5.1.5.2 Tabular Data Parameters

If the user chooses to supply the soil moisture relationships in tabular form, four parameters must be specified for each functional data point: moisture content, the corresponding pressure head and relative permeability, and water capacity. Sets of these parameters must be input for each type of material being simulated. The necessary tabular data for a large number of soils can be obtained from the interactive computer code, DBAPE, described in Section 5.1.5.1.1, with the exception of water capacity.

Moisture content was described in Section 5.1.5.1.1. Pressure head, relative permeability, and water capacity are briefly introduced below.

5.1.5.2.1 Relative Permeability (or Hydraulic Conductivity) [--]

In an unsaturated porous medium, the permeability of the water phase in the medium is a function of the degree of saturation. The larger the degree of saturation, the larger the permeability associated with the water phase. This unsaturated permeability is also known as the effective permeability.

Relative permeability is defined as the ratio of the effective permeability to the permeability at saturation. Because it is a ratio, relative permeability ranges in value between 0.0 and 1.0. It is generally assumed that relative permeability is a scalar, dimensionless non-linear function, even for anisotropic soils. Because of the relation of equivalence, relative permeability is equal to relative hydraulic conductivity (Mercer et al., 1982).

Curves showing the relationship between relative permeability and moisture content are determined experimentally for individual soils. The tabulated data available in the literature or in DBAPE (Imhoff et al., 1990) are extracted from these experimental results.

5.1.5.2.2 Pressure head [L]

In groundwater hydrology, the total hydraulic head, H, is usually considered to be the sum of two components: elevation head, z, and pressure head, h. The contribution of velocity to the total head is neglected because velocities are usually extremely low. Pressure head is measured in gage pressure. In the saturated zone, pressures are greater than atmospheric and are thus recorded as positive pressures. The water table is defined as the location at which pressure is equal to atmospheric. This implies that pressure head is zero and the total head is equal to the elevation head. Above the water table, pressure head is less than atmospheric and water is held in the pore spaces under tension or suction. Thus, pressure head values in the unsaturated zone are negative.

Pressure head in the unsaturated zone is a function of moisture content--the lower the moisture content, the more negative the pressure head. As moisture content increases, the surface tension forces holding the water in place between the grains of soil are lowered, resulting in less negative pressure heads (Freeze and Cherry, 1979). The characteristic curve showing the relationship between pressure head and moisture content is determined experimentally for each porous medium.

5.1.5.2.3 Moisture Content Capacity [1/L]

In an unsaturated soil, changes in moisture content, 2, are accompanied by changes in pressure head, h. As discussed above, the 2(h) relationship results in a characteristic curve for each soil. Example characteristic curves are shown in Figure 3.3a. The inverse of the slope of this curve is called the water capacity, C(2), or the moisture content capacity (Mercer et al., 1982). It is defined as:

$$C(2) = d2/dh \qquad (5\text{-}4)$$

The water capacity has no one unique value for a porous medium. Thus, the range of values of moisture content capacity is related to the nature of the water characteristic curve. (Mercer et al., 1982).

5.2 3DLEWASTE

5.2.1 Data Set 1: Title of the Simulation Run

5.2.1.1 Geometry, Boundary, and Pointer Array Control, IGEOM [--]

The integer IGEOM has two functions. It is used to specify if geometry, boundary, and pointer arrays should be printed so that the user can examine them. It also controls whether the boundary and pointer arrays are written to or read from binary files. Boundary arrays store data related to the boundary conditions. Pointer arrays store the global matrix in compressed form and are used to construct the subregional block matrices. For large problems, it takes too much time to generate these arrays for each computer execution of a particular scenario.

If 3DLEWASTE is being executed alone (i.e., without using 3DFEMWATER results), these arrays should be generated only once and stored in binary files using logical units LUBAR and LUPAR (see Table B-2). In order to compute and store the boundary and pointer arrays, the user should choose a value for IGEOM less than or equal to one. In subsequent runs, the boundary and pointer arrays can be read from the binary files by changing the value of IGEOM to a number greater than three. Whenever changes are made to the model which involve the geometry of the problem, the boundary conditions, and the configuration of the subregions, the arrays must be generated and stored again.

If 3DLEWASTE is run after executing 3DFEMWATER for the same scenario, the boundary array need not be recalculated (i.e., the boundary array calculated and stored by 3DFEMWATER can be used). The pointer array should be recalculated, however. This is done by setting IGEOM to a value greater than one and less than or equal to three.

For each of the options explained above, if the number chosen by the user is even, the arrays will be printed as output. If the number is odd, the arrays will not be printed.

5.2.2 <u>Data Set 2: Basic Integer Parameters</u>

5.2.2.1 Number of Material Types, NMAT [--]

This parameter is the total number of different material types being modeled. When material properties are assigned to each material type, using data set 5 (see Section 4.2.5), the first material type should be the predominant type. The number of material types used in 3DLEWASTE need not be identical to the number specified in 3DFEMWATER.

5.2.2.2 Number of Elements with Material Property Correction, NCM [--]

In the code, all the grid elements automatically are initialized as having a material type of one. To model more than one material type, the parameter NCM and the parameters in data set 9 of the input (see Section 4.2.9) are used to specify which elements have a material type other than material type one. The parameter NCM is the total number of elements which have a material type different than the first material type.

5.2.2.3 Number of Time-Steps, NTI [--]

For a constant time-step size, this number is obtained by dividing the simulation time by the time-step size, DELT. If the time-step size is variable, this number is computed using the formula given in the note at the end of data set 2 in Section 4.2.2.

5.2.2.4 Steady-State Control, KSS [--]

As noted in Section 4.2.2, a steady-state option may be used to provide either the final state of a system under study or the initial condition for a transient-state calculation. In the former case, both KSS and the number of time steps, NTI, should be set to zero. In the latter case (i.e., when KSS = 0 and NTI > 0), the code performs a steady-state calculation before beginning the transient computations. If KSS = 1, no steady-state calculation is performed. Rather, the code begins transient calculations using initial conditions supplied in data set 10 of the input.

5.2.2.5 Mass Lumping Flag, ILUMP [--]

This parameter indicates if the mass matrix is to be lumped or not. Normally, one should set this parameter to 0. Without lumping, the solution is more accurate. However, for occasions when negative concentrations or oscillating solutions occur, this parameter should be set to 1.

5.2.2.6 Weighting Function Control, IWET [--]

This parameter indicates if the upstream weighting function is to be used. For the present version of code, this parameter does not affect the solution when a transient solution is sought. If a steady-state solution is desired, one should set this parameter to 1. Thus, it is advisable to always set this parameter to 1 for the present version of the computer code.

5.2.2.7 Optimization Flag, IOPTIM [--]

This parameter specifies whether the upstream weighting factor is to be optimized. This parameter does not affect the solution if a transient solution is sought. For a steady-state solution, it is advisable to set IOPTIM to 1. When IOPTIM is set to 0, an upstream weighting factor of 1.0 is assumed.

5.2.2.8 Number of Iterations for the Nonlinear Equation, NITER [--]

This parameter is the number of iterations allowed for solving the nonlinear equation. Normally, a value of NITER equal to 40 should be sufficient. If this number is exceeded and the solution does not converge, the program will issue a warning message. When this occurs, the users should re-execute the program using a larger value of NITER.

5.2.2.9 Number of Times to Reset the Time Step, NDTCHG [--]

This parameter indicates how many times one should reset the time step size to the initially small time-step size. When we start a computation, we normally use a small time-step size. However, for every consecutive time step, we may gradually increase the time-step size by some amount specified by CHNG in Data Set 3 in Section 4.2.3. When we have a steep change in boundary conditions or in source/sink conditions, we will need to reset the time-step size to the initially small value. NDTCHG tells us how many times we want to reset the time-step size. The value of NDTCHG must be at least one. If the user does not want to reset the time step, a value of one should be entered here and a very large number, larger than the total simulation time, should be entered for TDTCH(1) in data set 4 (see Section 4.2.4).

5.2.2.10 Number of Iterations for Pointwise Solution, NPITER [--]

This parameter is used to input the number of iterations allowed for solving the matrix equations with the block iteration method. NPITER = 300 should be sufficient for most problems. If this number is exceeded and the solution does not converge, the program will issue a warning message. When this occurs, the user should first recheck the input values. If the input is correct, the program can be re-executed using a larger value for NPITER.

5.2.2.11 Sorption Model Control, KSORP [--]

Although the Freundlich isotherm option can be used to simulate a linear isotherm by setting the value of the exponent, n, equal to one, it is recommended that linear isotherms be simulated using only the linear isotherm option. This is because the linear isotherm option makes use of retarded seepage velocities, which result in a more accurate solution for the particle tracking scheme used in 3DLEWASTE than the pore velocities used in conjunction with the nonlinear adsorption models.

5.2.3 Data Set 3: Basic Real Parameters

5.2.3.1 Initial Time-Step Size, DELT [T]

This is the time-step size used for the first time-step computation if the variable CHNG is not equal 0.0. It is the time-step size used for every time step if the variable CHNG is set equal to 0.0. For a steady-state computation, DELT should be chosen such that no particle travels more than one element in one time step. For example, if an element has a size of 10 m and the averaged velocity over this element is 0.00001 m/sec, then DELT should be less then 1,000,000 seconds. For transient computations, one should choose a time-step size as large as possible with DELT less than DELX*DELX/D, where DELX is the size of the element and D is the dispersion coefficient. For example, if the element size is 10 m and the dispersion coefficient is 0.00001 m^2/sec, then DELT should be less than 10,000,000 seconds.

5.2.3.2 Fractional Change in Time-Step Size, CHNG [--]

This parameter specifies how much of an increase one would like to make to the time-step size for each subsequent time step. Normally, a value from 0.0 to 0.5 can be used.

5.2.3.3 Maximum Allowable Time Step, DELMAX [T]

The maximum time-step size allowed depends on how fast the system responds to change. Use of a value one to ten times the size of the initial time step is advised.

5.2.3.4 Maximum Simulation Time, TMAX [T]

This is the actual length of time to be simulated. If this time is exceeded before you have made NTI step computations, the simulation will be terminated.

5.2.3.5 Relaxation Parameter for Solving the Nonlinear Equation, OME [--]

Normally this parameter should be set to 1.0 (see Equation 3-48). If the convergence history shows sign of oscillation, then a value of 0.5 should be used. If the convergence history shows monotonic decreases but at a very slow rate, then OME should be set to somewhere between 1.7 to 1.9.

5.2.3.6 Iteration Parameter to Solve the Linearized Matrix Equation, OMI [--]

Normally this parameter should be set to 1.0 (see Equation 3-49). If the convergence history shows signs of oscillation, then set OMI to 0.5. If the solution converges monotonically but at a very slow rate, then set OMI to between 1.7 and 1.9.

5.2.3.7 Transient Convergence Criterion, TOLB [--]

This is the relative error allowed for assessing if a solution has converged for each time step. Setting TOLB equal to 0.000001 should be sufficient for most problems.

5.2.3.8 Steady-State Convergence Criterion, TOLA [--]

This is the relative error allowed for assessing if a steady-state solution has converged. TOLA = 0.00001 should be sufficient for most problems.

5.2.4 Data Set 5: Material Properties

5.2.4.1 Distribution Coefficient [L^3/M]

Freeze and Cherry (1979) state that adsorption/desorption reactions for contaminants in groundwater are normally viewed as being very rapid relative to the flow velocity and that the amount of contaminant adsorbed is commonly a function of concentration in the solution. At constant temperature and low-to-moderate concentrations, the functional relationship between the adsorbed concentration, S (M/L^3), and the dissolved concentration, C (M/L^3), is often approximated by the Freundlich equilibrium isotherm (Helfferich, 1962):

$$S = KC^n \tag{5-5}$$

where the coefficients K and n depend on several factors, including the solute species and the nature of the porous medium. If the isotherm is linear, n = 1, K is known as the distribution coefficient, K_d. The derivation of the distribution coefficient, which is different for each constituent, is discussed briefly in Section 3.3.1.

5.2.4.2 Bulk Density [M/L^3]

Bulk density can be defined as the mass of a unit volume of dry soil. The soil bulk density directly influences the retardation of solutes and is related to the structure and texture of a soil (Mercer et al., 1982).

The bulk density of soils typically range between 1.3 and 2.0 g/cm^3, but Mercer et al. (1982)

state that the bulk density can be as low as 0.3 g/cm^3 for soils high in organics or aluminum and iron hydroxides. Representative values for five different types of soils are shown in Table 5-8. In addition, values of bulk density for a large number of soils can be obtained from the interactive computer program DBAPE, which was discussed in Section 5.1.5.1.1.

The bulk density of aquifer materials may differ significantly from that of soils. Therefore, data on the ranges of bulk density for various geologic material are presented in Table 5-9. If site-specific data are not available, the bulk density of the saturated zone can be derived using an exact relationship between porosity, particle density and the bulk density (Freeze and Cherry, 1979). Assuming the particle density to be 2.65 g/cm^3, this relationship can be expressed as:

$$D_b = 2.65(1 - \theta) \tag{5-6}$$

where

D_b = bulk density of the soil (g/cm^3)

θ = saturated moisture content (porosity) (--)

TABLE 5-8. MEAN BULK DENSITY (g/cm^3) FOR FIVE SOIL TEXTURAL CLASSIFICATIONS[a,b]

Soil Texture	Mean Value	Range Reported
Silt Loams	1.32	0.86 - 1.67
Clay and Clay Loams	1.30	0.94 - 1.54
Sandy Loams	1.49	1.25 - 1.76
Gravelly Silt Loams	1.22	1.02 - 1.58
Loams	1.42	1.16 - 1.58
All Soils	1.35	0.86 - 1.76

[a] Baes, C.F., III and R.D. Sharp. 1983. A Proposal for Estimation of Soil Leaching Constants for Use in Assessment Models. J. Environ. Qual. 12(1):17-28 (Original reference).

[b] From Dean et al. (1989)

5.2.4.3 Longitudinal and Transverse Dispersivity [L]

Hydrodynamic dispersion is a non-steady, irreversible mixing process by which a contaminant spreads as it is transported through the subsurface. It results from the effects of two components: molecular diffusion and mechanical dispersion. The larger the hydrodynamic dispersion term is, the larger the spreading of an initially localized contaminant. Molecular diffusion is discussed in Section 5.2.4.4. Mechanical dispersion, **D**, is caused by variations in pore velocities in a soil or aquifer material. In addition, variations in the rate of advection caused by aquifer inhomogeneity and spatially-variable hydraulic conductivities results in plume spreading, which is often confused with dispersion (Keely, 1989).

Although mechanical dispersion is a second rank tensor, by assuming that a material is isotropic with respect to dispersion, the dispersion tensor can be expressed in terms of the average groundwater velocity and two constants: the longitudinal and transverse dispersivity (see Equation 3-20). Longitudinal dispersivity, "$_L$, is defined as the characteristic mixing length in the direction of groundwater flow and lateral dispersivity, "$_T$, is the mixing length in the directions perpendicular to flow.

Values for dispersivity are difficult to determine. Research has shown that the values are dependent on the scale of the problem being studied (EPRI, 1985). This can be seen in Figure 5.1. Usually, dispersion is determined by adjusting the dispersivity values until modeling results match historical data (Mercer et al., 1982). Transverse dispersivity values are commonly thought to be lower than longitudinal dispersivity values by a factor of 3 to 20. However, recent studies suggest that transverse dispersivity values should be at least an order-of-magnitude smaller than longitudinal dispersivity values (Gelhar et al., 1992) and may even be close to zero (U.S. EPA, 1989).

TABLE 5-9. RANGE AND MEAN VALUES OF DRY BULK DENSITY FOR VARIOUS GEOLOGIC MATERIALS

4

Material	Range (g/cm^3)	Mean (g/cm^3)
Clay	1.18-1.72	1.49
Silt	1.01-1.79	1.38
Sand, fine	1.13-1.99	1.55
Sand, medium	1.27-1.93	1.69
Sand, coarse	1.42-1.94	1.73
Gravel, fine	1.60-1.99	1.76
Gravel, medium	1.47-2.09	1.85
Gravel, coarse	1.69-2.08	1.93
Loess	1.25-1.62	1.45
Eolian sand	1.33-1.70	1.58
Till, predominantly silt	1.61-1.91	1.78
Till, predominantly sand	1.69-2.12	1.88
Till, predominantly gravel	1.72-2.12	1.91
Glacial drift, predominantly silt	1.11-1.66	1.38
Glacial drift, predominantly sand	1.36-1.83	1.55
Glacial drift, predominantly gravel	1.47-1.78	1.60
Sandstone, fine grained	1.34-2.32	1.76
Sandstone, medium grained	1.50-1.86	1.68
Siltstone	1.35-2.12	1.61
Claystone	1.37-1.60	1.51
Shale	2.20-2.72	2.53
Limestone	1.21-2.69	1.94
Dolomite	1.83-2.20	2.02

Granite, weathered	1.21-1.78	1.50
Gabbro, weathered	1.67-1.77	1.73
Basalt	1.99-2.89	2.53
Schist	1.42-2.69	1.76

Reference: Morris and Johnson (1967); Mills et al. (1985b)

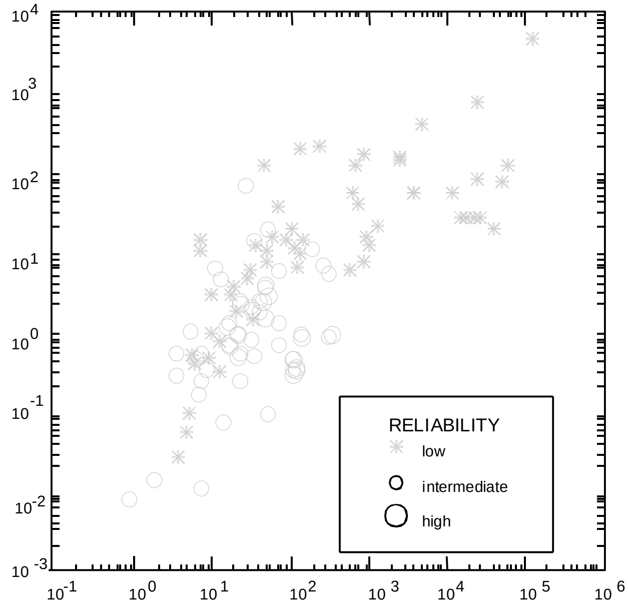


Figure 5.1 Longitudinal dispersivity versus scale with data classified by reliability (from Gelhar et al., 1992).

As <u>initial estimates</u> for longitudinal and transverse dispersivity, Dean et al. (1989) suggest the following relationships, based on values presented in the Federal Register (1986):

$$"_L = 0.1\, x_r \tag{5-7a}$$

$$"_T = "_L/3.0 \tag{5-7b}$$

where x_r is the distance from the source to a downgradient point of interest.

5.2.4.4 Molecular Diffusion Coefficient in Water [L^2/T]

As stated above, molecular diffusion and mechanical dispersion are both responsible for the dispersion of solutes in groundwater systems. Molecular diffusion, which is a non-reversible process, is typically small compared to mechanical dispersion and is often neglected in groundwater studies. However, when groundwater velocities are very low, molecular diffusion can become significant.

The flux of a solute in a fluid due to molecular diffusion is described by Fick's Law, which states that the flux is proportional to the concentration gradient. The coefficient of proportionality is called the molecular diffusion coefficient, a_m. Values for the molecular diffusion coefficient in a fluid continuum are generally well known and are typically in the range of 10^{-9} m^2/s or less at 20^oC. If necessary, a_m, which varies with temperature, can be estimated from methods described in Lyman et al. (1982).

5.2.4.5 Tortuosity [--]

The molecular diffusion coefficient for a solute in a porous medium is smaller than the coefficient of diffusion in a body of water because diffusion in solids is negligible. The amount by which the molecular diffusion coefficient is reduced is expressed by a coefficient called tortuosity. Tortuosity is a second-rank tensor which for isotropic conditions reduces to a scalar. It expresses the effect of the configuration of the water occupying a porous medium (Bear and Verruijt, 1987).

De Marsily (1986) states that a medium's tortuosity, J, can be defined as:

$$J = 1/FN \qquad (5\text{-}8)$$

where

F = formation factor (the ratio of a rock's electric resistivity over the resistivity of its contained water) (--)

N = total porosity (--)

The author states that tortuosity varies in practice from 0.1 for clays to 0.7 for sands. Freeze and Cherry (1979) state that the coefficient, which is always less than one, usually has a value between 0.01 and 0.5.

Bresler (1973), as found in Dean et al. (1989), provides the following equation to estimate diffusion coefficient in a porous medium:

$$D_m = D_w \, ae^{b2} \qquad (5\text{-}9)$$

where

D_m = coefficient of diffusion in a porous medium (cm^2/day)

D_w = coefficient of diffusion in water (cm^2/day)

a = soil constant having a range of 0.001 to 0.005

b = soil constant having an approximate value of 10

2 = volumetric water content (cm^3/cm^3)

In the above equation, the term ae^{b2} represents an estimate of the soil's tortuosity.

5.2.4.6 Decay Constant [1/T]

A number of processes, such as hydrolysis and biodegradation, contribute to the disappearance of chemicals in the subsurface. The extent to which these processes are important depends on both environmental conditions and the chemical's properties. In this model, the effects of individual processes on the degradation of a chemical in the subsurface are not considered. Instead, lumped first-order decay with respect to the concentration of the solute is assumed to occur, with a single first-order decay constant controlling the modelled rate of disappearance in each porous material.

When estimating a value for the first-order decay constant, one should determine which processes are likely to be important at the study area. Hydrolysis is a potentially significant elimination pathway for many organic chemicals. However, for chemicals that readily biodegrade, hydrolysis may be insignificant relative to biodegradation. Methods of estimating a first-order rate constant resulting from hydrolysis are presented in Lyman et al. (1982). Values for hydrolysis rate constants can be found in a large number of references, including Lyman et al. (1982), Mabey et al. (1982), and Mills et al. (1985a).

Although biodegradation is the most significant means of removal for many organics in the subsurface, it is a very complex and poorly understood process. Biodegradation in the subsurface depends on a number of variable and/or unknown processes, such as the number of microorganisms present, the availability of oxygen and other nutrients, and the Ph and temperature of the subsurface environment (Sharp-Hansen et al., 1990). Therefore it is very difficult to estimate the first-order decay coefficient resulting from biodegradation. Laboratory-derived biodegradation rate constants have been compiled by Lyman et al. (1982), Mabey et al. (1982), and Mills et al. (1985a), among others. However, these laboratory-based values may be inappropriate for field conditions. Therefore, considerable care should be exercised if these data are used.

5.2.5 Data Set 17: Hydrological Variables

For most wellhead protection applications of this code, the velocity field and moisture content field will not need to be specified in the input. Instead, these variables should be calculated and stored by the variably-saturated flow code, 3DFEMWATER. The stored arrays of data are then accessed by 3DLEWASTE. Only when 3DLEWASTE is executed without first running 3DFEMWATER does the user need to supply values for these variables. Moisture content was introduced in Section 5.1.5.1.1 and will not be discussed here.

5.2.5.1 Velocity Field [L/T]

The velocity distribution is needed to quantify transport by advection. Groundwater velocities are routinely determined indirectly using measurements of hydraulic head, hydraulic conductivity, and Darcy's equation. For the case when the x, y, and z axes coincide with the principal directions of anisotropy, Darcy's Law, in terms of the Darcy velocity, is written as:

$$v_x = -K_x\, dh/dx \tag{5-10a}$$

$$v_y = -K_y\, dh/dy \tag{5-10b}$$

$$v_z = -K_z\, dh/dz \tag{5-10c}$$

where K_x, K_y, and K_z are the hydraulic conductivity values in the x, y, and z directions, and dh/dx, dh/dy, and dh/dz are the hydraulic gradients in the x, y, and z directions. A more generalized form can be written as:

$$v_x = -K_{xx}\, dh/dx - K_{xy}\, dh/dy - K_{xz}\, dh/dz \quad (5\text{-}11a)$$

$$v_y = -K_{yx}\, dh/dx - K_{yy}\, dh/dy - K_{yz}\, dh/dz \quad (5\text{-}11b)$$

$$v_z = -K_{zx}\, dh/dx - K_{zy}\, dh/dy - K_{zz}\, dh/dz \quad (5\text{-}11c)$$

Since velocity depends on the gradient as well as the hydraulic conductivity, its range is somewhat arbitrary. A range of velocities is given in Figure 5.2.

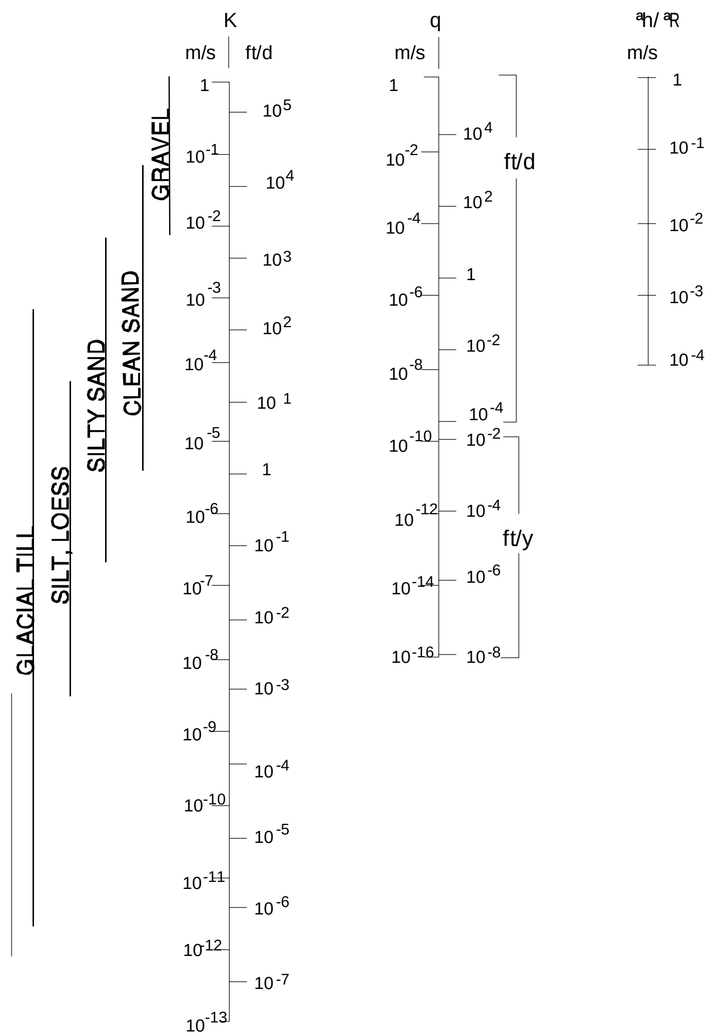


Figure 5.2. Nomograph for determining Darcy velocity (from Mercer et al., 1982)

SECTION 6

EXAMPLE PROBLEMS

6.1 3DFEMWATER

To demonstrate the application of 3DFEMWATER, three simple example problems are presented. These three problems represent one-, two-, and three-dimensional applications, respectively. For each problem, a brief description and a correctly-constructed input data set are given. The corresponding output is not included in this documentation. Rather, it is distributed along with the code by the EPA Center for Exposure Assessment Modeling (CEAM) at the Environmental Research Laboratory in Athens, Georgia. See Section 2 for information about obtaining the code.

6.1.1 One-Dimensional Column

One-dimensional transient flow through a column is simulated in this example. The column is 200 cm long and is 50 cm by 50 cm in cross-section (Figure 6.1). The soil in the column is assumed to be a sandy clay loam which has a saturated hydraulic conductivity of 31.4 cm/d, a porosity of 0.39 and a residual moisture content of 0.10. The unsaturated characteristic hydraulic properties of the soil in the column are represented by the van Genuchten analytical functions with the empirical coefficient alpha equal to 0.059 and the empirical coefficient beta equal to 1.48.

The initial conditions assumed are a pressure head of -90.0 cm imposed on the top surface of the column, 0.0 cm on the bottom surface of the column, and -97.0 cm elsewhere. The boundary conditions are as follows. No flux is imposed on the left, front, right, and back surfaces of the column (this is done automatically by the code). Pressure head is held at 0.0 cm on the bottom surface using a Dirichlet boundary condition. A variable boundary condition is used on the top surface of the column with a ponding depth of zero, minimum pressure of -90.0 cm, a rainfall of 5.0 cm/d for the first ten days, and a potential evaporation of 5.0 cm/d for the second 10 days.

The region of interest, that is, the whole column, is discretized with 1 x 1 x 40 = 40 elements with the element size equal to 50 x 50 x 5 cm. This results in 2 x 2 x 41 = 164 node points. For this simulation, each of the four vertical lines is considered a subregion. Thus, a total of four subregions, each with 41 node points, is used for the subregional block iteration simulation.

A variable time step size is used. The initial time step size is 0.05 days, and each subsequent time step size is increased by 0.2 times with a maximum time step

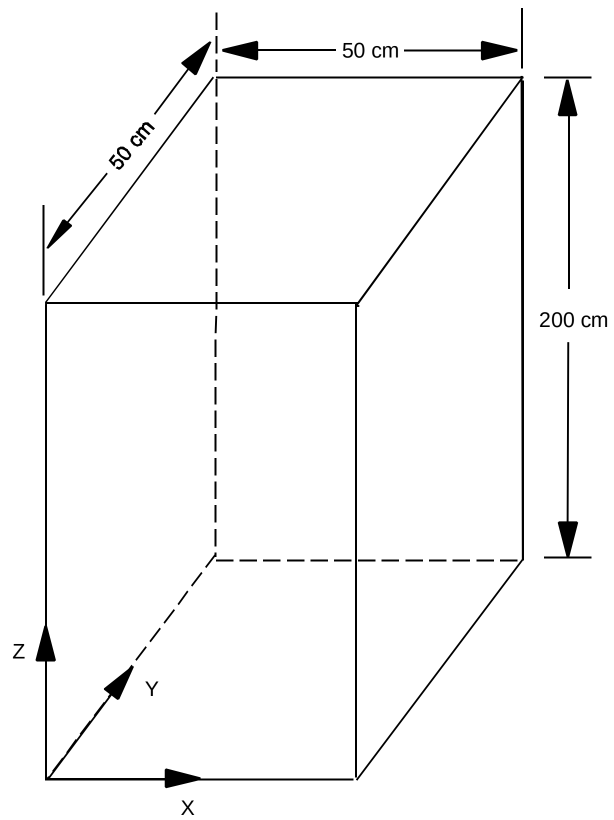


Figure 6.1. One-dimensional transient flow through a soil column.

size not greater than 1.0 d. Because there is an abrupt change in the flux value from 5 cm/d (infiltration) to -5 cm/d (evaporation) imposed on the top surface at day 10, the time step size is automatically reset to 0.05 d on the tenth day. Because a 20-day simulation is to be made, 44 time steps are needed.

A pressure head tolerance of .02 cm is selected for the nonlinear iteration and a tolerance of .01 cm is used for the block iteration. The relaxation factors for both the nonlinear iteration and block iteration are set equal to 0.5.

The input data set for this problem, prepared according to the instructions in Sections 4.1 and 5.1, is shown in Table 6-1.

