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**Results of Two- and Three-Dimensional Groundwater Flow Modeling
for the Design Criteria Studies in Waste Area Grouping 6
at Oak Ridge National Laboratory, Oak Ridge, Tennessee**

Date Issued—December 1993

Prepared by
Ebasco Environmental
Oak Ridge, Tennessee
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ABBREVIATIONS

DOE	U.S. Department of Energy
ECE	Environmental Consulting Engineers, Inc.,
FS/EA	feasibility study/environmental assessment
ICM	interim corrective measures
LLW	low-level radioactive wastes
MS	monitoring station
ORNL	Oak Ridge National Laboratory
RAM	random-access memory
RCRA	Resource Conservation and Recovery Act
SWSA	Solid Waste Storage Area
TARA	Test Area for Remedial Action
WAG	Waste Area Grouping

EXECUTIVE SUMMARY

In support of Title I design for Waste Area Grouping (WAG) 6 interim remediation at the Oak Ridge National Laboratory (ORNL), groundwater flow models were developed to assess the response of the groundwater system to various capping scenarios and boundary alternatives. The completed Title I design incorporated the cap boundary scheme known as Iteration 3.

The groundwater flow models are categorized as either two-dimensional (2-D) or three-dimensional (3-D). The 3-D model of the WAG 6 site was used to investigate the steady-state groundwater conditions for each cap boundary alternative or other scenario. Several 2-D models were developed to examine specific areas of the caps for both steady-state conditions and transient effects of subsurface stormflow with each model selected to best provide specific types of information.

There was agreement between the results for 3-D and 2-D models for the projected amounts of water table decline for comparable cap conditions. For Iteration 3 conditions, the projected decline under the Large Cap (21 acres) was 22 ft maximum (14.6 ft average). The amount of expected decline under the two major caps was 9 ft maximum (4.4 ft average) for the west area cap (3.5 acres) and 2 ft maximum (0.8 ft average) for the southern area cap (4.5 acres). The estimated time to achieve essential equilibrium under the west area cap is 1.5 yr. Groundwater response differed only slightly between the various boundary alternatives studied, with Iteration 3 producing the most favorable results.

A number of trenches will continue to be partially inundated. Although hydrologic isolation from the groundwater system is not achieved, indications are that a geomembrane capping system will be very effective and that contaminant as well as groundwater fluxes leaving the site will be substantially reduced. The cap boundaries as planned in Title I (e.g., nominally 15 ft beyond the outer edge of the trench) were found adequate for preventing off-cap rainfall from reaching the burial trenches.

The most favorable approach for a barrier to upgradient subsurface stormflow is to extend the cap to the planned road north of the cap boundary rather than constructing a cutoff trench at the cap boundary. Regardless of the barrier method, small amounts of groundwater flux continue through a number of burial trenches. No off-cap areas with significant groundwater recharge potential were identified, nor was it found justifiable to line stream bottoms to prevent recharge to burial trenches.

Preliminary analyses were made as a part of the 2-D simulations for the effects of cap leakage on overall performance. While deserving of further study, indications are that minor leakage rates associated with a cap of high quality construction and maintenance do not have significant impact on performance but that higher leakage rates may seriously affect the amount of groundwater decline and groundwater flux through the trenches.

1. INTRODUCTION

This report documents the application of groundwater flow models to the Waste Area Grouping (WAG) 6 site at the Oak Ridge National Laboratory (ORNL). WAG 6 is a disposal site for hazardous and low-level radioactive wastes (LLW). Because of the potential threat to human health from contaminated groundwater, the U.S. Department of Energy (DOE) intends to perform an interim remedial action at WAG 6. As part of the remediation effort, geomembrane caps are proposed to cover the various areas of waste trenches. The groundwater flow modeling was conducted to support remedial design.

The primary purpose of the groundwater modeling was to determine the effectiveness of a basic geomembrane capping system as outlined in the Feasibility Study/Environmental Assessment (FS/EA) (Radian 1992) in providing hydrologic isolation of the trench wastes from surface infiltration and the groundwater system in order to reduce off-site contaminant flux.

A secondary purpose of the modeling was to assess the relative effects on the cap performance of adjustments in the cap boundary to conform to ridge terrain, to accommodate drainage features, and to otherwise facilitate construction without exorbitant costs for clearing, earthwork, or disposal of contaminated debris. The modeling results thus are intended for guidance in performing Title I design.

This report describes the hydrogeologic setting, numerical models used, modeling processes employed, assumptions made, modeling results obtained, and conclusions reached. The modeling used both three-dimensional (3-D) and two-dimensional (2-D) models to evaluate the groundwater response. The geologic and hydrogeologic site conditions are described as necessary for the modeling. A more detailed description of the site may be found in the Resource Conservation and Recovery Act (RCRA) facility investigation report (BNI 1991).

1.1 SITE DESCRIPTION

The site is located east of Tennessee State Route 95 in the southwest corner of the ORNL reservation (Fig. 1). Topographic relief is high, with ground surface elevations ranging from an elevation (El) 750 ft at White Oak Lake in the southern border of the site to El 840 ft at the top of the two hills in the west and northwest portion of the site (Fig. 2). Surface drainage is generally to the south into several small intermittent streams that drain into White Oak Lake or White Oak Creek. Most of WAG 6 is grassy or wooded with mixed conifer and deciduous forest.

WAG 6 (Fig. 2) consists of three solid waste management units: Solid Waste Storage Area (SWSA) 6, the Emergency Waste Basin, and the Explosives Detonation Trench. SWSA 6, the largest of the WAG 6 units, covering approximately 68 acres, was opened in 1969 for shallow land burial of LLW. Wastes disposed in SWSA 6 include laboratory glassware and equipment, protective apparel, mechanical equipment, construction materials, filter media and resins, contaminated earth, and biological waste. Waste packaging has varied widely from unpacked waste and plastic bags to stainless steel drums (BNI 1991).

The Emergency Waste Basin, located in the northeast corner of WAG 6, is an emergency holding basin with a surface area of approximately 2 acres and storage capacity of 15 million gal. The basin has never been used for waste disposal or storage but does receive some runoff and groundwater discharge from SWSA 6.

Fig. 1. Map of Oak Ridge Reservation.

Fig. 2. Map of WAG 6 study area.

The Explosives Detonation Trench was approximately 15 ft long, 5 ft wide, and 4 ft deep and was used to detonate explosives and shock sensitive chemicals. The Explosives Detonation Trench is located in the southeastern corner of SWSA 6. The trench has been backfilled and its exact location is unknown (BNI 1991).

1.2 PURPOSE OF NUMERICAL MODELING

The main purpose of this modeling effort was to assess the probable response of the WAG 6 groundwater system to surface capping scenarios considered in Title I design. Through the use of these models, the study generated the expected changes in groundwater levels, soil saturations, and flow paths and velocities and the timing of these changes. More specifically, the modeling effort was initiated to answer the following questions.

- How much will groundwater levels decline after placement of the caps?
- How long will it take the groundwater system to decline to new levels once the caps are installed?
- Are upgradient subsurface stormflow cutoff trenches necessary to prevent lateral groundwater flow beneath the caps?

Preliminary results from the 3-D modeling indicated a need for 2-D modeling with greater detail. The 2-D modeling provided additional capabilities which the 3-D model, because of its scale and capabilities, lacked. Additional capabilities included the following:

- ability to model and evaluate the saturated/unsaturated conditions at WAG 6, thereby allowing a more precise simulation of the conceptual model's subsurface stormflow zone;
- ability to allow finer discretization around and critical areas of the cap design as the upgradient cap edges and steep slopes; and
- ability to evaluate both short-term and long-term transient responses of the capping on the groundwater system.

Five separate 2-D vertical cross-sectional models were selected to answer specific questions and are discussed in Sect. 2.0.

1.3 OBJECTIVES OF NUMERICAL MODELING

The objectives of this study included the following.

1. To develop a calibrated 3-D flow model of the WAG 6 site. This model is calibrated to conditions measured in February 1990, with the eight existing Interim Corrective Measures (ICM) caps in place.
2. To use the calibrated 3-D model to investigate the hydrologic impact of various capping configurations. One cap design was suggested in the FS/EA report (Radian 1992) and is known as the FS/EA cap. The other cap configurations are variations of the FS/EA cap and were generated as Title I design progressed. They are referred to as the Iteration 1, Iteration 2, and Iteration 3 Caps and represent successive states of design development. Iteration 3 conforms to final Title I design.

3. To develop and calibrate five 2-D vertical cross-sectional flow models (Sects. 21-21 through 25-25) (Fig. 3). These models were used to investigate how the caps would affect subsurface stormflow, soil saturation, and the timing of changes in the groundwater system. Table 1 lists the specific objectives for each cross section. The cap boundary used for the 2-D models conforms to Iteration 2 since Iteration 3 was a relatively late development in Title I design and the 2-D work was well advanced. Insofar as the effect on these models is concerned, there is very little difference between Iterations 2 and 3.

1.4 READER'S GUIDE TO THIS REPORT

1.4.1 Report Graphics

This report contains many figures because graphics are advantageous in effectively portraying modeling results. The more basic figures have been incorporated in the text, while others have been placed in the Appendix. Where a series of figures is used to demonstrate transient results, they are referenced, for example, as Figs. A27a-c. In this example, water table locations are shown in three plots (A27a, A27b, and A27c) for three different times in the same transient simulation. The time for each figure can be found in the lower right hand corner of the plot. In this type of series, only the first figure is fully annotated. See Table 2 for the terms used to annotate the figures.

1.4.2 Report Organization

This report combines results from 2-D and 3-D groundwater flow simulations. An overview of the hydrogeologic setting of WAG 6 is presented followed by a discussion of the numerical models used. Model development is discussed for both the 3-D and 2-D models. Results are then presented for the 3-D models followed by results from the 2-D models. The report concludes with an integrated summary of conclusions.

Fig. 3. Map of WAG 6 showing the 2-D cross sections.

Table 1. Modeling objectives for all cross sections

Section	Specific objectives
21-21	<ol style="list-style-type: none"> <li data-bbox="414 436 1388 513">1. To determine long-term (years) and short-term (days) groundwater responses to capping and precipitation. <li data-bbox="414 524 1388 633">2. To determine soil saturations and groundwater velocities near the upgradient edge of the cap boundaries and to evaluate the need for upgradient groundwater cutoff trenches. <li data-bbox="414 644 1388 720">3. To investigate the timing, extent, and importance of subsurface stormflow.
22-22	<ol style="list-style-type: none"> <li data-bbox="414 764 1388 808">1. To examine the water table decline under the proposed cap. <li data-bbox="414 819 1388 928">2. To determine soil saturations and groundwater velocities near the upgradient edge of the cap boundaries and evaluate the need for upgradient groundwater cutoff trenches.
23-23	<ol style="list-style-type: none"> <li data-bbox="414 971 1388 1048">1. To determine the effectiveness of the cap in reducing subsurface stormflow entering burial trenches. <li data-bbox="414 1059 1388 1146">2. To investigate the distribution of soil moisture on the steep slopes surrounding the Test Area for Remedial Activities (TARA).
24-24	<ol style="list-style-type: none"> <li data-bbox="414 1190 1388 1266">1. To determine the effectiveness of the cap in reducing subsurface stormflow entering the burial trenches. <li data-bbox="414 1277 1388 1310">2. To investigate subsurface stormflow along the eastside steep slopes.
25-25	<ol style="list-style-type: none"> <li data-bbox="414 1365 1388 1506">1. To determine if transient rises in stream levels are capable of causing localized groundwater recharge near cap boundaries and potentially water movement into trenches which, in turn, could increase the contaminant flux from the trenches. <li data-bbox="414 1539 1388 1605">2. To determine if lining of streams is required to prevent groundwater recharge.

Table 2. Terms used to annotate report graphics

Term	Description
Cap coverage	An impermeable cap covering the soil surface was simulated. The limits of the cap coverage are shown between the arrows.
Computed	Represents the computed steady-state groundwater table location (pressure head equal to 0 ft).
Initial conditions	The water table location is shown at time zero. This line is used as a reference to show water table movement during transient simulations.
Long cap	The extended cap is the short cap for Sect. 21-21 extended 70 ft to the north.
Max vector	The maximum Darcy velocity vector (ft/day) shown in the plot.
Measured	The manually measured groundwater table location during February 1990.
Min vector	The minimum Darcy velocity vector (ft/day) shown in the plot.
Post-cap	Represents simulation results made with the flexible cap placed on the ground surface.
Pre-cap	Represents simulation results made with natural soil conditions at the ground surface.
Proposed cap coverage	The simulation was conducted without the cap as an active component in the model; that is, natural soil conditions were simulated. The cap coverage is only shown for reference.
Rainfall	The 24-hr, 25-yr storm is used as the simulated storm. Rainfall begins at time equal to zero, the peak rainfall occurs at time equal to 0.5 days, and rainfall ends at 1.0 days.
Time	The time in days after the beginning of the simulation. When time equals zero days, the simulation is either a steady-state solution or an initial condition.
Trenches	The areas shown represent disposal areas containing many trenches. The areas do not represent individual trenches. All of these areas have been illustrated as 15 ft deep, although the depth of each area varies.
V.E.	Represents the vertical exaggeration of the graphic. Typically, the plots are vertically exaggerated to show more details than would be possible if the plot were created at equal graphic scales.

2. HYDROGEOLOGIC OVERVIEW

2.1 CONCEPTUAL GROUNDWATER FLOW MODEL OF WAG 6

The conceptual groundwater flow model at WAG 6 was originally presented as a model by Moore (1988) and has subsequently been updated with new information (Solomon, et al. 1991) (Moore and Toran 1992). According to the conceptual model, the groundwater flow system at WAG 6 consists of a shallow, an intermediate, and a deep flow zone (Moore 1988) (Fig. 4). The shallow groundwater flow zone extends from the ground surface to a depth of about 3–6 ft and is termed the subsurface stormflow zone. The subsurface stormflow zone has a large hydraulic conductivity relative to the underlying vadose zone. Nearly all subsurface flow occurs in the subsurface stormflow zone. Subsurface water flowing in this zone is mainly discharged to surface seeps and springs, lost through evapotranspiration, or held as soil moisture. About 5% (Moore 1988) of the water flowing through the subsurface stormflow zone percolates through the vadose zone toward the water table interval at the base of the saprolite.

Most water reaching the water table interval flows through a thin zone of discrete fractures and permeable clay to seep and spring discharge points. Groundwater that is not transmitted along this interval to surface discharge points moves downward through a series of dipping, imbricate fracture zones toward the intermediate groundwater interval.

The intermediate groundwater interval ranges from 100 to 300 ft in thickness and is characterized by carbonate rich waters. Hydraulic conductivity within the intermediate interval is low. Groundwater flow is relatively slow and occurs primarily through discrete fracture systems. Most groundwater in this interval flows to surface discharge points, but a small percentage flows toward the deep groundwater zone.

The deep groundwater interval is characterized by discrete fracture flow but with a significantly smaller number of fractures (thus less transmissive) than the overlying intermediate groundwater interval. The primary porosity of this zone is very low, and most water is found within discrete fractures. Water within the deep interval is typically more chloride rich than the carbonate rich water in the intermediate interval.

Site reworking has changed the subsurface flow characteristics of the site. The excavated burial trenches now intercept a large portion of the subsurface stormflow, which previously conveyed most of the percolating water into springs and seeps. The intercepted water forms perched water zones, either percolates toward the water table interval or is delayed, and then continues to flow downgradient in the subsurface stormflow zone. The importance of the spring and seeps as groundwater discharge points should be emphasized. Spring and seep discharge of subsurface water to the surface water system accounts for nearly all water leaving the site. Groundwater seeps and springs at WAG 6 are believed to be the major contaminant discharge points. Subsurface water flow to surface seeps and springs is discharged through one of the five well-defined perennial or ephemeral streams at WAG 6. Three of the streams have been monitored by Monitoring Stations (MSs) 1, 2, and 3 (Fig. 2). Flow past these monitoring stations accounts for drainage from approximately 80% of the area of WAG 6. The other 20% discharges to the Emergency Waste Basin (north), to the west seep drainage (east), and to White Oak Lake (south). Overall, it is thought that a substantial component of total groundwater discharge leaving WAG 6 occurs as streamflow within the WAG 6 boundary.

Fig. 4. Conceptual model of groundwater flow at WAG 6.

2.2 HYDROGEOLOGIC DATA

2.2.1 Hydraulic Conductivities

Hydraulic conductivities of the soils are described in detail in earlier works that characterized the hydrology and the geology of the Oak Ridge Reservation. Among these works, Solomon, et al. (1991) references earlier dye studies that indicate anisotropy. Table 3 summarizes the saturated conductivities used in the 3-D model. These values show that the top of the Maryville Limestone and the regolith above it has a slightly higher hydraulic conductivity than that of the Nolichucky shales. Higher hydraulic conductivity and a more isotropic soil is assumed for the trench areas where the soil has been reworked. Some soils of lower conductivity are the result of dynamic compaction, such as at the Test Area for Remedial Action (TARA). The conductivities in Table 3 are within the range defined by earlier works of Solomon, et al. (1991); Dreier and Toran (1989); Moore (1988); and Davis, et al. (1984). The anisotropic characteristics are delineated in Table 3 for the regolith above the bedrock, which preserved some of the layering structure of the bedrock beneath. The location of the Maryville and Nolichucky units are shown on the geologic map of WAG 6 (Fig. 5).

2.2.2 Soil Characteristic Curves

Pressure head (h), soil relative hydraulic conductivity [$K(h)$], and moisture content [$\theta(h)$] data were taken from the work of Wilson, et al. (1992). These nonlinear curves are given in Figs. A1 and A2 (Appendix A). These data were generated from in situ measurements at SWSA 7. SWSA 7 is located immediately east of WAG 6 and has the same geological and topographic characteristics. Figures A1 and A2 also show the two linearized $\theta(h)$ and $K(h)$ curves used for steady-state simulations. Linearized curves can be used for steady-state simulation because they should yield the same solution of saturated heads as the nonlinear curves. The difference between measured and computed pressure head in the saturated zone was the only parameter available to check the quality of the calibration. Linearized soil characteristic curves were used for the 3-D modeling to reduce computational time without affecting the saturated head results.

2.2.3 Water Level Data Used for Calibration

The observed water levels used for calibration purposes were collected February 20 and 21, 1990, and have been presented previously in the RCRA Facility Investigation Report (BNI 1991, Appendix 3A).

Fig. 5. Geologic map of WAG 6.

Table 3. Calibrated values of hydraulic conductivity (ft/day)

K_{xx}	K_{yy}	K_{zz}	K_{xz}	K_{yz}	Description
3.00	3.00	3.00	1.00	1.00	Subsurface stormflow zone
2.00	1.00	1.00	1.00	0.50	Subsurface stormflow zone
0.20	0.08	0.05	0.04	0.02	Most regolith above the Maryville and some regolith above Nolichucky
0.40	0.40	0.05	0.08	0.08	Trench areas
0.08	0.04	0.01	0.03	0.01	Most regolith above Nolichucky, top of Nolichucky bedrock, and some dense regolith above Maryville
0.03	0.01	0.01	0.01	0.003	Steep slopes above Maryville
0.45	0.25	0.05	0.08	0.05	Permeable areas above Maryville
0.01	0.003	0.003	0.000	0.000	Bedrock

3. MODELING PROCESS

The process used for creating the numerical models of WAG 6 consisted of the following steps:

- obtaining site-specific data,
- conceptual model refinement,
- model selection,
- numerical model grid generation,
- model calibration, and
- mathematical and conceptual model testing and application.

This process is iterative (Fig. 6), where the models are continuously improved. Because of time constraints, only a limited number of sensitivity analyses were conducted. However, as part of ongoing WAG 6 hydrologic modeling activities, more extensive sensitivity analyses will be conducted. A generalized summary for each topic listed above is discussed, with specific details about individual models given in subsequent sections.

Fig. 6. A diagram of the modeling process.

3.1 OBTAIN SITE SPECIFIC DATA

Site-specific data were obtained as an initial step in the modeling process. These data were obtained from the sources listed in Sect. 2.2.

3.2 CONCEPTUAL MODEL REFINEMENTS

The numerical models developed incorporated details from the conceptual model presented in Fig. 6. For each model, refinements were made to better represent both the measured conditions and the conceptual model. The details of particular refinements are given in the appropriate modeling results sections.

There were two differences between the 2-D and 3-D models that directly relate to conceptual model refinement. First, the hydraulic conductivity of the subsurface stormflow zone was increased from 2 to 3 ft/day, as used in the 3-D model, to 20 to 30 ft/day in the 2-D models, as suggested by Moore and Toran (1992). Secondly, as the 2-D model was used to investigate details in the unsaturated zone, it was necessary to incorporate the nonlinear unsaturated soil characteristic curves into the models. The fully nonlinear relative conductivity and soil moisture content curves (Figs. A1 and A2) were used. With these modifications, the 2-D models could reflect the conceptual model of the unsaturated zone at WAG 6.

3.3 MODEL SELECTION

The finite-element models, 3DFEMWATER (Yeh 1987b) and 2DFEMWATER (Yeh 1987a), were selected and used to quantify the groundwater conditions at WAG 6 and to predict the hydrogeologic response to different surface cap scenarios. The FEMWATER models were selected because of their proven ability to simulate groundwater flow in multidimensions under the natural conditions prevailing at the site, such as (1) heterogeneous and anisotropic media consisting of many geologic formations; (2) distributed and point sources/sinks that are spatially and temporally dependent (i.e., French drain); (3) transient heads distributed over Dirichlet (specified head) boundaries; (4) time-dependent flux distributed over Cauchy (specified flux) boundaries; (5) variable boundary conditions of evaporation, infiltration, or seepage at the soil-air interface; and (6) dipping geologic units, which result in off-diagonal hydraulic conductivity components in the modified Richard's equation (Yeh 1987a). In addition, Environmental Consulting Engineers, Inc., (ECE) has developed a graphical postprocessor titled 2DNAG (ECE 1992) for rapid graphical analyses of model output during both the calibration and the application stages of modeling.

3.4 METHODS OF FINITE-ELEMENT GRID GENERATION

The 3-D finite-element grid used for this application was generated using a combination of a database program written by ECE along with AutoCAD and an auxiliary program titled Quicksurf. The grid was generated in plan view with nodal points placed every 40 ft along the northing and easting coordinates of the ORNL coordinate system. This generated a total of 2,239 nodes in plan view. At each of these nodes, 11 nodes and 10 elements were placed vertically based on the location of the water table, the top of the bedrock, and a horizontal datum at 665 ft, representing the bottom of the significant flow zone (Fig. 7). The entire 3-D grid is described in more detail in Sect. 5.1.1.

An automatic grid generation program was developed to generate the 2-D finite-element grids. For all five cross sections, the grids were controlled by four main control points. The control points included the surface topography, the water table, the top of competent bedrock, and the horizontal datum at 665

Every 2-D model consisted of 21 vertical nodes and 20 elements (Fig. 8). The horizontal (i.e., x direction) discretization was manually specified based upon the degree of lateral detail desired. For example, cap boundaries and near surface soil disturbances (e.g., roads) were tightly discretized in contrast to the wider spacing under the caps themselves. Discretization for each of the five models is discussed in Sects. 7.1 through 7.5.

3.5 MODEL CALIBRATION

The 2-D models were calibrated to groundwater conditions observed in February 1990. Water level data were collected on February 21 and 22, 1990, with 0.5 in. of rain having fallen between February 18 and 21, 1990. This water level data set is hereafter referred to as "current conditions." Model calibration was conducted using the steady-state assumption as being representative of the current conditions. Calibration consisted of matching the water table location in all model runs. Since no unsaturated zone pressure head or moisture content data were available from the February 1990 data set, calibration of the unsaturated zone was not attempted. The steady-state calibrated solutions were used as initial conditions for the long-term and short-term transient simulations, as appropriate. This current condition data set occurs at a time when water table elevations are characteristically high. Thus, from a design perspective, calibration to this data set is a conservative approach relative to burial trench dewatering.

3.6 MODEL APPLICATION

The 3-D modeling efforts focused on steady-state solutions for various cap designs. The 2-D models were all calibrated to steady-state conditions followed by transient simulations. For all predictive simulations containing caps, recharge by leakage through the caps is a required input. For all 3-D models and for 2-D steady-state models, the input leakage was zero, which is representative of a perfectly impervious cap. For 2-D transient models, in some cases leakage was assumed to be zero but in others was assumed as either 1% or 5% of the design storm rainfall to assess sensitivity to actual cap conditions. The leakage was assumed to occur over the entire cap surface. Simulated cap leakage is a function of rainfall duration and intensity as well as quality of cap construction and maintenance. The rainfall duration and intensity used in the transient simulations was obtained from the 25-yr, 24-hr storm. Individual simulation results are listed with the percentage of cap leakage used. The results of these simulations are found in Sects. 6.0 and 7.0 of this report.

Fig. 7. Diagram showing 3-D grid nodal point placement relative to hydrogeologic features.

Fig. 8. Diagram showing 2-D grid nodal point placement relative to hydrogeologic features.

4. NUMERICAL MODEL OVERVIEW

2DFEMWATER is maintained by ECE as a verified groundwater flow model. The 2DFEMWATER computer code utilized in this study is ECE's version. ECE's 2DFEMWATER has enhanced capabilities relative to the original 2DFEMWATER (Yeh 1987a). These additional capabilities (discussed below) are also included in the ECE version of 3DFEMWATER.

The 3DFEMWATER source code used in this study was provided by ORNL (Toran 1992). ECE has added additional capabilities to the code that include the following:

- variable soil property functions,
- 2-D and 3D FEMWATER output to graphical postprocessors (2DNAG and 3DNAG),
- output of detailed boundary fluxes for accurate mass balance computations,
- variable relaxation factor used to over-relax or under-relax the matrix equation to add increased computational efficiency,
- 2-D or 3-D interpolation of hydraulic head at known well points,
- computation of average nodal saturation and moisture content, and
- other miscellaneous changes to the source codes to allow the models to run on a 80486 computer with 32 megabytes of random-access memory (RAM).

4.1 GOVERNING EQUATION

Both 2-D and 3DFEMWATER approximate the modified Richards equation (Yeh 1987a) to simulate saturated-unsaturated subsurface flow. The difference between the models is the number of spatial dimensions considered. 2DFEMWATER approximates the Richards equation in the x - z plane while 3DFEMWATER considers fully three-dimensional flow in an x , y , z coordinate system. The 3-D Richards equation can be written as

$$\left[\left(\frac{\beta_s \theta}{\eta_e} + \beta_w \theta \right) \rho_w g + \frac{d\theta}{dh} \right] \frac{\partial h}{\partial t} = \nabla \cdot [K(\nabla h + \nabla z)] + q, \quad (1)$$

where

h	=	pressure head;
g	=	the acceleration of gravity;
K	=	soil hydraulic conductivity, which is a function of pressure head
[i.e., $K = K(h)$];
η_e	=	effective soil porosity;
q	=	an internal source/sink term;
z	=	length along the vertical axis;
β_s and β_w	=	soil and water compressibility;

t = time;
 ρ_w = water density.

$K(h)$ and $\theta(h)$ may be specified in either tabular or equation form.

Equation (1) was developed under several assumptions. The assumptions include continuous water phase for the saturated zone; the flow can be described by Darcy's law; compressible water and void space, with incompressible soil grains; and heterogeneous and anisotropic porous medium that may undergo consolidation only along the vertical axis. Under these assumptions, K is a second rank, nine-element tensor; and this tensor is spatially dependent, $K = K(x, y, z)$.

