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Revision 0

KEY WORDS:
Saltstone Disposal Facility
Performance Assessment
Closure Cap

SALTSTONE DISPOSAL FACILITY MECHANICALLY STABILIZED EARTH VAULT CLOSURE CAP DEGRADATION BASE CASE: INSTITUTIONAL CONTROL TO PINE FOREST SCENARIO (U)

DECEMBER 18, 2003

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LIST OF ACRONYMS AND ABBREVIATIONS

ACRONYMS

CN	Curve Number
FC	field capacity
FML	flexible membrane liner
GCL	geosynthetic clay liner
GSE	GSE Lining Technology, Inc.
HELP	Hydrologic Evaluation of Landfill Performance
MMES	Martin Marietta Energy Systems, Inc.
PA	Performance Assessment
SCS	Soil Conservation Service
SDF	Saltstone Disposal Facility
SRP	Savannah River Plant
SRS	Savannah River Site
U.S.	United States
USCS	Unified Soil Classification System
USLE	Universal Soil Loss Equation
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
WP	wilting point
WSRC	Westinghouse Savannah River Company

LIST OF ACRONYMS AND ABBREVIATIONS

ABBREVIATIONS

A	Area
A	Universal Soil Loss Equation soil loss
C	Universal Soil Loss Equation vegetative cover factor
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
cu	cubic
d	thickness or depth
D	diameter
F	fraction
ft	feet
ft^2	square feet
ft^3	cubic feet
ft-msl	feet above mean sea level
g	gram
hr	hour
in	inch
Instal.	installation
K	saturated hydraulic conductivity
K	Universal Soil Loss Equation soil erodibility factor
L	liter
lbs	pounds
LS	Universal Soil Loss Equation slope length and steepness factor
m	meter
m^3	cubic meter
mg	milligram
mil	thousandth of an inch
mph	miles per hour

LIST OF ACRONYMS AND ABBREVIATIONS

ABBREVIATIONS (continued)

n	porosity
N	no
P	Universal Soil Loss Equation erosion control practice factor
R	Universal Soil Loss Equation rainfall erosion index
Recirc.	Recirculation
s	second
Sat. Hyd. Cond.	saturated hydraulic conductivity
sec	second
STD.	Standard
VEG.	vegetative
Vol	volume
Y	yes
yr	year
ρ_b	bulk density
ρ_p	particle density
‘	foot
“	inch
%	percent
#	number
/	per

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1.0 EXECUTIVE SUMMARY

As part of the current Saltstone Disposal Facility (SDF) Performance Assessment (PA) revision, the closure cap configuration was reevaluated and closure cap degradation mechanisms and their impact upon infiltration through the closure cap was evaluated for the existing SDF concrete vaults (i.e. vaults 1 and 4) for the base case land use scenario (i.e. institutional control to pine forest scenario) and documented in Phifer and Nelson (2003). The closure cap configuration was modified from a compacted kaolin barrier layer concept to a geosynthetic clay layer (GCL) barrier layer concept. The degradation mechanisms developed included pine forest succession, erosion, and colloidal clay migration. These degradation mechanisms resulted in changes in the hydraulic properties of the closure cap layers and resulting increases in infiltration through the closure cap over time.

Subsequently, Winship (2003) recommended that future SDF vaults be based upon Mechanically Stabilized Earth (MSE) technology rather then poured in place concrete technology. Due to these recommended SDF vault changes, the closure cap degradation mechanisms and their impact upon infiltration through the closure cap has been reevaluated for the proposed MSE vaults for the base case land use scenario (i.e. institutional control to pine forest scenario). This has been conducted as part of the PA revision and as documented herein. This land use scenario assumes a 100-year institutional control period following final SDF closure during which the closure cap is maintained. At the end of institutional control, it is assumed that a pine forest succeeds the cap’s original bamboo cover. Infiltration through the upper hydraulic barrier layer of the closure cap as determined by this evaluation will be utilized as the infiltration input to subsequent PORFLOW vadose zone contaminant transport modeling, which will also be performed as part of the PA revision.

The impact of pine forest succession, erosion, and colloidal clay migration as degradation mechanisms on the hydraulic properties of the closure cap layers over time has been estimated and the resulting infiltration through the MSE vault closure cap has been evaluated. The primary changes caused by the degradation mechanisms that result in increased infiltration are the formation of holes in the upper GCL by pine forest succession and the reduction in the saturated hydraulic conductivity of the drainage layers due to colloidal clay migration into the layers. Erosion can also result in significant increases in infiltration if it causes the removal of soil layers, which provide water storage for the promotion of evapotranspiration.

For the institutional control to pine forest, land use scenario, infiltration through the upper GCL was estimated at approximately 0.36 inches/year under initial intact conditions. Such infiltration increased from approximately 0.41 inches/year at the end of institutional control (i.e. year 100) to approximately 12.0 inches/year at year 1000 in nearly a linear fashion. From year 1800 to year 10,000 the infiltration approaches 14.1 inches/year. At year 1800 approximately 0.3 percent of the GCL area had holes due to root penetration resulting in an infiltration near that of typical background infiltration (i.e. as though the GCL were not there at all). A very small area of holes essentially controlled the hydraulic performance of the GCL. It is assumed that the infiltration remains at 14.1 inches/year until approximately year 97,000, at which point the thickness of the upper backfill above the erosion barrier is equal to the assumed evapotranspiration zone depth of 22 inches (Phifer and Nelson 2003). After year 97,000 it is assumed that infiltration through the upper GCL increases linearly from 14.1 inches/year to a maximum of 18.1 inches/year in year 280,000. As the thickness of the upper backfill layer decreases below 22 inches the evapotranspiration zone extends into the erosion barrier, which provides inadequate water storage for the promotion of evapotranspiration. This results in the infiltration increase over 14.1 inches/year after year 97,000.

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2.0 INTRODUCTION

The existing Saltstone Disposal Facility (SDF) vaults (i.e. vaults 1 and 4) are above grade, roofed, reinforced concrete vaults into which Saltstone is poured. Saltstone is a grout consisting of low-level radioactive salt solution mixed with blast furnace slag, flyash, and cement, which solidifies to form a dense, microporous, monolithic, low-level radioactive waste. It is anticipated that active Saltstone disposal operations will last for approximately 30 years. During the operations period the roofed, Saltstone-filled vaults remain above grade (interim closure). Final closure of all the filled vaults is not anticipated until near or at the end of the operational period and will consist of the placement of a closure cap over the vaults. (MMES 1992; Cook et al. 2000; Cook et al. 2002)

As part of the current SDF Performance Assessment (PA) revision, the closure cap configuration was reevaluated and closure cap degradation mechanisms and their impact upon infiltration through the closure cap was evaluated for the existing SDF concrete vaults for the base case land use scenario (i.e. institutional control to pine forest scenario) and documented in Phifer and Nelson (2003). The degradation mechanisms developed included pine forest succession, erosion, and colloidal clay migration. These degradation mechanisms resulted in changes in the hydraulic properties of the closure cap layers and resulting increases in infiltration through the closure cap over time. Phifer and Nelson (2003) additionally recommended that the SDF closure cap barrier layer be changed from a compacted kaolin layer to a geosynthetic clay layer (GCL). It was recommended that the revised SDF closure cap consist of the following major components from the ground surface to the top of the vault roof (i.e., top to bottom), as shown in Figure 2.0-1 (Phifer and Nelson 2003):

- Bamboo vegetative cover to promote evapotranspiration,
- 0.15 m (6 inch) vegetative soil (i.e., topsoil) at a three percent slope,
- 0.76 m (30 inch) upper backfill layer (i.e., structural fill),
- 0.3 m (12 inch) erosion barrier consisting of 2-inch to 6-inch granite stone with a d_{50} (i.e. median size) of 4 inches,
- 0.3 m (12 inch) middle backfill layer to provide additional water storage for the promotion of evapotranspiration in case the topsoil and upper backfill are eroded away,
- A geotextile filter fabric to minimize the migration of fines into the underlying drainage layer,
- 0.3 m (12 inch) upper drainage layer with an initial saturated hydraulic conductivity of 0.1 cm/s and a slope of three percent,
- 0.0051 m (0.2 inch) geosynthetic clay liner (GCL),
- A minimum 1.49 m (58.57 inch) lower backfill (this layer will vary in thickness) which is used to change the direction of slope by 90 degrees and increase the slope to three percent,
- A geotextile filter fabric to minimize the migration of fines into the underlying drainage layer,
- 0.61 m (24 inch) lower drainage layer with an initial saturated hydraulic conductivity of 0.1 cm/s and conforming to vault roof slope, and
- 0.0051 m (0.2 inch) GCL.

Subsequently, Winship (2003) recommended that future SDF vaults be based upon Mechanically Stabilized Earth (MSE) technology and consist of the following major components from the roof to the floor of the vault, as shown in Figure 2.0-2:

- 60 mil High Density Polyethylene (HDPE) membrane,

- 21 inch concrete roof at an 11.4 percent slope,
- 35 feet of Saltstone,
- 12 inch drainage layer with a saturated hydraulic conductivity of 0.1 cm/s and a slope of two percent,
- 0.0051 m (0.2 inch) geosynthetic clay liner (GCL),
- 60 mil HDPE membrane, and
- 12 inch concrete floor slab.

Due to these recommended SDF vault changes, the closure cap degradation mechanisms and their impact upon infiltration through the closure cap has been reevaluated for the proposed MSE vaults for the base case land use scenario (i.e. institutional control to pine forest scenario). This has been conducted as part of the PA revision and as documented herein. This land use scenario assumes a 100-year institutional control period following final SDF closure during which the closure cap is maintained. At the end of institutional control, it is assumed that a pine forest succeeds the cap's original bamboo cover. Infiltration through the upper hydraulic barrier layer of the closure cap as determined by this evaluation will be utilized as the infiltration input to subsequent PORFLOW vadose zone contaminant transport modeling, which will also be performed as part of the PA revision.

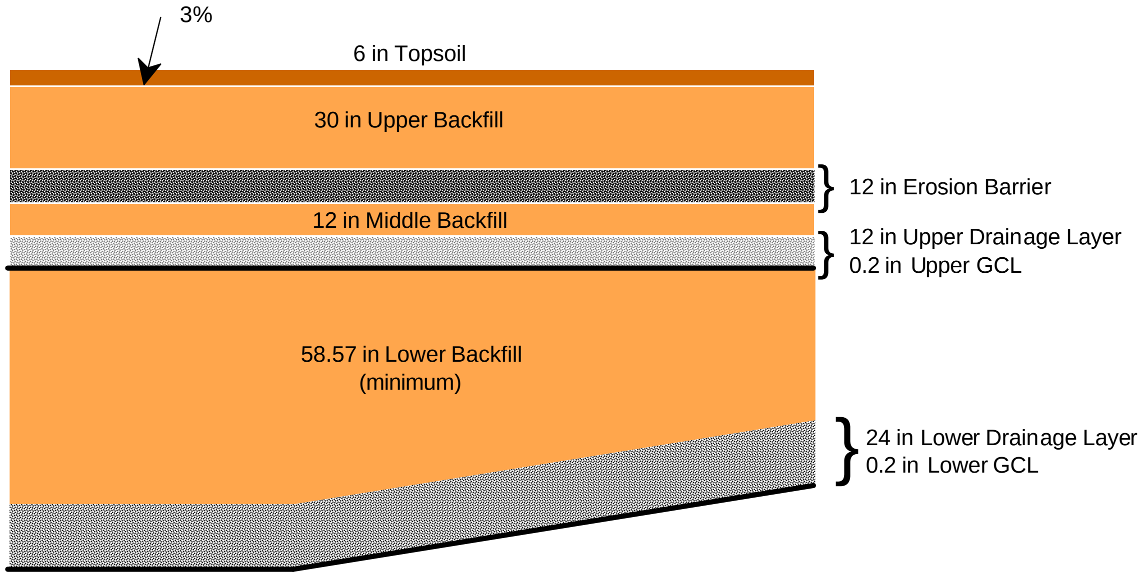

Figure 2.0-1. Saltstone Disposal Facility Closure Cap

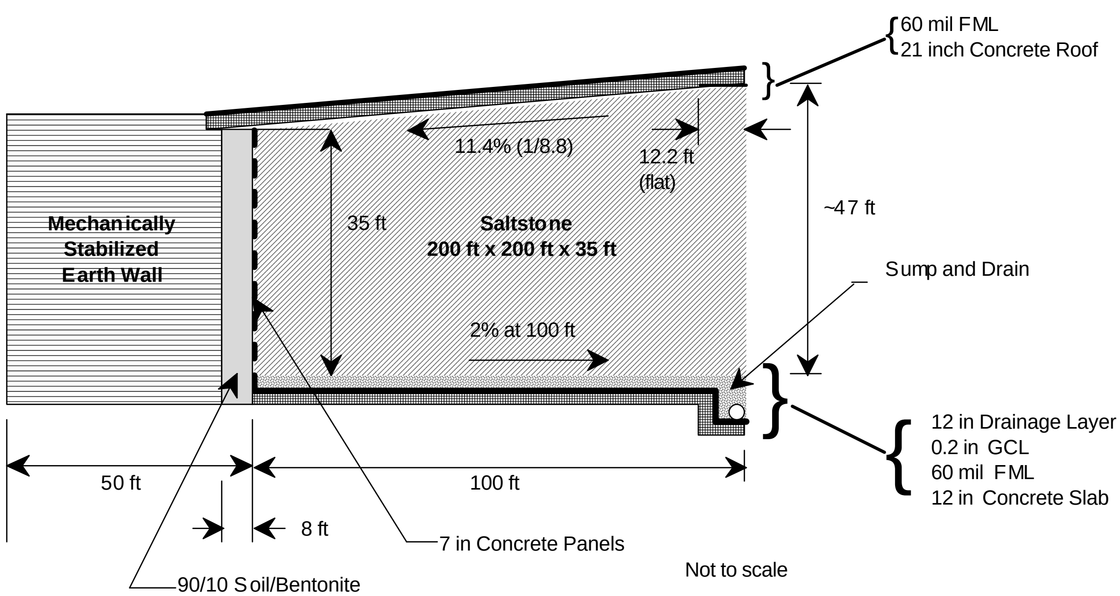

Figure 2.0-2. Saltstone Disposal Facility MSE Vault

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3.0 INTACT CLOSURE CAP INFILTRATION

3.1 Intact SDF GCL Closure Cap Footprint, Configuration, and Properties

The MSE vault layout presented in Figure 3.1-1 has been utilized for the evaluation presented herein. This layout assumes that three 200-foot by 200-foot MSE vaults are placed between existing vaults 1 and 4. The layout is based upon the following:

- The recommendations outlined within Appendix 7.5 of Winship 2003, and
- The Saltstone Project preference to initially locate MSE vaults between existing vaults 1 and 4.

Based upon this layout, a closure cap footprint and drainage system configuration (Figure 3.1-2) has been developed. The drainage system configuration is also based upon the drainage system previously selected by Phifer and Nelson (2003) for the existing vault design and layout (i.e. the concrete vaults). Figure 3.1-3 presents the MSE vault and closure cap cross-section as previously described in Section 2.0. The assumption has been made that the lower GCL only covers the MSE vault roof whereas the upper GCL is continuous over the entire closure cap footprint presented in Figure 3.1-2. Table 3.1-1 presents the intact SDF GCL closure cap configuration and soil properties as developed by Phifer and Nelson (2003).

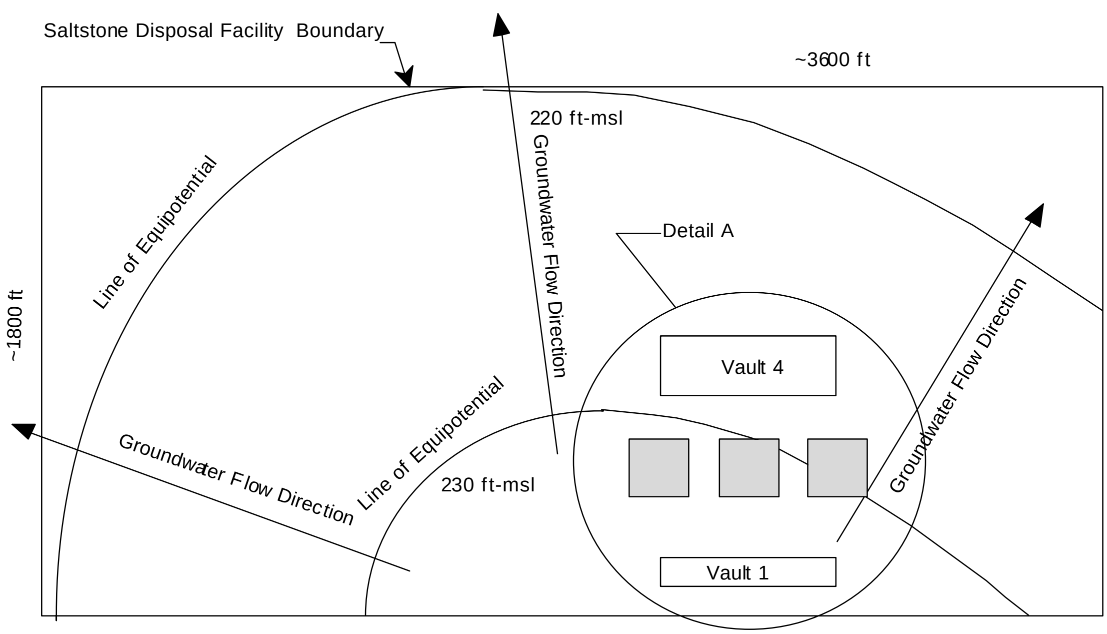

Figure 3.1-1. MSE Vault Layout

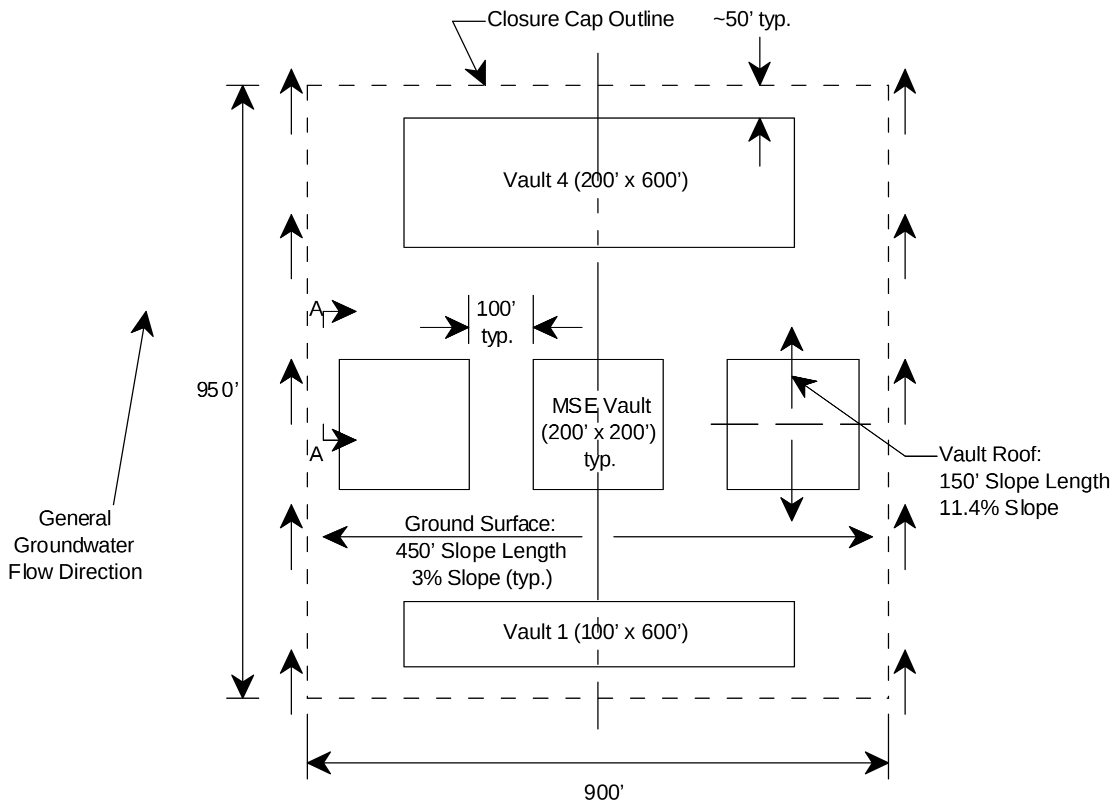

Figure 3.1-2. Closure Cap Footprint and Drainage System (Detail A)

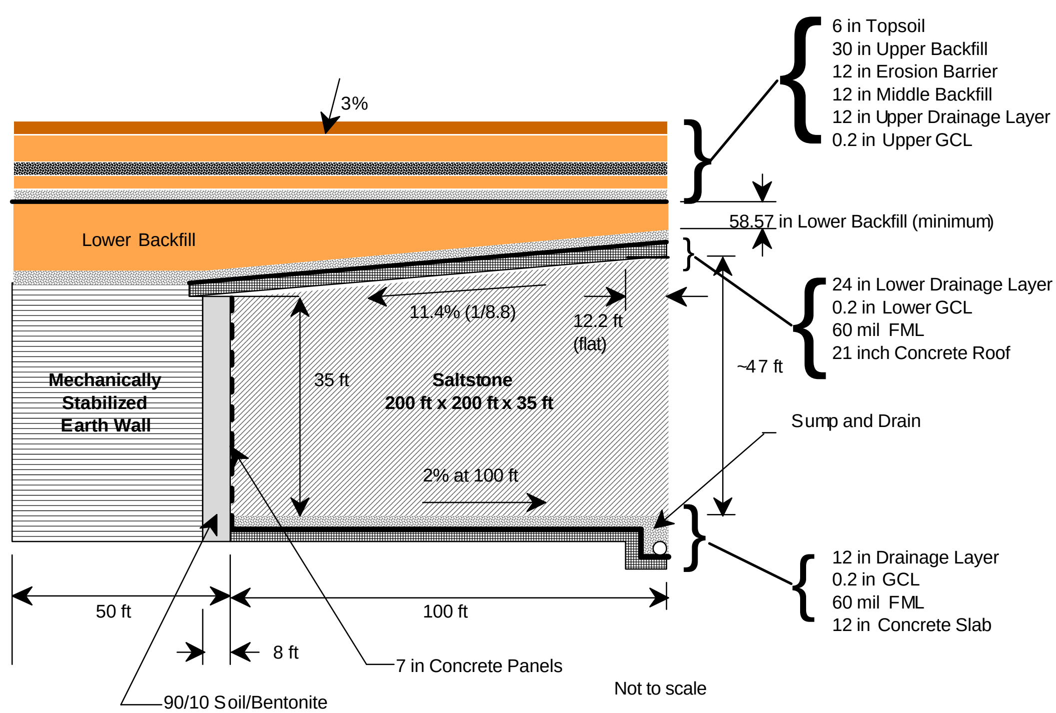

Figure 3.1-3. MSE Vault and Closure Cap Cross-Section (Section A-A)

Table 3.1-1. Intact SDF GCL Closure Cap Configuration and Properties (Phifer and Nelson 2003)

Layer	Thickness (inches)	Saturated Hydraulic Conductivity (cm/sec)	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)
Topsoil [1]	6	1.00E-03	0.4	0.11	0.058
Upper Backfill [1]	30	1.00E-04	0.37	0.24	0.136
Erosion Barrier [2]	12	3.97E-04	0.06	0.056	0.052
Middle Backfill [1]	12	1.00E-04	0.37	0.24	0.136
Geotextile Filter Fabric [3]	-	-	-	-	-
Upper Drainage Layer [1]	12	1.00E-01	0.38	0.08	0.013
Upper GCL	0.2 [4]	5.00E-09 [5]	0.75 [6]	0.747 [6]	0.40 [6]
Lower Backfill [1]	58.57 (minimum)	1.00E-04	0.37	0.24	0.136
Geotextile Filter Fabric [5]	-	-	-	-	-
Lower Drainage Layer [1]	24	1.00E-01	0.38	0.08	0.013
Lower GCL	0.2 [4]	5.00E-09 [5]	0.75 [6]	0.747 [6]	0.40 [6]

[1] WSRC 2002a
[2] Phifer and Nelson 2003
[3] It is assumed that a geotextile filter fabric will be placed above the drainage layers to minimize the infiltration of fines from the overlying layers into the drainage layer. However it is not necessary to include the filter fabric in the HELP models.
[4] USEPA 2001
[5] GSE 2002
[6] USEPA 1994a and USEPA 1994b

3.2 HELP Model and Generic Input Data

The Hydrologic Evaluation of Landfill Performance (HELP) model has been utilized to conduct the evaluation of the impact of closure cap degradation upon infiltration for the closure cap described in Section 3.1. The HELP model is a quasi-two-dimensional water balance model designed to conduct landfill water balance analyses. The model requires the input of weather, soil, and design data. It provides estimates of runoff, evapotranspiration, lateral drainage, vertical percolation (infiltration), hydraulic head, and water storage for the evaluation of various landfill designs. Personnel at the U.S. Army Engineer Waterways Experiment Station in Vicksburg, Mississippi developed the HELP model, under an interagency agreement with the U.S. Environmental Protection Agency (USEPA). HELP model version 3.07, issued on November 1, 1997, is the latest version of the model available from the Waterways Experiment Station (USEPA 1994a and USEPA 1994b). (WSRC 2002a)

The HELP model requires the input of evapotranspiration, precipitation, temperature, and solar radiation data. Phifer and Nelson (2003) developed the weather data utilized to conduct this evaluation. The HELP model weather data input files, which were utilized for all HELP model runs, are provided in the following appendices:

- Appendix A, Augusta Synthetic Precipitation Modified with SRS Specific Average Monthly Precipitation Data over 100 Years (file name: Zprec.d4),
- Appendix B, Augusta Synthetic Temperature Modified with SRS Specific Average Monthly Temperature Data over 100 Years (file name: Ztemp.d7),
- Appendix C, Augusta Synthetic Solar Radiation Data over 100 Years (file name: Zsolar.d13), and
- Appendix D, Augusta Evapotranspiration Data (file name: Zevap.d11).