6.1.2 Two-dimensional Drainage Problem

Two-dimensional steady-state flow is simulated in this problem. The region of interest is bounded on the left and right by parallel drains which fully penetrate the medium. The bottom is an impervious layer and the top is an air-soil interface (Figure 6.2). The distance between the two drains is 20 m. The medium is assumed to have a saturated horizontal hydraulic conductivity of 0.31 m/d and vertical hydraulic conductivity of 0.12 m/d, a porosity of 0.39, and
TABLE 6-1. INPUT DATA SET FOR THE ONE-DIMENSIONAL 3DFEMWATER PROBLEM
4

```
   1  SIMULATION OF ONE-D COLUMN INFILTRATION-EVAPORATION; L=CM, T=DAY,
M=G 011
C ******* DATA SET 2:  BASIC INTEGERS
  164   40    1    0   44    1    6    1    0    0   50   20    3  100
C ******* DATA SET 3:  BASIC REAL PARAMETERS
   0.05D0     0.2D0     1.0D0    20.0D0    2.0D-2    2.0D-2     1.0D0  7.316D12
  1.1232D2     1.0D0     0.5D0     0.5D0
C ******* DATA SET 4:  PRINTER, STORAGE CONTROL AND TIME STEP SIZE RESETTING
3330303000300030030000333030300030003003000003
1110101000100010010000111010100010001001000001
   1.0D01  2.0000D1    1.0D38
C ******* DATA SET 5:  MATERIAL PROPERTIES
    0.0D0     0.0D0   31.40D0     0.0D0     0.0D0     0.0D0
C ******* DATA SET 6:  SOIL PROPERTY PARAMETERS
   0    5    0
  0.100D0   0.390D0    0.00D0   0.059D0    1.48D0                  THPROP
C ******* DATA SET 7:  NODE COORDINATES
   1   40    1         0.0D0    50.0D0     0.0D0     0.0D0     0.0D0     5.0D0
  42   40    1          0.0D0     0.0D0     0.0D0     0.0D0     0.0D0     5.0D0
  83   40    1         50.0D0     0.0D0     0.0D0     0.0D0     0.0D0     5.0D0
 124   40    1         50.0D0    50.0D0     0.0D0     0.0D0     0.0D0     5.0D0
   0    0    0          0.0      0.0       0.0       0.0       0.0       0.0
C ******* DATA SET 8:  SUBREGIONAL DATA
   4
   1    3    1   41    0
   0    0    0    0    0                    END OF NNPLR(K)
   1   40    1    1    1
   0    0    0    0    0                    END OF GNLR(I,1)
   1   40    1   42    1
   0    0    0    0    0                    END OF GNLR(I,2)
   1   40    1   83    1
   0    0    0    0    0                    END OF GNLR(I,3)
   1   40    1  124    1
   0    0    0    0    0                    END OF GNLR(I,4)
C ******* DATA SET 9:  ELEMENT INCIDENCES
```

```
   1   39    1   42   83  124    1   43   84  125    2    1
   0    0    0    0    0    0    0    0    0    0    0   0         END OF IE
C ******* DATA SET 11:  INITIAL CONDITIONS
   1    3   41          0.0D0     0.0D0     0.0D0
   2   38    1        -9.70D1     0.0D0     0.0D0
  43   38    1        -9.70D1     0.0D0     0.0D0
  84   38    1        -9.70D1     0.0D0     0.0D0
 125   38    1        -9.70D1     0.0D0     0.0D0
  41    3   41        -9.00D1     0.0D0     0.0D0
```

TABLE 6-1. INPUT DATA SET FOR THE ONE-DIMENSIONAL 3DFEMWATER PROBLEM (concluded)

4

```
   0    0    0         0.0        0.0       0.0              END OF IC
C ******* DATA SET 12:  SOURCE/SINK AND B. C. CONTROL INTEGERS
   0    0    0    0    0    0    0    0    4    1    2    0
   1    4    1    4    0    0    0    0    0    0    0    0    0    0    0
C ******* DATA SET 14:  VARIABLE BOUNDARY CONDITIONS
    0.0D0     5.0D0    10.0D0     5.0D0  10.001D0    -5.0D0    1.0D38    -5.0D0
   1    0    0    1    0
   0    0    0    0    0        END OF IRTYP
   1    0    0   82  123  164   41    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0 END OF ISV(J,I) J=1,4
   1    3    1   41   41
   0    0    0    0    0                    END OF NPVB
   1    3    1         0.0D0     0.0D0       0.0
   0    0    0         0.0       0.0         0.0            END OF HCON
   1    3    1       -90.0D0     0.0D0       0.0
   0    0    0         0.0       0.0         0.0            END OF HMIN
C ******* DATA SET 15:  DIRICHLET BOUNDARY CONDITIONS
    0.0D0     0.0D0    1.0D38     0.0D0
   1   42   83  124
   1    3    1    1    0
   0    0    0    0    0                    END OF IDTYP
   0              END OF JOB  -----------------------------------------000
```

4

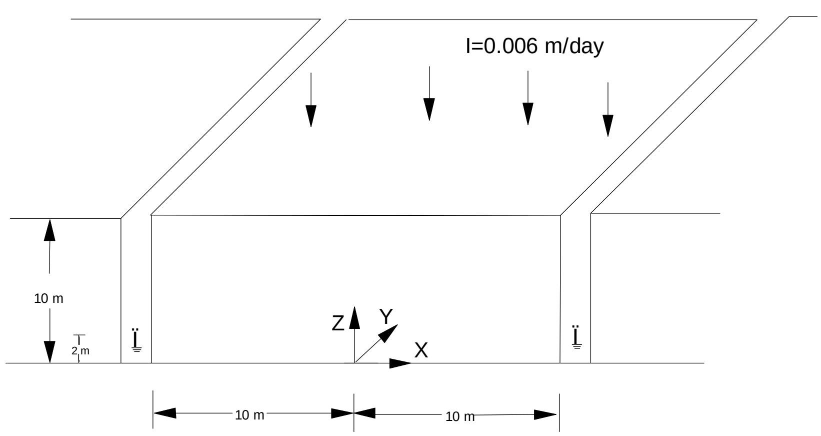


Figure 6.2. Two-dimensional steady-state flow to parallel drains.

a field capacity of 0.10. The unsaturated characteristic hydraulic properties of the medium are given by the van Genuchten analytical functions with the empirical coefficient alpha equal to 0.059 and the empirical coefficient beta equal to 1.48.

Because of symmetry, the region to be

simulated is 0.0 < x < 10.0 m and 0.0 < z < 10.0 m, with a width of 10 m assumed in the y-direction. A no flux boundary is imposed on the left (x = 0.0), front (y = 0.0), back (y = 10.0), and bottom (z = 0.0) sides of the region. Pressure head is assumed to vary from zero at the water surface (z = 2.0) to 2.0 m at the bottom (z = 0.0) on the right side (x = 10.0). Variable conditions are used elsewhere. Ponding depth is assumed to be zero meters on the whole variable boundary. Fluxes on the top of the variable boundary are assumed equal to 0.006 m/d and on the right side, above the water surface, are equal to zero. A pre-initial condition for the steady-state solution is set as h = 10 - z.

The region of interest is discretized with 10 x 1 x 10 = 100 elements with the element size equal to 1 x 10 x 1 cm. This results in 11 x 2 x 11 = 242 nodal points. Each of the two vertical planes is considered a subregion. Thus, a total of two subregions, each with 121 node points, is used for the subregional block iteration simulation.

A pressure head tolerance of .002 m is set for the for nonlinear iteration and a value of .001 m is used for the block iteration. The relaxation factors for both the nonlinear iteration and block iteration are set equal to 0.5.

The input data set for this problem, prepared according to the instructions in Sections 4.1 and 5.1, is shown in Table 6-2.

6.1.3 Three-Dimensional Pumping Problem

Three-dimensional steady-state flow to a pumping well is simulated in this problem. The region of interest is bounded on the left and right by hydraulically connected rivers; on the front, back, and bottom by impervious confining beds; and on the top by an air-soil interface (Figure 6.3). A pumping well is located at (x,y) = (540,400) in Figure 6.3. Initially, the water table is assumed to be horizontal and is 60 m above the bottom of the aquifer. The water level at the well is then lowered to a height of 30 m. This height is held until a steady state condition is reached. The medium in the region is assumed to be anisotropic and has saturated hydraulic conductivity components K_{xx} = 0.31 m/d, K_{yy} = 0.03 m/d, and K_{zz} = 0.12 m/d. The porosity of the medium is 0.10 and the field capacity is 0.39. The unsaturated characteristic hydraulic properties of the medium are given by the van Genuchten analytical functions with the empirical coefficient alpha equal to 0.059 and the empirical coefficient beta equal to 1.48.

Because of symmetry, the region to be simulated is taken as 0 < x < 1000 m, 0 < y < 400 m, and 0 < z < 72 m. Two types of boundary conditions are used. Pressure head is assumed hydrostatic on two vertical planes. The first is located at x = 0 and 0 < z < 60 and the second, at x = 1000 and 0 < z < 60. A no flux boundary is imposed on all other boundaries of the flow regime. The pre-initial condition for the steady-state solution is set so that the pressure head, h = 60 - z.

TABLE 6-2. INPUT DATA SET FOR THE TWO-DIMENSIONAL 3DFEMWATER PROBLEM

```
4

   2   SIMULATION OF TWO-D STEADY DRAINAGE; L=M, T=DAY, M=KG                111
C ******* DATA SET 2:  BASIC INTEGERS
  242  100    1    0    0    0    6    1    0    0   50   20    1  100
C ******* DATA SET 3:  BASIC REAL PARAMETERS
   0.05D0     0.2D0     1.0D0    20.0D0    2.0D-3    2.0D-3     1.0D0  7.316D10
  1.1232D4     1.0D0     0.5D0     0.5D0  0.0
C ******* DATA SET 4:  PRINTER, STORAGE CONTROL AND TIME STEP SIZE RESETTING
33
11
   1.0D38
C ******* DATA SET 5:  MATERIAL PROPERTIES
   0.31D0     0.0D0    0.12D0     0.0D0     0.0D0     0.0D0
C ******* DATA SET 6:  SOIL PROPERTY PARAMETERS
   0    5    0
  0.100D0   0.390D0    0.00D0   0.059D0    1.48D0                  THPROP
C ******* DATA SET 7:  NODE COORDINATES
   1   10   11         0.0D0     0.0D0     0.0D0     1.0D0     0.0D0     0.0D0
   2   10   11         0.0D0     0.0D0     1.0D0     1.0D0     0.0D0     0.0D0
   3   10   11         0.0D0     0.0D0     2.0D0     1.0D0     0.0D0     0.0D0
   4   10   11         0.0D0     0.0D0     3.0D0     1.0D0     0.0D0     0.0D0
   5   10   11         0.0D0     0.0D0     4.0D0     1.0D0     0.0D0     0.0D0
   6   10   11         0.0D0     0.0D0     5.0D0     1.0D0     0.0D0     0.0D0
   7   10   11         0.0D0     0.0D0     6.0D0     1.0D0     0.0D0     0.0D0
   8   10   11         0.0D0     0.0D0     7.0D0     1.0D0     0.0D0     0.0D0
   9   10   11         0.0D0     0.0D0     8.0D0     1.0D0     0.0D0     0.0D0
  10   10   11         0.0D0     0.0D0     9.0D0     1.0D0     0.0D0     0.0D0
  11   10   11         0.0D0     0.0D0    10.0D0     1.0D0     0.0D0     0.0D0
 122   10   11         0.0D0    10.0D0     0.0D0     1.0D0     0.0D0     0.0D0
 123   10   11         0.0D0    10.0D0     1.0D0     1.0D0     0.0D0     0.0D0
 124   10   11         0.0D0    10.0D0     2.0D0     1.0D0     0.0D0     0.0D0
 125   10   11         0.0D0    10.0D0     3.0D0     1.0D0     0.0D0     0.0D0
 126   10   11         0.0D0    10.0D0     4.0D0     1.0D0     0.0D0     0.0D0
 127   10   11         0.0D0    10.0D0     5.0D0     1.0D0     0.0D0     0.0D0
 128   10   11         0.0D0    10.0D0     6.0D0     1.0D0     0.0D0     0.0D0
 129   10   11         0.0D0    10.0D0     7.0D0     1.0D0     0.0D0     0.0D0
 130   10   11         0.0D0    10.0D0     8.0D0     1.0D0     0.0D0     0.0D0
 131   10   11         0.0D0    10.0D0     9.0D0     1.0D0     0.0D0     0.0D0
 132   10   11         0.0D0    10.0D0    10.0D0     1.0D0     0.0D0     0.0D0
   0    0    0         0.0       0.0       0.0       0.0       0.0       0.0
C ******* DATA SET 8:  SUBREGIONAL DATA
```

```
  2
  1    1    1  121    0
  0    0    0    0    0   END OF NNPLR(K)
  1  120    1    1    1
```

TABLE 6-2. INPUT DATA SET FOR THE TWO-DIMENSIONAL 3DFEMWATER PROBLEM (continued)

```
4
  0    0    0    0    0   END OF GNLR(I,1)
  1  120    1  122    1
  0    0    0    0    0   END OF GNLR(I,2)
C ******* DATA SET 9:  ELEMENT INCIDENCES
  1    9    1    1   12  133  122    2   13  134  123    1
 11    9    1   12   23  144  133   13   24  145  134    1
 21    9    1   23   34  155  144   24   35  156  145    1
 31    9    1   34   45  166  155   35   46  167  156    1
 41    9    1   45   56  177  166   46   57  178  167    1
 51    9    1   56   67  188  177   57   68  189  178    1
 61    9    1   67   78  199  188   68   79  200  189    1
 71    9    1   78   89  210  199   79   90  211  200    1
 81    9    1   89  100  221  210   90  101  222  211    1
 91    9    1  100  111  232  221  101  112  233  222    1
  0    0    0    0    0    0    0    0    0    0    0    0     END OF IE
C ******* DATA SET 11:  INITITAL CONDITIONS
  1   10   11        10.0D0     0.0D0     0.0D0
  2   10   11         9.0D0     0.0D0     0.0D0
  3   10   11         8.0D0     0.0D0     0.0D0
  4   10   11         7.0D0     0.0D0     0.0D0
  5   10   11         6.0D0     0.0D0     0.0D0
  6   10   11         5.0D0     0.0D0     0.0D0
  7   10   11         4.0D0     0.0D0     0.0D0
  8   10   11         3.0D0     0.0D0     0.0D0
  9   10   11         2.0D0     0.0D0     0.0D0
 10   10   11         1.0D0     0.0D0     0.0D0
 11   10   11         0.0D0     0.0D0     0.0D0
122   10   11        10.0D0     0.0D0     0.0D0
123   10   11         9.0D0     0.0D0     0.0D0
124   10   11         8.0D0     0.0D0     0.0D0
125   10   11         7.0D0     0.0D0     0.0D0
126   10   11         6.0D0     0.0D0     0.0D0
127   10   11         5.0D0     0.0D0     0.0D0
128   10   11         4.0D0     0.0D0     0.0D0
129   10   11         3.0D0     0.0D0     0.0D0
130   10   11         2.0D0     0.0D0     0.0D0
```

```
  131   10   11          1.0D0     0.0D0     0.0D0
  132   10   11          0.0D0     0.0D0     0.0D0
    0    0    0          0.0D0     0.0D0     0.0D0          END OF IC
C ******* DATA SET 12:  SOURCE/SINK AND B. C. CONTROL INTEGERS
    0    0    0    0    0    0    0    0    6    1    2    0
   18   38    2    2    0    0    0    0    0    0    0    0    0    0    0
```

TABLE 6-2. INPUT DATA SET FOR THE TWO-DIMENSIONAL 3DFEMWATER PROBLEM (concluded)

4

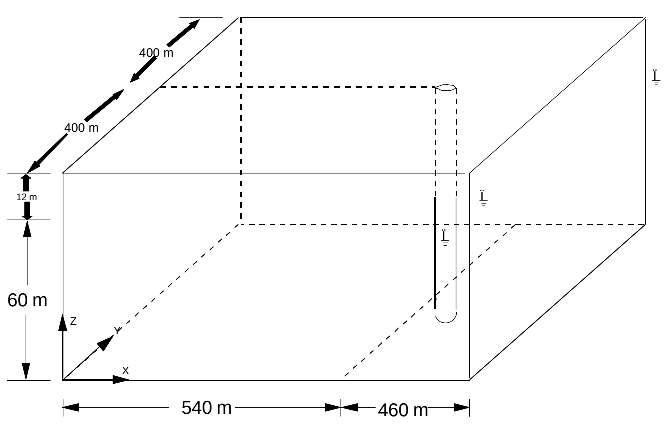
```
C ******* DATA SET 14:  VARIABLE BOUNDARY CONDITIONS
    0.0D0    6.0D-3    1.0D38    6.0D-3
    0.0D0    0.0D00    1.0D38    0.0D00
   1    9    1    1    0
  11    7    1    2    0
   0    0    0    0    0          END OF IRTYP
   1    9    1   11   22  143  132   11   11   11   11
  11    7    1  120  241  242  121   -1   -1   -1   -1
   0    0    0    0    0    0    0    0    0    0    0 END OF ISV(J,I) J=1,4
   1   10    1   11   11
  12    7    1  120   -1
  20   10    1  132   11
  31    7    1  241   -1
   0    0    0    0    0       END OF NPVB
   1   37    1         0.0D0     0.0D0     0.0D0
   0    0    0         0.0D0     0.0D0     0.0D0   END OF HCON
   1   37    1       -90.0D2     0.0D0     0.0D0
   0    0    0         0.0D0     0.0D0     0.0D0   END OF HMIN
C ******* DATA SET 15:  DIRICHLET BOUNDARY CONDITIONS
    0.0D0     2.0D0    1.0D38     2.0D0
 111  112  113  232  233  234
   1    5    1    1    0
   0    0    0    0    0  END OF IDTYP
   0               END OF JOB -----------------------------------------000
```

4

Figure 6.3. Three-dimensional steady-state flow to a pumping well.

The region of interest is discretized with 20 x 8 x 10 = 1600 elements, resulting in 21 x 9 x 11 = 2079 nodal points. The nodes are located at x = 0, 70, 120, 160, 200, 275, 350, 400, 450, 500, 540, 570, 600, 650, 750, 800, 850, 900, 950, and 1000 in the x-direction, and at z = 0, 15, 30, 35, 40, 45, 50, 55, 60, 66, and 72 in the z-direction. In the y-direction, nodes are spaced evenly at) z = 50 m. For the simulation, each of the nine vertical planes perpendicular to the y-axis is considered a subregion. Thus, a total of 9 subregions, each with 231 node points, is used for the subregional block iteration simulation.

The pressure head tolerance is set at .01 m for the nonlinear iteration and is .005 m for



the block iteration. The relaxation factors for the nonlinear iteration and block iteration are set equal to 1.0 and 1.5, respectively.

The input data set for this problem, prepared according to the instructions in Sections 4.1 and 5.1, is shown in Table 6-3.

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM 4

```
   3  SIMULATION OF THREE-D PUMPING WELL; L = M, T = DAY, M = KG            011
C ******* DATA SET 2:  BASIC INTEGER PARAMETERS
 2079 1600    1    0    0    0    6    1    0    0   50   20    1  100
C ******* DATA SET 3:  BASIC REAL PARAMETERS
   0.05D0     0.0D0     1.0D0    20.0D0    1.0D-2    1.0D-2     1.0D0  7.316D10
  1.1232D4     1.0D0     1.0D0     1.5D0
C ******* DATA SET 4:  PRINTER, STORAGE CONTROL AND TIME STEP SIZE RESETTING
55
11
   1.0D38
C ******* DATA SET 5:  MATERIAL PROPERTIES
   0.31D0    0.03D0    0.12D0     0.0D0     0.0D0     0.0D0
C ******* DATA SET 6: SOIL PROPERTY PARAMETERS
   0    5    0
  0.1000D0   0.390D0    0.00D0   0.059D0    1.48D0              THPROP
C ******* DATA SET 7:  NODE COORDINATES
   1    8  231       0.00D+00  0.00D+00  0.00D+00  0.00D+00  0.50D+02  0.00D+00
   2    8  231       0.00D+00  0.00D+00  0.15D+02  0.00D+00  0.50D+02  0.00D+00
   3    8  231       0.00D+00  0.00D+00  0.30D+02  0.00D+00  0.50D+02  0.00D+00
   4    8  231       0.00D+00  0.00D+00  0.35D+02  0.00D+00  0.50D+02  0.00D+00
   5    8  231       0.00D+00  0.00D+00  0.40D+02  0.00D+00  0.50D+02  0.00D+00
   6    8  231       0.00D+00  0.00D+00  0.45D+02  0.00D+00  0.50D+02  0.00D+00
   7    8  231       0.00D+00  0.00D+00  0.50D+02  0.00D+00  0.50D+02  0.00D+00
   8    8  231       0.00D+00  0.00D+00  0.55D+02  0.00D+00  0.50D+02  0.00D+00
   9    8  231       0.00D+00  0.00D+00  0.60D+02  0.00D+00  0.50D+02  0.00D+00
  10    8  231       0.00D+00  0.00D+00  0.66D+02  0.00D+00  0.50D+02  0.00D+00
  11    8  231       0.00D+00  0.00D+00  0.72D+02  0.00D+00  0.50D+02  0.00D+00
  12    8  231       0.70D+02  0.00D+00  0.00D+00  0.00D+00  0.50D+02  0.00D+00
  13    8  231       0.70D+02  0.00D+00  0.15D+02  0.00D+00  0.50D+02  0.00D+00
  14    8  231       0.70D+02  0.00D+00  0.30D+02  0.00D+00  0.50D+02  0.00D+00
  15    8  231       0.70D+02  0.00D+00  0.35D+02  0.00D+00  0.50D+02  0.00D+00
  16    8  231       0.70D+02  0.00D+00  0.40D+02  0.00D+00  0.50D+02  0.00D+00
  17    8  231       0.70D+02  0.00D+00  0.45D+02  0.00D+00  0.50D+02  0.00D+00
  18    8  231       0.70D+02  0.00D+00  0.50D+02  0.00D+00  0.50D+02  0.00D+00
  19    8  231       0.70D+02  0.00D+00  0.55D+02  0.00D+00  0.50D+02  0.00D+00
  20    8  231       0.70D+02  0.00D+00  0.60D+02  0.00D+00  0.50D+02  0.00D+00
  21    8  231       0.70D+02  0.00D+00  0.66D+02  0.00D+00  0.50D+02  0.00D+00
  22    8  231       0.70D+02  0.00D+00  0.72D+02  0.00D+00  0.50D+02  0.00D+00
  23    8  231       0.12D+03  0.00D+00  0.00D+00  0.00D+00  0.50D+02  0.00D+00
  24    8  231       0.12D+03  0.00D+00  0.15D+02  0.00D+00  0.50D+02  0.00D+00
```

25	8	231	0.12D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
26	8	231	0.12D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
27	8	231	0.12D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
28	8	231	0.12D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00

Table 6-3. Input Data Set for the Three-Dimensional 3DFEMWATER PROBLEM (continued)

4

29	8	231	0.12D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
30	8	231	0.12D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
31	8	231	0.12D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
32	8	231	0.12D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
33	8	231	0.12D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
34	8	231	0.16D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
35	8	231	0.16D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
36	8	231	0.16D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
37	8	231	0.16D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
38	8	231	0.16D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
39	8	231	0.16D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00
40	8	231	0.16D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
41	8	231	0.16D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
42	8	231	0.16D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
43	8	231	0.16D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
44	8	231	0.16D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
45	8	231	0.20D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
46	8	231	0.20D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
47	8	231	0.20D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
48	8	231	0.20D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
49	8	231	0.20D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
50	8	231	0.20D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00
51	8	231	0.20D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
52	8	231	0.20D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
53	8	231	0.20D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
54	8	231	0.20D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
55	8	231	0.20D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
56	8	231	0.28D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
57	8	231	0.28D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
58	8	231	0.28D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
59	8	231	0.28D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
60	8	231	0.28D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
61	8	231	0.28D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00
62	8	231	0.28D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
63	8	231	0.28D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00

64	8	231	0.28D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
65	8	231	0.28D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
66	8	231	0.28D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
67	8	231	0.35D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
68	8	231	0.35D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
69	8	231	0.35D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
70	8	231	0.35D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
71	8	231	0.35D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
72	8	231	0.35D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (continued)

4

73	8	231	0.35D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
74	8	231	0.35D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
75	8	231	0.35D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
76	8	231	0.35D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
77	8	231	0.35D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
78	8	231	0.40D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
79	8	231	0.40D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
80	8	231	0.40D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
81	8	231	0.40D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
82	8	231	0.40D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
83	8	231	0.40D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00
84	8	231	0.40D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
85	8	231	0.40D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
86	8	231	0.40D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
87	8	231	0.40D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
88	8	231	0.40D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
89	8	231	0.45D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
90	8	231	0.45D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
91	8	231	0.45D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
92	8	231	0.45D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
93	8	231	0.45D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
94	8	231	0.45D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00
95	8	231	0.45D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
96	8	231	0.45D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
97	8	231	0.45D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
98	8	231	0.45D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
99	8	231	0.45D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
100	8	231	0.50D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
101	8	231	0.50D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
102	8	231	0.50D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00

103	8	231	0.50D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
104	8	231	0.50D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
105	8	231	0.50D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00
106	8	231	0.50D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
107	8	231	0.50D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
108	8	231	0.50D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
109	8	231	0.50D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
110	8	231	0.50D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
111	8	231	0.54D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
112	8	231	0.54D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
113	8	231	0.54D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
114	8	231	0.54D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
115	8	231	0.54D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
116	8	231	0.54D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (continued)

4

117	8	231	0.54D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
118	8	231	0.54D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
119	8	231	0.54D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
120	8	231	0.54D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
121	8	231	0.54D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
122	8	231	0.57D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
123	8	231	0.57D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
124	8	231	0.57D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
125	8	231	0.57D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
126	8	231	0.57D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
127	8	231	0.57D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00
128	8	231	0.57D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
129	8	231	0.57D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
130	8	231	0.57D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
131	8	231	0.57D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
132	8	231	0.57D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
133	8	231	0.60D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
134	8	231	0.60D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
135	8	231	0.60D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
136	8	231	0.60D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
137	8	231	0.60D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
138	8	231	0.60D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00
139	8	231	0.60D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
140	8	231	0.60D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
141	8	231	0.60D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00

142	8	231	0.60D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
143	8	231	0.60D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
144	8	231	0.65D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
145	8	231	0.65D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
146	8	231	0.65D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
147	8	231	0.65D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
148	8	231	0.65D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
149	8	231	0.65D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00
150	8	231	0.65D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
151	8	231	0.65D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
152	8	231	0.65D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
153	8	231	0.65D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
154	8	231	0.65D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
155	8	231	0.70D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
156	8	231	0.70D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
157	8	231	0.70D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
158	8	231	0.70D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
159	8	231	0.70D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
160	8	231	0.70D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (continued)

4

161	8	231	0.70D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
162	8	231	0.70D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
163	8	231	0.70D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
164	8	231	0.70D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
165	8	231	0.70D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
166	8	231	0.75D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
167	8	231	0.75D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
168	8	231	0.75D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
169	8	231	0.75D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
170	8	231	0.75D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
171	8	231	0.75D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00
172	8	231	0.75D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
173	8	231	0.75D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
174	8	231	0.75D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
175	8	231	0.75D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
176	8	231	0.75D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
177	8	231	0.80D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
178	8	231	0.80D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
179	8	231	0.80D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
180	8	231	0.80D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00

181	8	231	0.80D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
182	8	231	0.80D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00
183	8	231	0.80D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
184	8	231	0.80D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
185	8	231	0.80D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
186	8	231	0.80D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
187	8	231	0.80D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
188	8	231	0.85D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
189	8	231	0.85D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
190	8	231	0.85D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
191	8	231	0.85D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
192	8	231	0.85D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
193	8	231	0.85D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00
194	8	231	0.85D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
195	8	231	0.85D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
196	8	231	0.85D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
197	8	231	0.85D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
198	8	231	0.85D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
199	8	231	0.90D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
200	8	231	0.90D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
201	8	231	0.90D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
202	8	231	0.90D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
203	8	231	0.90D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
204	8	231	0.90D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (continued)

4

205	8	231	0.90D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
206	8	231	0.90D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
207	8	231	0.90D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
208	8	231	0.90D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00
209	8	231	0.90D+03	0.00D+00	0.72D+02	0.00D+00	0.50D+02	0.00D+00
210	8	231	0.95D+03	0.00D+00	0.00D+00	0.00D+00	0.50D+02	0.00D+00
211	8	231	0.95D+03	0.00D+00	0.15D+02	0.00D+00	0.50D+02	0.00D+00
212	8	231	0.95D+03	0.00D+00	0.30D+02	0.00D+00	0.50D+02	0.00D+00
213	8	231	0.95D+03	0.00D+00	0.35D+02	0.00D+00	0.50D+02	0.00D+00
214	8	231	0.95D+03	0.00D+00	0.40D+02	0.00D+00	0.50D+02	0.00D+00
215	8	231	0.95D+03	0.00D+00	0.45D+02	0.00D+00	0.50D+02	0.00D+00
216	8	231	0.95D+03	0.00D+00	0.50D+02	0.00D+00	0.50D+02	0.00D+00
217	8	231	0.95D+03	0.00D+00	0.55D+02	0.00D+00	0.50D+02	0.00D+00
218	8	231	0.95D+03	0.00D+00	0.60D+02	0.00D+00	0.50D+02	0.00D+00
219	8	231	0.95D+03	0.00D+00	0.66D+02	0.00D+00	0.50D+02	0.00D+00

```
 220   8  231      0.95D+03  0.00D+00  0.72D+02  0.00D+00  0.50D+02  0.00D+00
 221   8  231      0.10D+04  0.00D+00  0.00D+00  0.00D+00  0.50D+02  0.00D+00
 222   8  231      0.10D+04  0.00D+00  0.15D+02  0.00D+00  0.50D+02  0.00D+00
 223   8  231      0.10D+04  0.00D+00  0.30D+02  0.00D+00  0.50D+02  0.00D+00
 224   8  231      0.10D+04  0.00D+00  0.35D+02  0.00D+00  0.50D+02  0.00D+00
 225   8  231      0.10D+04  0.00D+00  0.40D+02  0.00D+00  0.50D+02  0.00D+00
 226   8  231      0.10D+04  0.00D+00  0.45D+02  0.00D+00  0.50D+02  0.00D+00
 227   8  231      0.10D+04  0.00D+00  0.50D+02  0.00D+00  0.50D+02  0.00D+00
 228   8  231      0.10D+04  0.00D+00  0.55D+02  0.00D+00  0.50D+02  0.00D+00
 229   8  231      0.10D+04  0.00D+00  0.60D+02  0.00D+00  0.50D+02  0.00D+00
 230   8  231      0.10D+04  0.00D+00  0.66D+02  0.00D+00  0.50D+02  0.00D+00
 231   8  231      0.10D+04  0.00D+00  0.72D+02  0.00D+00  0.50D+02  0.00D+00
   0    0    0        0.0       0.0       0.0       0.0       0.0      0.0
C ******* DATA SET 8:  SUBREGIONAL DATA
   9
   1    8    1  231    0
   0    0    0    0    0    END OF NNPLR(9)
   1  230    1    1    1
   0    0    0    0    0    END OF GNLR(I,1)
   1  230    1  232    1
   0    0    0    0    0    END OF GNLR(I,2)
   1  230    1  463    1
   0    0    0    0    0    END OF GNLR(I,3)
   1  230    1  694    1
   0    0    0    0    0    END OF GNLR(I,4)
   1  230    1  925    1
   0    0    0    0    0    END OF GNLR(I,5)
   1  230    1 1156    1
   0    0    0    0    0    END OF GNLR(I,6)
```

