MODIFICATIONS AND CORRECTIONS TO THE
FINITE-DIFFERENCE MODEL FOR SIMULATION
OF THREE-DIMENSIONAL GROUND-WATER FLOW
By Lynn J. Torak
# MODIFICATIONS AND CORRECTIONS TO THE FINITE-DIFFERENCE MODEL FOR SIMULATION OF THREE-DIMENSIONAL GROUND-WATER FLOW

## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>1</td>
</tr>
<tr>
<td>Introduction</td>
<td>2</td>
</tr>
<tr>
<td>Modifications</td>
<td>3</td>
</tr>
<tr>
<td>Head-Dependent Source-Sink Functions</td>
<td>3</td>
</tr>
<tr>
<td>General mathematical form</td>
<td>3</td>
</tr>
<tr>
<td>Formulation in the 3-D model</td>
<td>4</td>
</tr>
<tr>
<td>Streams or rivers</td>
<td>6</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>11</td>
</tr>
<tr>
<td>Springs or drains</td>
<td>14</td>
</tr>
<tr>
<td>Features</td>
<td>14</td>
</tr>
<tr>
<td>Discussion</td>
<td>16</td>
</tr>
<tr>
<td>Acceleration or Dampening Factor for the Strongly Implicit Procedure</td>
<td>17</td>
</tr>
<tr>
<td>Optional Methods for Computing the Maximum Iteration Parameter</td>
<td>18</td>
</tr>
<tr>
<td>Corrections</td>
<td>24</td>
</tr>
<tr>
<td>Dimensional Nonhomogeneity of Coefficients in ENTRY ITER</td>
<td>24</td>
</tr>
<tr>
<td>Use of Transmissivities for Computing T-Coefficients for Water-Table</td>
<td>24</td>
</tr>
<tr>
<td>Simulations Using Equation 3</td>
<td>25</td>
</tr>
<tr>
<td>Occurrence of a Nonzero TK Value Between Active and Inactive Nodes</td>
<td>26</td>
</tr>
<tr>
<td>Computation of Vertical Flow from Inactive or Constant-Head Nodes</td>
<td>27</td>
</tr>
<tr>
<td>Assignment of N3=1 in COEF Subroutine</td>
<td>27</td>
</tr>
<tr>
<td>Incompatibility Between Formats for Punched Output of PHI Matrix and</td>
<td>28</td>
</tr>
<tr>
<td>Data-Input Requirements</td>
<td>28</td>
</tr>
<tr>
<td>Improper Dimensioning of JFLO and FLOW</td>
<td>28</td>
</tr>
<tr>
<td>References</td>
<td>30</td>
</tr>
<tr>
<td>Appendix I: Additional Data Input Instructions for Modifications</td>
<td>I-1</td>
</tr>
<tr>
<td>Appendix II: Definition of New Variables Used in the Modified Model</td>
<td>II-1</td>
</tr>
<tr>
<td>Appendix III: List of Model Corrections</td>
<td>III-1</td>
</tr>
<tr>
<td>Appendix IV: List of Model Modifications</td>
<td>IV-1</td>
</tr>
<tr>
<td>Appendix V: Example of Input to Modified Model</td>
<td>V-1</td>
</tr>
<tr>
<td>Appendix VI: Example of Output from Modified Model</td>
<td>VI-1</td>
</tr>
</tbody>
</table>
ILLUSTRATIONS

Figure 1 - Relationship between threshold elevations for head dependent source-sink functions and aquifer head..........................7

Figure 2 - Areal relationship between the streambed and the grid block used to compute CSS in equation 7...............................8

Figure 3 - Relationship of threshold elevations and aquifer head to the evapotranspiration rate, QSS.................................12
ABSTRACT

This report describes modifications that are incorporated into the finite-difference model for simulation of ground-water flow in three dimensions by Trescott, and Trescott and Larson. These modifications extend the application of this model to simulations involving head-dependent sources and sinks (i.e., rivers, evapotranspiration, and springs or drains). Other modifications are made that enhance the iterative-solution process of the Strongly Implicit Procedure (SIP). An acceleration (or dampening) factor is introduced to the matrix equation that is to be solved, and optional methods of computing iteration parameters are incorporated into the original model.

This report also describes corrections to the model that eliminate errors in the equation formulation and in mass-balance computations for certain types of simulations. Additional data-input instructions, definitions of new variables, and a list of program-statement changes are given in the Appendix.
MODIFICATIONS AND CORRECTIONS TO THE FINITE-DIFFERENCE MODEL
FOR SIMULATION OF THREE-DIMENSIONAL GROUND-WATER FLOW

INTRODUCTION

Users of the finite-difference model for simulation of three-dimensional ground-water flow by Trescott (1975), and Trescott and Larson (1976) have indicated a need for simulating head-dependent source-sink functions (i.e., rivers, evapotranspiration, and drains or springs). They have also exposed some shortcomings of the model which may cause errors in the equation formulation for certain types of problems. This report describes modifications that are incorporated into the standard 3-D model for simulating these types of functions and other modifications which, in general, may enhance convergence of an iterative solution by the Strongly Implicit Procedure (SIP). This report also contains corrections to the model that eliminate errors in (a) formulating coefficients for SIP when simulating a water-table aquifer with the Basic 3-D approach (Equation 3, Trescott, 1975); (b) formulating coefficients in the vertical direction when the Quasi 3-D approach is used (Equation 4, Trescott, 1975, with TK values input to the model); (c) computation of vertical flow; and (d) punched output format of the PHI matrix.

Two versions of the 3-D model are described in this report. One version contains all of the modifications and corrections listed above. The other version contains only corrections to the standard 3-D model as described in Trescott (1975), and Trescott and Larson (1976).
MODIFICATIONS

Head-Dependent Source-Sink Functions

(Notes pertaining to these modifications were originally distributed at the training course "Advanced Modeling of Ground-Water Flow," January 8-17, 1980, by Steven P. Larson.)

General mathematical form. The types of head-dependent source-sink functions that can be simulated with the modified finite-difference model are streams, evapotranspiration, and springs or drains. A general mathematical expression that can be used to approximate all of these functions is

\[ QSS = CSS(HSS-h) \ [L/T] \text{ or } [T^{-1}], \]  

(1)

where QSS is the flow rate derived from the head-dependent function. CSS is a constant that describes the linear relationship between the head difference and the flow rate. CSS functions like a leakance coefficient similar to the TK values used in Trescott (1975) to simulate steady leakage from a confining layer. Specific definitions of CSS will be given later for each type of head-dependent source-sink function. HSS is the fixed head [L] that controls the flow rate, such as the water level in a stream or river, the depth below land where the evapotranspiration rate is zero, or the spring or drain discharge elevation. The variable, h, is the computed head [L] at a node in the aquifer model.

The dimensions assigned to CSS and to equation 1 are determined by the type of 3-D modeling approach that is taken. For the Modified or Quasi 3-D approach (Equation 4, page 4 of Trescott, 1975), each term in the partial differential equation for ground-water flow, including QSS, has the dimensions
[L/T], representing a volumetric flow rate per unit surface area. CSS has the dimensions \([T^{-1}]\) for this approach.

For the Basic 3-D approach (Equation 3, page 3, Trescott, 1975), each term represents a volumetric flow rate per unit volume. The head-dependent source-sink term, QSS, would appear on the right-hand side of this equation and would also have the dimensions \([T^{-1}]\). For this approach, CSS has the dimensions \([L^{-1}T^{-1}]\).

The general form of the head-dependent source-sink functions given by (1) is modified according to the type of function to be simulated; rivers, springs or drains, or evapotranspiration. Formulation in the 3-D finite-difference model of the general form of the head-dependent source-sink functions is described, and the extension of this formulation to the specific types of functions is discussed. The model has been modified so that only one formulation of these functions is needed in the code. Checking procedures in the model allow this formulation to simulate the specific types of head-dependent source-sink functions.

The variable names used in this discussion are identical to those used in the modified model, with the exception that \(\text{PHI}\) in the model is replaced by \(h\) in this discussion. The head-dependent source-sink functions have been formulated in the model so that their effects can be simulated in any layer.

Formulation in the 3-D model. The head-dependent source-sink function is incorporated into the finite-difference equation for node \(i,j,k\) (Equation 9, page 9 of Trescott, 1975) as

\[
B_{i-1} + D_{j-1} + E_h + F_{h+1} + H_{h+1} + Z_{k-1} + S_{k+1} = Q - \text{QSS}, \quad (2)
\]
where the subscripts not containing a "+1" or a "-1" are eliminated. Substituting (1) into (2) yields

$$B_{h_{i-1}} + D_{h_{j-1}} + E_{h} + F_{h_{j+1}} + H_{h_{i+1}} + Z_{h_{k-1}} + S_{h_{k+1}} = Q - CSS(HSS-h). \quad (3)$$

The implicit part of the head-dependent function, CSS·h, is combined with $E_{h}$ on the left-hand side of (3), and the explicit part, CSS·HSS, remains on the right-hand side, yielding

$$B_{h_{i-1}} + D_{h_{j-1}} + E'_{h} + F_{h_{j+1}} + H_{h_{i+1}} + Z_{h_{k-1}} + S_{h_{k+1}} = 0 - O_{S}, \quad (4)$$

where

$$E' = E - CSS \quad (5a)$$

$$QS = CSS·HSS. \quad (5b)$$

Following the description of the numerical solution by SIP on pages 11-15 of Trescott (1975), equation 4 can be represented in matrix notation for all $i,j,k$ as

$$\bar{A}' \cdot \bar{h} = \bar{Q}' .$$

The matrix $A'$ contains the coefficients $R, D, E', F, H, S,$ and $Z,$ and the vector $Q'$ contains the additional term $QS$ for the head-dependent function described by (5). From Equation 12 on page 12 of Trescott (1975), the iterative scheme,

$$(\bar{A}' + \bar{B})\bar{h}_{n} = \bar{Q}' + \bar{R}\bar{h}_{n-1} ,$$
is placed in residual form by adding and subtracting $A'\bar{h}^{n-1}$ to the right-hand side:

$$(A + B)\bar{c}^n = \bar{R}^{n-1}$$

where $\bar{c}^n = \bar{h}^n - \bar{h}^{n-1}$;

$$\bar{R}^{n-1} = \bar{Q}' - \bar{A}'\bar{h}^{n-1}.$$ 

The superscript n is an iteration index and (B) is a modifying matrix used in SIP so that $(A + B)$ can be factored into a form that can be solved easily. The vector $R'^{n-1}$ is computed in the model as the right-hand-side variable, RES, and contains the implicit and explicit parts of the head-dependent source-sink function given by (5). At each node where a head-dependent source-sink function is to be simulated, the modified model reformulates the E coefficient so that it contains the leakance coefficient CSS. The explicit part of the head-dependent function is also computed in the model and subtracted from the right-hand-side variable RES. This general formulation is modified according to the specific type of head-dependent source-sink function that is simulated.

Streams or rivers. The general form of the head-dependent source-sink function given by (1) is modified to simulate the interaction of a stream with an aquifer,

$$QSS = \begin{cases} 
CSS(HSS-h), & h > HSL \\
CSS(HSS-HSL), & h \leq HSL.
\end{cases}$$

\[ (6a) \quad (6b) \]
HSS is the elevation of the water level in the stream. HSL is a threshold elevation which limits the maximum flow rate to the aquifer, equation 6b, whenever the computed head is below this elevation. HSL is frequently chosen as the elevation of the bottom of the streambed, or as the value of h which corresponds to a hydraulic gradient of unity between the streambed and the aquifer. The relationship of HSS and HSL to the aquifer head is shown in figure 1.

Another threshold elevation, HB, is embodied in the program modifications for head-dependent source-sink terms. This value, if used, would limit the maximum flow rate out of the aquifer and into the stream. However, as no physical basis exists for this type of effect, HB should be set equal to an arbitrarily high value so this threshold condition is eliminated. HR remains in the program logic for generality, so that only one formulation of head-dependent source-sink functions occurs in the code. The function of HB is described in a later section pertaining to evapotranspiration.
The streambed leakage coefficient, CSS, accounts for the percentage of the grid block covered by the streambed ($A_s/A$, see figure 2), the weighted harmonic mean of hydraulic conductivity between the stream bottom and the aquifer node ($k'$), and the vertical interval between the stream bottom and the node ($b'$).

Figure 2.--Areal relationship between the streambed and the grid block used to compute CSS in equation 7.
For many problems $k'$ is taken as the hydraulic conductivity of the streambed sediments and $b'$ is taken as their thickness. All of these factors are lumped together in one term for each stream node as

$$CSS = \frac{k'}{b'} \cdot \frac{A_S}{A}.$$ (7)

$A_S$ is the area of the streambed contained in the grid block and $A$ is the area of the grid block. The expression of CSS in (7) is for the Modified or Quasi 3-D approach, Equation 4 of Trescott (1975). For the Basic 3-D approach, Equation 3 of Trescott (1975), CSS is divided by $\Delta z_k$, the thickness of the finite-difference layer where the steam node is located.