The FEMWATER numerical models approximate this equation by using the standard Galerkin finite-element method to approximate the spatial derivatives and the finite difference method for the temporal derivatives. 3DFEMWATER uses hexahedron elements with trilinear basis functions, while 2DFEMWATER can use either quadrilateral or triangular elements with linear basis functions. The solution technique utilized for the 3DFEMWATER matrix equation is a preconditioned conjugate gradient method, whereas 2DFEMWATER uses either a Gaussian direct elimination method or a successive point iteration method. Soil properties are designated for each element so that heterogeneous and anisotropic conditions can be used. The model approximates the solution to the pressure head field but also computes total head, average nodal saturation, average nodal moisture content, and the Darcy velocity field. Boundary fluxes are computed for all boundary nodes, and an overall mass balance is computed using these fluxes. To reach a solution, initial and boundary conditions must be specified for the model.

4.2 INITIAL AND BOUNDARY CONDITIONS

Initial and boundary conditions have to be specified to derive a specific solution to Equation (1). Initial conditions can be specified from field data if one has knowledge of the total head field throughout the domain. This is a rather cumbersome procedure for natural subsurface domains; and the model has an option to create an initial condition data file by solving Equation (1) for a steady-state solution, where initial conditions for the steady-state solution may be arbitrarily specified. This steady-state solution is unique for a specified set of boundary conditions.

Boundary conditions for a groundwater flow system may include any of three types, including Dirichlet, Neumann, and Cauchy. These conditions can be specified as constant in time for steady-state simulations, or they may be specified as functions of time for transient simulations. From the hydrological perspective, these conditions translate into specified heads and/or fluxes, pumping or recharging wells, rain, ponding water, springs, and seeps.

The first type of condition, specified head (Dirichlet), can be specified along boundaries in contact with surface water bodies or along boundaries with other groundwater systems if the value of hydraulic head is known. Dirichlet conditions can act as either recharge zones or discharge zones, depending upon the ambient conditions in the hydrogeologic unit.

The second condition of fixed, varied fluxes (Neumann) requires that the gradient of hydraulic head normal to a boundary be specified. Many times, this information is difficult to determine. A flux condition can be used to specify inflow from a neighboring system or outflow from the domain.

The third condition, known total flux (Cauchy), requires that the total flux normal to a surface is specified. This flux condition can be used at the bottom of a pond, for example, where the pond leakage

rate is known. The total flux condition can also be used to describe the actual amount of rainfall that infiltrates and becomes groundwater recharge.

The special boundary condition, known as rainfall/seepage, can be used in both 2D- and 3DFEMWATER. This condition is applicable to soil surface conditions, where rainfall can become infiltration or where it can be allowed to pond at the surface. The boundary condition allows as much infiltration to occur (Cauchy flux) as the soil allows according to Darcy's law; but if the precipitation rate exceeds the soil infiltration capacity, surface ponding can occur. If ponding is allowed on the soil surface (ponding depth is defined by data input), Dirichlet conditions prevail until all the ponded water infiltrates. In addition, this boundary condition is used when seeps are expected along the model profile. This nonlinear boundary condition requires more computations to reach convergence compared to either specified flux or specified head. However, this boundary condition is a very useful feature of FEMWATER.

Internal boundary conditions are not allowed in either 2D- or 3DFEMWATER. However, wells and drains can be simulated by using either internal point source/sink terms or distributed sink/source terms. Typically, French drains are treated as distributed sinks whereas recharge wells are treated as point sources. For either sources or sinks, specified fluxes are required as input.

4.3 COMPUTER MODEL VERIFICATION

Both computer models used during this work have been verified for accuracy. The verification procedure uses example input data files supplied with the original model source codes to check that the ECE modified models have maintained accuracy through the changes.

4.3.1 2DFEMWATER Verification

2DFEMWATER is maintained by ECE as a verified groundwater flow model. The computer code utilized in this study is maintained on one computer at ECE. After changes were made to the source code, verification was accomplished by running an example problem presented in the original model manual (Yeh 1987a). This procedure has been accomplished for this project before, during, and after modeling was conducted. The results were compared to the results obtained by running the original, unmodified 2DFEMWATER model. The results were identical, thereby validating all changes made to the ECE version of 2DFEMWATER. A complete record of this model verification is kept on file at ECE.

4.3.2 3DFEMWATER Verification

The updated 3DFEMWATER source code was verified for accuracy by being used to compute two example problems supplied by Dr. George Yeh, the original author. The results from the example model runs were compared to the updated 3DFEMWATER results and found to be identical. These tests prove that the updated 3DFEMWATER has maintained consistency and accuracy after source code modifications. A complete record of this model verification is kept on file at ECE.

5. WAG 6 NUMERICAL MODEL DEVELOPMENT

5.1 3DFEMWATER MODEL GENERATION

5.1.1 3DFEMWATER Discretization

Using information about WAG 6, including geology, topography, the conceptual groundwater flow model, and surface water bodies, a 3-D finite-element grid was generated for WAG 6. The 3DFEMWATER model of WAG 6 was developed so that six 3-D subregions within WAG 6 could be separately modeled (Fig. A3). The subregions were chosen based on site hydrologic boundary conditions, such as streams and surface water bodies. The subregions were separately calibrated to reduce computational effort relative to the entire 3-D domain. Once a subregion was considered calibrated, the material property distribution of the subregion was transferred via a database program to the material property data set for the entire 3-D domain. After calibration of each subregion was complete with the material properties transferred to the entire 3-D model, the entire domain was calibrated as a single model.

The entire 3-D model consists of 24,629 nodes and 21,110 elements. Table 4 lists the discretization sizes used for all the subregions.

Table 4. Summary of the WAG 6 grid subregions

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 9*	Region 10†	Region 11
Number of rows	23	15	46	18	43	32	58	63	48
Number of columns	20	8	24	26	33	15	57	58	35
Number of layers	10	10	10	10	10	10	10	10	10
Number of nodes	3,212	1,078	4,433	4,059	8,767	3,773	23,133	24,629	10,274
Number of elements	2,480	740	3,280	3,240	7,030	2,950	19,740	21,110	8,400
Half bandwidth	222	112	156	189	277	167	607	607	299

*Region 9 is the combination of Regions 1 through 6 and represents the entire domain before elements were added to the northern portion of the domain near the Emergency Waste Basin.

†Region 10 is the current entire domain and is the combination of Regions 1 through 4, Region 11, and Region 6.

The 3-D grid was graphically verified for accuracy by printing 2-D slices along all rows, columns, and layers. Figures A4, A5, and A6 are examples of the 3-D grid slices along layer 1, row 23, and column 38. The entire 3-D domain is automatically sliced out into 2-D sections by the database program and graphically displayed by 3DNAG.

5.1.2 3DFEMWATER Groundwater Flow and Boundary Condition Assumptions

Several assumptions were made about the groundwater flow system of WAG 6 in the course of model development and calibration. These assumptions were made with respect to the boundary conditions and the hydraulic properties of the subsurface domain (Table 5). The assumptions were necessary to bridge the gap between the available data and the modeling needs. Thus, assumptions were made about water heads and/or fluxes along all the boundaries of the model, about the relationships between pressure head and both relative hydraulic conductivity and moisture content, and about the distribution of saturated hydraulic conductivities within the domain.

Table 5. Summary of major assumptions used in the WAG 6 3DFEMWATER groundwater flow model

Model assumptions	Actual conditions	Impact of assumption
Porous media	Fracture flow dominated system according to conceptual model of Moore (1988). Equivalent porous media are assumed on the scale of the model with effective porosities representing a fractured system.	The amount of water table suppression that actually occurs will be strongly influenced by the effective porosity of the system, which is a function of the fracture network.
Steady-state flow	Transient flow resulting from recent but minor rainfall preceding water level measurements	No substantial impact as the water table was not measured after a substantial rainfall
Aquifer properties are spatially averaged, generally into layers.	Aquifer properties are variable resulting from natural differences in lithology and soil properties or man-induced changes (i.e., trenches).	Computed hydraulic heads do not match measured head exactly. Aquifer property assignments affect the quality of the calibration.
Heterogenous and anisotropic aquifer material	Heterogeneous and anisotropic aquifer material	The anisotropy ratios will affect the magnitude and location of the dewatered zone.
Complex aquifer boundaries can be represented by a finite-element grid.	Hydrogeologic boundaries are complex, with some boundaries difficult to identify and quantify.	Boundary conditions affect the quality of the calibration. Improvements in boundary conditions are always necessary.

The assumptions that were made about boundary conditions include the values used to prescribe heads and fluxes. Constant heads were prescribed along lateral boundaries of lakes and perennial streams. This includes the southern boundary along the White Oak Lake and the eastern boundary from the pond at the Emergency Waste Basin to White Oak Lake. The heads that were specified along the streams and White Oak Lake are the water level elevations of these features.

Constant heads were also assumed along the saturated portion of the northern and northeastern boundary at the top of the hills. The heads used along this boundary were taken from the RFI (BNI 1991) for subregions 1, 2 and 5. For subregion 3, water elevations are unknown beneath the top of the hills, so the boundary heads were estimated. The calibrated values were achieved when the calculated

head approached observed heads at wells close to this boundary. Hilltops at the northern extent of WAG 6 were considered as surface water divides; thus, no-flow conditions were assumed along the unsaturated portion of the northern boundary. A surface boundary condition of constant head was prescribed along the streams within WAG 6 because field observations suggest that these streams act as drains, or groundwater discharge points.

The placement of the constant heads along the streams progressed in steps. The placement moved in an upstream direction until simulation results did not show water ponding at the creek locations. This assumption was found to be acceptable because if constant head conditions were not specified along the stream locations, the model results indicated higher heads at those locations than the actual depth of the streams. Appendix B contains a table of all constant head boundary conditions used in the 3-D model.

For the soil surface, water flux was prescribed to simulate the amount of infiltration that reaches the water table, including fluxes from the subsurface stormflow zone down to the water table. The calibrated fluxes are 0.0009 ft/day above the Nolichucky, 0.002 ft/day above the Maryville, and 0.008 and 0.02 ft/day above inundated trenches. The 0.0009 ft/day rate is approximately 7.5% of the annual rainfall at WAG 6. This rate was estimated from a flow net analysis conducted on subregion 1. The groundwater discharge leaving subregion 1 was divided by the area of this subregion, thereby indicating a net infiltration flux. The calibrated infiltration rate through the unsaturated zone above the Maryville is greater than the Nolichucky infiltration rate because the soils above the Maryville have higher hydraulic conductivities than the Nolichucky. The infiltration rate through the trenches is four times the rate through the Maryville to account for flow from the subsurface stormflow zone into the trenches.

The bottom of the domain was taken at 665 ft, and a no-flow condition was prescribed for this surface. The elevation of 665 ft is suggested as the approximate border between the shallow and intermediate flow zone (BNI 1991). No-flow conditions were assumed because available data do not support other conditions with a large degree of reliability.

Distributed sinks were used to represent the removal of water from the system via the 49 Trench Area French drain. The sinks were placed at nodal points along both legs of the 49 Trench Area French drain. The total water removal rate was about 2,750 gal/day, which is within the range of French drain outflows reported for high water table conditions (Black 1989). More water was removed from the north-south trending leg compared to the shorter, east-west trending leg. This was done to simulate measured French drain outflow conditions.

Assumptions were also made regarding the distribution of moisture content and relative hydraulic conductivity as functions of pressure heads. Values were assumed to be identical to those reported by Wilson, Jardine, and Gwo for SWSA 7 (1992). Saturated hydraulic conductivity was assumed to be controlled by the geologic units, soil layering, and structural properties (strike and dip). To account for anisotropy, K_{xx} and K_{yy} were assumed equal to K_{zz} and K_{yy} , respectively, times the sine of the dip. In addition, anisotropy with a ratio of 1 : 2 to 1 : 4 ($K_{yy} : K_{xx}$) was assumed because of preferential flow along the strike and is consistent with values described by Solomon, et al. (1991). The geology and the structure of the site also support the assumption of high hydraulic conductivity for soil horizons A and B (subsurface stormflow zone) (Moore 1988). Lower hydraulic conductivities were used where the soil was reworked by excavation and compaction operations.

5.2 2DFEMWATER MODEL GENERATION

5.2.1 2DFEMWATER Discretization

The five 2-D cross sections all have 21 nodes and 20 elements per vertical column. The horizontal spacing of the nodes is variable, and quadrilateral elements were used for all the models. Fine discretization is used in areas where material properties change rapidly or where more information on model response was required. Table 6 summarizes the 2-D model finite-element grids. Discussions about individual grid refinements are found in Sects. 7.1 through 7.5.

Table 6. Summary of 2-D model grids

Cross section	Number of nodes	Number of elements	Total length of cross section (ft)
21-21	3,801	3,600	1,192.5
22-22	6,552	6,220	2,209.0
23-23	1,974	1,860	505.0
24-24	1,995	1,880	432.0
25-25	1,197	1,120	306.0

5.2.2 DFEMWATER Groundwater Flow and Boundary Condition Assumptions

The boundary conditions used for the 2-D models include constant head, known flux, and no-flow conditions. Generally, constant head conditions were used at surface water body locations. Known flux conditions were used to represent groundwater recharge from precipitation. No-flow conditions were used during testing of some models. Details of the actual boundary conditions used are given in Sects. 7.1 through 7.5.

6. 3DFEMWATER MODELING RESULTS

Eight steady-state simulations were conducted to investigate the effect various capping alternatives might have on the groundwater system at WAG 6. The eight simulations included:

1. current conditions with eight ICM caps (Fig. 9) (in existence in February 1990),
2. Iteration 3 cap (Fig. 10),
3. Iteration 2 cap (Fig. 11),
4. Iteration 1 cap (Fig. 12),
5. FS/EA cap (Fig. 13),
6. bare ground (removal of eight ICM caps),
7. current condition calibrated model with 50% additional recharge to represent a very wet year, and
8. current condition calibrated model with -50% recharge to represent a very dry year.

Results from these simulations are presented in several ways. Graphical results of computed water tables, water table reductions after capping, Darcy velocity vectors, groundwater discharge zones, and total head residuals are presented. Tabular results of mass balance calculations, groundwater fluxes, and total head residuals are presented. Model input and output files are not presented in this report because of their excessive length. All input and output files are stored on diskette at ECE.

6.1 CURRENT CONDITIONS WITH EIGHT ICM CAPS PRESENT

The current condition calibrated model is defined as the conditions at WAG 6 during February 1990, with eight ICM caps having been in existence for about 1 yr. It is assumed that the transient response arising from the placement of the ICM caps had already occurred and that the groundwater system was in a steady-state condition. Water levels were measured throughout WAG 6 and are considered a relatively high water level condition.

V. E. = 1.00

Fig. 9. Plan view of 3-D model showing the ICM caps.

Fig. 10. Plan view of 3-D model showing the Iteration 3 caps.

Fig. 11. Plan view of 3-D model showing the Iteration 2 caps.

Fig. 12. Plan view of 3-D model showing the Iteration 1 caps.

Fig. 13. Plan view of 3-D model showing the FS/EA caps.

The current condition simulation was considered calibrated once the following three calibration targets were achieved:

1. The average of the sum of absolute values of the residual is less than 3 ft; that is,

$$\frac{\sum |h_k - h_c|}{151} < 3, \quad (2)$$

where

h_k = the known total head (ft),
 h_c = the computed total head (ft),
 151 = the total number of wells used in the computation.

2. All residuals were within the range of ± 10 ft.
3. The overall mass balance error was less than 10%.

Analysis of the results indicated that these conditions were achieved with a normally distributed residual (Fig. A7). The residual is defined as the difference between the computed and measured total head. The average absolute value of the residuals is 2.86 ft, with a standard deviation of 2.39 ft. The range of residuals was +7.69 to -9.05 ft (Table 7). The residuals were analyzed for spatial patterns both a really (relative to geographic position) and vertically. The residuals were equally distributed laterally throughout the domain, with no particular region having a consistently high or low overall residual (Fig. A8). The vertical distribution of residuals do not show any problematic depth zones (Fig. A9).

Mass balance computations are necessary to determine whether or not the model is properly posed from a numerical perspective. In this study, the mass balance error is defined as

$$\frac{\text{Volume in} - \text{Volume out}}{\text{Volume in}} * 100 .$$

The volumes of water in and out of the domain are computed by 3DFEMWATER as boundary fluxes. Boundary fluxes for all nodal boundary points are written out to the model output file. By summing up all positive (outflow) numbers and all negative (inflow) numbers, a total volume of water moving in and out of the domain is obtained. The mass balance errors (Table 8) for all simulations ranged between 6.4% and -5.8%. A positive mass balance error means more water has moved out of the domain than has moved in. The calibrated model has a mass balance error of 5%. This error is considered reasonable for a model of this size and complexity.

Table 7. Current calibration model results (sorted by residual)

Well ID	Easting (ft)	Northing (ft)	Elevation (ft)	Element located	Measured head	Calculated head	Residual (ft)
356	24451.00	16481.00	767.52	7236	762.62	770.31	7.69
4+77	24437.96	16943.31	773.46	12829	776.96	783.73	6.77
TARA-9	25041.76	17879.49	778.09	20389	789.69	796.38	6.69
848	24656.30	16942.40	778.85	12888	780.95	787.52	6.57
S-11	24620.80	17627.70	789.96	18669	804.46	810.99	6.53
840	25251.70	16928.60	748.14	12609	750.14	756.24	6.1
371	25090.00	16393.00	740.4	6379	746.73	752.8	6.07
TARA-13	25151.41	17895.08	776.03	20419	785.3	791.13	5.83
843	25221.40	17597.10	769.98	18509	781.93	787.49	5.56
TARA-10	24945.94	17697.16	780.01	19049	797.79	803.34	5.55
4+58	24440.75	16922.75	774.43	12409	777	782.29	5.29
640	24719.55	17614.70	783.34	18379	804.17	808.98	4.81
367	25091.00	17723.00	777.7	19369	792.92	797.73	4.81
362	23718.00	16588.00	771.54	8595	770.34	774.96	4.62
850	24793.50	16595.40	756.13	8869	767.28	771.84	4.56
839	24923.60	16308.80	711.06	5340	749.56	753.76	4.2
383	24895.00	16165.00	741.38	3529	747.78	751.83	4.05
832	24096.70	17385.60	766.4	16700	801.45	805.44	3.99
644	24848.36	16748.86	764.3	10749	771.84	775.81	3.97
636	24326.17	17668.04	786.53	18889	806.81	810.63	3.82
404	24159.05	16786.33	767.17	11039	771.74	775.49	3.75
405	24157.98	16791.79	764.26	11039	771.86	775.49	3.63
ETF-11	23702.60	16773.00	746.01	10470	780.57	784.17	3.60
345	24881.00	16361.00	751.09	5815	753.94	757.52	3.58
4+01	24445.99	16870.56	772.58	11979	777.00	780.36	3.36
4+27	24443.19	16893.80	775.10	11979	777.00	780.36	3.36
645	25274.60	17173.65	744.78	14859	759.66	762.96	3.30
386	24828.00	16892.00	773.19	12077	777.67	780.58	2.91
1229	24072.69	16453.32	758.74	6636	763.44	766.25	2.81
652	24900.00	16159.68	690.16	3530	749.57	752.28	2.71
405A	24178.24	16810.86	774.61	11047	774.20	776.86	2.66
310	23939.00	16697.00	777.24	9607	776.84	779.39	2.55
1231	24659.86	16403.79	760.57	6276	763.92	766.42	2.50
852	23911.60	16346.90	754.10	5579	763.35	765.76	2.41
EXP-5	24432.54	16927.81	778.27	12409	779.91	782.29	2.38
374	25346.00	17462.00	755.28	17639	767.85	770.09	2.24
403	24163.08	16777.67	764.75	10579	772.28	774.35	2.07

Table 7. (continued)

Well ID	Easting (ft)	Northing (ft)	Elevation (ft)	Element located	Measured head	Calculated head	Residual (ft)
1037	24175.72	16228.14	753.84	4239	758.72	760.75	2.03
318	24323.00	17225.00	791.84	15325	788.93	790.91	1.98
745	23808.30	16067.80	706.58	2390	753.98	755.83	1.85
1227	23838.21	16569.39	769.33	8126	770.26	772.11	1.85
854	23851.90	16711.90	765.33	10039	775.68	777.53	1.85
3+76	24449.03	16840.88	774.12	11549	776.92	778.65	1.73
274	23347.00	16210.00	777.51	3576	776.27	777.95	1.68
TARA-11	25256.02	17709.84	775.19	19419	785.08	786.70	1.62
838	24934.80	16308.70	739.04	5349	749.96	751.52	1.56
ETF-10	23609.80	16763.50	767.47	10439	785.11	786.63	1.52
HHMS-5 C	24561.12	15833.46	714.24	799	747.91	749.35	1.44
837	24352.60	15845.60	750.47	746	749.02	750.44	1.42
TARA-5	24928.23	17549.76	785.57	18129	801.62	802.98	1.36
2+02	24467.88	16674.21	772.38	9739	774.18	775.53	1.35
TARA-6	25086.38	17608.96	785.08	18469	796.41	797.74	1.33
653	24070.40	15792.51	708.54	480	747.80	749.08	1.28
ETF-12	23584.40	16737.90	744.05	9980	785.07	786.32	1.25
TARA-12	25295.15	17645.69	764.71	18839	779.32	780.52	1.20
295	23992.00	16703.00	776.90	10077	777.65	778.83	1.18
3+03	24458.03	16773.11	773.79	10659	777.00	778.10	1.10
1040	24103.13	16373.13	754.98	5629	761.35	762.40	1.05
ETF-22	23641.20	16788.00	780.61	10909	785.58	786.54	0.96
284	23983.00	16750.00	777.17	10537	778.66	779.60	0.94
2+26	24467.03	16695.99	772.98	9739	774.74	775.53	0.79
382	24025.00	15814.00	747.34	467	748.05	748.79	0.74
ETF-29	23651.40	16769.40	780.25	10449	783.94	784.50	0.56
HHMS-8 C	24668.21	16782.51	717.09	11170	778.88	779.43	0.55
836	24138.80	15748.20	745.72	308	748.42	748.89	0.47
833	23842.40	16056.90	732.64	1989	752.34	752.77	0.43
ETF-3	23672.80	16764.90	767.35	10459	782.06	782.40	0.34
380	23320.00	15977.00	746.55	1259	767.54	767.87	0.33
HHMS-4 C	24676.08	16170.59	736.71	3469	757.56	757.89	0.33
379	23206.00	16156.00	760.13	3099	775.11	775.43	0.32
3+52	24452.43	16818.25	772.28	11109	777.04	777.32	0.28
381	24266.00	16248.00	747.24	4259	759.24	759.50	0.26

Table 7. (continued)

Well ID	Easting (ft)	Northing (ft)	Elevation (ft)	Element located	Measured head	Calculated head	Residual (ft)
853	24047.50	16695.10	765.24	9629	773.29	773.41	0.12
835	23951.80	15767.70	743.73	259	747.93	748.01	0.08
365	23681.00	16454.00	764.72	6535	767.01	767.08	0.07
648	24524.24	17374.55	783.42	16469	801.83	801.87	0.04
363	23748.00	16420.00	761.97	6044	763.14	763.17	0.03
849	24215.20	16781.80	766.13	11059	779.78	779.78	0.00
639	24138.11	17395.38	778.41	16709	798.29	798.28	-0.01
1038	24096.88	16251.36	754.50	4219	759.58	759.57	-0.01
855	23427.70	16755.30	770.43	10399	799.88	799.85	-0.03
1+53	24469.22	16625.30	772.13	9269	773.59	773.45	-0.14
857	23106.30	16538.00	787.53	7429	798.58	798.35	-0.23
1228	23878.80	16334.67	759.65	5076	762.33	762.08	-0.25
ETF-27	23616.40	16745.50	777.43	10449	784.75	784.50	-0.25
ETF-25	23637.90	16773.90	779.95	10449	784.86	784.50	-0.36
ETF-17	23606.40	16782.90	783.45	10899	789.59	789.18	-0.41
1+85	24467.64	16656.08	772.62	9269	773.90	773.45	-0.45
ETF-1	23641.20	16756.00	770.68	10449	784.99	784.50	-0.49
ETF-6	23651.00	16724.10	766.22	9989	783.05	782.49	-0.56
856	23432.90	16764.40	742.07	10400	800.47	799.85	-0.62
305	23914.00	16660.00	774.41	9127	779.35	778.71	-0.64
EXP-4	24424.29	17017.56	786.76	13237	786.99	786.23	-0.76
401	24380.21	17022.31	782.21	13609	788.77	787.97	-0.80
ETF-40	23671.40	16743.60	777.37	10459	783.31	782.40	-0.91
ETF-7	23633.60	16723.20	765.55	9989	783.40	782.49	-0.91
ETF-4	23673.30	16749.10	766.53	10459	783.41	782.40	-1.01
654	24054.76	16618.16	695.14	8690	775.07	773.87	-1.20
1233	24211.90	17005.25	781.07	13179	784.41	783.12	-1.29
655	24815.30	17469.72	725.79	17510	801.92	800.57	-1.35
0+54	24474.94	16527.25	771.50	7766	772.69	771.33	-1.36
1039	24093.26	16313.32	756.40	5128	761.28	759.81	-1.47
847	24790.50	17769.90	784.02	19580	809.02	807.54	-1.48
851	24058.20	16485.00	754.36	7149	767.66	766.13	-1.53
ETF-9	23610.30	16745.30	765.11	10439	788.17	786.63	-1.54
276	23895.00	16211.00	755.53	3713	758.35	756.79	-1.56
642	24035.55	16580.96	750.53	8679	773.48	771.85	-1.63
ETF-8	23618.60	16729.20	765.68	9989	784.15	782.49	-1.66
1036	24231.08	16328.57	749.98	5169	764.50	762.83	-1.67

Table 7. (continued)

Well ID	Easting (ft)	Northing (ft)	Elevation (ft)	Element located	Measured head	Calculated head	Residual (ft)
ETF-36	23658.60	16749.10	778.27	10459	784.11	782.40	-1.71
TARA-4	25002.46	17654.24	789.26	18759	802.84	800.99	-1.85
ETF-2	23665.20	16778.30	767.68	10459	784.34	782.40	-1.94
109	24499.00	17330.00	737.65	16120	800.77	798.62	-2.15
400	24304.61	17065.08	785.76	13939	790.71	788.52	-2.19
376	23479.00	16584.00	776.46	8539	787.94	785.72	-2.22
ETF-5	23665.30	16732.50	766.22	9999	783.19	780.73	-2.46
TARA-7	25141.24	17689.47	786.68	19099	797.19	794.62	-2.57
394	24420.05	17010.56	783.88	13239	788.09	785.51	-2.58
ETF-15	23603.50	16841.40	763.83	11339	794.59	792.00	-2.59
389	24203.49	16798.40	773.91	11049	779.44	776.85	-2.59
279	24205.00	16696.00	774.27	9666	776.76	773.74	-3.02
ETF-39	23654.90	16735.80	776.43	9999	783.80	780.73	-3.07
ETF-18	23624.80	16791.20	783.75	10909	789.63	786.54	-3.09
656	24692.96	17923.92	737.59	20460	813.97	810.86	-3.11
393	24259.03	16953.14	778.85	12789	787.95	784.69	-3.26
831	24133.50	17387.40	798.26	16697	802.56	798.61	-3.95
ETF-14	23618.50	16849.20	715.37	11350	795.41	791.35	-4.06
1225	24603.65	17754.77	814.80	19523	818.97	814.25	-4.72
1232	24218.89	17020.14	791.53	13565	790.29	785.35	-4.94
650B	25150.56	17273.88	761.07	15910	781.63	776.68	-4.95
377	23297.00	16610.00	785.82	8499	798.32	793.33	-4.99
391	24192.39	16899.81	783.14	11917	785.53	780.50	-5.03
395	24235.26	16896.17	774.90	11929	787.98	782.73	-5.25
397	24227.29	16925.31	778.87	12359	788.77	783.36	-5.41
TARA-3	25062.08	17752.28	796.13	19649	802.86	797.39	-5.47
390	24199.67	16841.59	774.44	11489	784.21	778.73	-5.48
369	24805.00	17476.00	795.24	17499	810.00	804.25	-5.75
385	24669.00	17903.00	801.27	20459	819.69	813.90	-5.79
TARA-2	25102.46	17816.12	786.80	19919	802.01	795.69	-6.32
399	24349.51	16881.25	774.08	11959	787.69	781.12	-6.57
2+51	24464.48	16724.09	772.84	10199	776.94	770.08	-6.86
TARA-1	25192.38	17806.99	782.10	19939	799.86	792.96	-6.90
649	25075.50	17375.49	791.97	16608	793.95	786.68	-7.27
108	24584.00	17279.00	744.64	15770	805.41	797.52	-7.89
370	24981.00	17145.00	777.96	14789	790.03	781.88	-8.15
351	24661.00	16028.00	765.63	2196	765.47	757.12	-8.35

Table 7. (continued)

Well ID	Easting (ft)	Northing (ft)	Elevation (ft)	Element located	Measured head	Calculated head	Residual (ft)
368	25155.00	17348.00	785.50	16629	790.77	782.29	-8.48
317	24323.60	16768.49	785.32	10617	786.19	777.48	-8.71
402	24277.51	16816.65	777.60	11069	787.72	778.93	-8.79
267	23221.00	16118.00	781.06	2663	782.53	773.59	-8.94
845	24988.30	17108.20	777.78	14449	788.83	779.78	-9.05

Sum of absolute values of residual = 431.62

Average residual (ft) = 2.86

Standard deviation (ft) = 2.39

Table 8. Mass balance summaries

Simulation	Flow out (gal/day)	Flow in (gal/day)	Differenc e (gal/day)	Flow out (l/s)	Flow in (l/s)	Differenc e (l/s)	Mass balance error
Current condition*	72,426	-68,820	3,606	3.17	-3.01	0.16	5.0
Iteration 3	51,843	-54,236	-2,392	2.27	-2.37	-0.10	-4.4
Iteration 2	55,207	-58,423	-3,216	2.42	-2.56	-0.14	-5.8
Iteration 1	57,856	-59,025	-1,169	2.53	-2.59	-0.05	-2.0
Bare ground	74,765	-70,545	4,220	3.28	-3.09	0.18	5.6
FS/EA	57,266	-59,295	-2,030	2.51	-2.60	-0.09	-3.5
Current +50% recharge	90,270	-84,503	5,767	3.95	-3.70	0.25	6.4
Current -50% recharge	58,164	-56,812	1,352	2.55	-2.49	0.06	2.3

*Reflects ICM caps in place.