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (continued)

4

```
   1  230    1 1387    1
   0    0    0    0    0    END OF GNLR(I,7)
   1  230    1 1618    1
   0    0    0    0    0    END OF GNLR(I,8)
   1  230    1 1849    1
   0    0    0    0    0    END OF GNLR(I,9)
C ******** DATA SET 10:  ELEMENT INCIDENCES
   1    9    1    1   12  243  232    2   13  244  233    1
  11    9    1   12   23  254  243   13   24  255  244    1
  21    9    1   23   34  265  254   24   35  266  255    1
```

31	9	1	34	45	276	265	35	46	277	266	1
41	9	1	45	56	287	276	46	57	288	277	1
51	9	1	56	67	298	287	57	68	299	288	1
61	9	1	67	78	309	298	68	79	310	299	1
71	9	1	78	89	320	309	79	90	321	310	1
81	9	1	89	100	331	320	90	101	332	321	1
91	9	1	100	111	342	331	101	112	343	332	1
101	9	1	111	122	353	342	112	123	354	343	1
111	9	1	122	133	364	353	123	134	365	354	1
121	9	1	133	144	375	364	134	145	376	365	1
131	9	1	144	155	386	375	145	156	387	376	1
141	9	1	155	166	397	386	156	167	398	387	1
151	9	1	166	177	408	397	167	178	409	398	1
161	9	1	177	188	419	408	178	189	420	409	1
171	9	1	188	199	430	419	189	200	431	420	1
181	9	1	199	210	441	430	200	211	442	431	1
191	9	1	210	221	452	441	211	222	453	442	1
201	9	1	232	243	474	463	233	244	475	464	1
211	9	1	243	254	485	474	244	255	486	475	1
221	9	1	254	265	496	485	255	266	497	486	1
231	9	1	265	276	507	496	266	277	508	497	1
241	9	1	276	287	518	507	277	288	519	508	1
251	9	1	287	298	529	518	288	299	530	519	1
261	9	1	298	309	540	529	299	310	541	530	1
271	9	1	309	320	551	540	310	321	552	541	1
281	9	1	320	331	562	551	321	332	563	552	1
291	9	1	331	342	573	562	332	343	574	563	1
301	9	1	342	353	584	573	343	354	585	574	1
311	9	1	353	364	595	584	354	365	596	585	1
321	9	1	364	375	606	595	365	376	607	596	1
331	9	1	375	386	617	606	376	387	618	607	1
341	9	1	386	397	628	617	387	398	629	618	1
351	9	1	397	408	639	628	398	409	640	629	1
361	9	1	408	419	650	639	409	420	651	640	1

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (continued)

4

371	9	1	419	430	661	650	420	431	662	651	1
381	9	1	430	441	672	661	431	442	673	662	1
391	9	1	441	452	683	672	442	453	684	673	1
401	9	1	463	474	705	694	464	475	706	695	1
411	9	1	474	485	716	705	475	486	717	706	1

421	9	1	485	496	727	716	486	497	728	717	1
431	9	1	496	507	738	727	497	508	739	728	1
441	9	1	507	518	749	738	508	519	750	739	1
451	9	1	518	529	760	749	519	530	761	750	1
461	9	1	529	540	771	760	530	541	772	761	1
471	9	1	540	551	782	771	541	552	783	772	1
481	9	1	551	562	793	782	552	563	794	783	1
491	9	1	562	573	804	793	563	574	805	794	1
501	9	1	573	584	815	804	574	585	816	805	1
511	9	1	584	595	826	815	585	596	827	816	1
521	9	1	595	606	837	826	596	607	838	827	1
531	9	1	606	617	848	837	607	618	849	838	1
541	9	1	617	628	859	848	618	629	860	849	1
551	9	1	628	639	870	859	629	640	871	860	1
561	9	1	639	650	881	870	640	651	882	871	1
571	9	1	650	661	892	881	651	662	893	882	1
581	9	1	661	672	903	892	662	673	904	893	1
591	9	1	672	683	914	903	673	684	915	904	1
601	9	1	694	705	936	925	695	706	937	926	1
611	9	1	705	716	947	936	706	717	948	937	1
621	9	1	716	727	958	947	717	728	959	948	1
631	9	1	727	738	969	958	728	739	970	959	1
641	9	1	738	749	980	969	739	750	981	970	1
651	9	1	749	760	991	980	750	761	992	981	1
661	9	1	760	771	1002	991	761	772	1003	992	1
671	9	1	771	782	1013	1002	772	783	1014	1003	1
681	9	1	782	793	1024	1013	783	794	1025	1014	1
691	9	1	793	804	1035	1024	794	805	1036	1025	1
701	9	1	804	815	1046	1035	805	816	1047	1036	1
711	9	1	815	826	1057	1046	816	827	1058	1047	1
721	9	1	826	837	1068	1057	827	838	1069	1058	1
731	9	1	837	848	1079	1068	838	849	1080	1069	1
741	9	1	848	859	1090	1079	849	860	1091	1080	1
751	9	1	859	870	1101	1090	860	871	1102	1091	1
761	9	1	870	881	1112	1101	871	882	1113	1102	1
771	9	1	881	892	1123	1112	882	893	1124	1113	1
781	9	1	892	903	1134	1123	893	904	1135	1124	1
791	9	1	903	914	1145	1134	904	915	1146	1135	1
801	9	1	925	936	1167	1156	926	937	1168	1157	1

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (continued)

4

811	9	1	936	947	1178	1167	937	948	1179	1168	1
821	9	1	947	958	1189	1178	948	959	1190	1179	1
831	9	1	958	969	1200	1189	959	970	1201	1190	1
841	9	1	969	980	1211	1200	970	981	1212	1201	1
851	9	1	980	991	1222	1211	981	992	1223	1212	1
861	9	1	991	1002	1233	1222	992	1003	1234	1223	1
871	9	1	1002	1013	1244	1233	1003	1014	1245	1234	1
881	9	1	1013	1024	1255	1244	1014	1025	1256	1245	1
891	9	1	1024	1035	1266	1255	1025	1036	1267	1256	1
901	9	1	1035	1046	1277	1266	1036	1047	1278	1267	1
911	9	1	1046	1057	1288	1277	1047	1058	1289	1278	1
921	9	1	1057	1068	1299	1288	1058	1069	1300	1289	1
931	9	1	1068	1079	1310	1299	1069	1080	1311	1300	1
941	9	1	1079	1090	1321	1310	1080	1091	1322	1311	1
951	9	1	1090	1101	1332	1321	1091	1102	1333	1322	1
961	9	1	1101	1112	1343	1332	1102	1113	1344	1333	1
971	9	1	1112	1123	1354	1343	1113	1124	1355	1344	1
981	9	1	1123	1134	1365	1354	1124	1135	1366	1355	1
991	9	1	1134	1145	1376	1365	1135	1146	1377	1366	1
1001	9	1	1156	1167	1398	1387	1157	1168	1399	1388	1
1011	9	1	1167	1178	1409	1398	1168	1179	1410	1399	1
1021	9	1	1178	1189	1420	1409	1179	1190	1421	1410	1
1031	9	1	1189	1200	1431	1420	1190	1201	1432	1421	1
1041	9	1	1200	1211	1442	1431	1201	1212	1443	1432	1
1051	9	1	1211	1222	1453	1442	1212	1223	1454	1443	1
1061	9	1	1222	1233	1464	1453	1223	1234	1465	1454	1
1071	9	1	1233	1244	1475	1464	1234	1245	1476	1465	1
1081	9	1	1244	1255	1486	1475	1245	1256	1487	1476	1
1091	9	1	1255	1266	1497	1486	1256	1267	1498	1487	1
1101	9	1	1266	1277	1508	1497	1267	1278	1509	1498	1
1111	9	1	1277	1288	1519	1508	1278	1289	1520	1509	1
1121	9	1	1288	1299	1530	1519	1289	1300	1531	1520	1
1131	9	1	1299	1310	1541	1530	1300	1311	1542	1531	1
1141	9	1	1310	1321	1552	1541	1311	1322	1553	1542	1
1151	9	1	1321	1332	1563	1552	1322	1333	1564	1553	1
1161	9	1	1332	1343	1574	1563	1333	1344	1575	1564	1
1171	9	1	1343	1354	1585	1574	1344	1355	1586	1575	1
1181	9	1	1354	1365	1596	1585	1355	1366	1597	1586	1
1191	9	1	1365	1376	1607	1596	1366	1377	1608	1597	1
1201	9	1	1387	1398	1629	1618	1388	1399	1630	1619	1
1211	9	1	1398	1409	1640	1629	1399	1410	1641	1630	1
1221	9	1	1409	1420	1651	1640	1410	1421	1652	1641	1
1231	9	1	1420	1431	1662	1651	1421	1432	1663	1652	1

1241 9 1 1431 1442 1673 1662 1432 1443 1674 1663 1
TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (continued)
4

```
 1251    9    1 1442 1453 1684 1673 1443 1454 1685 1674    1
 1261    9    1 1453 1464 1695 1684 1454 1465 1696 1685    1
 1271    9    1 1464 1475 1706 1695 1465 1476 1707 1696    1
 1281    9    1 1475 1486 1717 1706 1476 1487 1718 1707    1
 1291    9    1 1486 1497 1728 1717 1487 1498 1729 1718    1
 1301    9    1 1497 1508 1739 1728 1498 1509 1740 1729    1
 1311    9    1 1508 1519 1750 1739 1509 1520 1751 1740    1
 1321    9    1 1519 1530 1761 1750 1520 1531 1762 1751    1
 1331    9    1 1530 1541 1772 1761 1531 1542 1773 1762    1
 1341    9    1 1541 1552 1783 1772 1542 1553 1784 1773    1
 1351    9    1 1552 1563 1794 1783 1553 1564 1795 1784    1
 1361    9    1 1563 1574 1805 1794 1564 1575 1806 1795    1
 1371    9    1 1574 1585 1816 1805 1575 1586 1817 1806    1
 1381    9    1 1585 1596 1827 1816 1586 1597 1828 1817    1
 1391    9    1 1596 1607 1838 1827 1597 1608 1839 1828    1
 1401    9    1 1618 1629 1860 1849 1619 1630 1861 1850    1
 1411    9    1 1629 1640 1871 1860 1630 1641 1872 1861    1
 1421    9    1 1640 1651 1882 1871 1641 1652 1883 1872    1
 1431    9    1 1651 1662 1893 1882 1652 1663 1894 1883    1
 1441    9    1 1662 1673 1904 1893 1663 1674 1905 1894    1
 1451    9    1 1673 1684 1915 1904 1674 1685 1916 1905    1
 1461    9    1 1684 1695 1926 1915 1685 1696 1927 1916    1
 1471    9    1 1695 1706 1937 1926 1696 1707 1938 1927    1
 1481    9    1 1706 1717 1948 1937 1707 1718 1949 1938    1
 1491    9    1 1717 1728 1959 1948 1718 1729 1960 1949    1
 1501    9    1 1728 1739 1970 1959 1729 1740 1971 1960    1
 1511    9    1 1739 1750 1981 1970 1740 1751 1982 1971    1
 1521    9    1 1750 1761 1992 1981 1751 1762 1993 1982    1
 1531    9    1 1761 1772 2003 1992 1762 1773 2004 1993    1
 1541    9    1 1772 1783 2014 2003 1773 1784 2015 2004    1
 1551    9    1 1783 1794 2025 2014 1784 1795 2026 2015    1
 1561    9    1 1794 1805 2036 2025 1795 1806 2037 2026    1
 1571    9    1 1805 1816 2047 2036 1806 1817 2048 2037    1
 1581    9    1 1816 1827 2058 2047 1817 1828 2059 2048    1
 1591    9    1 1827 1838 2069 2058 1828 1839 2070 2059    1
    0    0    0    0    0    0    0    0    0    0    0    0  END OF IE
C ******* DATA SET 11:  INITIAL CONDITIONS
    1    8  231       0.60D+02  0.00D+00       0.0
```

2	8	231	0.45D+02	0.00D+00	0.0
3	8	231	0.30D+02	0.00D+00	0.0
4	8	231	0.25D+02	0.00D+00	0.0
5	8	231	0.20D+02	0.00D+00	0.0
6	8	231	0.15D+02	0.00D+00	0.0
7	8	231	0.10D+02	0.00D+00	0.0

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (continued)

4

8	8	231	0.50D+01	0.00D+00	0.0
9	8	231	0.00D+00	0.00D+00	0.0
10	8	231	-0.60D+01	0.00D+00	0.0
11	8	231	-0.12D+02	0.00D+00	0.0
12	8	231	0.60D+02	0.00D+00	0.0
13	8	231	0.45D+02	0.00D+00	0.0
14	8	231	0.30D+02	0.00D+00	0.0
15	8	231	0.25D+02	0.00D+00	0.0
16	8	231	0.20D+02	0.00D+00	0.0
17	8	231	0.15D+02	0.00D+00	0.0
18	8	231	0.10D+02	0.00D+00	0.0
19	8	231	0.50D+01	0.00D+00	0.0
20	8	231	0.00D+00	0.00D+00	0.0
21	8	231	-0.60D+01	0.00D+00	0.0
22	8	231	-0.12D+02	0.00D+00	0.0
23	8	231	0.60D+02	0.00D+00	0.0
24	8	231	0.45D+02	0.00D+00	0.0
25	8	231	0.30D+02	0.00D+00	0.0
26	8	231	0.25D+02	0.00D+00	0.0
27	8	231	0.20D+02	0.00D+00	0.0
28	8	231	0.15D+02	0.00D+00	0.0
29	8	231	0.10D+02	0.00D+00	0.0
30	8	231	0.50D+01	0.00D+00	0.0
31	8	231	0.00D+00	0.00D+00	0.0
32	8	231	-0.60D+01	0.00D+00	0.0
33	8	231	-0.12D+02	0.00D+00	0.0
34	8	231	0.60D+02	0.00D+00	0.0
35	8	231	0.45D+02	0.00D+00	0.0
36	8	231	0.30D+02	0.00D+00	0.0
37	8	231	0.25D+02	0.00D+00	0.0
38	8	231	0.20D+02	0.00D+00	0.0
39	8	231	0.15D+02	0.00D+00	0.0
40	8	231	0.10D+02	0.00D+00	0.0

41	8	231	0.50D+01	0.00D+00	0.0
42	8	231	0.00D+00	0.00D+00	0.0
43	8	231	-0.60D+01	0.00D+00	0.0
44	8	231	-0.12D+02	0.00D+00	0.0
45	8	231	0.60D+02	0.00D+00	0.0
46	8	231	0.45D+02	0.00D+00	0.0
47	8	231	0.30D+02	0.00D+00	0.0
48	8	231	0.25D+02	0.00D+00	0.0
49	8	231	0.20D+02	0.00D+00	0.0
50	8	231	0.15D+02	0.00D+00	0.0
51	8	231	0.10D+02	0.00D+00	0.0

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (continued)

4

52	8	231	0.50D+01	0.00D+00	0.0
53	8	231	0.00D+00	0.00D+00	0.0
54	8	231	-0.60D+01	0.00D+00	0.0
55	8	231	-0.12D+02	0.00D+00	0.0
56	8	231	0.60D+02	0.00D+00	0.0
57	8	231	0.45D+02	0.00D+00	0.0
58	8	231	0.30D+02	0.00D+00	0.0
59	8	231	0.25D+02	0.00D+00	0.0
60	8	231	0.20D+02	0.00D+00	0.0
61	8	231	0.15D+02	0.00D+00	0.0
62	8	231	0.10D+02	0.00D+00	0.0
63	8	231	0.50D+01	0.00D+00	0.0
64	8	231	0.00D+00	0.00D+00	0.0
65	8	231	-0.60D+01	0.00D+00	0.0
66	8	231	-0.12D+02	0.00D+00	0.0
67	8	231	0.60D+02	0.00D+00	0.0
68	8	231	0.45D+02	0.00D+00	0.0
69	8	231	0.30D+02	0.00D+00	0.0
70	8	231	0.25D+02	0.00D+00	0.0
71	8	231	0.20D+02	0.00D+00	0.0
72	8	231	0.15D+02	0.00D+00	0.0
73	8	231	0.10D+02	0.00D+00	0.0
74	8	231	0.50D+01	0.00D+00	0.0
75	8	231	0.00D+00	0.00D+00	0.0
76	8	231	-0.60D+01	0.00D+00	0.0
77	8	231	-0.12D+02	0.00D+00	0.0
78	8	231	0.60D+02	0.00D+00	0.0
79	8	231	0.45D+02	0.00D+00	0.0

80	8	231	0.30D+02	0.00D+00	0.0
81	8	231	0.25D+02	0.00D+00	0.0
82	8	231	0.20D+02	0.00D+00	0.0
83	8	231	0.15D+02	0.00D+00	0.0
84	8	231	0.10D+02	0.00D+00	0.0
85	8	231	0.50D+01	0.00D+00	0.0
86	8	231	0.00D+00	0.00D+00	0.0
87	8	231	-0.60D+01	0.00D+00	0.0
88	8	231	-0.12D+02	0.00D+00	0.0
89	8	231	0.60D+02	0.00D+00	0.0
90	8	231	0.45D+02	0.00D+00	0.0
91	8	231	0.30D+02	0.00D+00	0.0
92	8	231	0.25D+02	0.00D+00	0.0
93	8	231	0.20D+02	0.00D+00	0.0
94	8	231	0.15D+02	0.00D+00	0.0
95	8	231	0.10D+02	0.00D+00	0.0

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (continued)

4

96	8	231	0.50D+01	0.00D+00	0.0
97	8	231	0.00D+00	0.00D+00	0.0
98	8	231	-0.60D+01	0.00D+00	0.0
99	8	231	-0.12D+02	0.00D+00	0.0
100	8	231	0.60D+02	0.00D+00	0.0
101	8	231	0.45D+02	0.00D+00	0.0
102	8	231	0.30D+02	0.00D+00	0.0
103	8	231	0.25D+02	0.00D+00	0.0
104	8	231	0.20D+02	0.00D+00	0.0
105	8	231	0.15D+02	0.00D+00	0.0
106	8	231	0.10D+02	0.00D+00	0.0
107	8	231	0.50D+01	0.00D+00	0.0
108	8	231	0.00D+00	0.00D+00	0.0
109	8	231	-0.60D+01	0.00D+00	0.0
110	8	231	-0.12D+02	0.00D+00	0.0
111	8	231	0.60D+02	0.00D+00	0.0
112	8	231	0.45D+02	0.00D+00	0.0
113	8	231	0.30D+02	0.00D+00	0.0
114	8	231	0.25D+02	0.00D+00	0.0
115	8	231	0.20D+02	0.00D+00	0.0
116	8	231	0.15D+02	0.00D+00	0.0
117	8	231	0.10D+02	0.00D+00	0.0
118	8	231	0.50D+01	0.00D+00	0.0

119	8	231	0.00D+00	0.00D+00	0.0
120	8	231	-0.60D+01	0.00D+00	0.0
121	8	231	-0.12D+02	0.00D+00	0.0
122	8	231	0.60D+02	0.00D+00	0.0
123	8	231	0.45D+02	0.00D+00	0.0
124	8	231	0.30D+02	0.00D+00	0.0
125	8	231	0.25D+02	0.00D+00	0.0
126	8	231	0.20D+02	0.00D+00	0.0
127	8	231	0.15D+02	0.00D+00	0.0
128	8	231	0.10D+02	0.00D+00	0.0
129	8	231	0.50D+01	0.00D+00	0.0
130	8	231	0.00D+00	0.00D+00	0.0
131	8	231	-0.60D+01	0.00D+00	0.0
132	8	231	-0.12D+02	0.00D+00	0.0
133	8	231	0.60D+02	0.00D+00	0.0
134	8	231	0.45D+02	0.00D+00	0.0
135	8	231	0.30D+02	0.00D+00	0.0
136	8	231	0.25D+02	0.00D+00	0.0
137	8	231	0.20D+02	0.00D+00	0.0
138	8	231	0.15D+02	0.00D+00	0.0
139	8	231	0.10D+02	0.00D+00	0.0

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (continued)

4

140	8	231	0.50D+01	0.00D+00	0.0
141	8	231	0.00D+00	0.00D+00	0.0
142	8	231	-0.60D+01	0.00D+00	0.0
143	8	231	-0.12D+02	0.00D+00	0.0
144	8	231	0.60D+02	0.00D+00	0.0
145	8	231	0.45D+02	0.00D+00	0.0
146	8	231	0.30D+02	0.00D+00	0.0
147	8	231	0.25D+02	0.00D+00	0.0
148	8	231	0.20D+02	0.00D+00	0.0
149	8	231	0.15D+02	0.00D+00	0.0
150	8	231	0.10D+02	0.00D+00	0.0
151	8	231	0.50D+01	0.00D+00	0.0
152	8	231	0.00D+00	0.00D+00	0.0
153	8	231	-0.60D+01	0.00D+00	0.0
154	8	231	-0.12D+02	0.00D+00	0.0
155	8	231	0.60D+02	0.00D+00	0.0
156	8	231	0.45D+02	0.00D+00	0.0
157	8	231	0.30D+02	0.00D+00	0.0

158	8	231	0.25D+02	0.00D+00	0.0
159	8	231	0.20D+02	0.00D+00	0.0
160	8	231	0.15D+02	0.00D+00	0.0
161	8	231	0.10D+02	0.00D+00	0.0
162	8	231	0.50D+01	0.00D+00	0.0
163	8	231	0.00D+00	0.00D+00	0.0
164	8	231	-0.60D+01	0.00D+00	0.0
165	8	231	-0.12D+02	0.00D+00	0.0
166	8	231	0.60D+02	0.00D+00	0.0
167	8	231	0.45D+02	0.00D+00	0.0
168	8	231	0.30D+02	0.00D+00	0.0
169	8	231	0.25D+02	0.00D+00	0.0
170	8	231	0.20D+02	0.00D+00	0.0
171	8	231	0.15D+02	0.00D+00	0.0
172	8	231	0.10D+02	0.00D+00	0.0
173	8	231	0.50D+01	0.00D+00	0.0
174	8	231	0.00D+00	0.00D+00	0.0
175	8	231	-0.60D+01	0.00D+00	0.0
176	8	231	-0.12D+02	0.00D+00	0.0
177	8	231	0.60D+02	0.00D+00	0.0
178	8	231	0.45D+02	0.00D+00	0.0
179	8	231	0.30D+02	0.00D+00	0.0
180	8	231	0.25D+02	0.00D+00	0.0
181	8	231	0.20D+02	0.00D+00	0.0
182	8	231	0.15D+02	0.00D+00	0.0
183	8	231	0.10D+02	0.00D+00	0.0

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (continued)

4

184	8	231	0.50D+01	0.00D+00	0.0
185	8	231	0.00D+00	0.00D+00	0.0
186	8	231	-0.60D+01	0.00D+00	0.0
187	8	231	-0.12D+02	0.00D+00	0.0
188	8	231	0.60D+02	0.00D+00	0.0
189	8	231	0.45D+02	0.00D+00	0.0
190	8	231	0.30D+02	0.00D+00	0.0
191	8	231	0.25D+02	0.00D+00	0.0
192	8	231	0.20D+02	0.00D+00	0.0
193	8	231	0.15D+02	0.00D+00	0.0
194	8	231	0.10D+02	0.00D+00	0.0
195	8	231	0.50D+01	0.00D+00	0.0
196	8	231	0.00D+00	0.00D+00	0.0

```
 197    8  231      -0.60D+01  0.00D+00       0.0
 198    8  231      -0.12D+02  0.00D+00       0.0
 199    8  231       0.60D+02  0.00D+00       0.0
 200    8  231       0.45D+02  0.00D+00       0.0
 201    8  231       0.30D+02  0.00D+00       0.0
 202    8  231       0.25D+02  0.00D+00       0.0
 203    8  231       0.20D+02  0.00D+00       0.0
 204    8  231       0.15D+02  0.00D+00       0.0
 205    8  231       0.10D+02  0.00D+00       0.0
 206    8  231       0.50D+01  0.00D+00       0.0
 207    8  231       0.00D+00  0.00D+00       0.0
 208    8  231      -0.60D+01  0.00D+00       0.0
 209    8  231      -0.12D+02  0.00D+00       0.0
 210    8  231       0.60D+02  0.00D+00       0.0
 211    8  231       0.45D+02  0.00D+00       0.0
 212    8  231       0.30D+02  0.00D+00       0.0
 213    8  231       0.25D+02  0.00D+00       0.0
 214    8  231       0.20D+02  0.00D+00       0.0
 215    8  231       0.15D+02  0.00D+00       0.0
 216    8  231       0.10D+02  0.00D+00       0.0
 217    8  231       0.50D+01  0.00D+00       0.0
 218    8  231       0.00D+00  0.00D+00       0.0
 219    8  231      -0.60D+01  0.00D+00       0.0
 220    8  231      -0.12D+02  0.00D+00       0.0
 221    8  231       0.60D+02  0.00D+00       0.0
 222    8  231       0.45D+02  0.00D+00       0.0
 223    8  231       0.30D+02  0.00D+00       0.0
 224    8  231       0.25D+02  0.00D+00       0.0
 225    8  231       0.20D+02  0.00D+00       0.0
 226    8  231       0.15D+02  0.00D+00       0.0
 227    8  231       0.10D+02  0.00D+00       0.0
```

TABLE 6-3. INPUT DATA SET FOR THE THREE-DIMENSIONAL 3DFEMWATER PROBLEM (concluded)

4

```
 228    8  231       0.50D+01  0.00D+00       0.0
 229    8  231       0.00D+00  0.00D+00       0.0
 230    8  231      -0.60D+01  0.00D+00       0.0
 231    8  231      -0.12D+02  0.00D+00       0.0
   0    0    0          0.0        0.0        0.0      END OF IC
C ******* DATA SET 12:  SOURCE/SINK AND B. C. CONTROL INTEGERS
   0    0    0    0    0    0    0    0  165    2    2    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
```

```
C ******* DATA SET 15:  DIRICHLET BOUNDARY CONDITIONS
    0.0D0    60.0D0    1.0D38    60.0D0
    0.0D0    30.0D0    1.0D38    30.0D0
   1    2    3    4    5    6    7    8    9  232  233  234  235  236  237  238
 239  240  463  464  465  466  467  468  469  470  471  694  695  696  697  698
 699  700  701  702  925  926  927  928  929  930  931  932  933 1156 1157 1158
1159 1160 1161 1162 1163 1164 1387 1388 1389 1390 1391 1392 1393 1394 1395 1618
1619 1620 1621 1622 1623 1624 1625 1626 1849 1850 1851 1852 1853 1854 1855 1856
1857  221  222  223  224  225  226  227  228  229  452  453  454  455  456  457
 458  459  460  683  684  685  686  687  688  689  690  691  914  915  916  917
 918  919  920  921  922 1145 1146 1147 1148 1149 1150 1151 1152 1153 1376 1377
1378 1379 1380 1381 1382 1383 1384 1607 1608 1609 1610 1611 1612 1613 1614 1615
1838 1839 1840 1841 1842 1843 1844 1845 1846 2069 2070 2071 2072 2073 2074 2075
2076 2077  111  112  113
   1  161    1    1    0
 163    2    1    2    0
   0    0    0    0    0    END OF IDTYP
   0          END OF JOB   -------------------------------------------------000
```

4

6.2 3DLEWASTE

To demonstrate the application of 3DLEWASTE, two simple example problems are presented. For each problem, a brief description and a correctly-constructed input data set are given. The corresponding output is not included in this documentation. Rather, it is distributed along with the code by the EPA Center for Exposure Assessment Modeling (CEAM) at the Environmental Research Laboratory in Athens, Georgia. See Section 2 for information about obtaining the code.

6.2.1 One-Dimensional Transport Problem

Transient one-dimensional transport through a horizontal column is simulated in this example (Figure 6.4). The dimensions of the column are identical to those of the column in Figure 6.1. It has a length of 200 cm and a 50 cm x 50 cm cross-section. Initially, the concentration is 0.0 g/cm^3 throughout the region of interest. The concentration at x = 0.0 cm is maintained at C = C_o = 1.0 g/cm^3 (a Dirichlet boundary). A variable boundary condition is used to specify the natural condition of zero gradient flux at x = 200.0 cm. A bulk density of 1.2 g/cm^3 and a longitudinal dispersivity of 5.0 cm are assumed. No adsorption or decay is allowed. A specific discharge (Darcy velocity) of 2.0 cm/d is assumed and a moisture content of 0.4 is used.

The region of interest, that is, the whole column, is discretized with 1 x 1 x 40 = 40 elements with the element size equal to 50 x 50 x 5 cm. This results in 2 x 2 x 41 = 164 node points. For this simulation, each of the four vertical lines is considered a subregion. Thus, a total of four subregions, each with 41 node points, is used for the subregional block iteration simulation. A constant time-step size of 0.5 is used and a 40 time-step simulation is run. For this discretization, the mesh Peclet number is P_e = 1 and the Courant number is C_r = 0.5.

The input data set for this problem, prepared according to the instructions in Sections 4.2 and 5.2, is shown in Table 6-4.

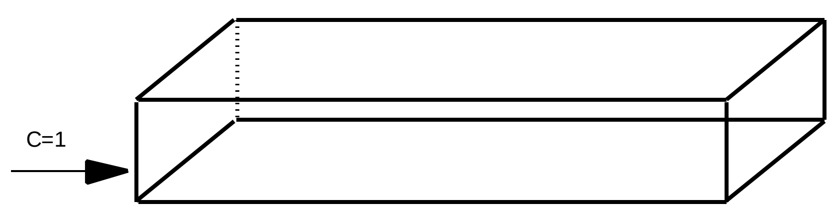


Figure 6.4. One-dimensional transient transport through a horizontal column.