Formulation of the threshold condition of (6b) is accomplished by two steps in the model. First, the implicit and explicit parts of the general form of the head-dependent function are computed using equations 5. Second, a check is made to determine if the computed head from the previous iteration is lower than HSL. If the computed head is lower than HSL, the excess amount, $CSS(HSL-h)$, is subtracted from $QS$, restricting the flow rate to the value given by (6b).

For $h < HSL$,

$$QS = CSS \cdot HSS - CSS(HSL-h),$$ (8)

Equation 4 becomes

$$B_{i-1} + D_{j-1} + Eh - CSSh + F_{hj+1} + H_{hi+1} + Z_{hk-1} + S_{hk+1} = Q - CSS \cdot HSS + CSS(HSL-h).$$ (9)

9
In the model, equation 9 is placed in residual form; that is, all terms of (9) are placed on the right side, and the left side is designated as the variable, RES,

\[
RES = -Bh_{i-1} - D\delta_{j-1} - Eh - CSS_h - Fh_{j+1} - Hh_{i+1} - Zh_{k-1} - Sh_{k+1} \\
+ Q - CSS'H_{SS} + CSS'H_{SL} - CSS'h_n^{-1},
\]  

(10)

where \( n-1 \) is the index for the iteration level. The goal of the iterative process is to bring the variable RES sufficiently close to zero so that (9) is essentially satisfied at all nodes of the mesh. The implicit parts of the head-dependent function in equation 10 (the \( CSS'h_n^{-1} \) terms) cancel, limiting the maximum flow rate into the aquifer from the stream to the value \( CSS(HSS-HSL) \) in equation 6b.

For conditions where the aquifer head is above the threshold elevation, HSL, equation 6a is used, and the implicit and explicit parts of the head-dependent function are formulated by equations 5.

My approach to these modifications has been to formulate the implicit part of the head-dependent function, \( E' \), in equation 5a, at every time step and iteration for the appropriate nodes, even though a threshold condition may exist which causes the formulation to be totally explicit. If the computed heads cause a threshold condition to exist, then corrections are made to the residual RES. The implicit formulation of the head-dependent term remains on the \( E \) coefficient; thus, the left-hand-side matrix (\( A' + B \)) is not changed during the simulation. An alternate approach would be to only place the implicit part of the head-dependent function on the \( E \) coefficient when the computed head is
between the threshold elevations. If the computed head is close to either
threshold, its value may cross the threshold elevation repeatedly during the
iterative-solution process. Thus, on successive iterations, the E coefficient
and the \((A' + B)\) matrix may or may not contain the implicit part of the head-
dependent function. This approach may cause numerical oscillations about a
solution as the computed heads approach the threshold elevations. These
oscillations tend to be reduced by formulating \(E'\) all the time at the nodes
where this function is to be simulated.

This approach yields a matrix \((A' + B)\) which is not entirely correct when the
threshold condition is invoked. As the formulation should be totally explicit,
no CSS term should appear on the main diagonal. The implicit term is compen­sated for in the residual, but not in the left-hand-side matrix. However,
convergence does occur with this formulation in simulations that did not
converge using the alternate approach described above. A comparison between
computed results obtained from this formulation and those obtained from the
alternate approach when convergence occurred shows insignificant differences
in values of head and volumetric flow rates.

Evapotranspiration. The general form of the head-dependent source-sink function
given in (1) is modified to simulate evapotranspiration,

\[
\begin{align*}
\text{CSS}(HSS-HB), & \quad h \geq HB \quad (11a) \\
QSS = \text{CSS}(HSS-h), & \quad HSS < h < HB \quad (11b) \\
0, & \quad h \leq HSS, \quad (11c)
\end{align*}
\]

where HB is the land-surface elevation and HSS is a water-table elevation below
which evapotranspiration from the water table is zero. The constant, CSS, is
computed as \(\frac{q_{\text{max}}}{d_{\text{ET}} \, [T^{-1}]}\), for the Modified or Quasi 3-D approach, Equation 4
of Trescott (1975). For the Basic 3-D approach, Equation 3 of Trescott (1975), CSS is divided by \( \Delta z_k \), the thickness of the finite-difference layer where ET is simulated. Here \( q_{\text{ET}}^{\text{max}} \) is the maximum evapotranspiration rate per unit area (such as 84 inches/year), \( [L/T] \) and \( d_{\text{ET}} [L] \) is the depth of the water table below land surface where the ET rate is zero; that is, \( d_{\text{ET}} = \text{HR}-\text{HSS} \) (see figure 3).

![Evapotranspiration Rate [L/T]](image)

Figure 3.—Relationship of threshold elevations and aquifer head to the evapotranspiration rate, QSS.

This formulation assumes the ET rate is a linear function of the head difference, \( (\text{HSS}-h) \), when the computed head is between land surface and HSS. This relationship is given in figure 3 and in (11b) as the expression for QSS.
A threshold condition for the ET rate is met when the computed head is above land surface, HB. For this condition, the ET rate is limited to $q_{\text{ET}}^{\text{max}}$, computed by (11a). When the aquifer head falls below HSS, the ET rate will be zero, as given by (11c).

The formulation of evapotranspiration in the model is identical to the formulation for streams and rivers. The implicit and explicit parts of the general form of the head-dependent source-sink function are computed using (5) for all elevations of head at the nodes where ET is simulated. The upper threshold condition, $h > HB$, is formulated in the model in the same fashion as for streams and rivers; the excessive amount of the ET rate, given by $CSS(HB-h)$, is subtracted from QS as in (8), limiting the maximum ET rate to $CSS(HSS-HB)$. The variable, QS, is then subtracted from the residual, RES, yielding equation 10.

Formulation of the lower threshold condition, $h < HSS$, is accomplished in the model by specifying $HSL = HSS$ during data input. The model checks if $h$ is less than HSL. If so, a correction is applied to QS which was formulated as in (5b) for the general case,

$$QS = QS - CSS(HSS - h), \quad (12)$$

causing the ET rate to be zero.

When the residual is computed, all head-dependent source-sink terms cancel, and an expression equivalent to (11c) results,

$$RES = -Bh_{i-1} - Dh_{j-1} - Eh_{i-1} + CSS_{n-1} - Fh_{j+1} - Hh_{i+1} - Zh_{k-1} - Sh_{k+1}$$
$$+ Q - CSS\cdot HSS + CSS\cdot HSS - CSS\cdot h^{n-1}.$$
Springs or drains. The form of the head-dependent source-sink function used for springs or drains is identical to the expression of QSS given by (11b-c) for evapotranspiration.

A spring (or drain) leakance coefficient, CSS, is used to describe the linear relationship assumed to exist between the head difference, (HSS-h), and the spring (or drain) discharge rate. This linear relationship is assumed to be for water levels greater than HSS. HSS is defined as the spring or drain discharge elevation, below which the discharge from the spring or drain is zero. For springs, as in streams, the physical basis for limiting the maximum discharge with the threshold HB may not exist, but the formulation remains in the model for generality. Therefore, a value of HB may be set arbitrarily high so the spring discharge rate is not limited.

Threshold conditions for spring or drain discharge are formulated in the model using the same convention as for evapotranspiration. The lower threshold, HSL, is not used for spring or drain discharge but its value is input as the value of HSS to allow the model to make the appropriate correction to QS given in (12).

Features. The input requirements for the head-dependent functions are designed so that a unique value of the leakance coefficient, CSS, can be input at each node where these functions are simulated. One variable, CSS, is used to represent either a streambed leakance, evapotranspiration rate, or a spring or drain leakance coefficient. Because of this design, only one type of head-dependent function can be simulated at any node. Values of CSS are input to the model in the same manner as the array data in Group III, page III-5,
of Trescott (1975), either with a single parameter card per layer, or with a parameter card followed by a matrix of CSS values. If the Basic 3-D approach is used (Equation 3 of Trescott, 1975), then CSS must be divided by \( \Delta z_k \), the thickness of the finite-difference layer where the head-dependent function is located. Thus, the dimensions of CSS change with respect to the type of modeling approach that is taken. (The additional data-input instructions for these modifications are given in Appendix I). Values of CSS are output either in matrix form or as one value per layer, depending upon the input convention selected.

The threshold elevations, HB, HSS, and HSL, are input and stored only for those nodes where a head-dependent function is to be simulated. This eliminates the allocation of storage for 3 three-dimensional arrays. The nodes simulating head-dependent functions are indexed by positive CSS values. Thus, the CSS array also serves as an indicator array for the head-dependent source-sink functions. The order in which threshold values are input to the model follows the indexing scheme for the finite-difference mesh with the normal ordering of nodes given on page 5 of the documentation by Trescott (1975). Threshold elevations are printed out for each node, for verification, according to the same node-ordering scheme used as input.

The arrays and vectors used to store the head-dependent terms in the model are incorporated into the general storage vector, \( Y \), and allocation of storage for these terms occurs at the time of execution. A description of the \( Y \) vector is given on page II-1 of Trescott (1975), and the \( Y \) locations for the new arrays and vectors are given in Appendix II.
Volumetric flow rates derived from head-dependent sources and sinks are printed out for each node with the standard printout of mass balance. The total volumetric flow rate and the total volume of water derived from head-dependent sources and sinks are also printed out with separate output for sources and sinks. In addition, the cumulative volume of water discharged by evapotranspiration and springs during the simulation, and the combined ET and spring-discharge rate for the last time step, is printed out in the location provided for ET by the original 3-D model.

**Discussion.** Checkout simulations with head-dependent source-sink functions in all layers were conducted using a steady-state model. The flow rates computed by the model were nearly identical to those obtained by hand calculations.

It would be impossible to test these modifications against every hydrogeologic system for which the effects of head-dependent source-sink functions are to be considered. Therefore, the user must exercise care in applying them to field problems to assure the specific type of function properly simulates the observed effects.

For the simulations I have conducted, I found that the inclusion of head-dependent terms into the matrix equation of (3) tended to slow down the iterative process of obtaining a solution using SIP. That is, more iterations were required per time step to achieve convergence. Because of this, an acceleration factor has been incorporated into the computation of the residual, RES, to enhance convergence. This factor is discussed in the next section. Also, other methods of computing the maximum iteration parameter have been added to the model in an effort to speed the convergence process. These methods are described in a later section.
Acceleration or Dampening Factor for the Strongly Implicit Procedure (SIP)

(This modification had previously been added to the standard 3-D model by Steven P. Larson for use in the training course "Advanced Modeling of Ground-Water Flow," and for numerical experiments, see Larson and Trescott, 1977.)

To reduce the number of iterations needed for SIP to converge when head-dependent source-sink functions are simulated, an acceleration factor, HMAX, is introduced into the calculation of the residual, RES. From Equation 13 on page 13 of Trescott (1975), the residual form of the finite-difference matrix equation is stated as

$$(\bar{A} + \bar{B}) \bar{\xi}^n = \bar{R}^{n-1},$$

where $\bar{R}^{n-1}$ is the right-hand-side variable, RES, previously discussed, and $\bar{\xi}^n$ is the head change during the $n$th iteration. The factor HMAX multiplies the right-hand side of this equation, changing the magnitude of the $\xi^n$ values which are obtained by solution using SIP. Overestimating the residual, RES, by multiplying it by a real number larger than 1.0 will, in most cases, increase the increments of head change that are solved for on each iteration of SIP, thus speeding up the convergence process. In this sense, HMAX is used as an acceleration factor to reduce the number of iterations needed for convergence.

For simulations I have conducted using an acceleration factor and the head-dependent functions, a value of HMAX = 1.2 seemed to give better convergence than simulations using smaller or larger values. However, the optimum value of HMAX to use is undoubtedly problem dependent. The value of HMAX can be increased (or decreased) slightly from 1.0 on successive simulations while
noting the number of iterations per time step required for solution. The number of iterations should decrease for those simulations, and then begin to increase, indicating that the optimum value of HMAX had been bypassed.

HMAX can also be used as an acceleration factor for simulations that do not invoke the head-dependent option. Larson and Trescott (1977) note that for two-dimensional problems, a value of HMAX greater than 1 may expedite convergence for simulations involving strongly anisotropic conditions. For water-table conditions, HMAX may be used as a dampening factor, its value less than unity, so that the iterative solution is approached slowly, reducing the incidence of nodes dropping out of the solution due to oscillations in SIP.

Other descriptions of an acceleration or dampening factor, $\beta'$, for SIP in the two-dimensional case can be found in Trescott, Pinder, and Larson (1976, p. 26-29) and in Larson and Trescott (1977). This factor is identical to HMAX used here in the 3-D model.

