PERMIT MODIFICATION

FOR PHASE III OF THE

WHITE STREET MUNICIPAL SOLID WASTE LANDFILL

FEBRUARY 2000

PREPARED FOR:

CITY OF GREENSBORO

PREPARED BY:

HDR ENGINEERING, INC. OF THE CAROLINAS
128 SOUTH TRYON STREET, SUITE 1400
CHARLOTTE, NORTH CAROLINA 28202-5001

NORTH CAROLINA
PROFESSIONAL
SEAL
19027
ENGINEER
ERIC ALAN WRIGHT

2/10/2000

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF DRAWINGS

EXECUTIVE SUMMARY

This application addresses four proposed modifications to the Greensboro White Street landfill, Permit No. 41-12:

- Alternate Liner Demonstration for Cells 2 and 3 of Phase III in accordance with Rule .1624,
- Adjustment to the Cell 2 northwest boundary,
- Adjustment to the proposed subgrade of Cell 2,
- Revision to the proposed final grades in the Cell 2 area.

Alternate Liner System

An alternate composite liner system is proposed for the White Street Municipal Solid Waste (MSW) Landfill in Greensboro, North Carolina. The proposed alternative liner system consists of the following components from the top down:

- 60-mil HDPE geomembrane.
- Geosynthetic clay liner (GCL).
- 18 inches of 1E-5 cm/sec compacted soil liner.

This application is intended to satisfy the Point of Compliance (POC) demonstration required by Subtitle D, 40 CFR 258.40(a)(1), and the North Carolina Department of Environment and Natural Resources (NCDENR) Division of Waste Management Rule 15A NCAC 13B .1624. The proposed alternative liner system, was examined for the following factors:

- The rate of leakage through the alternate liner system.
- Contaminant concentration levels.

A POC analysis was performed to demonstrate that the alternate composite liner system would prevent ground water contamination levels at the POC from exceeding the specified Maximum Contaminant Levels (MCLS). This analysis was performed using the Environmental Protection Agency (EPA) Multimedia Exposure Assessment Model (MULTIMED version 1.01) using both site-specific and default Subtitle D values. The model simulates a steady-state condition that may develop in the future. The conservative Subtitle D model assumptions, as recommended by the EPA, ignore several significant modes of attenuation. These include potential decay of the contamination, processes of chemical reaction, biodegradation, and chemical adsorption. The only mode of attenuation for contaminants entering the subsurface allowed by EPA guidelines is physical dispersion and dilution in the vadose zone and receiving aquifer.

The MULTIMED analysis predicts a minimum dilution-attenuation factor (DAF) of 252 for the White Street Landfill. This result is based on the worst-case conditions (12-inch head over the entire liner) for the site with horizontal permeability of the upper aquifer between 1E-6 and 1E-1 cm/sec. The DAF for the worst-case condition modeled by HELP (7.3 inch head) is 680. These results satisfy the DAF minimum of 100 per EPA. Therefore, the proposed alternate liner system satisfies the demonstration required by 40 CFR 258.40(a)(1) and NCDENR Rule 15A NCAC 13B .1624.

This report also concludes that the proposed alternative liner system is expected to allow a lower flow rate through a given penetration in the geomembrane than the regulatory liner (i.e., 60-mil HDPE geomembrane overlying 2 feet of 1E-7 cm/sec soil) under identical conditions. Therefore, for equivalent field CQA programs, the proposed alternative composite liner should produce a lower leakage rate. The alternative composite liner, therefore, should provide greater protection against long-term migration of contaminants from the landfill leachate.

Cell 2 Boundary Adjustment

A Duke Power substation is located within landfill property adjacent to Phase III. At the time of original permitting, Duke Power owned the property and the Phase III boundary was established to maintain the minimum 300-foot buffer off the substation property. The impact of this separation requirement on the Phase III footprint was a reduction in potential lined area of approximately 0.9 acres. This area was discussed during the permitting process with NC DENR and the decision was made to apply for this modification after the City acquired the substation property. To expedite the permitting process this area was deleted from the original MSWLF unit design drawings, however all other aspects of the permit were handled as if this would become part of the unit.

The City of Greensboro obtained title to the substation on December 10, 1997. Revised drawings are included in this application that depict the additional 0.9 acre lined area afforded by the City owning the substation property. The design adjustments comply with all NCDENR buffer requirements.

Cell 2 Subgrade Adjustment

This modification incorporates the expanded footprint into the subgrade design of Cell 2. The required separation between groundwater has been maintained. Improved bedrock surface information was obtained during preliminary preparation of the subgrade. The attached Bedrock Surface Map has been modified based on this information. This resulted in raising grades in some locations and lowering them in others. The proposed revision maintains the required four-foot separation between the bedrock surface and liner system.

Final Grade Revision

The final grading plan is revised to reflect the liner boundary change in Cell 2. The net result of these changes increases the gross operating capacity of the facility by slightly more than 1%.

1.0 PURPOSE

The purpose of this application is to gain approval for four proposed landfill modifications. They include:

- Alternate Liner Demonstration for Cells 2 and 3 of Phase III in accordance with Rule .1624,
- Adjustment to the Cell 2 northwest boundary,
- Adjustment to the proposed subgrade of Cell 2,
- Revision to the proposed final grades in the Cell 2 area.

2.0 BACKGROUND

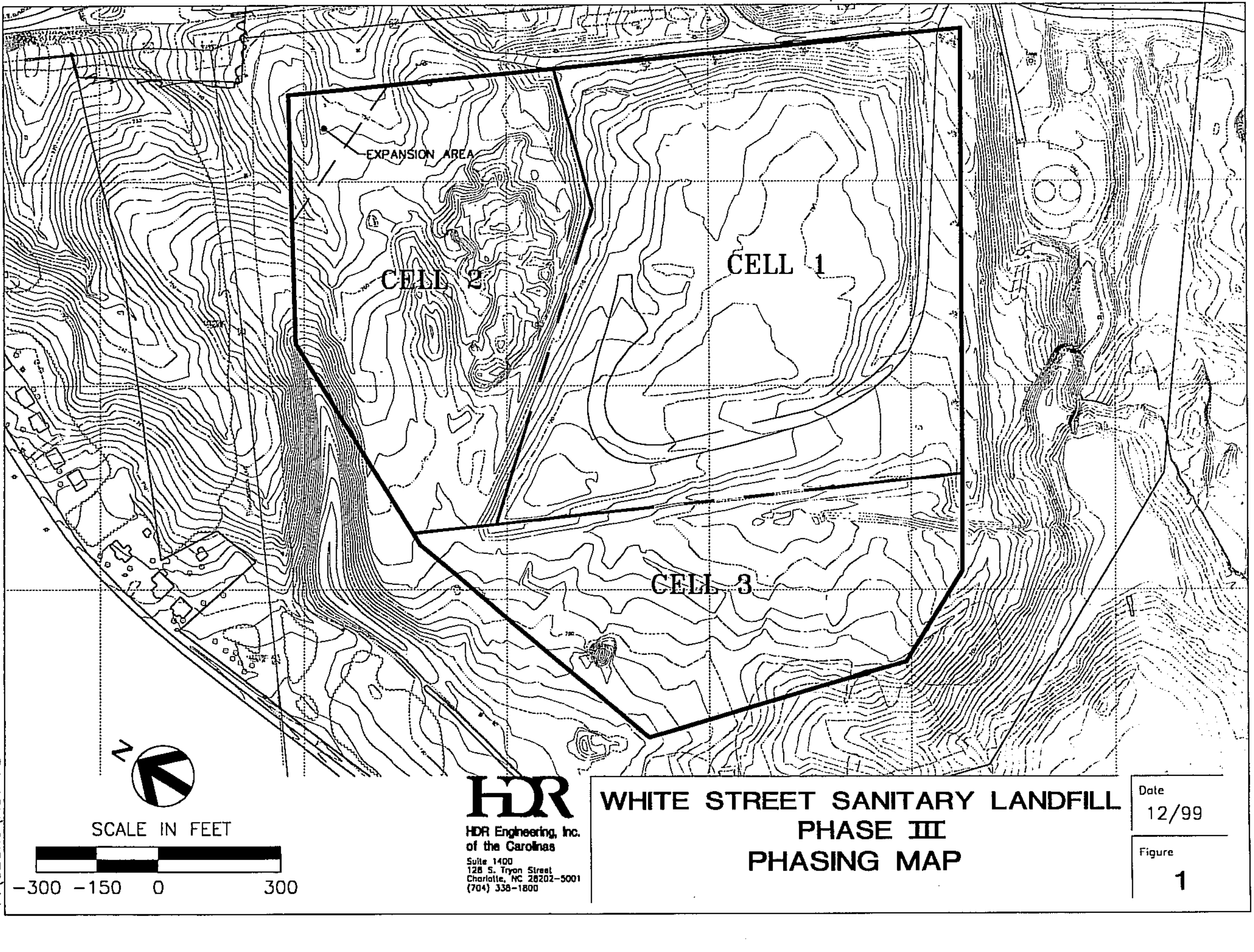
2.1 General History

The landfill is operated by the City of Greensboro as a municipal solid waste landfill under North Carolina Department of Environment and Natural Resources (NCDENR) permit 41-12. The landfill is located east of U.S. Highway 29, at the east end of White Street.

Waste disposal activities in the area now known as the White Street Sanitary Landfill began in 1943. The current landfill property covers an area of approximately 767 acres. As constructed, the landfill is divided into three Phases. Phase I is an 85-acre site that stopped receiving waste prior to 1978. Phase II consists of approximately 135 acres, which received municipal solid waste until the end of 1997. Phase III is the first area to be lined and consists of three cells totaling approximately 51 acres. Waste placement began in Cell 1 (approximately 25.5 acres) in December 1997.

2.2 Landfill Configuration

Cell 2 is located to the west of Cell 1, and Cell 3 is located South of Cells 1 and 2 (refer to Figure 1). The proposed subgrade ranges between 2 percent to 6 percent slope. Cells 2 and 3 consist of approximately 14 and 12 lined acres respectively. Based on information submitted with the Construction Permit Application, ground water generally flows in a north-northeast direction. The long axis of Cell 2 is roughly parallel to ground water flow. A minimum separation of 4 feet is required (by regulation) between the bottom of the liner and the estimated long-term seasonal high water table. A separation between the liner system and the long term seasonal high groundwater table of 5 feet was estimated based on data from boring B-1, as



HDR Engineering, Inc. of the Carolinas
Suite 1400
128 S. Tryon Street
Charlotte, NC 28202-5001
(704) 338-1800

WHITE STREET SANITARY LANDFILL
PHASE III
PHASING MAP

Date 12/99

Figure 1

P:\GBORO\FIG1-P3

reported in the Design Hydrogeologic Report. Boring B-1 is centrally located within Cell 2. This boring was chosen for modeling purposes to best represent the actual site conditions.

The proposed alternate liner system varies from the standard Subtitle D design by replacing the 2-foot thick 1E-7 cm/sec compacted clay liner with a geosynthetic clay (bentonite) liner (GCL) and 18 inches of 1E-5 cm/sec soil. The cell layout is illustrated in Figure 1.

3.0 ALTERNATE LINER DEMONSTRATION

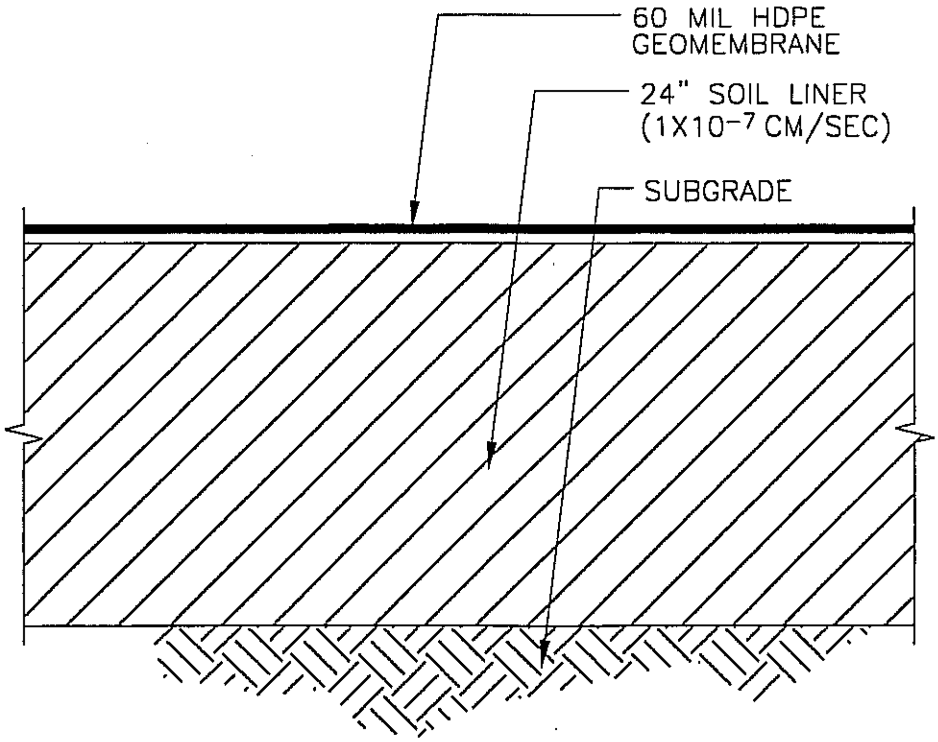
According to Rule 15A NCAC 13B .1624., the alternate liner design must demonstrate, through a modeling approach acceptable to NCDENR, that it meets the following criteria:

- The specified Maximum Concentration Levels (MCL's) will not be exceeded in the uppermost aquifer at the POC.

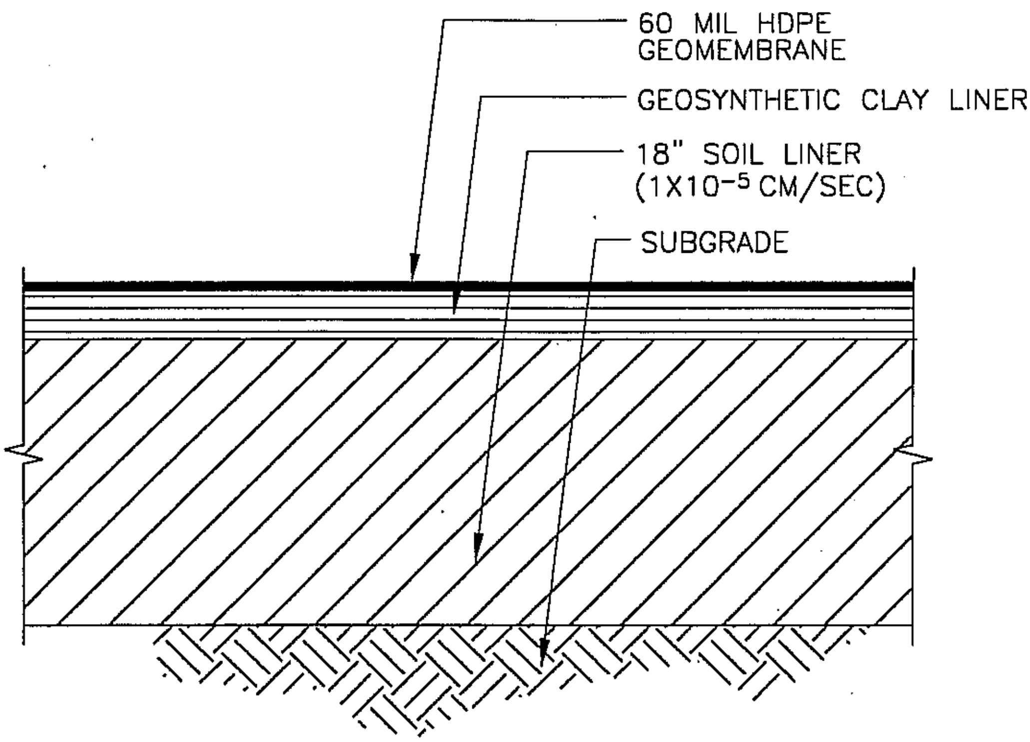
The demonstration following for the alternate liner system addresses several scenarios. Various Dilution Attenuation Factors (DAFs) are computed using the following variables:

- A range of soil hydraulic conductivities (1.0E-1 to 1.0E-5) that bounds the expected, site-specific average conductivity of 6.39E-4.
- Several head conditions, including:
    - the full 12 inches supported by the Section's Permitting Guidance for Alternative Composite Liner Systems, and
    - the calculated maximum head on liner (7.3 inch peak over the 10 year model period) from both the HELP Model and Giroud's Equation, using an inserted 24-hour 25-year storm event.