Table 3.2-1 provides a listing of generic input parameters (i.e., HELP model query) and the associated values selected. Use of selected fixed values for these HELP model queries provides compatibility between the different HELP model runs. The landfill area is based upon the Figure 3.1-2 length (950 feet) and width (900 feet), which results in a surface area of 760,000 feet squared or 19.6 acres. It has been assumed that the final covers are appropriately sloped so that 100 percent of the covers allow runoff to occur (i.e., there are no depressions). A yes response has been provided to the HELP model query, which asks, “Do you want to specify initial moisture storage? (Y/N).” The amount of water or snow on the surface of the covers was assumed to be zero as the initial model condition.

Table 3.2-1. Generic Input Parameter Values – Area and Initial Moisture

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area	19.63 acres
Percent of area where runoff is possible	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface	0 in.

As stated the initial moisture storage has been specified for all soil layers. While the initial moisture storage is not a fixed value for all runs, a fixed method of selecting the initial moisture storage value has been utilized for consistency. The initial, soil moisture storage value has been selected as follows:

- The initial moisture storage of soil layers designated as either a vertical percolation layer or a lateral drainage layer was set at the field capacity of the soil.
- The initial moisture storage of soil layers designated as a barrier soil liner was set at the porosity of the soil.

The Soil Conservation Service (SCS) runoff curve number (CN) is another required HELP model input parameter that has been made consistent. The HELP model provides three options to specify the CN. The option that produces a HELP model computed curve number, based on surface slope and slope length, soil texture of the top layer, and vegetation, was utilized. Table 3.2-2 provides the input values of surface slope and slope length, soil texture of the top layer, and vegetation that were utilized to produce the HELP model computed curve number. The 3 percent slope is that specified for the top surface of the Saltstone final cover within the Saltstone closure plan (Cook et al. 2000). The 450-foot slope length is based upon Figure 3.1-2. The soil texture selected as an input for calculation of the CN is a loamy fine sand per the United States Department of Agriculture (USDA) and a silty sand per Unified Soil Classification System (USCS), since it closely represents the typical vegetative soil layers utilized at the Savannah River Site (SRS). The corresponding number in the HELP default soil texture list is 5. Based upon these input parameter values the HELP model computed a CN of 54.4.

Table 3.2-2. Generic Input Parameter Values – Curve Number (CN)

CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope	3%
Slope length	450 ft
Soil Texture	5 (HELP model default soil texture)
Vegetation	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number	54.4

3.3 Intact Closure Cap Infiltration

HELP modeling of the Table 3.1-1 intact SDF MSE vault closure cap configuration has been performed utilizing the Section 3.2 generic input data. As documented in Phifer and Nelson (2003), the HELP model does not need to include the vault in order to obtain an appropriate infiltration through the upper GCL. Therefore the vault has not been included in any of the HELP modeling presented herein. Based upon this modeling the infiltration through the upper GCL has been estimated to be 0.36 inches per year for intact conditions. The following appendix provides the detailed HELP model, input data and output file for the intact condition:

- Appendix E, Intact SDF MSE Vault Closure Cap (0 Years): HELP Model Input Data and Output File (output file name: ZMSEIout.OUT)

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4.0 CLOSURE CAP DEGRADATION

The following three primary closure cap degradation mechanisms have been assumed to significantly impact the infiltration through the closure cap over time:

- Pine forest succession
- Erosion
- Colloidal clay migration

Phifer and Nelson (2003) discussed each of these degradation mechanisms in detail.

4.1 Pine Forest Succession

According to the PA and Closure Plan the SDF closure cap will be vegetated with bamboo. Bamboo is a shallow-rooted species that quickly establishes a dense ground cover and evapotranspirates year-round in the SRS climate. Pine trees are the most deeply rooted naturally occurring plants at SRS. (MMES 1992; Cook et al. 2000). The institutional control to pine forest, land use scenario evaluated herein assumes a 100-year institutional control period following final SDF closure during which the closure cap is maintained. It is assumed that a pine forest begins to encroach upon the bamboo at the end of institutional control, when the closure cap is no longer maintained.

The following assumptions, which were made relative to the succession of bamboo by a pine forest by Phifer and Nelson (2003), have also been utilized for this evaluation:

- 200 years after the end of institutional control it is assumed that the entire cap is dominated by pine.
- Complete turnover of the 400 mature trees per acre occurs every 100 years (in a staggered manner).
- There are 400 mature trees per acre with 4 roots to 6 feet and 1 root to 12 feet. The roots are 3 inches in diameter at a depth of 1 foot and 0.25 inches in diameter at either 6 or 12 feet, whichever is applicable.

4.2 Erosion

The topsoil and upper backfill layers, which are located above the erosion barrier, are subject to erosion. For the institutional control to pine forest land use scenario, it is assumed that the closure cap will be vegetated with bamboo during the institutional control period, with a combination of bamboo and pine trees for 200 years immediately following the institutional control period, and with a pine forest thereafter. The projected erosion rate for both the topsoil and upper backfill layers has been determined utilizing the Universal Soil Loss Equation (Horton and Wilhite 1978; Goldman et al. 1986). The Universal Soil Loss Equation (USLE) is expressed as:

$$A = R \times K \times LS \times C \times P \qquad \text{(Eq. 5.2-1)}$$

where

A = soil loss (tons/acre/year)

R = rainfall erosion index (100 ft·ton/acre per in/hr)

K = soil erodibility factor, tons/acre per unit of R

LS = slope length and steepness factor, dimensionless

C = vegetative cover factor, dimensionless

P = erosion control practice factor, dimensionless

Table 4.2-1 presents the USLE parameter values utilized and the source of the values for both the topsoil and backfill.

Table 4.2-1. USLE Parameter Values

USLE Parameter	Value Utilized	Source
R for SRS location	260	Horton and Wilhite 1978
K for topsoil	0.28	Phifer and Nelson 2003 and Goldman et al. 1986 Figure 5.6
K for backfill	0.20	Phifer and Nelson 2003 and Goldman et al. 1986 Figure 5.6
LS for 450-foot 3% slope (see Figure 3.1-2)	0.45	Goldman et al. 1986 Table 5.5
C for both bamboo and pine forest	0.001	Horton and Wilhite 1978
P for no supporting practices	1	Not applicable

Based upon the Universal Soil Loss Equation and the Table 4.2-1 parameter values the following soil losses were estimated:

- Topsoil with a natural successional forest has an estimated soil loss of 0.0328 tons/acre/year ($A = 260 \times 0.28 \times 0.45 \times 0.001 \times 1$). Based upon the dry bulk density the estimated soil loss can be converted to a loss in terms of depth of loss per year. From Jones and Phifer (2002), the dry bulk density of topsoil was taken as 90 lbs/ft^3. Topsoil with a natural successional forest has an estimated depth of soil loss of approximately 2.0E-04 inches/year.

  $$(\,Loss = \frac{0.0328\ tons/acre/year \times 2000\ lbs/ton \times 12\ inches/\ foot}{43560\ \ ft^2\ /acre \times 90\ lbs/\ ft^3}\,).$$

- Backfill with a natural successional forest has an estimated soil loss of 0.0234 tons/acre/year ($A = 260 \times 0.20 \times 0.45 \times 0.001 \times 1$). Based upon the dry bulk density the estimated soil loss can be converted to a loss in terms of depth of loss per year. From Jones and Phifer (2002), the dry bulk density of backfill was taken as 104 lbs/ft^3. Backfill with a natural successional forest has an estimated depth of soil loss of approximately 1.2E-04 inches/year.

  $$(\,Loss = \frac{0.0234\ tons/acre/year \times 2000\ lbs/ton \times 12\ inches/\ foot}{43560\ \ ft^2\ /acre \times 104\ lbs/\ ft^3}\,).$$

4.3 Colloidal Clay Migration

It is assumed that colloidal clay migrates from overlying backfill layers and accumulates in the drainage layers reducing the saturated hydraulic conductivity of the drainage layers over time. As previously documented in Phifer and Nelson (2003), it will be assumed that water-flux driven colloidal clay migration at a concentration of 63 mg/L occurs from overlying backfill layers to the drainage layers. It will be further assumed that the colloidal clay accumulates in the drainage layer from the bottom up filling the void space of the drainage layer with clay at a density of 1.1 g/cm^3 (Hillel 1982).

4.4 Closure Cap Degradation Summary

Based upon the assumed closure cap degradation mechanisms, pine forest succession, erosion, and colloidal clay migration, a degradation scenario has been assumed for each layer as outlined in Table 4.4-1. These degradation scenarios form the basis for modifying the thickness and hydraulic properties of each layer over time. This information has been utilized in Section 5.0 to determine infiltration though the upper GCL over time.

Table 4.4-1. SDF GCL Closure Cap Layer Degradation Scenarios (Phifer and Nelson 2003)

Layer	Degradation Scenario
Vegetation	Bamboo is maintained during the 100-year institutional control period, pine trees begin to encroach upon the bamboo at the end of institutional control, and a pine forest covers the cap 200 years after the end of institutional control.
Topsoil	Topsoil erosion occurs at 2.0E-04 inches per year.
Upper Backfill	Backfill erosion occurs at 1.2E-04 inches per year, after the topsoil layer has been depleted.
Erosion Control Barrier	Maintenance during institutional control period prevents degradation of the erosion control barrier. However pine forest succession and associated root penetration results in holes through the erosion control barrier. This does not impact its ability to function as an erosion barrier, however it allows the overlying backfill to fill the holes left after the roots decompose. Since degradation of the erosion barrier is assumed to be caused by intrusion of the overlying backfill following root decomposition, erosion barrier degradation will be assumed to cease once the upper backfill is eroded to three inches thick.
Middle Backfill	Colloidal clay migration from the 1-foot-thick middle backfill to the underlying 1-foot-thick upper drainage layer causes the saturated hydraulic conductivity to increase over time.
Geotextile Filter Fabric	For purposes of colloidal clay migration into the underlying drainage layer the geotextile filter fabric is assumed to be ineffective over the time period under consideration.
Upper Drainage Layer	Colloidal clay migration from the overlying 1-foot-thick backfill into the 1-foot-thick upper drainage layer causes the saturated hydraulic conductivity to decrease over time.
Upper GCL	Maintenance during institutional control period prevents degradation of the upper GCL. However pine forest succession and associated root penetration results in holes through the GCL. This allows the overlying drainage layer to fill the holes after the roots decompose.
Lower Backfill	None. While it is assumed that colloidal clay migration from this layer to the underlying lower drainage layer occurs, it is also assumed that the thickness of the lower backfill layer (minimum 5-foot) relative to the lower drainage layer (2-foot) prevents the quantity of clay loss necessary to change the hydraulic properties of the lower backfill.
Geotextile Filter Fabric	For purposes of colloidal clay migration into the underlying drainage layer the geotextile filter fabric is assumed to be ineffective over the time period under consideration.
Lower Drainage Layer	Colloidal clay migration from the overlying minimum 5-foot-thick lower backfill into the 1-foot-thick lower drainage layer reduces its saturated hydraulic conductivity over time.
Lower GCL	None. Pine tree roots do not penetrate to sufficient depth to impact this layer. Additionally, the underlying concrete vault roof along with the GCL produces a hard layer and continuous water saturation within and above these layers so that root elongation is stopped.

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5.0 CLOSURE CAP INFILTRATION

5.1 Degraded Layer Properties over Time

The SDF GCL closure cap initial (0 year) intact layer thickness and hydraulic property values from top to bottom are provided in Table 3.1-1. The degradation scenarios for each layer are provided in Table 4.4-1. Based upon the Table 4.4-1 degradation scenarios, the Table 3.3-1 initial SDF closure cap layer thickness and hydraulic property values have been modified to account for degradation at 100, 300, 550, 1,000, 1,800, 3,400, 5,600 and 10,000 years after closure of the SDF. The following discussions provide additional detail associated with determination of the degraded properties for the erosion barrier, upper GCL, middle backfill, upper drainage layer, and lower drainage layer as originally presented by Phifer and Nelson (2003).

5.1.1 Erosion Barrier

Maintenance during the institutional control period prevents degradation of the erosion barrier. However pine forest succession and associated root penetration results in holes through the erosion control barrier. This does not impact its ability to function as an erosion barrier, however it allows the overlying backfill to fill the holes after the roots decompose. It is assumed that the hydraulic conductivity of the infiltrating backfill increases one order of magnitude (i.e. from 1.0E-04 to 1.0E-03 cm/s) when it fills the hole since it will not be mechanically compacted at that time. The equivalent hydraulic properties of the overall erosion barrier change as the area of holes filled with backfill material increases with time. The equivalent hydraulic properties have been estimated over time by area proportioning the properties between that of the intact erosion barrier and infiltrating backfill.

5.1.2 Upper GCL

Maintenance during the institutional control period prevents degradation of the upper GCL. However pine forest succession and associated root penetration results in holes through the erosion barrier. This allows the overlying drainage layer to fill the holes after the roots decompose. The holes in the GCL essentially act as direct conduits from the upper drainage layer to the lower backfill layer. When saturated conditions occur in the drainage layer after major precipitation events, cones of depression are created around the holes in the GCL with a radius of influence much greater than the radius of the hole. This means that a small area of GCL holes can greatly reduce the lateral flow of water in the drainage layer and increase the vertical flow into the lower backfill. Due to the significant influence of holes in the GCL to the quantity of infiltration, the use of equivalent hydraulic properties is not appropriate, since it does not consider the radius of influence associated with holes. Therefore, within the HELP model the degraded GCL has been modeled as a geomembrane liner with leakage through holes. The HELP model considers both water flux through intact portions of the geomembrane using an “equivalent geomembrane hydraulic conductivity” and water flux through holes in the geomembrane. The HELP model does not assign a porosity, field capacity, or wilting point to geomembranes, however this is not considered essential to the GCL, since it is assumed that the GCL will remain fully saturated and it is below the depth where evapotranspiration is assumed to occur. The HELP model allows the input of up to 999,999 one square centimeter installation defects for a geomembrane liner. Therefore the calculated area of holes created by root penetration has been converted into an equivalent number of one square centimeter installation defects for input to the HELP model. Excellent contact is assumed between the GCL and underlying backfill layer as a HELP model input, since the GCL is put in dry and swells into the surrounding soil as it hydrates.

5.1.3 Middle Backfill and Upper Drainage Layer

It is assumed that water-flux driven colloidal-clay migration from the 1-foot-thick middle backfill to the underlying 1-foot-thick upper drainage layer causes the middle backfill saturated hydraulic conductivity to increase over time and that of the upper drainage layer to decrease over time. It has been assumed that clay migration occurs out of the backfill into the drainage layer with the water flux containing 63 mg/L of colloidal clay. Since both layers are of the same thickness and the middle backfill layer has limited clay content, it has been assumed that half the clay content of the backfill will migrate into the drainage layer. At which point the two layers essentially become the same material and material property changes cease. Based upon this it will be assumed that the endpoint saturated hydraulic conductivity of the layers will become that of the log mid-point between the initial backfill and upper drainage layer conditions. It will also be assumed that the endpoint porosity, field capacity, and wilting point will become the arithmetic average of the backfill and upper drainage layer. The hydraulic properties at times prior to the endpoint have been proportioned between that of the endpoint properties and the initial properties based upon the fraction of clay that has migrated out of the backfill.

5.1.4 Lower Drainage Layer

It is assumed that colloidal clay migration from the minimum 5-foot-thick overlying backfill into the 2-foot-thick lower drainage layer is driven by the water flux through the upper GCL. This water flux driven clay migration enters into the lower drainage layer and fills the lower drainage layer from the bottom up. This reduces the saturated hydraulic conductivity of the clay-filled portion from 1.0E-01 to 1.0E-04 cm/s (i.e. to the saturated hydraulic conductivity of the overlying backfill), while the conductivity of the clean portion remains at 1.0E-01 cm/s. As the thickness of the lower drainage layer filled with clay increases, the equivalent hydraulic conductivity of the entire layer decreases. The equivalent horizontal hydraulic conductivity for this layer has been determined from the following equation (Freeze and Cherry 1979):

$$K_h = \sum_{i=1}^{n} \frac{K_i \; d_i}{d} \qquad \text{(Eq. 6.1-1)}$$

where

K_h = equivalent horizontal saturated hydraulic conductivity,

K_i = horizontal saturated hydraulic conductivity of i^{th} layer,

d_i = thickness of i^{th} layer,

d = total thickness

This is different from that assumed for the upper drainage layer, since the lower drainage layer has significantly more backfill overlying it.

5.1.5 Summary Material Properties over Time

The calculations associated with determination of the layer thicknesses and hydraulic property values over time are provided in Appendix F. Table 5.1-1 provides the primary Appendix F, material property results (thickness, saturated hydraulic conductivity, and holes in the upper GCL), for layers which change with time and were utilized in subsequent HELP modeling. The porosity, field capacity, and wilting points are not provided in Table 5.1-1. Values for these parameters are provided in Appendix F.

Table 5.1-1. Material Property Summary Results for HELP Modeling from Appendix F

Year	Vegetation	Topsoil Layer Thickness (inches)	Erosion Barrier Saturated Hydraulic Conductivity (cm/s)	Middle Backfill Layer Saturated Hydraulic Conductivity (cm/s)
0	Bamboo	6	3.97E-04	1.00E-04
100	Bamboo	5.980	3.97E-04	1.20E-04
300	Pine Forest	5.940	3.98E-04	1.60E-04
550	Pine Forest	5.890	3.99E-04	2.30E-04
1,000	Pine Forest	5.800	4.01E-04	4.60E-04
1,800	Pine Forest	5.640	4.06E-04	1.60E-03
3,400	Pine Forest	5.320	4.15E-04	3.20E-03
5,600	Pine Forest	4.880	4.27E-04	3.20E-03
10,000	Pine Forest	4.0	4.51E-04	3.20E-03
Year	Upper Drainage Layer Saturated Hydraulic Conductivity (cm/s)	One Square Centimeter Holes in Upper GCL [1] (#/acre)	Lower Drainage Layer Saturated Hydraulic Conductivity (cm/s)	
0	1.00E-01	0	1.00E-01	
100	8.60E-02	0	1.00E-01	
300	6.30E-02	7,432	9.98E-02	
550	4.30E-02	26,013	9.89E-02	
1,000	2.10E-02	59,458	9.61E-02	
1,800	6.30E-03	118,916	8.96E-02	
3,400	3.20E-03	237,832	7.56E-02	
5,600	3.20E-03	401,341	5.62E-02	
10,000	3.20E-03	728,360	1.74E-02	

[1] Number of HELP model installation defects

5.2 Degraded Closure Cap Infiltration over Time

Table 5.1-1 and Appendix F data were utilized as input to the HELP model (USEPA 1994a and USEPA 1994b) in order to determine infiltration through the upper GCL at each degraded time step. The following appendices provide the detailed HELP model, input data and output files for each time step:

- Appendix G, Degraded SDF MSE Vault Closure Cap (100 Years): HELP Model Input Data and Output File (output file name: ZMSED1ou.OUT)
- Appendix H, Degraded SDF MSE Vault Closure Cap (300 Years): HELP Model Input Data and Output File (output file name: ZMSED2ou.OUT)
- Appendix I, Degraded SDF MSE Vault Closure Cap (550 Years): HELP Model Input Data and Output File (output file name: ZMSED3ou.OUT)
- Appendix J, Degraded SDF MSE Vault Closure Cap (1,000 Years): HELP Model Input Data and Output File (output file name: ZMSED4ou.OUT)

- Appendix K, Degraded SDF MSE Vault Closure Cap (1,800 Years): HELP Model Input Data and Output File (output file name: ZMSED5ou.OUT)
- Appendix L, Degraded SDF MSE Vault Closure Cap (3,400 Years): HELP Model Input Data and Output File (output file name: ZMSED6ou.OUT)
- Appendix M, Degraded SDF MSE Vault Closure Cap (5,600 Years): HELP Model Input Data and Output File (output file name: ZMSED7ou.OUT)
- Appendix N, Degraded SDF MSE Vault Closure Cap (10,000 Years): HELP Model Input Data and Output File (output file name: ZMSED8ou.OUT)

The following outputs from this evaluation are necessary inputs to the subsequent PORFLOW vadose zone modeling:

- Infiltration through the upper GCL
- Saturated hydraulic conductivity of the 2-foot-thick lower Drainage Layer

Table 5.2-1 provides a summary of these parameter values. Figure 5.2-1 additionally provides the infiltration through the upper GCL over time in graphical format.

Table 5.2-1. Inputs for PORFLOW Vadose Zone Modeling

Year	Infiltration through Upper GCL (in/yr)	Lower Drainage Layer Saturated Hydraulic Conductivity (cm/s)
0	0.36	1.00E-01
100	0.41	1.00E-01
300	3.05	9.98E-02
550	7.90	9.89E-02
1,000	12.04	9.61E-02
1,800	13.76	8.96E-02
3,400	14.03	7.56E-02
5,600	14.08	5.62E-02
10,000	14.09	1.74E-02
11,953	NA	1.00E-04
280,000	18.12	NA

NA = not applicable

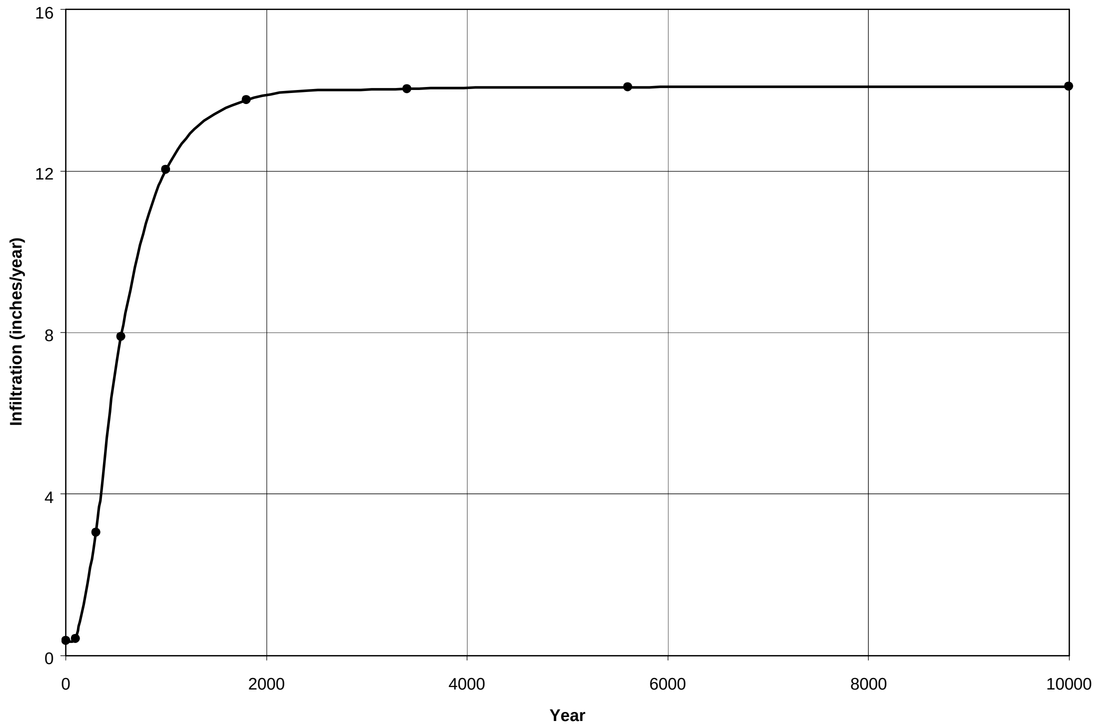

Figure 5.2-1. Infiltration through Upper GCL

5.3 Worse Case Infiltration

The worse case infiltration through the upper GCL and the associated time of occurrence have been determined based upon the following:

- As documented in Phifer and Nelson (2003), worse case infiltration occurs when both the topsoil and upper backfill have eroded away, since the underlying erosion barrier does not provide as efficient water storage for the promotion of evapotranspiration as the topsoil and upper backfill.
- Since degradation of the erosion barrier is assumed to be caused by intrusion of the overlying backfill following root decomposition, erosion barrier degradation will be assumed to cease once the upper backfill is eroded to three inches thick. Therefore erosion barrier properties will be taken as those at complete erosion of the topsoil and upper backfill for determination of the worse case infiltration through the upper GCL. (see Table 4.4-1)
- As outlined in Appendix F, it is assumed that the material properties of the middle backfill and upper drainage layer become the same at year 2246 and remain constant thereafter. Therefore the middle backfill and upper drainage layer material properties will be taken as those determined at year 2246 for determination of the worse case infiltration through the upper GCL.
- The upper GCL becomes ineffective as a barrier layer at year 1800 when holes comprise 0.29 percent of the layer's area (see Appendix F). Therefore for determination of the worse case infiltration the GCL will be assigned as a barrier soil liner with the same material properties as the overlying middle backfill and upper drainage layer at year 2246.