Optional Methods for Computing the Maximum Iteration Parameter

For some aquifer simulations, other methods of computing the maximum iteration parameter, WMAX, gave faster convergence than the method presently used in the 3-D model of Trescott (1975). Several approaches to computing the maximum iteration parameter are recognized in the literature and can be applied to nonhomogeneous, anisotropic aquifers discretized with unequal grid spacings. A brief description of these approaches is presented here to provide a basis for the methods incorporated into the 3-D model. It should be noted, however, that there is no theoretically based method which determines exactly the 'best' value for WMAX. All methods described here were empirically derived,
with the exception of the formula by Peaceman (1977), which was developed for the Alternating Direction Implicit Procedure (ADIP).

In a paper describing SIP for two-dimensional equations, Stone (1968) states that the best maximum value for \( \omega, \) \( W_{\text{MAX}} \), can be computed from

\[
(1 - \omega_{\text{max}}) = \min_{\text{over grid}} \left[ \frac{2\Delta x^2}{1 + \frac{K_y \Delta x^2}{K_x \Delta y^2}}, \frac{2\Delta y^2}{1 + \frac{K_x \Delta y^2}{K_y \Delta x^2}} \right], \tag{13}
\]

where

\( \Delta x, \Delta y \) are the grid spacings, and

\( K_x, K_y \) are the hydraulic conductivities in the \( x \) and \( y \) directions, respectively.

The assumptions made by Stone in arriving at equation 13 are that \( K_x \) and \( K_y \) and \( \Delta x \) and \( \Delta y \) are constant over the model area.

The equation for computing the maximum iteration parameter developed by Stone (1968) is "similar" to the one given below by Peaceman (1977) for ADIP.

\[
(1 - \omega_{\text{max}}) = \min_{\text{over grid}} \frac{\pi^2}{2J^2(1+AX)}, \frac{\pi^2}{2I^2(1+AY)} \tag{14}
\]

where

\( J \) is the number of grid spacings in the \( x \) direction
\( I \) is the number of grid spacings in the \( y \) direction

\( AY \) are the coefficients \( B \) and \( H = K_y/\Delta y^2 \)

\( AX \) are the coefficients \( D \) and \( F = K_x/\Delta x^2 \), \( K_x \) and \( K_y \) are hydraulic conductivities in the \( x \) and \( y \) directions, \( \Delta x \) and \( \Delta y \) are grid spacings
(1 + \frac{AY}{AX}) and (1 + \frac{AX}{AY}) are the same as the denominators in (13).

These equations were developed for problems involving two-dimensional grids, not three, and although (14) was derived for ADIP, it has been proven effective in the solution by SIP (see Weinstein, Stone, and Kwan, 1969).

In cases where \(K_x, K_y, \text{ and } \Delta x, \Delta y\) vary over the grid, Stone (1968) found it sufficient to compute local values of \(\omega_{\text{max}}\) at each grid point by equation 13 and to use the arithmetic average of these values for the value of \(\omega_{\text{max}}\). Cooley (1974) found that values of \(\omega_{\text{max}}\) computed by this procedure resulted in convergence of the SIP solution scheme in cases where divergence occurred using the absolute minimum over the grid for \((1-\omega_{\text{max}})\).

The method of computing an average \(\omega_{\text{max}}\) for two-dimensional problems has been extended to the three-dimensional case and is incorporated into the model as a modification. The equivalent of equation 14 for three dimensions is given by Weinstein, Stone, and Kwan (1969), as

\[
(1-\omega_{\text{max}}) = \min_{\text{over grid}} \left[ \frac{\pi^2}{2J^2(1+\rho_1)}, \frac{\pi^2}{2I^2(1+\rho_2)}, \frac{\pi^2}{2K^2(1+\rho_3)} \right],
\]

where \(K\) is the number of layers, and \(I\) and \(J\) are the same as for equation 14.

The equations for the \(\rho\) terms are

\[
\rho_1 = \frac{K_{yy}(i,j,k)(\Delta x_j)^2}{K_{xx}(i,j,k)(\Delta y_i)^2} + \frac{K_{zz}(i,j,k)(\Delta x_j)^2}{K_{xx}(i,j,k)(\Delta z_k)^2},
\]

\[
\rho_2 = \frac{K_{xx}(i,j,k)(\Delta y_i)^2}{K_{yy}(i,j,k)(\Delta x_j)^2} + \frac{K_{zz}(i,j,k)(\Delta y_i)^2}{K_{yy}(i,j,k)(\Delta z_k)^2},
\]
The first term in the expressions for $\rho_1$ and $\rho_2$ is identical to the second term in the denominators of (13), and to $\frac{AX}{AY}$ and $\frac{AY}{AX}$ in (14). By extending the 2-D expression for $\omega_{\text{max}}$ to three dimensions, Weinstein, Stone, and Kwan (1969) introduced a third term to (13) that considers the ratio of hydraulic conductivity and grid spacing between the x-z and y-z planes when computing the value of $\omega_{\text{max}}$. Also, another term appeared in the denominators of (13) and (14) yielding the full expressions for the $\rho$ terms. These are the second terms in the expressions for $\rho_1$ and $\rho_2$ which account for the ratio of hydraulic conductivity and grid spacing between the z-x and z-y planes.

The assumptions made by Stone (1968) which allowed Weinstein, Stone, and Kwan (1969) to develop equation 15 for computing $\omega_{\text{max}}$ were that $K_x = K_y = K_z = \text{constant}$ and $\Delta x = \Delta y = \Delta z = \text{constant}$ over the grid (see p. 285 of Weinstein, Stone, and Kwan, 1969). Therefore, only the values of $I$, $J$, or $K$, the number of grid spacings in the x, y, or z directions, determine which of the three terms in (15) would be used to compute $\omega_{\text{max}}$. For cases where values of the $\rho$ terms vary over the grid, either because of nonhomogeneity or variable grid spacing, Weinstein, Stone, and Kwan (1969) suggest computing local values of $\omega_{\text{max}}$ at each active grid point using (15); then selecting the maximum value as $\omega_{\text{max}}$.

In the original 3-D model, the expressions for the $\rho$ terms are changed so that the coefficients $D$, $F$, $B$, $H$, $Z$, and $S$ are used to compute $\omega_{\text{max}}$. These coefficients are defined by Equations 8, on page 8 of the documentation by Trescott (1975). This change allows harmonic means of transmissivities (Modified or Quasi 3-D approach) or hydraulic conductivities (Basic 3-D...
approach) to be used in computing the $\rho$ terms instead of the nodal values of these parameters.

The original 3-D model of Trescott (1975) changes the computation of $\rho_1$, $\rho_2$, and $\rho_3$ further by using only the first term in their expressions (see the expressions for the $\rho$ terms in equations 16). These truncated $\rho$ terms are then used in (15) to compute $\omega_{\text{max}}$ at each active grid point, and the maximum value over the grid is selected as $\omega_{\text{max}}$. Modifications to the model allow $\rho_1$, $\rho_2$, and $\rho_3$ to be computed using the full formulation (both terms for each $\rho$) given by equations 16. The new formulation computes the $\rho$ terms as

$$\rho_1 = \frac{\text{Max} \ [B, H]}{\text{Min} \ [D, F]} + \frac{\text{Max} \ [S, Z]}{\text{Min} \ [D, F]}$$

$$\rho_2 = \frac{\text{Max} \ [D, F]}{\text{Min} \ [B, H]} + \frac{\text{Max} \ [S, Z]}{\text{Min} \ [B, H]}$$

$$\rho_3 = \frac{\text{Max} \ [D, F]}{\text{Min} \ [S, Z]} + \frac{\text{Max} \ [B, H]}{\text{Min} \ [S, Z]}.$$

In the modified model, several options are available for computing $\omega_{\text{max}}$. Its value may be calculated as the maximum value over the entire grid of active nodes, or as the arithmetic average of the local maxima for $\omega_{\text{max}}$, as previously described. Both of these methods for determining $\omega_{\text{max}}$ use the full formulation of the $\rho$ terms, as defined by equations 16. The original method of computing $\omega_{\text{max}}$ from the truncated expressions of the $\rho$ terms in (16) is also available.

My experience with these methods of computing $\omega_{\text{max}}$ (WMAX) indicates the arithmetic-average approach may give faster convergence than the original method for aquifer problems consisting of widely varying transmissivities (or hydraulic conductivities) in combination with uneven grid spacings. An average $\omega_{\text{max}}$ would eliminate the possibility of one node with eccentric
aquifer and grid-spacing properties from dominating the computation of $\omega_{\text{max}}$, thereby generating a sequence of iteration parameters which may be inappropriate (give slow convergence) to the solution by SIP. For problems simulating isotropic layers in conjunction with grid spacings in the $x$, $y$, and $z$ directions of the same order of magnitude, the computation of $\omega_{\text{max}}$ as the maximum value over the grid with the full formulation of the $\rho$ terms in (16), may give faster convergence than the original method. Some guidelines for using the approach taken by Trescott in computing $\omega_{\text{max}}$ are given in his documentation (see page 25 of Trescott, 1975).

For those modelers who wish to bypass all computations of WMAX, the model was modified to allow its value to be input by the user. A sequence of iteration parameters is then generated from this value, as it is for all values of WMAX, using Equation 24 on page 25 of Trescott (1975). However, an error exists in this equation, and the correct expression is

$$W_{\varepsilon+1} = 1 - \frac{(1-W_{\text{max}})^2}{(L-1)}, \varepsilon = 0,1,\ldots,L-1.$$  

If the value of WMAX is being input by the user, the following hints from Weinstein, Stone, and Kwan (1969) may be helpful. If the sequence of iteration parameters computed by (15) causes divergence, then the value $(1-\omega_{\text{max}})$ should be multiplied by a factor of 2 to 10. If the iteration is slow to converge, $(1-\omega_{\text{max}})$ should be divided by a factor of 2 to 10.
CORRECTIONS

Dimensional Nonhomogeneity of Coefficients in ENTRY ITER

In this section of the program, the coefficients D, F, B, H, Z, and SU are calculated so that the maximum iteration parameter (WMAX) can be computed. The original code does not check for the particular equation being solved, either Equation 4, for the Modified or Quasi 3-D approach, or Equation 3, for the Basic 3-D approach. Only the Basic 3-D approach requires the coefficients in the vertical direction, Z and SU, to be divided by the thickness of the layer, DELZ(K); however, this division occurs for both Equation 3 and Equation 4 formulations.

To correct this problem, a check is made for the type of equation being solved in the model before Z and SU are divided by DELZ(K). If the Equation 4 approach is taken, division of these coefficients is not performed. A similar check was incorporated into the original 3-D model (see page XIX of Trescott and Larson, 1976) where these coefficients are computed again for the solution by SIP. The uncorrected version of ENTRY ITER would usually not cause any errors in the calculation of WMAX. As previously discussed, the vertical components in the formulation of $\rho_1$ and $\rho_2$ had been eliminated by Trescott in the original model, and $\rho_3$ usually does not determine the value for WMAX. However, if the complete formulation of the $\rho$ terms given by equations 16 are used, the improper formulation of Z and SU would always cause errors in determining the maximum iteration parameter.
Use of Transmissivity for Computing T-Coefficients for Water-Table Simulations Using Equation 3

The 3-D model was originally designed to solve Equation 4 on page 4 of Trescott (1975). This approach requires transmissivity to be input to the model. For water-table simulations, transmissivity values are updated after each iteration based on the newly computed thickness of the top layer. The 3-D model can also be used to solve Equation 3 on page 3 of Trescott (1975). With this formulation, hydraulic conductivities are input; thus transmissivities are not required. Regardless of whether Equation 3 or Equation 4 is used in a water-table simulation, the program calculates transmissivities and T-coefficients (TR, TC, and TK) for the upper layer as the initial start-up conditions and as updates after each iteration. These values are then used to compute the coefficients D, F, B, H, Z, and SU which are input to SIP. Because of this error, transmissivities are used to form TR and TC coefficients in the top layer of a water-table problem with Equation 3, when the correct formulation requires hydraulic conductivities. The TR and TC coefficients for the top layer of a water-table aquifer simulated with Equation 3 are calculated incorrectly as weighted harmonic means of transmissivities instead of the correct formulation using hydraulic conductivities.

The TK coefficient is also in error in the original model for water-table simulations using Equation 3. This term is defined as the weighted harmonic mean of vertical hydraulic conductivity and layer thickness; however, the transmissivity of the top layer is used in the model.

This condition has been corrected by converting the updated (or initial) values of transmissivity to hydraulic conductivities in ENTRY TRANS, where
the transmissivity calculations occur. The computation of transmissivity is necessary to determine if a node has become inactive by dewatering; therefore, ENTRY TRANS is still entered on each iteration for both Equation 3 and Equation 4 approaches.