The standard composite liner system consists of a geomembrane (normally 60 mil HDPE) and a compacted clay liner with a minimum thickness of 24 inches and permeability of no more than 1E-7 cm/sec. The proposed alternate liner design substitutes a GCL of 5E-9 cm/sec permeability and 18 inches of 1E-5 cm/sec compacted clay, for the 24 inches of 1E-7 cm/sec compacted clay in the standard composite liner. A typical cross-section for the alternate liner system is shown on Figure 2.



STANDARD COMPOSITE LINER



PROPOSED ALTERNATE LINER

HDR
HDR Engineering, Inc. of the Carolinas
Suite 1400
125 S. Tryon Street
Charlotte, NC 28202-5001
(704) 338-1800

WHITE STREET SANITARY LANDFILL PHASE III

CITY OF GREENSBORO NORTH CAROLINA

Date	Figure
12/99	2

P:\GBORO\ALTLINR

3.1 Leakage Rate of Leachate

It is necessary to first estimate the rate of leakage through the liner system to model the transport of contamination away from the landfill unit using MULTIMED. The amount of liquid available to leak out of the system is generally assumed equivalent to the rainfall over the site. MSW landfills are prohibited from accepting liquid waste and, on average, MSW is not fully saturated when it is landfilled. Landfill leakage can be attributed to defects in the liner and diffusion through the liner, both of which are highly dependent on leachate head. For this demonstration, one 5.75-inch, 25-year, 24-hour storm was added to the rainfall data file in the HELP model.

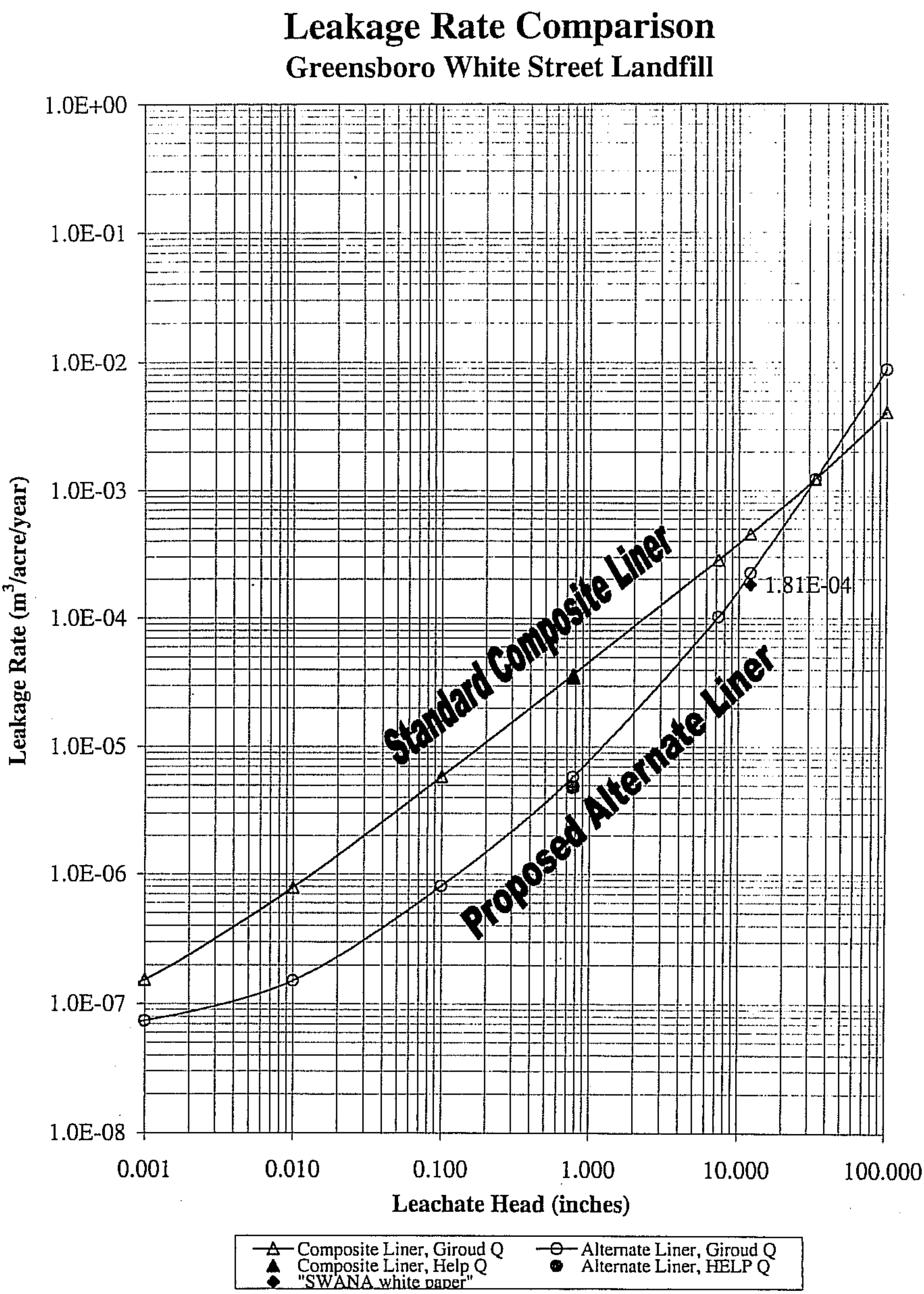
The modeling is intended to be representative for Cells 2 and 3. HELP model Version 3.07 was used to analyze the regulatory composite liner and alternate liner systems over a 10-year period. The 10-year period was used to estimate the average condition. The average annual head and leakage rates from the HELP model were compared with estimates based on equations by McEnroe and Giroud to check the results. The HELP model and McEnroe calculations are attached for information and review.

The predicted head on the geomembrane is approximately the same for the regulatory and the proposed alternate liner systems. The HELP model predicts an average head of 0.8 inches based on site-specific data. Modeling was performed for the constant 12-inch (30.48 cm) head condition. The SWANA white paper presented the leakage rate of 0.53 gal/acre/day (1.81E-4 meters/year). HDR conservatively modeled the higher leakage rate of 2.24E-4 meters/year predicted by the HELP model, which includes diffusion leakage.

The leachate collection layer (1E-1 cm/sec minimum permeability) and operational cover (2E-5 cm/sec minimum permeability) criteria were assumed for the HELP model to be the same as specified for Cell 1. The permeability of these layers impacts the head over the liner, however, since the worst case scenario of 12 inches of head is also modeled, the effect of these inputs is only useful as a comparison.

The calculated leakage rates for the alternate liner and the composite liner are shown on Figure 3. The lines indicate leakage based on Giroud's equation. The two points, a circle and a triangle, indicate HELP model calculations. It should be noted that, for heads in excess of 33 inches, the modeling indicates that the regulatory system is more effective. However, a head condition of 33 inches is not anticipated, as it violates the design premise of maintaining less than 1 foot of head on the liner.

Figure 3


Leakage Rate Comparison
Greensboro White Street Landfill
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
1.0E-07
1.0E-08
Leakage Rate (m³/acre/year)
Standard Composite Liner
Proposed Alternate Liner
1.81E-04
0.001
0.010
0.100
1.000
10.000
100.000
Leachate Head (inches)
Composite Liner, Giroud Q
Alternate Liner, Giroud Q
Composite Liner, Help Q
Alternate Liner, HELP Q
"SWANA white paper"

To confirm the HELP model results, McEnroe's Mound Equation was used to calculate the leachate head over the liner. This equation is purported to use the "true" shape of the piezometric surface rather than assuming an elliptical surface. This equation predicted somewhat higher heads than the HELP model. The HELP model predicted a head of 0.8 inches. McEnroe's equation calculated a head of 7.3 inches. The calculated heads and the HELP model head were input into Giroud's leakage evaluation. The calculated leakage through landfill liners accounted for defects and diffusion. Diffusion was based on the equation presented in the engineering documentation for the HELP model. A conservative estimate of leakage (2.24E-4 m/yr) was chosen for use in the MULTIMED model, based on a 12 inch head. Based on McEnroe's head calculation the leakage rate is estimated to be 1.02E-4 m/yr. The calculations are included in the Appendices.

3.2 Construction Implications

The evaluation for the alternative composite liner system is based on key assumptions regarding the GCL component and the quality of its field placement. These assumptions require that specific conditions be incorporated in the project specifications and construction quality assurance (CQA) program to ensure the constructed alternative composite liner system performs as predicted. The key assumptions made in the alternative composite liner evaluation are as follows:

1. The geomembrane is installed with less that eight punctures per acre.

2. The geomembrane and the GCL are in good contact.

3. The GCL has a fully hydrated permeability of ≤ 5E-9 cm/sec.

4. Under anticipated field loading conditions and fully hydrated, the GCL has a thickness of approximately 7 mm.

The first two assumptions relate to the level of CQA program maintained during construction. The third and fourth assumptions relate to the product specified for the project, and are achievable with a geotextile-bentonite-geotextile product.

Previous studies have shown that the number of penetrations that a geomembrane develops during construction is related to the quality of installation, testing, materials, surface preparation, equipment, and CQA program. Estimates of the number of penetrations for a range of installation quality are presented by EPA in the HELP Model User's Guide as follows:

concentration. The DAF describes the decrease in contaminant concentration decrease between the bottom of the landfill disposal unit (point of leakage) and the POC. A unit concentration of 1 mg/l is used in the MULTIMED model for the convenience of calculating the DAF. The DAF is defined as the initial leachate concentration divided by the predicted concentration at the POC. The design would, according to the USEPA, be acceptable if the DAF is 100 or greater, due to the maximum expected concentration of contaminants. Typical leachate contaminant concentrations found in municipal solid waste landfills are approximately 100 times greater than the MCL for each constituent (Ref. 20). The North Carolina Maximum Contaminant Levels (MCL) standards and associated DAFs are shown in Table 1. Though the North Carolina standards imply that a DAF of 5,000 is necessary for some constituents, the state threshold for acceptability is the same as the EPA.

MULTIMED has two options for landfill simulations: 1) generic landfill, and 2) Subtitle D landfill. For this report, the Subtitle D option was used. Under the Subtitle D option, the contaminant source is never removed, thereby creating a continuous source over time. This steady-state solution will estimate the maximum contaminant concentrations under long-term equilibrium conditions. The model does not address the time required for this steady-state condition to develop.

TABLE 1 PERFORMANCE STANDARDS AND MINIMUM DAF REQUIREMENTS		
Chemical	**NCDENR Maximum Contaminant Level[1] (mg/L)**	**Dilution Attenuation Factor[2] (DAF)**
Arsenic	0.05	20
Barium	1.0	1
Benzene	0.005	200
Cadmium	0.01	100
Carbon tetrachloride	0.005	200
Chromium (hexavalent)	0.05	20
2,4-Dichlorophenoxy acetic acid	0.1	10
1,4-Dichlorobenzene	0.075	13.3
1,2-Dichloroethane	0.005	200
1,1-Dichloroethylene	0.007	142.9
Endrin	0.0002	5000
Fluoride	4	0.25
Lindane	0.004	250
Lead[1]	0.05	20
Mercury	0.002	500
Methoxychlor	0.1	10
Nitrate	10.0	0.1
Selenium	0.01	100
Silver[2]	0.05	20
Toxaphene	0.005	200
1,1,1-Trichloroethane	0.2	5
Trichloroethylene	0.005	200
2.4.5-Trichlorophenoxy acetic acid	0.01	100
Vinyl Chloride	0.002	500

1) From Table 1 of 15A NCAC 13B.1624 Temporary Rule
2) DAF = initial concentration (1mg/l assumed) divided by allowable concentration (MCL)

As part of the alternative liner demonstration, leakage through the liner must be estimated and input into the MULTIMED model. The equations that calculated liner leakage, which were discussed in Section 3.1, were used to estimate the maximum anticipated leakage through the liner system at the landfill. These conservative leakage rates were input to the MULTIMED model to estimate leachate concentrations at the landfill's relative POC.

For Subtitle D applications, only a Gaussian source is allowed for MULTIMED models (Ref. 17). The mixing zone depth was also calculated by the program using a Gaussian distribution function.

Vertical, longitudinal, and transverse dispersivities were calculated by the model. The model calculates longitudinal dispersivity as one-tenth the distance from the unit boundary to the POC. The transverse dispersivity was calculated as one-third of the longitudinal dispersivity, or one-thirtieth the distance to the POC. Similarly, the model predicts the vertical dispersivity as 0.056 times the longitudinal dispersivity, or the distance to the POC divided by 178.57. These relationships are restated below, where x_r is the radial distance from the edge of the landfill unit to the POC.

$$Longitudinal\ Dispersivity\ (\alpha_L) = \frac{x_r}{10}$$

$$Transverse\ Dispersivity\ (\alpha_T) = \frac{\alpha_L}{3}$$

$$Vertical\ Dispersivity\ (\alpha_V) = \frac{(\alpha_L)}{17.857}$$

The model calculated the ground water seepage velocity assuming a uniform, saturated porous medium (Darcy's assumptions) as

$$Seepage\ Velocity\ (V_S) = \frac{KS}{\theta_e}$$

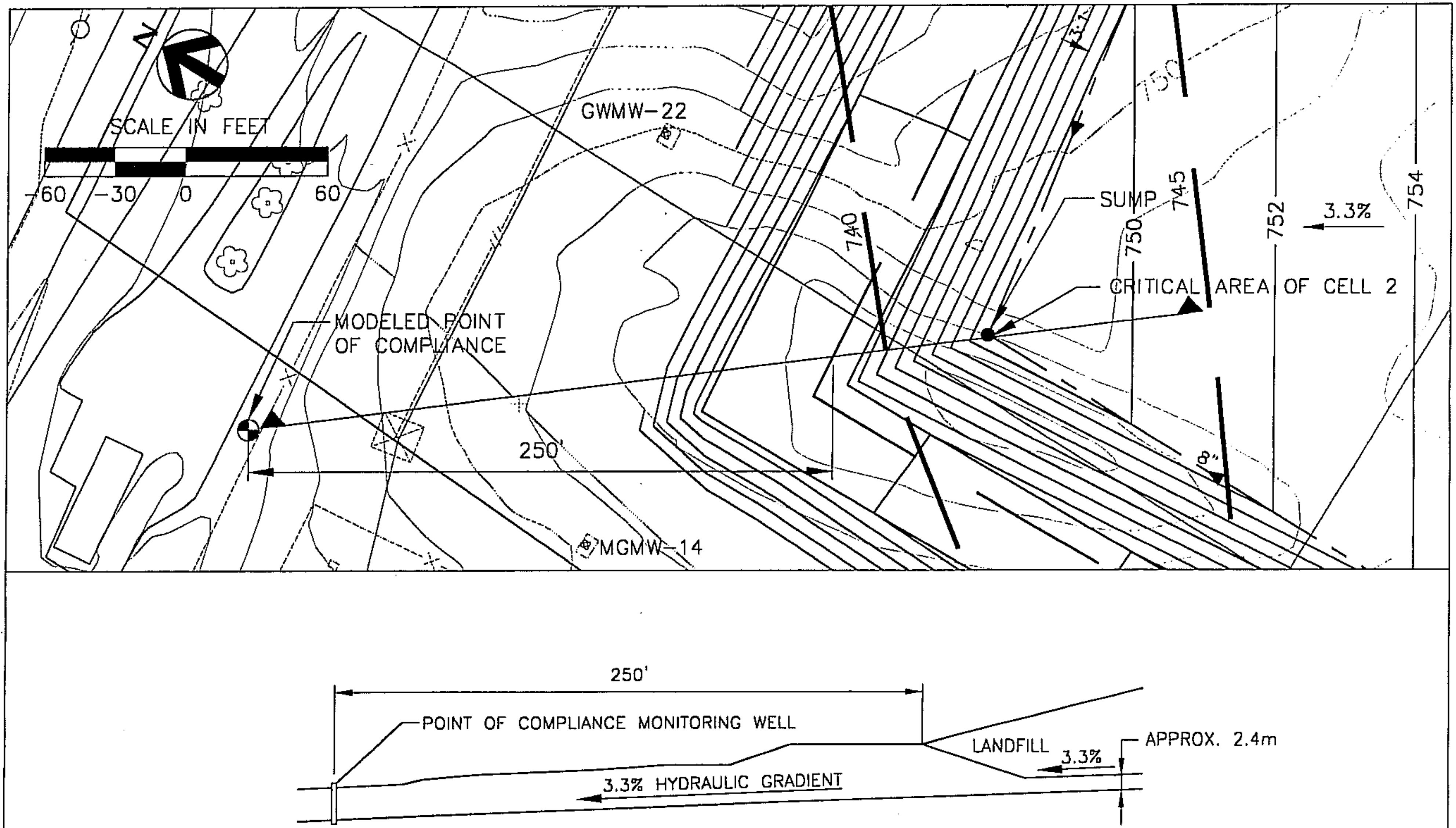
where K is the apparent hydraulic conductivity of the aquifer, S is the aquifer hydraulic gradient, and θ_e is the aquifer effective porosity.