The current condition water table represents the zero pressure head point in all vertical columns within the model (Fig. 14). In regions where a vertical hydraulic gradient exists, a misrepresentation of the water table elevation can be obtained if one chooses the value of total head at some depth beneath the actual water table. Therefore, instead of plotting total head for a completely saturated layer (e.g., layer 10), the zero pressure head point was found throughout the domain. Once all points were found, the water table was contoured.

The Darcy velocity vector distribution (Fig. 15) shows the groundwater system to have local groundwater discharge points to streams, springs, and White Oak Lake. In regions where the computed total head is greater than or equal to topography, groundwater discharge zones exist. Groundwater discharge zones (Fig. 16) were calculated by superimposing the computed 3-D water table surface over the topographic surface. These discharge zones correspond to actual conditions at WAG 6 during the wet season. It should be made clear that these discharge zones are not all controlled by boundary conditions on the surface layer. The numerical model computes discharge zones when the total head exceeds the land surface elevation. These discharge zones arise because of the interplay between topography, recharge patterns, and hydrogeologic properties.

Groundwater discharge from the upper surface of the model (Table 9) is 2.35 l/s, which accounts for 74% of the total volume of water leaving WAG 6. If the applied French drain removal rate of 0.12 l/s is added as a surface outflow component, 2.47 l/s are leaving WAG 6. Currently, it is not possible to determine the accuracy of this value. However, measured discharge through MS 3 during March 1992 (a similar time of year) was slightly less than 2 l/s (Yager 1992), lending credence to this value. Once a comprehensive monitoring program is implemented, better information on total surface water discharge from WAG 6 will become available.

Table 9. Groundwater discharge to surface streams

Simulation	Outflow to surface streams (percent total outflow)	Outflow volume (gal/day)	Outflow volume (l/s)
Current condition*	74.0	53,604	2.35
Iteration 3	76.0	39,409	1.72
Iteration 2	72.3	39,923	1.75
Iteration 1	71.6	41,448	1.82
Bare ground	73.4	54,875	2.40
FS/EA	71.9	41,153	1.80
Current +50% recharge	72.9	65,788	2.88
Current -50% recharge	75.7	44,001	1.93

* Reflects ICM caps in place

Fig. 14. Computed water table for current conditions.

Fig. 15. Darcy velocity vector plot for current conditions.

Fig. 16. Groundwater discharge zones (shaded) for current conditions.

The random spatial distribution of residuals suggests that small scale heterogeneity and man-made disturbances are the major causes of these residuals. It is always possible to continue to reduce the overall model residual by continuously changing boundary conditions and material property distributions (i.e., model refinement). However, additional refinements would yield little benefit for the purposes of cap design. Since this model reasonably represents measured data, using it in predictive mode to investigate various capping alternatives is considered feasible.

6.2 ITERATION 3 CAP (TITLE I DESIGN)

The Iteration 3 cap was simulated by placing zero flux conditions at all surface nodal points that would be covered by the caps. At all other points outside cap boundaries, the calibrated fluxes were used. The net result of eliminating direct infiltration is water table decline beneath the caps. The computed water table (Fig. 17) for the Iteration 3 cap shows that a substantial change is expected in the water table configuration after capping.

Based on the expected water table configuration and the Darcy velocity vectors (Fig. 18), there is a directional change in groundwater flow compared to the current conditions model. Comparing the current condition Darcy vectors (Fig. 14) and the Darcy vectors from the Iteration 3 cap (Fig. 18), the local north-south trending groundwater divide present at easting 24,600 ft no longer exists. Since groundwater is moving in different directions, discharge zones are expected to be different. The groundwater discharge zones (Fig. 19) for the Iteration 3 cap are substantially smaller than the current conditions discharge zones (Fig. 16). This is consistent with an overall decline of the water table.

A contour plot of water table suppression has been created (Fig. 20) by subtracting the Iteration 3 steady-state water table from the calibrated model water table. The water table change ranges from +22 ft to -1.5 ft, with an average change of 5.5 ft over the entire 77.5 acres of model surface area (Table 10). The majority of the water table decline is focused beneath the caps and diminishes rapidly away from the cap boundaries.

For current conditions, the total water volume beneath the water table is 326 million gal. For the Iteration 3 simulation, the total volume is 311.5 million gal. This implies that the dewatering caused by the cap emplacement produces a 14.5 million-gal reduction (4.5%) in total groundwater volume at WAG 6. This amount of water will drain from the WAG 6 system over time after the cap is installed and the groundwater system reaches equilibrium. Much of the dewatering will take place in the burial trench locations.

6.3 OTHER CAPPING ALTERNATIVES

Table 10 shows that the Iterations 1 and 2 caps and the FS/EA cap are slightly less effective than the Iteration 3 cap in lowering the water table. The predicted response of all caps is similar with respect to overall behavior (i.e., changing water flow directions).

Fig. 17. Computed water table for Iteration 3 caps.

Fig. 18. Darcy velocity vectors for Iteration 3 caps.

Fig. 19. Groundwater discharge zones (shaded) for Iteration 3 caps.

Fig. 20. Contours of water table decline (ft) below current conditions for Iteration 3 caps.

**Table 10. Water table differences between current condition*
and various simulations for the entire 77.5-acre model**

Simulation	Average change (ft)	Maximum change (ft)	Minimum change (ft)
Iteration 3	5.59	22.02	-0.05
Iteration 2I	5.45 5	21.93 2	-1.42 -1
Iteration 1I	4.96 4	20.67 2	-1.51 -1
Bare groundB	-0.46 -0	-2.78 -2	0.01 0
FS/EAF	5.12 5	21.36 2	-1.56 -1
Current (+50% recharge) [†]	-2.85	-11.89	0
Current (-50% recharge) [‡]	3.42	11.66	0

*Represents current condition reflects ICM caps in place.

[†]+ Water table decline.

[‡]- Water table rise.

The hydrologic response of the WAG 6 groundwater system to the eight ICM caps was examined by conducting the bare ground simulation. This simulation made it possible to look backwards in time at the expected water level change caused by the emplacement of the eight ICM caps. Table 10 shows that a 0.50-ft average water level change would be expected with a maximum change of less than 3 ft. These results are consistent with data collected during a groundwater monitoring program conducted before, during, and after ICM cap construction. As reported (Miller, et al. 1989), no water level changes were discernible at the selected monitoring wells after cap installation. Based on assumptions provided by Moore (1988) and a fluid mass balance approach, it was estimated that the water level change under the caps should be about 15 in. or 1.25 ft. This small change would not be recognized considering typical water level fluctuations measured at WAG 6. Historical water level fluctuations measured from wells beneath or near the ICM caps are up to 15 ft.

7. 2DFEMWATER MODELING RESULTS

Graphical results are presented for all modeled cross sections. The input data files for the current condition models are found in Appendix C. The following sections describe the steady-state and transient modeling efforts for each cross section. A more detailed discussion is presented for Sect. 21-21 than for the other cross sections. Section 21-21 is used to analyze subsurface stormflow development and groundwater flow through trenches. Much of this discussion is not repeated for Sects. 22-22 through 25-25. Rather, the discussions are to answer the specific modeling objectives as given in Table 1.

7.1 SECTION 21-21

Section 21-21 trends north-south through the west disposal area with a cap size of 3.5 acres. It was selected to investigate the hydrologic responses within the subsurface stormflow zone and the water table fluctuation zone after cap placement and to examine the spatial and temporal water table decline under the proposed cap. This includes the effect of upgradient subsurface stormflow development on groundwater flow beneath the cap.

Section 21-21 was initially calibrated in steady-state to the current condition water table (as measured in February 1990). After calibration, two capping alternatives (e.g., short cap and long cap) were simulated in steady-state mode. Finally, transient simulations of these cap configurations, plus the cap extended further to the road, were performed.

7.1.1 Discretization

The cross section was modeled with 3,801 nodes (Figs. A10a-d) and 3,600 elements and utilizes a heterogeneous distribution of soil and rock characteristics (Figs. A11 and A12). Figure A12 shows grid refinement at the edges of the proposed cap and at the road. Figure A12 also shows the location of the burial trenches and the estimated location of the boundary between the Maryville and the Nolichucky formations. The position of the trenches are notable with respect to the water table fluctuation zone.

7.1.2 Steady-State Calibration Precapping

Steady-state calibration was achieved with a 0.0002-ft/day recharge rate compared to the 0.0009-ft/day rate used for the calibrated 3-D model. As previously discussed, the difference between these values is accounted for by soil anisotropy, topography, and physical orientation. In the 3-D system, most of the recharge moves east-west along strike to drainages on both sides of this section. Therefore, this particular cross section does not transmit all of the recharge throughout its length. The remaining boundary conditions used were constant head at the downgradient southern boundary, constant head at the upgradient northern boundary equal to the measured water table elevation at that location, and a no-flow boundary condition at the bottom boundary at elevation of 665 ft.

The no flow condition at 665 ft was assumed because the available data used to estimate the flux across this boundary at the location of Sect. 21-21 indicated little to no vertical flow. In addition, the conceptual model for this area estimates that the flux through this boundary is insignificant compared to the lateral flow through the subsurface stormflow zone and the water table fluctuation zone (e.g., Moore 1988).

Figure 21 illustrates the difference between the calibrated water table and the current condition water table for an upgradient constant head boundary condition. This 2-D model was calibrated using the y and z components of the second rank hydraulic conductivity tensor from the 3-D case because of the north-south orientation. These conductivities are listed both in Table 3 and in the input data set for Sect. 21-21 (Appendix C).

Calibration was achieved with linearized hydraulic conductivity and moisture content functions for the unsaturated zone. Linearized curves were used because subsurface stormflow (a transient phenomena) cannot be simulated in steady-state scenarios.

Figure 22 illustrates the calibrated steady-state Darcy velocities for the constant head boundary conditions. The vector lengths in this figure are drawn relative to the maximum velocity, which occurs at the downgradient seep. The figure illustrates that the trenches collect and then distribute the lateral flux, from the narrow water table fluctuation zone (range) to the entire depth of the trenches.

To test the sensitivity of the upgradient constant head boundary condition, the model was resimulated with a no-flow condition on this boundary. The nonlinear properties of the unsaturated soil were also implemented. The upgradient boundary condition was changed to eliminate the possible effect of a constant head condition on the predicted water table levels. It was necessary to increase the recharge rate for this simulation to 0.0007 ft/day.

This simulation predicted a water table configuration similar to the constant head upgradient boundary condition model that used the linearized soil properties (Fig. 23). A lateral inflow through the bedrock along the northern boundary was determined to be about 5% of the total flux into the model. Although a no-flow boundary condition was specified, the small flux through the northern boundary was computed by 2DFEMWATER. This indicates that some water must flow across this boundary for mass balance to be satisfied. However, an exact match between these models is not needed to meet the remedial design objectives. In fact, a better match will not lead to a more accurate model because of the uncertainty of the hydrogeologic data, the three dimensionality of the actual flow system, and transient effects in the data.

The steady-state models are highly sensitive to the thickness of the water table fluctuation zone. Simulations with various hydraulic conductivities and recharge rates, both changing over one order of magnitude, did not change the overall water table distribution as much as varying the thickness (range) of the water table fluctuation zone by 2 ft. This sensitive behavior illustrates the importance of the thickness, continuity, and location of the water table fluctuation zone.

7.1.3 Steady-State Postcapping

Steady-state simulations were conducted for two alternative caps, which are referred to herein as the long cap (e.g., extended cap) and the short cap. The long cap covers the domain from about X-coordinate 230 ft to 892 ft. The short cap covers the domain from X coordinate 230 ft to 822 ft, differing from the long cap by 70 ft. A cutoff zone was incorporated into the short cap model. The changes in material properties are illustrated for the short cap in Fig. A13.

The cutoff zone was assigned a hydraulic conductivity two orders of magnitude less than that for the stormflow zone. This value is considered representative of changes caused by soil compaction resulting from construction equipment operations and used as an initial trial. For a properly designed and constructed formal cutoff trench, the hydraulic conductivity would probably be further reduced by one or two orders of magnitude.

Fig. 21. Section 21—Calibrated water table with upgradient constant head boundary condition.

V. E. = 4 500

Max Vector = 0.72235

Min Vector = 6.6382e-005

Time = 0

Fig. 22. Section 21—Darcy velocity vectors (ft/day) for calibrated model illustrated in Fig. 21.

Fig. 23. Section 21—Comparison between no-flow and constant-head upgradient boundary conditions.

Steady-state simulations of the two capping alternatives were conducted to examine the amount of water table reduction under each. These simulations were conducted assuming zero cap leakage. Figure 24 compares the postcapping response of the short cap to the long cap. The long cap is shown to be somewhat more effective at lowering the water table. These results showed that the water table is expected to drop by 3–8 ft. Figure 25 shows the long (extended) cap steady-state water table distribution for pre- and postcapping conditions. Figure 26 shows the same for the short cap. For both cap alternatives, the water table elevation is similar in all trench areas. These results are reasonable and can be explained by considering that the water table fluctuation zone is highly conductive, where small changes in flux result in very small changes in water levels.

7.1.4 Transient Postcapping

A long-term transient simulation for the short cap without cutoff, of a 4,500-day (12.3-yr) duration, was conducted to investigate the rate of water table decline. This simulation was made with the short cap and without accounting for possible changes in conductivity (e.g., ground compaction) resulting from cap or road construction. The pressure head response of this simulation is shown in Fig. A14. These results show that most of the transient activity occurs during the first 1.5 yr (nodes 300 and 1477), whereas the water table may take about 5 yr to fully equilibrate to the new conditions (nodes 2505, 3217, and 3223).

Two additional transient simulations were performed for the short cap to allow for assumed leakage through the cap and assess the effects on short-term (days) transient subsurface stormflow. These additional simulations assumed cap leakage rates of 1% and 5%, respectively. A cutoff zone, as described in Sect. 7.1.3, was incorporated into the short cap model but omitted for other models. These simulations were based on a 25-yr, 24-hr design storm as shown in Fig. 27.

The transient simulation results for the short cap with cutoff are shown in Figs. A15 through A17. Figures A15a–j illustrate the response of the water table and the development of perched water in the subsurface stormflow zone (assuming 1% cap leakage). This series of figures corresponds to times of 0.32, 0.45, 0.60, 0.77, 0.96, 1.18, 1.42, 1.70, 1.95, and 2.36 days from the beginning of the storm. Figures A16a–j illustrate the results for 5% cap leakage. Trench inundation occurs in both simulations but is magnified for 5% cap leakage, where the water table is about 3 ft higher than for 1% cap leakage.

Groundwater flux was calculated across four vertical cross sections marked at locations A, B, C, and D in Fig. A18. A total of four simulations were made to investigate how groundwater fluxes change in response to different cap extensions and/or leakage rates. The four simulations are as follows:

1. short cap, 1% cap leakage, and a 6-ft deep cutoff zone at the edge of the cap;
2. long cap, 70 ft longer than the short cap, 1% cap leakage, and no cutoff zone;
3. cap extending completely to the road, 1% cap leakage, and no cutoff zone; and
4. cap extending completely to the road, 0% cap leakage, and no cutoff zone.

By comparing Simulations 1, 2, and 3, determinations can be made about the relative effectiveness of extending the cap by various amounts compared with a subsurface cutoff. By comparing Simulations 3 and 4, an assessment can be made of the effect of differing cap leakages on subsurface stormflow development.

The fluxes shown in Table 11 represent the total amount of water that passes each location shown in Fig. A18 within 26.7 days after rainfall begins. In addition to the flux values for the full cross sections, values for the upper 15 ft are also shown since the trench depths are estimated to be approximately 15 ft.

V. E. = 4.500

Max = 146.51

Min = -19.361

Time = 0

Fig. 24. Section 21—Water table comparison between short cap and long cap.

Fig. 25. Section 21—Water tables for precapping and postcapping conditions for the long cap.

Fig. 26. Section 21—Water tables for precapping and postcapping conditions for the short cap.

Location a/A (Fig. A18) is immediately uphill of the cutoff zone, and location b/B is at the edge of the cap immediately downhill of the cutoff zone. In Simulation 1 the groundwater fluxes for the upper 15 ft at locations a/A and b/B are 20.17 and 3.89, respectively. The corresponding values in the upper 6 ft are 5.98 and 0.44. Thus, the flux at location b/B between 6 ft and 15 ft depth is 3.45, that is, 89% of the 3.89 total for the upper 15 ft. Below 6 ft depth at location b/B the flux is 10.51, that is 96% of the 10.95 total for the full section. Since such a very small percentage of the flux passed directly through the cutoff zone, it was not considered necessary to perform an additional simulation with a lower permeability cutoff zone consisting of a formal 6-ft-deep cutoff trench as considered in the FS/EA. Most of the flow that develops upgradient of the cutoff zone discharges as surface seeps.

The most effective barrier to transient subsurface stormflow was achieved by extending the cap to the road (e.g., an additional 35 ft), as modeled in Simulations 3 and 4. The effectiveness of extending the cap to the road is exhibited in Table 11. The subsurface stormflow is substantially reduced by the reduced tributary area as the cap is lengthened and by the reduced hydraulic conductivity under the road. The percentages of total flux at each full section that occur in the upper 15 ft increase towards the downgradient side of the model. This is because deeper groundwater begins moving up toward the discharge zones (Fig. 19) and because the water table is shallower on the downgradient side. Since the water table intersects the downgradient trenches, a higher percentage of flux occurs in the upper 15 ft progressively downgradient.

The trench fluxes showed little change when comparing Simulation 4 (zero leakage) with Simulation 3 (1% leakage). This suggests that minor cap leakage is of little consequence.

Although simulations of the 25-yr storm indicate that extending the cap to the road is more effective for keeping subsurface stormflow out of the trenches than a cutoff wall, several figures are included in Appendix A to show the postulated development of subsurface stormflow in a short-cap-with-cutoff-zone scenario.

Figures A15a-j and A16a-j show that shallow saturated zones emerge early in the storm and continue to grow during the rainfall. After rainfall subsides, subsurface stormflow diminishes, and the saturated zones exhibit delayed gravity drainage through the unsaturated zone. When water moving through the subsurface stormflow zone reaches a zone of significant lower hydraulic conductivity, saturation increases locally, and water flows out as seeps or moves vertically downward towards the water table fluctuation zone.

Figures A17a-j show the development of Darcy velocity vectors assuming 1% cap leakage. The vectors in these figures are drawn relative to the maximum velocities in each plot, which increase throughout the course of the storm. The maximum velocities increase from 0.34 ft/day at 0.0 days to 20.2 ft/day at 0.60 days, then decrease to 4.8 ft/day at 2.3 days. Subsurface stormflow velocities increase with respect to the water table fluctuation zone velocities as shown in the steady-state solution (Fig. 22). Seeps develop where the water table meets the soil surface, upgradient of the cutoff zone and also at the downgradient end of cross section 21-21.

In summary, a detailed 2-D model was developed, calibrated, and used to assess the proposed cap performance at the west disposal area. The calibrated model was able to reflect the conceptual groundwater flow model of the site. The model projected a water table decline very comparable to the 4.4-ft average /9-ft maximum for this area found in the 3-D model. This study indicates that most changes will occur within approximately 1.5 yr after capping, although minor adjustments may continue for 5 yr or more (Fig. A.14).

Fig. 27. Rainfall distribution for the 24-hr, 25-yr design storm.

Table 11. Total groundwater flux (horizontal) moving through each location (Fig. A18) over 26.7 days after beginning of 25-yr, 24-hr storm

Cap condition		Short cap, 1% leakage, with cutoff zone		Long cap; 1% leakage, no cutoff zone		Cap to road, 1% leakage, no cutoff zone		Cap to road, 0% leakage, no cutoff zone	
Location	Depth	Flux ft ³ /ft	Flux % of total	Flux ft ³ /ft	Flux % of total	Flux ft ³ /ft	Flux % of total	Flux ft ³ /ft	Flux % of total
a/A—Edge of cutoff zone (uphill)	a—Upper 15 ft	20.17	80	3.8	54	0.87	20	0.83	19
	A—Full sect	25.17	100	7.03	100	4.33	100	4.31	100
b/B—Edge of short cap (uphill)	b—Upper 15 ft	3.89	35	4.34	48	1.22	23	1.14	22
	B—Full sect	10.95	100	9.01	100	5.34	100	5.27	100
c/C—End of north trench (downhill)	c—Upper 15 ft	4.46	62	2.94	55	2.86	55	2.72	54
	C—Full sect	7.22	100	5.32	100	5.17	100	5.00	100
d/D—End of south trench (downhill)	d—Upper 15 ft	6.26	87	4.48	85	4.48	85	3.63	83
	D—Full sect	7.17	100	5.28	100	5.27	100	4.38	100

7.2 CROSS SECTION 22-22

Cross section 22-22 trends north-south through the middle of the largest proposed cap (Fig. 3). This section was selected to examine water table suppression under the proposed cap and the effect of upgradient subsurface stormflow on groundwater flow beneath the cap. The water table decline was investigated by a steady-state simulation of postcap conditions, and subsurface stormflow was examined through short-term transient simulations using the 25-yr, 24-hr design storm.

7.2.1 Discretization

Section 22-22 was modeled with 6,552 nodes (Figs. A19a-e) and 6,200 elements. Discretization was refined at the steeper slopes and edges of the cap for more accurate representation and numeric stability. Figures A20 and A21 show the material property distribution. Soil property element assignments are delineated through the use of color. The upgradient northern boundary is located at the swale near the fence at the north end of WAG 6. This boundary was selected to properly pose the numerical model (i.e., the swale acts as a natural hydrologic boundary).

7.2.2 Steady-State Calibration—Precapping

Section 22-22 was calibrated using nonlinear soil properties. The average net recharge rate was applied as a Cauchy flux (total known flux) and assumed to be 0.0007 ft/day for most of the domain, similar to Sect. 21-21. A reduced precipitation rate of 0.0003 ft/day was assumed for the northern part of the domain (1,640 ft north of the X-coordinate) to account for flow toward the Emergency Waste Basin (out of plane flow). A recharge rate of 0.0035 ft/day was used above the reported inundated trenches to account for lateral subsurface stormflow flux. The internal stream through MS 2 at $x = 549$ ft used Dirichlet (specified head) boundary conditions of 758 ft. The upgradient boundary condition was modeled with both a constant head and a no-flow condition.

Calibration revealed that the computed water table could not accurately reflect the current water table unless a fixed-head boundary condition was implemented at the bottom of the domain or the precipitation rate was decreased by one order-of-magnitude (below the rate used for Sect. 21-21). The bottom boundary condition was used since that condition introduced less ambiguity than if precipitation was reduced. The heads used for the bottom boundary condition were taken from three HHMS wells (HHMS-8B, HHMS-7B, and HHMS-5B). HHMS-4B was not used because close scrutiny revealed its value to be of suspect representativeness.

As for Sect. 21-21, Sect. 22-22 was modeled with the upgradient boundary condition being a specified head (Dirichlet) and also as a no-flow boundary. The predicted water table for the constant head condition (Fig. 28) is similar to the no-flow boundary condition water table (Fig. 29). It was found that the model is not sensitive to this upgradient boundary condition. However, the model was found to be highly sensitive to the thickness of the water table fluctuation zone.

7.2.3 Steady-State Postcapping

The steady-state water table after capping (Fig. 30) declines a maximum of about 20 ft. This predicted water table suppression is comparable to the 22-ft predicted maximum from the 3-D modeling. Saturated zones will occur at the bottom of the trenches (at $x = 660$ and 800 ft) both before and after capping. The Darcy velocity vectors for the steady-state simulation are shown in Fig. 31.

7.2.4 Transient Postcapping

Transient simulations were performed to investigate cap performance with respect to transient rainfall and subsurface stormflow. Constant head was applied at the northern boundary for these simulations, allowing transient subsurface stormflow to exit the domain through the northern swale. The simulation assumed a 1% cap leakage and used the 25-yr, 24-hr storm for recharge.

The rainfall-seepage boundary condition was implemented for this simulation. The results of the subsurface stormflow transient modeling were very similar to the Sect. 21-21 results, with numerous seeps developing along the ground surface. These results differed only in that the upgradient boundary (containing the small swale) acted as a discharge point for Sect. 22-22, and was not present in Sect. 21-21.

To further evaluate the effect of the cap on the transient simulations, time series plots of saturation were generated at a number of locations throughout the domain. Changes in soil moisture were then analyzed. The time series plot in Fig. A22 illustrates the response of soil moisture along the bottom of the second trench area from the northern boundary. Soil moisture levels rose abruptly by approximately 15% approximately 12 hr after the storm began, with approximately 1/3 of the examined nodes reaching full saturation for a very brief period (approximately 2 hr). The total transient response was short lived (less than 2 days) and the system quickly equilibrated to the prestorm conditions.