- As previously demonstrated in Appendix F, the material properties of the lower drainage layer do not impact infiltration through the upper GCL. Completely silted in conditions will be assumed for the lower drainage layer for determination of the worse case infiltration.

Appendix F provides the material property calculations based upon the above assumptions and the detailed HELP model input data and output file associated with this worse case infiltration through the upper GCL. The worse case infiltration through the upper GCL was determined to be 18.1 inches/year in year 280,000. This worse case infiltration has been included in Table 5.2-1 for comparison purposes. As seen the infiltration has been estimated at approximately 14.1 inches per year in year 10,000 and 18.1 inches per year in year 280,000. It is assumed that after the topsoil completely erodes and the upper backfill erodes to 22 inches thick in approximately year 97,000 (see Appendix F) that infiltration through the upper GCL would increase linearly from approximately 14.1 inches/year to approximately 18.1 inches/year in year 280,000. This is assumed since the evapotranspiration zone depth utilized in the HELP modeling is 22 inches (Phifer and Nelson 2003).

In addition to the worse case infiltration, the time that the lower drainage layer completely silts in and assumes the properties of the overlying backfill has been estimated to occur in approximately year 12,000 (see Appendix F). This has also been included in Table 5.2-1 as input to the PORFLOW modeling.

6.0 SUMMARY AND CONCLUSIONS

The impact of pine forest succession, erosion, and colloidal clay migration as degradation mechanisms on the hydraulic properties of the closure cap layers over time has been estimated and the resulting infiltration through the MSE vault closure cap has been evaluated. The primary changes caused by the degradation mechanisms that result in increased infiltration are the formation of holes in the upper GCL by pine forest succession and the reduction in the saturated hydraulic conductivity of the drainage layers due to colloidal clay migration into the layers. Erosion can also result in significant increases in infiltration if it causes the removal of soil layers, which provide water storage for the promotion of evapotranspiration.

For the institutional control to pine forest, land use scenario, infiltration through the upper GCL was estimated at approximately 0.36 inches/year under initial intact conditions. Such infiltration increased from approximately 0.41 inches/year at the end of institutional control (i.e. year 100) to approximately 12.0 inches/year at year 1000 in nearly a linear fashion. From year 1800 to year 10,000 the infiltration approaches 14.1 inches/year. At year 1800 approximately 0.3 percent of the GCL area had holes due to root penetration resulting in an infiltration near that of typical background infiltration (i.e. as though the GCL were not there at all). A very small area of holes essentially controlled the hydraulic performance of the GCL. It is assumed that the infiltration remains at 14.1 inches/year until approximately year 97,000, at which point the thickness of the upper backfill above the erosion barrier is equal to the assumed evapotranspiration zone depth of 22 inches (Phifer and Nelson 2003). After year 97,000 it is assumed that infiltration through the upper GCL increases linearly from 14.1 inches/year to a maximum of 18.1 inches/year in year 280,000. As the thickness of the upper backfill layer decreases below 22 inches the evapotranspiration zone extends into the erosion barrier, which provides inadequate water storage for the promotion of evapotranspiration. This results in the infiltration increase over 14.1 inches/year after year 97,000.

Table 5.2-1 provides a summary of the necessary inputs to the subsequent PORFLOW vadose zone modeling including infiltration through the upper GCL and the saturated hydraulic conductivity of the lower drainage layer, side vertical drainage layer, and vault base drainage layer.

Performance of the closure cap relative to infiltration through the upper GCL could be further improved, if necessary, as follows:

- Increasing the depth of the GCL, which would results in smaller diameter root penetrations.
- Placing a suitable biobarrier above the GCL to prevent root penetration into the GCL.

Optimization of layers within the evapotranspiration zone for water storage to promote subsequent evapotranspiration could also possibly be a means of increasing the performance of the closure cap.

A technical report design check of this report and associated calculations has been performed per WSRC (2002b) and documented in Appendix O.

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8.0 APPENDICES

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Appendix A, Augusta Synthetic Precipitation Modified with SRS Specific Average Monthly Precipitation Data over 100 Years (file name: Zprec.d4)

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Appendix B, Augusta Synthetic Temperature Modified with SRS Specific Average Monthly Temperature Data over 100 Years (file name: Ztemp.d7)

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Appendix C, Augusta Synthetic Solar Radiation Data over 100 Years (file name: Zsolar.d13)

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Appendix D, Augusta Evapotranspiration Data (file name: Zevap.d11)

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1
AUGUSTA         GEORGIA
33.22      68 323 3.5    22.    6.5  68.0 70.0 77.0 73.0
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Appendix E, Intact SDF MSE Vault Closure Cap (0 Years): HELP Model Input Data and Output File (output file name: ZMSEIout.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	19.63 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	450 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 54.4	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	3 (barrier soil liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	6		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.06	0.056	0.052	0.056
4	1	12		0.37	0.24	0.136	0.24
5	2	12		0.38	0.08	0.013	0.08
6	3	0.2		0.75	0.747	0.40	0.75
7	1	58.57		0.37	0.24	0.136	0.24
8	2	24		0.38	0.08	0.013	0.08
9	3	0.2		0.75	0.747	0.40	0.75

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity * (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	3.97E-04					
4	1	1.00E-04					
5	2	1.00E-01	450	3			
6	3	5.00E-09					
7	1	1.00E-04					
8	2	1.00E-01	150	11.4			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	3				
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.
* The HELP model output often produces an increased number of significant digits for the Effective Saturated Hydraulic Conductivity over that of the actual input.

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
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PRECIPITATION DATA FILE:     D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:       D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:   D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:     D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:   D:\HELP3\Hsdfmse\ZMSEI.D10
OUTPUT DATA FILE:            D:\HELP3\Hsdfmse\ZMSEIout.OUT

TIME:  14:56     DATE:  11/13/2003

******************************************************************************

     TITLE:  Intact SDF MSE Vault Closure Cap - 0 years

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.

                                   LAYER  1
                                   --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     6.00   INCHES
           POROSITY                   =     0.4000 VOL/VOL
           FIELD CAPACITY             =     0.1100 VOL/VOL
           WILTING POINT              =     0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =    30.00   INCHES
           POROSITY                   =     0.3700 VOL/VOL
           FIELD CAPACITY             =     0.2400 VOL/VOL
           WILTING POINT              =     0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

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                        LAYER  3
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.0600 VOL/VOL
FIELD CAPACITY               =      0.0560 VOL/VOL
WILTING POINT                =      0.0520 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0560 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.396999996000E-03 CM/SEC

                        LAYER  4
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3700 VOL/VOL
FIELD CAPACITY               =      0.2400 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                        LAYER  5
                        --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3800 VOL/VOL
FIELD CAPACITY               =      0.0800 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000     CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    450.0    FEET

                        LAYER  6
                        --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC
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                           LAYER  7
                           --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     58.57   INCHES
   POROSITY                     =      0.3700 VOL/VOL
   FIELD CAPACITY               =      0.2400 VOL/VOL
   WILTING POINT                =      0.1360 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                           LAYER  8
                           --------

                   TYPE 2 - LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     24.00   INCHES
   POROSITY                     =      0.3800 VOL/VOL
   FIELD CAPACITY               =      0.0800 VOL/VOL
   WILTING POINT                =      0.0130 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.0800 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.100000001000     CM/SEC
   SLOPE                        =     11.40   PERCENT
   DRAINAGE LENGTH              =    150.0    FEET

                           LAYER  9
                           --------

                     TYPE 3 - BARRIER SOIL LINER
                     MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =      0.20   INCHES
   POROSITY                     =      0.7500 VOL/VOL
   FIELD CAPACITY               =      0.7470 VOL/VOL
   WILTING POINT                =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

              GENERAL DESIGN AND EVAPORATIVE ZONE DATA
              ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  450. FEET.

SCS RUNOFF CURVE NUMBER            =     54.40
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =     19.630  ACRES
EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      4.500  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      8.320  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      2.524  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     28.649  INCHES
TOTAL INITIAL WATER                =     28.649  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                   0.004    0.000    0.004    0.000    0.000    0.002
                           0.027    0.091    0.016    0.006    0.002    0.001

  STD. DEVIATIONS          0.020    0.000    0.027    0.000    0.002    0.015
                           0.092    0.404    0.086    0.058    0.015    0.004

EVAPOTRANSPIRATION
------------------
  TOTALS                   1.577    2.093    3.072    3.553    3.661    4.141
                           4.897    4.522    3.384    1.619    0.948    1.114

  STD. DEVIATIONS          0.221    0.236    0.582    0.760    1.525    1.546
                           1.588    1.378    1.039    0.606    0.207    0.206

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
  TOTALS                   2.5102   2.0619   1.9352   1.2047   0.4142   0.3121
                           0.5589   0.8185   0.7450   0.7795   0.9036   1.5056

  STD. DEVIATIONS          1.8312   1.5189   1.4896   1.0415   0.4532   0.5842
                           0.8112   1.0393   1.0279   1.0745   1.2152   1.3333

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                   0.0617   0.0514   0.0488   0.0322   0.0142   0.0105
                           0.0162   0.0224   0.0208   0.0213   0.0239   0.0381

  STD. DEVIATIONS          0.0421   0.0351   0.0336   0.0239   0.0106   0.0141
                           0.0193   0.0244   0.0241   0.0253   0.0284   0.0312

LATERAL DRAINAGE COLLECTED FROM LAYER  8
----------------------------------------
  TOTALS                   0.0511   0.0483   0.0446   0.0307   0.0106   0.0070
                           0.0123   0.0180   0.0165   0.0174   0.0205   0.0327

  STD. DEVIATIONS          0.0320   0.0336   0.0343   0.0278   0.0152   0.0131
                           0.0178   0.0224   0.0227   0.0238   0.0276   0.0281

PERCOLATION/LEAKAGE THROUGH LAYER  9
------------------------------------
  TOTALS                   0.0051   0.0049   0.0053   0.0051   0.0049   0.0035
                           0.0036   0.0040   0.0040   0.0038   0.0036   0.0043