3.3.2 Selection of MULTIMED Parameters

Multiple MULTIMED analyses were performed to establish the sensitivity of the predicted ground water contaminant concentrations to changes in the assumed input parameters. To the extent possible, site-specific hydrogeologic and physical data were used to define applicable input parameters. The input data is consistent with the EPA recommended ranges of values in the MULTIMED Subtitle D Landfill Application Manual. Figure 4 shows a conceptual facility cross-section.

The following is a list of the general model assumptions used for the MULTIMED analyses:

- all model runs were steady-state Subtitle D simulations (deterministic), and
- only the Unsaturated and Saturated Zone Models were activated.



HDR Engineering, Inc. of the Carolinas
Suite 1400
128 S. Tryon Street
Charlotte, NC 28202-5001
(704) 338-1800

WHITE STREET SANITARY LANDFILL CELL 2 CONCEPTUAL HYDROLOGIC CROSS SECTION

Date 10/99

Figure 4

P:\GBORO\811HYDX

The use of the Subtitle D simulation implies that the following model assumptions were also made:

- the contaminant pulse is continuous and constant over time;
- the receptor (POC) is located downgradient in the center of the contaminant plume at the top of the aquifer;
- no attenuation of contaminants occurs in the leachate during flow through the composite liner;
- processes of chemical reaction, biodegradation, and chemical adsorption are neglected; and
- the primary mode of attenuation for contaminants entering the subsurface is physical dispersion and dilution in the receiving aquifer.

Based on NCDENR Rule .1631, Ground-Water Monitoring Systems, the MULTIMED models evaluated in this study, the POC is assumed to be 250 feet (76.2 m) from the leachate infiltration boundary (limit of liner). A summary of parameter values (or ranges) used in the MULTIMED simulations is provided in Table 2.

The Construction Permit Application contains hydraulic conductivity information on page 18 of the Design Hydrogeologic Report and in Appendix C. The hydraulic conductivity of the saprolite aquifer ranges from 0.049 to 6.6 feet per day (1.7E-5 to 2.3E-3). The model was run for hydraulic conductivities between 1.0E-5 and 1.0E-1 centimeters per second to illustrate the shape of the DAF curve. The hydraulic conductivity reported for B-1, which is located within Cell 2, is 6.39E-4 cm/sec. The Multimed model was run for the hydraulic conductivity at B-1.

The derived particle diameter of 0.25 cm was based on equation 6.6 of the MULTMED manual utilizing the porosity stated below. This diameter is equivalent to very coarse sand, which is not the predominant grain size of the geology of the critical area. A particle diameter between 0.0005 and 0.005 cm is within the range of a very fine to coarse silt.

Although these values are differ significantly, MULTMED does not utilize particle diameter during its analysis when a porosity value is given. A porosity value of 20% utilized in the MULTMED analyses was obtained from EPA literature.

The bulk density of soil at 1.44 g/cc, is representative of the type of material which is the predominant lithology of Cells 2 and 3.

The thickness of the aquifer is approximately .914 m. This thickness was derived from water table and soil boring data for B-1, located within the footprint of Cell 2 and is considered representative.

The recharge rate is based on personal communications between HDR and C.C. Daniel, III, of the United States Geological Survey located in North Carolina. He is a recognized and published expert in the field of surface and groundwater hydrology. It is our understanding that his work in the area of infiltration rates will be published.

TABLE 2

MULTIMED INPUT PARAMETERS

Variable	Source	Value
Vadoze Zone Specific:		
▪ Saturated Hydraulic Conductivity	DHR B-1 Avg. Rising/Falling Head	1.62 cm/hr
▪ Unsaturated Zone Porosity	DHR Avg. of Range	.225
▪ Depth of Unsaturated Zone	DHR B-1 (5' separation)	1.52 m
▪ Residual Water Content	MULTIMED Table 6-4 Silty Clay	0.07
▪ Alpha Coefficient	MULTIMED Table 6-5 Silty Clay	0.005
▪ Van Genuchten Exponent (Beta Coefficient)	MULTIMED Table 6-5 Silty Clay	1.09
Source Specific:		
▪ Infiltration Rate	Giroud @ 0.0053 inches of head	2.24 E-4 m/yr
▪ Area of Waste Unit (A)	14.34 acres	5.85 E+4 m^2
▪ Recharge Rate	C.C. Daniel III 7.5 inches/year	0.190 m/yr
▪ Initial Concentration	Unit Source	1 mg/L
▪ Length of Unit (L) (calculated)	Estimated by A/W	300 m
▪ Width of Unit (W) (measured from constant baseline on North side)	Estimated perpendicular to GW flow (640 feet)	195 m
Aquifer Specific:		
▪ Particle Diameter	Derived from MULTIMED Eq. 6.6	0.25 cm
▪ Aquifer Porosity	DHR	0.2
▪ Bulk Density	MULTIMED Table 6-11 for Silt and Clay Average	1.44 g/cc
▪ Aquifer Thickness	DHR B-1	0.914 m
▪ Hydraulic Conductivity	DHR Table 3-5 Lab Perms.	Varied
▪ Hydraulic Gradient	Drawing	0.033
▪ Temperature	GW Baseline Report MW-avg.	14°C
▪ pH	GW Baseline Report MW-avg.	6.48
▪ Organic Carbon Content (fraction)	A Piedmont Site	0.0008
▪ Point of Compliance	250 feet	76.2 m

DHR - Design Hydrogeologic Report, HDR April 1996.

MULTIMED – MULTIMED Subtitle D Application Manual, August 1990.

3.3.3 Hydrogeologic Conditions

A hydrogeologic study was performed for the site by HDR and was included with the approved Construction Permit Application approved. We have extracted the relevant information for Cells 2 and 3 and included it as follows.

1. The surficial/uppermost aquifer which exists in saprolite in the study area serves as the reservoir that recharges the underlying fractures rock aquifer (called shallow and deep herein). Hydraulic conductivities are lower in the rock aquifer, but actual pore water flow velocities can be relatively high due to the very low effective porosities. In rock, the available hydraulic head is forced to travel through a relatively small volume of fractures, which act as conduits for flow. In shallow bedrock where an effective porosity of 5% is appropriate, flow velocities of up to 0.46 feet/day (168 feet/year) can prevail. In deep bedrock, effective porosities of 0.1% result in calculated velocities of up to 3.3 feet/day (1,205 feet/year).

2. In the case of the deep bedrock aquifer, a published value of 0.1% for secondary porosity (Heath, 1980) and a hydraulic gradient of between 0.018 and 0.022 were used to calculate an estimated range of flow velocity of 2.7 to 3.3 feet/day. Given that the upper portion of the bedrock aquifer has more fractures, a correspondingly higher secondary porosity (estimated at 5%), and a hydraulic gradient of 0.023 to 0.033, a third intermediate range of groundwater velocity between 0.32 and 0.46 feet/day was calculated.

3. Hydraulic conductivities are generally highest in the saprolite aquifer, lowest in the deep rock aquifer, and intermediate in the shallow rock aquifer. In saprolite, the granite appears to be more conductive than the gneiss, but where saprolite is developed in a sheared, foliated, or fractured dike, the measured conductivity can be as much as an order of magnitude higher than in either gneiss or granite. In terms of groundwater flow velocity in saprolite, the same relative rates prevail with dike material having the highest value (up to 6.60 feet/day or 2,409 feet/year), granite having an intermediate value (up to 0.29 feet/day or 69 feet/year), and gneiss having the lowest pore velocity (up to 0.049 feet/day or 18 feet/year). It is expected that flow rates should be higher parallel to the orientation of foliations in the gneiss (i.e., N65E-N70E).

4. The permeability of the unsaturated saprolite is lowest near the original ground surface, where finer grained clay-rich soils (silty clays, clayey silts, clayey sands,

etc.) are common. Remolded permeability measurements for these soils ranged from 2.1 to 2.8 x 10^{-7} cm/sec, values. At greater depth in the lower portions of the unsaturated zone, it is expected that the coarser grained soils will have permeabilities in the 10^{-4} to 10^{-5} cm/sec range.

5. The most influential hydrogeological features for the Phase III Area are the unnamed creek east of the site, the topographic ridge/divide along Nealtown Road and Huffine Mill Road to the west and south of the Phase III area, and North Buffalo Creek. As a result of these features, groundwater flow in the surficial aquifer generally trends to the northeast. The horizontal potentiometric gradients for the surficial aquifer range from 0.004 to 0.056. The horizontal potentiometric gradients for the shallow and deep rock aquifers range from 0.023 to 0.033 and from the 0.018 to 0.022, respectively.

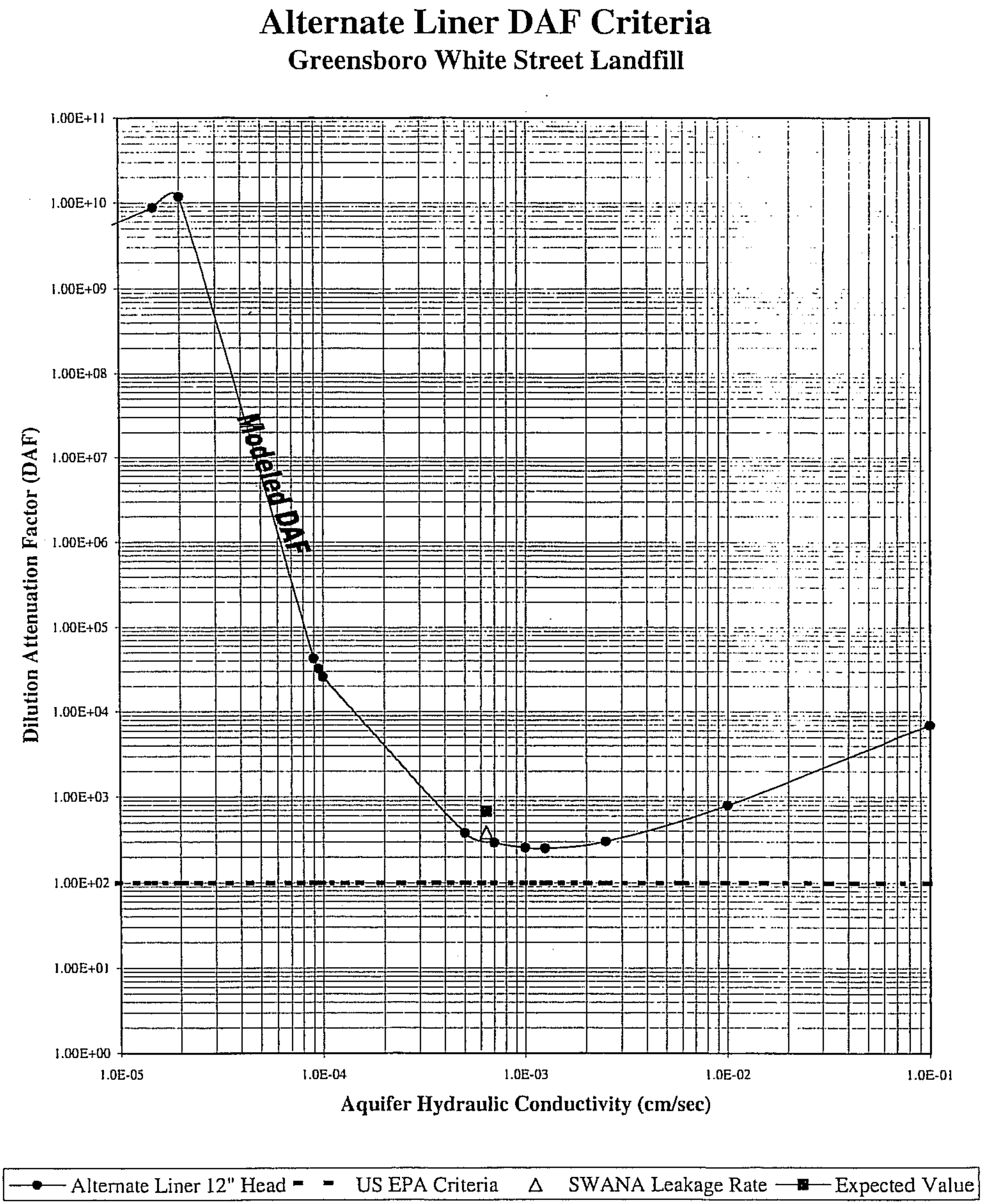
6. A comparison of hydraulic head differences for nested well pairs in the Phase III area, based upon the historical water level measurements from January 10, 1995, through August 29, 1996, indicated a downward gradient in the vertical direction for every well pair (except for B-22/22D). The gradient data for B-1/1D showed the greatest magnitude change from 0.08 ft/ft to 1.96 ft/ft. All of the other piezometer pairs showed minimal fluctuation over time. Although the vertical gradients measured at B22/22D are primarily slighted upward, these very low vertical gradients at this west pair indicate virtually horizontal groundwater flow.

7. Using the effective porosities given in the RCRA Facility Investigation Guidance Document (1987), the hydraulic conductivities mentioned above, and appropriate horizontal hydraulic gradients, a range of horizontal flow velocities of between 0.01 and 6.60 feet per day results for the uppermost (saprolite) aquifer. Note that the dike material (one slug test only) is at least an order of magnitude more conductive than saprolite developed in granite or gneiss, but at depth, these dikes may become essentially impermeable.

3.3.4 Output Results

For the given site geometry, varying the horizontal permeability of the saturated layer caused a significant variation in the value of the calculated DAF. Figure 5 shows the DAF value when the horizontal permeability of the saturated layer is between 1E-5 and 1E-1 cm/sec. Table 3 lists the values plotted in Figure 5.

Figure 5



Alternate Liner DAF Criteria
Greensboro White Street Landfill
Dilution Attenuation Factor (DAF)
1.00E+11
1.00E+10
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
Modeled DAF
1.0E-05
1.0E-04
1.0E-03
1.0E-02
1.0E-01
Aquifer Hydraulic Conductivity (cm/sec)
Alternate Liner 12" Head
US EPA Criteria
SWANA Leakage Rate
Expected Value

The results of the baseline modeling yielded a minimum DAF of greater than 252 for a 12-inch head. This value corresponds to an aquifer hydraulic conductivity of 1.25E-3 cm/sec. The anticipated condition of a 7.3-inch head results in a minimum DAF of 680.

