRIN 520
PRIN 525
PRIN 530
PRIN 535
PRIN 540
PRIN 545
PRIN 550
PRIN 555
PRIN 560
PRIN 565
PRIN 570
PRIN 575
PRIN 580
PRIN 585
PRIN 590
PRIN 595
PRIN 600
PRIN 605
PRIN 610
PRIN 615
PRIN 620
PRIN 625
PRIN 630
PRIN 635
PRIN 640
PRIN 645
PRIN 650
PRIN 655
PRIN 660
PRIN 665
PRIN 670
PRIN 675
PRIN 680
PRIN 685
PRIN 690
PRIN 695
PRIN 700

```

Appendix C (continued)

```

SUBROUTINE STORE(X,Z,IE,H,HT,TH,VX,VZ,DLB,DCOSXB,DCOSZB,NBE,ISB,
> NPB,TITLE,TIME,MAXNP,MAXEL,MAXBNP,MAXBEL,NPROB,NNP,NEL,NBN,NBEL,NTI,NRSN
> NTI,NPCON,NPFLX,MXRSNP,NRSN,NSTRT)

```

```

C
C
C FUNCTION OF SUBROUTINE--TO STORE PERTINENT QUANTITIES ON AUXILIARY
C DEVICE FOR FUTURE USE BY EITHER PLOTTING OR MATERIAL-TRANSPORT
C CODES. WHAT DEVICE IS TO BE USED MUST BE SPECIFIED BY APPROPRIATE
C JOB-CONTROL CARDS.

```

```

C      IMPLICIT REAL*8(A-H,O-Z)

```

```

C      DIMENSION TITLE(5)
C      DIMENSION X(MAXNP),Z(MAXNP),IE(MAXEL,5)
C      DIMENSION H(MAXNP),HT(MAXNP),VX(MAXNP),VZ(MAXNP),TH(MAXEL,4)
C      DIMENSION DLB(MAXBEL),DCOSXB(MAXBEL),DCOSZB(MAXBEL),NBE(4*MAXEL),
> ISB(MAXBEL,4),NPB(MAXBNP)
C      DIMENSION NPCON(MXRSNP),NPFLX(MXRSNP)

```

```

C      DATA NPPROB/-1/

```

```

C      IF (NSTRT.GT.0) GO TO 10
C      IF (NPPROB.EQ.(-1)) REWIND
C      IF (NPPROB.EQ.NPCON) GO TO 10
C      WRITE(1) (TITLE(I),I=1,9),NPCON,NNP,NEL,NBN,NBEL,NTI,NRSN
C      WRITE(1) (X(NP),NP=1,NNP),(Z(NP),NP=1,NNP),((IE(M,IQ),M=1,NEL),IQ=
> 1,4),(DLB(M),M=1,NBEL),(DCOSXB(M),M=1,NBEL),(DCOSZB(M),M=1,
> NBEL),(NBE(M),M=1,NBEL),(ISB(M,IQ),M=1,NBEL),IQ=1,4),
> (NPB(NP),NP=1,NBN)
C      NPPROB=NPROB

```

```

C
C
C DUE TO CHANGES IN THE MATERIAL-TRANSPORT CODE, DARCY VELOCITIES MAY
C BE USED DIRECTLY, AND IT IS UNNECESSARY TO COMPUTE PORE QUANTITIES

```

```

C      10 WRITE(1) TIME,(H(NP),NP=1,NNP),(HT(NP),NP=1,NNP),((TH(M,IQ),M=1,
> NEL),IQ=1,4),(VX(NP),NP=1,NNP),(VZ(NP),NP=1,NNP),
> (NPCON(NP),NP=1,NRSN),(NPFLX(NP),NP=1,NRSN)
C      RETURN
C      END

```

```

STOR 005
STOR 010
STOR 015
STOR 020
STOR 025
STOR 030
STOR 035
STOR 040
STOR 045
STOR 050
STOR 055
STOR 060
STOR 065
STOR 070
STOR 075
STOR 080
STOR 085
STOR 090
STOR 095
STOR 100
STOR 105
STOR 110
STOR 115
STOR 120
STOR 125
STOR 130
STOR 135
STOR 140
STOR 145
STOR 150
STOR 155
STOR 160
STOR 165
STOR 170
STOR 175
STOR 180
STOR 185
STOR 190
STOR 195
STOR 200

```