  STD. DEVIATIONS          0.0009   0.0001   0.0003   0.0005   0.0011   0.0019
                           0.0021   0.0020   0.0019   0.0021   0.0021   0.0019
```

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	2.1516	1.9398	1.6538	1.0666	0.3539	0.2755
	0.4775	0.6992	0.6594	0.6660	0.7977	1.2862
STD. DEVIATIONS	1.5865	1.4607	1.2739	0.9329	0.3872	0.5157
	0.6930	0.8878	0.9127	0.9179	1.0727	1.1390

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.0039	0.0040	0.0034	0.0024	0.0008	0.0005
	0.0009	0.0014	0.0013	0.0013	0.0016	0.0025
STD. DEVIATIONS	0.0024	0.0028	0.0026	0.0022	0.0012	0.0010
	0.0013	0.0017	0.0018	0.0018	0.0022	0.0021

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	48.90	(7.734)	3484469.2	100.00
RUNOFF	0.154	(0.4340)	10947.61	0.314
EVAPOTRANSPIRATION	34.582	(3.6251)	2464196.75	70.719
LATERAL DRAINAGE COLLECTED FROM LAYER 5	13.74952	(5.50704)	979748.062	28.11757
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.36170	(0.12899)	25773.611	0.73967
AVERAGE HEAD ON TOP OF LAYER 6	1.002	(0.403)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	0.30966	(0.12406)	22065.420	0.63325
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.05203	(0.00803)	3707.190	0.10639
AVERAGE HEAD ON TOP OF LAYER 9	0.002	(0.001)		
CHANGE IN WATER STORAGE	0.053	(1.9051)	3804.31	0.109

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	489534.875
RUNOFF	2.647	188618.8120
DRAINAGE COLLECTED FROM LAYER 5	0.45348	32313.73240
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.018346	1307.25354
AVERAGE HEAD ON TOP OF LAYER 6	21.373	
MAXIMUM HEAD ON TOP OF LAYER 6	31.170	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	121.6 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.01253	892.95929
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000195	13.90441
AVERAGE HEAD ON TOP OF LAYER 9	0.029	
MAXIMUM HEAD ON TOP OF LAYER 9	0.055	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	9.4 FEET	
SNOW WATER	2.36	168188.7190
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3692	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1147	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	1.6120	0.2687
2	9.2097	0.3070
3	0.7200	0.0600
4	4.1112	0.3426
5	2.0564	0.1714
6	0.1500	0.7500
7	14.0568	0.2400
8	1.9214	0.0801
9	0.1500	0.7500
SNOW WATER	0.000	

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Appendix F, SDF GCL Closure Cap Degraded Property Value Calculations

The SDF GCL closure cap initial (0 year) layer thickness and hydraulic property values from top to bottom are provided in Table 3.1-1. The degradation scenarios for each layer are provided in Table 4.4-1. Based upon the Table 4.4-1 degradation scenarios, the Table 3.1-1 initial SDF closure cap layer thickness and hydraulic property values have been modified to account for degradation at 100, 300, 550, 1,000, 1,800, 3,400, 5,600 and 10,000 years after closure of the SDF.

Topsoil and Upper Backfill Layer Thickness:

From Section 4.2 the soil loss in terms of depth of loss per year for the topsoil and upper backfill was estimated to be 2.0E-04 inches/year and 1.2E-04 inches/year, respectively.

Topsoil Thickness Over Time Calculation:

Year	Thickness
0	6” – (0 years × 2.0E-04 inches/year) = 6”
100	6” – (100 years × 2.0E-04 inches/year) = 5.980”
300	6” – (300 years × 2.0E-04 inches/year) = 5.940”
550	6” – (550 years × 2.0E-04 inches/year) = 5.890”
1,000	6” – (1000 years × 2.0E-04 inches/year) = 5.800”
1,800	6” – (1800 years × 2.0E-04 inches/year) = 5.640”
3,400	6” – (3400 years × 2.0E-04 inches/year) = 5.320”
5,600	6” – (5600 years × 2.0E-04 inches/year) = 4.880”
10,000	6” – (10000 years × 2.0E-04 inches/year) = 4.0”

Since the topsoil does not completely erode away within the 10,000 years of interest, no reduction in the upper backfill layer occurs.

Erosion Barrier Hydraulic Properties:

Maintenance during institutional control period prevents degradation of the erosion control barrier. Subsequent to the institutional control period, pine forest succession will results in root penetration through the erosion control barrier. This does not impact its ability to function as an erosion barrier, however it allows the overlying backfill to fill the holes after the roots decompose. It is assumed that the hydraulic conductivity of the infiltrating backfill increases one order of magnitude (i.e. from 1.0E-04 to 1.0E-03 cm/s) when it falls into the hole since it will not be mechanically compacted at that time. The hydraulic properties of the erosion barrier as a whole change as the backfill material fills the root penetration holes.

From Section 4.1 the following assumptions relative to the succession of bamboo by a pine forest that impact the erosion barrier hydraulic properties were made:

- 200 years after the end of institutional control it is assumed that the entire cap is covered with pine (i.e. 400 mature trees per acre).
- Complete turnover of the 400 mature trees per acre occurs every 100 years (in a staggered manner).
- There are 400 mature trees per acre with 4 roots to 6 feet and 1 root to 12 feet. The roots are 3 inches in diameter at a depth of 1 foot and 0.25 inches in diameter at either 6 or 12 feet, whichever is applicable.

Very little erosion of the topsoil is estimated for the institutional control to pine forest, land use scenario, within the 10,000 years of interest. Therefore the estimated thickness of the topsoil layer at 10,000 years (i.e. 4 inches) has been utilized to determine the area of the holes in the erosion barrier created by root penetration. This is a conservative assumption.

Area of holes in erosion barrier due to root penetration:

Average Erosion Barrier Depth (see Table 3.1-1) = 4” + 30” + ½(12”) = 40” ≈ 3.3’

Root Diameter for 4-6’ roots at 3.3’:

3” diameter at 1’ depth and 0.25” at 6’

$$(3''-0.25'')/(6'-1') = 0.55''/\ ft$$

Diameter = 0.25” + [(6’ – 3.3’) × 0.55”/ft] = 1.74”

Area of for 4-6’ roots at 3.3’:

Area = $4 \times \frac{1}{4}\pi D^2 = \pi D^2 = \pi(1.74'')^2 = 9.5\ in^2$

Root Diameter for 1-12’ root at 3.3’:

3” diameter at 1’ depth and 0.25” at 12’

$$(3''-0.25'')/(12'-1') = 0.25''/\ ft$$

Diameter = 0.25” + [(12’ – 3.3’) × 0.25”/ft] = 2.4”

Area of for 1-12’ roots at 3.3’:

Area = $\frac{1}{4}\pi D^2 = \frac{1}{4}\pi(2.4'')^2 = 4.5\ in^2$

Total area of holes in erosion barrier per tree:

Total area = $9.5\ in^2 + 4.5\ in^2 = 14\ in^2 \times ft^2/144\ in^2 \approx 0.1\ ft^2$/tree

Total area of holes per acre per 100 years:

400 trees/acre/100 years

Total area = $0.1\ ft^2$/tree × 400 trees/acre/100 years = $40\ ft^2$/ acre/100 years

Year	Area of holes in erosion barrier / acre
0	0
100	0
300 [1]	$40\ ft^2$/ acre
550	$40\ ft^2$/ acre + [(550 yrs – 300 yrs) × $40\ ft^2$/ acre/100 years = $140\ ft^2$/ acre
1,000	$40\ ft^2$/ acre + [(1000 yrs – 300 yrs) × $40\ ft^2$/ acre/100 years = $320\ ft^2$/ acre
1,800	$40\ ft^2$/ acre + [(1800 yrs – 300 yrs) × $40\ ft^2$/ acre/100 years = $640\ ft^2$/ acre
3,400	$40\ ft^2$/ acre + [(3400 yrs – 300 yrs) × $40\ ft^2$/ acre/100 years = $1280\ ft^2$/ acre
5,600	$40\ ft^2$/ acre + [(5600 yrs – 300 yrs) × $40\ ft^2$/ acre/100 years = $2160\ ft^2$/ acre
10,000	$40\ ft^2$/ acre + [(10000 yrs – 300 yrs) × $40\ ft^2$/ acre/100 years = $3920\ ft^2$/ acre

[1] 200 years after the end of institutional control (i.e. at year 300) it is assumed that the entire cap is covered with pine (i.e. 400 mature trees per acre). It is assumed that each “generation” of roots becomes instantaneous voids at the 100-year turnover period.

Year	Fraction (f) of erosion barrier area comprising holes
0	$0 \div 43560$ ft^2/ acre = 0
100	$0 \div 43560$ ft^2/ acre = 0
300	40 ft^2/ acre $\div$ 43560 ft^2/ acre = 0.00092
550	140 ft^2/ acre $\div$ 43560 ft^2/ acre = 0.00321
1,000	320 ft^2/ acre $\div$ 43560 ft^2/ acre = 0.00735
1,800	640 ft^2/ acre $\div$ 43560 ft^2/ acre = 0.0147
3,400	1280 ft^2/ acre $\div$ 43560 ft^2/ acre = 0.0294
5,600	2160 ft^2/ acre $\div$ 43560 ft^2/ acre = 0.0496
10,000	3920 ft^2/ acre $\div$ 43560 ft^2/ acre = 0.08999

The equivalent horizontal hydraulic conductivity for horizontal flow in a series of horizontal layers with different saturated hydraulic conductivities can be determined from the following equation (Freeze and Cherry 1979):

$$K_h = \sum_{i=1}^{n} \frac{K_i \; d_i}{d}$$

, where K_h = equivalent horizontal saturated hydraulic conductivity, K_i = horizontal saturated hydraulic conductivity of ith layer, d_i = thickness of ith layer, d = total thickness

In a similar manner the equivalent vertical hydraulic conductivity for vertical flow in a horizontal zone containing areas of materials with different saturated hydraulic conductivities can be determined based upon an area proportionality as follows:

$$K_v = \sum_{i=1}^{n} \frac{K_i \; A_i}{A}$$

, where K_v = equivalent vertical saturated hydraulic conductivity, K_i = vertical saturated hydraulic conductivity of ith layer, A_i = Area of ith layer, A = total area

The following are the input saturated hydraulic conductivities:

For backfill that drops into holes in the erosion barrier = 1.0E-03 cm/s

Intact erosion barrier = 3.97E-04 cm/s

The fraction (F) provided above is equivalent to A_i/A for the backfill that drops into holes in the erosion barrier and one minus the fraction (1 – F) is equivalent to A_i/A for the for the intact erosion barrier, making the equation:

K_v = (1.0E-03 $\times$ F) + (3.97E-04 $\times$ (1 – F))

Year	K_v
0	(1.0E-03 cm/s $\times$ 0) + (3.97E-04 cm/s $\times$ (1 – 0)) = 3.97E-04 cm/s
100	(1.0E-03 cm/s $\times$ 0) + (3.97E-04 cm/s $\times$ (1 – 0)) = 3.97E-04 cm/s
300	(1.0E-03 cm/s $\times$ 0.00092) + (3.97E-04 cm/s $\times$ (1 – 0.00092)) = 3.98 E-04 cm/s
550	(1.0E-03 cm/s $\times$ 0.00321) + (3.97E-04 cm/s $\times$ (1 – 0.00321)) = 3.99E-04 cm/s
1,000	(1.0E-03 cm/s $\times$ 0.00735) + (3.97E-04 cm/s $\times$ (1 – 0.00735)) = 4.01E-04 cm/s
1,800	(1.0E-03 cm/s $\times$ 0.0147) + (3.97E-04 cm/s $\times$ (1 – 0.0147)) = 4.06E-04 cm/s
3,400	(1.0E-03 cm/s $\times$ 0.0294) + (3.97E-04 cm/s $\times$ (1 – 0.0294)) = 4.15E-04 cm/s
5,600	(1.0E-03 cm/s $\times$ 0.0496) + (3.97E-04 cm/s $\times$ (1 – 0.0496)) = 4.27E-04 cm/s
10,000	(1.0E-03 cm/s $\times$ 0.08999) + (3.97E-04 cm/s $\times$ (1 – 0.08999)) = 4.51E-04 cm/s

In an analogous manner the equivalent porosity (n), field capacity (FC), and wilting point (WP) can be determined based upon an area proportionality as follows:

$$n = \sum_{i=1}^{n} n_i \ A_i$$

$$FC = \sum_{i=1}^{n} FC_i \ A_i$$

$$WP = \sum_{i=1}^{n} WP_i \ A_i$$

The following are the input properties:

Material	Porosity	Field Capacity	Wilting Point
Backfill	0.37	0.24	0.136
Erosion Barrier	0.06	0.056	0.052

Year	n
0	$(0.37 \times 0) + (0.06 \times (1 - 0)) = 0.06$
100	$(0.37 \times 0) + (0.06 \times (1 - 0)) = 0.06$
300	$(0.37 \times 0.00092) + (0.06 \times (1 - 0.00092)) = 0.06$
550	$(0.37 \times 0.00321) + (0.06 \times (1 - 0.00321)) = 0.061$
1,000	$(0.37 \times 0.00735) + (0.06 \times (1 - 0.00735)) = 0.062$
1,800	$(0.37 \times 0.0147) + (0.06 \times (1 - 0.0147)) = 0.065$
3,400	$(0.37 \times 0.0294) + (0.06 \times (1 - 0.0294)) = 0.069$
5,600	$(0.37 \times 0.0496) + (0.06 \times (1 - 0.0496)) = 0.075$
10,000	$(0.37 \times 0.08999) + (0.06 \times (1 - 0.08999)) = 0.088$

Year	FC
0	$(0.24 \times 0) + (0.056 \times (1 - 0)) = 0.056$
100	$(0.24 \times 0) + (0.056 \times (1 - 0)) = 0.056$
300	$(0.24 \times 0.00092) + (0.056 \times (1 - 0.00092)) = 0.562$
550	$(0.24 \times 0.00321) + (0.056 \times (1 - 0.00321)) = 0.0566$
1,000	$(0.24 \times 0.00735) + (0.056 \times (1 - 0.00735)) = 0.0574$
1,800	$(0.24 \times 0.0147) + (0.056 \times (1 - 0.0147)) = 0.0587$
3,400	$(0.24 \times 0.0294) + (0.056 \times (1 - 0.0294)) = 0.0614$
5,600	$(0.24 \times 0.0496) + (0.056 \times (1 - 0.0496)) = 0.0651$
10,000	$(0.24 \times 0.08999) + (0.056 \times (1 - 0.08999)) = 0.0726$

Year	WP
0	$(0.136 \times 0) + (0.052 \times (1 - 0)) = 0.052$
100	$(0.136 \times 0) + (0.052 \times (1 - 0)) = 0.052$
300	$(0.136 \times 0.00092) + (0.052 \times (1 - 0.00092)) = 0.521$
550	$(0.136 \times 0.00321) + (0.052 \times (1 - 0.00321)) = 0.0523$
1,000	$(0.136 \times 0.00735) + (0.052 \times (1 - 0.00735)) = 0.0526$
1,800	$(0.136 \times 0.0147) + (0.052 \times (1 - 0.0147)) = 0.0532$
3,400	$(0.136 \times 0.0294) + (0.052 \times (1 - 0.0294)) = 0.0545$
5,600	$(0.136 \times 0.0496) + (0.052 \times (1 - 0.0496)) = 0.0562$
10,000	$(0.136 \times 0.08999) + (0.052 \times (1 - 0.08999)) = 0.0596$

Summary Erosion Barrier Hydraulic Properties with Time:

Year	K_v	n	FC	WP
0	3.97E-04 cm/s	0.06	0.056	0.052
100	3.97E-04 cm/s	0.06	0.056	0.052
300	3.98 E-04 cm/s	0.06	0.562	0.521
550	3.99E-04 cm/s	0.061	0.0566	0.0523
1,000	4.01E-04 cm/s	0.062	0.0574	0.0526
1,800	4.06E-04 cm/s	0.065	0.0587	0.0532
3,400	4.15E-04 cm/s	0.069	0.0614	0.0545
5,600	4.27E-04 cm/s	0.075	0.0651	0.0562
10,000	4.51E-04 cm/s	0.088	0.0726	0.0596

Upper GCL Holes:

Maintenance during the institutional control period prevents degradation of the upper GCL. However pine forest succession and associated root penetration results in holes through the erosion barrier. This allows the overlying drainage layer to fill the holes after the roots decompose. The holes in the GCL essentially act as direct conduits from the upper drainage layer to the lower backfill layer. When saturated conditions occur in the drainage layer after major precipitation events, cones of depression are created around the holes in the GCL with a radius of influence much greater than the radius of the hole. This means that a small area of GCL holes can greatly reduce the lateral flow of water in the drainage layer and increase the vertical flow into the lower backfill.

From Section 4.1 the following assumptions were made relative to the succession of bamboo by a pine forest that result in root penetration into the upper GCL:

- 200 years after the end of institutional control it is assumed that the entire cap is covered with pine (i.e. 400 mature trees per acre).
- Complete turnover of the 400 mature trees per acre occurs every 100 years (in a staggered manner).
- There are 400 mature trees per acre with 4 roots to 6 feet and 1 root to 12 feet. The roots are 3 inches in diameter at a depth of 1 foot and 0.25 inches in diameter at either 6 or 12 feet, whichever is applicable.

Very little erosion of the topsoil is estimated for the institutional control to pine forest, land use scenario, within the 10,000 years of interest. Therefore the estimated thickness of the topsoil layer at 10,000 years (~4 inches) has been utilized to determine the area of the holes in the upper GCL created by root penetration. This is a conservative assumption.

Area of holes in upper GCL due to root penetration:

Upper GCL Depth (see Table 3.1-1) = 4” + 30” + 12” + 12” + 12” = 70” ≈ 5.8’

Root Diameter for 4-6’ roots at 5.8’:

3” diameter at 1’ depth and 0.25” at 6’

$$(3''-0.25'')/(6'-1') = 0.55''/\,ft$$

Diameter = 0.25” + [(6’ – 5.8’) × 0.55”/ft] = 0.36”

Area of for 4-6’ roots at 5.8’:

Area = $4 \times \frac{1}{4}\pi D^2 = \pi D^2 = \pi(0.36'')^2 = 0.41\ in^2$

Root Diameter for 1-12’ root at 3.3’:

3” diameter at 1’ depth and 0.25” at 12’

$$(3''-0.25'')/(12'-1') = 0.25''/\,ft$$

Diameter = 0.25" + [(12' – 5.8') × 0.25"/ft] = 1.8"

Area of for 1-12' roots at 3.3':

Area = $\frac{1}{4}\pi D^2 = \frac{1}{4}\pi(1.8")^2 = 2.54\ in^2$

Total area of holes in erosion barrier per tree:

Total area = $0.41\ in^2 + 2.54\ in^2 = 2.95\ in^2 \times ft^2/144\ in^2 \approx 0.02\ ft^2$/tree

Total area of holes per acre per 100 years:

400 trees/acre/100 years

Total area = $0.02\ ft^2$/tree × 400 trees/acre/100 years = $8\ ft^2$/ acre/100 years

Year	Area of holes in upper GCL / acre due to root penetration
0	0
100	0
300 [1]	8 ft^2/ acre
550	8 ft^2/ acre + [(550 yrs – 300 yrs) × 8 ft^2/ acre/100 years = 28 ft^2/ acre
1,000	8 ft^2/ acre + [(1000 yrs – 300 yrs) × 8 ft^2/ acre/100 years = 64 ft^2/ acre
1,800	8 ft^2/ acre + [(1800 yrs – 300 yrs) × 8 ft^2/ acre/100 years = 128 ft^2/ acre
3,400	8 ft^2/ acre + [(3400 yrs – 300 yrs) × 8 ft^2/ acre/100 years = 256 ft^2/ acre
5,600	8 ft^2/ acre + [(5600 yrs – 300 yrs) × 8 ft^2/ acre/100 years = 432 ft^2/ acre
10,000	8 ft^2/ acre + [(10000 yrs – 300 yrs) × 8 ft^2/ acre/100 years = 784 ft^2/ acre

[1] 200 years after the end of institutional control (i.e. at year 300) it is assumed that the entire cap is covered with pine (i.e. 400 mature trees per acre)

Number of one-square-centimeter holes in upper GCL per acre due to root penetration (each HELP model installation defect for a flexible membrane liner (FML) is assumed to be one square centimeter):

$1\ cm^2 = 0.001076391\ ft^2$ so $0.001076391\ ft^2$/installation defect

Year	Percent of GCL area degraded due to root penetration
0	0
100	0
300	(8 ft^2/ acre ÷ 43560 ft^2/ acre) × 100 = 0.018
550	(28 ft^2/ acre ÷ 43560 ft^2/ acre) × 100 = 0.064
1,000	(64 ft^2/ acre ÷ 43560 ft^2/ acre) × 100 = 0.15
1,800	(128 ft^2/ acre ÷ 43560 ft^2/ acre) × 100 = 0.29
3,400	(256 ft^2/ acre ÷ 43560 ft^2/ acre) × 100 = 0.59
5,600	(432 ft^2/ acre ÷ 43560 ft^2/ acre) × 100 = 0.99
10,000	(784 ft^2/ acre ÷ 43560 ft^2/ acre) × 100 = 1.8

Year	# of installation defects in upper GCL / acre due to root penetration
0	0
100	0
300	8 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 7,432
550	28 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 26,013
1,000	64 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 59,458
1,800	128 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 118,916
3,400	256 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 237,832
5,600	432 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 401,341
10,000	784 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 728,360

Middle Backfill Layer and Upper Drainage Layer Hydraulic Properties:

It is assumed that colloidal clay migration from the 1-foot-thick middle backfill to the underlying 1-foot-thick upper drainage layer causes the middle backfill saturated hydraulic conductivity to increase over time and that of the upper drainage layer to decrease over time.

Determine mass of clay to fill upper drainage layer void volume (0.38):

Assume clay bulk density is 1.1 g/cm^3

Look at a 1-ft^2 area of the 1-foot-thick upper drainage layer (i.e. 1 ft^3)

Void volume = 0.38×1 ft^3 = 0.38 ft^3

Clay mass per ft^3 = 1.1 g/cm^3 $\times$ 0.38 ft^3 $\times$ 2.831685E-02 m^3/ft^3 $\times$ 1,000,000 cm^3/m^3 = 11,836.3 g

Determine available clay mass in the middle backfill layer:

Assume that the middle backfill layer consists of 20% clay and 80% sand with a dry bulk density of 104-lbs/ ft^3.

Clay mass = 104 lbs/ft^3 $\times$ 0.20 $\times$ 453.59 g/lbs = 9,434.7 g/ft^3

There is not enough clay in the middle backfill layer to fill the upper drainage layer. Therefore it will be assumed that half the clay content of the middle backfill migrates into the upper drainage layer, at which point the two layers essentially become the same material and material property changes cease. Based upon this it will be assumed that the endpoint saturated hydraulic conductivity of the layers will become that of the log mid-point between the initial backfill and upper drainage layer conditions. It will also be assumed that the endpoint porosity, field capacity, and wilting point will become the arithmetic average of the backfill and upper drainage layer.

Endpoint hydraulic properties:

Intact hydraulic properties:

Hydraulic Parameter	Middle Backfill	Upper Drainage Layer
K	1.0E-04 cm/s	1.0E-01 cm/s
n	0.37	0.38
FC	0.24	0.08
WP	0.136	0.013

Endpoint saturated hydraulic conductivity:

Middle backfill: K_{MB} = 0.0001; log K_{MB} = -4

Upper drainage layer: K_{UDL} = 0.1; log K_{UDL} = -1

Log mid-point: $$\frac{Log\ K_{MB} + Log\ K_{UDL}}{2} = \frac{-1 + (-4)}{2} = -2.5$$

$K_E = 10^{-2.5} = 3.2E\text{-}03$ cm/s

Endpoint n, FC, and WP:

n = (0.37 + 0.38)/2 = 0.375

FC = (0.24 + 0.08)/2 = 0.16

WP = (0.136 + 0.013)/2 = 0.0745

It will be assumed that the clay migrates out of the middle backfill into the upper drainage layer with the water flux containing 63 mg/L of colloidal clay. It will also be assumed that the time to achieve the endpoint conditions will be based upon the estimated water flux into the upper drainage layer and migration of half the clay content of the middle backfill layer (i.e. 9,434.7 g/ft^3 ÷ 2 = 4717.4 g/ft^3).

Determine flux of water into the upper drainage layer:

Section 3.3 intact SDF closure cap Modeling determined the following average annual flux of water into the upper drainage layer (see Appendix E):

Precipitation = 48.90 inches/year

Runoff = 0.154 inches/year

Evapotranspiration = 34.582 inches/year

Flux of water into upper drainage layer = Precipitation – (Runoff + Evapotranspiration)

Flux of water into upper drainage layer = 48.90 in/yr – (0.154 in/yr + 34.582 in/yr)

Flux of water into upper drainage layer = 14.164 in/yr

The above flux is based upon the best case cap conditions; therefore, will determine the flux based upon the Preliminary 10,000 year conditions as follows:

- 10,000 year eroded topsoil at 4.0 inches (see above)
- 10,000 year erosion barrier conditions with K = 4.51E-04 cm/s; n = 0.088; FC = 0.0726; WP = 0.0596 (see above)
- Middle backfill and upper drainage layer at end state conditions with K = 3.2E-03 cm/s; n = 0.375; FC = 0.16; WP = 0.0745 (see above)
- Upper GCL with 728,360 holes
- Lower drainage layer with intact backfill properties (used since 10,000 year conditions for this layer not yet determined)

The detailed HELP model input data and output file associated with the 10,000-year conditions is provided at the end of this appendix. The following are the pertinent values extracted from the output file:

Precipitation = 48.90 inches/year

Runoff = 0.181 inches/year

Evapotranspiration = 34.556 inches/year

Flux of water into upper drainage layer = Precipitation – (Runoff + Evapotranspiration)

Flux of water into upper drainage layer = 48.90 in/yr – (0.181 in/yr + 34.556 in/yr)

Flux of water into upper drainage layer = 14.163 in/yr

There is essentially no difference between the flux into the upper drainage layer with either the intact or 10,000-year conditions. Therefore, a water flux into the upper drainage layer of ~14.2 in/yr will be used for determination of the time when the endpoint properties are reached.

Determine yearly clay migration into the upper drainage layer:

Flux into upper drainage layer = 14.2 in/yr

Colloidal clay concentration = 63 mg/L

Flux through a 1 ft^2 area = 14.2 in/yr × ft/12 in × 1 ft^2 = 1.18 ft^2/yr

Clay flux = 1.18 ft^2/yr × 63 mg/L × 2.831685E-02 m^3/ ft^3 × 1000L/ m^3 = 2,105 mg/yr = 2.1 g/yr

Determine time it takes for the 4717.4 g of clay to migrate from the middle backfill layer to the upper drainage layer:

Time = 4717.4 g ÷ 2.1 g/yr = 2,246 years

Determine middle backfill and upper drainage layer hydraulic property variation with time:

It will be assumed that the K of the middle backfill layer is increasing log linearly with time from 1.0E-04 cm/s to 3.2E-03 cm/s, until year 2,246 at which time the K becomes static. Conversely it will be assumed that the K of the upper drainage layer is decreasing log linearly with time from 1.0E-01 cm/s to 3.2E-03 cm/s, until year 2,246 at which time the K becomes static. Porosity (n), FC, and WP will be assumed to behave similarly but in an arithmetic linear manner.

Initial and End State hydraulic properties:

Hydraulic Parameter	Initial Middle Backfill	Initial Upper Drainage Layer	End State at 2,246 years
K	1.0E-04 cm/s	1.0E-01 cm/s	3.2E-03 cm/s
n	0.37	0.38	0.375
FC	0.24	0.08	0.16
WP	0.136	0.013	0.0745

Determine fraction change for each year:

Year	Fraction
0	0 ÷ 2246 = 0
100	100 ÷ 2246 = 0.0445
300	300 ÷ 2246 = 0.1336
550	550 ÷ 2246 = 0.2449
1,000	1000 ÷ 2246 = 0.4452
1,800	1800 ÷ 2246 = 0.8014
3,400	1.0
5,600	1.0
10,000	1.0

Determine variation in K, n, FC, and WP with time in the middle backfill:

Year	Fraction, F	K [1] (cm/s)	n [2]	FC [3]	WP [4]
0	0	0.0001	0.37	0.24	0.136
100	0.0445	0.00012	0.37	0.236	0.133
300	0.1336	0.00016	0.371	0.229	0.128
550	0.2449	0.00023	0.371	0.220	0.121
1,000	0.4452	0.00046	0.372	0.204	0.109
1,800	0.8014	0.0016	0.374	0.176	0.0867
3,400	1.0	0.0032	0.375	0.16	0.0745
5,600	1.0	0.0032	0.375	0.16	0.0745
10,000	1.0	0.0032	0.375	0.16	0.0745

[1] $K = 10^{[-4 + ((-2.5 - (-4))F)]} = 10^{(-4 + 1.5F)}$

[2] n = 0.37 + (0.375 – 0.37)F

[3] FC = 0.24 – (0.24 – 0.16)F

[4] WP = 0.136 – (0.136 – 0.0745)F

Determine variation in K, n, FC, and WP with time in the upper drainage layer:

Year	Fraction, F	K [1] (cm/s)	n [2]	FC [3]	WP [4]
0	0	0.1	0.38	0.08	0.013
100	0.0445	0.086	0.38	0.084	0.016
300	0.1336	0.063	0.379	0.089	0.021
550	0.2449	0.043	0.379	0.10	0.028
1,000	0.4452	0.021	0.378	0.116	0.040
1,800	0.8014	0.0063	0.376	0.144	0.062
3,400	1.0	0.0032	0.375	0.16	0.0745
5,600	1.0	0.0032	0.375	0.16	0.0745
10,000	1.0	0.0032	0.375	0.16	0.0745

[1] $K = 10^{[-1 + ((-2.5 - (-1))F)]} = 10^{(-1 - 1.5F)}$

[2] n = 0.38 - (0.38 – 0.375)F

[3] FC = 0.08 – (0.16 – 0.08)F

[4] WP = 0.013 – (0.0745 – 0.013)F

Lower Drainage Layer Hydraulic Properties:

It is assumed that colloidal clay migration from the overlying backfill is driven by the water flux through the upper GCL. This water flux driven clay migration enters into the 2-foot thick lower drainage layer and fills the lower drainage layer from the bottom up. This reduces the saturated hydraulic conductivity of the clay filled portion from 1.0E-01 to 1.0E-04 cm/s (i.e. the saturated hydraulic conductivity of the overlying backfill layer). As the thickness of the lower drainage layer filled with clay increases the overall hydraulic conductivity of the layer decreases. This is different from that assumed for the upper drainage layer since the lower drainage layer has significantly more backfill overlying it. The HELP model was run for each year with all of the previously degraded properties (see above) without degradation of the lower drainage layer in order to determine the infiltration through the upper GCL. The results are as follows:

Year	Infiltration through upper GCL (inches/year)
0	0.36170
100	0.41335
300	3.04724
550	7.89958
1,000	12.03710
1,800	13.76236
3,400	14.03487
5,600	14.07915
10,000	14.09278

It is assumed that there is a linear increase in the infiltration over time between data points.

Determine cumulative volume of water through the lower drainage layer over time:

Year	Infiltration through upper GCL (inches/year)	Time Step Volume [1] (inches)	Cumulative Volume [2] (inches)	Cumulative Volume over one ft^2 area [3] (ft^3)
0	0.36170	0	0	0
100	0.41335	38.752	38.752	3.2
300	3.04724	346.059	384.811	32.1
550	7.89958	1368.352	1753.163	146.1
1,000	12.03710	4485.753	6238.916	519.9
1,800	13.76236	10319.784	16558.700	1379.9
3,400	14.03487	22237.784	38796.484	3233.0
5,600	14.07915	30925.422	69721.906	5810.2
10,000	14.09278	61978.246	131700.152	10975.0

[1] $V = [I_1 \times (T_2 - T_1)] + [1/2 \times (I_2 - I_1)(T_2 - T_1)]$, where I = infiltration at time step 1 or 2; T = time at time step 1 or 2

[2] Cumulative Volume = Previous cumulative volume + Volume at current time step

[3] Cumulative Volume over one ft^2 area = (Cumulative Volume ÷ 12 in/ft) × 1 ft^2

Determine mass of clay to fill lower drainage layer void volume (0.38):

Assume clay bulk density is 1.1 g/cm^3

Look at a 1-ft^2 area of the 2-foot-thick upper drainage layer (i.e. 2 ft^3)

Void volume = 0.38 × 2 ft^3 = 0.76 ft^3

Clay mass per ft^3 = 1.1 g/cm^3 × 0.76 ft^3 × 2.831685E-02 m^3/ft^3 × 1,000,000 cm^3/m^3 = 23,672.9 g

Determine total flux of water into the lower drainage layer required to completely fill it with clay:

It will be assumed that the clay migrates out of the lower backfill into the lower drainage layer with the water flux containing 63 mg/L of colloidal clay.

$$V = \frac{23{,}672.9\ g \times 1000\ mg/g}{63\ mg/L \times 28.31685\ L/ft^3} = 13{,}269.8\ ft^3$$

Determine the mass of clay that has migrated into the lower drainage layer at the end of each time step:

Year	Mass of clay into lower drainage layer
0	0
100	3.2 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 5.7 g
300	32.1 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 57.3 g
550	146.1 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 260.6 g
1,000	519.9 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 927.5 g
1,800	1379.9 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 2,461.7 g
3,400	3233.0 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 5,767.5 g
5,600	5810.2 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 10,365.2 g
10,000	10975.0 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 19,579.0 g

Determine the fraction of the lower drainage layer filled at the end of each time step:

Year	Fraction of the lower drainage layer filled
0	0
100	5.7 g $\div$ 23,672.9 g = 0.000241
300	57.3 g $\div$ 23,672.9 g = 0.00242
550	260.6 g $\div$ 23,672.9 g = 0.0110
1,000	927.5 g $\div$ 23,672.9 g = 0.0392
1,800	2,461.7 g $\div$ 23,672.9 g = 0.104
3,400	5,767.5 g $\div$ 23,672.9 g = 0.244
5,600	10,365.2 g $\div$ 23,672.9 g = 0.438
10,000	19,579.0 g $\div$ 23,672.9 g = 0.827

The following are the hydraulic properties of the clean and clay filled portion of the lower drainage layer:

Material	Saturated Hydraulic Conductivity (cm/s)	Porosity	Field Capacity	Wilting Point
Clean	1.0E-01	0.38	0.08	0.013
Clay filled	1.0E-04	0.22 (see below)	0.21 (see below)	0.20 (see below)

Determine the porosity of the clay filled portion of the lower drainage layer:

Porosity of the clay:

Assumed clay bulk density, ρ_b = 1.1 g/cm^2

Assumed clay particle density, ρ_p = 2.6 g/cm^2

Resulting clay porosity, $n = 1 - \frac{\rho_b}{\rho_p} = 1 - \frac{1.1\ g/cm^2}{2.6\ g/cm^2} = 0.58$

Porosity of the clay filled portion = Porosity of clean portion $\times$ porosity of clay

Porosity of the clay filled portion = 0.38 $\times$ 0.58 = 0.22

Determine the field capacity and wilting point of the clay filled portion of the lower drainage layer:

Will assume that the field capacity and wilting point of the clay fill portion has the same ratio versus its porosity of 0.22 as the equivalent ratio for kaolin clay.