The timing, shape, and duration of the moisture development curves are very similar to the rainfall distribution curve (Fig. 27) and strongly suggest that moisture change in the trench is a direct result of rainfall percolating downward through the trench wastes and being delayed temporarily by lower permeability material (soil) at the trench bottom. There is no indication that water table fluctuation or other groundwater phenomena are affected.

In summary, a detailed 2-D saturated/unsaturated groundwater flow model was developed. The calibrated model indicated probable downward flux through the bottom of the model (El 665). This model generally agrees with the 3-D model in predicting a maximum water table decline of about 20 ft under the large cap.

7.3 CROSS SECTION 23-23

Cross section 23-23 runs through the TARA disposal area (Fig. 2). This cross section was selected to investigate the soil moisture content distribution on the steep slopes surrounding TARA.

7.3.1 Discretization

This cross section was modeled with 1,974 nodes (Figs. A23a-b) and 1,860 elements. Figures A24 and A25 represent the material property distribution using color to indicate soil property assignments. The grid for this cross section was refined around the steeper slopes and at the edges of the cap to provide detailed assessments of those areas.

7.3.2 Steady-State Calibration Precapping

The model was calibrated with a 0.002-ft/day recharge rate, as used for the 3-D model for this area. Constant head boundary conditions were assumed at the streams at both ends of the model domain. Hydraulic conductivities are shown in Fig. A24. The dynamic compaction conducted at the TARA site was incorporated into the model by decreasing the hydraulic conductivity of the subsurface stormflow zone by one order-of-magnitude in areas likely to have undergone compaction.

Fig. 28. Section 22—Calibrated water table using upgradient constant head boundary condition.

Fig. 29. Section 22—Calibrated water table using upgradient no-flow boundary condition.

Fig. 30. Section 22—Steady-state water table.

Fig. 31. Section 22—Steady-state Darcy velocity vectors (ft/day).

The difference between the calibrated water table and the current condition water table is shown in Fig. 32. Figure 33 shows the Darcy velocity distribution for the calibrated model. The greatest difference between the calibrated model results and the observed water table is on the right side of Fig. 32. This difference is probably a result of the lack of water level data in this area of rapidly changing topography. Overall, the calibration results are acceptable and adequately represent site conditions.

Section 23-23 was developed to study the transient unsaturated groundwater flow characteristics beneath the proposed cap. Precise simulation of all subsurface flow patterns in this area is not warranted, especially considering the complex, disturbed, and fractured nature of the system.

7.3.3 Transient Postcapping

Transient simulations were performed to determine moisture contents in the unsaturated zone on the steep slopes surrounding TARA and in the TARA trench area. The 25-yr storm was simulated as the recharge boundary condition on those areas not covered by the cap. On the capped area, three different recharge rates were used to evaluate the sensitivity to cap leakage. Values of cap leakage of zero, 1%, and 5% were modeled. Numerous plots of soil moistures with time were generated throughout the domain. Figure A26 shows a time series plot of soil moisture as percent saturation with time for node 855, which is located at a bottom corner of a trench. This figure shows the saturation response to precipitation under the three different cap leakages. The soil moisture increase at the trench bottom resulting from 1% cap leakage is very minor except for a brief period of approximately 3 hr, when the moisture increases 15% to a full saturation level before diminishing to prestorm conditions 24 hr later. As discussed for Sect. 22-22, this moisture change is mostly the direct result of rainfall percolating downward through the trench with no apparent effect on water table or other groundwater phenomena. The maximum soil moisture increase for zero cap leakage is approximately 6% and is probably a result of flow from off-cap areas through the unsaturated zone.

The transient response of soil moisture is presented in a time series of water table plots shown in Figs. A27a-c. These simulations assume a 0% cap leakage. This series of plots shows saturated zone growth and drainage of the subsurface stormflow zone throughout the duration of the storm. Figure A27a shows the computed water table prior to peak storm intensity, and Fig. A27b shows the saturated zone at 0.5 days into the storm. After the end of the storm, the newly developed saturated zone drains both to the adjacent streams and underneath the cap, raising the groundwater table. However, saturated groundwater levels remain well below the bottoms of burial trenches. No trenches become saturated during this simulation.

In summary, a 2-D saturated/unsaturated groundwater model was developed for the TARA site. This model focused on evaluating the effects of groundwater flow in the unsaturated zone. Groundwater flow in this area is highly complex and cannot be accurately represented by a 2-D model. It appears that the steep slopes surrounding TARA will become rapidly saturated as subsurface stormflow develops. Although the saturation may cause groundwater to flow under the capped area, it is not likely that the saturated zone will extend up into burial trenches.

7.4 CROSS SECTION 24-24

Cross section 24-24 is oriented east-west along the geologic strike near the eastern edge of WAG 6 and extends to the area known as the West Seep (Fig. 2). This section was selected to investigate subsurface stormflow near the eastern boundary of the large cap.

Fig. 32. Section 23—Calibrated water table.

Fig. 33. Section 23—Steady-state Darcy velocity vectors (ft/day).

7.4.1 Discretization

This cross section was modeled with 1,986 nodes (Figs. A28a-b) and 1,880 elements. The grid for this cross section was refined at the steeper slopes and edges of the cap to provide detailed results. Figures A29 and A30 represent the material property distribution using color to indicate soil property element assignments.

7.4.2 Steady-State Calibration Precapping

Section 24-24 was calibrated with a 0.002-ft/day recharge rate, as was used in the 3-D model. Constant head boundary conditions were used at the eastern boundary (West Seep) and at the western boundary of the model domain. The value for constant head at the western boundary was chosen based on the measured water level at that location.

Figure 34 illustrates the difference between the calibrated water table and the current condition measured water table. Figure 35 shows the Darcy velocity distribution for the calibrated model. The steady-state calibrated model illustrates that under steady-state conditions, flow within the subsurface stormflow zone is insignificant relative to flow through the water table fluctuation zone (Fig. 35).

7.4.3 Transient Postcapping

The transient simulation of the 25-yr storm was made to examine subsurface stormflow in the steep slopes and its potential impacts on groundwater flow in the trench areas under the cap. This simulation was conducted assuming 5% cap leakage.

The subsurface stormflow modeling results from Sect. 24-24 (Figs. A31a-g) are similar to the other cross sections. Figure A31a shows the water table in the early stages of the storm. Figure A31c shows the development of saturated zones within the subsurface stormflow zone just after the peak of the storm. A narrow saturated zone extends from the base of the slope almost all of the way to the cap boundary. However, Figure A31g shows that the subsurface stormflow saturated zone had drained by the second day. Thus, while a saturated subsurface stormflow zone develops along the slope up towards the cap boundary, a significant saturated zone does not develop under the cap. Figures A32a-g show the corresponding Darcy velocity vectors to the saturations shown in Figs. A21a-g.

The transient simulation results from Sect. 24-24 show that neither saturated nor unsaturated groundwater flow occurs from outside the cap boundary towards and beneath the cap. This is demonstrated by the velocity plot shown in Fig. A33. Figure A33 shows the horizontal velocities of selected nodes near the eastern wall of the trench nearest the cap boundary. Node 504 is at the top of the trench, node 497 is near the bottom of the trench, and the remaining nodes are intermediate. Positive velocities are toward the east (away from the cap), while negative velocities represent velocities toward the west (toward the cap). This figure shows some short duration (about 0.33 days), low velocity (0.15 ft/day) unsaturated flow toward the trench at node 504. Node 504 is at the top of the trench, and thus this small flow can be attributed to the 5% cap leakage used in this simulation. There is no transient groundwater flow into the trench as a result of the design storm.

7.5 CROSS SECTION 25-25

Cross section 25-25 is oriented east-west through the west disposal area (Fig. 2). This simulation was conducted to determine if Title 1 design should include lining of streams or other measures to prevent groundwater recharge from streamflow during periods of heavy rainfall and after groundwater levels have

Fig. 34. Section 24—Calibrated water table.

Fig. 35. Section 24—Steady-state Darcy velocity vectors (ft/day).

declined. Such recharge to the trenches could increase contaminant flux. This simulation also investigated water table decline beneath the west area cap.

7.5.1 Discretization

This cross section was modeled with 1,197 nodes (Fig. A34) and 1,120 elements. Figures A35 and A36 represent the material property distribution using color to indicate soil property element assignments for this model. Finer discretization was used in critical areas where accurate representation of transient flow was needed.

7.5.2 Steady-State Calibration and Postcapping

Boundary conditions used for calibration include constant head and prescribed flux. Constant head was prescribed on both sides of the domain (stream locations), with water levels set equal to the stream elevations. A no-flow condition was applied at the bottom of the domain. Recharge of 0.0007 ft/day was fluxed through the top boundary.

First, the model was calibrated to measured water levels. Then, recharge was eliminated in capped areas to obtain the steady-state capped result. The measured, calibrated, and capped steady-state water tables are shown in Fig. 36. The calculated water table suppression under the center of the cap is about 5 ft, in agreement with the 3-D model results. Figure 37 shows the Darcy velocity field for the calibrated model under capped conditions.

7.5.3 Transient Postcapping

Time varying Dirichlet conditions were used to investigate the potential effect of rising stream levels on the two streams bounding the model. A rise of 1.25 ft/hr for 1 hr was assumed for the eastern stream, while a rise of 1.0 ft/hr for 1 hr was assumed for the western stream.

The pressure head response to these rising stream conditions on the eastern side of the cap is shown in Fig. A37. Nodal point 1,195 (on the eastern boundary) exhibits the simulated stream level rise of 1.25 ft over 1 hr. Away from this boundary, the pressure head is attenuated as exhibited by the behavior of nodes 1,006 through 964. Node 964 is in the unsaturated zone and is 23 ft towards the cap, from the eastern boundary. At this distance, a small pressure head increase is observed, which corresponds to an increase in saturation. At 13 ft from the boundary at node 1,006, a pressure head response of about 0.5 ft is exhibited. Figure A37 also shows that the duration of the groundwater response near the stream is about 2 hr.

The pressure head response on the western side of the cap is shown in Fig. A38. Nodal point 19 (on the western boundary) exhibits the simulated stream level rise of 1 ft over 1 hr. Pressure head is attenuated away from this boundary as demonstrated by nodes 40 through 124. Node 124 is 35 ft towards the cap, away from the western boundary, where a very small pressure head response is exhibited. As for the eastern boundary, the duration of the response near the stream is about 2 hr. Thus, very limited groundwater recharge is probable under rising stream conditions. The movement of water from the streams into the domain is localized and is insignificant at distances greater than 50 ft from the stream. The eastern trenches in this area are at least 70 ft away from the stream. No impact on burial trenches is expected from the localized transient recharge.

V. E. = 1.125

Max = 106.13

Min = -10.448

Time = 0

Fig. 36. Section 25—Calibrated post-capping water tables.

V. E. = 1.125

Max Vector = 0.21613

Min Vector = 1.4235e-007

Time = 0

Fig. 37. Section 25—Darcy velocity vectors (ft/day) for post-capping conditions.

8. CONCLUSIONS

8.1 HYDROLOGIC ISOLATION

8.1.1 Groundwater Decline

The groundwater flow models indicate that groundwater levels will decline substantially under the proposed caps. Table 12 summarizes the simulated projected magnitude of steady-state groundwater decline from the 3-D model using the Iteration 3 cap alternative with assumed zero leakage through the cap.

Table 12. Groundwater decline (3-D model)

Entity	Area (acres)	Maximum groundwater decline (ft)	Average groundwater decline (ft)
Entire 3-D model area	77.5	22	5.5
Large Cap	21	22	14.6
West Area Cap	3.5	9	4.4
Southern Area Cap	4.5	2	0.8

Steady-state simulations with 2-D models on the Large Cap (Sect. 22-22) and the west disposal area cap (Sect. 21-21) generated estimates for groundwater decline very similar to those from 3-D modeling. Essential equilibrium of the lowered groundwater levels in the west disposal area is expected after approximately 1.5 yr, although minor adjustments may continue for 5 yr or more.

However, even with the lowered groundwater levels, several of the trenches will continue to be partially inundated. This will result primarily from the fact that trench bottoms extend below the nearby stream beds. Information on specific trench bottom elevations currently is not available, thus preventing identification of specific trenches that will remain partially saturated. Very little groundwater decline is expected under the Southern Area Cap because of its close proximity to White Oak Lake.

The 3-D modeling projects a 0.5-ft average decline in the steady-state groundwater level for the eight ICM caps compared with bare ground conditions. This, reportedly, is in general agreement with observed conditions.

8.1.2 Groundwater Flux

The 2-D transient flow analyses suggest that the groundwater flux, resulting from subsurface stormflow will be reduced in the west disposal area by a factor of at least 3 and perhaps as much as 10 or more when compared with uncapped conditions. This is in addition to the virtual elimination of the vertical component of flow through the wastes.

However, there will continue to be small amounts of groundwater flux through a number of burial trenches (see Table 11) regardless of cap boundary, membrane leakage or the presence of an uphill cutoff. This is most likely caused by deeper groundwater moving up towards the discharge zones on the lower areas of the site.

The 3-D steady-state analyses show that the groundwater outflow to surface streams from the full 77.5-acre model is reduced by 27% for Iteration 3 conditions. Even though the 29 acres of capped areas, including trenches, was not modeled independently, it would seem very probable that the steady-state groundwater flow through the trenches would be reduced by a much greater proportion.

The size of groundwater discharge zones is reduced by more than 50% (Figs. 16 and 19). This, combined with the lower groundwater levels and gradients under the caps, is expected to significantly reduce trench groundwater discharge through surface seeps and springs.

8.2 GROUNDWATER SENSITIVITY TO CAP BOUNDARIES

8.2.1 Variations in Cap Boundaries

The three sets of cap boundaries (e.g., Iterations 1 through 3) that were developed through the preliminary design process (Title I), together with that proposed in the FS/EA, all produce very similar results. Iteration 3 is based upon the cap boundary for Title I design and produces the most favorable results of all the alternatives, although it was selected primarily on constructibility considerations. As the detail design process continues, minor modifications may be made without impacting performance.

8.2.2 Cap Extensions Beyond Trench Edges

The typical Title I design cap extension of 15 ft beyond trench edges where near the top shoulder of a hillside sloping down and away appears quite adequate to prevent subsurface stormflow from off-cap precipitation from reaching the trenches. The only horizontal moisture movement detected at the trench edge in the 2-D transient simulation (Fig. A33) is at the trench top only, is extremely small, and is almost certainly a result of the 5% cap leakage rate assumed for that particular simulation.

8.3 SUBSURFACE STORMFLOW AND UPGRADIENT CUTOFF EFFECTIVENESS

Results of the 2-D transient flow analyses indicate that the most effective barrier to subsurface storm flow is accomplished by extending the cap to the road, which is generally located on or near the surface drainage divide. The tributary area for direct infiltration is essentially eliminated in this scenario.

A 6-ft deep upgradient cutoff is less effective than the extended cap because of the potential for flow bypassing underneath the cutoff as well as the undesirable effects of saturation zones forming upgradient of the cutoff. Where a cutoff zone is placed upgradient of the cap in the upper 6-ft of the soil profile, an interesting result occurs. Water moves horizontally through the stormflow zone towards the cutoff and a saturated zone develops upgradient of the cutoff. There is a localized increase in saturation and hydraulic gradients, with unsaturated hydraulic conductivities reaching their maximum values. These conditions cause increased groundwater flux in the stormflow zone, with groundwater seepage occurring at the soil surface with some water moving down around the cutoff zone. This downward moving water can increase groundwater flux through the trenches. Thus, upgradient groundwater cutoffs are not preferred for reducing groundwater fluxes through trenches.

In the case of the West Area Cap, and probably parts of the Large Cap as well, some groundwater flow continues through the trenches regardless of the upgradient capping scenario. However, this is greatly reduced and probably results from deeper groundwater moving downgradient toward the discharge zones while the water table becomes progressively shallower downgradient, as discussed in Sect. 8.1.2. With a well-constructed/maintained cap extended uphill to the road, subsurface stormflow potential is reduced to a minimum.

8.4 GROUNDWATER RECHARGE AREAS

The northern portions of the site were identified as having significantly more recharge potential than the balance of the site. Caps in these areas will be of special importance in effecting groundwater decline. No off-cap areas were identified that warrant remediation in order to limit recharge potential. No justification for lining streams to prevent recharge to burial trenches from streamflow was identified.

8.5 GROUNDWATER SENSITIVITY TO CAP LEAKAGE

Evaluation of the effects of cap leakage was not within the formal scope of this study. However, in recognition that some amount of cap leakage should be expected with even a high quality cap as planned in Title I design, allowances were made in several of the 2-D simulations to account for leakages of 1% and/or 5% of the 25-yr, 24-hr storm rainfall. Although an assessment of these results is presented in the following discussions, this information should be regarded as preliminary with further study required to confirm its reliability.

The 3-D modeling was based upon zero leakage. The majority of 2-D modeling for steady-state conditions was also based upon zero leakage. However, in the 2-D modeling for transient conditions several simulations were run with assumed leakage rates of 1% or 5% of the 25-yr, 24-hr storm rainfall, although cap leakage effects were not within the formal scope of this study. A leakage rate of 1% is considered to be representative of a well-constructed/maintained cap, whereas a 5% leakage rate is appropriate where standards for cap construction/maintenance are somewhat less stringent than considered acceptable in Title I design.

The 2-D simulations for groundwater flux through the west disposal area (Sect. 21-21) were the most in-depth for 1% assumed leakage and resulted in fluxes that were only slightly higher than for zero leakage.

The results for 1% leakage in 2-D simulations for Sects. 22-22 and 23-23 reflected a direct relationship between cap leakage and moisture increase at trench bottoms. However, the increase was only approximately 15% and only lasted for a few hours before readjusting to prestorm conditions. This appears to be the direct result of rainfall moisture percolating downward through the trench, even though vastly reduced compared to uncapped conditions. There is no indication that either water table or other groundwater phenomena are significantly affected by 1% cap leakage.

The results of 5% cap leakage indicate a strong possibility for impact on both the amount and the rate of groundwater decline. However, the leakage simulations are preliminary, and more study is necessary to reliably determine the severity of its effects. Although preliminary, these findings suggest that whereas the cap does not have to be leakproof, it should be of high quality or its effectiveness could be significantly reduced.

8.6 POTENTIAL FUTURE STUDIES

After current efforts are completed to define the bottom elevations of burial trenches, comparisons on a site-specific basis could be made with the projected groundwater levels from the 3-D modeling to better define which trenches will remain inundated and to what degree.

The 2-D simulations developed are not specifically applicable to uncapped conditions (e.g., 100%) leakage for transient flows without additional modeling effort. Further effort should be considered to better define this condition as a basis for more accurately assessing the effectiveness of the cap scenarios reported herein.

To confirm that minor leakage effects on water table decline are of little consequence, additional 3-D simulations could be performed with 1% or 5% assumed leakage. Additional development of selected 2-D simulations for 1% or 5% leakage would also be helpful to confirm or clarify the impact of leakage on cap performance.

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APPENDIX A

ADDITIONAL REPORT FIGURES

Fig. A1. Relative hydraulic conductivity vs pressure head.

Fig. A2. Moisture content vs pressure head.

AIM

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Inches

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2 of 3

Fig. A3. Six subregions within the 3-D grid.

V. E. = 1.00

Fig. A4. Finite-element grid for Layer 1.

V. E. = 10.42

Fig. A5. Six subregions within the 3-D grid.

V. F. = 10.98

Fig. A6. Finite-element grid for Column 38.

Fig. A7. Normal probability plot of computed errors.

Fig. A8. Plan view of computed residuals.

Fig. A9. Computed residuals at well screen center point.

V. E. = 1.42

Fig. A10a. Section 21—Nodal points between the coordinates of 0 and 360 ft.

V. E. = 1.81

Fig. A10b. Section 21—Nodal points between the coordinates of 360 and 818 ft.

V. E. = 0.64

Fig. A10c. Section 21—Nodal points between the coordinates of 818 and 980 ft.

V. E. = 0.84

Fig. A10d. Section 21—Nodal points between the coordinates of 980 and 1192 ft.

Section 21

Legend for Material Properties

Description of soil type

Porosity Ky Kz Kyz (all K's in ft/day)

Soil Type 1: Soil horizon A

0.385 30.00 10.00 5.00

Soil Type 2: Soil horizon B

0.385 20.00 2.00 1.00

Soil Type 3: Unsaturated soil and Nolichucky top fractured bedrock

0.285 0.08 0.05 0.002

Soil Type 4: Water table zone

0.315 0.20 0.05 0.04

Soil Type 5: Lower permeable soil and Nolichucky weathered rock

0.285 0.04 0.03 0.005

Soil Type 7: Trenches

0.300 0.80 0.20 0.00

Soil Type 8: Upslope soil horizon A

0.385 25.00 5.00 5.00

Soil Type 9: Upslope soil horizon B

0.385 20.00 3.50 4.00

Soil Type 10: Intermediate bedrock

0.100 0.003 0.003 0.000

Figure A11. Section 21 - Legend for material properties.

Fig. A12. Section 21—Elements showing lithologic distribution.

Fig. A14. Section 21—Pressure-head response to capping for the short cap.

Fig. A13. Section 21—Elements showing lithologic distribution with subsurface cutoffs added.

V. E. = 4.500 Max = 147.22 Min = -16.582 Time = 0.31999

Fig. A15a. Section 21—Saturated zone development during the 25-year storm for 1% cap leakage.

V. E. = 4.500 Max = 147.22

Min = -16.346

Time = 0.45462

Fig. A15b. Section 21—Saturated zone development during the 25-year storm for 1% cap leakage.

V. E. = 4.500 Max = 147.23

Min = -15.401

Time = 0.60625

Fig. A15c. Section 21—Saturated zone development during the 25-year storm for 1% cap leakage.

V. E. = 4.500

Max = 147.23

Min = -15.658

Time = 0.777

A15d. Section 21—Saturated zone development during the 25-year storm for 1% cap leakage.

V. E. = 4.500

Max = 147.23

Min = -15.792

Time = 0.9693

Fig. A15e. Section 21—Saturated zone development during the 25-year storm for 1% cap leakage.

V. E. = 4.500

Max = 147.24

Min = -15.886

Time = 1.1859

Fig. A15f. Section 21—Saturated zone development during the 25-year storm for 1% leakage.

V. E. = 4.500 Max = 147.25

Min = -15.968

Time = 1.4297

Fig. A15g. Section 21—Saturated zone development during the 25-year storm for 1% cap leakage.

Fig. A15h. Section 21—Saturated zone development during the 25-year storm for 1% cap leakage.

V. E. = 4.500

Max = 147.26

Min = -16.126

Time = 1.9595

Fig. A15I. Section 21—Saturated zone development during the 25-year storm for 1% cap leakage.

V. E. = 4.500 Max = 147.26 Min = -16.207 Time = 2.362

Fig. A15j. Section 21—Saturated zone development during the 25-year storm for 1% cap leakage.

V. E. = 4.500 Max = 146.51

Min = -17.383

Time = 0.31999

Fig. A16a. Section 21—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 4.500 Max = 146.51

Min = -17.375

Time = 0.45462

Fig. A16b. Section 21—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 4.500 Max = 146.51

Min = -17.034

Time = 0.60625

Fig. A16c. Section 21—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 4.500 Max = 146.51

Min = -16.302

Time = 0.777

Fig. A16d. Section 21—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 4.500 Max = 146.51

Min = -16.296

Time = 0.9693

Fig. A16e. Section 21—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 4.500 Max = 146.52

Min = -16.288

Time = 1.1859

Fig. A16f. Section 21—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 4.500

Max = 146.52

Min = -16.278

Time = 1.4297

Fig. A16g. Section 21—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 4.500 Max = 146.53

Min = -16.264

Time = 1.7044

Fig. A16h. Section 21—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 4.500 Max = 146.54

Min = -16.226

Time = 2.362

Fig. A16j. Section 21—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 4.500

Max Vector = 10.652

Min Vector = 1.5495e-005

Time = 0.31999

Fig. A17a. Section 21—Darcy velocity vectors during the 25-year storm for 1% cap leakage.

V. E. = 4.500 Max Vector = 2.4979 Min Vector = 1.6999e-005 Time = 0.45462

Fig. A17b. Section 21—Darcy velocity vectors during the 25-year storm for 1% cap leakage.

V. E. = 4.500 Max Vector = 20.252 Min Vector = 3.8172e-005 Time = 0.60625

Fig. A17c. Section 21—Darcy velocity vectors during the 25-year storm for 1% cap leakage.

V. E. = 4.500 Max Vector = 16.47 Min Vector = 3.8814e-005 Time = 0.777

Fig. A17d. Section 21—Darcy velocity vectors during the 25-year storm for 1% cap leakage.

V. E. = 4.500 Max Vector = 16.337 Min Vector = 3.9201e-005 Time = 0.9693

Fig. A17e. Section 21—Darcy velocity vectors during the 25-year storm for 1% cap leakage.

V. E. = 4.500 Max Vector = 16.363 Min Vector = 3.9569e-005 Time = 1.1859

Fig. A17f. Section 21—Darcy velocity vectors during the 25-year storm for 1% cap leakage.

V. E. = 4.500 Max Vector = 11.213 Min Vector = 4.0006e-005 Time = 1.4297

Fig. A17g. Section 21—Darcy velocity vectors during the 25-year storm for 1% cap leakage.

V. E. = 4.500

Max Vector = 5.5664

Min Vector = $4.0503e-005$

Time = 1.7044

Fig. A17h. Section 21—Darcy velocity vectors during the 25-year storm for 1% cap leakage.

V. E. = 4.500 Max Vector = 6.4325 Min Vector = 4.0984e-005 Time = 1.9595

Fig. A17i. Section 21—Darcy velocity vectors during the 25-year storm for 1% cap leakage.

V. E. = 4.500 Max Vector = 4.7938 Min Vector = 4.1647e-005 Time = 2.362

Fig. A17j. Section 21—Darcy velocity vectors during the 25-year storm for 1% cap leakage.

Fig. A18. Section 21—Vertical profiles used for flux calculations.

Fig. A19b. Section 22--Nodal points between the coordinates of 481 and 799 ft.

V. E. = 1.19

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V. E. = 1.88

Fig. A19c. Section 22—Nodal points between the coordinates of 799 and 1300 ft.

V. E. = 1.47

Fig. A19e. Section 22—Nodal points between the coordinates of 1817 and 2209 ft.

Section 22

Legend for Material Properties

Description of soil type

Porosity Ky Kz Kyz (all K's in ft/day)

Soil Type 1: Soil horizon A

0.385 30.00 10.00 5.00

Soil Type 2: Soil horizon B

0.385 20.00 2.00 1.00

Soil Type 3: Unsaturated soil and Nolichucky top fractured bedrock

0.285 0.08 0.05 0.002

Soil Type 4: Water table zone

0.315 0.20 0.05 0.04

Soil Type 5: Lower permeable soil and Nolichucky weathered rock

0.285 0.04 0.03 0.005

Soil Type 7: Trenches

0.300 0.80 0.20 0.00

Soil Type 9: Roads

0.385 20.00 3.50 4.00

Soil Type 10: Intermediate bedrock

0.100 0.003 0.003 0.000

Fig. A20. Section 22—Legend for material properties.

Fig. A21. Section 22—Elements showing lithologic distribution.

Fig. A22. Section 22—Transient stauration response during the 25-year storm.

V. E. = 1.10

Fig. A23a. Section 23—Nodal points between the coordinates of 0 and 258 ft.