TABLE 3 MULTIMED RESULTS				
Infiltration Rate (m/year)	Hydraulic Conductivity (m/year)	(cm/sec)	Concentration From Model	DAF
DAF Results for 12-inch Head, Giroud-Predicted Infiltration Rate, and Varying Hydraulic Conductivity				
2.24E-04	31500	1.00E-1	1.43E-04	6.97E+03
2.24E-04	3150	1.00E-2	1.26E-03	7.96E+02
2.24E-04	789	2.50E-03	3.31E-03	3.02E+02
2.24E-04	394	1.25E-03	3.97E-03	2.52E+02
2.24E-04	315	1.00E-03	3.90E-03	2.56E+02
2.24E-04	221	7.00E-04	3.43E-03	2.92E+02
2.24E-04	158	5.00E-04	2.64E-03	3.79E+02
2.24E-04	31.5	1.00E-04	3.87E-05	2.58E+04
2.24E-04	30	9.50E-05	3.07E-05	3.26E+04
2.24E-04	28.4	9.00E-05	2.34E-05	4.27E+04
2.24E-04	6.31	2.00E-05	8.45E-11	1.18E+10
2.24E-04	4.7	1.50E-05	1.14E-10	8.81E+09
2.24E-04	3.15	1.00E-05	1.69E-10	5.90E+09
2.24E-04	0.315	1.00E-06	1.69E-09	5.90E+08
DAF Results for 12-Inch Head, SWANA Infiltration Rate, at Predicted Site Hydraulic Conductivity of 6.39 E-4				
1.81E-04	201	6.39E-4	2.61E-03	2.83E+02
DAF Results for 7.3-Inch Head (Maximum Estimated by HELP Model) at Predicted Site Hydraulic Conductivity of 6.39 E-4				
1.02E-04	201	6.39E-4	1.47E-03	6.80E+02

4.0 CELL 2 BOUNDARY ADJUSTMENT

A Duke Power substation is located within landfill property adjacent to Phase III. At the time of original permitting, Duke Power owned the property, and the Phase III boundary was established to maintain the minimum 300-foot buffer off the substation property. The impact of this separation requirement on the Phase III footprint is reduction in lined area of approximately 0.9 acres. This area was discussed during the permitting process with NC DENR and the decision was made to apply for this modification after the City acquired the substation property. To expedite the permitting process this area was deleted from the original MSWLF unit design drawings, however all other aspects of the permit were handled as if this would become part of the unit. The City of Greensboro obtained title to the substation on December 10, 1997. Revised drawings are included in this application that depict the additional 0.9 acre area afforded by the City owning the substation property. The design adjustments comply with all NCDENR buffer requirements.

5.0 SUBGRADE REVISION

This modification incorporates the expanded footprint into the subgrade design of Cell 2. Before modifying the subgrade, the groundwater and rock data acquired since the Construction Permit application was evaluated. Groundwater elevations collected from recent monitoring events confirmed the seasonal high groundwater elevations set with the original piezometers. Drawing C-4 is included to illustrate the long term seasonal high groundwater elevations in the vicinity of the expanded footprint, see contours 740 and 745. The required separation between groundwater and base grades is maintained as illustrated in drawing C-1.

Additional bedrock surface information was obtained during preliminary preparation of the subgrade. The attached Bedrock Surface Map, drawing C-5, was modified based on this information. Contours 745 through 760 in Cell 2 were adjusted and the original location of the contour lines shown as dashes. The base grades for this area of the site are generally limited by groundwater.

This revision resulted in raising grades in some locations and lowering them in others. The addition of this area necessitated adding a sump in Cell 2. The proposed revision maintains the required four foot separation between the bedrock surface and liner system. Drawing C-2 illustrates the proposed top of liner grades and revised leachate collection layout for Cell 2.

6.0 FINAL GRADE REVISION

The final grading plan has been revised to address the expanded Cell 2 footprint. The revised final grades increase the total capacity of Phase III by slightly more than 1%.

7.0 CONCLUSIONS

The results of the alternate liner modeling yielded a minimum DAF of greater than 252 for a 12-inch head. This value corresponds to an aquifer hydraulic conductivity of 2E-4 cm/sec. The anticipated condition of a 7.3-inch head results in a minimum DAF of 680. The proposed design is, according to EPA guidance, acceptable because the DAF is greater than the EPA recommendation of 100.

The alternative composite liner should provide equivalent or greater protection to the public health and environment than that provided by the regulatory default liner, based on the demonstration provided.

The adjustment of the Cell 2 boundary complies with the required buffers based on the City's purchase of the substation property. The subgrade revisions comply with the required long term seasonal high groundwater and bedrock separations. The final grade revision is consistent with the concept of the original final grades.

8.0 REFERENCES AND RELATED BIBLIOGRAPHY

(1) Bonaparte, R., J.P. Giroud, and B.A. Gross, (1989), "Rates of Leakage Through Landfill Liners," Proceedings of Geosynthetics '89 Conference, San Diego, CA, IFAI, St. Paul, MN.

(2) Bonaparte, R., Ed., *Waste Containment Systems: Construction, Regulation and Performance*, ASCE Geotechnical Special Publication No. 26, 1990.

(3) Daniel, D.E., et. al., (1991), *Rate of Flow of Leachate Through Clay Soil Liners*, United States Environmental Protection Agency, Office of Research and Development, EPA/600/2-91/021, June, 1991.

(4) Daniel, D.E., and R.M. Koerner, (1993), *Quality Assurance and Quality Control for Waste Containment Systems*, United States Environmental Protection Agency, Office of Research and Development, Technical Guidance Document, EPA/600/R-93/182, September 1993.

(5) Giroud, J.P., and R. Bonaparte, R., (1989), "Leakage Through Liners Constructed with Geomembrane Liners - Parts I and II," *Geotextile and Geomembranes*, vol 8, 1989.

(6) Giroud, J.P., K. Badu-Tweneboah, and R. Bonaparte, (1992), "Rate of Leakage through a Composite Liner Due to Geomembrane Defects," *Geotextile and Geomembranes*, vol 11, 1992.

(7) Giroud, J.P., et.al., "New Developments in Landfill Liner Leakage Evaluation," 1998 Sixth International Conference on Geosynthetics, March 1998.

(8) HDR Engineering, Inc. of North Carolina, "Construction Permit Application," Gaston County, North Carolina, September 1996.

(9) Koerner, R.M., and D.E. Daniel, (1993), "Technical Equivalency Assessment of GCLs to CCLs," *Geosynthetic Liner Systems: Innovations, Concerns and Design*, R.M. Koerner and R.F. Wilson-Fahmy (Eds), Industrial Fabrics Association International, St. Paul, Minn. 1993.

(10) Lenhard, R. J., et al., "On the Correspondence Between Brooks-Corey and Van Genuchten Models", *Journal of Irrigation and Drainage Engineering*, August 1989.

(11) McEnroe, Bruce M., "Maximum Saturated Depth over Landfill Liner," Journal of Environmental Engineering, ASCE, Vol. 119, No. 2. pp. 262-270. March/April 1993.

(12) Mulkey, Lee A., et. al., *Evaluation of Source Term Initial Conditions for modeling Leachate Migration from Landfills,* United States Environmental Agency, Environmental Research Laboratory, Athens, GA, December, 1992.

(13) Oweis, I. S., et. al., "Hydraulic Characteristics of Municipal Solid Waste", *Journal of Geotechnical Engineering*, April, 1990.

(14) Peyton, R. L. and P.R. Schroeder, (1988), "Evaluation of Landfill-Liner Designs", *Journal of Environmental Engineering*, May/June, 1990.

(15) Resolve Environmental Services, PA, Initial Appendix II Ground Water Assessment, June 1995.

(16) Peyton, R. L. and P.R. Schroeder, (1988), "Field Verification of the HELP Model for Landfills", *Journal of Environmental Engineering,* April, 1988.

(17) Salhotra, A.M., et. al., (1990), *Multimedia Exposure Assessment Model (MULTIMED) for Evaluating Land Disposal of Wastes -- Model Theory*, United States Environmental Agency, Environmental Research Laboratory, Athens, GA.

(18) Schroeder, P.R, et. al., (1994), *The Hydrologic Evaluation of Landfill Performance (HELP) Model - User's Guide for Version 3*, United States Environmental Agency, Office of Research and Development, Cincinnati, OH, EPA/600/R-94/168a, September, 1994.

(19) Schroeder, P.R, et. al., (1994), *The Hydrologic Evaluation of Landfill Performance (HELP) Model - Engineering Documentation for Version 3*, United States Environmental Agency, Office of Research and Development, Cincinnati, OH, EPA/600/R-94/168b, September, 1994.

(20) Sharp-Hansen, et. al., (1990), *A Subtitle D Landfill Application Manual for the Multimedia Exposure Assessment Model (MULTIMED)*, United States Environmental Agency, Environmental Research Laboratory, Athens, GA.

(21) Travers, Constance, and Susan Sharp-Hansen, *Leachate Generation and Migration at Subtitle D Facilities: A Summary and Review of Processes and Mathematical Models*, United States Environmental Protection Agency, Office of Research and Development, August 1993.

APPENDICES

Appendix A

HELP MODEL OUTPUT

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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:      e:\help307\gboro\GBORO.D4
TEMPERATURE DATA FILE:        e:\help307\gboro\GBORO.D7
SOLAR RADIATION DATA FILE:    e:\help307\gboro\GBORO.D13
EVAPOTRANSPIRATION DATA:      e:\help307\gboro\GBORO.D11
SOIL AND DESIGN DATA FILE:    e:\help307\gboro\C2REG2FL.D10
OUTPUT DATA FILE:             e:\help307\gboro\C2REG2FL.OUT


TIME:   8:51      DATE:   9/21/1999


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

    TITLE:  Greensboro White Street Landfill Cell 2 (Reg 2% Floor)

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


    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
             COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  18
          THICKNESS                    =    120.00    INCHES
          POROSITY                     =      0.6710 VOL/VOL
          FIELD CAPACITY               =      0.2920 VOL/VOL
          WILTING POINT                =      0.0770 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3152 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4640 VOL/VOL
FIELD CAPACITY	=	0.3100 VOL/VOL
WILTING POINT	=	0.1870 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3721 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999995000E-04 CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.3970 VOL/VOL
FIELD CAPACITY	=	0.0320 VOL/VOL
WILTING POINT	=	0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0413 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000 CM/SEC
SLOPE	=	2.00 PERCENT
DRAINAGE LENGTH	=	250.0 FEET

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06 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.	=	0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	8.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 5

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4270 VOL/VOL
FIELD CAPACITY	=	0.4180 VOL/VOL
WILTING POINT	=	0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 250. FEET.

SCS RUNOFF CURVE NUMBER	=	80.00	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	9.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.740	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.039	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.693	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	53.029	INCHES
TOTAL INITIAL WATER	=	53.029	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM GREENSBORO NORTH CAROLINA

STATION LATITUDE	=	36.10	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	90	
END OF GROWING SEASON (JULIAN DATE)	=	305	
EVAPORATIVE ZONE DEPTH	=	9.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	7.60	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	68.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.51	3.37	3.88	3.16	3.37	3.93
4.27	4.19	3.64	3.18	2.59	3.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	39.90	48.00	58.30	66.50	73.50
77.20	76.30	69.90	58.40	48.50	40.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA
AND STATION LATITUDE = 36.10 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 10

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.01	3.14	4.14	2.51	3.56	4.49
	5.44	5.30	4.00	2.84	2.09	3.82
STD. DEVIATIONS	2.22	1.31	1.75	1.15	1.59	3.13
	1.77	2.81	2.73	1.83	1.29	1.71
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.533	1.923	3.011	2.980	2.985	3.505
	4.415	3.631	2.776	2.274	1.590	1.214
STD. DEVIATIONS	0.241	0.263	0.331	0.792	1.051	2.110
	0.871	1.235	0.893	0.831	0.340	0.300
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	1.4528	1.9196	1.2350	1.1949	0.5852	0.5462
	0.8146	1.1324	1.0724	1.4996	0.9211	0.3805
STD. DEVIATIONS	1.1430	1.5203	0.9552	0.7372	0.4721	0.7059
	1.1027	1.0928	1.2180	1.5423	0.7348	0.3047

PERCOLATION/LEAKAGE THROUGH LAYER 5

TOTALS	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0002	0.0001	0.0000
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0002	0.0001	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	1.0337	1.5034	0.8787	0.8785	0.4164	0.4016
	0.5796	0.8058	0.7885	1.0670	0.6772	0.2707
STD. DEVIATIONS	0.8133	1.1977	0.6797	0.5420	0.3359	0.5191
	0.7846	0.7776	0.8955	1.0974	0.5403	0.2168

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 10

	INCHES		CU. FEET	PERCENT
PRECIPITATION	44.35	(7.337)	161008.6	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	31.835	(2.9361)	115562.61	71.774
LATERAL DRAINAGE COLLECTED FROM LAYER 3	12.75431	(5.78703)	46298.141	28.75506
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00139	(0.00058)	5.040	0.00313
AVERAGE HEAD ON TOP OF LAYER 4	0.775	(0.354)		
CHANGE IN WATER STORAGE	-0.236	(1.6405)	-857.10	-0.532

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 10

	(INCHES)	(CU. FT.)
PRECIPITATION	5.75	20872.500
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 3	0.20718	752.07520
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000020	0.07323
AVERAGE HEAD ON TOP OF LAYER 4	4.570	
MAXIMUM HEAD ON TOP OF LAYER 4	7.246	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	51.7 FEET	
SNOW WATER	1.73	6282.1865
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.6710	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0770	

*** 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 10

LAYER	(INCHES)	(VOL/VOL)
1	35.8898	0.2991
2	4.1327	0.3444
3	0.3972	0.0331
4	0.0000	0.0000
5	10.2480	0.4270
SNOW WATER	0.000	

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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:      e:\help307\gboro\GBORO.D4
TEMPERATURE DATA FILE:        e:\help307\gboro\GBORO.D7
SOLAR RADIATION DATA FILE:    e:\help307\gboro\GBORO.D13
EVAPOTRANSPIRATION DATA:      e:\help307\gboro\GBORO.D11
SOIL AND DESIGN DATA FILE:    e:\help307\gboro\C2ALT2FL.D10
OUTPUT DATA FILE:             e:\help307\gboro\C2ALT2FL.OUT


TIME: 14:44      DATE:  9/21/1999


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

    TITLE:  Greensboro White Street Landfill Cell 2 (Alt 2% Floor)

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


    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
             COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                LAYER  1
                                --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  18
          THICKNESS                  =   120.00   INCHES
          POROSITY                   =     0.6710 VOL/VOL
          FIELD CAPACITY             =     0.2920 VOL/VOL
          WILTING POINT              =     0.0770 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.3152 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4640 VOL/VOL
FIELD CAPACITY	=	0.3100 VOL/VOL
WILTING POINT	=	0.1870 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3721 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999995000E-04 CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.3970 VOL/VOL
FIELD CAPACITY	=	0.0320 VOL/VOL
WILTING POINT	=	0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0413 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000 CM/SEC
SLOPE	=	2.00 PERCENT
DRAINAGE LENGTH	=	250.0 FEET

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06 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.	=	0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	8.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 5

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.28 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.	=	0.300000003000E-08 CM/SEC

LAYER 6

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	18.00 INCHES
POROSITY	=	0.4270 VOL/VOL
FIELD CAPACITY	=	0.4180 VOL/VOL
WILTING POINT	=	0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3773 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999975000E-05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 250. FEET.