From WSRC 2002a the following kaolin properties are found: n = 0.56; FC = 0.55; WP = 0.50

FC = 0.22 $\times$ (0.55 $\div$ 0.56) $\approx$ 0.21

WP = 0.22 $\times$ (0.50 $\div$ 0.56) $\approx$ 0.20

Determine the equivalent horizontal hydraulic conductivity of the lower drainage layer over time:

The equivalent horizontal hydraulic conductivity for horizontal flow in a series of horizontal layers with different saturated hydraulic conductivities can be determined from the following equation (Freeze and Cherry 1979):

$$K_h = \sum_{i=1}^{n} \frac{K_i \; d_i}{d}$$

, where K_h = equivalent horizontal saturated hydraulic conductivity, K_i = horizontal saturated hydraulic conductivity of i^{th} layer, d_i = thickness of i^{th} layer, d = total thickness

The fraction, F, equals d_i / d for the clay filled portion and d_i / d for the clean drainage layer material equals (1 – F), making the equation:

$$K_h = \left(K_{filled} \times F\right) + \left[K_{clean} \times (1 - F)\right]$$

Year	Equivalent K (cm/s)
0	0.1
100	(0.0001 × 0.000241) + [0.1 × (1 - 0.000241)] = 0.1
300	(0.0001 × 0.00242) + [0.1 × (1 - 0.00242)] = 0.0998
550	(0.0001 × 0.0110) + [0.1 × (1 - 0.0110)] = 0.0989
1,000	(0.0001 × 0.0392) + [0.1 × (1 - 0.0392)] = 0.0961
1,800	(0.0001 × 0.104) + [0.1 × (1 - 0.104)] = 0.0896
3,400	(0.0001 × 0.244) + [0.1 × (1 - 0.244)] = 0.0756
5,600	(0.0001 × 0.438) + [0.1 × (1 - 0.438)] = 0.0562
10,000	(0.0001 × 0.827) + [0.1 × (1 - 0.827)] = 0.0174

Determine the equivalent n, FC, and WP for the lower drainage layer over time:

In an analogous manner to that for K, the equivalent n, FC, and WP can be determined based upon the fraction filled as follows:

$$n = \left(n_{filled} \times F\right) + \left[n_{clean} \times (1 - F)\right]$$

$$FC = \left(FC_{filled} \times F\right) + \left[FC_{clean} \times (1 - F)\right]$$

$$WP = \left(WP_{filled} \times F\right) + \left[WP_{clean} \times (1 - F)\right]$$

Year	Equivalent n
0	(0.22 × 0) + [0.38 × (1 - 0)] = 0.38
100	(0.22 × 0.000241) + [0.38 × (1 - 0.000241)] = 0.38
300	(0.22 × 0.00242) + [0.38 × (1 - 0.00242)] = 0.38
550	(0.22 × 0.0110) + [0.38 × (1 - 0.0110)] = 0.378
1,000	(0.22 × 0.0392) + [0.38 × (1 - 0.0392)] = 0.374
1,800	(0.22 × 0.104) + [0.38 × (1 - 0.104)] = 0.363
3,400	(0.22 × 0.244) + [0.38 × (1 - 0.244)] = 0.341
5,600	(0.22 × 0.438) + [0.38 × (1 - 0.438)] = 0.310
10,000	(0.22 × 0.827) + [0.38 × (1 - 0.827)] = 0.248

Year	Equivalent FC
0	$(0.21 \times 0) + [0.08 \times (1 - 0)] = 0.08$
100	$(0.21 \times 0.000241) + [0.08 \times (1 - 0.000241)] = 0.08$
300	$(0.21 \times 0.00242) + [0.08 \times (1 - 0.00242)] = 0.0803$
550	$(0.21 \times 0.0110) + [0.08 \times (1 - 0.0110)] = 0.0814$
1,000	$(0.21 \times 0.0392) + [0.08 \times (1 - 0.0392)] = 0.0851$
1,800	$(0.21 \times 0.104) + [0.08 \times (1 - 0.104)] = 0.0935$
3,400	$(0.21 \times 0.244) + [0.08 \times (1 - 0.244)] = 0.112$
5,600	$(0.21 \times 0.438) + [0.08 \times (1 - 0.438)] = 0.137$
10,000	$(0.21 \times 0.827) + [0.08 \times (1 - 0.827)] = 0.188$

Year	Equivalent WP
0	$(0.20 \times 0) + [0.013 \times (1 - 0)] = 0.013$
100	$(0.20 \times 0.000241) + [0.013 \times (1 - 0.000241)] = 0.013$
300	$(0.20 \times 0.00242) + [0.013 \times (1 - 0.00242)] = 0.0134$
550	$(0.20 \times 0.0110) + [0.013 \times (1 - 0.0110)] = 0.0150$
1,000	$(0.20 \times 0.0392) + [0.013 \times (1 - 0.0392)] = 0.0203$
1,800	$(0.20 \times 0.104) + [0.013 \times (1 - 0.104)] = 0.0324$
3,400	$(0.20 \times 0.244) + [0.013 \times (1 - 0.244)] = 0.0586$
5,600	$(0.20 \times 0.438) + [0.013 \times (1 - 0.438)] = 0.0949$
10,000	$(0.20 \times 0.827) + [0.013 \times (1 - 0.827)] = 0.168$

Summary Lower Drainage Layer Hydraulic Properties with Time:

Year	K (cm/s)	n	FC	WP
0	0.1	0.38	0.08	0.013
100	0.1	0.38	0.08	0.013
300	0.0998	0.38	0.0803	0.0134
550	0.0989	0.378	0.0814	0.0150
1,000	0.0961	0.374	0.0851	0.0203
1,800	0.0896	0.363	0.0935	0.0324
3,400	0.0756	0.341	0.112	0.0586
5,600	0.0562	0.310	0.137	0.0949
10,000	0.0174	0.248	0.188	0.168

The HELP model was rerun for each time step with all of the degraded properties (see above) including that of the lower drainage layer. Infiltration through the upper GCL did not change with the addition of the degraded lower drainage layer properties. Therefore the above estimated lower drainage layer hydraulic properties over time are verified.

Worse Case Infiltration through the Upper GCL

The worse case infiltration through the upper GCL and the associated time of occurrence have been determined based upon the following:

- As documented in Phifer and Nelson (2003), worse case infiltration occurs when both the topsoil and upper backfill have eroded away, since the underlying erosion barrier does not provide as efficient water storage for the promotion of evapotranspiration as the topsoil and upper backfill.
- Since degradation of the erosion barrier is assumed to be caused by intrusion of the overlying backfill following root decomposition, erosion barrier degradation will be assumed to cease once the upper backfill is eroded to three inches thick. Therefore erosion barrier properties will be taken as those at

complete erosion of the topsoil and upper backfill for determination of the worse case infiltration through the upper GCL. (see Table 4.4-1)

- As outlined in Appendix F, it is assumed that the material properties of the middle backfill and upper drainage layer become the same at year 2246 and remain constant thereafter. Therefore the middle backfill and upper drainage layer material properties will be taken as those determined at year 2246 for determination of the worse case infiltration through the upper GCL.
- The upper GCL becomes ineffective as a barrier layer at year 1800 when holes comprise 0.29 percent of the layer's area (see Appendix F). Therefore for determination of the worse case infiltration the GCL will be assigned as a barrier soil liner with the same material properties as the overlying middle backfill and upper drainage layer at year 2246.
- As previously demonstrated in Appendix F, the material properties of the lower drainage layer do not impact infiltration through the upper GCL. Completely silted in conditions will be assumed for the lower drainage layer for determination of the worse case infiltration.

From Section 4.2 the soil loss in terms of depth of loss per year for the topsoil and upper backfill was estimated to be 2.0E-04 inches/year and 1.2E-04 inches/year, respectively.

Determine time required to completely erode the topsoil:

6" ÷ 2.0E-04 inches/year = 30,000 years

Determine time required to completely erode the upper backfill:

30" ÷ 1.2E-04 inches/year = 250,000 years

Total time required to completely erode both the topsoil and upper backfill:

30,000 years + 250,000 years = 280,000 years

Determine the hydraulic properties of the erosion barrier when the upper backfill has eroded to three inches thick:

Determine time required to erode the upper backfill to 3 inches thick:

((30" – 3") ÷ 1.2E-04 inches/year) + 30,000 years = 255,000 years

Will use the average thickness of the topsoil plus upper backfill over the 225,000 years to determine the average hole penetration size in the erosion barrier over that period:

((30" + 6") + 3") ÷ 2 = 19.5"

Area of holes in erosion barrier due to root penetration:

Average Erosion Barrier Depth = 19.5" + ½(12") = 25.5" ≈ 2.1'

Root Diameter for 4-6' roots at 2.1':

3" diameter at 1' depth and 0.25" at 6'

$$(3''-0.25'')/(6'-1') = 0.55''/ft$$

Diameter = 0.25" + [(6' – 2.1') × 0.55"/ft] = 2.4"

Area for 4-6' roots at 2.1':

Area = $4 \times \frac{1}{4}\pi D^2 = \pi D^2 = \pi(2.4'')^2 = 18.1\ in^2$

Root Diameter for 1-12' root at 2.1':

3" diameter at 1' depth and 0.25" at 12'

$$(3"-0.25")/(12'-1') = 0.25"/ft$$

Diameter = 0.25” + [(12’ – 2.1’) × 0.25”/ft] = 2.73”

Area of for 1-12’ roots at 3.3’:

Area = $\frac{1}{4}\pi D^2 = \frac{1}{4}\pi(2.73")^2 = 5.8\ in^2$

Total area of holes in erosion barrier per tree:

Total area = $18.1\ in^2 + 5.8\ in^2 = 23.9\ in^2 \times ft^2/144\ in^2 \approx 0.17\ ft^2$/tree

Total area of holes per acre per 100 years:

400 trees/acre/100 years

Total area = $0.17\ ft^2$/tree × 400 trees/acre/100 years = $68\ ft^2$/acre/100 years

Area of holes in erosion barrier at year 255,000:

$68\ ft^2$/ acre + [(255,000 yrs – 300 yrs) × $68\ ft^2$/acre/100 years = $173{,}264\ ft^2$/acre

This means that at 255,000 years the entire erosion barrier has been disturbed and mixed with the upper backfill layer. Therefore we will assume that the erosion barrier properties at this time becomes that of 2-inch to 6-inch granite stone filled with the backfill. This is different from the way the properties were determined for the erosion barrier through 10,000 years, where the area of the erosion barrier impacted by root penetrations and backfill intrusion was less than 10 percent. Consideration of the erosion barrier as stone with backfill fill pores is assumed to provide the properties for the erosion barrier after complete mixing with the backfill. For backfill dropping into hole and mixing with the stone will assume that the saturated hydraulic conductivity of the backfill increases from 1E-04 to 1E-03 cm/s.

Determine the combined soil material properties for the 2-inch to 6-inch granite stone filled with backfill:

The porosity of the 2-inch to 6-inch granite stone with a d_{50} (i.e. median size) of 4 inches is taken as 0.397 based upon the porosity of poorly graded gravel from USEPA 1994a and USEPA 1994b.

From Table 3.1-1 the properties of the backfill are as follows:

Property	Property Value
Saturated Hydraulic Conductivity	1.0E-03 cm/s [1]
Porosity	0.37
Field Capacity [1]	0.24
Wilting Point [1]	0.136

[1] For backfill dropping into hole and mixing with the stone will assume that the saturated hydraulic conductivity of the backfill increases from 1E-04 to 1E-03 cm/s.

The matrix of an individual granite stone itself is considered impermeable and non-porous. The porosity of a layer of granite stone is considered to be 0.397. When the granite stone porosity is filled with backfill, the resultant hydraulic properties, which are area or volume based, become that of the backfill times the granite stone porosity. The resultant hydraulic properties are shown below:

Property	Property Value
Saturated Hydraulic Conductivity	1.0E-03 cm/s × 0.397 = 3.97E-04 cm/s
Porosity	0.37 × 0.397 = 0.147
Field Capacity [1]	0.24 × 0.397 = 0.095
Wilting Point [1]	0.136 × 0.397 = 0.054

Based upon the above the following are the input properties utilized for the topsoil, upper backfill, erosion barrier, middle backfill, upper drainage layer, upper GCL, and lower drainage layer for determination of the worse case infiltration through the upper GCL.

Summary Hydraulic Properties layer for determination of the worse case infiltration through the upper GCL at 280,000 years:

Layer	Thickness (inches)	K (cm/s)	n	FC	WP
Topsoil	0	NA	NA	NA	NA
Upper Backfill	0	NA	NA	NA	NA
Erosion Barrier	12	3.97E-04	0.147	0.095	0.054
Middle Backfill	12	3.2E-03	0.375	0.16	0.0745
Upper Drainage Layer	12	3.2E-03	0.375	0.16	0.0745
Upper GCL	0.2	3.2E-03	0.375	0.16	0.0745
Lower Drainage Layer	24	1.0E-04	0.37	0.24	0.136

NA = not applicable

To determine the CN number for determination of runoff the HELP model utilizes default soil textures. The HELP model does not include any default soil textures equivalent to the erosion barrier therefore soil texture #5 which has been utilized for all other HELP model runs has also been utilized for this worse case run. This is considered appropriate since on a yearly average basis runoff is a very small percentage of the annual precipitation compared to evapotranspiration, lateral drainage, and infiltration.

The above parameter values were utilized as HELP model input to determine the worse case infiltration through the upper GCL at 280,000 years. The detailed HELP model input data and output file associated with this worse case infiltration are provided at the end of this appendix. The worse case infiltration through the upper GCL at 280,000 years was determined to be 18.118 inches/year.

Determine time required to completely erode the topsoil and erode the upper backfill to 22 inches thick (22 inches is the evapotranspiration zone depth utilized in the HELP modeling (Phifer and Nelson 2003)):

(6” ÷ 2.0E-04 inches/year) + ((30” – 22”) ÷ 1.2E-04 inches/year) = 96,667 years

From year 96,667 it is assumed that infiltration through the upper GCL would increase linearly from approximately 14.1 inches/year to approximately 18.1 inches/year in year 280,000.

Year that Lower Drainage Layer Completely Silts In

From year 10,000 to year 96,667 it is assumed that the infiltration through the upper GCL is 14.1 inches per year. From previous calculations above:

- It takes a total of 13,269.8 ft^3 of infiltrating water to completely silt in the lower drainage layer
- Through year 10,000 the infiltrating water volume was 10975.0 ft^3

Determine water volume remaining after year 10,000 to completely silt in the lower drainage layer:

V = 13,269.8 ft^3 – 10,975.0 ft^3 = 2,294.8 ft^3

Determine length of time to obtain this volume at 14.1 inches per year over a 1-ft^2 area:

Time = 2,294.8 ft^3 ÷ (14.1 in/yr/ft^2 ÷ 12 in/ft) = 1,953 years

Determine time to completely silt in the lower drainage layer:

Time = 10,000 years + 1,953 years = 11,953 years

Preliminary 10,000 Year Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	19.63 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 in
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	450 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 54.4	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	4 (flexible membrane liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	4.0		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.088	0.0726	0.0596	0.0726
4	1	12		0.375	0.16	0.0745	0.16
5	2	12		0.375	0.16	0.0745	0.16
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.57		0.37	0.24	0.136	0.24
8	2	24		0.37	0.24	0.136	0.24
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Preliminary 10,000 Year Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity * (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	4.51E-04					
4	1	3.20E-03					
5	2	3.20E-03	450	3			
6	4	5.00E-09					
7	1	1.00E-04					
8	2	1.00E-04	150	11.4			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	4	0	728,360	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data is missing from the table.

* The HELP model output often produces an increased number of significant digits for the Effective Saturated Hydraulic Conductivity over that of the actual input.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfmse\ZMSE10K.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfmse\ZMSE10Ko.OUT

TIME:  10: 6     DATE:  11/18/2003

******************************************************************************

     TITLE:  Degraded SDF MSE Vault Closure Cap - 10,000 Year Condition

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      4.00   INCHES
           POROSITY                   =      0.4000 VOL/VOL
           FIELD CAPACITY             =      0.1100 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     30.00   INCHES
           POROSITY                   =      0.3700 VOL/VOL
           FIELD CAPACITY             =      0.2400 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

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                         LAYER  3
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.0880 VOL/VOL
FIELD CAPACITY               =      0.0726 VOL/VOL
WILTING POINT                =      0.0596 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0726 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.451000000000E-03 CM/SEC

                         LAYER  4
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3750 VOL/VOL
FIELD CAPACITY               =      0.1600 VOL/VOL
WILTING POINT                =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.319999992000E-02 CM/SEC

                         LAYER  5
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3750 VOL/VOL
FIELD CAPACITY               =      0.1600 VOL/VOL
WILTING POINT                =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.319999992000E-02 CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    450.0    FEET

                         LAYER  6
                         --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS     = 728360.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  1 - PERFECT
```

```
                        LAYER  7
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     58.57   INCHES
   POROSITY                     =      0.3700 VOL/VOL
   FIELD CAPACITY               =      0.2400 VOL/VOL
   WILTING POINT                =      0.1360 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                        LAYER  8
                        --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     24.00   INCHES
   POROSITY                     =      0.3700 VOL/VOL
   FIELD CAPACITY               =      0.2400 VOL/VOL
   WILTING POINT                =      0.1360 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC
   SLOPE                        =     11.40   PERCENT
   DRAINAGE LENGTH              =    150.0    FEET

                        LAYER  9
                        --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =      0.20   INCHES
   POROSITY                     =      0.7500 VOL/VOL
   FIELD CAPACITY               =      0.7470 VOL/VOL
   WILTING POINT                =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
         GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
         AND A SLOPE LENGTH OF  450. FEET.

SCS RUNOFF CURVE NUMBER            =     54.40
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =     19.630  ACRES
EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      4.760  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.260  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.680  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     32.318  INCHES
TOTAL INITIAL WATER                =     32.318  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

RUNOFF

TOTALS	0.004	0.000	0.005	0.000	0.000	0.002
	0.035	0.102	0.019	0.009	0.002	0.000
STD. DEVIATIONS	0.021	0.000	0.031	0.003	0.003	0.018
	0.118	0.428	0.087	0.070	0.016	0.002

EVAPOTRANSPIRATION

TOTALS	1.585	2.108	3.139	3.595	3.564	4.118
	4.884	4.502	3.371	1.616	0.951	1.122
STD. DEVIATIONS	0.216	0.228	0.561	0.787	1.523	1.541
	1.589	1.382	1.045	0.605	0.211	0.203

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.0061	0.0040	0.0043	0.0018	0.0006	0.0009
	0.0015	0.0019	0.0017	0.0018	0.0023	0.0039
STD. DEVIATIONS	0.0044	0.0032	0.0038	0.0018	0.0011	0.0016
	0.0022	0.0026	0.0028	0.0027	0.0029	0.0034

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	2.8111	1.8484	1.9611	0.8245	0.2546	0.3913
	0.7036	0.8544	0.7993	0.8077	1.0512	1.7855
STD. DEVIATIONS	2.0300	1.4710	1.7572	0.8068	0.5189	0.7108
	1.0035	1.2114	1.2709	1.2375	1.3250	1.5606

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	0.4182	0.4907	0.5871	0.5667	0.4900	0.3788
	0.3217	0.2945	0.2785	0.2837	0.2830	0.3071
STD. DEVIATIONS	0.2832	0.2913	0.2837	0.2594	0.2084	0.1475
	0.1180	0.1321	0.1514	0.1573	0.2004	0.2202

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.8280	0.9637	1.1544	1.1168	0.9762	0.7602
	0.6480	0.5933	0.5605	0.5709	0.5665	0.6141
STD. DEVIATIONS	0.5440	0.5496	0.5330	0.4857	0.3999	0.2890
	0.2346	0.2621	0.2975	0.3100	0.3861	0.4260

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------------------------------------------------------------------------------
                AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
------------------------------------------------------------------------------

  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES                0.1639   0.1180   0.1143   0.0495   0.0148   0.0235
                            0.0410   0.0498   0.0481   0.0470   0.0633   0.1040

    STD. DEVIATIONS         0.1185   0.0941   0.1025   0.0486   0.0302   0.0428
                            0.0585   0.0707   0.0766   0.0722   0.0799   0.0910

  DAILY AVERAGE HEAD ON TOP OF LAYER  9
  -------------------------------------
    AVERAGES               31.2091  39.9104  43.5916  43.5755  36.8323  29.6012
                           24.3827  22.3049  21.7702  21.4581  22.0050  23.0932

    STD. DEVIATIONS        20.6375  22.8578  20.2177  19.0370  15.1675  11.3251
                            8.8948   9.9418  11.6603  11.7583  15.1337  16.1600

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     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
------------------------------------------------------------------------------
                                      INCHES           CU. FEET      PERCENT
                                 -------------------  -------------  ---------
 PRECIPITATION                    48.90    (   7.734)   3484469.2     100.00

 RUNOFF                            0.181   (  0.4657)     12875.48      0.370

 EVAPOTRANSPIRATION               34.556   (  3.5776)   2462356.25     70.667

 LATERAL DRAINAGE COLLECTED        0.03075 (  0.01239)     2191.156    0.06288
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH      14.09278 (  5.66993)  1004207.940   28.81954
   LAYER  6

 AVERAGE HEAD ON TOP               0.070 (    0.028)
   OF LAYER  6

 LATERAL DRAINAGE COLLECTED        4.69999 (  1.66647)   334906.437    9.61141
   FROM LAYER  8

 PERCOLATION/LEAKAGE THROUGH       9.35258 (  3.20171)   666435.500   19.12588
   LAYER  9

 AVERAGE HEAD ON TOP              29.978 (   10.348)
   OF LAYER  9

 CHANGE IN WATER STORAGE           0.080   (  3.8058)      5703.87      0.164

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              PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
   ------------------------------------------------------------------------
                                                  (INCHES)      (CU. FT.)
                                                 ----------   -------------
     PRECIPITATION                                 6.87        489534.875

     RUNOFF                                        2.803       199717.7340

     DRAINAGE COLLECTED FROM LAYER  5              0.00426        303.65695

     PERCOLATION/LEAKAGE THROUGH LAYER  6          1.950070    138955.95300

     AVERAGE HEAD ON TOP OF LAYER  6               3.527

     MAXIMUM HEAD ON TOP OF LAYER  6               6.344

     LOCATION OF MAXIMUM HEAD IN LAYER  5
           (DISTANCE FROM DRAIN)                  44.9 FEET

     DRAINAGE COLLECTED FROM LAYER  8              0.03765       2682.47388

     PERCOLATION/LEAKAGE THROUGH LAYER  9          0.070386      5015.48437

     AVERAGE HEAD ON TOP OF LAYER  9              82.570

     MAXIMUM HEAD ON TOP OF LAYER  9             101.074

     LOCATION OF MAXIMUM HEAD IN LAYER  8
           (DISTANCE FROM DRAIN)                  63.2 FEET

     SNOW WATER                                    2.36        168188.7190

     MAXIMUM VEG. SOIL WATER (VOL/VOL)                     0.3685

     MINIMUM VEG. SOIL WATER (VOL/VOL)                     0.1218

      ***  Maximum heads are computed using McEnroe's equations.  ***

           Reference:  Maximum Saturated Depth over Landfill Liner
                       by Bruce M. McEnroe, University of Kansas
                       ASCE Journal of Environmental Engineering
                       Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	1.1692	0.2923
2	9.0114	0.3004
3	0.8712	0.0726
4	2.9221	0.2435
5	2.3601	0.1967
6	0.0000	0.0000
7	15.8699	0.2710
8	7.9688	0.3320
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Worse Case Infiltration through Upper GCL at 280,000 years Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	19.63 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 in
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	450 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 54.4	

Layer	Layer Number	Layer Type
Erosion Barrier	1	1 (vertical percolation layer)
Middle Backfill	2	1 (vertical percolation layer)
Upper Drainage Layer	3	2 (lateral drainage layer)
Upper GCL	4	4 (flexible membrane liner)
Lower Backfill	5	1 (vertical percolation layer)
Lower Drainage Layer	6	2 (lateral drainage layer)
Lower GCL	7	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	12		0.147	0.095	0.054	0.095
2	1	12		0.375	0.16	0.0745	0.16
3	2	12		0.375	0.16	0.0745	0.16
4 *	4	0.2		0.75	0.747	0.40	0.75
5	1	58.57		0.37	0.24	0.136	0.24
6	2	24		0.37	0.24	0.136	0.24
7	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Worse Case Infiltration through Upper GCL at 280,000 years Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity * (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
3	1	3.97E-04					
4	1	3.20E-03					
5	2	3.20E-03	450	3			
6	3	3.20E-03					
7	1	1.00E-04					
8	2	1.00E-04	150	11.4			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	2				
4	3				
5	1				
6	2				
7	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data is missing from the table.
* The HELP model output often produces an increased number of significant digits for the Effective Saturated Hydraulic Conductivity over that of the actual input.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE              **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                  **
**                    USAE WATERWAYS EXPERIMENT STATION                    **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:     D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:       D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:   D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:     D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:   D:\HELP3\Hsdfmse\ZMSEW.D10
OUTPUT DATA FILE:            D:\HELP3\Hsdfmse\ZMSEWout.OUT

TIME:  10:14     DATE:  11/18/2003

******************************************************************************

     TITLE:  Degraded SDF MSE Vault Closure Cap - Worse Case Infiltration

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.

                                 LAYER  1
                                 --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     12.00   INCHES
           POROSITY                   =      0.1470 VOL/VOL
           FIELD CAPACITY             =      0.0950 VOL/VOL
           WILTING POINT              =      0.0540 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.0950 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.396999996000E-03 CM/SEC

                                 LAYER  2
                                 --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     12.00   INCHES
           POROSITY                   =      0.3750 VOL/VOL
           FIELD CAPACITY             =      0.1600 VOL/VOL
           WILTING POINT              =      0.0745 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1600 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.319999992000E-02 CM/SEC
```

```
                        LAYER  3
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3750 VOL/VOL
FIELD CAPACITY               =      0.1600 VOL/VOL
WILTING POINT                =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.319999992000E-02 CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    450.0    FEET

                        LAYER  4
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.319999992000E-02 CM/SEC
FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      0.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  4 - POOR

                        LAYER  5
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     58.57   INCHES
POROSITY                     =      0.3700 VOL/VOL
FIELD CAPACITY               =      0.2400 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                        LAYER  6
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     24.00   INCHES
POROSITY                     =      0.3700 VOL/VOL
FIELD CAPACITY               =      0.2400 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC
SLOPE                        =     11.40   PERCENT
DRAINAGE LENGTH              =    150.0    FEET
```

```
                         LAYER  7
                         --------

               TYPE 3 - BARRIER SOIL LINER
               MATERIAL TEXTURE NUMBER   0
 THICKNESS                    =      0.20   INCHES
 POROSITY                     =      0.7500 VOL/VOL
 FIELD CAPACITY               =      0.7470 VOL/VOL
 WILTING POINT                =      0.4000 VOL/VOL
 INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
 EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
         GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
         AND A SLOPE LENGTH OF  450. FEET.

SCS RUNOFF CURVE NUMBER            =     54.40
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =     19.630  ACRES
EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      2.740  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      5.514  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      1.393  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     24.947  INCHES
TOTAL INITIAL WATER                =     24.947  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR

           EVAPOTRANSPIRATION AND WEATHER DATA
           -----------------------------------

NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         AUGUSTA               GEORGIA

     STATION LATITUDE                        =  33.22 DEGREES
     MAXIMUM LEAF AREA INDEX                 =   3.50
     START OF GROWING SEASON (JULIAN DATE)   =     68
     END OF GROWING SEASON (JULIAN DATE)     =    323
     EVAPORATIVE ZONE DEPTH                  =  22.0  INCHES
     AVERAGE ANNUAL WIND SPEED               =   6.50 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  68.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  70.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  77.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  73.00 %

NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    AUGUSTA             GEORGIA
```