Section 23

Legend for Material Properties

Description of soil type

Porosity Kx Kz Kxz (all K's in ft/day)

Soil Type 1: Soil horizon A

0.385 30.00 6.00 0.00

Soil Type 2: Soil horizon B

0.385 20.00 4.00 0.00

Soil Type 3: Soil horizon C and Maryville weathered rock

0.285 0.08 0.05 0.02

Soil Type 4: Water table zone

0.315 0.40 1.00 0.40

Soil Type 6: Compacted cap materials

0.295 4.00 2.50 0.00

Soil Type 7: Trenches

0.300 0.40 0.20 0.05

Soil Type 10: Intermediate bedrock

0.100 0.01 0.01 0.002

Fig. A24. Section 23—Legend for material properties.

Fig. A25. Section 23—Elements showing lithologic distribution.

V. E = 1.05

Fig. A23b. Section 23—Nodal points between the coordinates of 258 and 505 ft.

Fig. A26. Section 23—Saturation response for Node 855 during the 25-year storm.

Fig. A27a. Section 23—Saturated zone development during the 25-year storm for 0% cap leakage.

V. E. = 1.875 Max = 127.36 Min = -48.721 Time = 0.49997

Fig. A27b. Section 23—Saturated zone development during the 25-year storm for 0% cap leakage.

V. E. = 1.875 Max = 128.68 , Min = -42.015 Time = 1.0069

Fig. A27c. Section 23—Saturated zone development during the 25-year storm for 0% cap leakage.

V. E. = 1.25

Fig. A28a. Section 24—Nodal points between the coordinates of 0 and 264 ft.

Section 24

Legend for Material Properties

Description of soil type

Porosity Kx Kz Kxz (all K's in ft/day)

Soil Type 1: Soil horizon A

0.385 3.00 1.00 0.00

Soil Type 2: Soil horizon B

0.385 2.00 1.00 0.00

Soil Type 3: Soil Horizon C and Maryville weathered rock

0.285 0.20 0.01 0.04

Soil Type 4: Water table zone

0.315 0.40 0.05 0.04

Soil Type 6: Unsaturated soil with mostly vertical flow

0.285 0.00 0.05 0.00

Soil Type 7: Trenches

0.300 0.40 0.20 0.05

Soil Type 10: Intermediate bedrock

0.100 0.01 0.01 0.002

Fig. A29. Section 24—Legend for material properties.

Fig. A30. Section 24—Elements showing lithologic distribution.

V. E. = 0.80

Fig. A28b. Section 24—Nodal points between the coordinates of 264 and 432 ft.

V. E. = 1.687

Max = 130.8

Min = -29.502

Time = 0.41664

Fig. A31a. Section 24—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 1.687

Max = 130.8

Min = -30.494

Time = 0.4583

Fig. A31b. Section 24—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 1.687

Max = 130.8

Min = -35.842

Time = 0.54858

Fig. A31c. Section 24—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 1.687

Max = 130.8

Min = -29.617

Time = 0.67357

Fig. A31d. Section 24—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 1.687

Max = 130.8

Min = -28.684

Time = 1.0069

Fig. A31e. Section 24—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 1.687

Max = 130.8

Min = -27.5

Time = 1.5138

Fig. A31f. Section 24—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 1.687

Max = 130.8

Min = -27.5

Time = 2.0207

Fig. A31g. Section 24—Saturated zone development during the 25-year storm for 5% cap leakage.

V. E. = 1.687 Max Vector = 16.536 Min Vector = 1.3957e-006 Time = 0.41664

Fig. A32a. Section 24—Darcy velocity vectors during the 25-year storm for 5% cap leakage.

V. E. = 1.687

Max Vector = 19.801

Min Vector = 1.1345e-006

Time = 0.4583

Fig. A32b. Section 24—Darcy velocity vectors during the 25-year storm for 5% cap leakage.

V. E. = 1.687 Max Vector = 33.37 Min Vector = 6.4802e-006 Time = 0.54858

Fig. A32c. Section 24—Darcy velocity vectors during the 25-year storm for 5% cap leakage.

V. E. = 1.687

Max Vector = 48.614

Min Vector = 4.0193e-006

Time = 0.67357

Fig. A32d. Section 24—Darcy velocity vectors during the 25-year storm for 5% cap leakage.

Fig. A32e. Section 24—Darcy velocity vectors during the 25-year storm for 5% cap leakage.

V. E. = 1.687 Max Vector = 13.482 Min Vector = 5.357e-007 Time = 1.5138

Fig. A32f. Section 24—Darcy velocity vectors during the 25-year storm for 5% cap leakage.

V. E. = 1.687

Max Vector = 9.4479

Min Vector = 1.9268e-006

Time = 2.0207

Fig. A32g. Section 24—Darcy velocity vectors during the 25-year storm for 5% cap leakage.

Fig. A33. Section 2A—Horizontal velocities during the 25-year storm.

Section 25

Legend for Material Properties

Description of soil type

Porosity Kx Kz Kxz (all K's in ft/day)

Soil Type 1: Soil horizon A

0.385 20.00 5.00 0.00

Soil Type 2: Soil horizon B

0.385 20.00 2.00 0.00

Soil Type 3: Soil horizon C and Maryville weathered rock

0.285 0.20 0.01 0.04

Soil Type 4: Water table

0.315 0.30 0.05 0.04

Soil Type 7: Trenches

0.300 0.40 0.20 0.05

Soil Type 10: Intermediate bedrock

0.100 0.01 0.01 0.002

Fig. A35. Section 25—Legend for material properties.

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Fig. A36. Section 25—Elements showing lithologic distribution.

Fig. A37. Section 25—Pressure head response due to rising stream levels near the eastern boundary.

Fig. A38. Section 25—Pressure head response due to rising stream levels near the western boundary.

APPENDIX B
CONSTANT HEAD BOUNDARY CONDITIONS
USED IN THE 3-D MODEL

B.1 WAG 6 3-D MODEL DIRICHLET BOUNDARY CONDITIONS

These are the Dirichlet boundary conditions (fixed head) used in the 3DFEMWATER WAG 6 model. On each page there are three columns of data, with each column containing the global node number, the model layer on which the node is located, and the total head value assigned to that node.

B-4

Node Layer Head (ft)			Node Layer Head (ft)			Node Layer Head (ft)		
1	1	745.83	50	6	746.7	121	11	747.04
2	2	745.83	51	7	746.7	122	1	748.09
3	3	745.83	52	8	746.7	123	2	748.09
4	4	745.83	53	9	746.7	124	3	748.09
5	5	745.83	54	10	746.7	125	4	748.09
6	6	745.83	55	11	746.7	126	5	748.09
7	7	745.83	78	1	748.1	127	6	748.09
8	8	745.83	79	2	748.1	128	7	748.09
9	9	745.83	80	3	748.1	129	8	748.09
10	10	745.83	81	4	748.1	130	9	748.09
11	11	745.83	82	5	748.1	131	10	748.09
12	1	747.15	83	6	748.1	132	11	748.09
13	2	747.15	84	7	748.1	133	1	747.23
14	3	747.15	85	8	748.1	134	2	747.23
15	4	747.15	86	9	748.1	135	3	747.23
16	5	747.15	87	10	748.1	136	4	747.23
17	6	747.15	88	11	748.1	137	5	747.23
18	7	747.15	89	1	748.18	138	6	747.23
19	8	747.15	90	2	748.18	139	7	747.23
20	9	747.15	91	3	748.18	140	8	747.23
21	10	747.15	92	4	748.18	141	9	747.23
22	11	747.15	93	5	748.18	142	10	747.23
23	1	747.93	94	6	748.18	143	11	747.23
24	2	747.93	95	7	748.18	144	1	747.25
25	3	747.93	96	8	748.18	145	2	747.25
26	4	747.93	97	9	748.18	146	3	747.25
27	5	747.93	98	10	748.18	147	4	747.25
28	6	747.93	99	11	748.18	148	5	747.25
29	7	747.93	100	1	747.7	149	6	747.25
30	8	747.93	101	2	747.7	150	7	747.25
31	9	747.93	102	3	747.7	151	8	747.25
32	10	747.93	103	4	747.7	152	9	747.25
33	11	747.93	104	5	747.7	153	10	747.25
34	1	747.88	105	6	747.7	154	11	747.25
35	2	747.88	106	7	747.7	221	1	748.18
36	3	747.88	107	8	747.7	222	2	748.18
37	4	747.88	108	9	747.7	223	3	748.18
38	5	747.88	109	10	747.7	224	4	748.18
39	6	747.88	110	11	747.7	225	5	748.18
40	7	747.88	111	1	747.04	226	6	748.18
41	8	747.88	112	2	747.04	227	7	748.18
42	9	747.88	113	3	747.04	228	8	748.18
43	10	747.88	114	4	747.04	229	9	748.18
44	11	747.88	115	5	747.04	230	10	748.18
45	1	746.7	116	6	747.04	231	11	748.18
46	2	746.7	117	7	747.04	232	1	747.75
47	3	746.7	118	8	747.04	233	2	747.75
48	4	746.7	119	9	747.04	234	3	747.75
49	5	746.7	120	10	747.04	235	4	747.75

B-5

Node Layer Head (ft)			Node Layer Head (ft)			Node Layer Head (ft)		
236	5	747.75	285	10	747.46	477	4	746.15
237	6	747.75	286	11	747.46	478	5	746.15
238	7	747.75	287	1	746.58	479	6	746.15
239	8	747.75	288	2	746.58	480	7	746.15
240	9	747.75	289	3	746.58	481	8	746.15
241	10	747.75	290	4	746.58	482	9	746.15
242	11	747.75	291	5	746.58	483	10	746.15
243	1	747.46	292	6	746.58	484	11	746.15
244	2	747.46	293	7	746.58	485	1	746.23
245	3	747.46	294	8	746.58	486	2	746.23
246	4	747.46	295	9	746.58	487	3	746.23
247	5	747.46	296	10	746.58	488	4	746.23
248	6	747.46	297	11	746.58	489	5	746.23
249	7	747.46	298	1	747.79	490	6	746.23
250	8	747.46	299	2	747.79	491	7	746.23
251	9	747.46	300	3	747.79	492	8	746.23
252	10	747.46	301	4	747.79	493	9	746.23
253	11	747.46	302	5	747.79	494	10	746.23
254	1	747.29	303	6	747.79	495	11	746.23
255	2	747.29	304	7	747.79	496	1	746.23
256	3	747.29	305	8	747.79	497	2	746.23
257	4	747.29	306	9	747.79	498	3	746.23
258	5	747.29	307	10	747.79	499	4	746.23
259	6	747.29	308	11	747.79	500	5	746.23
260	7	747.29	452	1	746.44	501	6	746.23
261	8	747.29	453	2	746.44	502	7	746.23
262	9	747.29	454	3	746.44	503	8	746.23
263	10	747.29	455	4	746.44	504	9	746.23
264	11	747.29	456	5	746.44	505	10	746.23
265	1	747.13	457	6	746.44	506	11	746.23
266	2	747.13	458	7	746.44	507	1	745.99
267	3	747.13	459	8	746.44	508	2	745.99
268	4	747.13	460	9	746.44	509	3	745.99
269	5	747.13	461	10	746.44	510	4	745.99
270	6	747.13	462	11	746.44	511	5	745.99
271	7	747.13	463	1	746.25	512	6	745.99
272	8	747.13	464	2	746.25	513	7	745.99
273	9	747.13	465	3	746.25	514	8	745.99
274	10	747.13	466	4	746.25	515	9	745.99
275	11	747.13	467	5	746.25	516	10	745.99
276	1	747.46	468	6	746.25	517	11	745.99
277	2	747.46	469	7	746.25	518	1	748.05
278	3	747.46	470	8	746.25	519	2	748.05
279	4	747.46	471	9	746.25	520	3	748.05
280	5	747.46	472	10	746.25	521	4	748.05
281	6	747.46	473	11	746.25	522	5	748.05
282	7	747.46	474	1	746.15	523	6	748.05
283	8	747.46	475	2	746.15	524	7	748.05
284	9	747.46	476	3	746.15	525	8	748.05

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Node Layer Head (ft)			Node Layer Head (ft)			Node Layer Head (ft)		
526	9	748.05	982	3	748.45	1240	8	748.72
527	10	748.05	983	4	748.45	1241	9	748.72
528	11	748.05	984	5	748.45	1242	10	748.72
727	1	746.31	985	6	748.45	1243	11	748.72
728	2	746.31	986	7	748.45	1453	1	754.88
729	3	746.31	987	8	748.45	1454	2	754.88
730	4	746.31	988	9	748.45	1455	3	754.88
731	5	746.31	989	10	748.45	1456	4	754.88
732	6	746.31	990	11	748.45	1457	5	754.88
733	7	746.31	1200	1	750.18	1458	6	754.88
734	8	746.31	1201	2	750.18	1459	7	754.88
735	9	746.31	1202	3	750.18	1460	8	754.88
736	10	746.31	1203	4	750.18	1461	9	754.88
737	11	746.31	1204	5	750.18	1462	10	754.88
738	1	747.56	1205	6	750.18	1463	11	754.88
739	2	747.56	1206	7	750.18	1464	1	754.94
740	3	747.56	1207	8	750.18	1465	2	754.94
741	4	747.56	1208	9	750.18	1466	3	754.94
742	5	747.56	1209	10	750.18	1467	4	754.94
743	6	747.56	1210	11	750.18	1468	5	754.94
744	7	747.56	1211	1	766.59	1469	6	754.94
745	8	747.56	1212	2	766.59	1470	7	754.94
746	9	747.56	1213	3	766.59	1471	8	754.94
747	10	747.56	1214	4	766.59	1472	9	754.94
748	11	747.56	1215	5	766.59	1473	10	754.94
749	1	748.27	1216	6	766.59	1474	11	754.94
750	2	748.27	1217	7	766.59	1475	1	767.87
751	3	748.27	1218	8	766.59	1476	2	767.87
752	4	748.27	1219	9	766.59	1477	3	767.87
753	5	748.27	1220	10	766.59	1478	4	767.87
754	6	748.27	1221	11	766.59	1479	5	767.87
755	7	748.27	1222	1	763.72	1480	6	767.87
756	8	748.27	1223	2	763.72	1481	7	767.87
757	9	748.27	1224	3	763.72	1482	8	767.87
758	10	748.27	1225	4	763.72	1483	9	767.87
759	11	748.27	1226	5	763.72	1484	10	767.87
969	1	748.44	1227	6	763.72	1485	11	767.87
970	2	748.44	1228	7	763.72	1486	1	765.53
971	3	748.44	1229	8	763.72	1487	2	765.53
972	4	748.44	1230	9	763.72	1488	3	765.53
973	5	748.44	1231	10	763.72	1489	4	765.53
974	6	748.44	1232	11	763.72	1490	5	765.53
975	7	748.44	1233	1	748.72	1491	6	765.53
976	8	748.44	1234	2	748.72	1492	7	765.53
977	9	748.44	1235	3	748.72	1493	8	765.53
978	10	748.44	1236	4	748.72	1494	9	765.53
979	11	748.44	1237	5	748.72	1495	10	765.53
980	1	748.45	1238	6	748.72	1496	11	765.53
981	2	748.45	1239	7	748.72	1497	1	764.34

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Node Layer Head (ft)			Node Layer Head (ft)			Node Layer Head (ft)		
1498	2	764.34	1767	7	755.93	1849	1	763.29
1499	3	764.34	1768	8	755.93	1850	2	763.29
1500	4	764.34	1769	9	755.93	1851	3	763.29
1501	5	764.34	1770	10	755.93	1852	4	763.29
1502	6	764.34	1771	11	755.93	1853	5	763.29
1503	7	764.34	1772	1	755.98	1854	6	763.29
1504	8	764.34	1773	2	755.98	1855	7	763.29
1505	9	764.34	1774	3	755.98	1856	8	763.29
1506	10	764.34	1775	4	755.98	1857	9	763.29
1507	11	764.34	1776	5	755.98	1858	10	763.29
1508	1	763.19	1777	6	755.98	1859	11	763.29
1509	2	763.19	1778	7	755.98	1860	1	761.8
1510	3	763.19	1779	8	755.98	1861	2	761.8
1511	4	763.19	1780	9	755.98	1862	3	761.8
1512	5	763.19	1781	10	755.98	1863	4	761.8
1513	6	763.19	1782	11	755.98	1864	5	761.8
1514	7	763.19	1783	1	756.64	1865	6	761.8
1515	8	763.19	1784	2	756.64	1866	7	761.8
1516	9	763.19	1785	3	756.64	1867	8	761.8
1517	10	763.19	1786	4	756.64	1868	9	761.8
1518	11	763.19	1787	5	756.64	1869	10	761.8
1519	1	761.71	1788	6	756.64	1870	11	761.8
1520	2	761.71	1789	7	756.64	1871	1	760.32
1521	3	761.71	1790	8	756.64	1872	2	760.32
1522	4	761.71	1791	9	756.64	1873	3	760.32
1523	5	761.71	1792	10	756.64	1874	4	760.32
1524	6	761.71	1793	11	756.64	1875	5	760.32
1525	7	761.71	1794	1	770.47	1876	6	760.32
1526	8	761.71	1795	2	770.47	1877	7	760.32
1527	9	761.71	1796	3	770.47	1878	8	760.32
1528	10	761.71	1797	4	770.47	1879	9	760.32
1529	11	761.71	1798	5	770.47	1880	10	760.32
1530	1	749.44	1799	6	770.47	1881	11	760.32
1531	2	749.44	1800	7	770.47	1882	1	758.94
1532	3	749.44	1801	8	770.47	1883	2	758.94
1533	4	749.44	1802	9	770.47	1884	3	758.94
1534	5	749.44	1803	10	770.47	1885	4	758.94
1535	6	749.44	1804	11	770.47	1886	5	758.94
1536	7	749.44	1805	1	768.89	1887	6	758.94
1537	8	749.44	1806	2	768.89	1888	7	758.94
1538	9	749.44	1807	3	768.89	1889	8	758.94
1539	10	749.44	1808	4	768.89	1890	9	758.94
1540	11	749.44	1809	5	768.89	1891	10	758.94
1761	1	755.93	1810	6	768.89	1892	11	758.94
1762	2	755.93	1811	7	768.89	1893	1	750.41
1763	3	755.93	1812	8	768.89	1894	2	750.41
1764	4	755.93	1813	9	768.89	1895	3	750.41
1765	5	755.93	1814	10	768.89	1896	4	750.41
1766	6	755.93	1815	11	768.89	1897	5	750.41

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Node Layer Head (ft)			Node Layer Head (ft)			Node Layer Head (ft)		
1898	6	750.41	2266	11	760.45	2315	5	754.04
1899	7	750.41	2267	1	759.05	2316	6	754.04
1900	8	750.41	2268	2	759.05	2317	7	754.04
1901	9	750.41	2269	3	759.05	2318	8	754.04
1902	10	750.41	2270	4	759.05	2319	9	754.04
1903	11	750.41	2271	5	759.05	2320	10	754.04
2146	1	758.24	2272	6	759.05	2321	11	754.04
2147	2	758.24	2273	7	759.05	2322	1	752.77
2148	3	758.24	2274	8	759.05	2323	2	752.77
2149	4	758.24	2275	9	759.05	2324	3	752.77
2150	5	758.24	2276	10	759.05	2325	4	752.77
2151	6	758.24	2277	11	759.05	2326	5	752.77
2152	7	758.24	2278	1	757.73	2327	6	752.77
2153	8	758.24	2279	2	757.73	2328	7	752.77
2154	9	758.24	2280	3	757.73	2329	8	752.77
2155	10	758.24	2281	4	757.73	2330	9	752.77
2156	11	758.24	2282	5	757.73	2331	10	752.77
2157	1	757.88	2283	6	757.73	2332	11	752.77
2158	2	757.88	2284	7	757.73	2333	1	751.58
2159	3	757.88	2285	8	757.73	2334	2	751.58
2160	4	757.88	2286	9	757.73	2335	3	751.58
2161	5	757.88	2287	10	757.73	2336	4	751.58
2162	6	757.88	2288	11	757.73	2337	5	751.58
2163	7	757.88	2289	1	756.48	2338	6	751.58
2164	8	757.88	2290	2	756.48	2339	7	751.58
2165	9	757.88	2291	3	756.48	2340	8	751.58
2166	10	757.88	2292	4	756.48	2341	9	751.58
2167	11	757.88	2293	5	756.48	2342	10	751.58
2168	1	771.17	2294	6	756.48	2343	11	751.58
2169	2	771.17	2295	7	756.48	2344	1	751
2170	3	771.17	2296	8	756.48	2345	2	751
2171	4	771.17	2297	9	756.48	2346	3	751
2172	5	771.17	2298	10	756.48	2347	4	751
2173	6	771.17	2299	11	756.48	2348	5	751
2174	7	771.17	2300	1	755.27	2349	6	751
2175	8	771.17	2301	2	755.27	2350	7	751
2176	9	771.17	2302	3	755.27	2351	8	751
2177	10	771.17	2303	4	755.27	2352	9	751
2178	11	771.17	2304	5	755.27	2353	10	751
2256	1	760.45	2305	6	755.27	2354	11	751
2257	2	760.45	2306	7	755.27	2608	1	757.71
2258	3	760.45	2307	8	755.27	2609	2	757.71
2259	4	760.45	2308	9	755.27	2610	3	757.71
2260	5	760.45	2309	10	755.27	2611	4	757.71
2261	6	760.45	2310	11	755.27	2612	5	757.71
2262	7	760.45	2311	1	754.04	2613	6	757.71
2263	8	760.45	2312	2	754.04	2614	7	757.71
2264	9	760.45	2313	3	754.04	2615	8	757.71
2265	10	760.45	2314	4	754.04	2616	9	757.71

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Node Layer Head (ft)			Node Layer Head (ft)			Node Layer Head (ft)		
2617	10	757.71	3093	2	773.59	3590	4	774.67
2618	11	757.71	3094	3	773.59	3591	5	774.67
2619	1	772.31	3095	4	773.59	3592	6	774.67
2620	2	772.31	3096	5	773.59	3593	7	774.67
2621	3	772.31	3097	6	773.59	3594	8	774.67
2622	4	772.31	3098	7	773.59	3595	9	774.67
2623	5	772.31	3099	8	773.59	3596	10	774.67
2624	6	772.31	3100	9	773.59	3597	11	774.67
2625	7	772.31	3101	10	773.59	3763	1	753.03
2626	8	772.31	3102	11	773.59	3807	1	756.95
2627	9	772.31	3268	1	752.58	4060	1	750.94
2628	10	772.31	3290	1	752.52	4061	2	750.94
2629	11	772.31	3301	1	753.86	4062	3	750.94
2630	1	772.2	3554	1	753.61	4063	4	750.94
2631	2	772.2	3555	2	753.61	4064	5	750.94
2632	3	772.2	3556	3	753.61	4065	6	750.94
2633	4	772.2	3557	4	753.61	4066	7	750.94
2634	5	772.2	3558	5	753.61	4067	8	750.94
2635	6	772.2	3559	6	753.61	4068	9	750.94
2636	7	772.2	3560	7	753.61	4069	10	750.94
2637	8	772.2	3561	8	753.61	4070	11	750.94
2638	9	772.2	3562	9	753.61	4071	1	776.17
2639	10	772.2	3563	10	753.61	4072	2	776.17
2640	11	772.2	3564	11	753.61	4073	3	776.17
2795	1	752.94	3565	1	753.49	4074	4	776.17
2806	1	752.88	3566	2	753.49	4075	5	776.17
3070	1	755.98	3567	3	753.49	4076	6	776.17
3071	2	755.98	3568	4	753.49	4077	7	776.17
3072	3	755.98	3569	5	753.49	4078	8	776.17
3073	4	755.98	3570	6	753.49	4079	9	776.17
3074	5	755.98	3571	7	753.49	4080	10	776.17
3075	6	755.98	3572	8	753.49	4081	11	776.17
3076	7	755.98	3573	9	753.49	4247	1	757.29
3077	8	755.98	3574	10	753.49	4302	1	755.33
3078	9	755.98	3575	11	753.49	4555	1	748.17
3079	10	755.98	3576	1	775.43	4556	2	748.17
3080	11	755.98	3577	2	775.43	4557	3	748.17
3081	1	755.96	3578	3	775.43	4558	4	748.17
3082	2	755.96	3579	4	775.43	4559	5	748.17
3083	3	755.96	3580	5	775.43	4560	6	748.17
3084	4	755.96	3581	6	775.43	4561	7	748.17
3085	5	755.96	3582	7	775.43	4562	8	748.17
3086	6	755.96	3583	8	775.43	4563	9	748.17
3087	7	755.96	3584	9	775.43	4564	10	748.17
3088	8	755.96	3585	10	775.43	4565	11	748.17
3089	9	755.96	3586	11	775.43	4566	1	781.67
3090	10	755.96	3587	1	774.67	4567	2	781.67
3091	11	755.96	3588	2	774.67	4568	3	781.67
3092	1	773.59	3589	3	774.67	4569	4	781.67

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Node Layer Head (ft)			Node Layer Head (ft)			Node Layer Head (ft)		
4570	5	781.67	5090	8	782.98	6121	5	751.7
4571	6	781.67	5091	9	782.98	6122	6	751.7
4572	7	781.67	5092	10	782.98	6123	7	751.7
4573	8	781.67	5093	11	782.98	6124	8	751.7
4574	9	781.67	5259	1	761.35	6125	9	751.7
4575	10	781.67	5270	1	757.93	6126	10	751.7
4576	11	781.67	5336	1	758.92	6127	11	751.7
4577	1	778.22	5567	1	750.85	6128	1	753.38
4578	2	778.22	5589	1	749.54	6129	2	753.38
4579	3	778.22	5590	2	749.54	6130	3	753.38
4580	4	778.22	5591	3	749.54	6131	4	753.38
4581	5	778.22	5592	4	749.54	6132	5	753.38
4582	6	778.22	5593	5	749.54	6133	6	753.38
4583	7	778.22	5594	6	749.54	6134	7	753.38
4584	8	778.22	5595	7	749.54	6135	8	753.38
4585	9	778.22	5596	8	749.54	6136	9	753.38
4586	10	778.22	5597	9	749.54	6137	10	753.38
4587	11	778.22	5598	10	749.54	6138	11	753.38
4753	1	758.21	5599	11	749.54	6139	1	754.09
4808	1	756.3	5600	1	784.97	6140	2	754.09
5061	1	747.27	5601	2	784.97	6141	3	754.09
5062	2	747.27	5602	3	784.97	6142	4	754.09
5063	3	747.27	5603	4	784.97	6143	5	754.09
5064	4	747.27	5604	5	784.97	6144	6	754.09
5065	5	747.27	5605	6	784.97	6145	7	754.09
5066	6	747.27	5606	7	784.97	6146	8	754.09
5067	7	747.27	5607	8	784.97	6147	9	754.09
5068	8	747.27	5608	9	784.97	6148	10	754.09
5069	9	747.27	5609	10	784.97	6149	11	754.09
5070	10	747.27	5610	11	784.97	6150	1	787.69
5071	11	747.27	5776	1	759.58	6151	2	787.69
5072	1	749.29	5853	1	759.64	6152	3	787.69
5073	2	749.29	6073	1	754.37	6153	4	787.69
5074	3	749.29	6084	1	750.04	6154	5	787.69
5075	4	749.29	6106	1	750.24	6155	6	787.69
5076	5	749.29	6107	2	750.24	6156	7	787.69
5077	6	749.29	6108	3	750.24	6157	8	787.69
5078	7	749.29	6109	4	750.24	6158	9	787.69
5079	8	749.29	6110	5	750.24	6159	10	787.69
5080	9	749.29	6111	6	750.24	6160	11	787.69
5081	10	749.29	6112	7	750.24	6315	1	762.91
5082	11	749.29	6113	8	750.24	6326	1	760.44
5083	1	782.98	6114	9	750.24	6403	1	760.5
5084	2	782.98	6115	10	750.24	6656	1	753.59
5085	3	782.98	6116	11	750.24	6689	1	749.59
5086	4	782.98	6117	1	751.7	6690	2	749.59
5087	5	782.98	6118	2	751.7	6691	3	749.59
5088	6	782.98	6119	3	751.7	6692	4	749.59
5089	7	782.98	6120	4	751.7	6693	5	749.59

AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

3 of 3

B-11

Node Layer Head (ft)			Node Layer Head (ft)			Node Layer Head (ft)		
6694	6	749.59	7279	8	748.47	8419	4	756.14
6695	7	749.59	7280	9	748.47	8420	5	756.14
6696	8	749.59	7281	10	748.47	8421	6	756.14
6697	9	749.59	7282	11	748.47	8422	7	756.14
6698	10	749.59	7283	1	794.48	8423	8	756.14
6699	11	749.59	7284	2	794.48	8424	9	756.14
6700	1	747.46	7285	3	794.48	8425	10	756.14
6701	2	747.46	7286	4	794.48	8426	11	756.14
6702	3	747.46	7287	5	794.48	8427	1	755.68
6703	4	747.46	7288	6	794.48	8428	2	755.68
6704	5	747.46	7289	7	794.48	8429	3	755.68
6705	6	747.46	7290	8	794.48	8430	4	755.68
6706	7	747.46	7291	9	794.48	8431	5	755.68
6707	8	747.46	7292	10	794.48	8432	6	755.68
6708	9	747.46	7293	11	794.48	8433	7	755.68
6709	10	747.46	7426	1	769.58	8434	8	755.68
6710	11	747.46	7437	1	767.08	8435	9	755.68
6711	1	791.47	7448	1	765.41	8436	10	755.68
6712	2	791.47	7459	1	764.17	8437	11	755.68
6713	3	791.47	7558	1	762.67	8438	1	798.35
6714	4	791.47	7789	1	760.9	8439	2	798.35
6715	5	791.47	7844	1	751.47	8440	3	798.35
6716	6	791.47	7845	2	751.47	8441	4	798.35
6717	7	791.47	7846	3	751.47	8442	5	798.35
6718	8	791.47	7847	4	751.47	8443	6	798.35
6719	9	791.47	7848	5	751.47	8444	7	798.35
6720	10	791.47	7849	6	751.47	8445	8	798.35
6721	11	791.47	7850	7	751.47	8446	9	798.35
6722	1	790.56	7851	8	751.47	8447	10	798.35
6723	2	790.56	7852	9	751.47	8448	11	798.35
6724	3	790.56	7853	10	751.47	8570	1	774.88
6725	4	790.56	7854	11	751.47	8614	1	769.88
6726	5	790.56	7855	1	797.13	8713	1	764.93
6727	6	790.56	7856	2	797.13	9010	1	757.61
6728	7	790.56	7857	3	797.13	9011	2	757.61
6729	8	790.56	7858	4	797.13	9012	3	757.61
6730	9	790.56	7859	5	797.13	9013	4	757.61
6731	10	790.56	7860	6	797.13	9014	5	757.61
6732	11	790.56	7861	7	797.13	9015	6	757.61
6887	1	763	7862	8	797.13	9016	7	757.61
6986	1	763.87	7863	9	797.13	9017	8	757.61
7228	1	754.93	7864	10	797.13	9018	9	757.61
7272	1	748.47	7865	11	797.13	9019	10	757.61
7273	2	748.47	7998	1	770.33	9020	11	757.61
7274	3	748.47	8031	1	765.08	9021	1	754.58
7275	4	748.47	8130	1	764.39	9022	2	754.58
7276	5	748.47	8416	1	756.14	9023	3	754.58
7277	6	748.47	8417	2	756.14	9024	4	754.58
7278	7	748.47	8418	3	756.14	9025	5	754.58

B-12

Node Layer Head (ft)			Node Layer Head (ft)			Node Layer Head (ft)		
9026	6	754.58	9633	8	795.35	10780	11	799.05
9027	7	754.58	9634	9	795.35	10789	9	798.93
9028	8	754.58	9635	10	795.35	10790	10	798.93
9029	9	754.58	9636	11	795.35	10791	11	798.93
9030	10	754.58	9645	9	795.54	10847	1	781.57
9031	11	754.58	9646	10	795.54	10902	1	773.05
9032	1	796.61	9647	11	795.54	10990	1	771.1
9033	2	796.61	9656	9	796.93	11298	1	755.58
9034	3	796.61	9657	10	796.93	11299	2	755.58
9035	4	796.61	9658	11	796.93	11300	3	755.58
9036	5	796.61	9747	1	777	11301	4	755.58
9037	6	796.61	9802	1	769.67	11302	5	755.58
9038	7	796.61	9890	1	769.33	11303	6	755.58
9039	8	796.61	10198	1	756.39	11304	7	755.58
9040	9	796.61	10199	2	756.39	11305	8	755.58
9041	10	796.61	10200	3	756.39	11306	9	755.58
9042	11	796.61	10201	4	756.39	11307	10	755.58
9043	1	796.78	10202	5	756.39	11308	11	755.58
9044	2	796.78	10203	6	756.39	11317	9	800.2
9045	3	796.78	10204	7	756.39	11318	10	800.2
9046	4	796.78	10205	8	756.39	11319	11	800.2
9047	5	796.78	10206	9	756.39	11328	9	799.51
9048	6	796.78	10207	10	756.39	11329	10	799.51
9049	7	796.78	10208	11	756.39	11330	11	799.51
9050	8	796.78	10217	9	796.04	11364	1	783.88
9051	9	796.78	10218	10	796.04	11430	1	774.2
9052	10	796.78	10219	11	796.04	11518	1	771.62
9053	11	796.78	10228	9	798.12	11826	1	756.04
9164	1	775.65	10229	10	798.12	11827	2	756.04
9219	1	768.94	10230	11	798.12	11828	3	756.04
9307	1	769.24	10239	9	798.63	11829	4	756.04
9615	1	756.26	10240	10	798.63	11830	5	756.04
9616	2	756.26	10241	11	798.63	11831	6	756.04
9617	3	756.26	10308	1	782.33	11832	7	756.04
9618	4	756.26	10363	1	771.83	11833	8	756.04
9619	5	756.26	10451	1	771.85	11834	9	756.04
9620	6	756.26	10759	1	755.88	11835	10	756.04
9621	7	756.26	10760	2	755.88	11836	11	756.04
9622	8	756.26	10761	3	755.88	11837	1	752.43
9623	9	756.26	10762	4	755.88	11838	2	752.43
9624	10	756.26	10763	5	755.88	11839	3	752.43
9625	11	756.26	10764	6	755.88	11840	4	752.43
9626	1	795.35	10765	7	755.88	11841	5	752.43
9627	2	795.35	10766	8	755.88	11842	6	752.43
9628	3	795.35	10767	9	755.88	11843	7	752.43
9629	4	795.35	10768	10	755.88	11844	8	752.43
9630	5	795.35	10769	11	755.88	11845	9	752.43
9631	6	795.35	10778	9	799.05	11846	10	752.43
9632	7	795.35	10779	10	799.05	11847	11	752.43

B-13

Node	Layer	Head (ft)	Node	Layer	Head (ft)	Node	Layer	Head (ft)
11856	9	800.87	13403	5	754.47	14863	2	750.62
11857	10	800.87	13404	6	754.47	14864	3	750.62
11858	11	800.87	13405	7	754.47	14865	4	750.62
11867	9	799.85	13406	8	754.47	14866	5	750.62
11868	10	799.85	13407	9	754.47	14867	6	750.62
11869	11	799.85	13408	10	754.47	14868	7	750.62
11958	1	778.97	13409	11	754.47	14869	8	750.62
12046	1	772.23	13418	9	797.87	14870	9	750.62
12365	1	753.83	13419	10	797.87	14871	10	750.62
12366	2	753.83	13420	11	797.87	14872	11	750.62
12367	3	753.83	13429	9	795.46	14881	9	798.16
12368	4	753.83	13430	10	795.46	14882	10	798.16
12369	5	753.83	13431	11	795.46	14883	11	798.16
12370	6	753.83	13487	1	785.3	14892	9	796.8
12371	7	753.83	13575	1	774.9	14893	10	796.8
12372	8	753.83	13894	1	752.82	14894	11	796.8
12373	9	753.83	13895	2	752.82	15016	1	776.77
12374	10	753.83	13896	3	752.82	15335	1	751.6
12375	11	753.83	13897	4	752.82	15336	2	751.6
12384	9	800.97	13898	5	752.82	15337	3	751.6
12385	10	800.97	13899	6	752.82	15338	4	751.6
12386	11	800.97	13900	7	752.82	15339	5	751.6
12475	1	778.29	13901	8	752.82	15340	6	751.6
12563	1	773.69	13902	9	752.82	15341	7	751.6
12882	1	754.78	13903	10	752.82	15342	8	751.6
12883	2	754.78	13904	11	752.82	15343	9	751.6
12884	3	754.78	13913	9	796.13	15344	10	751.6
12885	4	754.78	13914	10	796.13	15345	11	751.6
12886	5	754.78	13915	11	796.13	15354	9	798.68
12887	6	754.78	14059	1	775.88	15355	10	798.68
12888	7	754.78	14378	1	751.13	15356	11	798.68
12889	8	754.78	14379	2	751.13	15365	9	798.39
12890	9	754.78	14380	3	751.13	15366	10	798.39
12891	10	754.78	14381	4	751.13	15367	11	798.39
12892	11	754.78	14382	5	751.13	15376	9	798.3
12901	9	800.19	14383	6	751.13	15377	10	798.3
12902	10	800.19	14384	7	751.13	15378	11	798.3
12903	11	800.19	14385	8	751.13	15387	9	798.32
12912	9	800.19	14386	9	751.13	15388	10	798.32
12913	10	800.19	14387	10	751.13	15389	11	798.32
12914	11	800.19	14388	11	751.13	15478	1	778.02
12923	9	797.3	14397	9	797.98	15797	1	750.17
12924	10	797.3	14398	10	797.98	15798	2	750.17
12925	11	797.3	14399	11	797.98	15799	3	750.17
13080	1	773.99	14408	9	795.87	15800	4	750.17
13399	1	754.47	14409	10	795.87	15801	5	750.17
13400	2	754.47	14410	11	795.87	15802	6	750.17
13401	3	754.47	14543	1	776.33	15803	7	750.17
13402	4	754.47	14862	1	750.62	15804	8	750.17

B-14

Node	Layer	Head (ft)	Node	Layer	Head (ft)	Node	Layer	Head (ft)
15805	9	750.17	17007	1	762.96	17826	6	759.09
15806	10	750.17	17008	2	762.96	17827	7	759.09
15807	11	750.17	17009	3	762.96	17828	8	759.09
15816	9	798.31	17010	4	762.96	17829	9	759.09
15817	10	798.31	17011	5	762.96	17830	10	759.09
15818	11	798.31	17012	6	762.96	17831	11	759.09
15827	9	798.59	17013	7	762.96	17832	1	759.05
15828	10	798.59	17014	8	762.96	17833	2	759.05
15829	11	798.59	17015	9	762.96	17834	3	759.05
15838	9	796.94	17016	10	762.96	17835	4	759.05
15839	10	796.94	17017	11	762.96	17836	5	759.05
15840	11	796.94	17018	1	758.34	17837	6	759.05
15849	9	800.25	17019	2	758.34	17838	7	759.05
15850	10	800.25	17020	3	758.34	17839	8	759.05
15851	11	800.25	17021	4	758.34	17840	9	759.05
15918	1	780.29	17022	5	758.34	17841	10	759.05
16226	1	754.81	17023	6	758.34	17842	11	759.05
16227	2	754.81	17024	7	758.34	17851	9	816.53
16228	3	754.81	17025	8	758.34	17852	10	816.53
16229	4	754.81	17026	9	758.34	17853	11	816.53
16230	5	754.81	17027	10	758.34	17942	1	782.67
16231	6	754.81	17028	11	758.34	18250	1	764.85
16232	7	754.81	17037	9	805.27	18251	2	764.85
16233	8	754.81	17038	10	805.27	18252	3	764.85
16234	9	754.81	17039	11	805.27	18253	4	764.85
16235	10	754.81	17106	1	781.71	18254	5	764.85
16236	11	754.81	17414	1	757.01	18255	6	764.85
16245	9	797.6	17415	2	757.01	18256	7	764.85
16246	10	797.6	17416	3	757.01	18257	8	764.85
16247	11	797.6	17417	4	757.01	18258	9	764.85
16256	9	800.58	17418	5	757.01	18259	10	764.85
16257	10	800.58	17419	6	757.01	18260	11	764.85
16258	11	800.58	17420	7	757.01	18269	9	817.23
16314	1	779.93	17421	8	757.01	18270	10	817.23
16622	1	761.52	17422	9	757.01	18271	11	817.23
16623	2	761.52	17423	10	757.01	18371	1	785.24
16624	3	761.52	17424	11	757.01	18668	1	767.32
16625	4	761.52	17433	9	812.29	18669	2	767.32
16626	5	761.52	17434	10	812.29	18670	3	767.32
16627	6	761.52	17435	11	812.29	18671	4	767.32
16628	7	761.52	17444	9	810.07	18672	5	767.32
16629	8	761.52	17445	10	810.07	18673	6	767.32
16630	9	761.52	17446	11	810.07	18674	7	767.32
16631	10	761.52	17524	1	783.24	18675	8	767.32
16632	11	761.52	17821	1	759.09	18676	9	767.32
16641	9	803.66	17822	2	759.09	18677	10	767.32
16642	10	803.66	17823	3	759.09	18678	11	767.32
16643	11	803.66	17824	4	759.09	18679	1	763.82
16710	1	780.81	17825	5	759.09	18680	2	763.82

B-15

Node	Layer	Head (ft)	Node	Layer	Head (ft)	Node	Layer	Head (ft)
18681	3	763.82	19516	2	766.96	20284	11	807.77
18682	4	763.82	19517	3	766.96	20604	1	769.73
18683	5	763.82	19518	4	766.96	20605	2	769.73
18684	6	763.82	19519	5	766.96	20606	3	769.73
18685	7	763.82	19520	6	766.96	20607	4	769.73
18686	8	763.82	19521	7	766.96	20608	5	769.73
18687	9	763.82	19522	8	766.96	20609	6	769.73
18688	10	763.82	19523	9	766.96	20610	7	769.73
18689	11	763.82	19524	10	766.96	20611	8	769.73
18698	9	817.96	19525	11	766.96	20612	9	769.73
18699	10	817.96	19534	9	804.2	20613	10	769.73
18700	11	817.96	19535	10	804.2	20614	11	769.73
18709	9	812.27	19536	11	804.2	20623	9	809.36
18710	10	812.27	19545	9	806.28	20624	10	809.36
18711	11	812.27	19546	10	806.28	20625	11	809.36
18720	9	810.53	19547	11	806.28	20945	1	770.93
18721	10	810.53	19889	1	766.94	20946	2	770.93
18722	11	810.53	19890	2	766.94	20947	3	770.93
18731	9	805.77	19891	3	766.94	20948	4	770.93
18732	10	805.77	19892	4	766.94	20949	5	770.93
18733	11	805.77	19893	5	766.94	20950	6	770.93
18742	9	806.25	19894	6	766.94	20951	7	770.93
18743	10	806.25	19895	7	766.94	20952	8	770.93
18744	11	806.25	19896	8	766.94	20953	9	770.93
18811	1	786.8	19897	9	766.94	20954	10	770.93
19108	1	765.89	19898	10	766.94	20955	11	770.93
19109	2	765.89	19899	11	766.94	20964	9	809.54
19110	3	765.89	19908	9	804.72	20965	10	809.54
19111	4	765.89	19909	10	804.72	20966	11	809.54
19112	5	765.89	19910	11	804.72	21286	1	769.79
19113	6	765.89	19919	9	806.96	21287	2	769.79
19114	7	765.89	19920	10	806.96	21288	3	769.79
19115	8	765.89	19921	11	806.96	21289	4	769.79
19116	9	765.89	20252	1	767.59	21290	5	769.79
19117	10	765.89	20253	2	767.59	21291	6	769.79
19118	11	765.89	20254	3	767.59	21292	7	769.79
19127	9	817.04	20255	4	767.59	21293	8	769.79
19128	10	817.04	20256	5	767.59	21294	9	769.79
19129	11	817.04	20257	6	767.59	21295	10	769.79
19138	9	816.77	20258	7	767.59	21296	11	769.79
19139	10	816.77	20259	8	767.59	21297	1	764.66
19140	11	816.77	20260	9	767.59	21298	2	764.66
19149	9	804.34	20261	10	767.59	21299	3	764.66
19150	10	804.34	20262	11	767.59	21300	4	764.66
19151	11	804.34	20271	9	805.43	21301	5	764.66
19160	9	806.44	20272	10	805.43	21302	6	764.66
19161	10	806.44	20273	11	805.43	21303	7	764.66
19162	11	806.44	20282	9	807.77	21304	8	764.66
19515	1	766.96	20283	10	807.77	21305	9	764.66

B-16

Node Layer Head (ft)			Node Layer Head (ft)			Node Layer Head (ft)		
21306	10	764.66	22352	11	768.62	23010	9	813.11
21307	11	764.66	22361	9	808.76	23011	10	813.11
21316	9	809.67	22362	10	808.76	23012	11	813.11
21317	10	809.67	22363	11	808.76	23266	1	792.33
21318	11	809.67	22372	9	808.62	23267	2	792.33
21649	1	764.84	22373	10	808.62	23268	3	792.33
21650	2	764.84	22374	11	808.62	23269	4	792.33
21651	3	764.84	22672	1	771.78	23270	5	792.33
21652	4	764.84	22673	2	771.78	23271	6	792.33
21653	5	764.84	22674	3	771.78	23272	7	792.33
21654	6	764.84	22675	4	771.78	23273	8	792.33
21655	7	764.84	22676	5	771.78	23274	9	792.33
21656	8	764.84	22677	6	771.78	23275	10	792.33
21657	9	764.84	22678	7	771.78	23276	11	792.33
21658	10	764.84	22679	8	771.78	23277	1	786.01
21659	11	764.84	22680	9	771.78	23278	2	786.01
21668	9	810.9	22681	10	771.78	23279	3	786.01
21669	10	810.9	22682	11	771.78	23280	4	786.01
21670	11	810.9	22691	9	808.16	23281	5	786.01
21679	9	810.7	22692	10	808.16	23282	6	786.01
21680	10	810.7	22693	11	808.16	23283	7	786.01
21681	11	810.7	22702	9	807.21	23284	8	786.01
22001	1	766.43	22703	10	807.21	23285	9	786.01
22002	2	766.43	22704	11	807.21	23286	10	786.01
22003	3	766.43	22713	9	811.09	23287	11	786.01
22004	4	766.43	22714	10	811.09	23296	9	814.73
22005	5	766.43	22715	11	811.09	23297	10	814.73
22006	6	766.43	22980	1	787.89	23298	11	814.73
22007	7	766.43	22981	2	787.89	23530	1	790.24
22008	8	766.43	22982	3	787.89	23531	2	790.24
22009	9	766.43	22983	4	787.89	23532	3	790.24
22010	10	766.43	22984	5	787.89	23533	4	790.24
22011	11	766.43	22985	6	787.89	23534	5	790.24
22020	9	809.63	22986	7	787.89	23535	6	790.24
22021	10	809.63	22987	8	787.89	23536	7	790.24
22022	11	809.63	22988	9	787.89	23537	8	790.24
22031	9	809.21	22989	10	787.89	23538	9	790.24
22032	10	809.21	22990	11	787.89	23539	10	790.24
22033	11	809.21	22991	1	776.07	23540	11	790.24
22342	1	768.62	22992	2	776.07	23541	1	787.02
22343	2	768.62	22993	3	776.07	23542	2	787.02
22344	3	768.62	22994	4	776.07	23543	3	787.02
22345	4	768.62	22995	5	776.07	23544	4	787.02
22346	5	768.62	22996	6	776.07	23545	5	787.02
22347	6	768.62	22997	7	776.07	23546	6	787.02
22348	7	768.62	22998	8	776.07	23547	7	787.02
22349	8	768.62	22999	9	776.07	23548	8	787.02
22350	9	768.62	23000	10	776.07	23549	9	787.02
22351	10	768.62	23001	11	776.07	23550	10	787.02

B-17

Node Layer Head (ft)			Node Layer Head (ft)			Node Layer Head (ft)		
23551	11	787.02	23799	6	788.7	23955	8	785.59
23552	1	786.62	23800	7	788.7	23956	9	785.59
23553	2	786.62	23801	8	788.7	23957	10	785.59
23554	3	786.62	23802	9	788.7	23958	11	785.59
23555	4	786.62	23803	10	788.7	23959	1	784.32
23556	5	786.62	23804	11	788.7	23960	2	784.32
23557	6	786.62	23805	1	785.62	23961	3	784.32
23558	7	786.62	23806	2	785.62	23962	4	784.32
23559	8	786.62	23807	3	785.62	23963	5	784.32
23560	9	786.62	23808	4	785.62	23964	6	784.32
23561	10	786.62	23809	5	785.62	23965	7	784.32
23562	11	786.62	23810	6	785.62	23966	8	784.32
23571	9	814.96	23811	7	785.62	23967	9	784.32
23572	10	814.96	23812	8	785.62	23968	10	784.32
23573	11	814.96	23813	9	785.62	23969	11	784.32
23582	9	814.01	23814	10	785.62	23970	1	784.16
23583	10	814.01	23815	11	785.62	23971	2	784.16
23584	11	814.01	23824	9	813.62	23972	3	784.16
23593	9	813.66	23825	10	813.62	23973	4	784.16
23594	10	813.66	23826	11	813.62	23974	5	784.16
23595	11	813.66	23926	1	785.91	23975	6	784.16
23604	9	812.24	23927	2	785.91	23976	7	784.16
23605	10	812.24	23928	3	785.91	23977	8	784.16
23606	11	812.24	23929	4	785.91	23978	9	784.16
23615	9	812.36	23930	5	785.91	23979	10	784.16
23616	10	812.36	23931	6	785.91	23980	11	784.16
23617	11	812.36	23932	7	785.91	23989	9	816.47
23626	9	811.28	23933	8	785.91	23990	10	816.47
23627	10	811.28	23934	9	785.91	23991	11	816.47
23628	11	811.28	23935	10	785.91	24091	1	786.58
23637	9	811.63	23936	11	785.91	24092	2	786.58
23638	10	811.63	23937	1	785.28	24093	3	786.58
23639	11	811.63	23938	2	785.28	24094	4	786.58
23783	1	787.75	23939	3	785.28	24095	5	786.58
23784	2	787.75	23940	4	785.28	24096	6	786.58
23785	3	787.75	23941	5	785.28	24097	7	786.58
23786	4	787.75	23942	6	785.28	24098	8	786.58
23787	5	787.75	23943	7	785.28	24099	9	786.58
23788	6	787.75	23944	8	785.28	24100	10	786.58
23789	7	787.75	23945	9	785.28	24101	11	786.58
23790	8	787.75	23946	10	785.28	24110	9	819.62
23791	9	787.75	23947	11	785.28	24111	10	819.62
23792	10	787.75	23948	1	785.59	24112	11	819.62
23793	11	787.75	23949	2	785.59	24212	1	787.03
23794	1	788.7	23950	3	785.59	24213	2	787.03
23795	2	788.7	23951	4	785.59	24214	3	787.03
23796	3	788.7	23952	5	785.59	24215	4	787.03
23797	4	788.7	23953	6	785.59	24216	5	787.03
23798	5	788.7	23954	7	785.59	24217	6	787.03

B-18

Node	Layer	Head (ft)	Node	Layer	Head (ft)	Node	Layer	Head (ft)
24218	7	787.03	24519	11	828.49			
24219	8	787.03	24528	9	827.36			
24220	9	787.03	24529	10	827.36			
24221	10	787.03	24530	11	827.36			
24222	11	787.03	24539	9	825.2			
24223	1	784.69	24540	10	825.2			
24224	2	784.69	24541	11	825.2			
24225	3	784.69	24550	9	821.99			
24226	4	784.69	24551	10	821.99			
24227	5	784.69	24552	11	821.99			
24228	6	784.69	24561	9	817.69			
24229	7	784.69	24562	10	817.69			
24230	8	784.69	24563	11	817.69			
24231	9	784.69	24572	9	812.5			
24232	10	784.69	24573	10	812.5			
24233	11	784.69	24574	11	812.5			
24242	9	823.29	24583	9	806.79			
24243	10	823.29	24584	10	806.79			
24244	11	823.29	24585	11	806.79			
24355	1	785.62	24594	9	801.02			
24356	2	785.62	24595	10	801.02			
24357	3	785.62	24596	11	801.02			
24358	4	785.62	24605	9	795.66			
24359	5	785.62	24606	10	795.66			
24360	6	785.62	24607	11	795.66			
24361	7	785.62	24616	9	791.03			
24362	8	785.62	24617	10	791.03			
24363	9	785.62	24618	11	791.03			
24364	10	785.62	24619	1	787.07			
24365	11	785.62	24620	2	787.07			
24374	9	826.16	24621	3	787.07			
24375	10	826.16	24622	4	787.07			
24376	11	826.16	24623	5	787.07			
24487	1	786.64	24624	6	787.07			
24488	2	786.64	24625	7	787.07			
24489	3	786.64	24626	8	787.07			
24490	4	786.64	24627	9	787.07			
24491	5	786.64	24628	10	787.07			
24492	6	786.64	24629	11	787.07			
24493	7	786.64						
24494	8	786.64						
24495	9	786.64						
24496	10	786.64						
24497	11	786.64						
24506	9	828.51						
24507	10	828.51						
24508	11	828.51						
24517	9	828.49						
24518	10	828.49						

APPENDIX C
INPUT DATA FILES FOR THE 2-D MODELS CALIBRATED

**CROSS SECTION 21-21
INPUT DATA SET**

1 WAG6 CROSS-SECTION 21-21 STEADY STATE CALIBRATION 111

3801	3600	0	0	0	1	0	1	200	10	0
1	0	0	100	1	0					
1.D-0	0.1D-0	1.0D4		1.0D6	0.0D0	3.D-0	3.D-0			
28.3168D3	2.4D11	29.2D00		0.0D00						
1.00D0	0.50D0	-0.020D0		0.10D0	0.50D0	-0.020D0	0.10D0			
1	1	1	1	1	1	1	0	0		

11
22
1.0D38
10 0 0 0 0 0 0 0 0 0 0
1
soil horizon A
0.0D0 0.0D0 .385 30.00 10.00 5.00
13
99999.000 1.00E-00 0.385
0.000 1.00E-00 0.385
-0.295 0.15E-00 0.354
-0.656 2.19E-02 0.343
-0.984 4.53E-03 0.343
-2.297 1.04E-03 0.341
-2.953 6.18E-04 0.340
-3.281 1.23E-04 0.339
-6.562 2.96E-05 0.337
-8.200 1.93E-05 0.334
-16.400 7.60E-06 0.307
-32.800 1.51E-06 0.284
-10000.000 6.60E-06 0.240
2
soil horizon B
0.0D0 0.0D0 .385 20.00 2.00 1.00
13
99999.000 1.00E-00 0.385
0.000 1.00E-00 0.385
-0.295 0.15E-00 0.354
-0.656 2.19E-02 0.343
-0.984 4.53E-03 0.343
-2.297 1.04E-03 0.341
-2.953 6.18E-04 0.340
-3.281 1.23E-04 0.339
-6.562 2.96E-05 0.337
-8.200 1.93E-05 0.334
-16.400 7.60E-06 0.307
-32.800 1.51E-06 0.284
-10000.000 6.60E-06 0.240
3
unsaturated soil and Molichucky top fractured bedrock
0.0D0 0.0D0 .285 0.08 0.05 0.002
5
99999.000 1.00E-00 0.285
0.000 1.00E-00 0.285
-1.969 1.23E-01 0.241
-6.562 2.96E-03 0.237
-10000.000 6.60E-07 0.140
4
water table zone