As part of the above correction, the computation of the coefficients TR, TC, and TK needs only to be performed once for water-table simulations involving Equation 3. Therefore, the model has been changed so that portion of the subroutine which computes these values, ENTRY TCOF, is only passed through once under these conditions.

Despite these changes which allow a correct formulation of coefficients to be made for water-table simulations using Equation 3, this approach to a water-table problem should be avoided. The flow equation solved with the Equation 3 approach does not take into account the changing saturated thickness of the top layer. Because transmissivities are not used in this approach, values for the coefficients TR, TC, and TK do not change as the thickness of the water-table layer changes. These coefficients only change when the node goes dry; then they are set to zero.

**Occurrence of a Nonzero TK Value Between Active and Inactive Nodes**

When the Quasi 3-D approach to aquifer simulation is used, and one value of TK on a parameter card is assigned to the entire matrix of TK's, an error in the coefficient formulation for SIP will result if there is an inactive node (zero transmissivity) above or below an active node. A nonzero value for TK will exist between an active and an inactive node representing a vertical component of flow. This causes an error in the formulation of the coefficients, SU and Z,
as these coefficients should be set to zero. There should be no contribution of flow to a node from either above or below when the nodes above or below that node are inactive.

Several checks have been inserted in subroutine SOLVE where these coefficients are computed so that, if the transmissivity of the node directly above (or below) a particular node is zero, the SU (or Z) coefficient will be assigned a value of zero.

This correction is not necessary if the Modified 3-D approach is taken. The program computes values of TK and will automatically set TK = 0 if one of the vertical hydraulic conductivities is zero. This causes either the Z or SU coefficient to be zero.

Computation of Vertical Flow from Inactive or Constant Head Nodes
In ENTRY CWRITE of the CHECKI subroutine, a computation of vertical flow is made at all "interior" nodes in the two top layers and in the two bottom layers. (An interior node is one that is not located on the border of inactive nodes placed around the model.) No checks are made to determine if these "interior" nodes are inactive (zero transmissivity), or if they are constant-head nodes. Errors in the volumetric balance will result if vertical flow is computed between active and inactive nodes (if TK is nonzero), or between two constant-head nodes. Checks have been incorporated into the computation of vertical flow eliminating the problem.

Assignment of N3=1 in COEF Subroutine
Statement COF 195 which set N3=1 has been eliminated. In its place, the value of N3 is passed to ENTRY TCOF of subroutine COEF as a parameter on
the CALL statement in the MAIN program (statement MAN1700). Thus, N3 is set equal to 1 on the first pass through ENTRY TRANS and ENTRY TCOF when these parts of the COEF subroutine are called from the MAIN program. A value of zero for N3 is passed to ENTRY TRANS on subsequent CALL's from subroutine SOLVE. This correction supersedes that described as item II in the memorandum of May 6, 1977.

The change indicated by that memorandum appeared to be a source of confusion concerning the value and function of N3 during the simulation. The change indicated here causes N3 to be consistently given a value as it is needed in ENTRY TRANS and ENTRY TCOF.

**Incompatibility Between Formats for Punched Output of PHI Matrix and Data-Input Requirements**

The punched output of heads generated in ENTRY OUTPUT of subroutine STEP is not compatible with the format used to read these cards as input to the PHI matrix for continuation of a previous simulation. The output format statement STP1350 should be changed to FORMAT (8F10.4) for compatibility.

**Improper Dimensioning of JFLO and FLOW**

The dimensions of the array JFLO has been changed to (3,NCD) and the dimensions of the vector FLOW has been changed to (NCD) in statement CHK 120 and CHK 130 of subroutine CHECKI in both the corrected and modified models. The original model dimensions these terms with NCH, the number of constant-head nodes, instead of NCD which is defined as MAXO(1,NCH) in statement MAN0510. An error may occur in dimensioning JFLO and FLOW with NCH, as its value may be zero if no constant-head nodes are to be simulated.
In the modified model, statement MANO510 has also been changed so that NCD is the maximum value of 1, NCH, and NHD. The number of nodes where head-dependent sources or sinks are simulated, NHD, has been added to the maximum-value function in this statement. JFLO and FLOW, now dimensioned with NCD, store the nodal location and the volumetric flow rates of the head-dependent source-sink nodes, respectively, in addition to their original use with constant-head nodes. This change also requires NCD to be included in the COMMON/INTEGR/ statement of all subroutines for both the corrected and modified models.

Program statements constituting modifications or corrections to the standard 3-D model are identified by an asterisk (*) or a digit (0-9) in column 80. Every effort was made to preserve the original program sequence numbers in columns 73-79, so that the modified and/or corrected version can be compared with the standard model.

Many of the corrections, or the need for them, have been brought to my attention by users of the 3-D model. I would appreciate hearing from anyone implementing these modifications and/or corrections into the model, and am interested in learning about the types of field problems for which the modified model is applied.
REFERENCES


APPENDIX I

Additional Data-Input Instructions for Modifications (The sequence of Group and Card numbers identifying the additional data inputs is compatible with the data deck instructions given in Appendix III of Trescott, 1975.)

Group I: Title, Simulation Options, and Problem Dimensions

<table>
<thead>
<tr>
<th>Card</th>
<th>Columns</th>
<th>Format</th>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>61-70</td>
<td>I10</td>
<td>NHD</td>
<td>Number of nodes where head-dependent source-sink terms are computed.</td>
</tr>
<tr>
<td>4</td>
<td>61-64</td>
<td>A4</td>
<td>IHDEP</td>
<td>Code HDEP for head-dependent source-sink option.</td>
</tr>
</tbody>
</table>

Group II: Scalar Parameters

<table>
<thead>
<tr>
<th>Card</th>
<th>Columns</th>
<th>Format</th>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1-20</td>
<td>G20,10</td>
<td>HDVPT</td>
<td>Cumulative volume of head-dependent sources. For continuation of a previous simulation using the head-dependent option, replace this card with the fourth card of punched output from the previous run. See description of cards 3, 4, and 5, p. III-4 of Trescott (1975). For a new simulation, if HDEP is specified, insert a blank card. Not needed when HDEP is not specified.</td>
</tr>
</tbody>
</table>

Group III: Array Data

<table>
<thead>
<tr>
<th>Card</th>
<th>Columns</th>
<th>Format</th>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>8a</td>
<td>1-80</td>
<td>20F4,0</td>
<td>CSS(I,J,K)</td>
<td>Leakance values that describe the relationship between the hydraulic gradient and the head-dependent flux. For evapotranspiration (Equation 4, Trescott, 1975), code the maximum ET rate/depth where the ET rate is zero, ([T^{-1}]). See discussion for other leakances. Include a parameter card with this data set.</td>
</tr>
<tr>
<td>8b</td>
<td>1-30</td>
<td>3G10,0</td>
<td>HB(N) , HSS(N) , HSL(N)</td>
<td>Values for the upper, middle, and lower threshold heads for head-dependent source-sink terms. See discussion for</td>
</tr>
</tbody>
</table>
### Card Columns Format Variable Definition

8b (Cont'd) special data inputs of these values for simulating ET, rivers, and springs or drains. For ET and springs or drains, set HSL = HSS. For streams and springs, HB is set to an arbitrarily high value so this threshold is not invoked. Do not include a parameter card with this data set. Number of cards for this data set is the value of NHD. The order of these inputs follows the normal ordering of nodes given on page 5 of Trescott (1975). N = 1, NHD.

<table>
<thead>
<tr>
<th>Card</th>
<th>Columns</th>
<th>Format</th>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>1-20</td>
<td>2F10.0</td>
<td>WMAX</td>
<td>WMAX is the value of the maximum iteration parameter (0 &lt; WMAX &lt; 1), generally a value slightly less than 1 used to speed convergence. If 1. is coded, WMAX is an indicator that causes iteration parameters to be computed according to the original formulation. If 2. is coded, iteration parameters are computed according to equations 15 and 16. A value of 3. causes WMAX to be computed as the average WMAX over the entire grid, using the full formulation of ρ terms given by (16).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HMAX</td>
<td>HMAX is the acceleration (or dampening) factor used in SIP to reduce oscillations and speed convergence (see explanation of HMAX and β' in Trescott, Pinder, and Larson, 1976). Generally, 0 &lt; HMAX &lt; 2.</td>
</tr>
</tbody>
</table>
## APPENDIX II

### Definition of New Variables Used In The Modified Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSS</td>
<td>A constant describing the linear relationship between the hydraulic gradient and the head-dependent flux, ([T^{-1}]) or ([L^{-1}T^{-1}]) depending on whether Equation 3 or Equation 4 of Trescott (1975) is used. Its location in the (Y) vector is (L(26)).</td>
</tr>
<tr>
<td>HB</td>
<td>Value of head for the upper threshold of a head-dependent flux ([L]). Its location in the (Y) vector is (L(28)).</td>
</tr>
<tr>
<td>HDD</td>
<td>Hydraulic head used to compute HDRT.</td>
</tr>
<tr>
<td>HDEP</td>
<td>Value of IHDEP to be coded for head-dependent option.</td>
</tr>
<tr>
<td>HDFN</td>
<td>Total volumetric flow rate derived from head-dependent sinks ([L^3/T]).</td>
</tr>
<tr>
<td>HDFP</td>
<td>Total volumetric flow rate derived from head-dependent sources ([L^3/T]).</td>
</tr>
<tr>
<td>HDRT</td>
<td>Nodal volumetric flow rate for a head-dependent source or sink ([L^3/T]). Its location in the (Y) vector is (L(30)).</td>
</tr>
<tr>
<td>HDVNT</td>
<td>Cumulative volume of water derived from all head-dependent sinks ([L^3]).</td>
</tr>
<tr>
<td>HDVPT</td>
<td>Cumulative volume of water derived from all head-dependent sources ([L^3]).</td>
</tr>
<tr>
<td>HMAX</td>
<td>Acceleration or dampening factor for RES.</td>
</tr>
<tr>
<td>HSL</td>
<td>Value of head for the lower threshold of a head-dependent flux ([L]). Its location in the (Y) vector is (L(29)).</td>
</tr>
<tr>
<td>HSS</td>
<td>Value of head for the middle threshold of a head-dependent flux ([L]). Its location in the (Y) vector is (L(27)).</td>
</tr>
<tr>
<td>ICHK(13)</td>
<td>Element of vector that contains the value HDEP, used to invoke head-dependent option.</td>
</tr>
<tr>
<td>IE,JE,KE</td>
<td>Dimensions of CSS array.</td>
</tr>
<tr>
<td>IHDEP</td>
<td>Option for formulating head-dependent fluxes.</td>
</tr>
<tr>
<td>IR</td>
<td>Index for locating nodes that contain head-dependent sinks for printout of mass balance.</td>
</tr>
<tr>
<td>Variable</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>IRR</td>
<td>Counter for IR.</td>
</tr>
<tr>
<td>IWM</td>
<td>Indicator for computing a new WMIN.</td>
</tr>
<tr>
<td>LHD</td>
<td>Vector for locating a node containing a head-dependent source or sink in the SIP reverse algorithm. Its location in the Y vector is L(31).</td>
</tr>
<tr>
<td>NHD</td>
<td>Number of nodes where head-dependent fluxes are to be computed.</td>
</tr>
<tr>
<td>NNHD</td>
<td>Counter for NHD.</td>
</tr>
<tr>
<td>NWM</td>
<td>Counter for WMIN (integer variable).</td>
</tr>
<tr>
<td>QS</td>
<td>Head-dependent flux [L/T].</td>
</tr>
<tr>
<td>SUMWM</td>
<td>Sum of WMIN.</td>
</tr>
<tr>
<td>WMNUM</td>
<td>Counter for WMIN (real variable).</td>
</tr>
</tbody>
</table>
APPENDIX III

LIST OF MODEL CORRECTIONS

PROGRAM STATEMENTS CONSTITUTING CORRECTIONS TO THE ORIGINAL MODEL OF THREE-DIMENSIONAL GROUND-WATER FLOW OF TREVESOTT (1975), AND TREVESOTT AND LARSON (1976), ARE IDENTIFIED BY AN ASTERISK (*) OR A DIGIT (0-9) IN COLUMN 40. A FEW UNCORRECTED STATEMENTS ARE INCLUDED IN THIS LIST TO ASSURE PROPER SEQUENCING OF THE CORRECTIONS.