SCS RUNOFF CURVE NUMBER	=	80.00	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	9.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.740	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.039	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.693	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	49.783	INCHES
TOTAL INITIAL WATER	=	49.783	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
GREENSBORO NORTH CAROLINA

STATION LATITUDE	=	36.10 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	90
END OF GROWING SEASON (JULIAN DATE)	=	305
EVAPORATIVE ZONE DEPTH	=	9.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.51	3.37	3.88	3.16	3.37	3.93
4.27	4.19	3.64	3.18	2.59	3.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	39.90	48.00	58.30	66.50	73.50
77.20	76.30	69.90	58.40	48.50	40.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA
AND STATION LATITUDE = 36.10 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 10

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.01	3.14	4.14	2.51	3.56	4.49
	5.44	5.30	4.00	2.84	2.09	3.82
STD. DEVIATIONS	2.22	1.31	1.75	1.15	1.59	3.13
	1.77	2.81	2.73	1.83	1.29	1.71
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

EVAPOTRANSPIRATION

TOTALS	1.533	1.923	3.011	2.980	2.985	3.505
	4.415	3.631	2.776	2.274	1.590	1.214
STD. DEVIATIONS	0.241	0.263	0.331	0.792	1.051	2.110
	0.871	1.235	0.893	0.831	0.340	0.300

LATERAL DRAINAGE COLLECTED FROM LAYER 3

TOTALS	1.4529	1.9198	1.2351	1.1950	0.5853	0.5463
	0.8147	1.1325	1.0725	1.4997	0.9212	0.3805
STD. DEVIATIONS	1.1431	1.5204	0.9553	0.7372	0.4722	0.7060
	1.1028	1.0929	1.2181	1.5425	0.7349	0.3047

PERCOLATION/LEAKAGE THROUGH LAYER 5

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0021	0.0018	0.0019	0.0018	0.0017	0.0016
	0.0014	0.0014	0.0013	0.0013	0.0012	0.0012
STD. DEVIATIONS	0.0030	0.0025	0.0026	0.0024	0.0023	0.0021
	0.0021	0.0020	0.0019	0.0019	0.0017	0.0017

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	1.0338	1.5035	0.8788	0.8786	0.4164	0.4017
	0.5797	0.8058	0.7886	1.0671	0.6773	0.2708
STD. DEVIATIONS	0.8133	1.1978	0.6797	0.5421	0.3360	0.5191
	0.7847	0.7776	0.8956	1.0975	0.5403	0.2168

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 10

	INCHES		CU. FEET	PERCENT
PRECIPITATION	44.35	(7.337)	161008.6	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	31.835	(2.9361)	115562.61	71.774
LATERAL DRAINAGE COLLECTED FROM LAYER 3	12.75551	(5.78752)	46302.488	28.75776
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00019	(0.00010)	0.691	0.00043
AVERAGE HEAD ON TOP OF LAYER 4	0.775	(0.354)		
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.01877	(0.02611)	68.145	0.04232
CHANGE IN WATER STORAGE	-0.255	(1.6467)	-924.56	-0.574

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 10

	(INCHES)	(CU. FT.)
PRECIPITATION	5.75	20872.500
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 3	0.20720	752.12067
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000004	0.01465
AVERAGE HEAD ON TOP OF LAYER 4	4.570	
MAXIMUM HEAD ON TOP OF LAYER 4	7.246	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	51.7 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000315	1.14235
SNOW WATER	1.73	6282.1865

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.6710
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0770

*** 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 10

LAYER	(INCHES)	(VOL/VOL)
1	35.8898	0.2991
2	4.1327	0.3444
3	0.3972	0.0331
4	0.0000	0.0000
5	0.2100	0.7500
6	6.6060	0.3670
SNOW WATER	0.000	

****
****

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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:     e:\help307\gboro\GBORO.D4
TEMPERATURE DATA FILE:       e:\help307\gboro\GBORO.D7
SOLAR RADIATION DATA FILE:   e:\help307\gboro\GBORO.D13
EVAPOTRANSPIRATION DATA:     e:\help307\gboro\GBORO.D11
SOIL AND DESIGN DATA FILE:   e:\help307\gboro\C2REG3SL.D10
OUTPUT DATA FILE:            e:\help307\gboro\C2REG3SL.OUT


TIME:  14:57      DATE:   9/21/1999


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

    TITLE:  Greensboro White Street Landfill Cell 2 (Reg, 3:1 Slope)

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


    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
             COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                        TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER  18
          THICKNESS                    =    120.00    INCHES
          POROSITY                     =      0.6710 VOL/VOL
          FIELD CAPACITY               =      0.2920 VOL/VOL
          WILTING POINT                =      0.0770 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3161 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0766	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 34

THICKNESS	=	0.25	INCHES
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	33.0000000000	CM/SEC
SLOPE	=	33.00	PERCENT
DRAINAGE LENGTH	=	45.0	FEET

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	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.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	8.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 5

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4270	VOL/VOL
FIELD CAPACITY	=	0.4180	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 33.% AND A SLOPE LENGTH OF 45. FEET.

SCS RUNOFF CURVE NUMBER	=	83.20	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	9.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.941	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.039	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.693	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	50.017	INCHES
TOTAL INITIAL WATER	=	50.017	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM GREENSBORO NORTH CAROLINA

STATION LATITUDE	=	36.10 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	90
END OF GROWING SEASON (JULIAN DATE)	=	305
EVAPORATIVE ZONE DEPTH	=	9.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.51	3.37	3.88	3.16	3.37	3.93
4.27	4.19	3.64	3.18	2.59	3.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	39.90	48.00	58.30	66.50	73.50
77.20	76.30	69.90	58.40	48.50	40.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA
AND STATION LATITUDE = 36.10 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 10

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.01	3.14	4.14	2.51	3.56	4.49
	5.44	5.30	4.00	2.84	2.09	3.82
STD. DEVIATIONS	2.22	1.31	1.75	1.15	1.59	3.13
	1.77	2.81	2.73	1.83	1.29	1.71
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.530	1.937	3.019	2.987	3.010	3.503
	4.416	3.639	2.783	2.277	1.570	1.212
STD. DEVIATIONS	0.237	0.248	0.329	0.787	1.041	2.112
	0.875	1.229	0.883	0.817	0.361	0.304
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	1.9339	1.7109	1.2201	1.2033	0.3176	0.5517
	0.8753	1.2013	1.1596	1.4769	0.7659	0.2870
STD. DEVIATIONS	1.3432	1.5952	1.0434	0.9371	0.2559	0.7857
	1.2738	1.3074	1.2663	1.4819	0.8480	0.2886

PERCOLATION/LEAKAGE THROUGH LAYER 5

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0002	0.0002	0.0001	0.0001	0.0000	0.0001
	0.0001	0.0001	0.0001	0.0002	0.0001	0.0000
STD. DEVIATIONS	0.0002	0.0002	0.0001	0.0001	0.0000	0.0001
	0.0002	0.0002	0.0002	0.0002	0.0001	0.0000

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 10

	INCHES		CU. FEET	PERCENT
PRECIPITATION	44.35	(7.337)	161008.6	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	31.883	(2.9161)	115736.95	71.882
LATERAL DRAINAGE COLLECTED FROM LAYER 3	12.70355	(5.75336)	46113.879	28.64062
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00000	(0.00000)	0.002	0.00000
AVERAGE HEAD ON TOP OF LAYER 4	0.000	(0.000)		
CHANGE IN WATER STORAGE	-0.232	(1.6349)	-842.16	-0.523

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 10

	(INCHES)	(CU. FT.)
PRECIPITATION	5.75	20872.500
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 3	0.36359	1319.83850
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 4	0.001	
MAXIMUM HEAD ON TOP OF LAYER 4	0.018	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	1.73	6282.1865

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.5217
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0770

*** 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 10

LAYER	(INCHES)	(VOL/VOL)
1	35.9781	0.2998
2	1.4681	0.0612
3	0.0025	0.0101
4	0.0000	0.0000
5	10.2480	0.4270
SNOW WATER	0.000	

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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:     e:\help307\gboro\GBORO.D4
TEMPERATURE DATA FILE:       e:\help307\gboro\GBORO.D7
SOLAR RADIATION DATA FILE:   e:\help307\gboro\GBORO.D13
EVAPOTRANSPIRATION DATA:     e:\help307\gboro\GBORO.D11
SOIL AND DESIGN DATA FILE:   e:\help307\gboro\C2ALT3SL.D10
OUTPUT DATA FILE:            e:\help307\gboro\C2ALT3SL.OUT


TIME:   9:17     DATE:   9/21/1999


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

     TITLE:  Greensboro White Street Landfill Cell 2 (Alt, 3:1 Slope)

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER  18
          THICKNESS                    =    120.00   INCHES
          POROSITY                     =      0.6710 VOL/VOL
          FIELD CAPACITY               =      0.2920 VOL/VOL
          WILTING POINT                =      0.0770 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3160 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.00 INCHES
POROSITY	=	0.3970 VOL/VOL
FIELD CAPACITY	=	0.0320 VOL/VOL
WILTING POINT	=	0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0320 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999995000E-04 CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 34

THICKNESS	=	0.25 INCHES
POROSITY	=	0.8500 VOL/VOL
FIELD CAPACITY	=	0.0100 VOL/VOL
WILTING POINT	=	0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	33.0000000000 CM/SEC
SLOPE	=	33.00 PERCENT
DRAINAGE LENGTH	=	45.0 FEET

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06 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.	=	0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	8.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 5

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	0.28 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 6

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	18.00	INCHES
POROSITY	=	0.4530	VOL/VOL
FIELD CAPACITY	=	0.1900	VOL/VOL
WILTING POINT	=	0.0850	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1896	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999975000E-05	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 33.% AND A SLOPE LENGTH OF 45. FEET.

SCS RUNOFF CURVE NUMBER	=	83.20	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	9.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.875	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.039	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.693	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	42.315	INCHES
TOTAL INITIAL WATER	=	42.315	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM GREENSBORO NORTH CAROLINA

STATION LATITUDE	=	36.10	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	90	
END OF GROWING SEASON (JULIAN DATE)	=	305	
EVAPORATIVE ZONE DEPTH	=	9.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	7.60	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	68.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.51	3.37	3.88	3.16	3.37	3.93
4.27	4.19	3.64	3.18	2.59	3.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	39.90	48.00	58.30	66.50	73.50
77.20	76.30	69.90	58.40	48.50	40.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA
AND STATION LATITUDE = 36.10 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 10

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.01	3.14	4.14	2.51	3.56	4.49
	5.44	5.30	4.00	2.84	2.09	3.82
STD. DEVIATIONS	2.22	1.31	1.75	1.15	1.59	3.13
	1.77	2.81	2.73	1.83	1.29	1.71
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

EVAPOTRANSPIRATION

TOTALS	1.531	1.937	3.019	2.985	2.998	3.528
	4.393	3.637	2.781	2.274	1.570	1.212
STD. DEVIATIONS	0.239	0.247	0.330	0.792	1.043	2.087
	0.873	1.230	0.885	0.821	0.365	0.304

LATERAL DRAINAGE COLLECTED FROM LAYER 3

TOTALS	2.3215	1.4009	1.2444	1.0830	0.1845	0.5736
	1.0919	1.1040	1.3544	1.3726	0.5451	0.4102
STD. DEVIATIONS	1.2723	1.5175	0.9837	1.0772	0.3907	0.7007
	1.3575	1.2638	1.4158	1.2701	0.7028	0.3599

PERCOLATION/LEAKAGE THROUGH LAYER 5

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 6

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

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0037	0.0024	0.0019	0.0017	0.0003	0.0009
	0.0016	0.0017	0.0023	0.0022	0.0009	0.0006
STD. DEVIATIONS	0.0020	0.0025	0.0015	0.0016	0.0006	0.0012
	0.0019	0.0019	0.0025	0.0022	0.0011	0.0005

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 10

	INCHES		CU. FEET	PERCENT
PRECIPITATION	44.35	(7.337)	161008.6	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	31.865	(2.9244)	115668.62	71.840
LATERAL DRAINAGE COLLECTED FROM LAYER 3	12.68631	(5.77207)	46051.320	28.60177
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00000	(0.00000)	0.000	0.00000
AVERAGE HEAD ON TOP OF LAYER 4	0.002	(0.001)		
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00710	(0.00157)	25.763	0.01600
CHANGE IN WATER STORAGE	-0.203	(1.4299)	-737.01	-0.458

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 10

	(INCHES)	(CU. FT.)
PRECIPITATION	5.75	20872.500
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 3	0.37799	1372.11096
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000000	0.00001
AVERAGE HEAD ON TOP OF LAYER 4	0.022	
MAXIMUM HEAD ON TOP OF LAYER 4	0.001	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000044	0.15846
SNOW WATER	1.73	6282.1865

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.6320
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0770

*** 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 10

LAYER	(INCHES)	(VOL/VOL)
1	35.9620	0.2997
2	0.7680	0.0320
3	0.0025	0.0100
4	0.0000	0.0000
5	0.2100	0.7500
6	3.3425	0.1857
SNOW WATER	0.000	

****
****

Appendix B

LEACHATE HEAD CALCULATIONS

LEAKAGE RATE CALCULATIONS

Greensboro White Street Landfill

Alternate Liner Demonstration

Leachate Head Calculation

McEnroe's Mound Equation

ASCE Journal of Environmental Engineering, Vol. 119 No. 2, pp 262-270, March/April 1993

EQN 1
For R < 1/4

$$Ymax = \left(R - RS + R^2S^2\right)^{\frac{1}{2}}\left[\frac{(1-A-2R)(1+A-2RS)}{(1+A-2R)(1-A-2RS)}\right]^{\frac{1}{2A}}$$

EQN 2
For R = 1/4

$$Ymax = \frac{R(1-2RS)}{(1-2R)}\exp\left[\frac{2R(S-1)}{(1-2RS)(1-2R)}\right]$$

EQN 3
For R > 1/4

$$Ymax = \left(R - RS + R^2S^2\right)^{\frac{1}{2}}\exp\left[\frac{\tan^{-1}}{B}\left(\frac{2RS-1}{B}\right)-\frac{\tan^{-1}}{B}\left(\frac{2R-1}{B}\right)\right]$$

For:

$$R = \frac{r}{K\sin^2\alpha}$$ R = 1.09E-06 8.82E-02 => Use EQN 1

$$A = (1-4R)^{\frac{1}{2}}$$ A = 1.00 0.80

$$B = (4R-1)^{\frac{1}{2}}$$ B = #NUM! #NUM!

$y_{max} = Y_{max}(L(\tan\alpha))$; maximum head on the liner.

Where:

	Cell Slope	Cell Floor
L (drainage length, feet) =	45	250
r (impingement, in/day) =	0.12	0.12
K (hydr cond., cm/sec) =	33	0.1
C = r/K	1.07E-07	3.53E-05
S (slope, ft/ft) =	0.330	0.020
a (angle of inclination) =	18.263	1.146

Yields:

Y_{max} =	1.09E-06	1.21E-01
y_{max} (inches) =	1.94E-04	7.27E+00

Use Worst Case **7.27E+00** inches of Head

Greensboro White Street Landfill

Alternate Liner Demonstration

Leakage Rate Reference: Giroud et al. 1998 Sixth International Conference on Geosynthetics

$$Q = C_{qo}[1+0.1(h/t_{um})^{0.95}]a^{0.1}h^{0.9}k_{um}^{0.74}$$

Where:

Q = Leakage rate (m^3/s)

c_{qo} = coefficient that characterizes contact quality (dimensionless)

0.21 for good contact — 1.15 for poor contact

a = defect area (m^2)

		Estimated Number of defects per acre
7.85E-07	pin hole defect (m^2)	1
1.00E-04	installation defect (m^2)	8

h = leachate head on top of liner (m)

t_{um} = thickness of low permeability medium under the geomembrane (m)

k_{um} = hydraulic conductivity of low permeability medium under the geomembrane (m/s)

The equation is valid for conditions when:

- defect diameter between 0.5 mm and 25mm
- Head less than or equal to 3m
- k_{um} is less than k_G as described in the paper

The equation is valid.

Leakage by Diffusion Through HDPE *Reference: HELP Engineering Documentation* pg. 76. Eq'n 141 and Table 8

$$q_{diffusion} = K_s*(h+T_g)/T_g$$

Where: T_g Liner Thickness (mils) = 60

K_s (cm/sec)= 2E-13

		Composite Liner		Alternate Liner (GCL)				
		0.21 c_{qo}		c_{qo} 0.21				
		0.6 t_{um}		t_{um} 0.007				
		1.00E-09 k_{um}		k_{um} 5.00E-11			Composite	Alternate
Head (h)		Q_{hole} from Giroud				$Q_{diffusion}$	Q_{total}	Q_{total}
(in)	(m)	(m^3/s)	Infiltration Rate		(m^3/s)	(m^3/acre/yr)	(m^3/acre/yr)	(m^3/acre/yr)
100.0000	2.54E+00	5.08E-07	3.96E-03	8.68E-03	1.11E-06	1.05E-04	4.07E-03	8.78E-03
33.0555	8.40E-01	1.53E-07	1.19E-03	1.19E-03	1.53E-07	3.48E-05	1.23E-03	1.23E-03
12.0000	3.05E-01	5.69E-08	4.44E-04	2.12E-04	2.71E-08	1.27E-05	4.56E-04	**2.24E-04**
7.2659	1.85E-01	3.56E-08	2.77E-04	9.47E-05	1.22E-08	7.70E-06	2.85E-04	1.02E-04
0.7750	1.97E-02	4.61E-09	3.59E-05	4.94E-06	6.34E-10	8.78E-07	3.68E-05	5.82E-06
0.1000	2.54E-03	7.28E-10	5.67E-06	6.41E-07	8.23E-11	1.68E-07	5.84E-06	8.09E-07
0.0100	2.54E-04	9.16E-11	7.14E-07	7.81E-08	1.00E-11	7.36E-08	7.87E-07	1.52E-07
0.0010	2.54E-05	1.15E-11	8.99E-08	9.79E-09	1.26E-12	6.41E-08	1.54E-07	7.39E-08
0.0002	4.93E-06	2.64E-12	2.05E-08	2.24E-09	2.87E-13	6.33E-08	8.38E-08	6.55E-08
0.0000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.31E-08	6.31E-08	6.31E-08

Head (h) (in)	HELP Model	Composite (ft^3/year)	Qtotal from HELP Infiltration Rate (m/yr)		Alternate (ft^3/year)	HELP Model	slope	
0.000	C2Reg3Sl	2.00E-03	1.40E-08	0.00E+00	0.00E+00	C2Alt3Sl	33%	slope
0.775	C2Reg2Fl	5.04E+00	3.53E-05	4.84E-06	6.91E-01	C2Alt2Fl	2%	floor

Area Modeled

1 acre	Giroud Calculation
1 acres	HELP Model with 33% slope
1 acres	HELP Model with 2% slope

Conversion Factors

- 4046.856 m^2/acre
- 3.1536E+07 seconds/year
- 2.832E-02 m^3/ft^3
- 2.540E-02 m/in

Leakage rate for the alternate liner is less than for the composite liner system for heads less than 33 inches.
Giroud's equation predicts a more conservative leakage rate than the Help Model

Use Leakage rate at 12 inch head of **2.24E-04** meters/year per NC DENR.