C-5

	0.000	0.000	.315	0.20	0.05	0.04
16						
99999.000	1.00E-00		0.315			
0.000	1.00E-00		0.315			
-0.197	0.53E-00		0.296			
-0.295	0.15E-00		0.284			
-0.328	8.36E-02		0.274			
-0.656	2.19E-02		0.273			
-0.984	4.53E-03		0.273			
-2.297	1.04E-03		0.271			
-2.645	7.60E-04		0.270			
-3.281	1.23E-04		0.269			
-6.562	2.96E-05		0.267			
-8.200	1.93E-05		0.254			
-16.400	7.60E-06		0.207			
-32.800	1.51E-06		0.184			
-100.000	6.60E-07		0.140			
-10000.000	6.60E-07		0.100			
5						
Lower permeable soil and Nolichucky weathered rock						
	0.000	0.000	.285	0.04	0.03	0.005
4						
99999.000	1.00E-00		0.285			
0.000	1.00E-00		0.285			
-30.000	1.00E-02		0.180			
-10000.000	6.60E-04		0.140			
6						
soil horizon C and Maryville weathered rock						
	0.000	0.000	.285	0.08	0.05	0.005
23						
99999.000	1.00E-00		0.285			
0.000	1.00E-00		0.285			
-0.098	1.00E-00		0.280			
-0.164	0.66E-00		0.270			
-0.197	0.53E-00		0.266			
-0.230	0.43E-00		0.262			
-0.262	0.31E-00		0.258			
-0.295	0.15E-00		0.254			
-0.328	8.36E-02		0.244			
-0.656	2.19E-02		0.243			
-0.984	4.53E-03		0.243			
-1.312	2.94E-03		0.242			
-1.640	1.76E-03		0.242			
-1.969	1.23E-03		0.241			
-2.297	1.04E-03		0.241			
-2.645	7.60E-04		0.240			
-2.953	6.18E-04		0.240			
-3.281	1.23E-04		0.239			
-6.562	2.96E-05		0.237			
-8.200	1.93E-05		0.234			
-16.400	7.60E-06		0.207			
-100.000	6.60E-07		0.140			
-10000.000	6.60E-07		0.140			
7						
trenches						
	0.000	0.000	0.300	0.80	0.20	0.00

4
 99999.000 1.00E-00 0.300
 0.000 1.00E-00 0.300
 -30.000 1.00E-03 0.240
 -10000.000 6.60E-04 0.200

8
 upslope soil horizon A
 0.000 0.000 .385 25.00 5.00 5.00

7
 99999.000 1.00E-00 0.385
 0.000 1.00E-00 0.385
 -0.295 0.15E-00 0.354
 -0.656 2.19E-02 0.343
 -0.984 4.53E-03 0.343
 -6.562 2.96E-05 0.337
 -10000.000 6.60E-06 0.240

9
 upslope soil horizon B
 0.000 0.000 .385 20.00 3.50 4.00

7
 99999.000 1.00E-00 0.385
 0.000 1.00E-00 0.385
 -0.295 0.15E-00 0.354
 -0.656 2.19E-02 0.343
 -0.984 4.53E-03 0.343
 -6.562 2.96E-05 0.337
 -10000.000 6.60E-06 0.240

10
 intermediate bedrock
 0.000 0.000 0.100 0.003 0.003 0.000

4
 99999.000 1.00E-00 0.100
 0.000 1.00E-00 0.100
 -30.000 1.00E-03 0.080
 -100.000 6.60E-04 0.060

NODAL POINT DEFINITIONS REMOVED TO REDUCE THE LENGTH OF THE FILE
 ELEMENT DEFINITIONS REMOVED TO REDUCE THE LENGTH OF THE FILE

0	0	0	0	0	0	0	21	1	2	180	179	3	2	0	0
0	0	0	0	0											
		0	756.8	1.0D99	756.8										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
17	18	19	20	21											
1	20	1	1	0											

0.000 -6.00D-04 1.0d99 -6.00D-04 NATURAL RAINFALL

0.000 0.00D-05 1.0d99 0.00D-05 UNDER CAPS NOT USED

0.000 -6.00D-04 1.0d99 -6.00D-04 OVER TRENCHES

42	63	84	105	126	147	168	189	210	231	252	273	294	315	336	357
378	399	420	441	462	483	504	525	546	567	588	609	630	651	672	693
714	735	756	777	798	819	840	861	882	903	924	945	966	987	1008	1029
1050	1071	1092	1113	1134	1155	1176	1197	1218	1239	1260	1281	1302	1323	1344	1365
1386	1407	1428	1449	1470	1491	1512	1533	1554	1575	1596	1617	1638	1659	1680	1701
1722	1743	1764	1785	1806	1827	1848	1869	1890	1911	1932	1953	1974	1995	2016	2037
2058	2079	2100	2121	2142	2163	2184	2205	2226	2247	2268	2289	2310	2331	2352	2373
2394	2415	2436	2457	2478	2499	2520	2541	2562	2583	2604	2625	2646	2667	2688	2709
2730	2751	2772	2793	2814	2835	2856	2877	2898	2919	2940	2961	2982	3003	3024	3045

3066 3087 3108 3129 3150 3171 3192 3213 3234 3255 3276 3297 3318 3339 3360 3381
3402 3423 3444 3465 3486 3507 3528 3549 3570 3591 3612 3633 3654 3675 3696 3717
3738 3759 3780 3801

1	0	0	1	0
2	0	0	1	0
3	0	0	1	0
4	0	0	1	0
5	0	0	1	0
6	0	0	1	0
7	0	0	1	0
8	0	0	1	0
9	0	0	1	0
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14	0	0	1	0
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37	0	0	1	0
38	0	0	1	0
39	0	0	1	0
40	0	0	3	0
41	0	0	3	0
42	0	0	3	0
43	0	0	3	0
44	0	0	3	0
45	0	0	3	0
46	0	0	3	0
47	0	0	3	0
48	0	0	3	0
49	0	0	3	0
50	0	0	3	0
51	0	0	1	0
52	0	0	1	0
53	0	0	1	0

C-8

54	0	0	1	0
55	0	0	1	0
56	0	0	1	0
57	0	0	1	0
58	0	0	1	0
59	0	0	1	0
60	0	0	1	0
61	0	0	1	0
62	0	0	1	0
63	0	0	1	0
64	0	0	1	0
65	0	0	3	0
66	0	0	3	0
67	0	0	3	0
68	0	0	3	0
69	0	0	3	0
70	0	0	3	0
71	0	0	3	0
72	0	0	3	0
73	0	0	3	0
74	0	0	3	0
75	0	0	3	0
76	0	0	1	0
77	0	0	1	0
78	0	0	1	0
79	0	0	1	0
80	0	0	1	0
81	0	0	1	0
82	0	0	1	0
83	0	0	1	0
84	0	0	1	0
85	0	0	1	0
86	0	0	3	0
87	0	0	3	0
88	0	0	3	0
89	0	0	3	0
90	0	0	1	0
91	0	0	1	0
92	0	0	1	0
93	0	0	1	0
94	0	0	1	0
95	0	0	1	0
96	0	0	1	0
97	0	0	1	0
98	0	0	1	0
99	0	0	1	0
100	0	0	1	0
101	0	0	1	0
102	0	0	1	0
103	0	0	1	0
104	0	0	1	0
105	0	0	1	0
106	0	0	1	0
107	0	0	1	0
108	0	0	1	0
109	0	0	1	0

C-9

110	0	0	1	0
111	0	0	1	0
112	0	0	1	0
113	0	0	1	0
114	0	0	1	0
115	0	0	1	0
116	0	0	1	0
117	0	0	1	0
118	0	0	1	0
119	0	0	1	0
120	0	0	1	0
121	0	0	1	0
122	0	0	1	0
123	0	0	1	0
124	0	0	1	0
125	0	0	1	0
126	0	0	1	0
127	0	0	1	0
128	0	0	1	0
129	0	0	1	0
130	0	0	1	0
131	0	0	1	0
132	0	0	1	0
133	0	0	1	0
134	0	0	1	0
135	0	0	1	0
136	0	0	1	0
137	0	0	1	0
138	0	0	1	0
139	0	0	1	0
140	0	0	1	0
141	0	0	1	0
142	0	0	1	0
143	0	0	1	0
144	0	0	1	0
145	0	0	1	0
146	0	0	1	0
147	0	0	1	0
148	0	0	1	0
149	0	0	1	0
150	0	0	1	0
151	0	0	1	0
152	0	0	1	0
153	0	0	1	0
154	0	0	1	0
155	0	0	1	0
156	0	0	1	0
157	0	0	1	0
158	0	0	1	0
159	0	0	1	0
160	0	0	1	0
161	0	0	1	0
162	0	0	1	0
163	0	0	1	0
164	0	0	1	0
165	0	0	1	0

C-10

166	0	0	1	0
167	0	0	1	0
168	0	0	1	0
169	0	0	1	0
170	0	0	1	0
171	0	0	1	0
172	0	0	1	0
173	0	0	1	0
174	0	0	1	0
175	0	0	1	0
176	0	0	1	0
177	0	0	1	0
178	0	0	1	0
179	0	0	1	0
180	0	0	1	0

1	178	1	2	1	1	1
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CROSS SECTION 22-22
INPUT DATA SET

1 SECTION 22 S.S. NO-FLOW UPSTREAM B.C. and DIRICHLET BOTTOM

6552	6220	0	0	0	1	0	1	150	50	0
1	0	0	100	1	1					
9.5D-3	0.2D-0			3.0D0		30.0D0		0.0D0	2.5D-0	2.5D-0
28.3168D3	2.4D11			29.2D00		0.0D00				
0.50D0	0.40D0		-0.020D0		0.04D0		0.40D0	-0.020D0		0.04D0
1	1	1	1	1	1	1	0	0		

55
22
1.0D38
10 0 0 0 0 0 0 0 0 0 0
1
soil horizon A

0.0D0	0.0D0	.385	30.00	10.00	5.00
-------	-------	------	-------	-------	------

13

99999.000	1.00E-00	0.385
0.000	1.00E-00	0.385
-0.295	0.15E-00	0.354
-0.656	2.19E-02	0.344
-0.984	4.53E-03	0.343
-2.297	1.04E-03	0.341
-2.953	6.18E-04	0.340
-3.281	1.23E-04	0.339
-6.562	2.96E-05	0.337
-8.200	1.93E-05	0.334
-16.400	7.60E-06	0.307
-32.800	1.51E-06	0.284
-10000.000	6.60E-06	0.240

2
soil horizon B

0.0D0	0.0D0	.385	20.00	2.00	1.00
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13

99999.000	1.00E-00	0.385
0.000	1.00E-00	0.385
-0.295	0.15E-00	0.354
-0.656	2.19E-02	0.344
-0.984	4.53E-03	0.343
-2.297	1.04E-03	0.341
-2.953	6.18E-04	0.340
-3.281	1.23E-04	0.339
-6.562	2.96E-05	0.337
-8.200	1.93E-05	0.334
-16.400	7.60E-06	0.307
-32.800	1.51E-06	0.284
-10000.000	6.60E-06	0.240

3
unsaturated soil and Molichucky top fractured bedrock

0.0D0	0.0D0	.285	0.08	0.05	0.002
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5

99999.000	1.00E-00	0.285
0.000	1.00E-00	0.285
-1.969	1.23E-01	0.241
-6.562	2.96E-03	0.237
-10000.000	6.60E-07	0.140

4
water table zone

	0.000	0.000	.315	0.25	0.05	0.04
16						
99999.000	1.00E-00	0.315				
0.000	1.00E-00	0.315				
-0.197	0.53E-00	0.296				
-0.295	0.15E-00	0.284				
-0.328	8.36E-02	0.274				
-0.656	2.19E-02	0.273				
-0.984	4.53E-03	0.273				
-2.297	1.04E-03	0.271				
-2.645	7.60E-04	0.270				
-3.281	1.23E-04	0.269				
-6.562	2.96E-05	0.267				
-8.200	1.93E-05	0.254				
-16.400	7.60E-06	0.207				
-32.800	1.51E-06	0.184				
-100.000	6.60E-07	0.140				
-10000.000	6.60E-07	0.100				

5

Lower permeable soil and Molichucky weathered rock

	0.000	0.000	.285	0.04	0.03	0.005
4						
99999.000	1.00E-00	0.285				
0.000	1.00E-00	0.285				
-30.000	1.00E-02	0.180				
-10000.000	6.60E-04	0.140				

6

Not Used: ditch no vertical flow, soil 10 at the bottom and downstream side

	0.000	0.000	.285	100.00	0.00	0.00
23						
99999.000	1.00E-00	0.285				
0.000	1.00E-00	0.285				
-0.098	1.00E-00	0.280				
-0.164	0.66E-00	0.270				
-0.197	0.53E-00	0.266				
-0.230	0.43E-00	0.262				
-0.262	0.31E-00	0.258				
-0.295	0.15E-00	0.254				
-0.328	8.36E-02	0.244				
-0.656	2.19E-02	0.2438				
-0.984	4.53E-03	0.2432				
-1.312	2.94E-03	0.2428				
-1.640	1.76E-03	0.2422				
-1.969	1.23E-03	0.2418				
-2.297	1.04E-03	0.2412				
-2.645	7.60E-04	0.2408				
-2.953	6.18E-04	0.2402				
-3.281	1.23E-04	0.239				
-6.562	2.96E-05	0.237				
-8.200	1.93E-05	0.234				
-16.400	7.60E-06	0.207				
-100.000	6.60E-07	0.140				
-10000.000	6.60E-07	0.140				

7

trenches

	0.000	0.000	0.300	0.10	0.05	0.00
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4
 99999.000 1.00E-00 0.300
 0.000 1.00E-00 0.300
 -30.000 1.00E-03 0.240
 -10000.000 6.60E-04 0.200

8
 upslope soil horizon A
 0.000 0.000 .385 25.00 5.00 5.00

12
 99999.000 1.00E-00 0.385
 0.000 1.00E-00 0.385
 -0.295 0.15E-00 0.354
 -0.656 2.19E-02 0.343
 -0.984 4.53E-03 0.342
 -6.562 2.96E-05 0.337
 -8.200 1.93E-05 0.334
 -16.400 7.60E-06 0.307
 -32.800 6.61E-06 0.284
 -62.800 5.51E-06 0.264
 -162.800 3.51E-06 0.254
 -10000.000 1.60E-06 0.240

9
 upslope soil horizon B
 0.000 0.000 .385 20.00 3.50 4.00

12
 99999.000 1.00E-00 0.385
 0.000 1.00E-00 0.385
 -0.295 0.15E-00 0.354
 -0.656 2.19E-02 0.343
 -0.984 4.53E-03 0.342
 -6.562 2.96E-05 0.337
 -8.200 1.93E-05 0.334
 -16.400 7.60E-06 0.307
 -32.800 6.61E-06 0.284
 -62.800 5.51E-06 0.264
 -162.800 3.51E-06 0.254
 -10000.000 6.60E-06 0.240

10
 intermediate bedrock
 0.000 0.000 0.100 0.006 0.006 0.000

4
 99999.000 1.00E-00 0.100
 0.000 1.00E-00 0.100
 -30.000 1.00E-03 0.080
 -100.000 6.60E-04 0.060

NODAL POINT DEFINITIONS REMOVED TO REDUCE THE LENGTH OF THE FILE
 ELEMENT DEFINITIONS REMOVED TO REDUCE THE LENGTH OF THE FILE

0 0 0 0 0 0 0 336 317 2 307 306 6 2 0 0
 0 0 0 0 0

0.0 752.5 9.9D99 752.5 BOTTOM NODES
 0.0 752.5 9.9D99 752.5
 0.0 752.5 9.9D99 752.5
 0.0 752.5 9.9D99 752.5
 0.0 752.5 9.9D99 752.5
 0.0 752.5 9.9D99 752.5
 0.0 752.5 9.9D99 752.5

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[illegible]

C-16

0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.5	9.9099	752.5
0.0	752.7	9.9099	752.7
0.0	752.9	9.9099	752.9
0.0	753.1	9.9099	753.1
0.0	753.3	9.9099	753.3
0.0	753.5	9.9099	753.5
0.0	753.7	9.9099	753.7
0.0	753.9	9.9099	753.9
0.0	754.0	9.9099	754.0
0.0	754.2	9.9099	754.2
0.0	754.4	9.9099	754.4
0.0	754.6	9.9099	754.6
0.0	754.8	9.9099	754.8
0.0	755.0	9.9099	755.0
0.0	755.2	9.9099	755.2
0.0	755.4	9.9099	755.4
0.0	755.6	9.9099	755.6
0.0	755.8	9.9099	755.8
0.0	756.0	9.9099	756.0
0.0	756.2	9.9099	756.2
0.0	756.4	9.9099	756.4
0.0	756.8	9.9099	756.8
0.0	757.0	9.9099	757.0
0.0	757.2	9.9099	757.2
0.0	757.4	9.9099	757.4
0.0	757.6	9.9099	757.6
0.0	757.8	9.9099	757.8
0.0	758.0	9.9099	758.0
0.0	758.2	9.9099	758.2
0.0	758.4	9.9099	758.4
0.0	758.6	9.9099	758.6
0.0	758.8	9.9099	758.8
0.0	759.0	9.9099	759.0
0.0	759.2	9.9099	759.2
0.0	759.4	9.9099	759.4
0.0	759.6	9.9099	759.6
0.0	759.8	9.9099	759.8
0.0	760.0	9.9099	760.0
0.0	760.2	9.9099	760.2
0.0	760.4	9.9099	760.4
0.0	760.6	9.9099	760.6
0.0	760.8	9.9099	760.8

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0.0	761.0	9.9D99	761.0
0.0	761.2	9.9D99	761.2
0.0	761.4	9.9D99	761.4
0.0	761.6	9.9D99	761.6
0.0	761.8	9.9D99	761.8
0.0	762.0	9.9D99	762.0
0.0	762.2	9.9D99	762.2
0.0	762.4	9.9D99	762.4
0.0	762.6	9.9D99	762.6
0.0	762.8	9.9D99	762.8
0.0	764.0	9.9D99	764.0
0.0	764.2	9.9D99	764.2
0.0	764.4	9.9D99	764.4
0.0	764.6	9.9D99	764.6
0.0	764.8	9.9D99	764.8
0.0	765.0	9.9D99	765.0
0.0	765.3	9.9D99	765.3
0.0	765.6	9.9D99	765.6
0.0	765.9	9.9D99	765.9
0.0	766.2	9.9D99	766.2
0.0	766.5	9.9D99	766.5
0.0	766.8	9.9D99	766.8
0.0	767.1	9.9D99	767.1
0.0	767.4	9.9D99	767.4
0.0	767.7	9.9D99	767.7
0.0	768.0	9.9D99	768.0
0.0	768.3	9.9D99	768.3
0.0	768.6	9.9D99	768.6
0.0	768.9	9.9D99	768.9
0.0	769.2	9.9D99	769.2
0.0	769.4	9.9D99	769.4
0.0	769.6	9.9D99	769.6
0.0	769.8	9.9D99	769.8
0.0	770.0	9.9D99	770.0
0.0	770.2	9.9D99	770.2
0.0	770.4	9.9D99	770.4
0.0	770.8	9.9D99	770.8
0.0	771.0	9.9D99	771.0
0.0	771.2	9.9D99	771.2
0.0	771.4	9.9D99	771.4
0.0	771.6	9.9D99	771.6
0.0	771.8	9.9D99	771.8
0.0	772.0	9.9D99	772.0
0.0	772.4	9.9D99	772.4
0.0	772.6	9.9D99	772.6
0.0	772.8	9.9D99	772.8
0.0	773.0	9.9D99	773.0
0.0	773.1	9.9D99	773.1
0.0	773.2	9.9D99	773.2
0.0	773.3	9.9D99	773.3
0.0	773.4	9.9D99	773.4
0.0	773.6	9.9D99	773.6
0.0	773.8	9.9D99	773.8
0.0	774.0	9.9D99	774.0
0.0	774.1	9.9D99	774.1
0.0	774.2	9.9D99	774.2

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0.0	774.3	9.9D99	774.3
0.0	774.5	9.9D99	774.5
0.0	774.8	9.9D99	774.8
0.0	774.9	9.9D99	774.9
0.0	775.0	9.9D99	775.0
0.0	775.1	9.9D99	775.1
0.0	775.2	9.9D99	775.2
0.0	775.3	9.9D99	775.3
0.0	775.4	9.9D99	775.4
0.0	775.5	9.9D99	775.5
0.0	775.6	9.9D99	775.6
0.0	775.7	9.9D99	775.7
0.0	775.7	9.9D99	775.7
0.0	775.8	9.9D99	775.8
0.0	775.9	9.9D99	775.9
0.0	776.0	9.9D99	776.0
0.0	776.1	9.9D99	776.1
0.0	776.2	9.9D99	776.2
0.0	776.3	9.9D99	776.3
0.0	776.3	9.9D99	776.3
0.0	776.4	9.9D99	776.4
0.0	776.4	9.9D99	776.4
0.0	777.0	9.9D99	777.0
0.0	777.6	9.9D99	777.6
0.0	778.3	9.9D99	778.3
0.0	778.9	9.9D99	778.9
0.0	779.5	9.9D99	779.5
0.0	780.1	9.9D99	780.1
0.0	780.4	9.9D99	780.4
0.0	780.5	9.9D99	780.5
0.0	780.6	9.9D99	780.6
0.0	780.7	9.9D99	780.7
0.0	780.9	9.9D99	780.9
0.0	781.2	9.9D99	781.2
0.0	781.5	9.9D99	781.5
0.0	782.1	9.9D99	782.1
0.0	782.7	9.9D99	782.7
0.0	783.4	9.9D99	783.4
0.0	784.0	9.9D99	784.0
0.0	784.6	9.9D99	784.6
0.0	785.2	9.9D99	785.2
0.0	785.8	9.9D99	785.8
0.0	786.1	9.9D99	786.1
0.0	786.8	9.9D99	786.8
0.0	787.1	9.9D99	787.1
0.0	787.5	9.9D99	787.5
0.0	788.2	9.9D99	788.2
0.0	788.8	9.9D99	788.8
0.0	789.4	9.9D99	789.4
0.0	790.1	9.9D99	790.1
0.0	790.7	9.9D99	790.7
0.0	791.3	9.9D99	791.3
0.0	791.9	9.9D99	791.9
0.0	792.5	9.9D99	792.5
0.0	793.2	9.9D99	793.2
0.0	793.8	9.9D99	793.8

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0.0	794.4	9.9D99	794.4
0.0	795.0	9.9D99	795.0
0.0	795.7	9.9D99	795.7
0.0	796.3	9.9D99	796.3
0.0	796.9	9.9D99	796.9
0.0	797.5	9.9D99	797.5
0.0	798.1	9.9D99	798.1
0.0	798.8	9.9D99	798.8
0.0	799.4	9.9D99	799.4
0.0	800.0	9.9D99	800.0
0.0	800.3	9.9D99	800.3
0.0	800.6	9.9D99	800.6
0.0	800.7	9.9D99	800.7
0.0	800.9	9.9D99	800.9
0.0	801.0	9.9D99	801.0
0.0	801.1	9.9D99	801.1
0.0	801.2	9.9D99	801.2
0.0	801.3	9.9D99	801.3
0.0	801.7	9.9D99	801.7
0.0	802.0	9.9D99	802.0
0.0	802.3	9.9D99	802.3
0.0	802.6	9.9D99	802.6
0.0	802.9	9.9D99	802.9
0.0	803.2	9.9D99	803.2
0.0	803.5	9.9D99	803.5
0.0	803.8	9.9D99	803.8
0.0	804.1	9.9D99	804.1
0.0	804.5	9.9D99	804.5
0.0	804.8	9.9D99	804.8
0.0	805.1	9.9D99	805.1
0.0	805.2	9.9D99	805.2
0.0	805.4	9.9D99	805.4
0.0	805.4	9.9D99	805.4
0.0	805.5	9.9D99	805.5
0.0	805.6	9.9D99	805.6
0.0	805.6	9.9D99	805.6
0.0	805.7	9.9D99	805.7
0.0	805.8	9.9D99	805.8
0.0	805.8	9.9D99	805.8
0.0	806.0	9.9D99	806.0
0.0	806.2	9.9D99	806.2
0.0	806.5	9.9D99	806.5
0.0	806.8	9.9D99	806.8
0.0	807.1	9.9D99	807.1
0.0	807.4	9.9D99	807.4
0.0	807.7	9.9D99	807.7
0.0	808.0	9.9D99	808.0
0.0	808.3	9.9D99	808.3
0.0	808.7	9.9D99	808.7
0.0	809.0	9.9D99	809.0
0.0	809.3	9.9D99	809.3
0.0	809.6	9.9D99	809.6
0.0	809.9	9.9D99	809.9
0.0	810.2	9.9D99	810.2
0.0	810.5	9.9D99	810.5
0.0	810.8	9.9D99	810.8

C-20

0.0	811.1	9.9D99	811.1
0.0	811.4	9.9D99	811.4
0.0	811.8	9.9D99	811.8
0.0	812.1	9.9D99	812.1
0.0	812.3	9.9D99	812.3
0.0	812.4	9.9D99	812.4
0.0	812.5	9.9D99	812.5
0.0	812.6	9.9D99	812.6
0.0	812.6	9.9D99	812.6
0.0	812.7	9.9D99	812.7
0.0	812.8	9.9D99	812.8
0.0	812.9	9.9D99	812.9
0.0	813.2	9.9D99	813.2
0.0	813.4	9.9D99	813.4
0.0	813.5	9.9D99	813.5
0.0	813.7	9.9D99	813.7
0.0	813.7	9.9D99	813.7
0.0	813.8	9.9D99	813.8
0.0	813.8	9.9D99	813.8
0.0	813.9	9.9D99	813.9
0.0	814.2	9.9D99	814.2
0.0	814.3	9.9D99	814.3
0.0	814.5	9.9D99	814.5
0.0	814.6	9.9D99	814.6
0.0	814.8	9.9D99	814.8
0.0	746.3	9.9D99	746.3
0.0	758.3	9.9D99	758.3
0.0	758.0	9.9D99	758.0
0.0	757.7	9.9D99	757.7
0.0	758.4	9.9D99	758.4