****** MAIN ******

COMMON /INTCR/ IO,JO,K0,I1,J1,K1,I,J,K,NPER,KTM,ITMAX,LENGTH,KP,NMAN0150
1WEL,NUMT,IFINAL,IT,KT,MCAS,ODRAW,IFLO,ICRR,12,J2,K2,IMAX,ITMX1,NCDAT0160
2H,IDK1,IDK2,1WATER,IORE,IP,JP,IT,JO,IK,K5,IPU1,IPU2,ITK,IEQN, DAT0170
3NCD MAN0171
3C ---COMPUTE T COEFFICIENTS---
CALL 1CSG(1)
3C MAN1710

****** DATAI ******

COMMON /INTGR/ IO,JO,K0,I1,J1,K1,I,J,K,NPER,KTM,ITMAX,LENGTH,KP,NDAT0160
1WEL,NUMT,IFINAL,IT,KT,MCAS,ODRAW,IFLO,ICRR,12,J2,K2,IMAX,ITMX1,NCDAT0170
2H,IDK1,IDK2,1WATER,IORE,IP,JP,IT,JO,IK,K5,IPU1,IPU2,ITK,IEQN, DAT0180
3NCD DAT0181

****** STEP ******

COMMON /INTGR/ IO,JO,K0,I1,J1,K1,I,J,K,NPER,KTM,ITMAX,LENGTH,KP,NSTP 160
1WEL,NUMT,IFINAL,IT,KT,MCAS,ODRAW,IFLO,ICRR,12,J2,K2,IMAX,ITMX1,NCSTP 170
2H,IDK1,IDK2,1WATER,IORE,IP,JP,IT,JO,IK,K5,IPU1,IPU2,ITK,IEQN, STP 160
3NCD STP 161
220 FORMAT (8F10.4) STP1350

****** SOLVE ******

COMMON /INTGR/ IO,JO,K0,I1,J1,K1,I,J,K,NPER,KTM,ITMAX,LENGTH,KP,NSP3 160
1WEL,NUMT,IFINAL,IT,KT,MCAS,ODRAW,IFLO,ICRR,12,J2,K2,IMAX,ITMX1,NCSP3 170
2H,IDK1,IDK2,1WATER,IORE,IP,JP,IT,JO,IK,K5,IPU1,IPU2,ITK,IEQN, SP3 180
3NCD SP3 181
SU=0.00 SP3 480
2=0.00 SP3 490
IF (K.EQ.1) GO TO 5 SP3 491*
IF (T(N-NIJ).EQ.0) GO TO 5 SP3 492*
Z=TK(N-NIJ) SP3 493*
1F (ICGN.EQ.ICHK(11)) Z=Z/DEZK(K) SP3 494*
5 IF (K.EQ.KL) GO TO 10 SP3 495*
IF (T(N-NIJ).EQ.0) GO TO 10 SP3 496*
SU=SU(K) SP3 497*
1F (ICGN.EQ.ICHK(11)) SU=SU/DEZK(K) SP3 498*
10 CONTINUE SP3 560
1F (K.EQ.1) GO TO 124 SP3 51361
1F (T(NKB).EQ.0) GO TO 124 SP3 513611
2=1K(NKB) SP3 51362

III-1
***** COEF *****

COMMON /INTEGR/ I0,J0,K0,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NCOF
1WEL,NUMT,FINAL,IT,KT,IHEAD,IKRAW,IFLO,IERR,I2,J2,K2,ITMX1,NCCOF
2H,IDK1,IDK2,IWATER,IGRE,JP,JG,JK,K5,IPU1,IPU2,ITK,IEGN,
3NCD

T(I,J,K) = PCM(I,J)*(PHI(I,J,K0)-BOTTOM(I,J))
IF (T(I,J,K) .GT. 0.) GO TO 5

5 IF (ICON.EQ.ICMK(11)) T(I,J,K) = PERM(I,J)

10 CONTINUE

245 IF (K.EQ.K0) GO TO 250
IF (T(IN,NA),EQ.0.) GO TO 125
SU=TK(IN)
124 IF (K.EQ.K0) GO TO 125
IF (T(IN,NA),EQ.0.) GO TO 125
Z=TK(NKU)
174 IF (K.EQ.K0) GO TO 175
IF (T(IN,NA),EQ.0.) GO TO 175
SU=TK(N)

***** CHECKI *****

2J0,K0), DELX(J0), DELY(I0), DELZ(K0), FACT(K0,3), IFLO(NCD,3), FLOCHK

3W(NCD), ORE(IQ,JQ),

C COMMON /INTEGR/ I0,J0,K0,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NCHK
1WEL,NUMT,FINAL,IT,KT,IHEAD,TKRAW,IFLO,ICERR,I2,J2,K2,ITMX1,NCCM
2H,IDK1,IDK2,IWATER,IGRE,JP,JG,JK,K5,IPU1,IPU2,ITK,IEGN,
3NCD

DO 250 J=2,J1
IF (T(I,J,K),EQ.0.) OR T(I,J,K),EQ.0.) GO TO 245
IF(S(I,J,K),LT.0.) AND S(I,J,K),LT.0.) GO TO 245
K=X*(PHI(I,J,K1)-PHI(I,J,K2)+TK(I,J,K)+DELX(J)+DELY(T))
CHK1500
245 IF (T(I,J,K1),EQ.0.) OR T(I,J,K0),EQ.0.) GO TO 250
IF(S(I,J,K1),LT.0.) AND S(I,J,K0),LT.0.) GO TO 250
Y=Y*(PHI(I,J,K1)-PHI(I,J,K0))*TK(I,J,K1)+DELX(J)+DELY(T)

250 CONTINUE

***** PRINTAI *****

COMMON /INTEGR/ I0,J0,K0,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NPRN
1WEL,NUMT,FINAL,IT,KT,IHEAD,IKRAW,IFLO,IERR,I2,J2,K2,ITMX1,NCCPRN
2H,IDK1,IDK2,IWATER,IGRE,JP,JG,JK,K5,IPU1,IPU2,ITK,IEGN,
3NCD

III-2
APPENDIX IV

LIST OF MODEL MODIFICATIONS

PROGRAM STATEMENTS CONSTITUTING MODIFICATIONS (AND CORRECTIONS) TO THE ORIGINAL MODEL OF THREE-DIMENSIONAL GROUND-WATER FLOW OF TREVSCOTT (1975), AND TREVSCOTT AND LAASON (1976), ARE IDENTIFIED BY AN ASTERISK (*) OR A DIGIT (0-9) IN COLUMN 60. A FEW UNMODIFIED STATEMENTS ARE INCLUDED IN THIS LIST TO ASSURE PROPER SEQUENCING OF THE MODIFICATIONS.

****** MAIN ******

DIMENSION Y(102000), L(31), HEADING(33), NAME(42), INF(2,2), IOF(T(MAN0100, 194), DUM(3)) MAN0110
COMMON /INTEGR/ IO,J0,K0,11,J1,K1,1,JK,MPER,KTH,ITMAX,LENGTH,KP,NMAN0150
1VEL,NUMT,IFINAL,IT,KT,HEAD,DRADD,IFLO,IERR,12,J2,K2,IMAX,ITMX1,NCMAN0160
2H,IKDK1,IKDK2,IWATER,IGRE,IP,JP,IO,JG,IK,JK,K5,IPU1,IPU2,ITK,IEOE,IMAN0170
3DEP,ITL,NMD,IE,JE,KE,NCD MAN0171
    WRITE (6,190) HEADNG MAN0360
    READ (5,160) IO,J0,K0,ITMAX,NCH,NMD MAN0370
    WRITE (6,180) IO,J0,K0,ITMAX,NCH,NMD MAN0380
    READ (5,210) IDRAW,HEAD,IFLO,IKD1,IKD2,IWATER,IGRE,IPU1,IPU2,ITK MAN0390
1*IEOE,ITL,IMD MAN0391
    WRITE (6,223) IDRAW,HEAD,IFLO,IKD1,IKD2,IWATER,IGRE,IPU1,IPU2,ITK MAN0400
1*IEOE,ITL,IMD MAN0401
    ICRR=0 MAN0410
    IMAX=MAXO(IO,J0) MAN0500
    NCD=MAXO(1,NCH,NMD) MAN0510
    JQ=1 MAN110
70 IF(IHOEP.NE.ICHK(13)) GO TO 75 MAN111
      L(26)=ISUM MAN112
      ISUM=ISUM+ISIZ MAN113
      L(27)=ISUM MAN114
      ISUM=ISUM+NMD MAN115
      L(28)=ISUM MAN116
      ISUM=ISUM+NMD MAN117
      L(29)=ISUM MAN118
      ISUM=ISUM+NMD MAN119
      L(30)=ISUM MAN119
      ISUM=ISUM+NMD MAN119
      L(31)=ISUM MAN119
      ISUM=ISUM+NMD MAN119
      IE=10 MAN1110
      JE=1 MAN119
      KE=1 MAN119
    GO TO 77 MAN120
75 L(26)=ISUM MAN112
      L(27)=ISUM MAN113
      L(28)=ISUM MAN114
      L(29)=ISUM MAN115
      L(30)=ISUM MAN116
      L(31)=ISUM MAN117
      IE=1 MAN118
      JE=1 MAN119
      KE=1 MAN119
    GO TO 77 MAN119

IV-1
**---PASS INITIAL ADDRESSES OF ARRAYS TO SUBROUTINES---**

CALL DATAI(Y(L1), Y(L2), Y(L3), Y(L4), Y(L5), Y(L6), Y(L7))
1YL(8), Y(L9), Y(L10), Y(L11), Y(L12), Y(L13), Y(L14), Y(L15), Y(L16), Y(L17), Y(L18), Y(L19), Y(L20), Y(L21), Y(L22), Y(L23), Y(L24), Y(L25), Y(L26), Y(L27), Y(L28), Y(L29), Y(L30), Y(L31)

CALL STCP(Y(L1), Y(L2), Y(L3), Y(L4), Y(L5), Y(L6), Y(L7))

CALL SOLVE(Y(L1), Y(L2), Y(L3), Y(L4), Y(L5), Y(L6), Y(L7))

CALL COEF(Y(L1), Y(L2), Y(L3), Y(L4), Y(L5), Y(L6), Y(L7), Y(L8), Y(L9), Y(L10), Y(L11), Y(L12), Y(L13), Y(L14), Y(L15), Y(L16), Y(L17), Y(L18), Y(L19), Y(L20), Y(L21), Y(L22), Y(L23), Y(L24), Y(L25), Y(L26), Y(L27), Y(L28), Y(L29), Y(L30)

CALL CHECKI(Y(L1), Y(L2), Y(L3), Y(L4), Y(L5), Y(L6), Y(L7), Y(L8), Y(L9), Y(L10), Y(L11), Y(L12), Y(L13), Y(L14), Y(L15), Y(L16), Y(L17), Y(L18), Y(L19), Y(L20), Y(L21), Y(L22), Y(L23), Y(L24), Y(L25), Y(L26), Y(L27), Y(L28), Y(L29), Y(L30)

CALL PRNTAI(Y(L1), Y(L2), Y(L3), Y(L4), Y(L5), Y(L6), Y(L7), Y(L8), Y(L9), Y(L10), Y(L11), Y(L12), Y(L13), Y(L14), Y(L15), Y(L16), Y(L17), Y(L18), Y(L19), Y(L20), Y(L21), Y(L22), Y(L23), Y(L24), Y(L25), Y(L26), Y(L27), Y(L28), Y(L29), Y(L30)

**---READ LEAKANCES FOR HEAD-DEPENDENT TERMS---**

IF (IHINDP. NE. 1) GO TO 138

DO 132 K = 1, K0

LOC = L(26) * (K - 1) - NJ

132 CALL ARRAY (Y(loc), INFT(1, 1), IOFT(1, 3), 24MHEAD-DEPENDENT LEAKANCE)

**---READ THRESHOLD VALUES FOR HEAD-DEPENDENT SOURCE-SINK TERMS---**

CALL MDPDAT

**---COMPUTE TRANSMISSIVITY FOR UNCONFINED LAYER---**

IF (IWATER .EQ. 1CHK) CALL TRANS1

**---COMPUTE T COEFFICIENTS---**

CALL TCOF1

**---SIMULATION OPTIONS:  *13(A4,4X)**

**---TRANSMISSIVITY MULTIPLICATION FACTORS MAN 2110**

**---CALCULATION OF HEAD-DEPENDENT LEAKANCE**

SUBROUTINE DATAI(PHI, STRT, OLDO, TST, TSTC, TK, DELL, DELY, DELZ, FACDAT0, 100, ...
COMMON /INTGR/ IO,J0,K0,J1,J2,K1,J3,K3,NPER,KTH,ITMAX,LENGTH,KP,NSTP 160
1VEL,NUMT,IFINAL,IT,KT,HEAD,IDRAME,IFLO,IER,L2,J2,K2,ITMAX1,NCD 170
2H,IKDK1,IKDK2,IVATE,IP,JP,IP,JO,J0,K0,K5,IPU1,IPU2,ITK,IEQN,IMDAT 180
3DEP,ITL,NHD,IC,EK,NC 190
COMMON /SPARAM/ TMAX,CDLT,DEL,ERR,TEST,SUMP,QR 200
COMMON /SARRAY/ ICHK(13),LEVEL(9),LEVEL(2) 210
COMMON /CK/ ETFLXT,STRT,GRET,CHST,CHDT,FLUXT,PUMP,CFUXT,FLXNT,DAT 220
1HDVNT,HDVPT 230
READ (5,450) SUM,SUMP,PUMP,CFUXT,GRET,CHST,CHDT,FLUXT,STRT,ETF 231
1XT,FLXNT,HDVNT 240
HDVPT=0 250
IF (IHDEP.EQ.ICHK(13)) READ (5,450) HDVPT 260
IF (IHDEP.EQ.ICHK(4)) GO TO 20 270
20 READ (4) PHI,SUMP,PUMP,CFUXT,GRET,CHST,CHDT,FLUXT,STRT,ETF 280
1XT,FLXNT,HDVNT 290
RETURN 300