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.011	0.001	0.001	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.002	0.067	0.005	0.009	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.690	2.159	3.068	2.683	2.899	3.642
	4.134	3.680	2.853	1.542	1.096	1.308
STD. DEVIATIONS	0.207	0.242	0.626	0.929	1.233	1.379
	1.358	1.215	0.988	0.681	0.275	0.183

LATERAL DRAINAGE COLLECTED FROM LAYER 3

TOTALS	0.0008	0.0004	0.0006	0.0001	0.0002	0.0003
	0.0007	0.0012	0.0006	0.0004	0.0003	0.0004
STD. DEVIATIONS	0.0010	0.0008	0.0008	0.0004	0.0005	0.0006
	0.0012	0.0030	0.0012	0.0010	0.0007	0.0007

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	2.9374	1.5545	1.9390	0.4182	0.7096	1.1286
	1.6798	1.6670	1.5253	1.2088	1.3831	1.9667
STD. DEVIATIONS	2.1374	1.4918	1.9054	0.6376	1.1873	1.3010
	1.5902	1.8269	1.6880	1.6071	1.4554	1.7034

LATERAL DRAINAGE COLLECTED FROM LAYER 6

TOTALS	0.5667	0.5846	0.6452	0.5865	0.4836	0.4112
	0.4215	0.4714	0.4704	0.4870	0.4528	0.4781
STD. DEVIATIONS	0.2933	0.2630	0.2670	0.2508	0.2069	0.1793
	0.1902	0.2291	0.2192	0.2254	0.2358	0.2441

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	1.1134	1.1444	1.2654	1.1550	0.9630	0.8223
	0.8426	0.9371	0.9352	0.9680	0.8984	0.9484
STD. DEVIATIONS	0.5537	0.4871	0.4955	0.4677	0.3943	0.3467
	0.3696	0.4405	0.4206	0.4305	0.4447	0.4654

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0443	0.0284	0.0300	0.0070	0.0116	0.0180
	0.0297	0.0412	0.0274	0.0188	0.0224	0.0294
STD. DEVIATIONS	0.0378	0.0321	0.0326	0.0134	0.0213	0.0246
	0.0390	0.0832	0.0395	0.0323	0.0274	0.0291

DAILY AVERAGE HEAD ON TOP OF LAYER 7

AVERAGES	42.0370	47.4128	47.8032	45.0757	36.3302	32.0331
	31.7643	35.3471	36.4579	36.5203	35.0154	35.7764
STD. DEVIATIONS	21.0024	20.2134	18.7953	18.3316	14.9590	13.5913
	14.0198	16.7107	16.4870	16.3315	17.4309	17.6528

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     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                  INCHES              CU. FEET        PERCENT
                            -------------------   -------------   ---------
 PRECIPITATION              48.90    (   7.734)   3484469.2      100.00

 RUNOFF                      0.013   (  0.0681)       930.67       0.027

 EVAPOTRANSPIRATION         30.755   (  3.0768)   2191490.50      62.893

 LATERAL DRAINAGE COLLECTED  0.00600 (  0.00409)      427.798     0.01228
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH 18.11800 (  6.24708)  1291032.500    37.05105
   LAYER  4

 AVERAGE HEAD ON TOP         0.026 (    0.012)
   OF LAYER  4

 LATERAL DRAINAGE COLLECTED  6.05887 (  1.88577)   431736.125   12.39030
   FROM LAYER  6

 PERCOLATION/LEAKAGE THROUGH 11.99337 (  3.58072)   854610.312    24.52627
   LAYER  7

 AVERAGE HEAD ON TOP        38.464 (   11.538)
   OF LAYER  7

 CHANGE IN WATER STORAGE     0.074   (  3.2947)      5273.99       0.151
*******************************************************************************

******************************************************************************

              PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
   ------------------------------------------------------------------------
                                               (INCHES)      (CU. FT.)
                                              ----------   -------------
      PRECIPITATION                              6.87        489534.875

      RUNOFF                                     0.588        41918.4062

      DRAINAGE COLLECTED FROM LAYER  3           0.01519       1082.25757

      PERCOLATION/LEAKAGE THROUGH LAYER  4       3.401600    242387.45300

      AVERAGE HEAD ON TOP OF LAYER  4           12.569

      MAXIMUM HEAD ON TOP OF LAYER  4           19.880

      LOCATION OF MAXIMUM HEAD IN LAYER  3
            (DISTANCE FROM DRAIN)               93.8 FEET

      DRAINAGE COLLECTED FROM LAYER  6           0.03765       2682.47388
```

```
PERCOLATION/LEAKAGE THROUGH LAYER  7       0.070386      5015.48437

AVERAGE HEAD ON TOP OF LAYER  7          82.570

MAXIMUM HEAD ON TOP OF LAYER  7         101.074

LOCATION OF MAXIMUM HEAD IN LAYER  6
      (DISTANCE FROM DRAIN)              63.2 FEET

SNOW WATER                                2.36        168188.7190

MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.1884

MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.0633

 ***  Maximum heads are computed using McEnroe's equations.  ***

      Reference:  Maximum Saturated Depth over Landfill Liner
                  by Bruce M. McEnroe, University of Kansas
                  ASCE Journal of Environmental Engineering
                  Vol. 119, No. 2, March 1993, pp. 262-270.
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             FINAL WATER STORAGE AT END OF YEAR  100
    ----------------------------------------------------------------------
               LAYER        (INCHES)       (VOL/VOL)
               -----        --------       ---------
                 1            1.2473         0.1039

                 2            2.5310         0.2109

                 3            2.0266         0.1689

                 4            0.0000         0.0000

                 5           17.7582         0.3032

                 6            8.6350         0.3598

                 7            0.1500         0.7500

             SNOW WATER       0.000
```

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Appendix G, Degraded SDF MSE Vault Closure Cap (100 Years): HELP Model Input Data and Output File (output file name: ZMSED1ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	19.63 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	450 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 54.4	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	3 (barrier soil liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	5.980		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.06	0.056	0.052	0.056
4	1	12		0.37	0.236	0.133	0.236
5	2	12		0.38	0.084	0.016	0.084
6	3	0.2		0.75	0.747	0.40	0.75
7	1	58.57		0.37	0.24	0.136	0.24
8	2	24		0.38	0.08	0.013	0.08
9	3	0.2		0.75	0.747	0.40	0.75

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity * (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	3.97E-04					
4	1	1.20E-04					
5	2	8.60E-02	450	3			
6	3	5.00E-09					
7	1	1.00E-04					
8	2	1.00E-01	150	11.4			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	3				
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.
* The HELP model output often produces an increased number of significant digits for the Effective Saturated Hydraulic Conductivity over that of the actual input.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfmse\ZMSED1.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfmse\ZMSED1ou.OUT

TIME:  10: 3     DATE:  11/14/2003

******************************************************************************

     TITLE:  Degraded SDF MSE Vault Closure Cap - 100 years

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.

                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      5.98   INCHES
           POROSITY                   =      0.4000 VOL/VOL
           FIELD CAPACITY             =      0.1100 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                  LAYER  2
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     30.00   INCHES
           POROSITY                   =      0.3700 VOL/VOL
           FIELD CAPACITY             =      0.2400 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

```
                         LAYER  3
                         --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                  =     12.00   INCHES
POROSITY                   =      0.0600 VOL/VOL
FIELD CAPACITY             =      0.0560 VOL/VOL
WILTING POINT              =      0.0520 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0560 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.396999996000E-03 CM/SEC

                         LAYER  4
                         --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                  =     12.00   INCHES
POROSITY                   =      0.3700 VOL/VOL
FIELD CAPACITY             =      0.2360 VOL/VOL
WILTING POINT              =      0.1330 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.2360 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC

                         LAYER  5
                         --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                  =     12.00   INCHES
POROSITY                   =      0.3800 VOL/VOL
FIELD CAPACITY             =      0.0840 VOL/VOL
WILTING POINT              =      0.0160 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0840 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.860000029000E-01 CM/SEC
SLOPE                      =      3.00   PERCENT
DRAINAGE LENGTH            =    450.0    FEET

                         LAYER  6
                         --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                  =      0.20   INCHES
POROSITY                   =      0.7500 VOL/VOL
FIELD CAPACITY             =      0.7470 VOL/VOL
WILTING POINT              =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.499999997000E-08 CM/SEC
```

```
                         LAYER  7
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     58.57   INCHES
   POROSITY                     =      0.3700 VOL/VOL
   FIELD CAPACITY               =      0.2400 VOL/VOL
   WILTING POINT                =      0.1360 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                         LAYER  8
                         --------

               TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     24.00   INCHES
   POROSITY                     =      0.3800 VOL/VOL
   FIELD CAPACITY               =      0.0800 VOL/VOL
   WILTING POINT                =      0.0130 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.0800 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.100000001000     CM/SEC
   SLOPE                        =     11.40   PERCENT
   DRAINAGE LENGTH              =    150.0    FEET

                         LAYER  9
                         --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =      0.20   INCHES
   POROSITY                     =      0.7500 VOL/VOL
   FIELD CAPACITY               =      0.7470 VOL/VOL
   WILTING POINT                =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  450. FEET.

SCS RUNOFF CURVE NUMBER            =     54.40
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =     19.630  ACRES
EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      4.503  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      8.319  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      2.526  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     28.647  INCHES
TOTAL INITIAL WATER                =     28.647  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                  0.004    0.000    0.004    0.000    0.000    0.002
                          0.027    0.091    0.016    0.006    0.002    0.001

  STD. DEVIATIONS         0.020    0.000    0.027    0.000    0.002    0.015
                          0.093    0.404    0.086    0.058    0.015    0.004

EVAPOTRANSPIRATION
------------------
  TOTALS                  1.577    2.093    3.072    3.553    3.657    4.141
                          4.898    4.520    3.385    1.619    0.948    1.115

  STD. DEVIATIONS         0.221    0.236    0.582    0.761    1.521    1.545
                          1.589    1.377    1.040    0.606    0.207    0.205

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
  TOTALS                  2.4637   2.0770   1.9305   1.2378   0.4334   0.3122
                          0.5454   0.8086   0.7465   0.7762   0.8953   1.4750

  STD. DEVIATIONS         1.7880   1.5043   1.4526   1.0508   0.4452   0.5705
                          0.7811   1.0159   1.0054   1.0565   1.1950   1.2982

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                  0.0705   0.0597   0.0558   0.0377   0.0163   0.0121
                          0.0180   0.0252   0.0237   0.0243   0.0271   0.0429

  STD. DEVIATIONS         0.0501   0.0418   0.0382   0.0287   0.0120   0.0156
                          0.0214   0.0275   0.0276   0.0289   0.0323   0.0351

LATERAL DRAINAGE COLLECTED FROM LAYER  8
----------------------------------------
  TOTALS                  0.0570   0.0532   0.0544   0.0394   0.0137   0.0081
                          0.0140   0.0206   0.0187   0.0201   0.0235   0.0377

  STD. DEVIATIONS         0.0354   0.0340   0.0407   0.0385   0.0217   0.0149
                          0.0199   0.0253   0.0244   0.0260   0.0305   0.0319

PERCOLATION/LEAKAGE THROUGH LAYER  9
------------------------------------
  TOTALS                  0.0051   0.0049   0.0054   0.0051   0.0050   0.0039
                          0.0037   0.0041   0.0040   0.0039   0.0037   0.0043

  STD. DEVIATIONS         0.0009   0.0002   0.0003   0.0005   0.0009   0.0017
                          0.0020   0.0020   0.0019   0.0020   0.0021   0.0019
```

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	2.4840	2.2841	1.9194	1.2805	0.4305	0.3204
	0.5418	0.8032	0.7723	0.7744	0.9190	1.4652
STD. DEVIATIONS	1.8885	1.7392	1.4460	1.1237	0.4423	0.5856
	0.7759	1.0092	1.0497	1.0610	1.2266	1.2896

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.0043	0.0044	0.0041	0.0031	0.0010	0.0006
	0.0011	0.0016	0.0015	0.0015	0.0018	0.0029
STD. DEVIATIONS	0.0027	0.0028	0.0031	0.0030	0.0016	0.0012
	0.0015	0.0019	0.0019	0.0020	0.0024	0.0024

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	48.90	(7.734)	3484469.2	100.00
RUNOFF	0.154	(0.4339)	10950.01	0.314
EVAPOTRANSPIRATION	34.578	(3.6236)	2463907.00	70.711
LATERAL DRAINAGE COLLECTED FROM LAYER 5	13.70162	(5.47438)	976335.062	28.01962
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.41335	(0.15024)	29453.703	0.84529
AVERAGE HEAD ON TOP OF LAYER 6	1.166	(0.472)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	0.36024	(0.14546)	25669.234	0.73668
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.05310	(0.00792)	3783.417	0.10858
AVERAGE HEAD ON TOP OF LAYER 9	0.002	(0.001)		
CHANGE IN WATER STORAGE	0.054	(1.9521)	3824.79	0.110

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	489534.875
RUNOFF	2.648	188654.3750
DRAINAGE COLLECTED FROM LAYER 5	0.39526	28164.91210
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.032853	2341.00708
AVERAGE HEAD ON TOP OF LAYER 6	38.433	
MAXIMUM HEAD ON TOP OF LAYER 6	50.445	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	156.8 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.01464	1042.84534
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000199	14.20408
AVERAGE HEAD ON TOP OF LAYER 9	0.034	
MAXIMUM HEAD ON TOP OF LAYER 9	0.071	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	2.36	168188.7190

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3691

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1148

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

****

FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	1.6080	0.2689
2	8.9916	0.2997
3	0.7200	0.0600
4	4.2406	0.3534
5	2.1757	0.1813
6	0.1500	0.7500
7	14.0568	0.2400
8	1.9215	0.0801
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix H, Degraded SDF MSE Vault Closure Cap (300 Years): HELP Model Input Data and Output File (output file name: ZMSED2ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	19.63 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	450 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 54.4	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	4 (flexible membrane liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	5.940		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.06	0.0562	0.0521	0.0562
4	1	12		0.371	0.229	0.128	0.229
5	2	12		0.379	0.089	0.021	0.089
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.57		0.37	0.24	0.136	0.24
8	2	24		0.38	0.0803	0.0134	0.0803
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity * (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	3.98E-04					
4	1	1.60E-04					
5	2	6.30E-02	450	3			
6	4	5.00E-09					
7	1	1.00E-04					
8	2	9.98E-02	150	11.4			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	4	0	7,432	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.
* The HELP model output often produces an increased number of significant digits for the Effective Saturated Hydraulic Conductivity over that of the actual input.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfmse\ZMSED2.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfmse\ZMSED2ou.OUT

TIME:  13: 3     DATE:  11/14/2003

******************************************************************************

     TITLE:  Degraded SDF MSE Vault Closure Cap - 300 years

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.

                                   LAYER  1
                                   --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      5.94   INCHES
           POROSITY                   =      0.4000 VOL/VOL
           FIELD CAPACITY             =      0.1100 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     30.00   INCHES
           POROSITY                   =      0.3700 VOL/VOL
           FIELD CAPACITY             =      0.2400 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

```
                     LAYER  3
                     --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.0600 VOL/VOL
FIELD CAPACITY              =     0.0562 VOL/VOL
WILTING POINT               =     0.0521 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0562 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.398000004000E-03 CM/SEC

                     LAYER  4
                     --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.3710 VOL/VOL
FIELD CAPACITY              =     0.2290 VOL/VOL
WILTING POINT               =     0.1280 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.2290 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.159999996000E-03 CM/SEC

                     LAYER  5
                     --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.3790 VOL/VOL
FIELD CAPACITY              =     0.0890 VOL/VOL
WILTING POINT               =     0.0210 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0890 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.630000010000E-01 CM/SEC
SLOPE                       =     3.00   PERCENT
DRAINAGE LENGTH             =   450.0    FEET

                     LAYER  6
                     --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     0.20   INCHES
POROSITY                    =     0.0000 VOL/VOL
FIELD CAPACITY              =     0.0000 VOL/VOL
WILTING POINT               =     0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY         =     0.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =  7432.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  1 - PERFECT
```

```
                         LAYER  7
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
 THICKNESS                   =     58.57   INCHES
 POROSITY                    =      0.3700 VOL/VOL
 FIELD CAPACITY              =      0.2400 VOL/VOL
 WILTING POINT               =      0.1360 VOL/VOL
 INITIAL SOIL WATER CONTENT  =      0.2400 VOL/VOL
 EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC

                         LAYER  8
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
 THICKNESS                   =     24.00   INCHES
 POROSITY                    =      0.3800 VOL/VOL
 FIELD CAPACITY              =      0.0803 VOL/VOL
 WILTING POINT               =      0.0134 VOL/VOL
 INITIAL SOIL WATER CONTENT  =      0.0803 VOL/VOL
 EFFECTIVE SAT. HYD. COND.   =  0.997999981000E-01 CM/SEC
 SLOPE                       =     11.40   PERCENT
 DRAINAGE LENGTH             =    150.0    FEET

                         LAYER  9
                         --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
 THICKNESS                   =      0.20   INCHES
 POROSITY                    =      0.7500 VOL/VOL
 FIELD CAPACITY              =      0.7470 VOL/VOL
 WILTING POINT               =      0.4000 VOL/VOL
 INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
 EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC

            GENERAL DESIGN AND EVAPORATIVE ZONE DATA
            ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  450. FEET.

 SCS RUNOFF CURVE NUMBER            =     54.40
 FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE =     19.630  ACRES
 EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE  =      4.508  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE =      8.318  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE =      2.529  INCHES
 INITIAL SNOW WATER                 =      0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS   =     28.478  INCHES
 TOTAL INITIAL WATER                =     28.478  INCHES
 TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                 0.004    0.000    0.004    0.000    0.000    0.002
                         0.027    0.091    0.016    0.006    0.002    0.001

  STD. DEVIATIONS        0.019    0.000    0.027    0.000    0.002    0.014
                         0.092    0.404    0.086    0.058    0.014    0.004

EVAPOTRANSPIRATION
------------------
  TOTALS                 1.577    2.094    3.075    3.555    3.655    4.138
                         4.896    4.521    3.385    1.618    0.948    1.115

  STD. DEVIATIONS        0.221    0.236    0.581    0.760    1.525    1.545
                         1.588    1.379    1.041    0.606    0.207    0.205

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
  TOTALS                 1.9675   1.6811   1.5612   1.0183   0.3681   0.2529
                         0.4394   0.6497   0.6048   0.6276   0.7212   1.1759

  STD. DEVIATIONS        1.4134   1.1907   1.1489   0.8430   0.3598   0.4555
                         0.6216   0.8081   0.8015   0.8449   0.9563   1.0331

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                 0.5469   0.4622   0.4273   0.2803   0.1015   0.0710
                         0.1209   0.1782   0.1674   0.1730   0.1974   0.3210

  STD. DEVIATIONS        0.4156   0.3409   0.3176   0.2402   0.0971   0.1234
                         0.1688   0.2203   0.2228   0.2328   0.2601   0.2812

LATERAL DRAINAGE COLLECTED FROM LAYER  8
----------------------------------------
  TOTALS                 0.1837   0.3398   0.4655   0.4517   0.4250   0.2963
                         0.1338   0.0828   0.1195   0.1636   0.1507   0.1796

  STD. DEVIATIONS        0.1968   0.3374   0.3167   0.2435   0.2283   0.1928
                         0.1367   0.1042   0.1457   0.1809   0.1784   0.2299

PERCOLATION/LEAKAGE THROUGH LAYER  9
------------------------------------
  TOTALS                 0.0044   0.0047   0.0058   0.0058   0.0060   0.0048
                         0.0040   0.0038   0.0038   0.0040   0.0038   0.0041

  STD. DEVIATIONS        0.0016   0.0016   0.0012   0.0009   0.0009   0.0019
                         0.0020   0.0021   0.0021   0.0022   0.0021   0.0021
```

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	2.7195	2.5205	2.1254	1.4394	0.4991	0.3543
	0.5958	0.8820	0.8562	0.8558	1.0106	1.5945
STD. DEVIATIONS	2.0691	1.8623	1.5804	1.2367	0.4879	0.6382
	0.8428	1.0989	1.1477	1.1616	1.3399	1.4009

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.0140	0.0283	0.0354	0.0355	0.0323	0.0233
	0.0102	0.0063	0.0094	0.0124	0.0118	0.0137
STD. DEVIATIONS	0.0150	0.0280	0.0241	0.0191	0.0174	0.0151
	0.0104	0.0079	0.0114	0.0138	0.0140	0.0175

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.90 (7.734)	3484469.2	100.00
RUNOFF	0.153 (0.4340)	10931.62	0.314
EVAPOTRANSPIRATION	34.578 (3.6248)	2463907.00	70.711
LATERAL DRAINAGE COLLECTED FROM LAYER 5	11.06777 (4.39790)	788655.062	22.63344
PERCOLATION/LEAKAGE THROUGH LAYER 6	3.04724 (1.22367)	217136.625	6.23156
AVERAGE HEAD ON TOP OF LAYER 6	1.288 (0.519)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	2.99194 (1.09253)	213196.031	6.11847
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.05487 (0.00829)	3909.907	0.11221
AVERAGE HEAD ON TOP OF LAYER 9	0.019 (0.007)		
CHANGE IN WATER STORAGE	0.054 (2.1676)	3869.66	0.111

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	489534.875
RUNOFF	2.646	188573.8440
DRAINAGE COLLECTED FROM LAYER 5	0.28968	20641.51170
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.239722	17081.85940
AVERAGE HEAD ON TOP OF LAYER 6	36.972	
MAXIMUM HEAD ON TOP OF LAYER 6	48.836	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	154.2 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.08807	6275.57715
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000347	24.69121
AVERAGE HEAD ON TOP OF LAYER 9	0.207	
MAXIMUM HEAD ON TOP OF LAYER 9	0.410	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	2.36	168188.7190
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3688	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1149	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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****

FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	1.6020	0.2697
2	9.2013	0.3067
3	0.7200	0.0600
4	3.9758	0.3313
5	2.2321	0.1860
6	0.0000	0.0000
7	14.0999	0.2407
8	1.9272	0.0803
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix I, Degraded SDF MSE Vault Closure Cap (550 Years): HELP Model Input Data and Output File (output file name: ZMSED3ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	19.63 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	450 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 54.4	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	4 (flexible membrane liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	5.890		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.061	0.0566	0.0523	0.0566
4	1	12		0.371	0.220	0.121	0.220
5	2	12		0.379	0.10	0.028	0.10
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.57		0.37	0.24	0.136	0.24
8	2	24		0.378	0.0814	0.0150	0.0814
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity * (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	3.99E-04					
4	1	2.30E-04					
5	2	4.30E-02	450	3			
6	4	5.00E-09					
7	1	1.00E-04					
8	2	9.89E-02	150	11.4			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	4	0	26,013	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.
* The HELP model output often produces an increased number of significant digits for the Effective Saturated Hydraulic Conductivity over that of the actual input.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfmse\ZMSED3.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfmse\ZMSED3ou.OUT

TIME:  13: 8     DATE:  11/14/2003

******************************************************************************

     TITLE:  Degraded SDF MSE Vault Closure Cap - 550 years

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.

                                   LAYER  1
                                   --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      5.89   INCHES
           POROSITY                   =      0.4000 VOL/VOL
           FIELD CAPACITY             =      0.1100 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     30.00   INCHES
           POROSITY                   =      0.3700 VOL/VOL
           FIELD CAPACITY             =      0.2400 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

```
                          LAYER  3
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    12.00   INCHES
POROSITY                     =     0.0610 VOL/VOL
FIELD CAPACITY               =     0.0566 VOL/VOL
WILTING POINT                =     0.0523 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.0566 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.399000011000E-03 CM/SEC

                          LAYER  4
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    12.00   INCHES
POROSITY                     =     0.3710 VOL/VOL
FIELD CAPACITY               =     0.2200 VOL/VOL
WILTING POINT                =     0.1210 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.2200 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.230000005000E-03 CM/SEC

                          LAYER  5
                          --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    12.00   INCHES
POROSITY                     =     0.3790 VOL/VOL
FIELD CAPACITY               =     0.1000 VOL/VOL
WILTING POINT                =     0.0280 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.1000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.430000015000E-01 CM/SEC
SLOPE                        =     3.00   PERCENT
DRAINAGE LENGTH              =   450.0    FEET

                          LAYER  6
                          --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     0.20   INCHES
POROSITY                     =     0.0000 VOL/VOL
FIELD CAPACITY               =     0.0000 VOL/VOL
WILTING POINT                =     0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY          =     0.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =  26013.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  1 - PERFECT
```

```
                    LAYER  7
                    --------

       TYPE 1 - VERTICAL PERCOLATION LAYER
           MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     58.57   INCHES
POROSITY                    =      0.3700 VOL/VOL
FIELD CAPACITY              =      0.2400 VOL/VOL
WILTING POINT               =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC

                    LAYER  8
                    --------

         TYPE 2 - LATERAL DRAINAGE LAYER
           MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.3780 VOL/VOL
FIELD CAPACITY              =      0.0814 VOL/VOL
WILTING POINT               =      0.0150 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0814 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.988999978000E-01 CM/SEC
SLOPE                       =     11.40   PERCENT
DRAINAGE LENGTH             =    150.0    FEET

                    LAYER  9
                    --------

           TYPE 3 - BARRIER SOIL LINER
           MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC

        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
        ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  450. FEET.