TABLE 6-4. INPUT DATA SET FOR THE ONE-DIMENSIONAL 3DLEWASTE PROBLEM

4

```
   1  ONE-D FIRST TYPE BOUNDARY VALUE PROBLEM WITH 3DLEWASTE
L=CM,T=DAY,M=G 00
C ******* DATA SET 2:  BASIC INTEGER PARAMETERS ********************************
 164 40 1 0 40 1 8  -1  1  0  1  1  1  100  1
C ******* DATA SET 3:  BASIC REAL PARAMETERS ***********************************
  0.50D0 0.0D0 1.0D0 20.0D0 1.0D00 1.0D0 1.0D-3 1.0D-4
C ******* DATA SET 4:  PRINTER, STORAGE AND TIME RESETTING CONTROL *************
5500000000500000000050000000005000000000005
1100000000100000000010000000001000000000001
   1.0D38
C ******* DATA SET 5:  MATERIAL PROPERTIES *************************************
  0.0D0 1.2D0 5.0D0 0.0D0 0.0D0 1.0D0 0.0D0 0.0D0
C ******* DATA SET 6:  NODE COORDINATES ****************************************
  1 40  1  0.0D0 50.0D0 0.0D0 0.0D0 0.0D0 5.0D0
 42 40  1  0.0D0 0.0D0  0.0D0 0.0D0 0.0D0 5.0D0
 83 40  1  50.0D0 0.0D0 0.0D0 0.0D0 0.0D0 5.0D0
124 40  1  50.0D0 50.0D0 0.0D0 0.0D0 0.0D0 5.0D0
  0 0 0    0.0    0.0     0.0   0.0  0.0  0.0     END OF COORDINATES
C ******* DATA SET 7:  ELEMENT CONNECTIVITY ************************************
  1 39  1 42 83 124  1 43 84 125 2  1
  0 0  0   0   0  0   0   0   0   0 0  0      END OF IE
C ******* DATA SET 8:  SUBREGIONAL DATA ****************************************
   4
  1  3  1  41  0
  0 0 0 0 0                          END OF NNPLR(K)
  1 40  1  1  1
  0 0 0 0 0                          END OF GNLR(I,1)
  1 40  1 42  1
  0 0 0 0 0                          END OF GNLR(I,2)
  1 40  1 83 1
 0 0 0 0 0                           END OF GNLR(I,3)
   1   40    1  124    1
 0 0 0 0 0                           END OF GNLR(I,4)
C ******* DATA SET 10:  INITIAL CONDITIONS *************************************
   1    3   41        1.0D0     0.0D0  0.0
   2   38    1        0.0D0     0.0D0  0.0
  43   38    1         0.0D0     0.0D0  0.0
  84   38    1         0.0D0     0.0D0  0.0
 125   38    1          0.0D0     0.0D0  0.0
  41    3   41         0.0D0     0.0D0  0.0
```

```
   0 0 0 0.0 0.0 0.0                              END OF IC
C ******* DATA SET 11:  SOURCE/SINK AND B. C. CONTROL INTEGERS *****************
 0 0 0 0  0 0 0 0  4 1 2 0
 1 4 1 2 0  0 0 0 0 0  0 0 0 0 0
```

TABLE 6-4. INPUT DATA SET FOR THE ONE-DIMENSIONAL 3DLEWASTE PROBLEM (concluded)

4

```
C ******* DATA SET 13:  VARIABLE BOUNDARY CONDITIONS ***************************
  0.0D0 0.0D0  1.0D38 0.0D0
    1    0    0    1    0
    0    0    0    0    0                    END OF IRTYP
    1  0  0  82 123 164 41 0 0 0 0
    0  0  0   0   0   0  0 0 0 0 0            END OF ISV(J,I) J=1,4
    1    3    1   41   41
    0    0    0    0    0                    END OF NPVB
C ******* DATA SET 14:  DIRICHLET BOUNDARY CONDITIONS **************************
     0.0D0     1.0D0    1.0D38     1.0D0
    1   42   83  124
    1    3    1    1    0
    0    0    0    0    0                    END OF IDTYP
C ******* DATA SET 16:  HYDROLOGICAL BOUNDARY CONDITIONS ***********************
 1 163 1  0.0D0 0.0D0 2.0D0 0.0D0 0.0D0 0.0D0
 0   0 0    0.0   0.0   0.0   0.0   0.0   0.0  END OF VELOCITY
    1   39    1 0.4D0 0.0
    0    0    0    0.0      0.0               END OF TH
    0 **************** END OF JOB ********************************************00
```

4

6.2.2 Two-Dimensional Transport in a Rectangular Region

This is a two-dimensional transport problem in a rectangular region 600.0 cm long, 270.0 cm high, and 1.0 cm thick (Figure 6.5). Initially, the concentration is zero g/cm^3 throughout the region of interest. A concentration of 1.0 g/cm^3 is maintained at x = 0.0 cm and 180.0 cm < y < 270.0 cm by applying a Dirichlet boundary condition. A concentration of 0.0 g/cm^3 is maintained at x = 0.0 cm and 0.0 cm < y < 90.0 cm and 180.0 cm < y < 270.0 cm. A natural condition is imposed at x = 600 cm using a variable boundary condition (Equation 3-39b). A single material with a bulk density of 1.2 g/cm^3, a longitudinal dispersivity of 10.0 cm, and a lateral dispersivity of 1.0 cm modeled. No adsorption or decay is allowed. A specific discharge (Darcy velocity) of 2.0 cm/d is used and a moisture content of 0.2 is assumed.

The region is divided into 9 x 9 x 1 = 81 elements, resulting in 10 x 10 x 2 = 200 nodes. The element size is 60.0 cm x 30.0 cm x 1.0 cm. Each of the two vertical planes is considered a subregion. Thus, a total of two subregions, each with 100 nodal points, is used for the subregional block iteration simulation. A time-step size of 4.5 is used and 40 time steps are simulated.

The input data set for this problem, prepared according to the instructions in Sections 4.2 and 5.2, is shown in Table 6-5.

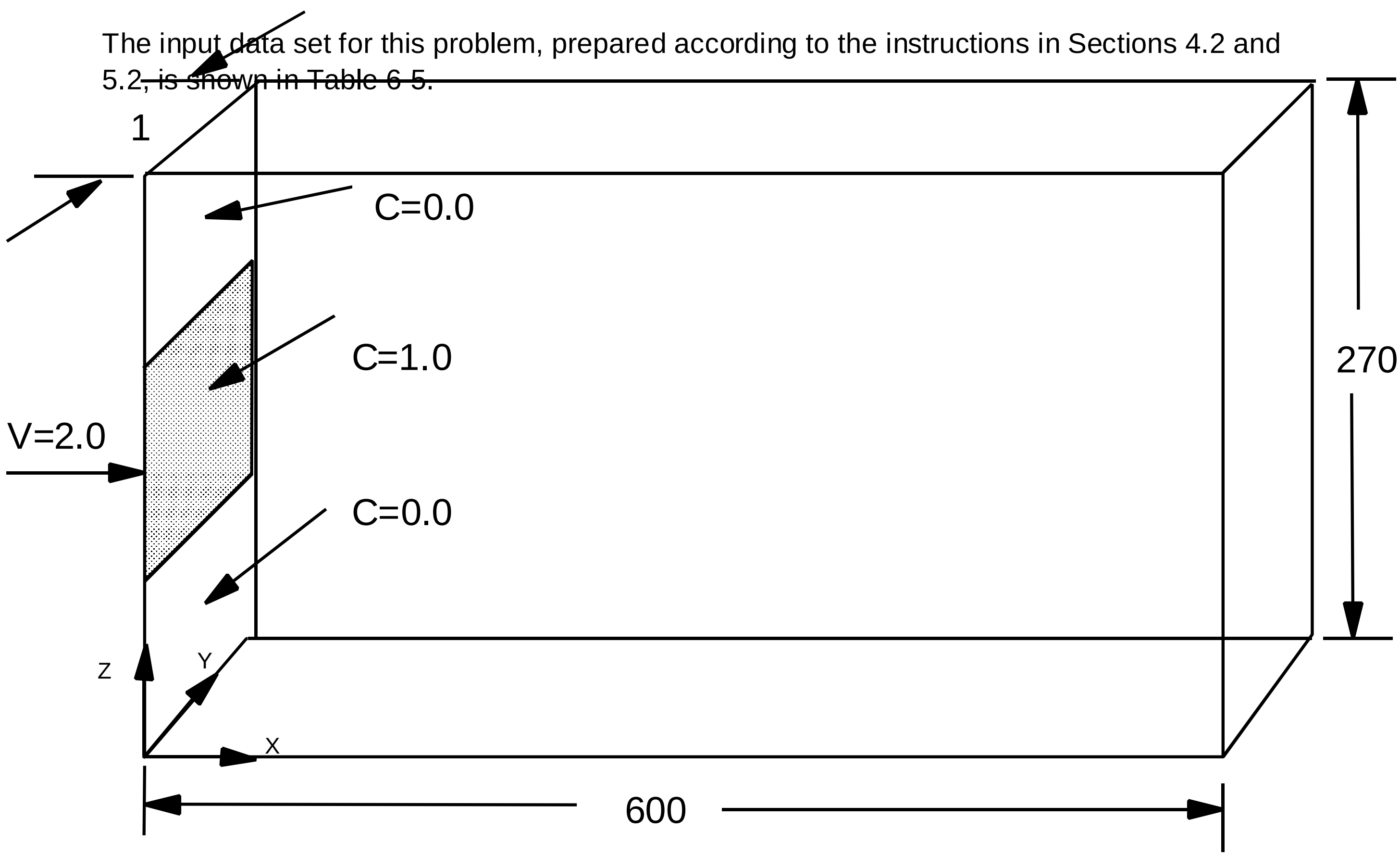


Figure 6.5. Two-dimensional transient transport in a rectangular region.

TABLE 6-5. INPUT DATA SET FOR THE TWO-DIMENSIONAL 3DLEWASTE PROBLEM

```
4

   1  TWO-D FIRST TYPE BOUNDARY VALUE PROBLEM WITH 3DLEWASTE
L=CM,T=DAY,M=G 00
C ******* DATA SET 2:  BASIC INTEGER PARAMETERS ********************************
 200 81 1 0 40 1 8  -1  1  0  1  1  1   200  1
C ******* DATA SET 3:  BASIC REAL PARAMETERS ***********************************
  0.45D1 0.0D0 9.0D0 3.60D2 1.0D00 1.78D0 1.0D-3 1.0D-4
C ******* DATA SET 4:  PRINTER, STORAGE AND TIME RESETTING CONTROL *************
5500000000500000000050000000005000000005
1100000000100000000010000000001000000001
   1.0D38
C ******* DATA SET 5:  MATERIAL PROPERTIES *************************************
  0.0D0 1.2D0 10.0D0 1.0D0 0.0D0 1.0D0 0.0D0 0.0D0
C ******* DATA SET 6:  NODE COORDINATES ****************************************
  1 9  10  0.0D0  0.0D0 0.0D0 6.0D1 0.0D0 0.0D0
  2 9  10  0.0D0  3.0D1 0.0D0 6.0D1 0.0D0 0.0D0
  3 9  10  0.0D0  6.0D1 0.0D0 6.0D1 0.0D0 0.0D0
  4 9  10  0.0D0  9.0D1 0.0D0 6.0D1 0.0D0 0.0D0
  5 9  10  0.0D0 12.0D1 0.0D0 6.0D1 0.0D0 0.0D0
  6 9  10  0.0D0 15.0D1 0.0D0 6.0D1 0.0D0 0.0D0
  7 9  10  0.0D0 18.0D1 0.0D0 6.0D1 0.0D0 0.0D0
  8 9  10  0.0D0 21.0D1 0.0D0 6.0D1 0.0D0 0.0D0
  9 9  10  0.0D0 24.0D1 0.0D0 6.0D1 0.0D0 0.0D0
 10 9  10  0.0D0 27.0D1 0.0D0 6.0D1 0.0D0 0.0D0
 101 9  10  0.0D0  0.0D0 1.0D0 6.0D1 0.0D0 0.0D0
 102 9  10  0.0D0  3.0D1 1.0D0 6.0D1 0.0D0 0.0D0
 103 9  10  0.0D0  6.0D1 1.0D0 6.0D1 0.0D0 0.0D0
 104 9  10  0.0D0  9.0D1 1.0D0 6.0D1 0.0D0 0.0D0
 105 9  10  0.0D0 12.0D1 1.0D0 6.0D1 0.0D0 0.0D0
 106 9  10  0.0D0 15.0D1 1.0D0 6.0D1 0.0D0 0.0D0
 107 9  10  0.0D0 18.0D1 1.0D0 6.0D1 0.0D0 0.0D0
 108 9  10  0.0D0 21.0D1 1.0D0 6.0D1 0.0D0 0.0D0
 109 9  10  0.0D0 24.0D1 1.0D0 6.0D1 0.0D0 0.0D0
 110 9  10  0.0D0 27.0D1 1.0D0 6.0D1 0.0D0 0.0D0
  0 0 0     0.0      0.0       0.0    0.0  0.0  0.0      END OF COORDINATES
C ******* DATA SET 7:  ELEMENT CONNECTIVITY ************************************
  1  8  1 1 11 12 2  101 111 112 102  1
```

```
 10 8  1 11 21 22 12  111 121 122 112  1
 19 8  1 21 31 32 22  121 131 132 122  1
 28 8  1 31 41 42 32  131 141 142 132  1
 37 8  1 41 51 52 42  141 151 152 142  1
 46 8  1 51 61 62 52  151 161 162 152  1
 55 8  1 61 71 72 62  161 171 172 162  1
 64 8  1 71 81 82 72  171 181 182 172  1
 73 8  1 81 91 92 82  181 191 192 182  1
 0 0  0   0   0  0   0   0   0   0 0  0       END OF IE
```

TABLE 6-5. INPUT DATA SET FOR THE TWO-DIMENSIONAL 3DLEWASTE PROBLEM (concluded)

```
4

C ******* DATA SET 8:  SUBREGIONAL DATA ****************************************
   2
 1  1  1  100 0
 0 0 0 0 0                           END OF NNPLR(K)
 1 99  1  1  1
 0 0 0 0 0                           END OF GNLR(I,1)
 1 99  1 101 1
 0 0 0 0 0                           END OF GNLR(I,2)
C ******* DATA SET 10:  INITIAL CONDITIONS *************************************
   1  199    1         0.0D0     0.0D0  0.0
   0 0 0 0.0 0.0 0.0                    END OF IC
C ******* DATA SET 11:  SOURCE/SINK AND B. C. CONTROL INTEGERS *****************
 0 0 0 0  0 0 0 0  8 1 2 0
 9 10 1 2 0  0 0 0 0 0  0 0 0 0 0
C ******* DATA SET 13:  VARIABLE BOUNDARY CONDITIONS ***************************
 0.0D0 0.0D0  1.0D38 0.0D0
   1    8    1    1    0
   0    0    0    0    0                   END OF IRTYP
   1  8  1  91 92 192 191 1 1 1 1
   0  0  0   0   0   0  0 0 0 0 0           END OF ISV(J,I) J=1,4
   1    9    1   91    1
   0    0    0    0    0                   END OF NPVB
C ******* DATA SET 14:  DIRICHLET BOUNDARY CONDITIONS **************************
    0.0D0     1.0D0    1.0D38     1.0D0
   4   5  6  7  104  105  106  107
   1    7    1    1    0
   0    0    0    0    0                   END OF IDTYP
C ******* DATA SET 16:  HYDROLOGICAL BOUNDARY CONDITIONS ***********************
 1 199 1  2.0D0 0.0D0 0.0D0 0.0D0 0.0D0 0.0D0
 0   0 0    0.0   0.0   0.0   0.0   0.0   0.0  END OF VELOCITY
```

```
1   80    1 0.2D0 0.0
0    0    0    0.0       0.0                  END OF TH
0 **************** END OF JOB *********************************************00
```

4

SECTION 7

REFERENCES

Bear, J. and A. Verruijt. 1987. Modeling Groundwater Flow and Pollution. D. Reidel Publishing Company, Dordrecht, Holland. 414 p.

Bresler, E. 1973. Simultaneous Transport of Solutes and Water Under Transient Unsaturated Flow Conditions. Water Resour. Res. 9(4):975-986.

Brooks, R.H. and A.T. Corey. 1966. Properties of Porous Media Affecting Fluid Flow. ASCE J. Irrig. Drain Div. 92 (IR2):61-68.

Carsel, R.F. and R.S. Parrish. 1988. Developing Joint Probability Distributions of Soil-Water Retention Characteristics. Water Resour. Res. 24(5):755-769.

CRC. 1965. Handbook of Chemistry and Physics, 46th Edition. CRC Press, Boca Raton, Florida.

CRC. 1981. Handbook of Chemistry and Physics, 62nd Edition. CRC Press, Boca Raton, Florida.

Davis, S.N., and J.M. DeWiest. 1966. Hydrogeology. John Wiley & Sons, Inc.

Dean, J.D., P.S. Huyakorn, A.S. Donigian, Jr., K.A. Voos, R.W. Schanz, and R.F. Carsel. 1989. Risk of Unsaturated/Saturated Transport and Transformation of Chemical Concentrations (RUSTIC). Volume II: User's Guide. U.S. Environmental Protection Agency, Athens, Georgia.
EPA/600/3-89-048b.

de Marsily, G. 1986. Quantitative Hydrogeology: Groundwater Hydrology for Engineers. Academic Press, San Diego, California. 440 p.

Electric Power Research Institute. 1985. A Review of Field Scale Physical Solute Transport Processes in Saturated and Unsaturated Porous Media. EPRI EA-4190, Project 2485-5, Palo Alto, California.

Federal Register. 1986. Hazardous Waste Management System: Land Disposal Restrictions. U.S. Environmental Protection Agency, Vol. 51, No. 9.

Freeze, R.A. and J.A. Cherry. 1979. Groundwater. Prentice-Hall, New Jersey. 604 pp.

Gelhar, L.W., C. Welty, and K.R. Rehfeldt. 1992. A Critical Review of Data on Field-Scale Dispersion in Aquifers. Water Resour. Res. 28(7):1956-1974.

Golder Associates. 1977. Development of Site Suitability Criteria for a High Level Waste Repository. Lawrence Livermore Laboratory, UCRL-13793.

Helfferich, F. 1962. Ion Exchange. McGraw-Hill, New York, New York.

Imhoff, J.C., R.F. Carsel, J.L. Kittle, Jr., and P.R. Hummel. 1990. Database Analyzer and Parameter Estimator, DBAPE (User's Manual). EPA/600/3-89/083. Environmental Research Laboratory, U.S Environmental Protection Agency, Athens, Georgia.

Karickhoff, S.W., D.S. Brown, and T.A. Scott. 1979. Sorption of Hydrophobic Pollutants on Natural Sediments. Water Research 13:241-248.

Keely, J.F. 1989. Performance Evaluations of Pump-and-Treat Remediations. EPA/540/4-89/005, U.S. Environmental Protection Agency, Ada, Oklahoma. 19 pp.

Lyman, W.J., W.F. Reehl, and D.H. Rosenblatt. 1982. Handbook of Chemical Property Estimation Methods: Environmental Behavior of Organic Compounds. McGraw-Hill, New York. 960 pp.

Mabey, W.R., J.H. Smith, R.T. Podoll, H.L. Johnson, T. Mill, T.W. Chou, J. Gates, I. Waight Partridge, J. Jaber, and D. Vandenberg. 1982. Aquatic Fate Process Data for Organic Priority Pollutants. EPA/440/4-81-014. Office of Water Regulations and Standards, U.S. Environmental Protection Agency, Washington, DC.

Meyer, C.A., R.B. McClintock, G.J. Silvestri, and R.C. Spencer. 1968. 1967 ASME SteamTables, 2nd Edition. The American Society of Mechanical Engineers, New York, New York.

Mercer, J.W., S.D. Thomas, and B. Ross. 1982. Parameters and Variables Appearing in Repository Siting Models. NUREG/CR-3066. U.S. Nuclear Regulatory Commission, Washington, D.C.

Mills, W.B., D.B. Porcella, M.J. Ungs, S.A. Gherini, K.V. Summers, L. Mok, G.L. Rupp, G.L. Bowie, and D.A. Haith. 1985a. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water: Part I. EPA/600/6-85/002a. U.S. Environmental Protection Agency, Athens, GA.

Mills, W.B., D.B. Porcella, M.J. Ungs, S.A. Gherini, K.V. Summers, L. Mok, G.L. Rupp, G.L. Bowie, and D.A. Haith. 1985b. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water: Part II. EPA/600/6-85/002b. U.S. Environmental Protection Agency, Athens, GA.

Morris, D.A., and A.I. Johnson. 1967. Summary of Hydrologic and Physical Properties of Rock and Soil Materials as Analyzed by the Hydrologic Laboratory of the U.S. Geological Survey. U.S. Geological Survey Water Supply Paper 1839-D, 1967.

Mualem, Y. 1976. A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media. Water Resour. Res. 12(3):513-522.

Mullins, J.A., R.F. Carsel, J.E. Scarbrough, and A.M. Ivery. 1992. PRZM-2 User's Manual, Version 1.0. Office of Research and Development, U.S. Environmental Protection Agency, Athens, GA.

Pinder, G.F., and W. G. Gray. 1977. Finite Element Simulation in Surface and Subsurface Hydrology, Academic Press, New York.

Sharp-Hansen, S., C. Travers, P. Hummel, and T. Allison. 1990. A Subtitle D Landfill Application Manual for the Multimedia Exposure Assessment Model (MULTIMED). Office of Research and Development, Environmental Protection Agency, Athens, GA.

U.S. Environmental Protection Agency. 1987. Guidelines for Delineating Wellhead Protection Areas. EPA No. 440/6-87-010. Office of Groundwater Protection, U.S. Environmental Protection Agency, Washington, DC. NTIS No. PB88-111430-AS.

U.S. Environmental Protection Agency. 1989. Transport and Fate of Contaminants in the Subsurface: Seminar Publication. EPA/625/4-89/019. Center for Environmental Research Education, U.S. Environmental Protection Agency, Cincinnati, OH.

van Genuchten, M.T. 1980. A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils. Soil Sci. Soc. J. 44:892-898.

APPENDIX A

PROGRAM STRUCTURE AND SUBROUTINE DESCRIPTIONS

A.1 3DFEMWATER

3DFEMWATER consists of a main program, FEMWAT3D, and 22 subroutines. Figure A.1 shows the structure of the program. The subroutines are listed in Table A-1 and the functions of these subroutines are briefly described below.

A.1.1 Subroutine ALLFCT

This subroutine is called by subroutine GW3D to compute values for all the source/sink and boundary nodes and elements. It uses linear interpolation of tabular data to simulate variations in time for these conditions.

A.1.2 Subroutine ASEMBL

This subroutine is called by subroutine GW3D. After calling subroutine Q8 to evaluate the element matrices, it sums over all element matrices to form a global matrix equation governing the pressure head at all nodes.

A.1.3 Subroutine BASE

This subroutine is called by subroutines Q8DV and Q8 to evaluate the value of the base function at a Gaussian point.

A.1.4 Subroutine BC

This subroutine, which is called by subroutine GW3D, incorporates Dirichlet, variable composite, specified-flux (Cauchy), and specified-pressure-head gradient (Neumann) boundary conditions. For a Dirichlet boundary condition, an identity algebraic equation is generated for each Dirichlet nodal point. Any other equation having this nodal variable is modified accordingly to simplify the computation. For a specified-flux surface, the integration of the surface source is obtained by calling subroutine Q4S and the result is added to the load vector. For a specified-pressure-head gradient surface, the integrations of both the gradient and gravity fluxes are obtained by calling the subroutine Q4S. These fluxes are added to the load vector. The subroutine BC also implements the variable composite boundary condition. First, it checks all infiltration-evapotranspiration-seepage points, identifying any of them that are Dirichlet

```
* FEMWAT3D *

     *                                SURF     *
     *                          *
                                *
* GW3D                 DATAIN             READR    *
                                *
     *                          *
     *                                    READN    *
     *                          *
     *                          *
     *                                    PAGEN    *
     *
     *
                       PRINTT   *
     *
     *
                       STORE    *
     *
     *
                       SPROP    *
     *
     *
                       SFLOW              Q8TH     *
     *                          *
     *                          *
     *
     *                                        *
     *
                       BCPREP             Q4S      *
     *
     *                                        *
                       BC
     *
     *
                       VELT               Q8DV                *
     *
     *
                       ALLFCT   *                           * BASE     *
     *
     *                                                            *
                       ASEMBL             Q8
     *
     *
                       BLKITR             SOLVE    *
```

Figure A.1. Program structure of 3DFEMWATER

TABLE A-1. SUBROUTINES INCLUDED IN 3DFEMWATER
4

Subroutine	Called By	Description
ALLFCT	GW3D	Interpolates functional values for source/sink and boundary conditions.
ASEMBL	GW3D	Evaluates the element matrices and then sums over all element matrices to form a global matrix equation governing the pressure head at all nodes.
BASE	Q8DV, Q8	Evaluates the value of the base function at a Gaussian point.
BC	GW3D	Incorporates Dirichlet, specified-flux (Cauchy), specified-pressure-head gradient (Neumann), and variable composite boundary conditions.
BCPREP	GW3D	Prepares the infiltration/seepage boundary conditions during a rainfall period or the seepage/evapotranspiration boundary conditions during non-rainfall periods.
BLKITR	GW3D	Solves the matrix equation with block iteration methods.
DATAIN	GW3D	Reads and prints all input information.
GW3D	FEMWAT3	Controls the entire sequence of operations. Performs either the steady- state computation alone, or a transient- state computation using the steady-state solution as the initial condition, or a transient computation using user-supplied initial conditions.
PAGEN	DATAIN	Preprocesses pointer arrays that are needed to store the global matrix in compressed form and to construct the subregional block matrices.

PRINTT	GW3D	Prints the flow variables, which include the fluxes through variable boundary surfaces, pressure head, total head, moisture content, and Darcy velocity components.

TABLE A-1. SUBROUTINES INCLUDED IN 3DFEMWATER (continued)
4

Subroutine	Called By	Description
Q4S	BCPREP, BC, SFLOW	Evaluates the boundary surface load vector over a SFLOW boundary segment.
Q8	ASEMBL	Computes the element matrices and element load vector.
Q8DV	VELT	Computes the integration of N(I)*N(J) and -N(I)*K@GRAD(HT) over an element.
Q8TH	SFLOW	Evaluates the integration of moisture content and sources/sinks over an element.
READN	DATAIN	Automatically generates integer input if required.
READR	DATAIN	Automatically generates real number input if required.
SFLOW	GW3D	Computes the fluxes through boundaries and the rate at which water content increases in the region of interest.
SOLVE	BLKITR	Solves a matrix equation with the direct band method.
SPROP	GW3D	Calculates the values of moisture content, relative hydraulic conductivity, and water capacity using van Genuchten analytical functions.
STORE	GW3D	Stores the solution in binary on logical unit LUSTO. Information stored includes regional geometry, subregion data, and hydrological variables such as pressure head, total head, moisture content, and the Darcy velocity components.
SURF	DATAIN	Identifies the boundary sides, sequences

the boundary nodes, and of the surface sides.

TABLE A-1. SUBROUTINES INCLUDED IN 3DFEMWATER (concluded)
4

Subroutine	Called By	Description
VELT	GW3D	Evaluates the element matrices and the derivatives of the total head, and then sums over all element matrices to form a matrix equation governing the velocity components at all nodal points.

points. If there are Dirichlet points, they are incorporated using the method described above. If a given point is not a Dirichlet point, the point is bypassed. Second, it checks all rainfall-evaporation-seepage points again to see if any of them is a specified-flux point. If it is, then the computed flux by infiltration or potential evapotranspiration is added to the load vector. If a given point is not a specified-flux point, it is bypassed. Because the infiltration-evaporation-seepage points are either Dirichlet or specified-flux points, all points are taken care of in this manner.

A.1.5 Subroutine BCPREP

This subroutine is called by GW3D to prepare the infiltration-seepage boundary conditions during a rainfall period or the seepage-evapotranspiration boundary conditions during non-rainfall periods. It decides the number of nodal points on the variable boundary to be considered as Dirichlet or specified-flux (Cauchy) points. It computes the number of points that change boundary conditions from 1) ponding depth (Dirichlet types) to infiltration (specified-flux types), or 2) infiltration to ponding depth, or 3) minimum pressure (Dirichlet types) to infiltration during rainfall periods. It also computes the number of points that change boundary conditions from potential evapotranspiration (specified-flux types) to minimum pressure, or from ponding depth to potential evapotranspiration, or from minimum pressure to potential evapotranspiration during non-rainfall periods. Upon completion, this subroutine returns the Darcy flux (DCYFLX), infiltration/potential evapotranspiration rate (FLX), the ponding depth nodal index (NPCON), the flux-type nodal index (NPFLX), the minimum pressure nodal index (NPMIN), and the number of nodal points (NCHG) that have changed boundary conditions.

A.1.6 Subroutine BLKITR

This subroutine is called by subroutine GW3D to solve the matrix equation with block iteration methods. For each subregion, a block matrix equation is constructed based on the global matrix equation and two pointer arrays, GNPLR and LNOJCN (see subroutine PAGEN), and the resulting block matrix equation is solved with the direct band matrix solver by calling subroutine SOLVE. This is done for all subregions for each iteration until a convergent solution is obtained.

A.1.7 Subroutine DATAIN

Subroutine DATAIN is called by subroutine GW3D. It reads all data input described in Section 4.1 except data set 1. It also calls subroutine SURF to identify the surface elements and boundary nodes, and subroutines READR and READN, respectively, to automatically generate real and integer numbers.

A.1.8 Subroutine GW3D

Subroutine GW3D controls the entire sequence of operations. It performs either a steady-state computation alone (KSS = 0 and NTI = 0), or a transient- state computation using the steady-state solution as the initial condition (KSS = 0, NTI > 0), or a transient computation using user-supplied initial conditions (KSS = 1, NTI > 0).

GW3D calls subroutine DATAIN to read and print input data; subroutine PAGEN to generate pointer arrays; subroutine ALLFCT to obtain source/sink and boundary values; subroutine SPROP to obtain the relative hydraulic conductivity, water capacity, and moisture content from the pressure head; subroutine VELT to compute Darcy velocity; subroutine BCPREP to determine if a change of boundary conditions is required; subroutine ASEMBL to assemble the element matrices over all elements; subroutine BC to implement the boundary conditions; subroutine BLKITR to form and solve the subregional block matrix equations; subroutine SFLOW to calculate flux through all types of boundaries and water accumulated in the media; subroutine PRINTT to print out the results; and subroutine STORE to store the flow variables for input to 3DLEWASTE or for plotting.

A.1.9 Subroutine PAGEN

This subroutine is called by subroutine DATAIN to preprocess pointer arrays that are needed to store the global matrix in compressed form and to construct the subregional block matrices. The pointer arrays automatically generated in this subroutine include the global node connectivity (stencil), GNOJCN(J,N), regional node connectivity, LNOJCN(J,I,K), total node number for each subregion, NTNPLR(K), the bandwidth indicator for each subregion, LMAXDF(K), and a partial fill-up for the mapping array between global node number and local subregion node number, GNPLR(I,K), with I = NNPLR(K) + 1 to NTNPLR(K). Here GNOJCN(J,N) is the global node number of the J-th node connected to the global node N; LNOJCN(J,I,K) is the local node number of the J-th node connected to the local node I in the K-th subregion; NTNPLR(K) is the total number of nodes in the K-th subregion, including the interior nodes, the global boundary nodes, and intra-boundary nodes; LMAXDF(K) is the maximum difference between any two nodes of any element in the K-th subregion; and GNPLR(I,K) is the global node number of the I-th local-region node in the K-th subregion. These pointer arrays are generated based on the element connectivity, IE(M,J), the number of nodes for each subregion, NNPLR(K), and the mapping between global node and local-region node, GNLR(I,K), with I = 1, NNPLR(K). Here IE(M,J) is the global node number of J-th node of element M; NNPLR(K) is the number of nodes in the K-th subregion, including the interior nodes and the global boundary nodes, but not the intraboundary nodes.

A.1.10 Subroutine PRINTT

This subroutine, which is called by GW3D, is used to line-print the flow variables. These include the fluxes through variable boundary surfaces, the pressure head, total head, moisture content, and Darcy velocity components.

A.1.11 <u>Subroutine Q4S</u>

This subroutine is called by subroutines BC, BCPREP, and SFLOW to compute the surface node flux of the type:

$$RQ(I) = \int_{B_e} N_i^e q \, dB \qquad \text{(A-1)}$$

where q is either the specified-flux, specified-pressure-head gradient flux, or gravity flux; B is the global boundary of the region of interest; N_i^e is the basis functions for nodal point i of element e; and RQ(I) is a 3DFEMWATER code parameter.