C ENTRY H2AD 310

A ******************* 320
WRITE (6,480) 330
N=0 340
DO 142 K=1,K0 350
DO 142 I=2,I1 360
DO 142 J=2,J1 370
IF (CSS(I,J,K).LE.0.) GO TO 142 380
N=N+1 390
IF (N.GT.NHO) GO TO 144 400
READ (5,490) HD(N),HSS(N),HSL(N) 410
WRITE (6,500) K,I,J,HD(N),HSS(N),HSL(N) 420
142 CONTINUE 430
RETURN 440
144 WRITE (6,510) I,J,K 450
STOP 460
C ENTRY MMAT 470

A ******************* 480
515.7 * PRINTED FOR LAYERS*912) 490
480 FORMAT (1HO*40X,* THRESHOLD HEADS FOR HEAD-DEPENDENT SOURCE-SINK TD 500
1ERMS*///36X,* LAYER*4X,* ROW*4X,* COLUMN*8X,* UPPER*7X,* MIDDLE*8X,* HDAT 510
2X,* FLOW*///38X,* K*7X,* I*,* J*,* CHB >*,* HSS*///,* HSL*///,* (HB) ,* 3X,* (HSS) * DAT 520
34X,*(HSL) ,/*,/*) 530
490 FORMAT (5010,D0) 540
500 FORMAT (1H*,*33X, *3(15,3X),*3(5X,F8.2)) 550
510 FORMAT (1HO*,*15X,* WARNING: NUMBER OF THRESHOLD HEADS EXCEEDDAT 560
1 THE NUMBER OF NONZERO LEAKANCES (CSS) CODED ***,*,*,*,*,*,*,*HDAT 570
2AD-DEPENDENT TERMS STARTING WITH NODE*,*J15*,*2X,*WERE NOT READ*) DAT 580
END 590

***** STEP *****

C ---IF MAXIMUM ITERATIONS EXCEEDED, WRITE RESULTS ON DISK OR CARDS--STP 580
IF (IDK2.EQ.ICHK(5)) WRITE (*) PHI,SUMP,PUMP,CFUXT,GRET,CHSTSTP 590

IV-3
SUBROUTINE SOLVE (PHI, STRT, OLD, T, S, TR, TC, WELL, DELX, DELY, DELZ, FACT, PM, CI, CL, FL, GL, V, XI, TEST3, ORE, CSS, HSS, HS, LHD, SPS) SP3 10

REAL -8PHI, RHO, D, F, H, Z, SUM, RHO1, RHO2, HSS, HS, FL, GL, V, XI, ORE, CSS, HSS, HS, LHD, SPS 90

REAL PHI, RHO, D, F, H, Z, SUM, RHO1, RHO2, RHO3, HSS, HS, LHD, SPS 90

DIMENSION PHI(1), STRT(1), OLD(1), T(1), S(1), TR(1), TC(1), WELL(1), DELX(1), DELY(1), DELZ(1), FACT(1), PM, CI, CL, FL, GL, V, XI, TEST3, ORE, CSS, HSS, HS, LHD, SPS 120

COMMON /INTEGR/ I0, J0, K0, I1, J1, K1, I, J, K, NPER, KTH, ITMAX, LENGTH, KP, NSP3 160

READ (5, 250) UMAX, HMAX SP3 320

IF CYMAX.LT.1. WRITE (6, 260) UMAX, HMAX SP3 321

IF CYMAX.EQ.1. WRITE (6, 270) UMAX, HMAX SP3 322

IF CYMAX.EQ.2. WRITE (6, 280) UMAX, HMAX SP3 323

IF CYMAX.EQ.3. WRITE (6, 290) UMAX, HMAX SP3 324

IF (K.EQ.1) GO TO 5 SP3 491

IF (T(N-NIJ).CQ.O.) GO TO 5 SP3 492

ZSTK(N) SP3 493

IF (IEQN.EQ.ICHK(11)) Z=Z/DELZ(K) SP3 494

5 IF (K.EQ.KO) GO TO 10 SP3 495

IF (T(N-NIJ).EQ.0.) GO TO 10 SP3 496

SU=TK(N) SP3 497

IF (IEQN.EQ.ICHK(11)) SU=SU/DELZ(K) SP3 498

10 CONTINUE SP3 500

TXM=DMAX1(D*F) SP3 570

TYM=DMAX1(B*H) SP3 580

TZM=DMAX1(SU,Z) SP3 590

DEN=DMIN1(D*F) SP3 600

IF (DEN.EQ.0.00) DEN=TXM SP3 610

IF (DEN.EQ.0.00) GO TO 20 SP3 620

IF (UW.EQ.1.) RHO1=DMAX1(RHO1, TYM/DEN) SP3 630

IF (UW.EQ.2.) RHO1=DMAX1(RHO1, (TYM+TZM)/DEN) SP3 631

IV-4
IF (WMAX.EQ.3.) RH01=(TYM+TZM)/DEN
IWM=IWM+1

20 DEN=DMIN1(B*H)
IF (DEN.EQ.0.DO) DEN=TYM
IF (DEN.EQ.0.DO) GO TO 30
IF (WMAX.EQ.1.) RH02=DMAX1(RH02,TXM/DEN)
IF (WMAX.EQ.2.) RH02=DMAX1(RH02,(TXM+TZM)/DEN)
IF (WMAX.EQ.3.) RH02=(TXM+TZM)/DEN
IWM=IWM+1

30 DEN=DMIN1(SU+Z)
IF (DEN.EQ.0.DO) DEN=TXM
IF (WMAX.EQ.1.) RH03=NMAX1(RH03,TYM/DEN)
IF (WMAX.EQ.2.) RH03=DMAX1(RH03,(TXM+TYM)/DEN)
IF (WMAX.EQ.3.) RH03=(TXM+TYM)/DEN
IWM=IWM+1

39 IF (WMAX.LE.3.) GO TO 40
IF (IWM.EQ.0) GO TO 40
XPART=XT/(1.0*RHO1)
YPART=YT/(1.0+RHO2)
ZPART=ZT/(1.0+RHO3)
WMIN=DMIN1(XPART,YPART,ZPART)
SUMUM=SUMUM+WMIN
NWM=NWM+1

40 CONTINUE
IF (WMAX.LE.3.) GO TO 42
WNUM=WUM
WNUM=SUMUM/WNUM
GO TO 44

42 XPART=XT/(1.0+RHO1)
YPART=YT/(1.0+RHO2)
ZPART=ZT/(1.0+RHO3)
WMIN=DMIN1(XPART,YPART,ZPART)

44 WMAX=1.0+WMIN

45 PJ=-1.
DO 50 I=1,LENGTH
BIG=0.
NNHD=0
IF (T(N).EQ.0,.OR.S(N).LT.0.) GO TO 148
IF (K.EQ.1) GO TO 124
IF (T(NKB).EQ.0.) GO TO 124
Z=TK(NKB)

124 IF (K.EQ.KO) GO TO 125
IF (T(NKA).EQ.0.) GO TO 125
SU=TK(N)
QR=0.
QS=0.

138 E=*D-O-D-F-H-SU-Z-RHO

C ---COMPUTE IMPLICIT AND EXPLICIT PARTS OF HEAD-DEPENDENT TERMS---
IF (IMDEP.NE.ICHK(13)) GO TO 138
LHD(N)=0
IF (CSS(N).EQ.0.) GO TO 138
NNHD=NNHD+1
IF (NNHD.GT.NNHD) GO TO 138
LHD(N)=NNHD
E=E+CSS(N)
QS=CSS(N)*HSS(NNHD)
IF (PHI(N).LT.HSL(NNHD).OR.S(N).LT.HSL(NNHD)) QS=QS-CSS(N)*HSL(NNHD)-PHI(N))
IF (PHI(N).GT.HB(NNHD)) QS=QS-CSS(N)*HB(NNHD)-PHI(N))

138 BL=B/(1.+M*(EL(NIB)+GL(NIB)))
CL=D/(1.+M*(FL(NJB)+GL(NJB)))
RES = -B * PHI(NIB) - D * PHI(NJBJ) - E * PHI(N) - F * PHI(NJA) - H * PHI(NIA) - SUPH - Z * \( \Phi \) SP31620
1H(NKB) = WELL(N) - RHO - OLD(N) - OR - QS
V(N) = RES + HMAX - AL + V(NKB) - BL + V(N) - CL + V(NJB))/DL SP31630
GO TO 150 SP31650
RES = -B * PHI(NIB) - D * PHI(NJBJ) - E * PHI(N) - F * PHI(NJA) - H * PHI(NIA) - SUPH - WELL SP31620
1L(N) = RHO - OLD(N) - OR - QS
V(N) = RES + HMAX - BL + V(N) - CL + V(NJB))/DL SP31640
GO TO 150 SP31670

148 IF (INDEPENDENT) GO TO 150
IF (CSS(N) .NE. 0.) GO TO 150
NNHD = NNHO + 1
150 CONTINUE
IF (K - EQ. 1) GO TO 174
IF (T(NKB) .EQ. 0.) GO TO 174
Z = TK(NKB)
174 IF (K - EQ. K0) GO TO 175
IF (T(NKA) .EQ. 0.) GO TO 175
SU = TK(N)
QR = 0.
QS = 0.
IF (K .NE. K0) GO TO 180
180 E = -D - F - H - SU - Z - RHO
C --- COMPUTE IMPLICIT AND EXPLICIT PARTS OF HEAD-DEPENDENT TERMS ---
IF (INDEPENDENT) GO TO 188
IF (CSS(N) .LE. 0.) GO TO 188
NNHD = LHD(N)
IF (NNHD .GT. NNHD) GO TO 188
E = -CSS(N)
QS = CSS(N) * HMAX
IF (P(H) .LT. HSL(NNHD)) QS = QS - CSS(N) * (HSL(NNHD) - PHI(N))
IF (CSS(N) .GT. HB(NNHD)) QS = QS - CSS(N) * (HB(NNHD) - PHI(N))
188 DL = H/(1. + W (EL(NIA) + GL(NIA)) )
CL = D/(1. + W (FL(NJB) + GL(NJB)))
RES = -B * PHI(NIB) - D * PHI(NJBJ) - E * PHI(N) - F * PHI(NJA) - H * PHI(NIA) - SUPH - Z * \( \Phi \)
1H(A) = WELL(N) - RHO - OLD(N) - OR - QS
V(N) = RES + HMAX - AL + V(NKA) - BL + V(N) - CL + V(NJB))/DL SP31610
GO TO 200 SP31620
RES = -B * PHI(NIB) - D * PHI(NJBJ) - E * PHI(N) - F * PHI(NJA) - H * PHI(NIA) - SUPH - WELL
1L(N) = RHO - OLD(N) - OR - QS
V(N) = RES + HMAX - BL + V(N) - CL + V(NJB))/DL
200 CONTINUE
143 (****)
C
250 FORMAT (2F10.0)
260 FORMAT (45X, **MAXIMUM ITERATION PARAMETER, WMAX = \( \tau \), F10.7, **/45X, **ACSP32932
1CELERATION (OR DAMPING) FACTOR, HMAX = \( \tau \), F5.2)
270 FORMAT (1H0, **4X, **INDICATOR FOR WMAX = \( \tau \), F5.2) SP32933
1H0, **4X, **INDICATOR FOR WMAX = \( \tau \), F5.2) SP32934
145X, **MAXIMUM ITERATION PARAMETER COMPUTED ACCORDING TO** SP32935
245X, **THE ORIGINAL FORMULATION OF TRECOTT (1975)** SP32936
345X, **ACCELERATION (OR DAMPING) FACTOR HMAX = \( \tau \), F5.2)** SP32937
280 FORMAT (1H0, **4X, **INDICATOR FOR WMAX = \( \tau \), F5.2)** SP32938
140X, **MAXIMUM ITERATION PARAMETER COMPUTED AS THE ABSOLUTE MAX** SP32939
240X, **VALUE OVER THE GRID USING FULL FORMULATION OF RHO TERMS** SP32940
340X, **ACCELERATION (OR DAMPING) FACTOR HMAX = \( \tau \), F5.2)** SP32941
290 FORMAT (1H0, **4X, **INDICATOR FOR WMAX = \( \tau \), F5.2)** SP32942
140X, **MAXIMUM ITERATION PARAMETER COMPUTED AS THE ARITHMETIC** SP32943
240X, **AVERAGE OF THE LOCAL MAXIMA OF WMAX FOR EACH ACTIVE NODE** SP32944
340X, **USING THE FULL FORMULATION OF RHO TERMS** SP32945
440X, **ACCELERATION (OR DAMPING) FACTOR HMAX = \( \tau \), F5.2)** SP32946
END
*****  COEF  *****