SCS RUNOFF CURVE NUMBER            =     54.40
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =     19.630  ACRES
EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      4.514  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      8.317  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      2.533  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     28.527  INCHES
TOTAL INITIAL WATER                =     28.527  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                  0.004    0.000    0.004    0.000    0.000    0.002
                          0.027    0.091    0.017    0.006    0.002    0.001

  STD. DEVIATIONS         0.019    0.000    0.027    0.000    0.002    0.014
                          0.092    0.405    0.087    0.058    0.014    0.004

EVAPOTRANSPIRATION
------------------
  TOTALS                  1.578    2.094    3.079    3.557    3.651    4.139
                          4.896    4.520    3.383    1.619    0.948    1.116

  STD. DEVIATIONS         0.221    0.236    0.581    0.759    1.525    1.546
                          1.589    1.381    1.040    0.605    0.207    0.205

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
  TOTALS                  1.1341   0.9257   0.8726   0.5419   0.1879   0.1415
                          0.2566   0.3693   0.3376   0.3535   0.4110   0.6826

  STD. DEVIATIONS         0.8224   0.6765   0.6756   0.4618   0.2027   0.2667
                          0.3678   0.4673   0.4642   0.4849   0.5508   0.6048

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                  1.4438   1.1770   1.1064   0.6896   0.2394   0.1811
                          0.3262   0.4687   0.4304   0.4504   0.5215   0.8651

  STD. DEVIATIONS         1.0609   0.8738   0.8575   0.5957   0.2560   0.3372
                          0.4653   0.5914   0.5930   0.6196   0.6973   0.7657

LATERAL DRAINAGE COLLECTED FROM LAYER  8
----------------------------------------
  TOTALS                  0.8559   1.1571   1.1806   1.0663   0.7649   0.4994
                          0.3038   0.2637   0.3633   0.4507   0.4561   0.4664

  STD. DEVIATIONS         0.8485   0.9655   0.6764   0.7197   0.3397   0.2480
                          0.2485   0.3425   0.4941   0.4482   0.5846   0.5382

PERCOLATION/LEAKAGE THROUGH LAYER  9
------------------------------------
  TOTALS                  0.0057   0.0064   0.0074   0.0071   0.0068   0.0056
                          0.0046   0.0039   0.0043   0.0047   0.0045   0.0045

  STD. DEVIATIONS         0.0028   0.0027   0.0017   0.0018   0.0008   0.0015
                          0.0021   0.0023   0.0025   0.0026   0.0026   0.0027
```

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	2.2638	2.0233	1.7350	1.1168	0.3732	0.2905
	0.5098	0.7337	0.6960	0.7048	0.8438	1.3561
STD. DEVIATIONS	1.6644	1.5031	1.3451	0.9661	0.4027	0.5475
	0.7307	0.9283	0.9618	0.9726	1.1308	1.2015

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.0656	0.0973	0.0905	0.0845	0.0587	0.0396
	0.0233	0.0202	0.0288	0.0346	0.0361	0.0358
STD. DEVIATIONS	0.0651	0.0813	0.0519	0.0570	0.0260	0.0197
	0.0191	0.0263	0.0392	0.0344	0.0463	0.0413

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	48.90	(7.734)	3484469.2	100.00
RUNOFF	0.153	(0.4344)	10929.73	0.314
EVAPOTRANSPIRATION	34.580	(3.6253)	2464038.00	70.715
LATERAL DRAINAGE COLLECTED FROM LAYER 5	6.21423	(2.47878)	442806.406	12.70800
PERCOLATION/LEAKAGE THROUGH LAYER 6	7.89958	(3.15969)	562899.812	16.15454
AVERAGE HEAD ON TOP OF LAYER 6	1.054	(0.422)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	7.82825	(2.95993)	557816.812	16.00866
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.06554	(0.01153)	4669.966	0.13402
AVERAGE HEAD ON TOP OF LAYER 9	0.051	(0.019)		
CHANGE IN WATER STORAGE	0.059	(2.5916)	4208.62	0.121

```
******************************************************************************

            PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
   --------------------------------------------------------------------------
                                                 (INCHES)      (CU. FT.)
                                                ----------    -------------
      PRECIPITATION                                6.87        489534.875

      RUNOFF                                       2.652       188986.2810

      DRAINAGE COLLECTED FROM LAYER  5             0.19569      13944.58300

      PERCOLATION/LEAKAGE THROUGH LAYER  6         0.447973     31921.14650

      AVERAGE HEAD ON TOP OF LAYER  6             21.780

      MAXIMUM HEAD ON TOP OF LAYER  6             31.661

      LOCATION OF MAXIMUM HEAD IN LAYER  5
            (DISTANCE FROM DRAIN)                122.6 FEET

      DRAINAGE COLLECTED FROM LAYER  8             0.31282      22290.66990

      PERCOLATION/LEAKAGE THROUGH LAYER  9         0.000802        57.18127

      AVERAGE HEAD ON TOP OF LAYER  9              0.744

      MAXIMUM HEAD ON TOP OF LAYER  9              1.445

      LOCATION OF MAXIMUM HEAD IN LAYER  8
            (DISTANCE FROM DRAIN)                  2.4 FEET

      SNOW WATER                                   2.36        168188.7190

      MAXIMUM VEG. SOIL WATER (VOL/VOL)                    0.3691

      MINIMUM VEG. SOIL WATER (VOL/VOL)                    0.1151

       ***  Maximum heads are computed using McEnroe's equations.  ***

            Reference:  Maximum Saturated Depth over Landfill Liner
                        by Bruce M. McEnroe, University of Kansas
                        ASCE Journal of Environmental Engineering
                        Vol. 119, No. 2, March 1993, pp. 262-270.

******************************************************************************
```

****

FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	1.5974	0.2712
2	9.1911	0.3064
3	0.7320	0.0610
4	3.8417	0.3201
5	2.3313	0.1943
6	0.0000	0.0000
7	14.6255	0.2497
8	1.9646	0.0819
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix J, Degraded SDF MSE Vault Closure Cap (1,000 Years): HELP Model Input Data and Output File (output file name: ZMSED4ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	19.63 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	450 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 54.4	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	4 (flexible membrane liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	5.8		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.062	0.0574	0.0526	0.0574
4	1	12		0.372	0.204	0.109	0.204
5	2	12		0.378	0.116	0.040	0.116
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.57		0.37	0.24	0.136	0.24
8	2	24		0.374	0.0851	0.0203	0.0851
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity * (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	4.01E-04					
4	1	4.60E-04					
5	2	2.10E-02	450	3			
6	4	5.00E-09					
7	1	1.00E-04					
8	2	9.61E-02	150	11.4			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	4	0	59,458	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

* The HELP model output often produces an increased number of significant digits for the Effective Saturated Hydraulic Conductivity over that of the actual input.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfmse\ZMSED4.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfmse\ZMSED4ou.OUT

TIME:  13:11     DATE:  11/14/2003

******************************************************************************

     TITLE:  Degraded SDF MSE Vault Closure Cap - 1,000 years

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.

                                  LAYER  1
                                  --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      5.80   INCHES
           POROSITY                   =      0.4000 VOL/VOL
           FIELD CAPACITY             =      0.1100 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT  =     0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC

                                  LAYER  2
                                  --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     30.00   INCHES
           POROSITY                   =      0.3700 VOL/VOL
           FIELD CAPACITY             =      0.2400 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT  =     0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC
```

```
                          LAYER  3
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.0620 VOL/VOL
FIELD CAPACITY              =      0.0574 VOL/VOL
WILTING POINT               =      0.0526 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0574 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.400999998000E-03 CM/SEC

                          LAYER  4
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3720 VOL/VOL
FIELD CAPACITY              =      0.2040 VOL/VOL
WILTING POINT               =      0.1090 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2040 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.460000010000E-03 CM/SEC

                          LAYER  5
                          --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3780 VOL/VOL
FIELD CAPACITY              =      0.1160 VOL/VOL
WILTING POINT               =      0.0400 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.1160 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.209999997000E-01 CM/SEC
SLOPE                       =      3.00   PERCENT
DRAINAGE LENGTH             =    450.0    FEET

                          LAYER  6
                          --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY         =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =  59458.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  1 - PERFECT
```

```
                    LAYER  7
                    --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     58.57   INCHES
   POROSITY                     =      0.3700 VOL/VOL
   FIELD CAPACITY               =      0.2400 VOL/VOL
   WILTING POINT                =      0.1360 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                    LAYER  8
                    --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     24.00   INCHES
   POROSITY                     =      0.3740 VOL/VOL
   FIELD CAPACITY               =      0.0851 VOL/VOL
   WILTING POINT                =      0.0203 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.0851 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.961000025000E-01 CM/SEC
   SLOPE                        =     11.40   PERCENT
   DRAINAGE LENGTH              =    150.0    FEET

                    LAYER  9
                    --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =      0.20   INCHES
   POROSITY                     =      0.7500 VOL/VOL
   FIELD CAPACITY               =      0.7470 VOL/VOL
   WILTING POINT                =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  450. FEET.

SCS RUNOFF CURVE NUMBER             =     54.40
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =     19.630  ACRES
EVAPORATIVE ZONE DEPTH              =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      4.526  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.314  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.540  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     28.616  INCHES
TOTAL INITIAL WATER                 =     28.616  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                 0.003    0.000    0.004    0.000    0.000    0.002
                         0.027    0.092    0.016    0.006    0.002    0.001

  STD. DEVIATIONS        0.018    0.000    0.027    0.000    0.002    0.013
                         0.093    0.405    0.086    0.058    0.014    0.004

EVAPOTRANSPIRATION
------------------
  TOTALS                 1.578    2.095    3.082    3.559    3.648    4.138
                         4.895    4.520    3.383    1.618    0.949    1.116

  STD. DEVIATIONS        0.220    0.236    0.580    0.763    1.523    1.546
                         1.589    1.379    1.040    0.606    0.207    0.205

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
  TOTALS                 0.3927   0.2975   0.2914   0.1649   0.0552   0.0486
                         0.0904   0.1249   0.1121   0.1190   0.1402   0.2395

  STD. DEVIATIONS        0.2858   0.2265   0.2395   0.1471   0.0705   0.0939
                         0.1316   0.1629   0.1621   0.1698   0.1887   0.2141

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                 2.2751   1.7252   1.6884   0.9555   0.3215   0.2825
                         0.5245   0.7242   0.6502   0.6896   0.8127   1.3875

  STD. DEVIATIONS        1.6563   1.3201   1.3880   0.8510   0.4075   0.5434
                         0.7613   0.9431   0.9382   0.9830   1.0922   1.2393

LATERAL DRAINAGE COLLECTED FROM LAYER  8
----------------------------------------
  TOTALS                 1.6204   1.8444   1.7499   1.5010   0.9001   0.6044
                         0.4122   0.4847   0.6129   0.6970   0.7249   0.8009

  STD. DEVIATIONS        1.5405   1.4319   1.0925   1.0296   0.3834   0.3480
                         0.3822   0.6385   0.7505   0.7434   0.9149   0.8815

PERCOLATION/LEAKAGE THROUGH LAYER  9
------------------------------------
  TOTALS                 0.0075   0.0082   0.0088   0.0081   0.0071   0.0059
                         0.0050   0.0045   0.0049   0.0053   0.0053   0.0053

  STD. DEVIATIONS        0.0043   0.0035   0.0025   0.0023   0.0009   0.0016
                         0.0021   0.0028   0.0029   0.0030   0.0031   0.0033
```

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	1.5980	1.3284	1.1858	0.6932	0.2247	0.2042
	0.3676	0.5081	0.4713	0.4839	0.5894	0.9744
STD. DEVIATIONS	1.1637	1.0167	0.9753	0.6182	0.2868	0.3947
	0.5352	0.6628	0.6814	0.6908	0.7931	0.8709

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.1279	0.1596	0.1381	0.1224	0.0710	0.0493
	0.0325	0.0383	0.0500	0.0550	0.0591	0.0632
STD. DEVIATIONS	0.1216	0.1241	0.0862	0.0840	0.0303	0.0284
	0.0302	0.0504	0.0612	0.0587	0.0746	0.0696

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	48.90	(7.734)	3484469.2	100.00
RUNOFF	0.153	(0.4349)	10917.36	0.313
EVAPOTRANSPIRATION	34.581	(3.6232)	2464161.75	70.718
LATERAL DRAINAGE COLLECTED FROM LAYER 5	2.07646	(0.83367)	147962.172	4.24633
PERCOLATION/LEAKAGE THROUGH LAYER 6	12.03710	(4.83070)	857726.625	24.61571
AVERAGE HEAD ON TOP OF LAYER 6	0.719	(0.289)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	11.95268	(4.59408)	851710.875	24.44306
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.07579	(0.01481)	5400.314	0.15498
AVERAGE HEAD ON TOP OF LAYER 9	0.081	(0.031)		
CHANGE IN WATER STORAGE	0.061	(2.7895)	4316.20	0.124

****

```
*******************************************************************************

              PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
   ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------    -------------
      PRECIPITATION                               6.87         489534.875

      RUNOFF                                      2.657        189337.1870

      DRAINAGE COLLECTED FROM LAYER  5            0.09351        6663.55762

      PERCOLATION/LEAKAGE THROUGH LAYER  6        0.696376      49621.60160

      AVERAGE HEAD ON TOP OF LAYER  6            15.165

      MAXIMUM HEAD ON TOP OF LAYER  6            22.898

      LOCATION OF MAXIMUM HEAD IN LAYER  5
            (DISTANCE FROM DRAIN)               102.0 FEET

      DRAINAGE COLLECTED FROM LAYER  8            0.51557       36738.02340

      PERCOLATION/LEAKAGE THROUGH LAYER  9        0.001243         88.55154

      AVERAGE HEAD ON TOP OF LAYER  9             1.261

      MAXIMUM HEAD ON TOP OF LAYER  9             2.416

      LOCATION OF MAXIMUM HEAD IN LAYER  8
            (DISTANCE FROM DRAIN)                 4.5 FEET

      SNOW WATER                                  2.36         168188.7190

      MAXIMUM VEG. SOIL WATER (VOL/VOL)                   0.3690

      MINIMUM VEG. SOIL WATER (VOL/VOL)                   0.1154

       ***  Maximum heads are computed using McEnroe's equations.  ***

            Reference:  Maximum Saturated Depth over Landfill Liner
                        by Bruce M. McEnroe, University of Kansas
                        ASCE Journal of Environmental Engineering
                        Vol. 119, No. 2, March 1993, pp. 262-270.

*******************************************************************************
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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	1.5626	0.2694
2	8.9814	0.2994
3	0.7440	0.0620
4	3.8030	0.3169
5	2.4691	0.2058
6	0.0000	0.0000
7	14.9074	0.2545
8	2.0558	0.0857
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix K, Degraded SDF MSE Vault Closure Cap (1,800 Years): HELP Model Input Data and Output File (output file name: ZMSED5ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	19.63 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	450 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 54.4	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	4 (flexible membrane liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	5.64		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.065	0.0587	0.0532	0.0587
4	1	12		0.374	0.176	0.0867	0.176
5	2	12		0.376	0.144	0.062	0.144
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.57		0.37	0.24	0.136	0.24
8	2	24		0.363	0.0935	0.0324	0.0935
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity * (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	4.06E-04					
4	1	1.60E-03					
5	2	6.30E-03	450	3			
6	4	5.00E-09					
7	1	1.00E-04					
8	2	8.96E-02	150	11.4			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	4	0	118,916	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.
* The HELP model output often produces an increased number of significant digits for the Effective Saturated Hydraulic Conductivity over that of the actual input.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfmse\ZMSED5.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfmse\ZMSED5ou.OUT

TIME:  13:14     DATE:  11/14/2003

******************************************************************************

     TITLE:  Degraded SDF MSE Vault Closure Cap - 1,800 years

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =      5.64   INCHES
           POROSITY                     =      0.4000 VOL/VOL
           FIELD CAPACITY               =      0.1100 VOL/VOL
           WILTING POINT                =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT   =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =     30.00   INCHES
           POROSITY                     =      0.3700 VOL/VOL
           FIELD CAPACITY               =      0.2400 VOL/VOL
           WILTING POINT                =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC
```

```
                        LAYER  3
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.0650 VOL/VOL
FIELD CAPACITY              =      0.0587 VOL/VOL
WILTING POINT               =      0.0532 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0587 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.406000006000E-03 CM/SEC

                        LAYER  4
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3740 VOL/VOL
FIELD CAPACITY              =      0.1760 VOL/VOL
WILTING POINT               =      0.0867 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.1760 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.159999996000E-02 CM/SEC

                        LAYER  5
                        --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3760 VOL/VOL
FIELD CAPACITY              =      0.1440 VOL/VOL
WILTING POINT               =      0.0620 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.1440 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.630000001000E-02 CM/SEC
SLOPE                       =      3.00   PERCENT
DRAINAGE LENGTH             =    450.0    FEET

                        LAYER  6
                        --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY         =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS    = 118916.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  1 - PERFECT
```

```
                          LAYER  7
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     58.57   INCHES
   POROSITY                     =      0.3700 VOL/VOL
   FIELD CAPACITY               =      0.2400 VOL/VOL
   WILTING POINT                =      0.1360 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                          LAYER  8
                          --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     24.00   INCHES
   POROSITY                     =      0.3630 VOL/VOL
   FIELD CAPACITY               =      0.0935 VOL/VOL
   WILTING POINT                =      0.0324 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.0935 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.895999968000E-01 CM/SEC
   SLOPE                        =     11.40   PERCENT
   DRAINAGE LENGTH              =    150.0    FEET

                          LAYER  9
                          --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =      0.20   INCHES
   POROSITY                     =      0.7500 VOL/VOL
   FIELD CAPACITY               =      0.7470 VOL/VOL
   WILTING POINT                =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

            GENERAL DESIGN AND EVAPORATIVE ZONE DATA
            ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  450. FEET.

SCS RUNOFF CURVE NUMBER              =     54.40
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =     19.630  ACRES
EVAPORATIVE ZONE DEPTH               =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      4.547  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =      8.309  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      2.552  INCHES
INITIAL SNOW WATER                   =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =     28.816  INCHES
TOTAL INITIAL WATER                  =     28.816  INCHES
TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

RUNOFF

TOTALS	0.003	0.000	0.004	0.000	0.000	0.002
	0.026	0.092	0.016	0.006	0.002	0.000
STD. DEVIATIONS	0.015	0.000	0.028	0.000	0.001	0.013
	0.093	0.406	0.086	0.058	0.013	0.004

EVAPOTRANSPIRATION

TOTALS	1.579	2.097	3.087	3.559	3.641	4.137
	4.892	4.519	3.382	1.619	0.949	1.116
STD. DEVIATIONS	0.220	0.234	0.583	0.762	1.521	1.548
	1.588	1.378	1.040	0.606	0.207	0.205

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.0700	0.0495	0.0502	0.0253	0.0081	0.0088
	0.0166	0.0221	0.0195	0.0205	0.0251	0.0438
STD. DEVIATIONS	0.0508	0.0387	0.0433	0.0239	0.0128	0.0167
	0.0245	0.0298	0.0298	0.0304	0.0334	0.0388

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	2.6781	1.8952	1.9205	0.9690	0.3130	0.3356
	0.6367	0.8448	0.7456	0.7847	0.9621	1.6771
STD. DEVIATIONS	1.9460	1.4797	1.6539	0.9131	0.4905	0.6373
	0.9360	1.1402	1.1404	1.1611	1.2755	1.4820

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	1.9928	2.1103	2.0045	1.6221	0.9250	0.6154
	0.4429	0.5908	0.7472	0.7958	0.8309	0.9919
STD. DEVIATIONS	1.8473	1.6167	1.3180	1.1053	0.4060	0.4058
	0.4629	0.7955	0.8463	0.8817	1.0550	1.0806

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0088	0.0092	0.0096	0.0086	0.0072	0.0059
	0.0049	0.0046	0.0053	0.0057	0.0057	0.0060
STD. DEVIATIONS	0.0051	0.0041	0.0031	0.0027	0.0012	0.0018
	0.0023	0.0033	0.0033	0.0033	0.0036	0.0038

```
---------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
---------------------------------------------------------------------------

  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES                0.9493   0.7364   0.6806   0.3547   0.1104   0.1227
                            0.2254   0.2992   0.2728   0.2780   0.3522   0.5944

    STD. DEVIATIONS         0.6900   0.5751   0.5865   0.3348   0.1740   0.2335
                            0.3320   0.4043   0.4179   0.4117   0.4674   0.5255

  DAILY AVERAGE HEAD ON TOP OF LAYER  9
  -------------------------------------
    AVERAGES                0.1687   0.1959   0.1697   0.1419   0.0783   0.0538
                            0.0375   0.0500   0.0654   0.0674   0.0727   0.0840

    STD. DEVIATIONS         0.1564   0.1502   0.1116   0.0967   0.0344   0.0355
                            0.0392   0.0673   0.0740   0.0746   0.0923   0.0915

***************************************************************************

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     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
---------------------------------------------------------------------------
                                    INCHES            CU. FEET      PERCENT
                              -------------------  -------------  ---------
 PRECIPITATION                  48.90    (   7.734)    3484469.2    100.00

 RUNOFF                          0.153   (  0.4366)     10870.63      0.312

 EVAPOTRANSPIRATION             34.577   (  3.6265)    2463843.25    70.709

 LATERAL DRAINAGE COLLECTED      0.35957 (  0.14519)     25621.561    0.73531
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH    13.76236 (  5.55344)    980663.312   28.14384
   LAYER  6

 AVERAGE HEAD ON TOP             0.415 (    0.167)
   OF LAYER  6

 LATERAL DRAINAGE COLLECTED     13.66948 (  5.30758)    974044.625  27.95389
   FROM LAYER  8

 PERCOLATION/LEAKAGE THROUGH     0.08138 (  0.01726)      5799.073    0.16643
   LAYER  9

 AVERAGE HEAD ON TOP             0.099 (    0.038)
   OF LAYER  9

 CHANGE IN WATER STORAGE         0.060   (  2.7630)       4290.53     0.123

***************************************************************************
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*******************************************************************************

            PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
   ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------    -------------
      PRECIPITATION                              6.87         489534.875

      RUNOFF                                     2.665        189884.2500

      DRAINAGE COLLECTED FROM LAYER  5           0.02681        1910.22375

      PERCOLATION/LEAKAGE THROUGH LAYER  6       1.094036      77957.62500

      AVERAGE HEAD ON TOP OF LAYER  6           12.024

      MAXIMUM HEAD ON TOP OF LAYER  6           18.107

      LOCATION OF MAXIMUM HEAD IN LAYER  5
            (DISTANCE FROM DRAIN)               88.7 FEET

      DRAINAGE COLLECTED FROM LAYER  8           0.75273       53637.29300

      PERCOLATION/LEAKAGE THROUGH LAYER  9       0.001850        131.80533

      AVERAGE HEAD ON TOP OF LAYER  9            1.975

      MAXIMUM HEAD ON TOP OF LAYER  9            3.720

      LOCATION OF MAXIMUM HEAD IN LAYER  8
            (DISTANCE FROM DRAIN)                6.9 FEET

      SNOW WATER                                 2.36         168188.7190

      MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.3688

      MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.1160

       ***  Maximum heads are computed using McEnroe's equations.  ***

            Reference:  Maximum Saturated Depth over Landfill Liner
                        by Bruce M. McEnroe, University of Kansas
                        ASCE Journal of Environmental Engineering
                        Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	1.5522	0.2752
2	8.9327	0.2978
3	0.7800	0.0650
4	3.2243	0.2687
5	2.7466	0.2289
6	0.0000	0.0000
7	15.1942	0.2594
8	2.2567	0.0940
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix L, Degraded SDF MSE Vault Closure Cap (3,400 Years): HELP Model Input Data and Output File (output file name: ZMSED6ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	19.63 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	450 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 54.4	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	4 (flexible membrane liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	5.320		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.069	0.0614	0.0545	0.0614
4	1	12		0.375	0.16	0.0745	0.16
5	2	12		0.375	0.16	0.0745	0.16
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.57		0.37	0.24	0.136	0.24
8	2	24		0.341	0.112	0.0586	0.112
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	4.15E-04					
4	1	3.20E-03					
5	2	3.20E-03	450	3			
6	4	5.00E-09					
7	1	1.00E-04					
8	2	7.56E-02	150	11.4			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	4	0	237,832	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.
* The HELP model output often produces an increased number of significant digits for the Effective Saturated Hydraulic Conductivity over that of the actual input.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfmse\ZMSED6.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfmse\ZMSED6ou.OUT