A.1.12 <u>Subroutine Q8</u>

This subroutine is called by the subroutine ASEMBL to compute the element matrix given by:

$$QA(I,J) = \int_{R_e} N_i^e F N_j^e \, dR \qquad \text{(A-2a)}$$

$$QB(I,J) = \int_{R_e} (\nabla N_i^e) \cdot \mathbf{K_s} k_r \cdot (\nabla N_j^e) \, dR \qquad \text{(A-2b)}$$

where

F	= soil property function
N_j^e	= basis function for nodal point j of element e
$\mathbf{K_s}$	= saturated hydraulic conductivity tensor
k_r	= relative hydraulic conductivity
R	= region of interest
∇	= del operator indicating gradient
$\nabla\cdot$	= del operator indicating divergence

and where QA(I,J) and QB(I,J) are 3DFEMWATER code parameters. Subroutine Q8 also calculates the element load vector given by:

$$RQ(I) = \int_{R_e} [(LN_i^e)\cdot\mathbf{K_s}k_r\cdot(Lz) - N_i^e q]dR \tag{A-2c}$$

where q is the source/sink.

A.1.13 Subroutine Q8DV

Subroutine Q8DV is called by subroutine VELT to compute the element matrices given by:

$$QR(I,J) = \int_{R_e} N_i^e N_j^e \, dR \tag{A-3a}$$

where QR(I,J) is a 3DFEMWATER program variable. Subroutine Q8DV also evaluates the element load vector:

$$QRX(I) = -\int_{R_e} N_i^e \mathbf{i} \cdot \mathbf{K_s} k_r \cdot (\nabla N_j^e) H_j \, dR \tag{A-3b}$$

$$QRY(I) = -\int_{R_e} N_i^e \mathbf{j} \cdot \mathbf{K_s} k_r \cdot (\nabla N_j^e) H_j \, dR \tag{A-3c}$$

$$QRZ(I) = -\int_{R_e} N_i^e \mathbf{k} \cdot \mathbf{K_s} k_r \cdot (\nabla N_j^e) H_j \, dR \tag{A-3d}$$

where

H_j	= total head at nodal point j
$\mathbf{i}$	= unit vector along the x-coordinate
$\mathbf{j}$	= unit vector along the y-coordinate
$\mathbf{k}$	= unit vector along the z-coordinate

and where QRX(I), QRY(I), and QRZ(I) are 3DFEMWATER program variables.

A.1.14 Subroutine Q8TH

This subroutine, which is called by subroutine SFLOW, is used to compute the contribution from an element to the change in water content over time, using the following equation:

$$QTHP = \int_{R_e} \frac{d\theta}{dh} \frac{\partial h}{\partial t} \, dR \tag{A-4}$$

where

h = pressure head

2 = moisture content

QTHP = 3DFEMWATER program variable

A.1.15 Subroutine READN

This subroutine is called by subroutine DATAIN to generate integer numbers for input data sets 8, 9, 12(c), 12(f), 14(b) through 14(d), 15(c), 16(b), 16(c), 17(b), and 17(c), which are described in Section 4.1.

A.1.16 Subroutine READR

This subroutine is called by subroutine DATAIN to generate real numbers input for data sets 7, 14(e), and 14(f) (see Section 4.1). Automatic generation of regularly patterned data is built into this subroutine.

A.1.17 Subroutine SFLOW

This subroutine is called by subroutine GW3D. It is used to compute the fluxes through various types of boundaries and the rate at which water content increases in the region of interest. In this subroutine, the function of variable FRATE(7) is to store the flux through the whole boundary enclosing the region of interest. It is given by:

$$\mathrm{FRATE}(7) = \int_B (V_x n_x + V_y n_y + V_z n_z)\, dB \tag{A-5}$$

where V_x, V_y, and V_z are Darcy velocity components, and n_x, n_y, and n_z are the directional cosines of the outward unit vector normal to the boundary B. FRATE(1) through FRATE(5) store the flux through the Dirichlet boundary, B_D, specified-flux boundary, B_C, specified-pressure-head boundary, B_N, the seepage/evapotranspiration boundary, B_S, and infiltration boundary, B_R, respectively, and are given by:

$$\mathrm{FRATE}(1) = \int_{B_d} (V_x n_x + V_y n_y + V_z n_z)\, dB \tag{A-6a}$$

$$\mathrm{FRATE}(2) = \int_{B_c} (V_x n_x + V_y n_y + V_z n_z)\, dB \tag{A-6b}$$

$$\mathrm{FRATE}(3) = \int_{B_n} (V_x n_x + V_y n_y + V_z n_z)\, dB \tag{A-6c}$$

$$FRATE(4) = \int_{B_s} (V_x n_x + V_y n_y + V_z n_z) dB \qquad \text{(A-6d)}$$

$$FRATE(5) = \int_{B_r} (V_x n_x + V_y n_y + V_z n_z) dB \qquad \text{(A-6e)}$$

FRATE(6), which is related to the numerical loss, is given by:

$$FRATE(6) = FRATE(7) - \sum_{I=1}^{5} FRATE(I) \qquad \text{(A-7)}$$

FRATE(8) and FRATE(9) are used to store the source/sink and increased rate of water accumulation within the media, respectively:

$$FRATE(8) = -\int_R q dR \qquad \text{(A-8)}$$

and

$$FRATE(9) = \int_R F \frac{\partial h}{\partial t} dR \qquad \text{(A-9)}$$

If there is no numerical error in the computation, the following equation should be satisfied:

$$FRATE(9) = -[FRATE(7) + FRATE(8)] \qquad \text{(A-10)}$$

and FRATE(6) should be equal to zero.

A.1.18 Subroutine SOLVE

This subroutine is called by the subroutine BLKITR to solve a matrix equation of the type:

$$[C]\{x\} = \{y\} \qquad \text{(A-11)}$$

where [C] is the coefficient matrix and {x} and {y} are two vectors. {x} is the unknown to be solved, and {y} is the known load vector. The computer returns the solution and stores it in {y}. The computation is a standard banded Gaussian direct elimination procedure.

A.1.19 Subroutine SPROP

This subroutine is called by subroutine GW3D. It calculates the values for moisture content, relative hydraulic conductivity, and water capacity, using the van Genuchten functional relationships (see Equations 3-3a through 3-3d).

A.1.20 Subroutine STORE

This subroutine, which is called by GW3D, is used to store the flow variables in a binary file. The stored data is intended for use in 3DLEWASTE or for plotting. The information stored includes region geometry, subregion data, and hydrological variables such as pressure head, total head, moisture content, and Darcy velocity components.

A.1.21 Subroutine SURF

Subroutine SURF is called by subroutine DATAIN. It identifies the boundary sides, sequences the boundary nodes, and computes the directional cosine of the surface sides. The mappings from boundary nodes to global nodes are stored in NPBB(I) (where NPBB(I) is the global node number of the I-th boundary node). The boundary node numbers of the four nodes for each boundary side are stored in ISB(I,J) (where ISB(I,J) is the boundary node number of I-th node of J-th side, I = 1 to 4). There are six sides for each element. Which of these six sides is the boundary side is determined automatically in the subroutine SURF and is stored in ISB(5,J). The global element number, to which the J-th boundary side belongs, is also preprocessed in the subroutine SURF and is stored in ISB(6,J). The directional cosines of the J-th boundary side are computed and stored in DCOSB(I,J) (where DCOSB(I,J) is the directional cosine of the J-th surface with I-th coordinate, I = 1 to 3). The information contained in NPBB, ISB, and DOSB, along with the number of boundary nodes and the number of boundary sides is returned to subroutine DATAIN for other uses.

A.1.22 Subroutine VELT

This subroutine is called by subroutine GW3D. It calls subroutine Q8DV to evaluate the element matrices and the derivatives of the total head. It then sums over all element matrices to form a matrix equation governing the velocity components at all nodal points. To save computational time, the matrix is diagonalized by lumping. The velocity components can thus be solved point by point. The computed velocity field is then returned to GW3D through the argument. This velocity field is also passed to subroutine BCPREP to evaluate the Darcy flux across the seepage-infiltration-evapotranspiration surfaces.

A.2 3DLEWASTE

LEWASTE consists of a main program, LEWAST3D, 30 subroutines, and a function. Figure A.2 shows the structure of the program. The subroutines and function are listed in Tables A-2 and A-3, respectively, and the purposes of the subroutines are briefly described below.

A.2.1 Subroutine ADVBC

This subroutine is called by GM3D to implement the boundary conditions. For a Dirichlet boundary, the Lagrangian concentration is specified. For variable boundaries, if the flow is directed out of the region, the fictitious particle associated with the boundary node must come from the interior nodes. Hence the Lagrangian concentration for the boundary node has already been computed from subroutine ADVTRN and the implementation for such a boundary segment is bypassed. For variable boundaries, if the flow is directed into the region, the concentration of incoming fluid is specified. The Lagrangian concentration is then calculate as:

$$C_i^* = \int_{B_v^-} N_i V_n C_{in} dB / \int_{B_v^-} N_i V_n dB \qquad \text{(A-12)}$$

where

C_i^*	= Lagrangian concentration at the boundary node i
V_n	= normal vertically integrated Darcy velocity
C_{in}	= concentration of incoming fluid
B	= global boundary of the region of interest
N_i^e	= basis function for nodal point i of element e

Specified-flux (Cauchy) boundary conditions are normally applied to the boundary where flow is directed into the region, where the material flux of incoming fluid is specified. The Lagrangian concentration is thus calculate as:

$$C_i^* = \int_{B_c} N_i q_c dB / \int_{B_c} N_i V_n dB \qquad \text{(A-13)}$$

where C_i^* is the Lagrangian concentration at the boundary node i and q_c is the Cauchy flux of the incoming fluid.

A.2.2 Subroution ADVTRN

This subroutine is called by GM3D to compute the Lagrangian concentrations at all nodes. It calls subroutine MPLOC to find which element a fictitious particle is located in. It also calls subroutine

XSI3D to compute the local coordinate, given the global coordinate, of the fictitious particle. If the fictitious particle associated with a particular node is located in the

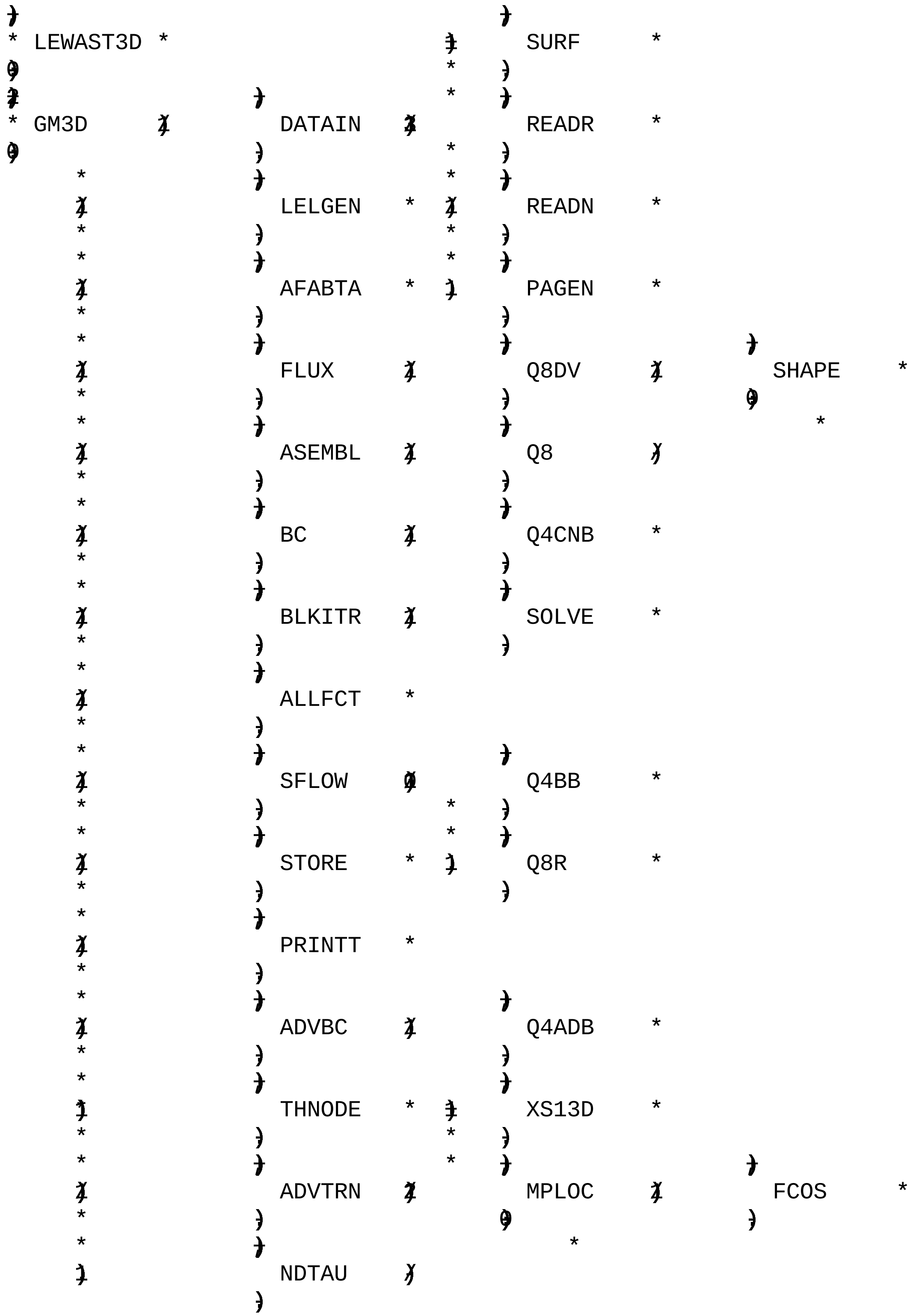


Figure A.2. Program structure of 3DLEWASTE

TABLE A-2. SUBROUTINES INCLUDED IN 3DLEWASTE

4

Subroutine	Called By	Description
ADVBC	GM3D	Applies specified-flux (Cauchy), variable, and Dirichlet boundary conditions.
ADVTRN	GM3D	Computes the Lagrangian concentrations at all nodes and finds in which element the fictitious particle is located.
AFABTA	GM3D	Calculates the values of the upstream weighting factors along the 12 sides of all elements.
ALLFCT	GM3D	Interpolates functional values for source/sinkand boundary conditions.
ASEMBL	GM3D	Evaluates the element matrices and then sums over all element matrices to form a global matrix equation governing the concentration distribution at all nodes.
BC	GM3D	Incorporates Dirichlet, variable composite, specified-flux (Cauchy), and specified-dispersive-flux (Neumann) boundary conditions.
BLKITR	GM3D	Solves the matrix equations with block iteration methods.
DATAIN	GM3D	Reads and prints system parameters, geometry, boundary and initial conditions, and properties of the solute and media.
FLUX	GM3D	Evaluates the element matrices and the derivatives of concentrations and then sums over all element matrices to form a matrix equation governing the flux components at all nodal points.
GM3D	LEWAST3D	Controls the entire sequence of operations. Performs either the steady-state computation alone, or a transient- state computation using the steady-state solution as the initial condition, or a

transient computation using user-supplied initial conditions.

TABLE A-2. SUBROUTINES INCLUDED IN 3DLEWASTE (continued)
4

Subroutine	Called By	Description
LELGEN	GM3D	Finds the elements connecting to each node.
MPLOC	NDTAU, ADVTRN	Locates the fictitious particle associated with a particular node. Computes the product of the outward unit vector with the vector from a node on the surface to the fictitious particle.
NDTAU	GM3D	Determines the number of subtime steps and the subtime step size for Lagrangian intrgration.
PAGEN	DATAIN	Preprocesses pointer arrays that are needed to store the global matrix in compressed form and to construct the subregional block matrices.
PRINTT	GM3D	Prints material flow, concentration, and material flux output as specified by the parameter KPR.
Q4ADB	ADVBC	Implements Dirichlet, specified-flux (Cauchy), and variable boundary conditions in the Lagrangian step computation.
Q4BB	SFLOW	Computes normal flow rates (M/T) by integrating the normal fluxes ($M/L^2/T$) over a boundary surface.
Q4CNB	BC	Computes the boundary-surface matrix and the boundary-surface load vector over a boundary surface.
Q8	ASEMBL	Computes element matrices and element load vectors.
Q8DV	FLUX	Computes the integration of N(I)*N(J) and -N(I)*D>GRAD(C) over an element.
Q8R	SFLOW	Computes the material integration and element

		source integration over an element.
READN	DATAIN	Automatically generates integer input if required.

TABLE A-2. SUBROUTINES INCLUDED IN 3DLEWASTE (concluded)
4

Subroutine	Called By	Description
READR	DATAIN	Automatically generates real number input if required.
SFLOW	GM3D	Computes the flux rates through various types of boundaries and the rate at which material increases in the region of interest.
SHAPE	Q8DV, Q8	Computes the base and weighting functions, their derivatives with respect to X, Y, Z, and the Jacobian at a Gaussian point.
SOLVE	BLKITR	Solves a matrix equation with a band matrix solver.
STORE	GM3D	Stores pertinent quantities on a auxiliary device for future uses (e.g., for plotting).
SURF	DATAIN	Identifies the boundary sides and sequences of the boundary nodes, and computes the directional cosine of the surface sides.
THNODE	GM3D	Computes moisture content at a node.
XSI3D	ADVTRN	Computes the local coordinate of an element given the global coordinate within that element.

TABLE A-3. FUNCTIONS INCLUDED IN 3DLEWASTE
4

Function	Called By	Description
FCOS	MPLOC	Computes the inner product of an outward normal of the surface with a vector connecting a point on the surface and the fictitious particle to determine if the fictitious particle lies inside the surface.

interior of the region, the Lagrangian concentration is obtained by finite element interpolation of the concentration at the previous time step. If the fictitious particle associated with a particular node is outside the region of interest, the Lagrangian concentration is set equal to the previous time-step concentration of the boundary node that is closest to the fictitious particle.

A.2.3 Subroutine AFABTA

This subroutine, which is called by subroutine GM3D, calculates the values of upstream weighting factors along 12 sides of all elements.

A.2.4 Subroutine ALLFCT

This subroutine is called by subroutine GM3D to compute values for all the source/sink and boundary nodes and elements. It uses linear interpolation of tabular data to simulate variations in time for these conditions.

A.2.5 Subroutine ASEMBL

This subroutine is called by subroutine GM3D. After calling subroutine Q8 to evaluate the element matrices, it sums over all element matrices to form a global matrix equation governing the concentration distribution at all nodes.

A.2.6 Subroutine BC

This subroutine, which is called by subroutine GM3D, incorporates Dirichlet, variable composite, specified-flux, and specified-dispersive flux boundary conditions. For a Dirichlet boundary condition, an identity algebraic equation is generated for each Dirichlet nodal point. Any other equation having this nodal variable is modified accordingly to simplify the computation. For a variable composite surface, the integration of the normal velocity times the incoming concentration is added to the load vector and the integration of normal velocity is added to the matrix. For the specified-flux boundaries, the integration of flux is added to the load vector and the integration of normal velocity is added to the matrix. For a specified-dispersive-flux boundary, the integration of gradient flux is added to the load vector.

A.2.7 Subroutine BLKITR

This subroutine is called by subroutine GM3D to solve the matrix equation with block iteration methods. For each subregion, a block matrix equation is constructed based on the global matrix equation and two pointer arrays, GNPLR and LNOJCN (see subroutine PAGEN). The resulting block matrix equation is solved with the direct band matrix solver by calling subroutine SOLVE. This is done for all subregions for each iteration until a convergent solution is obtained.

A.2.8 Subroutine DATAIN

Subroutine DATAIN is called by subroutine GM3D. It reads and prints all data input described in the Section 4.2 except data set 1. It also calls subroutine SURF to identify the boundary segments and boundary nodes and subroutines READR and READN, respectively, to automatically generate real and integer numbers.

A.2.9 Subroutine FLUX

This subroutine is called by subroutine GM3D. It calls subroutine Q8DV to evaluate the element matrices and the derivatives of concentrations. It then sums over all element matrices to form a matrix equation governing the flux components at all nodal points. To save computational time, the matrix is diagonalized by lumping. The flux components due to dispersion can thus be solved point by point. The flux due to velocity is then added to the computed flux due to dispersion. The computed total flux field is then returned to GM3D through the argument.

A.2.10 Subroutine GM3D

The subroutine GM3D controls the entire sequence of operations. It performs either a steady-state computation alone (KSS = 0 and NTI = 0), or a transient- state computation using the steady-state solution as the initial condition (KSS = 0, NTI > 0), or a transient computation using user-supplied initial conditions (KSS = 1, NTI > 0).

GM3D calls subroutine DATAIN to read and print input data; subroutine LELGEN to generate the pointer array element stencil that describes all elements connected to any node; subroutine ALLFCT to obtain sources/sinks and boundary values; subroutine AFABTA to obtain the upstream weighting factor based on velocity and dispersivity (the upstream weighting factor is needed for solving the steady-state option of 3DLEWASTE); subroutine FLUX to compute material flux; subroutine ASEMBL to assemble the element matrices over all elements; subroutine BC to implement the boundary conditions; subroutine BLKITR to solve the resulting matrix equations with block iteration methods; subroutine SFLOW to calculate flux through all types of boundaries and the water accumulated in the media; subroutine PRINTT to print out the results; subroutine STORE to store the results for plotting; subroutine THNODE to compute the value of moisture content plus bulk density times distribution coefficient in the case of a linear isotherm, or the moisture content in the case of a nonlinear isotherm at all nodes; subroutine NDTAU to compute the number of subtime steps nd the subtime step sizes used for integration in the Lagrangian step;

ADVTRN to compute the Lagrangian concentrations at all nodes; and subroutine ADVBC to implement boundary conditions in the Lagrangian step.

A.2.11 Subroutine LELGEN

This subroutine is called by subroutine GM3D to preprocess the pointer array (the global elements stencil), LRL(K,N), where LRL(K,N) is the global element number of the K-th element connected to the global node N. This pointer array is generated based on the element connectivity IE(M,J). Here IE(M,J) is the global node number of the J-th node of element M. This pointer array is needed to facilitate the location of fictitious particles.

A.2.12 Subroutine MPLOC

This subroutine is called by NDTAU and ADVTRN to locate the fictitious particle associated with a particular node. It uses the function FCOS to compute the product of the outward unit vector with the vector from a node on the surface to the fictitious particle.

A.2.13 Subroutine NDTAU

This subroutine is called by GM3D to compute the subtime-step size and the number of subtime steps such that no fictitious particle travels over an element within a subtime step. The subtime-step size and the number of subtime steps are used in subroutine ADVTRN.

A.2.14 Subroutine PAGEN

This subroutine is called by subroutine DATAIN to preprocess pointer arrays that are needed to store the global matrix in compressed form and to construct the subregional block matrices. The pointer arrays automatically generated in this subroutine include the global node connectivity (stencil), GNOJCN(J,N), regional node connectivity, LNOJCN(J,I,K), total node number for each subregion, NTNPLR(K), the bandwidth indicator for each subregion, LMAXDF(K), and a partial fill-up for the mapping array between global node number and local subregion node number, GNPLR(I,K), with I = NNPLR(K) + 1 to NTNPLR(K). Here GNOJCN(J,N) is the global node number of the J-th node connected to the global node N; LNOJN(J,I,K) is the local node number of the J-th node connected to the local node I in K-th subregion; NTNPLR(K) is the total number of nodes in the the K-th subregion, including the interior nodes, the global boundary nodes, and intra-boundary nodes; LMAXDF(K) is the maximum difference between any two nodes of any element in the K-th subregion; and GNPLR(I,K) is the global node number of the I-th local-region node in the K-th subregion. These pointer arrays are generated based on the element connectivity, IE(M,J), the number of nodes for each subregion, NNPLR(K), and the mapping between global node and local-region node, GNLR(I,K), with I = 1, NNPLR(K). Here IE(M,J) is the global node number of the J-th node of element M; NNPLR(K) is the number of nodes in the K-th subregion, including the interior nodes and the global boundary nodes, but not the intraboundary nodes.

A.2.15 Subroutine PRINTT

This subroutine, which is called by GM3D, is used to line-print the simulation results. These include the fluxes through variable boundary surfaces, the concentration, and vertically integrated material flux components.

A.2.16 Subroutine Q4ADB

This subroutine is called by subroutine ADVBC and implements Dirichlet, specified-flux, and variable boudary conditions in a Lagrangian step computation.

A.2.17 Subroutine Q4BB

This subroutine is called by subroutine SFLOW to perform surface integration of the following type:

$$RRQ(I) = \int_{B_e} N_i^e F dB \qquad \text{(A-14)}$$

where F is the normal flux and RRQ(I) is a 3DLEWASTE program variable.

A.2.18 Subroutine Q4CNB

This subroutine is called by the subroutine BC to compute the surface node flux of the type:

$$RQ(I) = \int_{B_e} N_i^e q dB \qquad \text{(A-15a)}$$

where q is either the specified- (or Cauchy) flux, specified-dispersive- (or Neumann) flux, or $\mathbf{n} \cdot \mathbf{V} C_v$; and RQ(I) is a 3DLEWASTE program variable. It also computes the boundary element matrices:

$$BQ(I,J) = \int_{B_e} N_i^e \mathbf{V} N_j^e dR \qquad \text{(A-15b)}$$

where N_j^e is the basis function for nodal point j of element e, R is the region of interest, **V** is the Darcy velocity, and BQ(I,J) is a 3DLEWASTE program variable.

A.2.19 Subroutine Q8

This subroutine is called by the subroutine ASEMBL to compute the element matrix given by:

$$QA(I,J) = \int_{R_e} N_i^e \theta N_j^e \, dR \tag{A-16a}$$

$$QAA(I,J) = \int_{R_e} N_j^e D_b \frac{dS}{dC} N_j^e \, dR \tag{A-16b}$$

$$QB(I,J) = \int_{R_e} (\nabla N_i^e) \cdot \theta \mathbf{D} \cdot (\nabla N_j^e) \, dR \tag{A-16c}$$

$$QV(I,J) = \int_{R_e} N_i^e \mathbf{V} \cdot (\nabla N_j^e) \, dR \tag{A-16d}$$

$$QC(I,J) = \int_{R_e} N_i^e [\lambda(\theta + D_b \frac{dS}{dC}) + Q] N_j^e \, dR \tag{A-16e}$$

where

C_w	= dissolved concentration at the previous iteration
$\mathbf{D}$	= dispersion coefficient tensor
θ	= moisture content
S	= species concentration in the adsorbed phase
Q	= source rate of water
D_b	= bulk density of the porous medium
λ	= material decay constant
∇	= del operator indicating gradient
$\nabla\cdot$	= del operator indicating divergence

and where QA(I,J), QAA(I,J), QB(I,J), QV(I,J), and QC(I,J) are 3DLEWASTE program variables. Note that dS/dC should be evaluated at C_w. Subroutines Q8 also calculates the element load vector given by:

$$QR(I) = \int_{R_e} N_i^e [-\lambda \rho_b (S_w - \frac{dS}{dC} C_w) + QC_{in}] dR \qquad \text{(A-16f)}$$

where C_w and S_w are the dissolved and adsorbed concentrations at the previous iteration, respectively, and QR(I) is a program variable.

A.2.20 Subroutine Q8DV

Subroutine Q8DV is called by subroutine FLUX to compute the element matrices given by:

$$QB(I,J) = \int_{R_e} N_i^e N_j^e dR \qquad \text{(A-17a)}$$

Subroutine Q8DV also evaluates the element load vector:

$$QRX(I) = -\int_{R_e} N_i^e \mathbf{i} \cdot \theta \mathbf{D} \cdot (\nabla N_j^e) C_j dR \qquad \text{(A-17b)}$$

$$QRY(I) = -\int_{R_e} N_i^e \mathbf{j} \cdot \theta \mathbf{D} \cdot (\nabla N_j^e) C_j dR \qquad \text{(A-17c)}$$

$$QRZ(I) = -\int_{R_e} N_i^e \mathbf{k} \cdot \theta \mathbf{D} \cdot (\nabla N_j^e) C_j dR \qquad \text{(A-17d)}$$

where

C_j	= concentration at nodal point j
i	= unit vector along the x-direction
j	= unit vector along the y-coordinate
k	= unit vector along the z-coordinate

and where QRX(I), QRY(I), AND QRZ(I) are program variables.

A.2.21 Subroutine Q8R

This subroutine, which is called by subroutine SFLOW, is used to compute contributions to FRATE(8), FRATE(9), FRATE(1), and FRATE(14), discussed in Section A.2.24, by performing material integration and element source integration over an element.

$$QRM = \int_R 2C\,dR \tag{A-18a}$$

$$QDM = \int_R S\,dR \tag{A-18b}$$

$$SOSM = \int_R [QC_{in}(1+sign(Q))+QC(1-sign(Q))]/2\,dR \tag{A-18c}$$

where QRM, QDM, and SOSM are 3DLEWASTE program variables.

A.2.22 Subroutine READN

This subroutine is called by subroutine DATAIN to generate integer numbers for the input data sets if required.

A.2.23 Subroutine READR

This subroutine is called by subroutine DATAIN to automatically generate real numbers for the input data sets if required. Automatic generation of regularly patterned data is built into this subroutine.

A.2.24 Subroutine SFLOW

This subroutine is called by subroutine GM3D. It is used to compute flux rates through various types of boundaries and the rate at which material increases in the region of interest. In this subroutine, the variable FRATE(7) stores the flux through the whole boundary. It is given by:

$$FRATE(7) = \int_B (F_x n_x + F_y n_y)\,dB \tag{A-19}$$

where B is the global boundary of the region of interest; F_x, and F_y are the vertically integrated flux components and n_x and n_y are the directional cosines of the outward unit vector normal to the boundary B. FRATE(1) stores the flux rates through a Dirichlet boundary B_d. FRATE(2) and FRATE(3) store the flux rate through specified-flux (Cauchy) and specified-dispersive-flux (Neumann) boundaries, respectively.

$$FRATE(1) = \int_{B_d} (F_x n_x + F_y n_y)\, dB \tag{A-20a}$$

$$FRATE(2) = \int_{B_c} (F_x n_x + F_y n_y)\, dB \tag{A-20b}$$

$$FRATE(3) = \int_{B_n} (F_x n_x + F_y n_y)\, dB \tag{A-20c}$$

FRATE(4) and FRATE(5) store incoming flux and outgoing flux rates, respectively, through the variable boundaries B_v^- and B_v^+, as given by:

$$FRATE(4) = \int_{B_{v^-}} (F_x n_x + F_y n_y)\, dB \tag{A-20d}$$

$$FRATE(5) = \int_{B_{v^+}} (F_x n_x + F_y n_y)\, dB \tag{A-20e}$$

where B_{V^-} and B_{V^+} are that part of variable boundary where the fluxes are directed into the region and out from the region, respectively. The integration of Equations A-20a through A-20e is carried out by the subroutine Q4BB.