COMMON /INTEGR/ I0,J0,K0,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NCOF
150
1WE,JNUMT,JFINAL,JIT,K,HEAD,IMLAMT,IFLO,IER2,J2,K2,IMAX,NCCOF
160
2N1,1DK1,1DK2,1WATER,1GRE,1P,J,P1,J,P2,J,IK,JK,JS,IPUI1,IPUI2,ITK1,IEQN,INCOF
170
3DEP,1NLH,1D,E,JE,KE,NCD

COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR
180
T(I,J,K0)=PERM(I,J)*(PHI(I,J,K)-BOTTOM(I,J))
200
IF (T(I,J,K0).GT.0.) GO TO 5
400
IF (WELL(I,J,K0).LT.0.) WRITE (6,60) I,J,K0
210
PHII(I,J,K0)=1.030
410
GO TO 10

5 IF (IEQN.EQ.ICHK(11)) T(I,J,K0)=PERM(I,J)

10 CONTINUE

IF (N3.EQ.1) RETURN

IF (IEQN.EQ.ICHK(11)) AND N3.EQ.0 RETURN

N1=K0

C ****************************
ENTRY TCOFCN3

C ****************************

SUBROUTINE CHECKI PHII,STRT,OLD,TS,TR,TK,WELL,DELX,DELY,DELZ,FACHK
10
ICT,JFL0,TFL0,ORC,CSS,HSS,HS1,HST,HDRT

DIMENSION PHII(I0,J0,K0),STRT(I0,J0,K0),OLD(I0,J0,K0),T(I0,J0,K0),
10,TS(I0,J0,K0),TR(I0,J0,K0),TK(I0,J0,K0),WELL(I0,K0CHK
100
2J0,K0),DELX(J0),DELY(I0),DELZ(K0),FACT(K0,3),FLOTNCD,FLCHK
120
3WNC,D,GRDR(I0,J0),CSS,IE,JE,KE,HSS(NHD),HB(NHD),HSL(NHD),

4HDRT(NHD),HDRT(NHD)

C

COMMON /INTEGR/ I0,J0,K0,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NCHK
150
1WE,JNUMT,JFINAL,JIT,K,HEAD,IMLAMT,IFLO,IER2,J2,K2,IMAX,NCCMK
160
2N1,1DK1,1DK2,1WATER,1GRE,1P,J,P1,J,P2,J,IK,JK,JS,IPUI1,IPUI2,ITK1,IEQN,INCHK
170
3DEP,1NLH,1D,E,JE,KE,NCD

COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR
180
COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9)
190
COMMON /CK/ EFLX,STOR,STOR,GRD,CHDF,CHDT,FLUXT,FLUXT,FLXNT
200
1HDVNT,HDVPT

FLXN=0

210
FDFN=0

MDFP=0

NNHD=0

HDRT(1)=0

II=0

IF (IMDEP.NE.ICHK(13)) GO TO 5

DO 4 N=2,NHD

4 HDRT(N)=0.

C ****************************

IF (T(I,J,K0).EQ.0.) GO TO 218

210 STOR=STOR+S(I,J,K0)*((OLD(I,J,K)-PHII(I,J,K))*AREA

C

C ---COMPUTE FLOW RATES FROM HEAD-DEPENDENT TERMS---

IV-7
IF (HDRT(NNHD) .LT. 0.) HDFN=HDFN+HDRT(NNHD)                     CHK10912
IF (HSS(NNHD) .EQ. HSL(NNHD)) ETFLUX=ETFLUX+HDRT(NNHD)            CHK10913
GO TO 220                                                        CHK1091

214 STOR=STOR+S(I,J,K)*(OLD(I,J,K)-PHI(I,J,K))*VOLUME             CHK1102

C ---COMPUTE FLOW RATES FROM HEAD-DEPENDENT TERMS---              CHK11021
C
C IF (IHDEP .NE. ICHK(13)) GO TO 220                                CHK11022
IF (CSS(I,J,K) .EQ. 0.) GO TO 220                                  CHK11023

NNHD=NNHD+1                                                       CHK11024
IF (NNHD.GT.NNHD) GO TO 220                                        CHK11025

HDD=PHI(I,J,K)                                                   CHK11026
IF (HDD .LT. HSL(NNHD)) HDD=HSL(NNHD)                              CHK11027
IF (HDD .LT. HSL(NNHD)) HDD=HSL(NNHD)                              CHK11028
HDD=PHI(I,J,K)                                                   CHK11029
ETFUX=ETFUX+HDD                                                   CHK11030
ETFUX=ETFUX+HDD                                                   CHK11031
ETFUX=ETFUX+HDD                                                   CHK11032
ETFUX=ETFUX+HDD                                                   CHK11033

GO TO 220                                                        CHK11034

218 IF (IHDEP .NE. ICHK(13)) GO TO 220                              CHK11035
IF (CSS(I,J,K) .EQ. 0.) GO TO 220                                  CHK11036

NNHD=NNHD+1                                                       CHK11037

220 CONTINUE                                                     CHK11038

C****************************************************************************** CHK1110
CFUXT=CFLUXT+CFLUX*DELT                                          CHK1210
ETFUXX=ETFUXX-ETFUX*DELT                                         CHK1211
HDVNT=HDVNT-HDFN*DELT                                           CHK1212
HDVPT=HDVPT-HDFP*DELT                                           CHK1213
TOTAL=TOTAL+QRET+CFUXT+CHST*FLXPT+HDVPT                         CHK1214
TOTAL=TOTAL+QRET+CFUXT+CHST*FLXPT+HDVPT                         CHK1215
SUM=QRET+CFUXT+CHST*FLXPT+HDVPT                                 CHK1216
DIFF=TOTAL2-TOTAL1                                             CHK1217

2L2,DIFF,PERCENT                                                CHK1390
IF (NCH.EQ.0) GO TO 231                                         CHK1400
WRITE (6,270)                                                   CHK1410
WRITE (6,280) ((JFLO(I,J),J=1,3),FLOW(I),I=1,NCH)              CHK1420

C****************************************************************************** CHK1430
---PRINT OUT FLOW RATES FROM HEAD-DEPENDENT SOURCES AND SINKS---    CHK14301
231 IF (IHDEP .NE. ICHK(13)) GO TO 240                            CHK14302
IRR=0                                                           CHK14303
NNHD=0                                                         CHK14304
II=0                                                           CHK14305
DO 234 K=1,NK                                                  CHK14306
DO 234 I=2,11                                                 CHK14307
DO 234 J=2,NJ                                                 CHK14308
IF (CSS(I,J,K) .EQ. 0.) GO TO 234                               CHK14309
NNHD=NNHD+1                                                   CHK14310
IF (NNHD.GT.NNHD) GO TO 240                                     CHK14311
IF (HDRT(NNHD).LE.0.) GO TO 232                                 CHK14312
II=II+1                                                      CHK14313
JFLO(I,J,1)=K                                                 CHK14314
JFLO(I,J,2)=I                                                 CHK14315
JFLO(I,J,3)=J                                                 CHK14316
FLOW(I)=HDRT(NNHD)                                             CHK14317
GO TO 234                                                  CHK14318

232 IR=NNHD-IRR                                               CHK14319
JFLO(IR,1)=K                                               CHK14320
JFLO(IR,2)=I                                               CHK14321
JFLO(IR,3)=J                                               CHK14322
FLOW(IR)=HDRT(NNHD)                                         CHK14323
IRR=IRR+1                                                  CHK14324

234 CONTINUE                                                    CHK14324

IV-8
IF (II.EQ.0) GO TO 236
WRITE(6,300)
WRITE(6,280) ((JFL0(I, J), J=1, 3), FLOW(I), I=1, II)
WRITE(6,310) HDPV, HDVPT
236 IF (IRR.EQ.0) GO TO 240
WRITE(6,320)
WRITE(6,280) ((JFL0(I, J), J=1, 3), FLOW(I), I=IR, NhD)
WRITE(6,330) HDFN, HDVNT
CHK14328
--- COMPUTE VERTICAL FLOW ---
240 X=0.
WRITE (6, 290) Y = 0.
IF (K0 .EQ. 1) RETURN
DO 250 I=2, II
DO 250 J=2, J1
IF (T(I, J, 1).EQ. 0 .. OR. T(I, J, 2).EQ. 0.) GO TO 245
IF (S(I, J, 1) .LT. 0 .. AND. S(I, J, 2) .LT. 0.) GO TO 250
X=X+(PHI(I, J, 1)-PHI(I, J, 2))*TK(I, J, 1)*DELX(J)*DELY(I)
245 IF (T(I, J, K1).EQ. 0 .. OR. T(I, J, KO).EQ. 0.) GO TO 250
IF (S(I, J, K1) .LT. 0 .. AND. S(I, J, KO) .LT. 0.) GO TO 250
Y=Y+(PHI(I, J, K1)-PHI(I, J, KO))*TK(I, J, K1)*DELX(J)*DELY(I)
250 CONTINUE
WRITE (6, 290) Y, X
STOP STORAGE = F20.2, 35X*CONSTANT FLUX = F20.4/26X*RECHARGE = F20.4/26X
40.2, 41X*PUMPING = F20.4/21X*CONSTANT FLUX = F20.2, 30X*ET C ANDCHK1670*
5 OR SPRINGS = F20.4/21X*CONSTANT HEAD = F20.2, 34X*CONSTANT HEACHK1680*
60.2, 42X*LEAKAGE = F20.2, 46X*IN = F20.4/21X*TOTAL SOURCES = F20.4/21X
720.2, 43X*OUT = F20.2, 44X*DISCHARGES = F20.4/21X*TOTAL SOURCCHK1810*
E PREVIOUS PUMPING PERIOD = F20.4/20X*11(-1)*68X*TOTAL = F20.4/1CHK1710*
96X*ET. AND/OR SPRINGS = F20.2, 36X*SUM OF RATES = F20.4/19X*QUANTITY PUMPED = F20.2, 27X*LEAKAGE = F20.4/28X
115.7, 9 POSITIVE UPWARD*) CHK1820-
300 FORMAT (*0FLOW RATES FROM HEAD-DEPENDENT SOURCES:* ,/,*, *, 39(*-*) CHK1811-
1 *, 31*X, *, 4X, *, I*, 4X, *, J, *, 5X, *, RATE (L=3/T)*/ CHK1812-
24X, *, *, 5X, *, 12(-*) CHK1813-
310 FORMAT (*0FLOW RATES FROM HEAD-DEPENDENT SOURCES = G18CHK1814-
1*7, 10X*, TOTAL FLOW RATE FROM HEAD-DEPENDENT SOURCES = G18CHK1815-
320 FORMAT (*0FLOW RATES FROM HEAD-DEPENDENT SINKS:*,,*, *, 37(*-*) CHK1816-
1*3, 49*X, *, 4X, *, I, *, 4X, *, J, *, 5X, *, RATE (L=3/T)*/ CHK1817-
24X, *, *, 5X, *, 13(-*) CHK1818-
330 FORMAT (*0FLOW RATES FROM HEAD-DEPENDENT SINKS = G18CHK1819-
1*10, *, TOTAL FLOW RATE FROM HEAD-DEPENDENT SINKS = G18CHK1820-
1* END
**** PRINTAI ****
COMMON /INTLGR/ I 0, J0, K0, I1, J1, K1, I0, J2, K2, ITMAX, LENGTH, KP, NPNR 180
1WEL, NUMT, IFINAL, IT, IHED, IDRA, IFLO, IERR, I2, J2, MAX, IMAX, NCPNK, NCPN 180
2H, IDK1, IDK2, IHEA, IMA, IP, J, J0, IK, JK, K5, IPU1, IPU2, ITK, IECN, IHPN 180
3DEP, ITL, NMD, IE, JE, KE, NCO
PRN 151* COMMON /PR/ XLABEL(3), YLABEL(6), TITLE(6), XN1, MESUR, PRNT(122), BLANKP RN 160
**** BLOCK DATA ****
DATA ICHK/*DRAW*, *HEAD*, *MASS*, *DK1*, *DK2*, *WATE*, *RECH*, *PUN1*, *BLK 130
1UN2*, *ITK*, *EZN3*, *ITL*, *HDEP*/
BLK 140*
IV-9
APPENDIX V