DOWNSTREAM BOUNDARY
4 MIDDLE STREAM WATER LEVEL

1	22	43	64	85	106	127	148	169	190	211	232	253	274	295	316
337	358	379	400	421	442	463	484	505	526	547	568	589	610	631	652
673	694	715	736	757	778	799	820	841	862	883	904	925	946	967	988
1009	1030	1051	1072	1093	1114	1135	1156	1177	1198	1219	1240	1261	1282	1303	1324
1345	1366	1387	1408	1429	1450	1471	1492	1513	1534	1555	1576	1597	1618	1639	1660
1681	1702	1723	1744	1765	1786	1807	1828	1849	1870	1891	1912	1933	1954	1975	1996
2017	2038	2059	2080	2101	2122	2143	2164	2185	2206	2227	2248	2269	2290	2311	2332
2353	2374	2395	2416	2437	2458	2479	2500	2521	2542	2563	2584	2605	2626	2647	2668
2689	2710	2731	2752	2773	2794	2815	2836	2857	2878	2899	2920	2941	2962	2983	3004
3025	3046	3067	3088	3109	3130	3151	3172	3193	3214	3235	3256	3277	3298	3319	3340
3361	3382	3403	3424	3445	3466	3487	3508	3529	3550	3571	3592	3613	3634	3655	3676
3697	3718	3739	3760	3781	3802	3823	3844	3865	3886	3907	3928	3949	3970	3991	4012
4033	4054	4075	4096	4117	4138	4159	4180	4201	4222	4243	4264	4285	4306	4327	4348
4369	4390	4411	4432	4453	4474	4495	4516	4537	4558	4579	4600	4621	4642	4663	4684
4705	4726	4747	4768	4789	4810	4831	4852	4873	4894	4915	4936	4957	4978	4999	5020
5041	5062	5083	5104	5125	5146	5167	5188	5209	5230	5251	5272	5293	5314	5335	5356
5377	5398	5419	5440	5461	5482	5503	5524	5545	5566	5587	5608	5629	5650	5671	5692
5713	5734	5755	5776	5797	5818	5839	5860	5881	5902	5923	5944	5965	5986	6007	6028
6049	6070	6091	6112	6133	6154	6175	6196	6217	6238	6259	6280	6301	6322	6343	6364
6385	6406	6427	6448	6469	6490	6511	6532	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18	19	20	21	1512	1533	1554	1575
1	311	1	1	1											
313	19	1	313	0											
333	3	1	314	1											

0.000 -7.00D-04 1.0d99 -7.00D-04 NATURAL RAINFALL over Maryville

0.000	-1.000-06	1.0d99	-1.000-06	UNDER CAPS
0.000	-7.000-04	1.0d99	-7.000-04	OVER TRENCHES
0.000	-7.000-04	1.0d99	-7.000-04	NATURAL RAINFALL over Nolichucky
0.000	-3.000-04	1.0d99	-3.000-04	NATURAL RAINFALL over Maryville, northern, eastwa
0.000	-3.500-03	2.0d99	-3.500-03	OVER TRENCHES + LATERAL INPUT

42	63	84	105	126	147	168	189	210	231	252	273	294	315	336	357
378	399	420	441	462	483	504	525	546	567	588	609	630	651	672	693
714	735	756	777	798	819	840	861	882	903	924	945	966	987	1008	1029
1050	1071	1092	1113	1134	1155	1176	1197	1218	1239	1260	1281	1302	1323	1344	1365
1386	1407	1428	1449	1470	1491	1512	1533	1554	1575	1596	1617	1638	1659	1680	1701
1722	1743	1764	1785	1806	1827	1848	1869	1890	1911	1932	1953	1974	1995	2016	2037
2058	2079	2100	2121	2142	2163	2184	2205	2226	2247	2268	2289	2310	2331	2352	2373
2394	2415	2436	2457	2478	2499	2520	2541	2562	2583	2604	2625	2646	2667	2688	2709
2730	2751	2772	2793	2814	2835	2856	2877	2898	2919	2940	2961	2982	3003	3024	3045
3066	3087	3108	3129	3150	3171	3192	3213	3234	3255	3276	3297	3318	3339	3360	3381
3402	3423	3444	3465	3487	3507	3528	3549	3570	3591	3612	3633	3654	3675	3696	3717
3738	3759	3780	3801	3822	3843	3864	3885	3906	3927	3948	3969	3990	4011	4032	4053
4074	4095	4116	4137	4158	4179	4200	4221	4242	4263	4284	4305	4326	4347	4368	4389
4410	4431	4452	4473	4494	4515	4536	4557	4578	4599	4620	4641	4662	4683	4704	4725
4746	4767	4788	4809	4830	4851	4872	4893	4914	4935	4956	4977	4998	5019	5040	5061
5082	5103	5124	5145	5166	5187	5208	5229	5250	5271	5292	5313	5334	5355	5376	5397
5418	5439	5460	5481	5502	5523	5544	5565	5586	5607	5628	5649	5670	5691	5712	5733
5754	5775	5796	5817	5838	5859	5880	5901	5922	5943	5964	5985	6006	6027	6048	6069
6090	6111	6132	6153	6174	6195	6216	6237	6258	6279	6300	6321	6342	6363	6384	6405
6426	6447	6468	6489	6510	6531	6552									

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C-22

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87	0	0	4	0

C-23

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89	0	0	4	0
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139	0	0	3	0
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141	0	0	3	0
142	0	0	2	0
143	0	0	2	0

C-24

144	0	0	2	0
145	0	0	2	0
146	0	0	4	0
147	0	0	4	0
148	0	0	4	0
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150	0	0	4	0
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C-25

200	0	0	6	0
201	0	0	1	0
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204	0	0	1	0
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250	0	0	5	0
251	0	0	5	0
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253	0	0	5	0
254	0	0	5	0
255	0	0	5	0

C-26

256	0	0	5	0
257	0	0	5	0
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260	0	0	5	0
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302	0	0	1	0
303	0	0	1	0
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305	0	0	1	0
306	0	0	1	0
307	0	0	1	0

1	305	1	2	1
---	-----	---	---	---

**CROSS SECTION 23-23
INPUT DATA SET**

1 WAG6 CROSS-SECTION 23A						STEADY STATE CALIBRATION				
1974	1860	0	0	0	1	0	1	100	50	0
1	0	0	100	1	0					
1.0-0	0.1D-0			1.0D4		1.0D6	0.0D0	1.0D-0	1.0D-0	
28.3168D3	2.4D11			29.2D00		0.0D00				
1.00D0	0.50D0	-0.020D0				0.01D0	0.50D0	-0.020D0	0.10D0	
1	1	1	1	1	1	1	0	0		
55										
22										
1.0D38										
10	0	0	0	0	0	0	0	0	0	0
1										
soil horizon A										
	0.0D0	0.0D0		0.385		30.00	6.00	0.0		
8										
	99999.000	1.00E-00		0.385						
	0.000	1.00E-00		0.385						
	-0.295	0.16E-00		0.360						
	-0.984	4.53E-03		0.345						
	-2.645	7.60E-04		0.340						
	-8.200	1.93E-05		0.334						
	-100.000	6.60E-07		0.240						
	-100000.000	6.60E-07		0.240						
2										
soil horizon B										
	0.0D0	0.0D0		0.385		20.00	4.00	0.00		
8										
	99999.000	1.00E-00		0.385						
	0.000	1.00E-00		0.385						
	-0.295	0.16E-00		0.360						
	-0.984	4.53E-03		0.345						
	-2.645	7.60E-04		0.340						
	-8.200	1.93E-05		0.334						
	-100.000	6.60E-07		0.240						
	-100000.000	6.60E-07		0.240						
3										
soil horizon C and Maryville weathered rock										
	0.0D0	0.0D0		0.285		0.08	0.05	0.02		
3										
	99999.000	1.00E-00		0.285						
	-0.000	1.00E-00		0.285						
	-100000.000	6.60E-07		0.140						
4										
water table zone										
	0.0D0	0.0D0		0.315		0.40	1.00	0.40		
3										
	99999.000	1.00E-00		0.315						
	0.000	1.00E-00		0.315						
	-100000.000	6.60E-07		0.140						
5										
Lower permeable soil and Nolichucky weathered rock										
	0.0D0	0.0D0		0.285		0.04	0.12	0.01		
8										
	99999.000	1.00E-00		0.285						
	-0.000	1.00E-00		0.285						
	-0.295	0.15E-00		0.254						

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-2.297 1.04E-03 0.241
 -2.645 7.60E-04 0.240
 -8.200 1.93E-05 0.234
 -100.000 6.60E-07 0.140
 -100000.000 6.60E-07 0.140

6

Compacted cap materials

0.000 0.000 0.295 4.00 2.50 0.00

3

99999.000 1.00E-00 0.295
 0.000 1.00E-00 0.295
 -100.000 6.60E-07 0.140

7

trenches

0.000 0.000 0.300 0.40 0.20 0.05

4

99999.000 1.00E-00 0.300
 -0.000 1.00E-00 0.300
 -100.000 6.60E-07 0.140
 -100000.000 6.60E-07 0.140

8

Fractured Maryville rock

0.000 0.000 0.285 0.02 0.01 0.003

3

99999.000 1.00E-00 0.285
 -0.000 1.00E-00 0.285
 -100.000 6.60E-07 0.140

9

Fractured Molichucky rock

0.000 0.000 0.100 0.05 0.03 0.000

3

99999.000 1.00E-00 0.100
 0.000 1.00E-00 0.100
 -100.000 1.00E-10 0.001

10

INTERMEDIATE BEDROCK

0.000 0.000 0.100 0.01 0.01 0.002

3

99999.000 1.00E-00 0.100
 0.000 1.00E-00 0.100
 -100.000 1.00E-10 0.001

MODAL POINT DEFINITIONS REMOVED TO REDUCE THE LENGTH OF THE FILE

ELEMENT DEFINITIONS REMOVED TO REDUCE THE LENGTH OF THE FILE

0	0	0	0	0	0	0	42	2	2	92	91	3	2	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			792.3	9.9D09	792.3										
			766.8	9.9D09	766.8										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
17	18	19	20	21	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
1965	1966	1967	1968	1969	1970	1971	1972	1973	1974						
1	20	1	1	0											
22	20	1	2	0											

0.000 -2.00D-03 9.9D09 -2.00D-03 NATURAL RAINFALL
 0.000 -2.00D-03 9.9D09 -2.00D-03 UNDER CAPS
 0.000 -2.00D-03 9.9D09 -2.00D-03 OVER TRENCHES

42	63	84	105	126	147	168	189	210	231	252	273	294	315	336	357
378	399	420	441	462	483	504	525	546	567	588	609	630	651	672	693
714	735	756	777	798	819	840	861	882	903	924	945	966	987	1008	1029
1050	1071	1092	1113	1134	1155	1176	1197	1218	1239	1260	1281	1302	1323	1344	1365
1386	1407	1428	1449	1470	1491	1512	1533	1554	1575	1596	1617	1638	1659	1680	1701
1722	1743	1764	1785	1806	1827	1848	1869	1890	1911	1932	1953				
1	0	0	1	0											
2	0	0	1	0											
3	0	0	1	0											
4	0	0	1	0											
5	0	0	1	0											
6	0	0	1	0											
7	0	0	1	0											
8	0	0	1	0											
9	0	0	1	0											
10	0	0	1	0											
11	0	0	1	0											
12	0	0	1	0											
13	0	0	2	0											
14	0	0	2	0											
15	0	0	2	0											
16	0	0	2	0											
17	0	0	2	0											
18	0	0	2	0											
19	0	0	2	0											
20	0	0	2	0											
21	0	0	2	0											
22	0	0	2	0											
23	0	0	2	0											
24	0	0	2	0											
25	0	0	2	0											
26	0	0	2	0											
27	0	0	2	0											
28	0	0	2	0											
29	0	0	2	0											
30	0	0	2	0											
31	0	0	2	0											
32	0	0	2	0											
33	0	0	2	0											
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36	0	0	2	0											
37	0	0	2	0											
38	0	0	2	0											
39	0	0	2	0											
40	0	0	3	0											
41	0	0	3	0											
42	0	0	3	0											

C-31

51	0	0	2	0
52	0	0	2	0
53	0	0	2	0
54	0	0	2	0
55	0	0	2	0
56	0	0	2	0
57	0	0	2	0
58	0	0	2	0
59	0	0	2	0
60	0	0	2	0
61	0	0	2	0
62	0	0	2	0
63	0	0	2	0
64	0	0	2	0
65	0	0	2	0
66	0	0	2	0
67	0	0	2	0
68	0	0	2	0
69	0	0	1	0
70	0	0	1	0
71	0	0	1	0
72	0	0	1	0
73	0	0	1	0
74	0	0	1	0
75	0	0	1	0
76	0	0	1	0
77	0	0	1	0
78	0	0	1	0
79	0	0	1	0
80	0	0	1	0
81	0	0	1	0
82	0	0	1	0
83	0	0	1	0
84	0	0	1	0
85	0	0	1	0
86	0	0	1	0
87	0	0	1	0
88	0	0	1	0
89	0	0	1	0
90	0	0	1	0
91	0	0	1	0
92	0	0	1	0

1 90 1 2 1 1 1

**CROSS SECTION 24-24
INPUT DATA SET**

```

1 WAG6 CROSS-SECTION 24          STEADY STATE CALIBRATION          111
1995 1880    0    0    0    1    0    1 300 50 0
    0    0    0 100    0    0
    1.D-0    0.1D-0    1.0D4    1.0D6    0.0D0    2.D-0    2.D-0
28.3168D3 2.231D10 218.0D00    0.0D00
    1.00D0    0.30D0 -0.02D0    0.04D0    0.30D0 -0.02D0    0.04D0
    1    1    1    1    1    1    1    0    0
11
22
    1.0D38
10 0 0 0 0 0 0 0 0 0
1
soil horizon A
    0.0D0    0.0D0    0.385    3.00    1.00    0.0
8
99999.000 1.00E-00 0.385
    0.000 1.00E-00 0.385
    -0.295 0.16E-00 0.360
    -0.984 4.53E-03 0.345
    -2.645 7.60E-04 0.340
    -8.200 1.93E-05 0.334
    -100.000 6.60E-07 0.240
-100000.000 6.60E-07 0.240
2
soil horizon B
    0.0D0    0.0D0    0.385    2.00    1.00    0.0
8
99999.000 1.00E-00 0.385
    0.000 1.00E-00 0.385
    -0.295 0.15E-00 0.354
    -2.297 1.04E-03 0.341
    -2.645 7.60E-04 0.340
    -8.200 1.93E-05 0.334
    -100.000 6.60E-07 0.240
-100000.000 6.60E-07 0.240
3
soil horizon C and Maryville weathered rock
    0.0D0    0.0D0    0.285    0.20    0.01    0.04
8
99999.000 1.00E-00 0.285
    -0.000 1.00E-00 0.285
    -0.295 0.15E-00 0.254
    -2.297 1.04E-03 0.241
    -2.645 7.60E-04 0.240
    -8.200 1.93E-05 0.234
    -100.000 6.60E-07 0.140
-100000.000 6.60E-07 0.140
4
water table zone
    0.0D0    0.0D0    .315    0.40    0.05    0.04
12
99999.000 1.00E-00 0.315
    0.000 1.00E-00 0.315
    -0.295 0.15E-00 0.284
    -0.656 2.19E-02 0.273
    -0.984 4.53E-03 0.273

```


C-34

-2.645	7.60E-04	0.270
-3.281	1.23E-04	0.269
-6.562	2.96E-05	0.267
-16.400	7.60E-06	0.207
-32.800	1.51E-06	0.184
-100.000	6.60E-07	0.140
-10000.000	6.60E-07	0.100

5

Lower permeable soil and Molechucky weathered rock

0.000	0.000	0.285	0.04	0.12	0.01
-------	-------	-------	------	------	------

8

99999.000	1.00E-00	0.285
-0.000	1.00E-00	0.285
-0.295	0.15E-00	0.254
-2.297	1.04E-03	0.241
-2.645	7.60E-04	0.240
-8.200	1.93E-05	0.234
-100.000	6.60E-07	0.140
-100000.000	6.60E-07	0.140

6

unsaturated soil with mostly vertical flow

0.000	0.000	.285	0.00	0.05	0.00
-------	-------	------	------	------	------

5

99999.000	1.00E-00	0.285
0.000	1.00E-00	0.285
-33.800	1.51E-06	0.184
-100.000	6.60E-07	0.140
-10000.000	6.60E-07	0.140

7

trenches

0.000	0.000	0.300	0.40	0.20	0.05
-------	-------	-------	------	------	------

8

99999.000	1.00E-00	0.300
-0.000	1.00E-00	0.300
-0.295	0.15E-00	0.254
-2.297	1.04E-03	0.241
-2.645	7.60E-04	0.240
-8.200	1.93E-05	0.234
-100.000	6.60E-07	0.140
-100000.000	6.60E-07	0.140

8

Fractured Maryville rock

0.000	0.000	0.285	0.02	0.01	0.003
-------	-------	-------	------	------	-------

3

99999.000	1.00E-00	0.285
-0.000	1.00E-00	0.285
-100.000	6.60E-07	0.140

9

Fractured Molechucky rock

0.000	0.000	0.100	0.05	0.03	0.000
-------	-------	-------	------	------	-------

3

99999.000	1.00E-00	0.100
0.000	1.00E-00	0.100
-100.000	1.00E-10	0.001

10

intermediate bedrock

C-35

	0.000	0.000	0.100	0.01	0.01	0.002												
--	-------	-------	-------	------	------	-------	--	--	--	--	--	--	--	--	--	--	--	--

3

99999.000	1.00E-00	0.100												
0.000	1.00E-00	0.100												
-100.000	1.00E-10	0.001												

NODAL POINT DEFINITIONS REMOVED TO REDUCE THE LENGTH OF THE FILE

ELEMENT DEFINITIONS REMOVED TO REDUCE THE LENGTH OF THE FILE

0	0	0	0	0	0	0	42	2	2	93	92	2	2	0	0
0	0	0	0	0											
0	795.8	9.9D99	795.8												
0	754.0	9.9D99	754.0												

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
17	18	19	20	21	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
1986	1987	1988	1989	1990	1991	1992	1993	1994	1995						
1	20	1	1	0											
22	20	1	2	0											

0.000	-9.00D-04	9.9D99	-9.00D-4	NATURAL RAINFALL												
0.000	0.00D-00	9.9D99	0.00D-0	UNDER CAPS												

42	63	84	105	126	147	168	189	210	231	252	273	294	315	336	357
378	399	420	441	462	483	504	525	546	567	588	609	630	651	672	693
714	735	756	777	798	819	840	861	882	903	924	945	966	987	1008	1029
1050	1071	1092	1113	1134	1155	1176	1197	1218	1239	1260	1281	1302	1323	1344	1365
1386	1407	1428	1449	1470	1491	1512	1533	1554	1575	1596	1617	1638	1659	1680	1701
1722	1743	1764	1785	1806	1827	1848	1869	1890	1911	1932	1953	1974			

1	0	0	2	0											
2	0	0	2	0											
3	0	0	2	0											
4	0	0	2	0											
5	0	0	2	0											
6	0	0	2	0											
7	0	0	2	0											
8	0	0	2	0											
9	0	0	2	0											
10	0	0	2	0											
11	0	0	2	0											
12	0	0	2	0											
13	0	0	2	0											
14	0	0	2	0											
15	0	0	2	0											
16	0	0	2	0											
17	0	0	2	0											
18	0	0	2	0											
19	0	0	2	0											
20	0	0	2	0											
21	0	0	2	0											
22	0	0	2	0											
23	0	0	2	0											
24	0	0	2	0											
25	0	0	2	0											
26	0	0	2	0											
27	0	0	2	0											
28	0	0	2	0											
29	0	0	2	0											
30	0	0	1	0											
31	0	0	1	0											

C-36

32	0	0	1	0
33	0	0	1	0
34	0	0	1	0
35	0	0	1	0
36	0	0	1	0
37	0	0	1	0
38	0	0	1	0
39	0	0	1	0
40	0	0	1	0
41	0	0	1	0
42	0	0	1	0
43	0	0	1	0
44	0	0	1	0
45	0	0	1	0
46	0	0	1	0
47	0	0	1	0
48	0	0	1	0
49	0	0	1	0
50	0	0	1	0
51	0	0	1	0
52	0	0	1	0
53	0	0	1	0
54	0	0	1	0
55	0	0	1	0
56	0	0	1	0
57	0	0	1	0
58	0	0	1	0
59	0	0	1	0
60	0	0	1	0
61	0	0	1	0
62	0	0	1	0
63	0	0	1	0
64	0	0	1	0
65	0	0	1	0
66	0	0	1	0
67	0	0	1	0
68	0	0	1	0
69	0	0	1	0
70	0	0	1	0
71	0	0	1	0
72	0	0	1	0
73	0	0	1	0
74	0	0	1	0
75	0	0	1	0
76	0	0	1	0
77	0	0	1	0
78	0	0	1	0
79	0	0	1	0
80	0	0	1	0
81	0	0	1	0
82	0	0	1	0
83	0	0	1	0
84	0	0	1	0
85	0	0	1	0
86	0	0	1	0
87	0	0	1	0

C-37

88	0	0	0	1	0
89	0	0	0	1	0
90	0	0	0	1	0
91	0	0	0	1	0
92	0	0	0	1	0
93	0	0	0	1	0
1	91	1	2	1	1
					.

**CROSS SECTION 25-25
INPUT DATA SET**

111

1 WAG6 CROSS-SECTION 25						STEADY STATE CALIBRATION				
1197	1120	0	0	0	1	0	1	300	50	0
1	0	0	100	1	0					
1.D-0	0.1D-0	1.0D4	1.0D6	0.0D0	2.0D-0	2.0D-0				
28.3168D3	2.4D11	29.2D00	0.0D00							
1.0D0	0.25D0	-0.01D0	0.01D0	1.0D0	0.00D0	1.0D0				
1	1	1	1	1	1	1	0	0		

55
22
1.0D38
10 0 0 0 0 0 0 0 0 0 0
1
soil horizon A
0.0D0 0.0D0 0.385 20.00 5.00 0.0
8
99999.000 1.00E-00 0.385
0.000 1.00E-00 0.385
-0.295 0.16E-00 0.360
-0.984 4.53E-03 0.345
-2.645 7.60E-04 0.340
-8.200 1.93E-05 0.334
-100.000 6.60E-07 0.240
-100000.000 6.60E-07 0.240
2
soil horizon B
0.0D0 0.0D0 0.385 20.00 2.00 0.0
8
99999.000 1.00E-00 0.385
0.000 1.00E-00 0.385
-0.295 0.15E-00 0.354
-2.297 1.04E-03 0.341
-2.645 7.60E-04 0.340
-8.200 1.93E-05 0.334
-100.000 6.60E-07 0.240
-100000.000 6.60E-07 0.240
3
soil horizon C and Maryville weathered rock
0.0D0 0.0D0 0.285 0.20 0.01 0.04
8
99999.000 1.00E-00 0.285
-0.000 1.00E-00 0.285
-0.295 0.15E-00 0.254
-2.297 1.04E-03 0.241
-2.645 7.60E-04 0.240
-8.200 1.93E-05 0.234
-100.000 6.60E-07 0.140
-100000.000 6.60E-07 0.140
4
water table zone
0.0D0 0.0D0 .315 0.30 0.05 0.04
12
99999.000 1.00E-00 0.315
0.000 1.00E-00 0.315
-0.295 0.15E-00 0.284
-0.656 2.19E-02 0.273
-0.984 4.53E-03 0.273

-2.645	7.60E-04	0.270
-3.281	1.23E-04	0.269
-6.562	2.96E-05	0.267
-16.400	7.60E-06	0.207
-32.800	1.51E-06	0.184
-100.000	6.60E-07	0.140
-10000.000	6.60E-07	0.100

5

Lower permeable soil and Molichucky weathered rock

0.000	0.000	0.285	0.04	0.12	0.01
-------	-------	-------	------	------	------

8

99999.000	1.00E-00	0.285
-0.000	1.00E-00	0.285
-0.295	0.15E-00	0.254
-2.297	1.04E-03	0.241
-2.645	7.60E-04	0.240
-8.200	1.93E-05	0.234
-100.000	6.60E-07	0.140
-100000.000	6.60E-07	0.140

6

unsaturated soil with mostly vertical flow

0.000	0.000	.285	0.00	0.05	0.00
-------	-------	------	------	------	------

5

99999.000	1.00E-00	0.285
0.000	1.00E-00	0.285
-33.800	1.51E-06	0.184
-100.000	6.60E-07	0.140
-10000.000	6.60E-07	0.140

7

trenches

0.000	0.000	0.300	0.40	0.20	0.05
-------	-------	-------	------	------	------

8

99999.000	1.00E-00	0.300
-0.000	1.00E-00	0.300
-0.295	0.15E-00	0.254
-2.297	1.04E-03	0.241
-2.645	7.60E-04	0.240
-8.200	1.93E-05	0.234
-100.000	6.60E-07	0.140
-100000.000	6.60E-07	0.140

8

Fractured Maryville rock

0.000	0.000	0.285	0.02	0.01	0.003
-------	-------	-------	------	------	-------

3

99999.000	1.00E-00	0.285
-0.000	1.00E-00	0.285
-100.000	6.60E-07	0.140

9

Fractured Molichucky rock

0.000	0.000	0.100	0.05	0.03	0.000
-------	-------	-------	------	------	-------

3

99999.000	1.00E-00	0.100
0.000	1.00E-00	0.100
-100.000	1.00E-10	0.001

10

intermediate bedrock

```

      0.000      0.000 0.100      0.01      0.01      0.002
3
99999.000 1.00E-00 0.100
  0.000 1.00E-00 0.100
-100.000 1.00E-10 0.001
NODAL POINT DEFINITIONS REMOVED TO REDUCE THE LENGTH OF THE FILE
ELEMENT DEFINITIONS REMOVED TO REDUCE THE LENGTH OF THE FILE
  0  0  0  0  0  0  0  42  2  2  55  54.  3  2  0  0
  0  0  0  0  0
  0.000 770.6 9.009 770.6
  0.000 767.6 9.009 767.6
  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16
17 18 19 20 21 1177 1178 1179 1180 1181 1182 1183 1184 1185 1186 1187
1188 1189 1190 1191 1192 1193 1194 1195 1196 1197
  1 20 1 1 0
22 20 1 2 0

      0.000 -7.00D-04 9.00D9 -7.00D-04 NATURAL RAINFALL
      0.000 -0.00D-00 9.00D9 -0.00D-00 UNDER CAPS
      0.000 -5.00D-03 9.00D9 -5.00D-03 OVER TRENCHES
42 63 84 105 126 147 168 189 210 231 252 273 294 315 336 357
378 399 420 441 462 483 504 525 546 567 588 609 630 651 672 693
714 735 756 777 798 819 840 861 882 903 924 945 966 987 1008 1029
1050 1071 1092 1113 1134 1155 1176
1 0 0 1 0 1 1 column = current condition 2nd = capped
2 0 0 1 0 1
3 0 0 1 0 1
4 0 0 1 0 1
5 0 0 1 0 1
6 0 0 1 0 1
7 0 0 1 0 1
8 0 0 1 0 1
9 0 0 1 0 1
10 0 0 1 0 1
11 0 0 1 0 1
12 0 0 1 0 1
13 0 0 1 0 1
14 0 0 1 0 1
15 0 0 1 0 1
16 0 0 1 0 1
17 0 0 1 0 1
18 0 0 1 0 1
19 0 0 1 0 1
20 0 0 1 0 1
21 0 0 1 0 1
22 0 0 1 0 2
23 0 0 1 0 2
24 0 0 1 0 2
25 0 0 1 0 2
26 0 0 3 0 2
27 0 0 3 0 2
28 0 0 3 0 2
29 0 0 3 0 2
30 0 0 3 0 2
31 0 0 3 0 2
32 0 0 3 0 2

```


C-43

33	0	0	3	0	2
34	0	0	3	0	2
35	0	0	3	0	2
36	0	0	3	0	2
37	0	0	3	0	2
38	0	0	3	0	2
39	0	0	3	0	2
40	0	0	1	0	2
41	0	0	1	0	2
42	0	0	1	0	2
43	0	0	1	0	1
44	0	0	1	0	1
45	0	0	1	0	1
46	0	0	1	0	1
47	0	0	1	0	1
48	0	0	1	0	1
49	0	0	1	0	1
50	0	0	1	0	1
51	0	0	1	0	1
52	0	0	1	0	1
53	0	0	1	0	1
54	0	0	1	0	1
55	0	0	1	0	1

1 53 1 2 1 1 1

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