FRATE(6), which is related to the numerical loss, is given by:

$$FRATE(6) = FRATE(7) - \sum_{I=1}^{5} FRATE(I) \tag{A-21}$$

FRATE(8) and FRATE(9) store the accumulate rate in the dissolved and adsorbed phases, respectively, as given by:

$$FRATE(8) = \int_R 2C\, dR \tag{A-22}$$

$$FRATE(9) = \int_R \rho_b S \, dR \tag{A-23}$$

FRATE(10) stores the rate loss due to decay and FRATE(11) through FRATE(13) are set to zero as given by:

$$FRATE(10) = \int_R \lambda(\theta C + \rho_b S) \, dR \tag{A-24}$$

$$FRATE(11) = FRATE(12) = FRATE(13) = 0 \tag{A-25}$$

FRATE(14) is used to store the source/sink rate as:

$$FRATE(14) = \int_R [QC_{in}(1 + sign(Q)) + QC(1 - sign(Q))]/2 \, dR \tag{A-26}$$

If there is no numerical error in the computation, the following equation should be satisfied:

$$\sum_{I=7}^{14} FRATE(I) = 0 \tag{A-27}$$

and FRATE(6) should be equal to zero.

A.2.25 Subroutine SHAPE

This subroutine is called by subroutines Q8DV and Q8 to evaluate the value of the base and weighting functions and their derivatives at a Gaussian point.

A.2.26 Subroutine SOLVE

This subroutine is called by the subroutine BLKITR to solve a matrix equation of the type:

$$[C]\{x\} = \{y\} \tag{A-28}$$

where [C] is the coefficient matrix and {x} and {y} are two vectors. {x} is the unknown to be solved, and {y} is the known load vector. The computer returns the solution {y} and stores it in {y}. The computation is a standard banded Gaussian direct elimination procedure.

A.2.27 Subroutine STORE

This subroutine, which is called by subroutine GM3D, stores the simulation results in a binery file for use in plotting. The information stored includes regional geometry, concentrations, and vertically integrated material flux components at all nodes for any desired time step.

A.2.28 Subroutine SURF

Subroutine SURF is called by subroutine DATAIN. It identifies the boundary sides, sequences the boundary nodes, and computes the directional cosine of the surface sides. The mappings from boundary nodes to global nodes are stored in NPBB(I) (where NPBB(I) is the global node number of the I-th boundary node). The boundary node numbers of the four nodes for each boundary side are stored in ISB(I,J) (where ISB(I,J) is the boundary node number of the I-th node of the J-th side, I = 1 to 4). There are six sides for each element. Which of these six sides is the boundary side is determined automatically in the subroutine SURF and is stored in ISB(5,J). The global element number, to which the J-th boundary side belongs, is also preprocessed in the subroutine SURF and is stored in ISB(6,J). The directional cosines of the J-th boundary side are computed and stored in DCOSB(I,J) (where DCOSB(I,J) is the directional cosine of the J-th surface with I-th coordinate, I = 1 to 3). The information contained in NPBB, ISB, and DOSB, along with the number of boundary nodes and the number of boundary sides is returned to subroutine DATAIN for other uses.

A.2.29 Subroutine THNODE

This subroutine is called by GM3D to compute (2 +D_bdS/dC) for the linear isotherm model or 2 for the Freundlich and Langmuir nonlinear isotherm models.

A.2.30 Subroutine XSI3D

This subroutine is called by ADVTRN to compute the local coordinate of an element given the global coordinate within that element. With the local coordinate, the Lagrangian concentration can then easily be interpolated from those on the nodes of the element.

APPENDIX B

INPUT AND OUTPUT DEVICES

TABLE B-1. LOGICAL UNITS USED IN 3DFEMWATER
4

Logical Unit	Number	Purpose
LUSTO	11	Logical unit for storing binary output for use in 3DLEWASTE or for plotting purposes.
LUBAR	13	Logical unit for storing binary boundary arrays, if they are generated in the present job, for use in subsequent executions of the same scenario.
LUPAR	14	Logical unit for storing binary pointer arrays, if they are generated in the present job, for use in subsequent executions of the same scenario.
LUINP	15	Logical unit for reading input data.
LUOUT	16	Logical unit for writing output data.

4
TABLE B-2. LOGICAL UNITS USED IN 3DLEWASTE
4

Logical Unit	Number	Purpose
LUFLW	11	Logical unit for reading flow data from the 3DFEMWATER simulation.
LUSTO	12	Logical unit for storing binary output for use in 3DLEWASTE or for plotting purposes.
LUBAR	13	Logical unit for storing binary boundary arrays, if they are generated in the present job, for use in subsequent executions of the same scenario.
LUPAR	14	Logical unit for storing binary pointer arrays, if they are generated in the present job, for use in subsequent executions of the same scenario.

LUINP	15	Logical unit for reading input data.
LUOUT	16	Logical unit for writing output data.

4

APPENDIX C

DEFAULT VALUES FOR THE MAXIMUM CONTROL PARAMETERS

TABLE C-1. MAXIMUM CONTROL PARAMETERS USED IN 3DFEMWATER
4

Parameter	Definition	Default Value	Location
Maximum Control-Integers for the Spatial Domain			
MAXNPK	Maximum Number of Nodes	25578	PMXSD.INC
MAXELK	Maximum Number of Elements	22080	PMXSD.INC
MXBESK	Maximum Number of Boundary-Element Surfaces	7138	PMXSD.INC
MXBNPK	Maximum Number of Boundary Nodal Points	7140	PMXSD.INC
MXJBDK	Maximum Number of Nonzero Elements in Any Row	27	PMXSD.INC
MXKBDK	Maximum Number of Elements Connecting to Any Node	8	PMXSD.INC
Maximum Control-Integers for the Time Domain			
MXNTIK	Maximum Number of Time Steps	100	PMXTD.INC
MXDTCK	Maximum Number of DELT Changes	10	PMXTD.INC
Maximum Control-Integers for Subregions			
LTMXNK	Maximum Number of Total Nodal Points in any Subregion, Including Interior Nodes, Global Boundary Nodes, and Intraboundary Nodes	3654	PMXSR.INC
LMXNPK	Maximum Number of Nodal Points in any Subregion Including Interior Nodes and Global Boundary Nodes	1218	PMXSR.INC
LMXBWK	Maximum Number of the Bandwidth in any Subregion	59	PMXSR.INC
MXRGNK	Maximum Number of Subregions	21	PMXSR.INC
Maximum Control-Integers for Source/Sinks			
MXSELK	Maximum Number of Source Elements	1	PMXSS.INC
MXSPRK	Maximum Number of Source Profiles	1	PMXSS.INC
MXSDPK	Maximum Number of Data Points on Each Element Source/Sink Profile	1	PMXSS.INC
MXWNPK	Maximum Number of Point (Well) Nodal Points	2	PMXSS.INC
MXWPRK	Maximum Number of Point (Well) Source/Sink Profiles	2	PMXSS.INC

MXWDPK	Maximum Number of Data Points on Each Point (Well) Source/Sink Profile	2	PMXSS.INC (continued)

TABLE C-1. MAXIMUM CONTROL PARAMETERS USED IN 3DFEMWATER (concluded)

4

Parameter	Definition	Default Value	Location
Maximum Control-Integers for Specified-Flux (Cauchy) Boundary Conditions			
MXCNPK	Maximum Number of Specified-Flux Nodal Points	147	PMXCB.INC
MXCESK	Maximum Number of Specified-Flux Element Surfaces	120	PMXCB.INC
MXCPRK	Maximum Number of Specified-Flux Profiles	1	PMXCB.INC
MXCDPK	Maximum Number of Data Points on Each Specified-Flux Profile	2	PMXCB.INC
Maximum Control-Integers for Specified-Pressure-Head Gradient Boundary Conditions			
MXNNPK	Maximum Number of Specified-Pressure-Head Gradient Nodal Points	1	PMXNB.INC
MXNESK	Maximum Number of Specified-Pressure-Head Gradient Element Surfaces	1	PMXNB.INC
MXNPRK	Maximum Number of Specified-Pressure-Head Gradient Flux Profiles	1	PMXNB.INC
MXNDPK	Maximum Number of Data Points on Each Specified-Pressure-Head Gradient Flux Profile	2	PMXNB.INC
Maximum Control-Integers for Variable (Rainfall/Evaporation-Seepage) Boundary Conditions			
MXVNPK	Maximum Number of Variable Nodal Points	2079	PMXRSB.INC
MXVESK	Maximum Number of Variable Element Surfaces	1960	PMXRSB.INC
MXVPRK	Maximum Number of Rainfall Profiles	2	PMXRSB.INC
MXVDPK	Maximum Number of Data Point on Each Rainfall Profile	2	PMXRSB.INC
Maximum Control-Integers for Dirichlet Boundary Conditions			
MXDNPK	Maximum Number of Dirichlet Nodal Points	210	PMXDB.INC
MXDPRK	Maximum Number of Dirichlet Total Head Profiles	2	PMXDB.INC
MXDDPK	Maximum Number of Data Points on Each Dirichlet Profile	2	PMXDB.INC
Maximum Control-Integers for Material and Soil Properties			

MXMATK	Maximum Number of Material Types	6	PMXMS.INC
MXSPMK	Maximum Number of Soil Parameters Per Material to Describe Soil Characteristic Curves	5	PMXMS.INC
MXMPMK	Maximum Number of Material Properties per Material	6	PMXMS.INC

TABLE C-2. MAXIMUM CONTROL PARAMETERS USED IN 3DLEWWASTE
4

Parameter	Definition	Default Value	Location
Maximum Control-Integers for the Spatial Domain			
MAXNPK	Maximum Number of Nodes	25578	PMXSD.INC
MAXELK	Maximum Number of Elements	22080	PMXSD.INC
MXBESK	Maximum Number of Boundary-Element Surfaces	7138	PMXSD.INC
MXBNPK	Maximum Number of Boundary Nodal Points	7140	PMXSD.INC
MXJBDK	Maximum Number of Nonzero Elements in Any Row	27	PMXSD.INC
MXKBDK	Maximum Number of Elements Connecting to Any Node	8	PMXSD.INC
Maximum Control-Integers for the Time Domain			
MXNTIK	Maximum Number of Time Steps	500	PMXTD.INC
MXDTCK	Maximum Number of DELT Changes	20	PMXTD.INC
Maximum Control-Integers for Subregions			
LTMXNK	Maximum Number of Total Nodal Points in any Subregion, Including Interior Nodes, Global Boundary Nodes, and Intraboundary Nodes	3654	PMXSR.INC
LMXNPK	Maximum Number of Nodal Points in any Subregion, Including Interior Nodes and Global Boundary Nodes	1218	PMXSR.INC
LMXBWK	Maximum Number of the Bandwidth in any Subregion	59	PMXSR.INC
MXRGNK	Maximum Number of Subregions	21	PMXSR.INC
Maximum Control-Integers for Source/Sinks			
MXSELK	Maximum Number of Source Elements	180	PMXSS.INC
MXSPRK	Maximum Number of Source Profiles	1	PMXSS.INC
MXSDPK	Maximum Number of Data Points on Each Element Source/Sink Profile	8	PMXSS.INC

MXWNPK	Maximum Number of Point (Well) Nodal Points	1	PMXSS.INC
MXWPRK	Maximum Number of Point (Well) Source/Sink Profiles	1	PMXSS.INC
MXWDPK	Maximum Number of Data Points on Each Point (Well) Source/Sink Profile	4	PMXSS.INC (continued)

TABLE C-2. MAXIMUM CONTROL PARAMETERS USED IN 3DLEWWASTE (concluded)
4

Parameter	Definition	Default Value	Location
Maximum Control-Integers for Specified-Flux (Cauchy) Boundary Conditions			
MXCNPK	Maximum Number of Specified-Flux Nodal Points	8	PMXCB.INC
MXCESK	Maximum Number of Specified-Flux Element Surfaces	2	PMXCB.INC
MXCPRK	Maximum Number of Specified-Flux Profiles	2	PMXCB.INC
MXCDPK	Maximum Number of Data Points on Each Specified-Flux Profile	4	PMXCB.INC
Maximum Control-Integers for Specified-Dispersive-Flux Boundary Conditions			
MXNNPK	Maximum Number of Specified-Dispersive-Flux Nodal Points	8	PMXNB.INC
MXNESK	Maximum Number of Specified-Dispersive-Flux Element Surfaces	2	PMXNB.INC
MXNPRK	Maximum Number of Specified-Dispersive-Flux Profiles	2	PMXNB.INC
MXNDPK	Maximum Number of Data Points on Each Specified-Dispersive-Flux Profile	4	PMXNB.INC
Maximum Control-Integers for Variable (Run-In/Flow-Out) Boundary Conditions			
MXVNPK	Maximum Number of Variable Nodal Points	38	PMXRSB.INC
MXVESK	Maximum Number of Variable Element Surfaces	18	PMXRSB.INC
MXVPRK	Maximum Number of Rainfall Profiles	2	PMXRSB.INC
MXVDPK	Maximum Number of Data Point on Each Rainfall Profile	4	PMXRSB.INC
Maximum Control-Integers for Dirichlet Boundary Conditions			
MXDNPK	Maximum Number of Dirichlet Nodal Points	81	PMXDB.INC
MXDPRK	Maximum Number of Dirichlet Total Head Profiles	81	PMXDB.INC

MXDDPK	Maximum Number of Data Points on Each Dirichlet Profile	2	PMXDB.INC

Maximum Control-Integers for Material

MXMATK	Maximum Number of Material Types	6	PMXMS.INC
MXMPMK	Maximum Number of Material Properties per Material	8	PMXMS.INC

APPENDIX D

PROGRAM VARIABLE DESCRIPTIONS

Information about the program variables is given in two tables in this appendix. 3DFEMWATER program variables are listed in Table D-1 and 3DLEWASTE program variables are shown in Table D-2. In the tables, the definition, type, and units of each variable are provided. In addition, the tables indicate 1) the subroutines associated with each variable and 2) whether a variable is an input (I), output (O), or modified (M) variable in the subroutines. Also, if a variable is included in a COMMON block, the COMMON block name is given.

COMMON blocks are used in 3DFEMWATER/3DLEWASTE to minimize the use of subroutine arguments. Each COMMON block, which contains related variables, is stored as a file separate from the 3DFEMWATER/3DLEWASTE code and is accessed by the use of INCLUDE statements at the beginning of the main program and each subroutine. Only those COMMON blocks needed for the execution of a subroutine are included in the subroutine.

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
AGRAV	--	Scalar	Gravity Term Included? 0.0 = no, 1.0 = yes	Q8		I
AKPROP (I,J)	L/T	Array	I-th Parameter to Describe the Relative Conductivity as a Function of Pressure Head for the J-th Material or the I-th Data Point of Relative Conductivity for the J-th Material	GW3D DATAIN SPROP		M O I
AKR(I,M)	--	Array	Relative Conductivity at the I-th Node of the M-th Element	GW3D VELT SPROP ASEMBL BC		M I O I I
AKXG(8)	L/T	Array	XX-Hydraulic Conductivity at Eight Gaussian Points	Q8DV Q8		I I
AKXYG(8)	L/T	Array	XY-Hydraulic Conductivity at Eight Gaussian Points	Q8DV Q8		I I
AKXZG(8)	L/T	Array	XZ-Hydraulic Conductivity at Eight Gaussian Points	Q8DV Q8		I I
AKYG(8)	L/T	Array	YY-Hydraulic Conductivity at Eight Gaussian Points	Q8DV Q8		I I
AKYZG(8)	L/T	Array	YZ-Hydraulic Conductivity at Eight Gaussian Points	Q8DV Q8		I I
AKZG(8)	L/T	Array	ZZ-Hydraulic Conductivity at Eight Gaussian Points	Q8DV Q8		I I
BFLX(I)	L^3/T	Array	Present Time Flux at the	GW3D		M

			I-th Boundary Node	SFLOW PRINTT		M I
BFLXP(I)	L^3/T	Array	Previous Time Flux at the I-th Boundary Node	GW3D SFLOW		M M

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

<u>Variable</u>	<u>Units</u>	<u>Type</u>	<u>Description</u>	Sub- <u>routine</u>	Common <u>Block</u>	<u>I,M,O</u>
C(MAXNP)	L	Array	Final Solution	BLKITR SOLVE		O M
CAPROP (I,J)	1/L	Array	I-th Data Point of Water Capacity for the J-th Material	GW3D DATAIN SPROP		M O I
CHNG	--	Scalar	Multiplier for Increasing DELT		CREAL	
CMATRX (N,I)	--	Array	An Array to Store the assembled Global Matrix	GW3D VELT ASEMBL BC		M O O M
CMTRXG (MAXNP, JBAND)	--	Array	Global Matrix	BLKITR		I
CMTRXL	--	Array	Assembled Matrix for a	GW3D		M
(N,I)			subregion	BLKITR		M
CW(MAXNP)	 M	L	Array		BLKITR	
DCOSB(1,I)	--	Array	X-Directional Cosine of the I-th Boundary Side	GW3D DATAIN SURF BCPREP		M O O I

				BC		I
				SFLOW		I
				STORE		I
DCOSB(2,I)	--	Array	Y-Directional Cosine of the I-th Boundary Side	GW3D		M
				DATAIN		O
				SURF		O
				BCPREP		I
				BC		I
				SFLOW		I
				STORE		I

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
DCOSB(3,I)	--	Array	Z-Directional Cosine of the I-th Boundary Side	GW3D		M
				DATAIN		O
				SURF		O
				BCPREP		I
				BC		I
				SFLOW		I
				STORE		I
DCYFLX(NP)	GW3D	L^3/T	Array M	Darcy Flux Through the		
			NP-th Variable Boundary Node	BCPREP		O
				PRINTT		I
DELMAX	T	Scalar	Maximum Value of DELT		CREAL	
DELT	T	Scaler	Time Increment	ASEMBL	CREAL	I
				SFLOW		I
				PRINTT		I
DELTO	T	Scalar	Time Increment		CREAL	
DHQ(8)	L	Array	Pressure Difference Between the Present Time Step and the Previous	Q8TH		I

			Time Step at Eight Nodes of the Element			
DJAC	L^3	Scalar	Determinant of the Jacobian	BASE		O
DNX(8)	1/L	Array	Partial Derivative of the Base Function with Respect to x	BASE		O
DNY(8)	1/L	Array	Partial Derivative of the Base Function with Respect to y	BASE		O
DNZ(8)	1/L	Array	Partial Derivative of the Base Function with Respect to z	BASE		O

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
DTH(I,M)	1/L	Array	Water Capacity at the I-th Node of the M-th Element	GW3D SPROP ASEMBL SFLOW		M O I I
DTHG(8)	1/L	Array	Water Capacity at Eight Gaussian Points of the Element	Q8		I
F(MAXNOD)	--	Array	Array of Real Numbers that are to be Read and Generated Automatically	READR		O
FLOW(10)	L^3	Array	Increment of Flow		CFLOW	
FLX(NP)	L^3/T	Array	Rainfall Flux Through the NP-th VB Node	GW3D BCPREP BC		M O I
FRATE(10)	L^3/T	Array	Flow Rate		CFLOW	

F1Q(4)	$L^3/T/L^2$	Array	Specified Normal Flux at Four Nodes of the Surface	Q4S		I
F2Q(4)	$L^3/T/L^2$	Array	Gravity Flux at Four Nodes of a Specified-Pressure-Head Gradient (Neumann) Surface	Q4S		I
GNLR(I,K)	--	Array	Global Node Number of the I-th Node in the K-th Subregion	GW3D		M
				DATAIN		O
				PAGEN		M
				BLKITR		I
				STORE		I
H(N)	L	Array	Pressure Head at the Present Time	GW3D		O
				DATAIN		O
				VELT		I
				SPROP		I
				BCPREP		I
				SFLOW		I
				PRINTT		I
				STORE		I

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	**Units**	**Type**	**Description**	**Sub-routine**	**Common Block**	**I,M,O**
HCON(NP)	L	Array	Ponding Depth of the NP-th Variable Boundary Node	GW3D		M
				DATAIN		O
				BCPREP		I
				BC		I
HDB(J)	L	Array	Total Head of the J-th Profile at the Present Time	GW3D		M
				BC		I
HDBF(I,J)	L	Array	Total Head of the I-th Data Point in the J-th Profile	GW3D		M
				DATAIN		O
HMIN(NP)	L	Array	Minimum Pressure Allowed for the NP-th VB Node	GW3D		M
				DATAIN		O

				BCPREP		I
				BC		I
HP(N)	L	Array	Previous-Time Pressure Head at the N-th Node	GW3D		M
				ASEMBL		I
				SFLOW		I
HPROP(I,J)	L	Array	I-th Data Point of Pressure for the J-th Material	GW3D		M
				DATAIN		O
				SPROP		I
HT(N)	L	Array	Total Head the N-th Node	GW3D		M
				PRINTT		I
				STORE		I
				VELT		O
HTQ(8)	L	Array	Total Head at Eight Nodes of the Element	Q8DV		I
HW(N)	L	Array	Nonlinear Pressure Head Iterate at the N-th Node	GW3D		M
IBUG	--	Scalar	Diagnostic Print-Out Indicator	BLKITR		I
ICTYP(MP)	--	Array	Type of Specified-Flux (Cauchy) Profile Assigned to the MP-th Side	GW3D		M
				DATAIN		O
				BC		I

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
IDTYP(NP)	--	Array	Total Head Profile Type of NP-th Dirichlet Node	GW3D		M
				DATAIN		O
				BC		I
IE(M,I)	--	Array	Global Node Number of the I-th Node of the M-th Element if I is Between 1	GW3D		M
				DATAIN		O
				SURF		I

			and 8, Material Type of the M-th Element if I = 9	PAGEN VELT SPROP BCPREP ASEMBL BC SFLOW STORE		I I I I I I I I
IGEOM	--	Scalar	Geometry Description Output Control		CINTE	
IHALFB	--	Scalar	Half Band with Plus 1	SOLVE		I
ILUMP	--	Scalar	Lumping Indicator	Q8	OPTN	I
IMID	--	Scalar	Mid-Difference Indicator		OPTN	
INDTYP(MXTYP)	--	Array	Array of Integers that are to be Read or Generated Automatically	READN		O
INTYP(MP)	--	Array	Type of Specified-Pressure-Head Gradient (Neumann) Flux Profile Assigned to the MP-th Neumann Side	GW3D DATAIN BC		M O I
IRTYP(MP)	--	Array	Type of Rainfall Profile Assigned to the MP-th Variable Boundary Side	GW3D DATAIN BCPREP		M O I

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
ISB(1,I)	--	Array	Boundary Node Number of the First Node of the	GW3D DATAIN		M O

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
			I-th Boundary Side	SURF		O
				BCPREP		I
				BC		I
				SFLOW		I
				STORE		I
ISB(2,I)	--	Array	Boundary Node Number of	GW3D		M
			the Second Node of the	DATAIN		O
			I-th Boundary Side	SURF		O
				BCPREP		I
				BC		I
				SFLOW		I
				STORE		I
ISB(3,I)	--	Array	Boundary Node Number of	GW3D		M
			the Third Node of the	DATAIN		O
			I-th Boundary Side	SURF		O
				BCPREP		I
				BC		I
				SFLOW		I
				STORE		I
ISB(4,I)	--	Array	Boundary Node Number of	GW3D		M
			the Fourth Node of the	DATAIN		O
			I-th Boundary Side	SURF		O
				BCPREP		I
				BC		I
				SFLOW		I
				STORE		I
ISB(5,I)	--	Array	Element Side Index of the	GW3D		M
			I-th Boundary Side:	DATAIN		O
			1=left side, 2=front side,	SURF		O
			3=right side, 4=back side,	BCPREP		I
			5=bottom side, 6=top side	BC		I
				SFLOW		I
				STORE		I

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

ISB(6,I)	--	Array	Element Number to which the I-th Boundary Side Belongs	GW3D DATAIN SURF BCPREP BC SFLOW STORE	M O O I I I I
ISC(1,MP)	--	Array	Global Node Number of the First Node of the MP-th Cauchy Side	GW3D DATAIN BC	M O I
ISC(2,MP)	--	Array	Global Node Number of the Second Node of the MP-th Cauchy Side	GW3D DATAIN BC	M O I
ISC(3,MP)	--	Array	Global Node Number of the Third Node of the MP-th Cauchy Side	GW3D DATAIN BC	M O I
ISC(4,MP)	--	Array	Global Node Number at the Fourth Node of the MP-th Cauchy Side	GW3D DATAIN BC	M O I
ISC(5,MP)	--	Array	Boundary Side Number of the MP-th Cauchy Side	GW3D DATAIN BC	M O I
ISN(1,MP)	--	Array	Global Node Number of the First Node of the MP-th Neumann Side	GW3D DATAIN BC	M O I
ISN(2,MP)	--	Array	Global Node Number of the Second Node of the MP-th Neumann Side	GW3D DATAIN BC	M O I
ISN(3,MP)	--	Array	Global Node Number of the Third Node of the MP-th Neumann Side	GW3D DATAIN BC	M O I
ISN(4,MP)	--	Array	Global Node Number of the Fourth Node of the MP-th Neumann Side	GW3D DATAIN BC	M O I

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
ISN(5,MPF)	--	Array	Boundary Side Number of the MP-th Neumann Side	GW3D DATAIN BC		M O I
ISTYP(MP)	--	Array	Source/Sink Type Assigned to the MP-th S/S Element	GW3D DATAIN ASEMBL SFLOW		M O I I
ISV(1,MP)	--	Array	Global Node Number of the First Node of the MP-th Variable Side	GW3D DATAIN BCPREP		M O I
ISV(2,MP)	--	Array	Global Node Number of the Second Node of the MP-th Variable Side	GW3D DATAIN BCPREP		M O I
ISV(3,MP)	--	Array	Global Node Number of the Third Node of the MP-th Variable Side	GW3D DATAIN BCPREP		M O I
ISV(4,MP)	--	Array	Global Node Number of the Fourth Node of the MP-th Variable Side	GW3D DATAIN BCPREP		M O I
ISV(5,MP)	--	Array	Boundary Node Number of the MP-th VB Side	GW3D DATAIN BCPREP		M O I
ITIM	--	Scalar	Time Step Number	PRINTT		I
IWTYP(NP)	--	Array	Source/Sink Type Assigned to the NP-th Well Node	GW3D DATAIN ASEMBL SFLOW		M O I I
KANALY	--	Scalar	Analytical Input Control	ALLFCT		I

KCAI	--	Scalar	Analytical Specified-Flux (Cauchy) Input Control		CCBC	
KDAI	--	Scalar	Analytical Dirichlet Input Control		CDBC	

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	**Units**	**Type**	**Description**	**Sub-routine**	**Common Block**	**I,M,O**
KDIAG	--	Scalar	Diagnostic Print-Out Table Number	PRINTT		M
KDSK(I)	--	Array	Auxilliary Output Control for the I-th Time Step; 0 = no auxiliary output 1 = output stored	GW3D DATAIN		M O
KDSKO	--	Scalar	Disk Output Control		CINTE	
KFLOW	--	Scalar	System Flow Counter	SFLOW		I
KGRAV	--	Scalar	Index of Gravity Control		CGEOM	
KKK	--	Scalar	Decomposition or Back Substitution Indicator 1 = decomposition, 2 = back substitution	SOLVE		I
KNAI	--	Scalar	Analytical Neumann Flux Input Control		CNBC	
KOUT	--	Scalar	Print-Out Table Number	PRINTT		M
KPR(I)	--	Array	Line-Printer Control for I-th Time Step: 0 = print nothing 1 = print system mass balance plus above 2 = print pressure head plus above 3 = print total head plus	GW3D DATAIN BLKITR PRINTT		M O I I

			above 4 = print moisture content plus above 5 = print Darcy velocity plus above			
KPRO	--	Scalar	Output Control		CINTE	
KRAI	--	Scalar	Analytical Rainfall Input Control		CVBC	

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	**Units**	**Type**	**Description**	**Sub- routine**	**Common Block**	**I,M,O**
KSAI	--	Scalar	Analytical Distributed Source/Sink Input Control		CS	
KSP	--	Scalar	Soil Property Tabular Input Control	SPROP	CINTE	I
KSS	--	Scalar	Steady-State I.C. Control	ASEMBL	CINTE	I
KWAI	--	Scalar	Analytical Well Source/ Sink Input Control		CW	
LES(MP)	--	Array	Global Element Number of the MP-th S/S Element	GW3D DATAIN ASEMBL SFLOW		M O I I
LMAXDF(K)	--	Array	Maximum Difference Between Eight Nodes of Any Element	GW3D PAGEN BLKITR DATAIN		M O I O
LMXBW	--	Scalar	Maximum No. of the Bandwidth in any Subregion	BLKITR	LGEOM	I
LMXBWK	--	Scalar	Maximum No. of the Bandwidth			

			in Any Subregion			
LMXNP	--	Scalar	Maximum No. of Nodal Points in any Subregion, Including Interior Nodes and Global Boundary Nodes	BLKITR	LGEOM	I
LMXNPK	--	Scalar	Maximum No. of Nodal Points in any Subregion, Including Interior Nodes and Global Boundary Nodes			
LNOJCN (J,I,K)	--	Array	Local Node No. of the J-th Compressed Number Connect-ing to the I-th Local Node in the K-th Subregion	GW3D PAGEN BLKITR DATAIN		M O I O

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
LRL(I,N)	--	Array	Global Element Number of the I-th Element Connect-ing to the N-th Global Node	GW3D DATAIN SURF PAGEN		M O I O
LRN(I,N)	--	Array	Global Node Number of the I-th Node Connecting to the N-th Global Node	GW3D PAGEN ASEMBL BC DATAIN		M O I I O
LTMXNK	--	Scalar	Maximum No. of Total Nodal Points in any Subregion, Including Interior Nodes, and Global Boundary Nodes			
LTMXNP	--	Scalar	Maximum No. of Total Nodal Points in any Subregion, Including Interior Nodes, and Global Boundary Nodes	BLKITR STORE	LGEOM	I I

LUBAR	--	Scalar	Logical Unit for Storing	GW3D		I
			Binary Boundary Arrays	DATAIN		I
LUINP	--	Scalar	Logical Unit for Input	GW3D		I
			Data	DATAIN		I
				READR		I
				READN		I
LUOUT	--	Scalar	Logical Unit for Output	GW3D		I
			Data	DATAIN		I
				SURF		I
				PAGEN		I
				ASEMBL		I
				BLKITR		I
				PRINTT		I
				READR		I
				READN		I
LUPAR	--	Scalar	Logical Unit for Storing	GW3D		I
			Binary Pointer Arrays			

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
LUSTO	--	Scalar	Logical Unit for Storing	GW3D		I
			Binary Output	STORE		I
MAXBES	--	Scalar	Maximum No. of Boundary	STORE	SGEOM	I
			Element Surfaces			
MAXBNP	--	Scalar	Maximum No. of Boundary	PRINTT	SGEOM	I
			Nodal Points	STORE		I
MAXBW	--	Scalar	Maximum No. of Bandwidth	SOLVE		I
MAXEL	--	Scalar	Maximum No. of Elements	SPROP	SGEOM	I
				PRINTT		I
				STORE		I
MAXELK	--	Scalar	Maximum No. of Elements			

MAXMAT	--	Scalar	Maximum No. of Materials	SPROP	SMTL	I
MAXNOD	--	Scalar	Maximum No. of Data Points to be Read	READR		I
MAXNP	--	Scalar	Maximum no. of Nodal Points	SPROP BLKITR SOLVE PRINTT STORE	SGEOM	I I I I I
MAXNPK	--	Scalar	Maximum No. of Nodes			
MAXNTI	--	Scalar	Maximum No. of Time Steps		SGEOM	
MXBESK	--	Scalar	Maximum No. of Boundary Element Surfaces			
MXBNPK	--	Scalar	Maximum No. of Boundary Nodal Points			
MXCDP	--	Scalar	Maximum No. of Data Points on Each Cauchy-Flux Profile		CCBC	
MXCDPK	--	Scalar	Maximum No. of Data Points on Each Cauchy-Flux Profile			