Appendix C

MULTIMED MODEL OUTPUT

12-Inch Head

7.3-Inch Head

1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options

K=1e-1 2.24E-4

Cell 2 WHITE STREET MSWLF, GREENSBORO, NC
Chemical simulated is DEFAULT CHEMICAL

Option Chosen	Saturated and unsaturated zone models
Run was	DETERMIN

Infiltration input by user
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model

1

1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN

Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.52	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.62	-999.	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.225	-999.	0.100E-08	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.52	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	CONSTANT	0.700E-01	-999.	0.100E-08	1.00
Brook and Corey exponent, EN	--	CONSTANT	-999.	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.500E-02	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.09	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Thickness of layer	m	CONSTANT	1.52	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.138	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Base catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Reference temperature	C	CONSTANT	-999.	-999.	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Infiltration rate	m/yr	CONSTANT	0.224E-03	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.585E+05	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.190	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	300.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	195.	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Particle diameter	cm	CONSTANT	0.250	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.200	-999.	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	0.914	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	0.315E+05	-999.	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.330E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	14.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.48	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.800E-03	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	76.2	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.1434E-03

1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1
Run options
--- -------

K=1e-2 2.24E-4

Cell 2 WHITE STREET MSWLF, GREENSBORO, NC
Chemical simulated is DEFAULT CHEMICAL

Option Chosen — Saturated and unsaturated zone models
Run was — DETERMIN
Infiltration input by user
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model
1
1
UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------
Van Genuchten functional coefficients
User defined coordinate system
1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.52	1

DATA FOR MATERIAL 1
---- --- --------
VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.62	-999.	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.225	-999.	0.100E-08	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.52	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1
---- --- --------
VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	CONSTANT	0.700E-01	-999.	0.100E-08	1.00
Brook and Corey exponent,EN	--	CONSTANT	-999.	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.500E-02	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.09	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations
1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.52	-999.	0.100E-05	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.138	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Base catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Reference temperature	C	CONSTANT	-999.	-999.	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.224E-03	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.585E+05	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-09	0.100E+11
Recharge rate	m/yr	CONSTANT	0.190	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	300.	-999.	0.100E-09	0.100E+11
Width scale of facility	m	CONSTANT	195.	-999.	0.100E-09	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.250	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.200	-999.	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	0.914	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	0.315E+04	-999.	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.330E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	14.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.48	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.800E-03	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	76.2	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.1257E-02

1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options

K=2.50E-3 2.24E-4

Cell 2 WHITE STREET MSWLF, GREENSBORO, NC
Chemical simulated is DEFAULT CHEMICAL

Option Chosen	Saturated and unsaturated zone models
Run was	DETERMIN

Infiltration input by user
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model
1
1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN

Van Genuchten functional coefficients
User defined coordinate system
1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.52	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.62	-999.	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.225	-999.	0.100E-08	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.52	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Residual water content	--	CONSTANT	0.700E-01	-999.	0.100E-08	1.00
Brook and Corey exponent, EN	--	CONSTANT	-999.	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.500E-02	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.09	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations
1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Thickness of layer	m	CONSTANT	1.52	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.138	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Base catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Reference temperature	C	CONSTANT	-999.	-999.	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Infiltration rate	m/yr	CONSTANT	0.224E-03	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.585E+05	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-09	0.100E+11
Recharge rate	m/yr	CONSTANT	0.190	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	300.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	195.	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Particle diameter	cm	CONSTANT	0.250	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.200	-999.	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	0.914	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	789.	-999.	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.330E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	14.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.49	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.800E-03	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	76.2	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.3311E-02

1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1
Run options
--- -------

K=1.25E-3 2.24E-4

Cell 2 WHITE STREET MSWLF, GREENSBORO, NC
Chemical simulated is DEFAULT CHEMICAL

Option Chosen — Saturated and unsaturated zone models
Run was — DETERMIN
Infiltration input by user
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model
1
1
UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------
Van Genuchten functional coefficients
User defined coordinate system
1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.52	1

DATA FOR MATERIAL 1
---- --- --------
VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.62	-999.	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.225	-999.	0.100E-08	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.52	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1
---- --- --------
VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	CONSTANT	0.700E-01	-999.	0.100E-08	1.00
Brook and Corey exponent, EN	--	CONSTANT	-999.	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.500E-02	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.09	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations
1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Thickness of layer	m	CONSTANT	1.52	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.138	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Base catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Reference temperature	C	CONSTANT	-999.	-999.	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Infiltration rate	m/yr	CONSTANT	0.224E-03	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.585E+05	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.190	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	300.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	195.	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Particle diameter	cm	CONSTANT	0.250	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.200	-999.	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	0.914	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	394.	-999.	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.330E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	14.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.48	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.800E-03	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	76.2	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.3972E-02

1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options

--- -------

K=1e-3 2.24E-4

Cell 2 WHITE STREET MSWLF, GREENSBORO, NC
Chemical simulated is DEFAULT CHEMICAL

Option Chosen	Saturated and unsaturated zone models
Run was	DETERMIN

Infiltration input by user
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model

1

1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN

Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.52	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.62	-999.	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.225	-999.	0.100E-08	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.52	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Residual water content	--	CONSTANT	0.700E-01	-999.	0.100E-08	1.00
Brook and Corey exponent,EN	--	CONSTANT	-999.	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.500E-02	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.09	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

	VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
	Thickness of layer	m	CONSTANT	1.52	-999.	0.100E-09	-999.
	Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	0.100E-02	0.100E+05
	Percent organic matter	--	CONSTANT	0.139	-999.	0.000E+00	100.
	Bulk density of soil for layer	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
1	Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

CHEMICAL SPECIFIC VARIABLES

	VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
	Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
	Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
	Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
	Acid catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
	Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
	Base catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
	Reference temperature	C	CONSTANT	-999.	-999.	0.000E+00	100.
	Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
	Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
	Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
	Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E+00	10.0
	Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
	Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
	Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-08	1.00
	Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
	Henry's law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
	Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
1	Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
	Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

SOURCE SPECIFIC VARIABLES

	VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
	Infiltration rate	m/yr	CONSTANT	0.224E-03	-999.	0.100E-09	0.100E+11
	Area of waste disposal unit	m^2	CONSTANT	0.585E+05	-999.	0.100E-01	-999.
	Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
	Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
	Recharge rate	m/yr	CONSTANT	0.190	-999.	0.000E+00	0.100E+11
	Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
	Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
	Length scale of facility	m	CONSTANT	300.	-999.	0.100E-09	0.100E+11
	Width scale of facility	m	CONSTANT	195.	-999.	0.100E-08	0.100E+11
1	Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

AQUIFER SPECIFIC VARIABLES

	VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
	Particle diameter	cm	CONSTANT	0.250	-999.	0.100E-08	100.
	Aquifer porosity	--	CONSTANT	0.200	-999.	0.100E-08	0.990
	Bulk density	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
	Aquifer thickness	m	CONSTANT	0.914	-999.	0.100E-08	0.100E+06
	Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
	Conductivity (hydraulic)	m/yr	CONSTANT	315.	-999.	0.100E-06	0.100E+09
	Gradient (hydraulic)		CONSTANT	0.330E-01	-999.	0.100E-07	-999.
	Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
	Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
	Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
	Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
	Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
	Temperature of aquifer	C	CONSTANT	14.0	-999.	0.000E+00	100.
	pH	--	CONSTANT	6.48	-999.	0.300	14.0
	Organic carbon content (fraction)		CONSTANT	0.800E-03	-999.	0.100E-05	1.00
	Well distance from site	m	CONSTANT	76.2	-999.	1.00	-999.
	Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
	Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.3903E-02

1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options

K=7e-4 2.24E-4

Cell 2 WHITE STREET MSWLF, GREENSBORO, NC
Chemical simulated is DEFAULT CHEMICAL

Option Chosen	Saturated and unsaturated zone models
Run was	DETERMIN

Infiltration input by user
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model
1
1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN

Van Genuchten functional coefficients
User defined coordinate system
1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.52	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.62	-999.	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.225	-999.	0.100E-08	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.52	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	CONSTANT	0.700E-01	-999.	0.100E-08	1.00
Brook and Corey exponent,EN	--	CONSTANT	-999.	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.500E-02	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.09	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations
1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Thickness of layer	m	CONSTANT	1.52	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.138	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E-11
Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Base catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Reference temperature	C	CONSTANT	-999.	-999.	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Infiltration rate	m/yr	CONSTANT	0.224E-03	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.585E+05	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.190	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	300.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	195.	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Particle diameter	cm	CONSTANT	0.250	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.200	-999.	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	0.914	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	321.	-999.	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.330E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	14.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.48	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.800E-03	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	76.2	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.3428E-02

1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options

--- -------

K=5e-4 2.24E-4

Cell 2 WHITE STREET MSWLF, GREENSBORO, NC
Chemical simulated is DEFAULT CHEMICAL

Option Chosen Saturated and unsaturated zone models
Run was DETERMIN
Infiltration input by user
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model

1

1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN

------- ------

Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.52	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.62	-999.	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.225	-999.	0.100E-08	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.52	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	CONSTANT	0.700E-01	-999.	0.100E-08	1.00
Brook and Corey exponent,EN	--	CONSTANT	-999.	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.500E-02	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.09	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

------- ------

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Thickness of layer	m	CONSTANT	1.52	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.138	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E-00	-999.	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Base catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Reference temperature	C	CONSTANT.	-999.	-999.	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E-00	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E-00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Infiltration rate	m/yr	CONSTANT	0.224E-03	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.585E+05	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.190	-999.	0.000E+00	0.100E-11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	300.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	195.	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Particle diameter	cm	CONSTANT	0.250	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.200	-999.	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	0.914	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	158.	-999.	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.330E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	14.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.48	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.800E-03	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	76.2	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.2636E-02

1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options

--- -------

K=1e-4 2.24E-4

Cell 2 WHITE STREET MSWLF, GREENSBORO, NC
Chemical simulated is DEFAULT CHEMICAL

Option Chosen Saturated and unsaturated zone models
Run was DETERMIN
Infiltration input by user
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model
1
1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN

------- ------

Van Genuchten functional coefficients
User defined coordinate system
1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.52	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.62	-999.	0.100E-10	0.100E-05
Unsaturated zone porosity	--	CONSTANT	0.225	-999.	0.100E-05	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.52	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	CONSTANT	0.700E-01	-999.	0.100E-05	1.00
Brook and Corey exponent, EN	--	CONSTANT	-999.	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.500E-02	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.09	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

------- ------

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations
1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Thickness of layer	m	CONSTANT	1.52	-999.	0.100E-05	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.139	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Base catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Reference temperature	C	CONSTANT	-999.	-999.	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Infiltration rate	m/yr	CONSTANT	0.224E-03	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.585E+05	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.190	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	300.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	195.	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Particle diameter	cm	CONSTANT	0.250	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.200	-999.	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	0.914	-999.	0.100E-08	0.100E-06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	31.5	-999.	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.330E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	14.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.48	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.800E-03	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	76.2	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.3874E-04

1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options
--- -------

K=1e-5 2.24E-4

Cell 2 WHITE STREET MSWLF, GREENSBORO, NC
Chemical simulated is DEFAULT CHEMICAL

Option Chosen — Saturated and unsaturated zone models
Run was — DETERMIN
Infiltration input by user
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model

1

1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------

Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.52	1

DATA FOR MATERIAL 1
---- --- --------
VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.62	-999.	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.225	-999.	0.100E-08	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.52	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1
---- --- --------
VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	CONSTANT	0.700E-01	-999.	0.100E-08	1.00
Brook and Corey exponent, EN	--	CONSTANT	-999.	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.500E-02	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.09	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1
---- --- -----
VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.52	-999.	0.100E-09	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.138	-999.	0.000E-00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E-00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Base catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Reference temperature	C	CONSTANT	-999.	-999.	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E-00	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.224E-03	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.585E+05	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.190	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E-00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	300.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	195.	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.250	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.200	-999.	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	0.914	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	3.15	-999.	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.330E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	14.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.48	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.800E-03	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	76.2	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.1693E-09
*** WARNING *** Near field mixing factor is greater than 1.
Mixing factor = 1.69

1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1
Run options
--- -------

K=1e-6 2.34E-4

Cell 2 WHITE STREET MSWLF, GREENSBORO, NC
Chemical simulated is DEFAULT CHEMICAL

Option Chosen — Saturated and unsaturated zone models
Run was — DETERMIN
Infiltration input by user
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model
1
1
UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------
Van Genuchten functional coefficients
User defined coordinate system
1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.52	1

DATA FOR MATERIAL 1
---- --- --------
VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.62	-999.	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.225	-999.	0.100E-05	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.52	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1
---- --- --------
VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	CONSTANT	0.700E-01	-999.	0.100E-08	1.00
Brook and Corey exponent, EN	--	CONSTANT	-999.	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.500E-02	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.09	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1
---- --- -----
VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Thickness of layer	m	CONSTANT	1.52	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	0.100E-02	0.100E-05
Percent organic matter	--	CONSTANT	0.139	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Base catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Reference temperature	C	CONSTANT	-999.	-999.	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Infiltration rate	m/yr	CONSTANT	0.224E-03	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.585E+05	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.190	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	300.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	195.	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Particle diameter	cm	CONSTANT	0.250	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.200	-999.	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	0.914	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	0.315	-999.	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.330E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	14.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.48	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.800E-03	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	76.2	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.1693E-08
*** WARNING *** Near field mixing factor is greater than 1.
Mixing factor = 16.9

1 U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1
Run options
--- -------

K=6.39e-5 Leakage = 1.02e-4m/year

WHITE STREET MSWLF, GREENSBORO, NC
Chemical simulated is DEFAULT CHEMICAL

Option Chosen	Saturated and unsaturated zone models
Run was	DETERMIN

Infiltration input by user
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model
1
1
UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------
Van Genuchten functional coefficients
User defined coordinate system
1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.52	1

DATA FOR MATERIAL 1
---- --- --------
VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.62	-999.	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.225	-999.	0.100E-02	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.52	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1
---- --- --------
VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Residual water content	--	CONSTANT	0.700E-01	-999.	0.100E-05	1.00
Brook and Corey exponent,EN	--	CONSTANT	-999.	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.500E-02	-999.	0.000E+00	1.00
Van Genuchten exponent, EN	--	CONSTANT	1.09	-999.	1.00	5.00

1
UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations
1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Thickness of layer	m	CONSTANT	1.52	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.138	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Base catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Reference temperature	C	CONSTANT	-999.	-999.	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Infiltration rate	m/yr	CONSTANT	0.102E-03	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.585E+05	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.190	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	300.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	195.	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Particle diameter	cm	CONSTANT	0.250	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.200	-999.	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	0.914	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	201.	-999.	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.330E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	14.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.48	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.800E-03	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	76.2	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.1471E-02

1 U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options
--- -------

K=6.39e-5 Leakage = 1.81e-4m/year

Cell 2 WHITE STREET MSWLF, GREENSBORO, NC
Chemical simulated is DEFAULT CHEMICAL

Option Chosen	Saturated and unsaturated zone models
Run was	DETERMIN

Infiltration input by user
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model
1
1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------
Van Genuchten functional coefficients
User defined coordinate system
1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.52	1

DATA FOR MATERIAL 1
---- --- --------
VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.62	-999.	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.225	-999.	0.100E-08	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.52	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1
---- --- --------
VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	CONSTANT	0.700E-01	-999.	0.100E-08	1.00
Brook and Corey exponent,EN	--	CONSTANT	-999.	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.500E-02	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.09	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations
1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.52	-999.	0.100E-05	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.139	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Base catalyzed hydrolysis rate	1/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Reference temperature	C	CONSTANT	-999.	-999.	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.181E-03	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.585E+05	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-05	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.190	-999.	0.000E+00	0.100E-11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	300.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	195.	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.250	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.200	-999.	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.44	-999.	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	0.914	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	201.	-999.	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.330E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	14.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.48	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.800E-03	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	76.2	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.2610E-02

Appendix D

SPECIFICATIONS

SECTION 02775

HDPE GEOMEMBRANE LINER SYSTEM

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Furnish all labor, materials, tools, and equipment, and perform all work and services necessary for or incidental to the furnishing and installation, complete, of an impermeable, HDPE geomembrane liner as shown on Drawings and specified in accordance with provisions of the Contract Documents.
   2. Completely coordinate work with that of all other trades.
   3. Work items in project include, but are not necessarily limited to, the liner for the landfill lateral expansion.
   4. Although such work is not specifically shown or specified, all supplementary or miscellaneous items, appurtenances, and devices incidental to or necessary for a sound, secure, complete, and compatible installation shall be furnished and installed as part of this work.
   5. Furnish CQC Consultant to monitor work of Geomembrane Installer and to perform CQC testing in accordance with provisions of the Contract Documents.
   6. The Contractor, Geomembrane Installer, and CQC Consultant are required to attend the CQA/CQC Resolution Meeting and the CQA/CQC Preconstruction Meeting, Section 01200.