TIME:  13:18     DATE:  11/14/2003

******************************************************************************

     TITLE:  Degraded SDF MSE Vault Closure Cap - 3,400 years

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      5.32   INCHES
           POROSITY                   =      0.4000 VOL/VOL
           FIELD CAPACITY             =      0.1100 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     30.00   INCHES
           POROSITY                   =      0.3700 VOL/VOL
           FIELD CAPACITY             =      0.2400 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

```
                      LAYER  3
                      --------

        TYPE 1 - VERTICAL PERCOLATION LAYER
            MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.0690 VOL/VOL
FIELD CAPACITY               =      0.0614 VOL/VOL
WILTING POINT                =      0.0545 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0614 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.414999988000E-03 CM/SEC

                      LAYER  4
                      --------

        TYPE 1 - VERTICAL PERCOLATION LAYER
            MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3750 VOL/VOL
FIELD CAPACITY               =      0.1600 VOL/VOL
WILTING POINT                =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.319999992000E-02 CM/SEC

                      LAYER  5
                      --------

          TYPE 2 - LATERAL DRAINAGE LAYER
            MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3750 VOL/VOL
FIELD CAPACITY               =      0.1600 VOL/VOL
WILTING POINT                =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.319999992000E-02 CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    450.0    FEET

                      LAYER  6
                      --------

          TYPE 4 - FLEXIBLE MEMBRANE LINER
            MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS     = 237832.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  1 - PERFECT
```

```
                         LAYER  7
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     58.57   INCHES
   POROSITY                     =      0.3700 VOL/VOL
   FIELD CAPACITY               =      0.2400 VOL/VOL
   WILTING POINT                =      0.1360 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                         LAYER  8
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     24.00   INCHES
   POROSITY                     =      0.3410 VOL/VOL
   FIELD CAPACITY               =      0.1120 VOL/VOL
   WILTING POINT                =      0.0586 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.1120 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.755999982000E-01 CM/SEC
   SLOPE                        =     11.40   PERCENT
   DRAINAGE LENGTH              =    150.0    FEET

                         LAYER  9
                         --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =      0.20   INCHES
   POROSITY                     =      0.7500 VOL/VOL
   FIELD CAPACITY               =      0.7470 VOL/VOL
   WILTING POINT                =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

            GENERAL DESIGN AND EVAPORATIVE ZONE DATA
            ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  450. FEET.

SCS RUNOFF CURVE NUMBER            =     54.40
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =    19.630  ACRES
EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      4.588  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.300  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.577  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     29.257  INCHES
TOTAL INITIAL WATER                =     29.257  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

RUNOFF

TOTALS	0.003	0.000	0.004	0.000	0.000	0.001
	0.027	0.092	0.016	0.007	0.002	0.000
STD. DEVIATIONS	0.018	0.000	0.027	0.000	0.003	0.010
	0.096	0.406	0.085	0.058	0.012	0.003

EVAPOTRANSPIRATION

TOTALS	1.581	2.100	3.102	3.564	3.620	4.135
	4.894	4.514	3.379	1.618	0.949	1.118
STD. DEVIATIONS	0.217	0.232	0.570	0.774	1.518	1.544
	1.591	1.379	1.041	0.606	0.209	0.204

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.0185	0.0126	0.0130	0.0060	0.0019	0.0024
	0.0045	0.0057	0.0051	0.0054	0.0067	0.0117
STD. DEVIATIONS	0.0133	0.0099	0.0114	0.0058	0.0035	0.0045
	0.0066	0.0080	0.0080	0.0081	0.0087	0.0103

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	2.7669	1.8857	1.9557	0.9004	0.2867	0.3563
	0.6795	0.8575	0.7684	0.8050	1.0118	1.7608
STD. DEVIATIONS	1.9888	1.4840	1.7064	0.8759	0.5289	0.6697
	0.9921	1.2030	1.2063	1.2172	1.3089	1.5409

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	2.0604	2.0833	2.0322	1.6062	0.9464	0.6431
	0.4864	0.6193	0.7343	0.8150	0.8581	1.0438
STD. DEVIATIONS	1.9061	1.6308	1.3617	1.0531	0.4006	0.3762
	0.4640	0.8203	0.7920	0.8766	1.0482	1.1181

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0099	0.0100	0.0105	0.0093	0.0077	0.0065
	0.0055	0.0053	0.0057	0.0062	0.0063	0.0068
STD. DEVIATIONS	0.0060	0.0047	0.0037	0.0029	0.0013	0.0017
	0.0023	0.0035	0.0034	0.0036	0.0038	0.0042

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.4926	0.3679	0.3481	0.1654	0.0509	0.0654
	0.1208	0.1525	0.1412	0.1432	0.1860	0.3134
STD. DEVIATIONS	0.3543	0.2898	0.3040	0.1613	0.0942	0.1232
	0.1767	0.2143	0.2220	0.2168	0.2409	0.2745

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.2067	0.2292	0.2039	0.1665	0.0949	0.0667
	0.0488	0.0621	0.0761	0.0818	0.0890	0.1047
STD. DEVIATIONS	0.1912	0.1793	0.1366	0.1092	0.0402	0.0390
	0.0466	0.0823	0.0821	0.0879	0.1087	0.1122

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.90 (7.734)	3484469.2	100.00
RUNOFF	0.153 (0.4378)	10886.89	0.312
EVAPOTRANSPIRATION	34.575 (3.6119)	2463673.75	70.704
LATERAL DRAINAGE COLLECTED FROM LAYER 5	0.09355 (0.03765)	6665.974	0.19131
PERCOLATION/LEAKAGE THROUGH LAYER 6	14.03487 (5.64284)	1000081.060	28.70110
AVERAGE HEAD ON TOP OF LAYER 6	0.212 (0.085)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	13.92841 (5.42028)	992495.500	28.48341
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.08953 (0.01941)	6379.354	0.18308
AVERAGE HEAD ON TOP OF LAYER 9	0.119 (0.046)		
CHANGE IN WATER STORAGE	0.061 (2.7396)	4367.94	0.125

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	489534.875
RUNOFF	2.661	189584.9220
DRAINAGE COLLECTED FROM LAYER 5	0.00949	676.41058
PERCOLATION/LEAKAGE THROUGH LAYER 6	1.422909	101392.05500
AVERAGE HEAD ON TOP OF LAYER 6	7.856	
MAXIMUM HEAD ON TOP OF LAYER 6	13.160	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	72.8 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.99945	71217.62500
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.002813	200.46278
AVERAGE HEAD ON TOP OF LAYER 9	3.108	
MAXIMUM HEAD ON TOP OF LAYER 9	5.724	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	10.1 FEET	
SNOW WATER	2.36	168188.7190
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3692	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1171	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	1.4484	0.2723
2	8.9111	0.2970
3	0.8280	0.0690
4	2.9062	0.2422
5	2.7051	0.2254
6	0.0000	0.0000
7	15.5532	0.2655
8	2.8846	0.1202
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix M, Degraded SDF MSE Vault Closure Cap (5,600 Years): HELP Model Input Data and Output File (output file name: ZMSED7ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	19.63 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	450 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 54.4	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	4 (flexible membrane liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	4.880		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.075	0.0651	0.0562	0.0651
4	1	12		0.375	0.16	0.0745	0.16
5	2	12		0.375	0.16	0.0745	0.16
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.57		0.37	0.24	0.136	0.24
8	2	24		0.310	0.137	0.0949	0.137
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity * (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	4.27E-04					
4	1	3.20E-03					
5	2	3.20E-03	450	3			
6	4	5.00E-09					
7	1	1.00E-04					
8	2	5.62E-02	150	11.4			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	4	0	401,341	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.
* The HELP model output often produces an increased number of significant digits for the Effective Saturated Hydraulic Conductivity over that of the actual input.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfmse\ZMSED7.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfmse\ZMSED7ou.OUT

TIME:  13:21     DATE:  11/14/2003

******************************************************************************

     TITLE:  Degraded SDF MSE Vault Closure Cap - 5,600 years

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      4.88   INCHES
           POROSITY                   =      0.4000 VOL/VOL
           FIELD CAPACITY             =      0.1100 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     30.00   INCHES
           POROSITY                   =      0.3700 VOL/VOL
           FIELD CAPACITY             =      0.2400 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

```
                         LAYER  3
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.0750 VOL/VOL
FIELD CAPACITY              =      0.0651 VOL/VOL
WILTING POINT               =      0.0562 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0651 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.426999992000E-03 CM/SEC

                         LAYER  4
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3750 VOL/VOL
FIELD CAPACITY              =      0.1600 VOL/VOL
WILTING POINT               =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.319999992000E-02 CM/SEC

                         LAYER  5
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3750 VOL/VOL
FIELD CAPACITY              =      0.1600 VOL/VOL
WILTING POINT               =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.319999992000E-02 CM/SEC
SLOPE                       =      3.00   PERCENT
DRAINAGE LENGTH             =    450.0    FEET

                         LAYER  6
                         --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY         =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS    = 401341.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  1 - PERFECT
```

```
                           LAYER  7
                           --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     58.57   INCHES
   POROSITY                     =      0.3700 VOL/VOL
   FIELD CAPACITY               =      0.2400 VOL/VOL
   WILTING POINT                =      0.1360 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                           LAYER  8
                           --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     24.00   INCHES
   POROSITY                     =      0.3100 VOL/VOL
   FIELD CAPACITY               =      0.1370 VOL/VOL
   WILTING POINT                =      0.0949 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.1370 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.562000014000E-01 CM/SEC
   SLOPE                        =     11.40   PERCENT
   DRAINAGE LENGTH              =    150.0    FEET

                           LAYER  9
                           --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =      0.20   INCHES
   POROSITY                     =      0.7500 VOL/VOL
   FIELD CAPACITY               =      0.7470 VOL/VOL
   WILTING POINT                =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

            GENERAL DESIGN AND EVAPORATIVE ZONE DATA
            ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  450. FEET.

SCS RUNOFF CURVE NUMBER             =     54.40
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =     19.630  ACRES
EVAPORATIVE ZONE DEPTH              =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      4.646  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.286  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.611  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     29.853  INCHES
TOTAL INITIAL WATER                 =     29.853  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

RUNOFF

TOTALS	0.003	0.000	0.004	0.000	0.000	0.001
	0.028	0.093	0.017	0.007	0.002	0.000
STD. DEVIATIONS	0.017	0.000	0.026	0.000	0.002	0.009
	0.100	0.412	0.084	0.060	0.014	0.001

EVAPOTRANSPIRATION

TOTALS	1.583	2.102	3.114	3.573	3.599	4.130
	4.890	4.510	3.379	1.617	0.950	1.120
STD. DEVIATIONS	0.217	0.231	0.570	0.784	1.518	1.539
	1.588	1.379	1.042	0.606	0.209	0.203

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.0110	0.0074	0.0078	0.0034	0.0011	0.0015
	0.0027	0.0034	0.0031	0.0032	0.0041	0.0071
STD. DEVIATIONS	0.0080	0.0058	0.0069	0.0034	0.0021	0.0028
	0.0039	0.0048	0.0049	0.0049	0.0052	0.0062

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	2.7836	1.8675	1.9591	0.8652	0.2705	0.3734
	0.6899	0.8524	0.7855	0.8140	1.0352	1.7829
STD. DEVIATIONS	2.0180	1.4745	1.7347	0.8474	0.5318	0.7042
	0.9934	1.2032	1.2476	1.2381	1.3092	1.5546

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	2.0981	2.0464	2.0430	1.5722	0.9337	0.6243
	0.4902	0.6397	0.7510	0.8199	0.8511	1.0811
STD. DEVIATIONS	1.9548	1.5809	1.4156	1.0091	0.4004	0.3635
	0.4752	0.8390	0.7733	0.8911	1.0444	1.1379

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0124	0.0119	0.0124	0.0107	0.0085	0.0073
	0.0068	0.0072	0.0075	0.0079	0.0078	0.0089
STD. DEVIATIONS	0.0072	0.0059	0.0052	0.0036	0.0015	0.0013
	0.0018	0.0032	0.0029	0.0033	0.0039	0.0042

```
----------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
----------------------------------------------------------------------------

  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES                0.2942   0.2162   0.2069   0.0943   0.0285   0.0407
                            0.0728   0.0900   0.0857   0.0860   0.1130   0.1884

    STD. DEVIATIONS         0.2135   0.1710   0.1835   0.0926   0.0562   0.0769
                            0.1050   0.1272   0.1363   0.1309   0.1431   0.1644

  DAILY AVERAGE HEAD ON TOP OF LAYER  9
  -------------------------------------
    AVERAGES                0.2831   0.3028   0.2757   0.2192   0.1260   0.0871
                            0.0662   0.0863   0.1047   0.1106   0.1187   0.1459

    STD. DEVIATIONS         0.2638   0.2340   0.1910   0.1407   0.0540   0.0507
                            0.0641   0.1132   0.1078   0.1203   0.1456   0.1536

*******************************************************************************

*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                     INCHES            CU. FEET      PERCENT
                                -------------------  -------------  ---------
 PRECIPITATION                   48.90    (   7.734)    3484469.2     100.00

 RUNOFF                           0.155   (  0.4458)     11053.73      0.317

 EVAPOTRANSPIRATION              34.566   (  3.6067)   2463066.00     70.687

 LATERAL DRAINAGE COLLECTED       0.05570 (  0.02249)     3969.001    0.11391
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH     14.07915 (  5.67674)  1003236.310   28.79165
   LAYER  6

 AVERAGE HEAD ON TOP              0.126 (    0.051)
   OF LAYER  6

 LATERAL DRAINAGE COLLECTED      13.95068 (  5.44356)   994082.125   28.52894
   FROM LAYER  8

 PERCOLATION/LEAKAGE THROUGH      0.10931 (  0.02037)     7789.155    0.22354
   LAYER  9

 AVERAGE HEAD ON TOP              0.161 (    0.063)
   OF LAYER  9

 CHANGE IN WATER STORAGE          0.063   (  2.7107)      4509.50      0.129

*******************************************************************************
```

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	489534.875
RUNOFF	2.694	191995.7030
DRAINAGE COLLECTED FROM LAYER 5	0.00687	489.31158
PERCOLATION/LEAKAGE THROUGH LAYER 6	1.733660	123535.20300
AVERAGE HEAD ON TOP OF LAYER 6	5.683	
MAXIMUM HEAD ON TOP OF LAYER 6	9.834	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	60.3 FEET	
DRAINAGE COLLECTED FROM LAYER 8	1.07658	76713.51560
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.004000	285.03003
AVERAGE HEAD ON TOP OF LAYER 9	4.504	
MAXIMUM HEAD ON TOP OF LAYER 9	8.100	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	13.4 FEET	
SNOW WATER	2.36	168188.7190
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3698	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1187	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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****

FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	1.4151	0.2900
2	9.0114	0.3004
3	0.7812	0.0651
4	2.8376	0.2365
5	2.7251	0.2271
6	0.0000	0.0000
7	15.5211	0.2650
8	3.7397	0.1558
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix N, Degraded SDF MSE Vault Closure Cap (10,000 Years): HELP Model Input Data and Output File (output file name: ZMSED8ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	19.63 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	450 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 54.4	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	4 (flexible membrane liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	4		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.088	0.0726	0.0596	0.0726
4	1	12		0.375	0.16	0.0745	0.16
5	2	12		0.375	0.16	0.0745	0.16
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.57		0.37	0.24	0.136	0.24
8	2	24		0.248	0.188	0.168	0.188
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity * (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	4.51E-04					
4	1	3.20E-03					
5	2	3.20E-03	450	3			
6	4	5.00E-09					
7	1	1.00E-04					
8	2	1.74E-02	150	11.4			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	4	0	728,360	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

* The HELP model output often produces an increased number of significant digits for the Effective Saturated Hydraulic Conductivity over that of the actual input.

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE              **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfmse\ZMSED8.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfmse\ZMSED8ou.OUT

TIME:  13:24     DATE:  11/14/2003

******************************************************************************

     TITLE:  Degraded SDF MSE Vault Closure Cap - 10,000 years

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      4.00   INCHES
           POROSITY                   =      0.4000 VOL/VOL
           FIELD CAPACITY             =      0.1100 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     30.00   INCHES
           POROSITY                   =      0.3700 VOL/VOL
           FIELD CAPACITY             =      0.2400 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

```
                        LAYER  3
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.0880 VOL/VOL
FIELD CAPACITY              =      0.0726 VOL/VOL
WILTING POINT               =      0.0596 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0726 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.451000000000E-03 CM/SEC

                        LAYER  4
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3750 VOL/VOL
FIELD CAPACITY              =      0.1600 VOL/VOL
WILTING POINT               =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.319999992000E-02 CM/SEC

                        LAYER  5
                        --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3750 VOL/VOL
FIELD CAPACITY              =      0.1600 VOL/VOL
WILTING POINT               =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.319999992000E-02 CM/SEC
SLOPE                       =      3.00   PERCENT
DRAINAGE LENGTH             =    450.0    FEET

                        LAYER  6
                        --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY         =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS    = 728360.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  1 - PERFECT
```

```
                    LAYER  7
                    --------

         TYPE 1 - VERTICAL PERCOLATION LAYER
            MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     58.57   INCHES
POROSITY                     =      0.3700 VOL/VOL
FIELD CAPACITY               =      0.2400 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                    LAYER  8
                    --------

           TYPE 2 - LATERAL DRAINAGE LAYER
            MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     24.00   INCHES
POROSITY                     =      0.2480 VOL/VOL
FIELD CAPACITY               =      0.1880 VOL/VOL
WILTING POINT                =      0.1680 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1880 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.174000002000E-01 CM/SEC
SLOPE                        =     11.40   PERCENT
DRAINAGE LENGTH              =    150.0    FEET

                    LAYER  9
                    --------

            TYPE 3 - BARRIER SOIL LINER
            MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

  NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
           SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
           GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
           AND A SLOPE LENGTH OF  450. FEET.

SCS RUNOFF CURVE NUMBER            =     54.40
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =     19.630  ACRES
EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      4.760  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      8.260  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      2.680  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     31.070  INCHES
TOTAL INITIAL WATER                =     31.070  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

RUNOFF

TOTALS	0.004	0.000	0.005	0.000	0.000	0.002
	0.035	0.102	0.019	0.009	0.002	0.000
STD. DEVIATIONS	0.021	0.000	0.031	0.003	0.003	0.018
	0.118	0.428	0.087	0.070	0.016	0.002

EVAPOTRANSPIRATION

TOTALS	1.585	2.108	3.139	3.595	3.564	4.118
	4.884	4.502	3.371	1.616	0.951	1.122
STD. DEVIATIONS	0.216	0.228	0.561	0.787	1.523	1.541
	1.589	1.382	1.045	0.605	0.211	0.203

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.0061	0.0040	0.0043	0.0018	0.0006	0.0009
	0.0015	0.0019	0.0017	0.0018	0.0023	0.0039
STD. DEVIATIONS	0.0044	0.0032	0.0038	0.0018	0.0011	0.0016
	0.0022	0.0026	0.0028	0.0027	0.0029	0.0034

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	2.8111	1.8484	1.9611	0.8245	0.2546	0.3913
	0.7036	0.8544	0.7993	0.8077	1.0512	1.7855
STD. DEVIATIONS	2.0300	1.4710	1.7572	0.8068	0.5189	0.7108
	1.0035	1.2114	1.2709	1.2375	1.3250	1.5606

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	2.1246	2.0599	2.0191	1.5171	0.8924	0.5721
	0.4621	0.6511	0.7839	0.8055	0.8492	1.1155
STD. DEVIATIONS	1.9402	1.5671	1.4295	0.9680	0.4016	0.3762
	0.5028	0.8779	0.7824	0.9085	1.0739	1.1815

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0294	0.0283	0.0284	0.0225	0.0155	0.0116
	0.0103	0.0125	0.0139	0.0143	0.0146	0.0179
STD. DEVIATIONS	0.0226	0.0182	0.0165	0.0112	0.0048	0.0044
	0.0059	0.0102	0.0091	0.0105	0.0125	0.0137

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.1639	0.1180	0.1143	0.0495	0.0148	0.0235
	0.0410	0.0498	0.0481	0.0470	0.0633	0.1040
STD. DEVIATIONS	0.1185	0.0941	0.1025	0.0486	0.0302	0.0428
	0.0585	0.0707	0.0766	0.0722	0.0799	0.0910

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.9261	0.9846	0.8801	0.6833	0.3890	0.2577
	0.2014	0.2838	0.3531	0.3511	0.3825	0.4862
STD. DEVIATIONS	0.8457	0.7497	0.6231	0.4360	0.1751	0.1694
	0.2192	0.3827	0.3524	0.3960	0.4837	0.5150

****

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.90 (7.734)	3484469.2	100.00
RUNOFF	0.181 (0.4657)	12875.48	0.370
EVAPOTRANSPIRATION	34.556 (3.5776)	2462356.25	70.667
LATERAL DRAINAGE COLLECTED FROM LAYER 5	0.03075 (0.01239)	2191.156	0.06288
PERCOLATION/LEAKAGE THROUGH LAYER 6	14.09278 (5.66993)	1004207.940	28.81954
AVERAGE HEAD ON TOP OF LAYER 6	0.070 (0.028)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	13.85254 (5.41675)	987088.687	28.32824
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.21922 (0.06364)	15620.731	0.44830
AVERAGE HEAD ON TOP OF LAYER 9	0.515 (0.201)		
CHANGE IN WATER STORAGE	0.061 (2.5632)	4336.44	0.124

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	489534.875
RUNOFF	2.803	199717.7340
DRAINAGE COLLECTED FROM LAYER 5	0.00426	303.65695
PERCOLATION/LEAKAGE THROUGH LAYER 6	1.950070	138955.95300
AVERAGE HEAD ON TOP OF LAYER 6	3.527	
MAXIMUM HEAD ON TOP OF LAYER 6	6.344	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	44.9 FEET	
DRAINAGE COLLECTED FROM LAYER 8	1.27885	91127.16410
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.014865	1059.20911
AVERAGE HEAD ON TOP OF LAYER 9	17.280	
MAXIMUM HEAD ON TOP OF LAYER 9	27.052	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	31.1 FEET	
SNOW WATER	2.36	168188.7190
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3685	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1218	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	1.1692	0.2923
2	9.0114	0.3004
3	0.8712	0.0726
4	2.9221	0.2435
5	2.3601	0.1967
6	0.0000	0.0000
7	15.8699	0.2710
8	4.8018	0.2001
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix O, Technical Report Design Checklist

TECHNICAL REPORT DESIGN CHECKLIST

Report Title: Saltstone Disposal Facility Mechanically Stabilized Earth Vault Closure Cap Degradation Base Case: Institutional Control to Pine Forest Scenario (U)

Reviewer: Jones, William E.

Activity Code:

Document No. WSRC-TR-2003-00523

Current Date: 12/09/03

Authors(s): Phifer, Mark A.

Date Needed: 12/10/03

Location of report and supplemental information: Final report available through Document Control. Supp. Info. available thru Mark A. Phifer; design check focused on report's HELP modeling

☑	Analytical/Experimental Approach	Instruction: The modeling is appropriate. The HELP model is long-established and widely accepted for water-balance analyses of cover systems.
☑	Mathematical Check	Instruction: Verified correct output for equations presented. Inputs are correct in magnitude. Units are correct.
☑	Inputs	Instruction: Inputs are applicable, representative and accurate. Selected values are reasonable for geographic location and expected construction.
☑	Assumptions	Instruction: Model assumptions, approach and input are reasonable and clearly presented.
☑	Output	Instruction: Model and report results are reasonable and clearly presented.
☑	Transcription	Instruction: Post-processing software not used, and therefore not checked against final results. Input spreadsheet tables were checked against model printouts.

Design check completed by: William E. Jones Date: 12/09/03

Comment resolution accepted by: Mark A. Phifer Date: 12/09/03

Date:

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