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
MXCES	--	Scalar	Maximum No. of Specified-Flux (Cauchy) Element Surfaces		CCBC	
MXCESK	--	Scalar	Maximum No. of Specified-Flux (Cauchy) Element Surfaces			
MXCNP	--	Scalar	Maximum No. of Specified-Flux (Cauchy) Nodal Points		CCBC	
MXCNPK	--	Scalar	Maximum No. of Specified-Flux (Cauchy) Nodal Points			

MXCPR	--	Scalar	Maximum No. of Specified-Flux (Cauchy) Profiles		CCBC	
MXCPRK	--	Scalar	Maximum No. of Specified-Flux (Cauchy) Profiles			
MXDDP	--	Scalar	Maximum No. of Data Points on Each Dirichlet Profile		CDBC	
MXDDPK	--	Scalar	Maximum No. of Data Points on Each Dirichlet Profile			
MXDNP	--	Scalar	Maximum No. of Dirichlet Nodal Points		CDBC	
MXDNPK	--	Scalar	Maximum No. of Dirichlet Nodal Points			
MXDP	--	Scalar	Maximum No. of Data Points in any Profile	ALLFCT		I
MXDPR	--	Scalar	Maximum No. of Dirichlet Total Head Profiles		CDBC	
MXDPRK	--	Scalar	Maximum No. Dirichlet Total Head Profiles			
MXDTCK	--	Scalar	Maximum No. of DELT Changes			
MXJBD	--	Scalar	Maximum No. of Nonzero Elements in any Row	BLKITR PRINTT		I I

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
MXJBDK	--	Scalar	Maximum No. of Nonzero Elements in any Row			
MXMATK	--	Scalar	Maximum No. of Material Types			
MXMPMK	--	Scalar	Maximum No. of Material			

			Properties per Material			
MXMPPM	--	Scalar	Maximum No. of Material Properties per Material		SMTL	
MXNDP	--	Scalar	Maximum No. of Data Points on Each Neumann-Flux Profile		CNBC	
MXNDPK	--	Scalar	Maximum No. of Data Points on Each Neumann-Flux Profile			
MXNDTC	--	Scalar	Maximum No. of DELT Changes		SGEOM	
MXNES	--	Scalar	Maximum No. of Neumann Element Surfaces		CNBC	
MXNESK	--	Scalar	Maximum No. of Neumann Element Surfaces			
MXNNP	--	Scalar	Maximum No. of Neumann Nodal Points		CNBC	
MXNNPK	--	Scalar	Maximum No. of Neumann Nodal Points			
MXNPR	--	Scalar	Maximum No. of Neumann-Flux Profiles		CNBC	
MXNPRK	--	Scalar	Maximum No. of Neumann-Flux Profiles			
MXNTIK	--	Scalar	Maximum No. of Time Steps			

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
MXPR	--	Scalar	Maximum No. of Profiles	ALLFCT		I

MXRDP	--	Scalar	Maximum No. of Data Points on Each Rainfall Profile		CVBC	
MXREGN	--	Scalar	Maximum No. of Subregions	BLKITR STORE	LGEOM	I I
MXRGNK	--	Scalar	Maximum No. of Subregions			
MXRPR	--	Scalar	Maximum No. of Rainfall Profiles		CVBC	
MXSDP	--	Scalar	Maximum No. of Data Points on Each Element Source/ Sink Profile		CS	
MXSDPK	--	Scalar	Maximum No. of Data Points on Each Element Source/ Sink Profile			
MXSEL	--	Scalar	Maximum No. of Source Elements		CS	
MXSELK	--	Scalar	Maximum No. of Source Elements			
MXSPMK	--	Scalar	Maximum No. of Soil Parameters per Material to Describe Soil Charac- teristic Curves			
MXSPPM	--	Scalar	Maximum No. of Soil Parameter Per Material to Describe Soil Characteristic Curves	SPROP	SMTL	I
MXSPR	--	Scalar	Maximum No. of Source Profiles		CS	
MXSPRK	--	Scalar	Maximum No. of Source Profiles			

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
MXTYP	--	Scalar	Maximum No. of Integers Allowed to be Read	READN		I
MXVDPK	--	Scalar	Maximum No. of Data Points on Each Rainfall Profile			
MXVES	--	Scalar	Maximum No. of Variable Element Surfaces		CVBC	
MXVESK	--	Scalar	Maximum No. of Variable Element Surfaces			
MXVNP	--	Scalar	Maximum No. of Variable Nodal Points	PRINTT	CVBC	I
MXVNPK	--	Scalar	Maximum No. of Variable Nodal Points			
MXVPRK	--	Scalar	Maximum No. of Rainfall Profiles			
MXWDP	--	Scalar	Maximum No. of Data Points on Each Well Source/Sink Profile		CW	
MXWDPK	--	Scalar	Maximum No. of Data Points on Each Well Source/Sink Profile			
MXWNP	--	Scalar	Maximum No. of Well Nodal Points		CW	
MXWNPK	--	Scalar	Maximum No. of Well Nodal Points			
MXWPR	--	Scalar	Maximum No. of Well Source/Sink Profiles		CW	
MXWPRK	--	Scalar	Maximum No. of Well Source/Sink Profiles			

N	--	Scalar	Base Functions Associated with 8 Nodes of the Element	BASE		O

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
NBES	--	Scalar	Number of Boundary Element Surfaces	STORE	CGEOM	I
NBNP	--	Scalar	Number of Boundary Nodal Points	STORE	CGEOM	I
NCDP	--	Scalar	Number of Data Points on Specified-Flux (Cauchy) Profiles		CCBC	
NCES	--	Scalar	Number of Specified-Flux (Cauchy) Boundary Element Sides		CCBC	
NCHG	--	Scalar	Number of Variable Boundary Nodes that has Changed Boundary Conditions	BCPREP		O
NCNP	--	Scalar	Number of Specified-Flux (Cauchy) Boundary Nodal Points		CW	
NCPR	--	Scalar	Number of Specified-Flux (Cauchy) Profiles		CCBC	
NCYL	--	Scalar	Number of Cycles per Time Step		CINTE	
NDDP	--	Scalar	Number of Data Points on Dirichlet Profiles		CDBC	
NDNP	--	Scalar	Number of Dirichlet Nodal Points		CDBC	
NDP	--	Scalar	Number of Data Points in Any Profile	ALLFCT		I

NDPR	--	Scalar	Number of Dirichlet Profiles		CDBC	
NDTCHG	--	Scalar	Number of Times to Reset Time Step Size		CGEOM	

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
NEL	--	Scalar	Number of Elements	SPROP PRINTT STORE	CGEOM	I I I
NITER	--	Scalar	Number of Iterations per Cycle	BLKITR	CINTE	I
NMAT	--	Scalar	Number of Materials		CMTL	
NMPPM	--	Scalar	Number of Material Properties per Material		CMTL	
NNDP	--	Scalar	Number of Data Points on Neumann-Flux Profiles		CNBC	
NNES	--	Scalar	Number of Neumann Boundary Element Sides		CNBC	
NNNP	--	Scalar	Number of Neumann Boundary Nodal Points		CNBC	
NNP	--	Scalar	Number of Nodal Points	BLKITR SOLVE PRINTT STORE READR	CGEOM	I I I I I
NNPLR(K)	--	Array	Number of Node Points in the K-th Subregion	GW3D DATAIN PAGEN		M O I

				BLKITR STORE		I I
NNPR	--	Scalar	Number of Neumann-Flux Profiles		CNBC	
NPBB(I)	--	Array	Global Node Number of the I-th Boundary Node	GW3D DATAIN SURF SFLOW STORE		M O O I I

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
NPCB(MP)	--	Array	Global Node Number of the MP-th Cauchy Node on Input, then is Changed to Contain the Boundary Node Number	GW3D DATAIN SFLOW		M O I
NPCNV(I)	--	Array	Global Node Number of the I-th Nonconvergent Node	GW3D		M
NPCON(NP)	--	Array	Ponding Condition Indicator of the NP-th VB Node: 0 = this is not a Pondidng-Condition Node for the Present Time Step, Global Node Number = this is a Ponding-Condition Node for the Present Time	GW3D BCPREP BC PRINTT		M O I I
NPDB(MXDNP)	--	Array	Global Node Number of the NP-th Dirichlet Node	GW3D DATAIN BC SFLOW		M O I I

NPFLX(NP)	--	Array	Flux Boundary Condition Indicator of the NP-th VB Node; 0 = this is not a Flux-Condition Node for the Present Time Step, Global Node Number = This is a Flux-Condition Node for the Present Time	GW3D BCPREP BC PRINTT		M O I I
NPITER	--	Scalar	Number of Blockwise Iterations Allowed		CINTE	
NPMIN(NP)	--	Array	Minimum-Pressure Condition Indicator of the NP-th VB Node; 0 = this is not a Minimum-Pressure-Condition	GW3D BCPREP BC PRINTT		M O I I

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
NPNB(MP)	--	Array	Global Node Number of the MP-th Neumann Node on Input, then is Changed to Contain the Boundary Node Number	GW3D DATAIN SFLOW		M O I
NPR	--	Scalar	Number of Profiles	ALLFCT		I
NPROB	--	Scalar	Problem Number	STORE		I
NPVB(NP)	--	Array	Global Node Number of the NP-th VB Node on Input, then is Changed to Contain the Boundary Node Number	GW3D DATAIN SFLOW PRINTT		M O I I
NPW(NP)	--	Array	Global Node Number of the NP-th S/S Well Node	GW3D DATAIN ASEMBL		M O I
NRDP	--	Scalar	Number of Data Points on Rainfall Profiles		CVBC	

NREGN	--	Scalar	Number of Subregions	BLKITR STORE	LGEOM	I I
NRPR	--	Scalar	Number of Rainfall Profiles		CVBC	
NSDP	--	Scalar	Number of Data Points on Element-Source/Sink Profile		CS	
NSEL	--	Scalar	Number of Element-Source/ Sink and B.C. Control Integer		CS	
NSPPM	--	Scalar	Number of Soil Parameters per Material to Describe Soil Characteristic Curves	SPROP	CMTL	I
NSPR	--	Scalar	Number of Element-Source/ Sink Profiles		CS	

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	**Units**	**Type**	**Description**	**Sub-routine**	**Common Block**	**I,M,O**
NTI	--	Scalar	Number of Time Increments	STORE	CGEOM	I
NTNPLR(K)	--	Array	Total Number of Nodes for the K-th Subregion Including Interior, Global Boundary, and Intra-boundary Nodes	GW3D PAGEN DATAIN		M O O
NTYPE	--	Scalar	Number of Integers to be Read	READN		I
NVES	--	Scalar	Number of Variable Boundary Element Sides	CVBC		

NVNP	--	Scalar	Number of Variable Boundary Nodal Points	PRINTT	CVBC	I
NWDP	--	Scalar	Number of Data Points on Each Well Source/Sink Profile		CW	
NWNP	--	Scalar	Number of Well Source/Sink Nodal Points		CW	
NWPR	--	Scalar	Number of Well Source/Sink Profiles		CW	
OME	--	Scalar	Iteration Parameter for a Non-Linear Equation	BLKITR	CREAL	I
OMI	--	Scalar	Relaxation Parameter for Pointwise Solution		CREAL	
PR(MXPR)	L or L^3/L^2	Array	Profile Values at T	ALLFCT		O
PRF(MXDP, MXPR)	L or L^3/L^2	Array	Profile Value of the Data Point on the Profile	ALLFCT		I

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	**Units**	**Type**	**Description**	**Sub-routine**	**Common Block**	**I,M,O**
PROP(I,J)	L/T or L^2	Array	I-th Material Property of the J-th Material; I = 1 = saturated xx-hydraulic conductivity I = 2 = saturated yy-hydraulic conductivity I = 3 = saturated zz-	GW3D DATAIN VELT ASEMBL BC		M O I I I

			hydraulic conduc- tivity I = 4 = saturated xy- hydraulic conduc- tivity I = 5 = saturated xz- hydraulic conduc- tivity I = 6 = saturated yz- hydraulic conduc- tivity			
QA(8,8)	--	Array	Integration of N(I) *DTH/DH*N(J)	Q8		O
QB(8,8)	--	Array	8 x 8 Element Matrix	Q8DV Q8		O O
QCB(J)	$L^3/T/L^2$	Array	Cauchy Flux of the J-th Profile at the Present Time	GW3D BC		M I
QCBF(I,J)	$L^3/T/L^2$	Array	Cauchy Flux of the I-th Data Point in the J-th Profile	GW3D DATAIN		M O
QNB(J)	(L^3/T) $/L^2$	Array	Neumann Flux of the J-th Profile at the Present Time	GW3D BC		M I

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub- routine	Common Block	I,M,O
QNBF(I,J)	$L^3/T/L^2$	Array	Neumann Flux of the I-th Data Point in the J-th Profile	GW3D DATAIN		M O
QRX(8)	--	Array	X-Velocity Element Vector	Q8DV		O
QRY(8)	--	Array	Y-Velocity Element Vector	Q8DV		O

QRZ(8)	--	Array	Z-Velocity Element Vector	Q8DV	O
QSOSM	L^3	Scalar	Integration of SOURCE	Q8TH	O
QTHM	L^3	Scalar	Integration of DHQ*THG	Q8TH	O
R(MAXNP)	--	Array	Load Vector	SOLVE	M
RF(I,J)	L/T	Array	Rainfall Rate of I-th Data Point in J-th Profile	GW3D DATAIN	M O
RFALL(J)	L/T	Array	Rainfall Rate of J-th Profile at the Present Time	GW3D BCPREP	M I
RI(N)	L	Array	Pressure Head Iterate in BLKITR	GW3D	M
RL	--	Scalar	A Working Array to Contain the Final Solution of the Pressure Head in BLKITR	GW3D	M
RLD(N)	--	Array	An Array to Store the Assembled Global Load Vector	GW3D ASEMBL BC	M O M
RLDG(MAXNP)	--	Array	Global Load Vector	BLKITR	I
RLDL(N)	--	Array	Assembled Load Vector for a Subregion	GW3D BLKITR	M M
RQ(8)	--	Array	Integration of N(I).K. (Unit Vector in Z)	Q8	O

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O

R1Q(4)	--	Array	Integration of N(I)*F1Q Over the Boundary Segment	Q4S	O
R2Q(4)	--	Array	Integration of N(I)*F2Q Over the Boundary Segment	Q4S	O
SOS(J)	$(L^3/T)/L^3$	Array	Value of J-th Element Source/Sink at Present Time	GW3D ASEMBL SFLOW	M I I
SOSF(I,J)	$L^3/T/L^2/L$	Array	S/S Rate of the I-th Data Point in the J-th Profile	GW3D DATAIN	M O
SOSM	L^3/T	Scalar	Source/Sink Strength of the Element	Q8	I
SOURCE	L^3/T	Scalar	Element Source/Sink Strength	Q8TH	I
SS	--	Scalar	Xsi-Coordinate of the Gaussian Point	BASE	I
SUBHD	--	Char.	Subheading	PRINTT	I
T	T	Scalar	Time	ALLFCT	I
TDTCH(I)	T	Array	Time of the I-th Time to Reset the Time Step Size to Initial Time Step Size	GW3D DATAIN	M O
TFLOW(10)	L^3	Array	Total Flow	CFLOW	
TH(I,M)	--	Array	Moisture Content at the I-th Node of the M-th Element	GW3D SPROP SFLOW PRINTT STORE	M O I I I
THDBF(I,J)	T	Array	Time of the I-th Data Point in J-th Head Profile	GW3D DATAIN	M O

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
THG(8)	--	Array	Moisture Content at Eight Gaussian Points of the Element	Q8TH		I
THPROP (I,J)	--	Array	I-th Parameter to Describe the Moisture Content as a Function of Pressure Head for the J-th Material or I-th Data Point of Moisture Content for the J-th Material	GW3D DATAIN SPROP		M O I
TIME	T	Scalar	Real Simulation Time	PRINTT STORE		I I
TITLE	--	Char.	Title of the Problem	STORE		I
TMAX	T	Scalar	Maximum Value of Time		CREAL	
TOLA	L	Scalar	Steady-State Tolerance		CREAL	
TOLB	L	Scalar	Transient State Tolerance	BLKITR	CREAL	I
TPRF(MXDP, MXPR)	T	Array	Time of the Data Point on the Profile	ALLFCT		I
TQCBF(I,J)	T	Array	Time of the I-th Data Point in the J-th Specified-Flux (Cauchy) Profile	GW3D DATAIN		M O
TQNBF(I,J)	T	Array	Time of the I-th Data Point in the J-th Neumann Profile	GW3D DATAIN		M O
TRF(I,J)	T	Array	Time of the I-th Date Point in J-th Rainfall Profile	GW3D DATAIN		M O

TSOSF(I,J)	T	Array	Time of the I-th Data Point in the J-th Profile	GW3D DATAIN		M O

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	**Units**	**Type**	**Description**	**Sub-routine**	**Common Block**	**I,M,O**
TT	--	Scalar	Eta-Coordinate of the Gaussian Point	BASE		I
TWSSF(I,J)	T	Array	Time of the I-th Data Point in the J-th Profile	GW3D DATAIN		M O
UU	--	Scalar	Zeta-Coordinate of the Gaussian Point	BASE		I
VX(N)	L/T	Array	X-Component Velocity at the N-th Node	GW3D VELT BCPREP SFLOW PRINTT STORE		O O I I I I
VY(N)	L/T	Array	Y-Component Velocity at the N-th Node	GW3D VELT BCPREP SFLOW PRINTT STORE		O O I I I I
VZ(N)	L/T	Array	Z-Component Velocity at the N-th Node	GW3D VELT BCPREP SFLOW PRINTT STORE		O O I I I I
W(8)	--	Array	Weighting Function at Eight Points of the	ASEMBL	CREAL	I

			Element			
WSS(J)	L^3/T	Array	Value of the J-th Well Source/Sink at Present Time	GW3D SFLOW ASEMBL		M I I
WSSF(I,J)	L^3/T	Array	S/S Rate of the I-th Data Point in the J-th Profile	GW3D DATAIN		M O

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
X(N)	L	Array	X-Coordinate of the N-th Node	GW3D DATAIN SURF VELT BCPREP ASEMBL BC SFLOW STORE		M O I I I I I I I
XQ(8)	L	Array	X-Coordinate at Eight Nodes of the Element	Q8DV Q8 BASE Q4S Q8TH		I I I I I
Y(N)	L	Array	Y-Coordinate of the N-th Node	GW3D DATAIN SURF VELT BCPREP ASEMBL BC SFLOW STORE		M O I I I I I I I
YQ(8)	L	Array	Y-Coordinate at Eight Nodes of the Element	Q8DV Q8		I I

				BASE		I
				Q4S		I
				Q8TH		I
Z(N)	L	Array	Z-Coordinate of the N-th Node	GW3D		M
				DATAIN		O
				SURF		I
				VELT		I
				BCPREP		I
				ASEMBL		I
				BC		I
				SFLOW		I
				STORE		I

TABLE D-1. 3DFEMWATER PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (concluded)

4

Variable	**Units**	**Type**	**Description**	**Sub-routine**	**Common Block**	**I,M,O**
ZQ(8)	L	Array	Z-Coordinate at Eight Nodes of the Element	Q8DV		I
				Q8		I
				BASE		I
				Q4S		I
				Q8TH		I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
AL	L	Scalar	Longitudinal Dispersivity	Q8DV Q8		I I
AM	L^2/T	Scalar	Modecular Diffusion Coefficient	Q8		I
APHA1	--	Scalar	Weighting Factor for Side 1-2 Parallel to the X-direction		WETX	
APHA2	--	Scalar	Weighting Factor for Side 4-3 Parallel to the X-direction		WETX	
APHA3	--	Scalar	Weighting Factor for Side 5-6 Parallel to the X-direction		WETX	
APHA4	--	Scalar	Weighting Factor for Side 8-7 Parallel to the X-direction		WETX	
AT	L	Scalar	Lateral Dispersivity	Q8DV Q8		I I
BETA1	--	Scalar	Weighting Factor for Side 1-4 Parallel to the Y-direction		WETY	
BETA2	--	Scalar	Weighting Factor for Side 2-3 Parallel to the Y-direction		WETY	
BETA3	--	Scalar	Weighting Factor for Side 5-8 Parallel to the Y-direction		WETY	
BETA4	--	Scalar	Weighting Factor for		WETY	

			Side 6-7 Parallel to the Y-direction			
BFLX(I)	M/T	Array	Boundary Flux at the I-th Boundary Node	GM3D SFLOW		M M

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
BFLXP(I)	M/T	Array	Value of BFLX(I) at the Previous Time	GM3D SFLOW		M M
BQ(4,4)	--	Array	A 2 by 2 Boundary Surface Matrix	Q4CNVB		O
C(N)	M/L^3	Array	Concentration of the N-th Node at the Present Time	GM3D FLUX BLKITR SOLVE SFLOW PRINTT STORE		O I O M I I I
CDB(I)	M/L^3	Array	Dirichlet Concentration of the I-th Profile at Present Time	GM3D BC ADVBC		M I I
CDBF(I,J)	M/L^3	Array	Concentration of the I-th Data Point in the J-th Dirichlet Concentration vs. Time Profile	GM3D DATAIN		M M
CHNG	--	Scalar	Multiplier for Increasing DELT		CREAL	
CMATRX (N,I)	--	Array	An Array to Store the I-th Non-Zero Entry of the N-th Equation of the Assembled Global Matrix	GM3D FLUX ASEMBL BC		M O O O

CMTRXG (N,I)	--	Array	Global Matrix	BLKITR		I
CMTRXL (N,I)	--	Array	Assembled Matrix for a Subregion	GM3D BLKITR		M I
CP(N)	M/L^3	Array	Concentration of the N-th Node at the Previous Time	GM3D DATAIN ASEMBL ADVTRN		O M I I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub- routine	Common Block	I,M,O
CQ(8)	M/L^3	Array	Dissolved Concentration at Eight Points of an Element	Q8DV Q8R		I I
CSQ(8)	M/M	Array	Adsorbed Concentration at Eight Points of an Element	Q8R		I
CSTAR(N)	M/L^3	Array	Lagrangian Concentration at the N-th Node	GM3D ASEMBL ADVTRN ADVBC		O I O O
CVB(I)	M/L^3	Array	Variable Concentration of the I-th Profile at the Present Time	GM3D BC ADVBC		M I I
CVBF(I,J)	M/L^3	Array	Concentration of the I-th Data Point in the J-th Variable Concentration vs. Time Profile	GM3D DATAIN		M M
CW(N)	M/L^3	Array	Nonlinear Iterate of the Concentration at the N-th	GM3D ASEMBL		O I

			Node			
CWQ(8)	M/L^3	Array	Iterate of the Dissolved Concentration at Eight Gaussian Points of the Element	Q8		I
DCOSB(1,I)	--	Array	X-Directional Cosine of the I-th Boundary Side	GM3D DATAIN SURF BC Q4CNVB SFLOW ADVBC Q4ADB		M M O I I I I I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub- routine	Common Block	I,M,O
DCOSB(2,I)	--	Array	Y-Directional Cosine of the I-th Boundary Side	GM3D DATAIN SURF BC Q4CNVB SFLOW ADVBC Q4ADB		M M O I I I I I
DCOSB(3,I)	--	Array	Z-Directional Cosine of the I-th Boundary Side	GM3D DATAIN SURF BC Q4CNVB SFLOW ADVBC Q4ADB		M M O I I I I I
DD	L^2/T	Scalar	Effective Molecular	Q8DV		I

			Diffusion Coefficient			
DELMAX	T	Scalar	Maximum Value of DELT		CREAL	
DELT	T	Scalar	Time Increment	ASEMBL SFLOW PRINTT NDTAU	CREAL	I I I I
DELTO	T	Scalar	Time Increment		CREAL	
DJAC	L^3	Scalar	Determinant of the Jacobian	SHAPE		O
DNX(8)	1/L	Array	Partial Derivative of the Base Function with Respect to X	SHAPE		O
DNY(8)	1/L	Array	Partial Derivative of the Base Function with Respect to Y	SHAPE		O

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)
4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
DNZ(8)	1/L	Array	Partial Dervative of the Base Function wtih Respect to Z	SHAPE		O
DSDCQ(8)	L^3/M	Array	The Derivative of Adsorbed Concentration with Respect to Dissolved Concentration at Eight Points of the Element	Q8		I
DTAU	T	Scalar	Sub-Time Step Size	NDTAU ADVTRN		O I

DTH(I,M)	1/T	Array	(TH(I,M)-THP(I,M))/DELT	GM3D ASEMBL		M I
DTHG(8)	1/T	Array	dTH/dt at Eight Gaussian Points of the Element	Q8		I
ETA	--	Scalar	Local Coordinate of the Particle	XSI3D		O
F(MAXNOD)	--	Array	Array of Real Numbers that are to be Read and Generated Automatically	READR		O
FLOW	M/L	Scalar	Increment of Flow		CFLOW	
FQ(4)	$M/L^2/T$	Array	Normal Flux at Four Points of the Element Surface	Q4BB		I
FRATE	M/T	Scalar	Flow Rate		CFLOW	
FX(N)	$(M/L^2)/T$	Array	X-Direction Material Flux at the N-th Node	GM3D FLUX SFLOW PRINTT STORE		O O I I I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
FY(N)	$M/L^2/T$	Array	Y-Direction Material Flux at the N-th Node	GM3D FLUX SFLOW PRINTT STORE		O O I I I
FZ(N)	$M/L^2/T$	Array	Z-Direction Material Flux at the N-th Node	GM3D FLUX SFLOW PRINTT STORE		O O I I I

GAMA1	--	Scalar	Weighting Factor for Side 1-5 Parallel to the Z-direction		WETZ	
GAMA2	--	Scalar	Weighting Factor for Side 2-6 Parallel to the Z-direction		WETZ	
GAMA3	--	Scalar	Weighting Factor for Side 4-8 Parallel to the Z-direction		WETZ	
GAMA4	--	Scalar	Weighting Factor for Side 3-7 Parallel to the Z-direction		WETZ	
GNLR(I,K)	--	Array	Global Nodal Number of the I-th Local Nodal Number in the K-th Sub-region. This Array is an Input for I = 1, 2, .., NNPLR(K). For I = NNPLR(K)+1, ... NTNPLR(K), this Array is Generated Based on IE(NEL,8) and Inputted GNLR.	GM3D DATAIN PAGEN BLKITR		M M M I
IBC	--	Scalar	Index of Boundary Condition Type	Q4CNVB Q4ADB		I I
IBUG	--	Scalar	Debugging Indicator	BLKITR		I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
ICTYP(MP)	--	Array	Type of Specified-Flux (Cauchy) Profile Assigned to the MP-th Cauchy Side	GM3D DATAIN BC ADVBC		M M I I
IDTYP(NP)	--	Array	Type of Dirichlet Concentration Profile	GM3D DATAIN		M M

			Assigned to the NP-th Dirichlet Node	BC ADVBC		I I
IE(M,I)	--	Array	Global Node Number of the I-th Node of the M-th Element if I is Between 1 and 8. When I = 9, This is an Integer to Indicate the Material Type of the M-th Element.	GM3D DATAIN SURF PAGEN LELGEN AFABTA ASEMBL BC FLUX SFLOW STORE THNODE NDTAU ADVTRN MPLOC ADVBC		M M I I I I I I I I I I I I I I
IGEOM	--	Scalar	Geometry Description Output Control	LELGEN	CINTE	I
IHALFB	--	Scalar	Half Band Width Plus 1	SOLVE		I
ILUMP	--	Scalar	Lumping Indicator		OPTN	
INDTYP(MXTYP)	--	Array	Array of Integers that are to be Read or Generated Automatically	READN		O
INTYP(MP)	--	Array	Type of Specified-Dispersive-Flux (Neumann) Profile Assigned to the MP-th Neumann Side	GM3D DATAIN BC		M M I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O

IOPTIM	--	Scalar	Optimizing Weighting Factor Indicator	AFABTA	OPTN	I
ISB(1,I)	--	Array	Boundary Node Number of the First Node of the I-th Boundary Side	GM3D DATAIN SURF BC SFLOW ADVBC		M M O I I I
ISB(2,I)	--	Array	Boundary Node Number of the Second Node of the I-th Boundary Side	GM3D DATAIN SURF BC SFLOW ADVBC		M M O I I I
ISB(3,I)	--	Array	Boundary Node Number of the Third Node of the I-th Boundary Side	GM3D DATAIN SURF BC SFLOW ADVBC		M M O I I I
ISB(4,I)	--	Array	Boundary Node Number of the Fourth Node of the I-th Boundary Side	GM3D DATAIN SURF BC SFLOW ADVBC		M M O I I I
ISB(5,I)	--	Array	Element Side Index of the I-th Boundary Side: 1=left side, 2=front side, 3=right side, 4=back side, 5=bottom side, 6=top side	GM3D DATAIN SURF BC SFLOW ADVBC		M M O I I I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
ISB(6,I)	--	Array	Element Number to which the I-th Boundary Side Belongs	GM3D DATAIN SURF BC SFLOW ADVBC		M M O I I I
ISC(1,MP)	--	Array	Global Node Number of the First Node of the MP-th Specified-Flux (Cauchy) Side	GM3D DATAIN BC ADVBC		M M I I
ISC(2,MP)	--	Array	Global Node Number of the Second Node of the MP-th Specified-Flux (Cauchy) Side	GM3D DATAIN BC ADVBC		M M I I
ISC(3,MP)	--	Array	Global Node Number of the Third Node of the MP-th Specified-Flux (Cauchy) Side	GM3D DATAIN BC ADVBC		M M I I
ISC(4,MP)	--	Array	Global Node Number of the Fourth Node of the MP-th Specified-Flux (Cauchy) Side	GM3D DATAIN BC ADVBC		M M I I
ISC(5,MP)	--	Array	Boundary Side Number of the MP-th Specified-Flux (Cauchy) Side	GM3D DATAIN BC ADVBC		M M I I
ISN(1,MP)	--	Array	Global Node Number of the First Node of the MP-th Specified-Dispersive-Flux (Neumann) Side	GM3D DATAIN BC		M M I
ISN(2,MP)	--	Array	Global Node Number of the Second Node of the MP-th	GM3D DATAIN		M M

			Specified-Dispersive-Flux (Neumann) Side	BC		I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
ISN(3,MP)	--	Array	Global Node Number of the Third Node of the MP-th Specified-Dispersive-Flux (Neumann) Side	GM3D DATAIN BC		M M I
ISN(4,MP)	--	Array	Global Node Number of the Fourth Node of the MP-th Specified-Dispersive-Flux (Neumann) Side	GM3D DATAIN BC		M M I
ISN(5,MP)	--	Array	Boundary Side Number of the MP-th Neumann Side	GM3D DATAIN BC		M M I
ISTYP(M)	--	Array	Type of Source Profile Assigned to the M-th Element	GM3D DATAIN ASEMBL SFLOW		M M I I
ISV(1,MP)	--	Array	Global Node Number of the First Node of the MP-th Variable Side	GM3D DATAIN BC ADVBC		M M I I
ISV(2,MP)	--	Array	Global Node Number of the Second Node of the MP-th Variable Side	GM3D DATAIN BC ADVBC		M M I I
ISV(3,MP)	--	Array	Global Node Number of the Third Node of the MP-th Variable Side	GM3D DATAIN BC ADVBC		M M I I
ISV(4,MP)	--	Array	Global Node Number of the	GM3D		M