B. Related Sections include but are not necessarily limited to:
   1. Section 02220 - Earthwork.
   2. Section 02221 - Trenching, Backfilling, and Compacting.
   3. Section 02240 - Operational Cover and Leachate Collection Layer.
   4. Section 02276 - Soil Liner System.
   5. Construction Quality Assurance Plan.

1.2 QUALITY STANDARDS

A. Referenced Standards:
   1. American Society for Testing and Materials (ASTM).
      a. ASTM D638, Standard Test Method for Tensile Properties of Plastics.
      b. ASTM D792, Standard Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
      c. ASTM D1004, Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting.
      d. ASTM D1238 Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.
      e. ASTM D1603 Standard Test Method for Carbon Black in Olefin Plastics.
      f. ASTM D3015 Standard Practice for Microscopic Examination of Pigment Dispersion in Plastic Compounds. Refer to Subpart 2.2 for property to be tested.
      g. ASTM D3895 Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis.
      h. ASTM D4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique.
      i. ASTM D4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
      j. ASTM D5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.

k. ASTM D5397 Procedure to Perform a Single Point Notched Constant Tensile Load – Appendix (SP-NCTL) Test.
l. ASTM D5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
m. ASTM D5721 Practice for Air-Oven Aging of Polyolefin Geomembranes.
n. ASTM D5885 Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry.
o. ASTM D5994 Test Method for Measuring the Core Thickness of Textured Geomembranes.
p. ASTM D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.

2. The Geosynthetic Research Institute (GRI).
   a. GRI GM5(a) Notched Constant Tensile Load (NCTL) Test for Polyolefin Geomembranes.
   b. GRI GM6 Pressurized Air Channel Test for Dual Seam Geomembranes.
   c. GRI GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet.
   d. GRI GM11 Accelerated Weathering of Geomembranes Using a Fluorescent UVA-Condensation Exposure Device.
   e. GRI GM12 Measurement of the Asperity Height of Textured Geomembranes Using a Depth Gauge.
   f. GRI GM13 Standard Specification for Test Properties, Testing Frequency, and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembrane.

B. Qualifications:
1. Each geomembrane manufacturing or installation firm shall demonstrate 5 years continuous experience, including a minimum of 10,000,000 SF of HDPE geomembrane manufacture or installation.
2. Geomembrane Installer Personnel Qualifications: Installation Superintendent shall have worked in a similar capacity on at least five HDPE geomembrane liner jobs similar in size and complexity to the project described in the Contract Documents. The Master Welder shall have completed a minimum of 5,000,000 sf of HDPE geomembrane seaming work using the type of seaming apparatus proposed for use on this Project. Other welders shall have seamed a minimum of 1,000,000 sf of HDPE geomembrane.
3. The CQC Consultant shall meet the qualification requirements of Section 01410 of these Specifications.

C. CQA Plan Implementation: Construction Quality Assurance for the HDPE geomembrane installation will be performed for the Owner by the CQA Consultant in accordance with the CQA Plan prepared for this project. The work performed under the CQA Plan is paid for by the Owner and is not a part of this contract. The Contractor, CQC Consultant, and Geomembrane Installer, however, should familiarize themselves with the CQA Plan and are responsible for providing reasonable notice of and access to work elements that the CQA Consultant is required by the CQA Plan to overview.

1.3 SUBMITTALS

A. Submit for Engineer's approval prior to placement of geomembrane liner, including:
1. Manufacturer's Submittals.
   a. Manufacturer's Quality Control (MQC) Program: Submit for review a complete description of the geosynthetic manufacturer's formal quality control program for manufacturing HDPE geomembrane. The MQC program shall at a minimum conform to GRI GM13 standards. The manufacturer shall reject resin and geomembrane that does not conform with the requirements of the approved MQC program.
   b. Manufacturer's Field Installation Procedures Manual: Submit complete geomembrane manufacturer's specifications, descriptive drawings, and literature for the recommended installation of the HDPE geomembrane liner system, including recommended methods

for handling and storage of all materials prior to installation, and field installation guidelines that the manufacturer feels are relevant and important to the success of this project. The manual clearly identifies any exceptions taken by the manufacturer in the specified execution of the Work. Unless excepted and approved by the Engineer, the procedures herein shall be considered part of the manual.

   c. Manufacturer's Material Data: Submit statement of planned production date(s) for the geosynthetics to be provided for this Project. Prior to shipment of geomembrane, submit quality control certificates for each roll demonstrating conformance with the requirements of these Specifications. Submit statement of production dates for the resin and the HDPE geomembrane for this work.
   d. Manufacturer's written acceptance of Geomembrane Installer's qualifications for installation of the HDPE geomembrane.
   e. Warranty: Submit a warranty signed by the manufacturer regarding the material supplied.

2. Geomembrane Installer's Submittals.
   a. The Geomembrane Installer will submit written documentation that their personnel satisfy the qualifications of 1.2 B.
   b. Geomembrane Installer's Construction Quality Control Program: Submit for review a complete description of the Geomembrane Installer's formal construction quality control programs to include, but not be limited to, product acceptance testing, installation testing, including both nondestructive and destructive quality control field testing of the sheets and seams during installation of the geomembrane, proposed methods of testing geosynthetic joints and connections at appurtenances for continuity, documentation and changes, alterations, repairs, retests, and acceptance.
   c. Geomembrane Installer's Installation Procedures Manual: Submit for approval the Installer's installation manual to include: ambient temperature at which the seams are made, control of panel lift up by wind, acceptable condition of the subsurface beneath the geomembrane, quality and consistency of the welding material, proper preparation of the liner surfaces to be joined, cleanliness of the seam interface (e.g., the amount of airborne dust and debris present), and proposed details for connecting the HDPE liner to appurtenances, i.e. penetrations of the containment facilities. The document shall include a complete description of seaming by extrusion welding and hot-wedge welding. The Geomembrane Installer's Installation Manual will by reference include requirements of the Manufacturer's Installation Manual unless exceptions are noted and approved by the Engineer. After this manual has been approved by the Engineer, the Geomembrane Installer shall not deviate from the procedures included in the manual.
   d. Geomembrane panel layout with proposed size, number, position, and sequencing of panels and showing the location and direction of all field joints. Joints shall be perpendicular to flow direction where possible, unless approved otherwise.
   e. Warranty: The Geomembrane Installer shall agree in writing to warranty the geomembrane system.
3. CQC Consultants Submittals:
   a. CQC Consultant shall submit written documentation that their personnel satisfy the qualifications of Section 01400.
   b. CQC Consultants CQC Geomembrane Manual: Submit CQC Consultant's written program for meeting the geomembrane material conformance and CQC requirements of these Specifications.
4. Provide all submittals in a single coordinated transmittal. Partial submittals will not be accepted. All submittals must be submitted prior to the Geomembrane Preconstruction Meeting, Section 01200.

B. Submittals for Engineer's Approval Required for Final Acceptance of HDPE Geomembrane Liner System:
   1. Geomembrane Installer's Submittals.

a. Warranty: Submit a warranty signed by the Geomembrane Installer that the installed geomembrane liner, attachments, and appurtenances are free of defects in material, manufacturing, and workmanship.
b. Record Drawings: Submit reproducible drawings of record showing changes from the approved installation drawings. The record drawings shall include the identity and location of each repair, cap strip, penetration, boot, and sample taken from the installed geosynthetic for testing. The record drawings shall show locations of each type of material anchor trenches and the construction baseline.
c. Welder Certification: Submit certification for each welder and performance records that include linear feet of weld completed, number of samples tested, and test failure rate for each welder. Submit field notes with daily equipment reports.

2. CQC Consultant's Submittals.
a. Certification: Submit written certification that the geomembrane liner was installed in accordance with this Specification and with the approved shop drawings.
b. CQC Records: Submit copies of all material and seam test results. Each test shall be identified by date of sample, date of test, sample location, name of individual who performed the test, and standard test method used.
c. CQC Weld Test Summary Report: The CQC Consultant shall submit a report showing normal distribution of all CQC seam test results, identifying the high, low, and average of the five coupon samples in each test.

3. Provide all submittals in a single coordinated transmittal. Partial submittals will not be accepted.

1.4 PROJECT CONDITIONS

A. When the weather is of such a nature as to endanger the integrity and quality of the installation, whether this is due to rain, high winds, cold temperatures, or other weather elements, the installation of the geomembrane shall be halted at the direction of, or with the concurrence of, the Owner until the weather conditions are satisfactory.

B. The Contractor shall ensure that adequate dust control methods are in effect to prevent the unnecessary accumulation of dust and dirt on geosynthetic surfaces which hamper the efficient field seaming of geosynthetic panels.

C. The Contractor shall maintain natural surface water drainage diversions around the work area and provide for the disposal of water which may collect in the work area directly from precipitation falling within the area or from inadequate diversion structures or practices.

D. The Contractor shall be responsible to coordinate the installation of the leachate collection system which shall be in accordance with Geomembrane Installer's Installation Manual and as specified in these Specifications and shown on the Contract Drawings.

E. Vehicles will not be allowed on the liner area unless at least 24 inches of cover has been placed over the liner except as noted in these Specifications.

F. Vehicles larger than one and one-half ton pickup trucks are prohibited on the exterior berms. Contractor shall repair any damage to exterior berms prior to final payment.

1.5 DEFINITIONS AND RESPONSIBILITIES

A. Geomembrane Manufacturer: Manufacturer of geomembranes producing geomembrane sheets from resin and additives. The manufacturer is responsible for producing geomembrane sheet which complies with these Specifications. These responsibilities include but are not limited to:
1. Acceptance of the resin and additives from chemical formulators. Testing of the raw resin and additives to ensure compliance with the manufacturer's specifications and with this Specification.
2. Formulation of the resin and additives into geomembrane sheeting using mixing and extrusion equipment.

3. Testing of the geomembrane sheet to ensure compliance with manufacturer's specification and this Specification.
4. Shipping of the geomembrane sheet to installer designated facilities.
5. Certification of the raw materials and finished geomembrane sheet to comply with this Specification.
6. Certification of installer's training, experience, and methods for welding and inspection of geomembrane installations in compliance with manufacturer's standards.

B. Geomembrane Installer. Installer of geomembranes are responsible for handling, fitting, welding, and testing of geomembrane sheets or blankets in the field. These responsibilities include but are not limited to:
1. Acceptance (in writing) of the geomembrane from the manufacturer.
2. Acceptance (in writing) of the CSL surface which will serve as a base for the geomembrane. This acceptance shall precede installation of the geomembrane, and shall state that the installer has inspected the surface, and reviewed the Specifications for material and placement, and finds all conditions acceptable for placement of geomembrane liners. The written acceptance shall explicitly state any and all exceptions to acceptance.
3. Handling, welding, testing, and repair geomembrane liners in compliance with this Specification and the Geomembrane Installer's Installation Procedures Manual.
4. Performance of QA/QC testing and record keeping as required by the approved Geomembrane Installer's Field Installation Procedures Manual.
5. Repair or replacement of defects in the geomembrane as required by the CQC Consultant or the CQA Consultant.

C. Engineer: Responsible for approval of submittals from the Contractor.

D. CQC Consultant: Responsible for observing field installation of the geomembrane and performance of material conformance and CQC testing to provide the Contractor with verbal and written documentation of the compliance of the installation with these Specifications. The CQC Consultant reports to the Contractor and is part of this contract.

E. CQA Consultant: Responsible for implementing CQA Plan including overviewing material conformance testing, field installation of the geomembrane, and CQC activities, and to perform limited CQA conformance testing to provide Owner with verbal and written documentation of the compliance of the installation with these Specifications. The CQA Consultant will use the written results of the CQC program and the CQA program in the preparation of the facility Certification Document. The CQA Consultant reports to the Owner and is not part of this contract.

F. Refer to the accompanying CQA Plan for additional definitions.

1.6 WARRANTIES

A. The Manufacturer's warranty shall be against manufacturing defects and workmanship and against deterioration due to ozone, ultra- violet, and other exposure to the elements, for a period of 20 years on a pro rata basis. The warranty shall be limited to replacement of material, and shall not cover installation of replacement geomembrane.

B. The geomembrane supplied shall be capable of preventing the leachate produced by the solid waste (refuse) from reaching the underlying soil. The material supplied including factory and field seams shall have a manufacturer's warranty that it will remain impermeable when exposed over twenty (20) years to a raw landfill leachate having the following range of values*:

LEACHATE QUALITY

Component	Range of Values**	
pH	3.6	8.5
Hardness (Carbonate)	35	8,120
Alkalinity (Carbonate)	310	9,500

Calcium	240	2,570
Magnesium	64	410
Sodium	85	3,800
Iron (Total)	6	1,640
Chloride	96	2,350
Sulfate	40	1,220
Organic Nitrogen	2.4	550
Ammonia Nitrogen	0.2	845
Conductivity	100	1,200
BOD	7,050	32,400
COD	800	50,700
Suspended Solids	13	26,500

* Gewsein, Allen J., USEPA: EPA/530/SE-137, March 1975

** Values are in milligrams per liter except pH (pH units) and conductivity (Micromhos per cubic centimeter).

C. The Installer's warranty shall be against defects in the system installed for a period of two years from the date of final acceptance of the Work by the Owner.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS AND/OR GEOMEMBRANE INSTALLERS

A. Subject to compliance with the Contract Documents, the following manufacturers and Geomembrane Installers are acceptable:
1. HDPE Geomembrane liners:
   a. GSE, Inc., 19103 Gundle Road, Houston, Texas 77073.
   b. National Seal Company, 1255 Monmouth Blvd., Galesburg, IL 61401.
   c. Serrot Corporation, 271 Highway 74 North, Suite 4, Peachtree City, Georgia 30269.
   d. Poly-Flex Inc., 2000 W. Marshall Drive, Grand Prairie, TX 75051.
   e. Agru/America, Inc., 500 Garrison Road, Georgetown, SC 29440.
   f. Other installers may qualify by providing references for a minimum of 10,000,000 SF of liner installations.

B. Submit requests for substitution in accordance with Specification Section 01640.

2.2 MATERIALS

A. HDPE Geomembrane Liners:
1. Geomembrane liners shall consist of unsupported polyethylene in thickness as shown on Drawings and manufactured from virgin, first quality resin designed and formulated specifically for liquid containment in hydraulic structures. Reclaimed polymer shall not be added to the resin; except use of polymer recycled during the manufacturing process shall be allowed provided that recycled polymer shall be clean and shall not exceed 2 percent by weight.
2. The geomembrane liner shall be manufactured to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter. Any such defects shall be cause for rejection of the defective geomembrane material. Minor defects may be repaired in accordance with manufacturer's recommendations if this repair is approved by the Engineer.
3. The geomembrane liner shall be manufactured as seamless rolls or as prefabricated panels with a minimum width of 22 FT as delivered to the site. All factory seams shall be inspected and tested for strength and continuity prior to delivery to the site.
4. No additives or fillers may be added to the resin prior to or during manufacture of the geomembrane.