Example of Input to Modified Model

//STEP1 EXEC FORTRAN*PROC=HEDEP*REGION=490K*ULIB=*VC4E91L*THREDEE*
//GO*SYIN DD *
**** CHECKOUT SIMULATION OF 3-D FINITE-DIFFERENCE MODEL (TRESCOTT), MODIFIED TO
INCLUDE HEAD-DEPENDENT SOURCE/SINK TERMS ****

<table>
<thead>
<tr>
<th>HEAD MASS</th>
<th>H</th>
<th>1</th>
<th>2</th>
<th>.01</th>
<th>5</th>
<th>HDEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td>1</td>
<td></td>
<td>115</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td>1</td>
<td></td>
<td>115</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td>1</td>
<td></td>
<td>115</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td>1</td>
<td></td>
<td>115</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td>1</td>
<td></td>
<td>115</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td>1</td>
<td></td>
<td>115</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td>1</td>
<td></td>
<td>115</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td>1</td>
<td></td>
<td>115</td>
<td>115</td>
<td>115</td>
</tr>
</tbody>
</table>

V-1
C   0  -1  -1  -1  -1  -1  -1  0
C   1.  1
C   0  -1  -1  -1  -1  -1  -1  0
C   1
C
C   0  -1  -1  -1  -1  -1  -1  0
C
C
C   0  -1  -1  -1  -1  -1  -1  0
C
C
C   8.669
   25.976
   17.317
   3.624E-08
1  **** CSS ARRAY: LAYER 1 ****
C
C   1
   1
   1
C
C
C   3.624E-08
1  **** CSS ARRAY: LAYER 2 ****
C
C   1
   1
   1
C
C
C   3.624E-08
1  **** CSS ARRAY: LAYER 3 ****
C
C   1
   1
   1
C
C
C   110. 100. 100.  H(N)  H(N)  H(N)
   110. 100. 100. 
   110. 100. 100. 
   110. 100. 100. 
   110. 100. 100. 
   110. 100. 100. 
   110. 100. 100. 
   110. 100. 100. 
   110. 100. 100. 
   110. 100. 100. 
   110. 100. 100. 
   110. 100. 100. 
   3.  1.2  WMAX  HMAX
   1  0  0  1  1  1.0  24.
C
*/
**
APPENDIX VI

Example of Output from Modified Model

**** CHECKOUT SIMULATION OF 3-D FINITE-DIFFERENCE MODEL (TRESCOIT), MODIFIED TO INCLUDE HEAD-DEPENDENT SOURCE/SINK TERMS ****

NUMBER OF ROWS = 8
NUMBER OF COLUMNS = 8
NUMBER OF LAYERS = 3

MAXIMUM PERMITTED NUMBER OF ITERATIONS = 60

NUMBER OF CONSTANT HEAD NODES = 36

NUMBER OF HEAD-DEPENDENT SOURCE-SINK NODES = 12

SIMULATION OPTIONS:

HEAD MASS

WORDS OF VECTOR Y USED = 3493

NUMBER OF PUMPING PERIODS = 1
TIME STEPS BETWEEN PRINTOUTS = 2
ERROR CRITERIA FOR CLOSURE = .10000001-01
### STARTING HEAD MATRIX, LAYER 1

<table>
<thead>
<tr>
<th></th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.0</td>
<td>115.0</td>
<td>115.0</td>
<td>115.0</td>
<td>115.0</td>
<td>115.0</td>
<td>115.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>---</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>115.0</td>
<td>115.0</td>
<td>115.0</td>
<td>115.0</td>
<td>115.0</td>
<td>115.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
### STARTING HEAD MATRIX, LAYER 3

<table>
<thead>
<tr>
<th></th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>115.0</td>
<td>115.0</td>
<td>115.0</td>
<td>115.0</td>
<td>115.0</td>
<td>115.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>---</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>---</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>0.0</td>
</tr>
<tr>
<td>P</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**STORAGE COEFFICIENT MATRIX, LAYER 2**

VI-6
### Storage Coefficient Matrix: Layer 3

<table>
<thead>
<tr>
<th></th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.0</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>-1.00000</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Transmissivity: 8.659000 for Layer 1**

**Directional Transmissivity Multiplication Factors for Layer 1**

\[ X = 1.000000 \]
\[ Y = 1.000000 \]
\[ Z = 1.00000001 \]

**Transmissivity: 25.976000 for Layer 2**

**Directional Transmissivity Multiplication Factors for Layer 2**

\[ X = 1.000000 \]
\[ Y = 3.000000 \]
\[ Z = 1.00000001 \]

**Transmissivity: 17.317000 for Layer 3**

**Directional Transmissivity Multiplication Factors for Layer 3**

\[ X = 1.000000 \]
\[ Y = 1.000000 \]
\[ Z = 1.00000001 \]
## HEAD-DEPENDENT LEAKANCES MATRIX, LAYER 1

<table>
<thead>
<tr>
<th></th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.36240E-07</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.36240E-07</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.36240E-07</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.36240E-07</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

VI-8
<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>3.6240E-07</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>3.6240E-07</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>3.6240E-07</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>3.6240E-07</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
HEAD-DEPENDENT LEAKANCES MATRIX: LAYER 3

<table>
<thead>
<tr>
<th></th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

THRESHOLD HEADS FOR HEAD-DEPENDENT SOURCE-SINK TERMS

<table>
<thead>
<tr>
<th>LAYER</th>
<th>ROW</th>
<th>COLUMN</th>
<th>UPPER</th>
<th>MIDDLE</th>
<th>LOWER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(IUH)</td>
<td>(HSS)</td>
<td>(HSL)</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>3</td>
<td>110.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>3</td>
<td>110.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>3</td>
<td>110.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4</td>
<td>110.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>4</td>
<td>110.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>4</td>
<td>110.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>4</td>
<td>110.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>5</td>
<td>110.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>5</td>
<td>110.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>5</td>
<td>110.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>5</td>
<td>110.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

DELX = 10000.00
DELY = 10000.00
DELZ = 100.0000

SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE

INDICATOR FOR WMAX = 3.00

MAXIMUM ITERATION PARAMETER COMPUTED AS THE ARITHMETIC AVERAGE OF THE LOCAL MAXIMA OF WMAX FOR EACH ACTIVE NODE USING THE FULL FORMULATION OF WGO TERMS

ACCELERATION (OR DAMPING) FACTOR WMAX = 1.20

5 ITERATION PARAMETERS: 0.0  0.834380D+00  0.964240D+00  0.795420D+00  0.937670D+00
PUMPING PERIOD NO. 1: 1.00 DAYS

NUMBER OF TIME STEPS = 1
DELT IN HOURS = 24,000
MULTIPLIER FOR DELT = 1,000

9 WELLS

K I J PUMPING RATE
### Cumulative Mass Balance:

**SOURCES:**
- STORAGE = 0.0
- RECHARGE = 0.0
- CONSTANT FLUX = 0.0
- CONSTANT HEAD = 144628.64

**TOTAL SOURCES:** = 144628.64

**DISCHARGES:**
- CT. AND/OR SPRINGS = 1310635.1
- CONSTANT HEAD = 131013952.0

**TOTAL DISCHARGE:** = 131020288.0

**DISCHARGE-SOURCES:** = -588576.00

**PER CENT DIFFERENCE:** = -0.35

### Flow Rates to Constant Head Nodes:

<table>
<thead>
<tr>
<th>K</th>
<th>I</th>
<th>J</th>
<th>RATE (L**3/1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
<td>45.42071</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>5</td>
<td>47.49749</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>2</td>
<td>-92.04755</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>5</td>
<td>-42.05698</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>7</td>
<td>137.40533</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>5</td>
<td>142.4294</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>2</td>
<td>-126.1377</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>5</td>
<td>-126.1914</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>2</td>
<td>91.60337</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>5</td>
<td>95.13852</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>2</td>
<td>-94.80986</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>K</th>
<th>I</th>
<th>J</th>
<th>RATE (L**3/1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>47.05675</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>7</td>
<td>47.31520</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>3</td>
<td>-41.94511</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>6</td>
<td>-142.2932</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>3</td>
<td>145.0099</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>6</td>
<td>195.927</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>3</td>
<td>-129.4305</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>6</td>
<td>-129.4976</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>3</td>
<td>95.2438</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>6</td>
<td>90.62414</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>3</td>
<td>-85.88835</td>
</tr>
</tbody>
</table>

---

**FLOW RATES TO CONSTANT HEAD NODES:**

<table>
<thead>
<tr>
<th>K</th>
<th>I</th>
<th>J</th>
<th>RATE (L**3/1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>4</td>
<td>48.46759</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>7</td>
<td>49.59529</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>4</td>
<td>-41.99555</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>7</td>
<td>-42.6457</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>4</td>
<td>144.3306</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>7</td>
<td>133.7762</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>4</td>
<td>-127.7403</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>7</td>
<td>-127.3403</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>4</td>
<td>96.1104</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>7</td>
<td>89.1832</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>4</td>
<td>-83.46249</td>
</tr>
</tbody>
</table>

---

**VI-12**
<table>
<thead>
<tr>
<th>Layer</th>
<th>Flow from Head-Dependent Sinks</th>
<th>Total Flow Rate from Head-Dependent Sinks</th>
<th>Flow to Top Layer</th>
<th>Flow to Bottom Layer</th>
<th>Total Upward</th>
<th>Positive Upward</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0172</td>
<td>0.0172</td>
<td>35.4161</td>
<td>35.4161</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>1</td>
<td>0.0848</td>
<td>0.0848</td>
<td>30.2570</td>
<td>30.2570</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>2</td>
<td>0.4763</td>
<td>0.4763</td>
<td>35.181</td>
<td>35.181</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>3</td>
<td>0.3963</td>
<td>0.3963</td>
<td>35.3872</td>
<td>35.3872</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>4</td>
<td>1.6410</td>
<td>1.6410</td>
<td>35.1933</td>
<td>35.1933</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>5</td>
<td>4.5919</td>
<td>4.5919</td>
<td>10.9403</td>
<td>10.9403</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>6</td>
<td>12.0000</td>
<td>12.0000</td>
<td>10.9403</td>
<td>10.9403</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>7</td>
<td>25.0000</td>
<td>25.0000</td>
<td>10.9403</td>
<td>10.9403</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Maximum Head Change: 52.3669

Flow Rairs from MCAD-DEPCN, T Sinks:

- Rate \( \text{L}^3/\text{T} \)

Total Volume: 0.5862
### HEAD MATRIX, LAYER 1

<table>
<thead>
<tr>
<th></th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>115.00</td>
<td>115.00</td>
<td>115.00</td>
<td>115.00</td>
<td>115.00</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>109.71</td>
<td>109.47</td>
<td>109.45</td>
<td>109.52</td>
<td>109.77</td>
<td>109.85</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>104.64</td>
<td>104.48</td>
<td>104.45</td>
<td>104.52</td>
<td>104.71</td>
<td>104.79</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>99.72</td>
<td>99.66</td>
<td>99.67</td>
<td>99.70</td>
<td>99.78</td>
<td>99.82</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>0.0</td>
<td>94.86</td>
<td>94.84</td>
<td>94.84</td>
<td>94.86</td>
<td>94.88</td>
<td>94.90</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**VI-14**
<table>
<thead>
<tr>
<th></th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
<th>0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.0</td>
<td>115.00</td>
<td>115.00</td>
<td>115.00</td>
<td>115.00</td>
<td>115.00</td>
<td>115.00</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>109.71</td>
<td>109.49</td>
<td>109.44</td>
<td>109.52</td>
<td>109.77</td>
<td>109.85</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>104.64</td>
<td>104.47</td>
<td>104.45</td>
<td>104.52</td>
<td>104.71</td>
<td>104.79</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>99.72</td>
<td>99.68</td>
<td>99.67</td>
<td>99.70</td>
<td>99.78</td>
<td>99.82</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>0.0</td>
<td>94.86</td>
<td>94.84</td>
<td>94.84</td>
<td>94.86</td>
<td>94.88</td>
<td>94.90</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>---</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>115.00</td>
<td>115.00</td>
<td>115.00</td>
<td>115.00</td>
<td>115.00</td>
<td>115.00</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>109.71</td>
<td>109.50</td>
<td>109.45</td>
<td>109.51</td>
<td>109.77</td>
<td>109.85</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>104.64</td>
<td>104.49</td>
<td>104.45</td>
<td>104.51</td>
<td>104.71</td>
<td>104.79</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>99.72</td>
<td>99.68</td>
<td>99.67</td>
<td>99.70</td>
<td>99.78</td>
<td>99.82</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>0.0</td>
<td>94.86</td>
<td>94.84</td>
<td>94.84</td>
<td>94.86</td>
<td>94.88</td>
<td>94.90</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>90.00</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**HLAD MATRIX, LAYER 3**

VI-16