			Fourth Node of the MP-th Variable Side	DATAIN BC ADVBC		M I I
ISV(5,MP)	--	Array	Boundary Side Number of the MP-th Variable Side	GM3D DATAIN BC ADVBC		M M I I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
ITIM	--	Scalar	Time-Step Index	PRINTT		I
IVTYP(MP)	--	Array	Type of Variable Concen-tration Profile Assigned to the MP-th Variable Side	GM3D DATAIN BC ADVBC		M M I I
IWET	--	Scalar	Upstream Weighting Indicator		OPTN	
IWTYP(I)	--	Array	Type of Source Profile Assigned to the I-th Node	GM3D DATAIN ASEMBL SFLOW		M M I I
KANALY	--	Scalar	Analytical Input Control	ALLFCT		I
KCAI	--	Scalar	Analytical Cauchy-Flux Input Control		CCBC	
KDAI	--	Scalar	Analytical Dirichlet Input Control		CDBC	
KDIAG	--	Scalar	Diagnostic Output Table Index	PRINTT		O
KDSK(I)	--	Array	Store Results on Logical Unit 12 for the I-th Time Step? 0=no, 1=yes	GM3D DATAIN		M M

KDSKO	--	Scalar	Disk Output Control		CINTE	
KFLOW	--	Scalar	Flow Indicator -1 = Initial or Pre- initial Condition 0 = Steady-state 1 = Transient	SFLOW		I
KKK	--	Scalar	Decomposition or Back Substitution Indicator 1 = Decomposition 2 = Back Substitution	SOLVE		I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
KNAI	--	Scalar	Analytical Neumann Flux Input Control		CNBC	
KOUT	--	Scalar	Output-Table Number Index	PRINTT		O
KPR(I)	--	Array	Line Printing Indicator for the I-th Time Step: 0 = print nothing 1 = print fluxes through all types of boundaries 2 = print concentration also 3 = print material flux also	GM3D DATAIN BLKITR PRINTT		M M I I
KPRO	--	Scalar	Output Control		CINTE	
KRAI	--	Scalar	Analytical Rainfall Input Control		CVBC	
KSAI	--	Scalar	Element-source Input Control		CELS	
KSORP	--	Scalar	Sorption Model Indicator	THNODE	OPTN	I

KSS	--	Scalar	Steady-State I.C. Control	ASEMBL	CINTE	I
KVI	--	Scalar	Flow Variable Input Control		CINTE	
KWAI	--	Scalar	Well Source Input Control 0 = Tabular Input 1 = Analytical Input		CNPS	
LAMBDA	1/T	Scalar	Decay Constant	Q8		I
LES(I)	--	Array	Global Element Number of the I-th Element-Source	GM3D DATAIN ASEMBL SFLOW		M M I I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
LMAXDF(K)	--	Array	Maximum No. of Difference Between Nodes for Any Element in the K-th Local Region. This Array is Generated from the Array LNOJCN.	GM3D PAGEN BLKITR DATAIN		M O I M
LMXBW	--	Scalar	Maximum No. of the Band-width in Any Subregion		LGEOM	
LMXBWK	--	Scalar	Maximum No. of the Band-width in Any Subregion			
LMXNP	--	Scalar	Maximum No. of Nodal Points in Any Subregion, Including Interior Nodes and Global Boundary Nodes		LGEOM	
LMXNPK	--	Scalar	Maximum No. of Nodal Points in Any Subregion,			

			Including Interior Nodes and Global Boundary Nodes			
LNOJCN(J, I,K)	--	Array	Local Node Number of the J-th Node Connecting to I-th Local Node for the K-th Subregion. This Array is Generated from GNLR and I = 1, 2, 3, ...,NNPLR(K).	GM3D PAGEN BLKITR DATAIN		M O I M
LOCP	--	Scalar	Indicator of the Location of the Fictitious Particle	MPLOC		O
LRL(I,N)	--	Array	Global Element Number of the I-th Element Connect- ing to the N-th Global Node	GM3D LELGEN NDTAU ADVTRN MPLOC DATAIN PAGEN SURF		M O I I I M O I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
LRN(I,N)	--	Array	Global Node Number of the I-th Node Connecting to the N-th Global Node	GM3D PAGEN ASEMBL BC NDTAU DATAIN		M O I I I M
LTMXNK	--	Scalar	Maximum No. of Total Nodal Points in Any Subregion, Including Interior Nodes, and Global Boundary Nodes			
LTMXNP	--	Scalar	Maximum No. of Total Nodal Points in Any Subregion, Including Interior Nodes,		LGEOM	

			and Global Boundary Nodes			
LUBAR	--	Scalar	Logical Unit for Storing Binary Boundary Arrays	GM3D DATAIN		I I
LUFLW	--	Scalar	Logical Unit for Flow Data	GM3D DATAIN		I I
LUINP	--	Scalar	Logical Unit for Input Data	GM3D DATAIN READR READN		I I I I
LUOUT	--	Scalar	Logical Unit for Output Data	GM3D DATAIN SURF PAGEN LELGEN ASEMBL BLKITR PRINTT READR READN NDTAU ADVTRN XSI3D BC		I I I I I I I I I I I I I I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
LUPAR	--	Scalar	Logical Unit for Storing Binary Pointer Arrays	GM3D		I
LUSTO	--	Scalar	Logical Unit for Storing Binary Output	GM3D STORE		I I
M	--	Scalar	Element Number where the Fictitious Particle is Located	XSI3D		I
MAXBES	--	Scalar	Maximum No. of Boundary		SGEOM	

			Element Surfaces			
MAXBNP	--	Scalar	Maximum No. of Boundary Nodal Points		SGEOM	
MAXBW	--	Scalar	Maximum No. of Band Width	SOLVE		I
MAXEL	--	Scalar	Maximum No. of Elements		SGEOM	
MAXELK	--	Scalar	Maximum No. of Elements			
MAXMAT	--	Scalar	Maximum No. of Materials		MATL	
MAXNOD	--	Scalar	Maximum No. of Data Points to be Read	READR		I
MAXNP	--	Scalar	Maximum No. of Nodal Points	SOLVE FCOS	SGEOM	I I
MAXNPK	--	Scalar	Maximum No. of Nodes			
MP	--	Scalar	Element where the Fictitious Particle is Located	MPLOC		O
MXBESK	--	Scalar	Maximum No. of Boundary-Element Surfaces			
MXBNPK	--	Scalar	Maximum No. of Boundary Nodal Points			

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
MXCDP	--	Scalar	Maximum No. of Data Points on Each Specified-Flux (Cauchy) Profile		CCBC	
MXCDPK	--	Scalar	Maximum No. of Data Points on Each Specified-Flux			

Variable	Units	Type	Description	Subroutine	Common Block	I,M,O
			(Cauchy) Profile			
MXCES	--	Scalar	Maximum No. of Cauchy Element Surfaces		CCBC	
MXCESK	--	Scalar	Maximum No. of Cauchy Element Surfaces			
MXCNP	--	Scalar	Maximum No. of Cauchy Nodal Points		CCBC	
MXCNPK	--	Scalar	Maximum No. of Cauchy Nodal Points			
MXCPR	--	Scalar	Maximum No. of Cauchy-Flux Profiles		CCBC	
MXCPRK	--	Scalar	Maximum No. of Cauchy-Flux Profiles			
MXDDP	--	Scalar	Maximum No. of Data Points on Each Dirichlet Profile		CDBC	
MXDDPK	--	Scalar	Maximum No. of Data Points on Each Dirichlet Profile			
MXDNP	--	Scalar	Maximum No. of Dirichlet Nodal Points		CDBC	
MXDNPK	--	Scalar	Maximum No. of Dirichlet Nodal Points			
MXDP	--	Scalar	Maximum No. of Data Points in Any Profile	ALLFCT		I
MXDPR	--	Scalar	Maximum No. of Dirichlet Total Head Profiles		CDBC	

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

MXDPRK	--	Scalar	Maximum No. of Dirichlet Total Head Profiles	
MXDTC	--	Scalar	Maximum No. of DELT Changes	SGEOM
MXDTCK	--	Scalar	Maximum No. of DELT Changes	
MXJBD	--	Scalar	Maximum No. of Nonzero Elements in Any Row	SGEOM
MXJBDK	--	Scalar	Maximum No. of Nonzero Elements in Any Row	
MXKBD	--	Scalar	Maximum No. of Elements Surrounding a Global Node	SGEOM
MXKBDK	--	Scalar	Maximum No. of Elements Surrounding a Global Node	
MXMATK	--	Scalar	Maximum No. of Material Types	
MXMPMK	--	Scalar	Maximum No. of Material Properties per Material	
MXMPPM	--	Scalar	Maximum No. of Material Properties per Material	MATL
MXNDP	--	Scalar	Maximum No. of Data Points on Each Specified Dispersive-Flux (Neumann) Profile	CNBC
MXNDPK	--	Scalar	Maximum No. of Data Points on Each Neumann-Flux Profile	
MXNES	--	Scalar	Maximum No. of Neumann Element Surfaces	CNBC

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
MXNESK	--	Scalar	Maximum No. of Neumann Element Surfaces			
MXNNP	--	Scalar	Maximum No. of Neumann Nodal Points		CNBC	
MXNNPK	--	Scalar	Maximum No. of Neumann Nodal Points			
MXNPR	--	Scalar	Maximum No. of Neumann-Flux Profiles		CNBC	
MXNPRK	--	Scalar	Maximum No. of Neumann-Flux Profiles			
MXNTI	--	Scalar	Maximum No. of Time Steps		SGEOM	
MXNTIK	--	Scalar	Maximum No. of Time Steps			
MXPR	--	Scalar	Maximum No. of Profiles	ALLFCT		I
MXRDP	--	Scalar	Maximum No. of Data Points on Each Rainfall Profile		CVBC	
MXREGN	--	Scalar	Maximum No. of Subregions		LGEOM	
MXRGNK	--	Scalar	Maximum No. of Subregions			
MXRPR	--	Scalar	Maximum No. of Rainfall Profiles		CVBC	
MXSDP	--	Scalar	Maximum No. of Data Points in Any Element Source/Sink Profile		CELS	
MXSDPK	--	Scalar	Maximum No. of Data Points in Any Element Source/ Sink Profile			

MXSEL	--	Scalar	Maximum No. of Source Elements		CELS	

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)
4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
MXSELK	--	Scalar	Maximum No. of Source Elements			
MXSPR	--	Scalar	Maximum No. of Element Source Profiles		CELS	
MXSPRK	--	Scalar	Maximum No. of Element Source Profiles			
MXTYP	--	Scalar	Maximum No. of Integers Allowed to be Read	READN		I
MXVDPK	--	Scalar	Maximum No. of Data Points on Each Rainfall Profile			
MXVES	--	Scalar	Maximum No. of Variable Element Surfaces		CVBC	
MXVESK	--	Scalar	Maximum No. of Variable Element Surfaces			
MXVNP	--	Scalar	Maximum No. of Variable Nodal Points		CVBC	
MXVNPK	--	Scalar	Maximum No. of Variable Nodal Points			
MXVPRK	--	Scalar	Maximum No. of Rainfall Profiles			
MXWDP	--	Scalar	Maximum No. of Data Points on Each Well Source/Sink Profile		CNPS	

MXWDPK	--	Scalar	Maximum No. of Data Points on Each Well Source/Sink Profile			
MXWNP	--	Scalar	Maximum No. of Well Nodal Points		CNPS	
MXWNPK	--	Scalar	Maximum No. of Well Nodal Points			

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
MXWPR	--	Scalar	Maximum No. of Well Source/Sink Profile		CNPS	
MXWPRK	--	Scalar	Maximum No. of Well Source/Sink Profiles			
N(8)	--	Array	Base Function of Eight Points of the Element	SHAPE		O
NBES	--	Scalar	Number of Boundary Element Surfaces		CGEOM	
NBNP	--	Scalar	Number of Boundary Nodal Points		CGEOM	
NCDP	--	Scalar	Number of Data Points on Specified-Flux (Cauchy) Profiles		CCBC	
NCES	--	Scalar	Number of Cauchy Boundary Element Sides		CCBC	
NCM	--	Scalar	Number of Cycles per Time Step		CINTE	
NCNP	--	Scalar	Number of Cauchy Boundary Nodal Points		CCBC	
NCPR	--	Scalar	Number of Specified-Flux		CCBC	

			(Cauchy) Profiles			
NDDP	--	Scalar	Number of Data Points on Dirichlet Profiles		CDBC	
NDNP	--	Scalar	Number of Dirichlet Nodal Points		CDBC	
NDP	--	Scalar	Number of Data Points in Any Profile	ALLFCT		I
NDPR	--	Scalar	Number of Dirichlet Profiles		CDBC	

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
NDTCHG	--	Scalar	Number of Times to Reset Time Step Size		CGEOM	
NEL	--	Scalar	Number of Elements		CGEOM	
NITER	--	Scalar	Number of Iterations per Cycle	BLKITR	CINTE	I
NMAT	--	Scalar	Number of Materials		MATL	
NMPPM	--	Scalar	Number of Material Properties per Material		MATL	
NNDP	--	Scalar	Number of Data Points on Specified-Dispersive-Flux (Neumann) Profiles		CNBC	
NNES	--	Scalar	Number of Neumann Boundary Element Sides		CNBC	
NNNP	--	Scalar	Number of Neumann Boundary Nodal Points		CNBC	
NNP	--	Scalar	Number of Nodal Points	SOLVE	CGEOM	I

				READR		I
NNPLR(K)	--	Array	Number of Nodes for the K-th Subregion Including Interior and Global Boundary Nodes	GM3D DATAIN PAGEN BLKITR		M M I I
NNPR	--	Scalar	Number of Specified-Dispersive-Flux (Neumann) Profiles		CNBC	
NODENP	--	Scalar	Nodal Point of Interest	MPLOC		I
NP1	--	Scalar	First Node on the Surface	FCOS		I
NP2	--	Scalar	Second Node on the Surface	FCOS		I
NP3	--	Scalar	Third Node on the Surface	FCOS		I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	**Units**	**Type**	**Description**	**Sub-routine**	**Common Block**	**I,M,O**
NPBB(I)	--	Array	Global Node Number on the I-th Boundary Node	GM3D DATAIN SURF SFLOW NDTAU ADVTRN ADVBC		M M O I I I I
NPCB(NP)	--	Array	Global Nodal Number of the NP-Cauchy Node on Input. Then it is Changed to Contain the Boundary Node Number	GM3D DATAIN SFLOW ADVBC		M M I I
NPDB(NP)	--	Array	Global Node Number of the NP-Dirichlet Node on Input. Then it is Changed to Contain the Boundary Node Number	GM3D DATAIN BC ADVBC SFLOW		M M I I I

NPITER	--	Scalar	Number of Blockwise Iterations Allowed		CINTE	
NPNB(NP)	--	Array	Global Nodal Number of the NP-Neumann Node on Input. Then it is Changed to Contain the Boundary Node Number.	GM3D DATAIN SFLOW		M M I
NPR	--	Scalar	Number of Profiles	ALLFCT		I
NPROB	--	Scalar	Problem Number	STORE		I
NPVB(NP)	--	Array	Global Nodal Number of the NP-Variable Node on Input. Then it is Changed to Contain the Boundary Node Number	GM3D DATAIN SFLOW ADVBC		M M I I
NPW(I)	--	Array	Global Node Number of the I-th Well Node	GM3D DATAIN ASEMBL SFLOW		M M I I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
NRDP	--	Scalar	Number of Data Points on Rainfall Profiles		CVBC	
NREGN	--	Scalar	Number of Subregions		LGEOM	
NRPR	--	Scalar	Number of Rainfall Profiles		CVBC	
NSDP	--	Scalar	Number of Data Points in Any Element Source/ Sink Profile		CELS	
NSEL	--	Scalar	Number of Source/Sink		CELS	

Variable	Units	Type	Description	Subroutine	Common Block	I,M,O
			Elements			
NSPR	--	Scalar	Number of Source/Sink Profiles		CELS	
NTAU	--	Scalar	Number of Subtime Steps	NDTAU ADVTRN		O I
NTI	--	Scalar	Number of Time Increments		CGEOM	
NTNPLR(K)	--	Array	Total Number of Nodes for the K-th Subregion Including Interior, Global Boundary, and Intraboundary Nodes	GM3D DATAIN PAGEN		M M O
NTYPE	--	Scalar	Number of Integers to be Read	READN		I
NVES	--	Scalar	Number of Variable Boundary Element Sides	CVBC		
NVNP	--	Scalar	Number of Variable Boundary Nodal Points	CVBC		
NWDP	--	Scalar	Number of Data Points in Any Point-Source Profile		CNPS	
NWNP	--	Scalar	Number of Wells		CNPS	

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Subroutine	Common Block	I,M,O
NWPR	--	Scalar	Number of Well Source Profiles		CNPS	
OME	--	Scalar	Iteration Parameter for a Non-Linear Equation	BLKITR	CREAL	I

Variable	Units	Type	Description	Subroutine	Common Block	I,M,O
OMI	--	Scalar	Relaxation Parameter for Pointwise Solution		CREAL	
PR(MXPR)	L/T,L, M/L^3	Array	Profile Value at Time t	ALLFCT		O
PRF(MXDP, MXPR)	L/T,L, M/L^3	Array	Profile Value of the Data Point on the Profile	ALLFCT		I
PROP(1,I)	L^3/M	Array	Distribution Coefficient or Freudlich K or Langmuir K	GM3D		M
				DATAIN		M
				AFABTA		I
				FLUX		I
				ASEMBL		I
				SFLOW		I
				THNODE		I
PROP(2,I)	M/L^3	Array	Bulk Density	GM3D		M
				DATAIN		M
				AFABTA		I
				FLUX		I
				ASEMBL		I
				SFLOW		I
				THNODE		I
PROP(3,I)	L	Array	Longitudinal Dispersivity	GM3D		M
				DATAIN		M
				AFABTA		I
				FLUX		I
				ASEMBL		I
				SFLOW		I
				THNODE		I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Subroutine	Common Block	I,M,O
PROP(4,I)	L	Array	Transverse Dispersivity	GM3D		M
				DATAIN		M
				AFABTA		I
				FLUX		I

				ASEMBL	I
				SFLOW	I
				THNODE	I
PROP(5,I)	L^2/T	Array	Molecular Diffusion Coefficient	GM3D	M
				DATAIN	M
				AFABTA	I
				FLUX	I
				ASEMBL	I
				SFLOW	I
				THNODE	I
PROP(6,I)	--	Array	Tortuosity	GM3D	M
				DATAIN	M
				AFABTA	I
				FLUX	I
				ASEMBL	I
				SFLOW	I
				THNODE	I
PROP(7,I)	1/L	Array	Decay Constant	GM3D	M
				DATAIN	M
				AFABTA	I
				FLUX	I
				ASEMBL	I
				SFLOW	I
				THNODE	I
PROP(8,I)	--	Array	Freundlich N or Langmuir SMAX	GM3D	M
				DATAIN	M
				AFABTA	I
				FLUX	I
				ASEMBL	I
				SFLOW	I
				THNODE	I
QA(8,8)	--	Array	An Element Matrix	Q8	O
QAA(8,8)	--	Array	An Element Matrix	Q8	O

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Sub- Common

Variable	Units	Type	Description	routine	Block	I,M,O
QB(8,8)	--	Array	An Element Matrix	Q8DV Q8		O O
QBMP	$M/L^2/T$	Scalar	Flux or Concentration of the Boundary Side	Q4CNVB Q4ADB		I I
QC(8,8)	--	Array	An Element Matrix	Q8		O
QCB(I)	$M/L^2/T$	Array	Value of Cauchy Flux at the Present Time of the I-th Cauchy Flux Profile	GM3D BC ADVBC		M I I
QCBF(I,J)	$M/T/L^2$	Array	Flux of the I-th Data Point in the J-th Cauchy Flux vs. Time Profile	GM3D DATAIN		M M
QDM	--	Scalar	Integration of Local Variable S	Q8R		O
QNB(I)	$M/L^2/T$	Array	Value of Neumann Flux at the Present Time of the I-th Neumann Flux Profile	GM3D BC		M I
QNBF(I,J)	$M/T/L^2$	Array	Flux of the I-th Data Point in the J-th Neumann Flux vs. Time Profile	GM3D DATAIN		M M
QR(8)	--	Array	An Element Load Vector	Q8		O
QRM	--	Scalar	Integration of TH*C	Q8R		O
QRX(8)	--	Array	Element Load Vector for X-Flux	Q8DV		O
QRY(8)	--	Array	Element Load Vector for Y-Flux	Q8DV		O
QRZ(8)	--	Array	Element Load Vector for Z-Flux	Q8DV		O
QV(8,8)	--	Array	An Element Matrix	Q8		O

R(MAXNP)	--	Array	Load Vector	SOLVE		M

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
RHOB	M/L^3	Scalar	Bulk Density of the Material in Element	Q8		I
RI(N)	--	Array	Working Array Used in Subroutines BLKITR and ADVBC	GM3D BLKITR ADVBC		M O M
RL(N)	--	Array	Working Array Used in Subroutine ADVBC	GM3D ADVBC		M M
RLD(N)	--	Array	An Array to Store the Right Hand Side of the N-th Equation of the Assembled Global Load Vector	GM3D ASEMBL BC		M O O
RLDG(MAXNP)	--	Array	Global Load Vector	BLKITR		I
RLDL(N)	--	Array	Assembled Load Vector for a Subregion	GM3D BLKITR		M I
RQ(4)	M/T	Array	Integrated Flux at Four Nodes of the Element Surface	Q4CNVB Q4BB		O O
RQI(4)	$M/L^2/T$	Array	Material-Flux at Four Nodes of the Surface	Q4ADB		O
RQL(4)	$L^3/L^2/T$	Array	Flow-Flux at Four Nodes of the Surface	Q4ADB		O
SOS(I,1)	$L^3/L^2/T$	Array	Source Flow Rate of the I-th Profile at Time t	GM3D ASEMBL SFLOW		M I I

SOS(I,2)	$L^3/L^2/T$	Array	Source Concentration of the I-th Profile at Time t	GM3D ASEMBL SFLOW		M I I
SOSC	M/L^3	Scalar	Source Concentration	Q8		I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
SOSCP	M/L^3	Scalar	Concentration in Element-Source	Q8R		I
SOSF (I,J,1)	$L^3/T/L^3$	Array	Source Flow Rate of the I-th Data Point in the J-th Profile	GM3D DATAIN		M M
SOSF (I,J,2)	M/L^3	Array	Source Concentration of the I-th Data Point in the J-th Profile	GM3D DATAIN		M M
SOSM	M/T	Scalar	Integration of Q*Cin	Q8R		O
SOSQ	L^3/T	Scalar	Element-Source Flow Rate	Q8		I
SOSQP	L^3/T	Scalar	Element-Source Flow Rate	Q8R		I
SS	--	Scalar	XSI-Coordinate of the Gaussian Point	SHAPE		I
SWQ(8)	M/T	Array	Iterate of the Adsorbed Concentration at Eight Gaussian Points of the Element	Q8		I
T	T	Scalar	Time	ALLFCT		I
TAU	--	Scalar	Tortuosity	Q8		I
TCDBF(I,J)	T	Array	Time of the I-th Data Point in the J-th Dirichlet Concentration	GM3D DATAIN		M M

			vs. Time Profile			
TCVBF(I,J)	T	Array	Time of the I-th Data Point in the J-th Variable Concentration vs. Time Profile	GM3D DATAIN		M M
TDTCH(I)	T	Array	Time of the I-th Time to Reset Time-Step Size (= DELT0)	GM3D DATAIN		M M

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
TFLOW	M/L	Scalar	Total Flow		CFLOW	
TH(I,M)	--	Array	Moisture Content at the I-th Node of the M-th Element	GM3D FLUX ASEMBL SFLOW THNODE		M I I I I
THG(8)	--	Array	Moisture Content at Eight Gaussian Points of the Element	Q8 Q8R		I I
THN(N)	--	Array	Moisture Content at the N-th Node	GM3D THNODE NDTAU ADVTRN ADVBC		M O I I I
THP(I,M)	--	Array	Value of TH(I,M) at the Previous Time	GM3D ASEMBL THNODE		M I I
THQ(8)	--	Array	Moisture Content at Eight Points of the Element	Q8DV		I

TIME	T	Scalar	Time	DATAIN PRINTT STORE		M I I
TITLE	--		Title of the Problem	STORE		I
TMAX	T	Scalar	Maximum Value of Time		CREAL	
TOLA	L	Scalar	Steady-State Tolerance		CREAL	
TOLB	L	Scalar	Transient-State Tolerance	BLKITR	CREAL	I
TPRF(MXDP, MXPR)	T	Array	Time of the Data Point on the Profile	ALLFCT		I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
TQCBF(I,J)	T	Array	Time of the I-th Data Point in the J-th Cauchy Flux vs. Time Profile	GM3D DATAIN		M M
TQNBF(I,J)	T	Array	Time of the I-th Data Point in the J-th Neumann Flux vs. Time Profile	GM3D DATAIN		M M
TSOSF(I,J)	T	Array	Time of the I-th Data Point in the J-th Element Source Profile	GM3D DATAIN		M M
TT	--	Scalar	Eta-Coordinate of the Gaussian Point	SHAPE		I
TWSSF(I,J)	T	Array	Time of the I-th Data Point in J-th Well Source Profile	GM3D DATAIN		M M
UU	--	Scalar	Zeta-Coordinate of the Gaussian Point	SHAPE		I

VX(N)	L/T	Array	X-Component Velocity at the N-th Node	GM3D		M
				FLUX		I
				AFABTA		I
				ASEMBL		I
				BC		I
				NDTAU		I
				ADVTRN		I
				ADVBC		I
VXP(N)	L/T	Array	Value of VX(N) at the Previous Time	GM3D		M
				AFABTA		I
				ASEMBL		I
				BC		I
				NDTAU		I
				ADVTRN		I
				ADVBC		I
VXQ(8)	L/T	Array	X-Velocity of Eight Nodes of the Element	Q8DV		I
				Q8		I
				Q4CNVB		I
				Q4ADB		I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	**Units**	**Type**	**Description**	**Sub-routine**	**Common Block**	**I,M,O**
VY(N)	L/T	Array	Y-Component Velocity at the N-th Node	GM3D		M
				AFABTA		I
				FLUX		I
				ASEMBL		I
				BC		I
				NDTAU		I
				ADVTRN		I
				ADVBC		I
VYP(N)	L/T	Array	Value of VY(N) at the Previous Time	GM3D		M
				AFABTA		I
				ASEMBL		I
				BC		I
				NDTAU		I
				ADVTRN		I
				ADVBC		I

VYQ(8)	L/T	Array	Y-Velocity of Eight Nodes of the Element	Q8DV		I
				Q8		I
				Q4CNVB		I
				Q4ADB		I
VZ(N)	L/T	Array	Z-Component Velocity at the N-th Node	GM3D		M
				AFABTA		I
				FLUX		I
				ASEMBL		I
				BC		I
				NDTAU		I
				ADVTRN		I
				ADVBC		I
VZP(N)	L/T	Array	Value of VZ(N) at the Previous Time	GM3D		M
				AFABTA		I
				ASEMBL		I
				BC		I
				NDTAU		I
				ADVTRN		I
				ADVBC		I
VZQ(8)	L/T	Array	Z-Velocity of Eight Nodes of the Element	Q8DV		I
				Q8		I
				Q4CNVB		I
				Q4ADB		I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	**Units**	**Type**	**Description**	**Sub-routine**	**Common Block**	**I,M,O**
W(8)	--	Array	Weighting Function at Eight Points of the Element	SHAPE		O
WETAB(J, M)	--	Array	Weighting Factor for the J-th Side of the M-th Element	GM3D		M
				AFABTA		O
				FLUX		I
				ASEMBL		I
WSS(I,1)	L^3/T	Array	Well Source Flow Rate of the I-th Profile at Time t	GM3D		M
				ASEMBL		I
				SFLOW		I

WSS(I,2)	M/L^3	Array	Well Source Concentration at the I-th Profile	GM3D ASEMBL SFLOW	M I I
WSSF (J,I,1)	L^3/T	Array	Well Source Flow Rate of the I-th Data Point in the J-th Profile	GM3D DATAIN	M M
WSSF (J,I,2)	M/L^3	Array	Well Source Concentration of the I-th Data Point in the J-th Profile	GM3D DATAIN	M M
WWRK(N)	--	Array	Working Array Used in Subroutine THNODE	GM3D THNODE	M O
X(N)	L	Array	X-Coordinate of the N-th Node	GM3D DATAIN SURF AFABTA FLUX ASEMBL BC SFLOW STORE THNODE NDTAU ADVTRN MPLOC XSI3D ADVBC	M M I I I I I I I I I I I I I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (continued)

4

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
XP	L	Scalar	X-Coordinate of the Fictitious Particle	MPLOC FCOS XSI3D		I I I
XQ(8)	L	Array	X-Coordinate at Eight Points of the Element	Q8DV Q8 SHAPE Q4CNVB		I O I I

Variable	Units	Type	Description	Sub-routine	Common Block	I,M,O
				Q4BB		I
				Q8R		I
				Q4ADB		I
XSI	--	Scalar	Local Coordinate of the Particle	XSI3D		O
Y(N)	L	Array	Y-Coordinate of the N-th Node	GM3D		M
				DATAIN		M
				SURF		I
				AFABTA		I
				FLUX		I
				ASEMBL		I
				BC		I
				SFLOW		I
				STORE		I
				THNODE		I
				NDTAU		I
				ADVTRN		I
				MPLOC		I
				FCOS		I
				XSI3D		I
				ADVBC		I
YP	L	Scalar	Y-Coordinate of the Fictitious	MPLOC		I
				FCOS		I
				XSI3D		I
YQ(8)	L	Array	Y-Coordinate at Eight Points of the Element	Q8DV		I
				Q8		O
				SHAPE		I
				Q4CNVB		I
				Q4BB		I
				Q8R		I
				Q4ADB		I

TABLE D-2. 3DLEWASTE PROGRAM VARIABLES, UNITS, LOCATION, AND VARIABLE DESIGNATION (concluded)

4

Z(N)	L	Array	Z-Coordinate of the N-th Node	GM3D	M
				DATAIN	M
				SURF	I
				AFABTA	I
				FLUX	I
				ASSEMBL	
	I				
				BC	I
				SFLOW	I
				STORE	I
				THNODE	I
				NDTAU	I
				ADVTRN	I
				MPLOC	I
				FCOS	I
				XSI3D	I
				ADVBC	I
ZP	L	Scalar	Z-Coordinate of the Fictitious Particle	MPLOC	I
				FCOS	I
				XSI3D	I
ZQ(8)	L	Array	Z-Coordinate at Eight Points of the Element	Q8DV	I
				Q8	O
				SHAPE	I
				Q4CNVB	I
				Q4BB	I
				Q8R	I
				Q4ADB	I
ZTA	--	Scalar	Local Coordinate of the Particle	XSI3D	O