5. Prior to shipment, the geomembrane manufacturer will provide the Project Manager and the CQC Consultant with a quality control certificate for each roll of geomembrane provided. The quality control certificate will be signed by a responsible party employed by the geomembrane manufacturer and will include:
   a. Roll numbers and identification; and
   b. The results of quality control tests performed under the MQC program.
6. The CQC Consultant will verify that a control certificate has been received for each roll and that the certified roll properties meet the requirements of these Specifications.
7. Textured HDPE sheet (both sides) shall be used on all lined slopes of 25 percent or greater with a minimum runout of 6 feet. Smooth HDPE shall be used in all other lined areas.
8. The geomembrane liner material shall consist of **60 MIL NOMINAL HDPE** and meet or exceed GRI GM13 and the following requirements:

PROPERTY	TEST METHOD	TEST VALUE TEXTURED HDPE	 SMOOTH HDPE
a. Sheet Thickness, Mils • Minimum Average • Lowest Individual 8 of 10 • Lowest Individual 10 of 10	ASTM D5994 or D5199 (for smooth)	 nominal ± 5% nominal ± 10% nominal ± 15%	 Nominal ± 5% Nominal ± 5% Nominal ± 10%
b. Sheet Density (g/cc)	ASTM D792 or D1505	≥ 0.940	≥ 0.940
c. Melt Flow Index (g/10 min.)	ASTM D1238 Condition 190/2.16	≤ 1.00	≤1.00
d. Minimum Tensile Properties • Yield Stress • Break Stress • Elongation at Yield • Elongation at Break (2-inch gage length)	ASTM D638, Type IV, Dumb-bell at 2 imp. (each direction)	 126 ppi 90 ppi 12% 100%	 126 ppi 228 ppi 12% 700%
e. Min. Tear Resistance Initiation	ASTM D1004, Die C	45 lbs	45 lbs
f. Carbon Black	ASTM D1603 or ASTM D4218	2.0-3.0%	2.0-3.0%
g. Carbon Black Dispersion • 8 of 10 • 10 of 10	ASTM D5596	Category 1 or 2 1, 2, or 3	Category 1 or 2 1, 2, or 3
h. Puncture Resistance, Minimum Average	ASTM D4833	90 lbs	90 lbs
i. Oxidative Induction Time, Minimum Average	ASTM D3895 or ASTM D5885	100 min. 400 min.	100 min. 400 min.
j. Asperity Height, Minimum Average	GRI GM12	7 mil	NA

B. Extrusion rod shall be manufactured from identical resin to that used in geomembrane manufacture. Manufactured extrusion rod shall be tested for carbon black content and dispersion, specific gravity, and melt index at a frequency of not less than one test per batch.

2.3 INTERFACE FRICTION TESTS

A. Interface Friction Tests.
   1. Test both materials using ASTM D 5321. Section 01060-Special Conditions, paragraph 1.13, outlines the conditions under which this material shall be tested.
   2. This material is part of a system. The system shall meet the requirements before the component material can be deemed acceptable.
   3. The costs associated with this testing shall be included in the bid price for each material. Any retesting or other additional testing required to meet the Specification shall be at no additional cost to the Owner.

2.4 EQUIPMENT

A. Welding Equipment: Extrusion welding equipment shall be provided with thermocouples and temperature readout devices which continuously monitor the temperature of the extrudate. Radiant wedge welding equipment shall be provided with thermocouples and temperature readout devices which continuously monitor the temperature of the wedge. Equipment shall be maintained in adequate number to avoid delaying work, and shall be supplied by a power source capable of providing constant voltage under a combined-line load. Use a rub sheet, sand bags, or other method approved by the CQA Consultant to separate the electric generators from the geomembrane.

B. Field Tensiometer: The Geomembrane Installer shall provide a tensiometer for on-site shear and peel testing of geomembrane seams. The tensiometer shall be in good working order, built to ASTM D638 (Type IV, 2 ipm) specifications, and accompanied by evidence of recent calibration. The tensiometer shall be motor driven and be equipped with a gauge that measures the force in unit pounds exerted between the jaws as displayed on a digital readout.

C. Vacuum Box: The Geomembrane Installer shall provide a minimum of 2 vacuum box assemblies consisting of a rigid housing, a transparent viewing window, a soft closed cell neoprene gasket attached to the bottom, a port hole or valve assembly, a vacuum gauge, a vacuum pump assembly equipped with a pressure control, a rubber pressure/vacuum hose with fittings and connections, and a soapy solution and an applicator. The equipment shall be capable of inducing and holding a minimum vacuum of 5 psi.

D. Air Pressure Test: The Geomembrane Installer shall provide the necessary air pump and fittings required to perform the GRI GM6 air pressure test on dual seams.

E. Roll Handling Equipment: The Geomembrane Installer shall provide handling equipment that is adequate and does not pose a risk to the geomembrane rolls. The CQC Consultant shall inspect the equipment and confirm its adequacy.

PART 3 - EXECUTION

3.1 LINER SYSTEM CONSTRUCTION

A. Compacted Soil Liner (CSL) Component:
   1. The CSL component shall be constructed in accordance with Section 02276 and the Contractor shall protect the CSL from freezing, desiccation, flooding with water, and freezing.
   2. Prior to placement of the geomembrane, the CSL must be prepared as follows:
      a. Lines and grade must be verified by a Licensed Land Surveyor.
      b. The surface must be proofrolled to verify the supporting soil condition.
      c. The surface must be inspected for rocks larger than 0.75 IN.
      d. Steel drum rolled in preparation for the geomembrane.
   3. CSL acceptance: Geomembrane liner materials shall not be placed until the required CSL preparation has been completed and the CSL has been accepted and certified in writing by the Geomembrane Installer and approved by the CQA Engineer.

B. Geomembrane Liner:

1. The geomembrane liner shall be manufactured in accordance with the approved MQC program. The manufacturer shall not deviate from the program without written approval of the Engineer.
2. Transportation and handling of the geomembrane shall meet the following requirements:
   a. Transportation of the geomembrane is the responsibility of the Geomembrane Installer. Contractor, or other party as agreed upon.
   b. All handling on site is the responsibility of the Geomembrane Installer.
   c. The CQC Consultant will verify that the handling equipment used on the site is adequate and will not damage the geomembrane.
   d. Upon delivery to the site, the Geomembrane Installer and the CQC Consultant will conduct a surface examination of all rolls for defects or damage. This inspection will be conducted without unrolling rolls. The CQC Consultant will ensure that defective rolls are rejected and removed from the site.
   e. The Geomembrane Installer will be responsible for the storage of the geomembrane on site. The Project Manager will provide a storage location on site. The Geomembrane Installer shall ensure that the storage space is adequate to protect the geomembrane from theft, vandalism, vehicular damage, etc.
3. Field Panel Identification: The CQC Consultant will document that the Geomembrane Installer labels each field panel with an "identification code" consistent with the approved panel layout plan. The location of the label and the color of marker used must be as agreed to in the QA/QC Preconstruction Meeting.
4. Geomembrane Installation: Geomembrane liner shall be installed in accordance with the approved Geomembrane Installer's Field Installation Procedure Manual and panel layout drawing. The Geomembrane Installer shall maintain a weekly updated as-built drawing showing the location of all field panels.
   a. Geomembrane shall not be placed upon standing water or other conditions which will result in deterioration of the soil liner.
   b. The Geomembrane Installer shall remove any materials placed to protect the soil liner prior to placement of the geomembrane liner.
   c. Geomembrane liner shall be handled and placed in a manner which minimizes wrinkles, scratches, and crimps.
   d. Test seams shall be made upon each start of work for each seaming crew, upon every four hours of continuous seaming, every time seaming equipment is changed, or if significant changes in geomembrane temperature and weather conditions are observed. These test welds shall be tested using daily record that summarizes panels deployed, seams completed, seam testing, seam repair, personnel on site, and equipment on site using field tensiometer and, at a minimum, exhibit the required seam strength.
   e. Surfaces to be welded shall be clean and dry at the time of welding. Geomembrane shall not be welded when ambient temperatures are below 40 Deg F (5 Deg C) or above 104 Deg F (40 Deg C) unless the Geomembrane Installer can demonstrate that the seam quality is not compromised.
   f. Geomembrane liners shall be welded continuously without fishmouths or breaks in the weld. Where fishmouths are unavoidable, the geomembrane sheet shall be slit to a point such that the sheet lies flat and with no remaining wrinkle. The two edges of the slit shall be welded together provided that the overlap for this weld shall be a minimum of 3 IN. Areas of the slit which do not achieve an overlap of 3 IN, including the terminus of the slit, shall be provided with a patch as discussed below.
   g. Defects in and damage to geomembrane sheets shall be repaired by welding a patch over the defect using extrusion welding equipment. The patch material shall consist of an undamaged piece of geomembrane cut to provide a minimum of 3 IN of overlap in all directions from the defect. Torn or permanently twisted geomembrane shall be replaced at no expense to the Owner.

h. Personnel walking on the geosynthetic shall not engage in activities or wear types of shoes, that could damage the geosynthetic. Smoking shall not be permitted while working on the geomembrane.

i. Vehicular traffic directly on the geosynthetic shall not be permitted. Equipment shall not damage the geosynthetic materials by handling, trafficking, leakage of hydrocarbons, or any other means. The unprotected geomembrane surface shall not be used as a work area, for preparing patches, storing tools and supplies, or other uses.

5. Geomembrane Testing (Nondestructive): The Geomembrane Installer shall test and document all seam welds continuously using one of the following nondestructive seam tests:
   a. Vacuum testing shall conform to the following procedure: Brush soapy solution on geomembrane. Place vacuum box over the wetted seam area. Ensure that a leak-tight seal is created. Apply a pressure of approximately five (5) psi. Examine the geomembrane through the viewing window for the presence of soap bubbles for not less than 15 seconds. All areas where soap bubbles appear shall be marked and repaired as described in this Section.
   b. Air Pressure Testing (for double seam with an enclosed space) shall conform to GRI GM6 requirements.
6. Destructive Testing: The Geomembrane Installer shall field test seams destructively at a minimum frequency of one test per 500 LF of weld. Destructive testing of these samples shall also be performed by the CQC Consultant using the CQC Geosynthetics Laboratory. The CQC Consultant shall determine the location of destructive test samples. Conformance testing will be performed by the CQA Consultant in accordance with the project CQA Plan.
   a. The destructive sample shall be 16 IN wide by 42 IN long with the seam centered lengthwise. The sample shall be cut into three (3) equal parts for distribution to the geomembrane installer, the Owner, and the CQC Consultant.
   b. All tests shall exhibit a Film Tearing Bond type of separation in which the geomembrane material tears before the weld. At least 5 coupons shall be tested by each test method. Four of five coupons shall meet minimum requirements, as specified below:

Description	Test Method	Value (lbs/in width)
HDPE Peel	ASTM D6392	90
HDPE Shear	ASTM D6392	120

7. Documentation: The following documentation must be maintained at the project site for review by the Project Manager or CQA Consultant:
   a. Geomembrane Installer's Documentation:
      1) Daily Log: daily record that summarizes panels deployed, seams completed, seam testing, seam repair, personnel on site, and equipment on site.
      2) Panel Log: provides geomembrane roll number used and subgrade acceptance for each panel deployed.
      3) Seam Testing Log: provides a complete record of all nondestructive and destructive seam tests performed as part of the Geomembrane Installer's QC program.
      4) Seam/Panel Repair Log: provides a complete record of all repairs and vacuum box testing of repairs made to defective seams or panels.
      5) As-Built Drawing: maintain an as-built drawing updated on a weekly basis.
   b. CQC Consultant's Documentation:
      1) Daily Log: daily record that summarizes panels deployed, seams completed, CQC seam testing, seam repair, personnel on site, equipment on site, weather conditions, etc.
      2) CQC Testing Log: record of all seam destructive tests and material conformance tests performed by the CQC Geosynthetics Laboratory.

3) Material Conformance: maintain original conformance certificate(s) from geomembrane manufacturer.
4) Subgrade Acceptance Log: maintained originals of subgrade acceptance forms for each panel and signed by the Geomembrane Installer.

3.2 GEOMEMBRANE ACCEPTANCE

A. The Geomembrane Installer shall retain all Ownership and responsibility for the geomembrane liner system until final acceptance by the Owner. Owner will accept the geosynthetic installation when the installation is finished and all required submittals from the Geomembrane Installer and CQC Consultant have been received and approved, and CQA verification of the adequacy of all field seams and repairs, including associated testing, is complete.

END OF SECTION

SECTION 02276
SOIL LINER SYSTEM

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Soil used in the containment system.

B. Related Sections include but are not necessarily limited to:
   1. Section 02110 - Site Clearing.
   2. Section 02220 - Earthwork.
   3. Section 02775 – HDPE Geomembrane Liner Systems.
   4. Section 02800 - Geosynthetic Clay Liner.
   5. Construction Quality Assurance Plan.

1.2 QUALITY STANDARDS

A. Reference Standards:
   1. ASTM - American Society for Testing and Materials:
      a. ASTM D-422 - Particle Size Analysis.
      b. ASTM D-698 - Standard Proctor.
      c. ASTM D-854 - Specific Gravity.
      d. ASTM D-1140 - Fines Content in Soils.
      e. ASTM D-1556 - In-situ Density Measurement Using the Sand Cone.
      f. ASTM D-1557 - Modified Proctor.
      g. ASTM D-2166 - Unconfined Compressive Strength.
      h. ASTM D-2216 - Moisture Content Using Over-Dry Method.
      i. ASTM D-2487 - Soils Classification.
      j. ASTM D-2573 - Field Vane Shear Test.
      k. ASTM D-2922 - In-situ Density Using Nuclear Methods.
      l. ASTM D-3017 - In-situ Moisture Content Using Nuclear Methods.
      m. ASTM D-4318 - Atterberg Limits.
      n. ASTM D-5084 - Flexible Wall permeameter.
   2. USEPA - United States Environmental Protection Agency
      a. EPA/600/R-93/182 -"Quality Assurance and Quality Control for Waste Containment Facilities," September, 1993.
   3. ASCE – American Society of Civil Engineers.
      a. ASCE Paper No. 25333 – Water Content – Density Criteria for Compacted Soil Liners (Daniel et at, 1998).
      b. ASCE Paper No. 23827 – In-Site Hydraulic Conductivity for Compacted Clay (Daniel et at, 1989).
   4. Construction Quality Assurance (CQA) Plan.

1.3 SUBMITTALS

A. See Section 01300 - Submittals.

B. Refer to the CQA Plan.

1.4 JOB CONDITIONS

A. Verify conditions of subgrade prior to commencing work.

1.5 TOLERANCES

A. The soil liner system must meet the following tolerances:
   1. The saturated hydraulic permeability of the soil liner must be equal to or less than 1.0×10^{-5} cm/sec, as determined by ASTM D5084.
   2. The thickness of the soil liner must be equal to or greater than 18 IN. Any excess shall be on the bottom of the layer.
   3. The work should be constructed to lines, grades, and control points indicated on the Drawings, and shall be controlled and documented with survey methods. Laser based survey systems are preferred for grading.
   4. Finished grade tolerance; plus 0.1 FT from required elevation.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Low Permeability Soil - General:
   1. Contractor shall provide natural, fine-grained soil or bentonite amended soil that is capable of being worked to produce a soil layer of thickness shown on the Drawings that meets the hydraulic conductivity requirements.
   2. In accordance with these Specifications, the Contractor is responsible for conducting a borrow soil characterization study (BSCS).
   3. Contractor shall provide the CQA Consultant and Owner access to information about the borrow source of the low permeability soil and certify that it is not contaminated with hazardous materials or hazardous wastes.
   4. The soil shall be relatively homogeneous in color and texture and shall be free from roots, stones, foreign objects, and other deleterious materials.

B. Natural Fine-Grained Soil
   1. Classification: Natural fine-grained soil shall have a classification of CH, CL, MH, or ML as determined by ASTM D2488.
   2. Grain sizes shall be within the following gradation:

Sieve Size	Percent Passing by Weight
3/4 IN	100
No. 4	> 90
No. 200	> 30

   3. Hydraulic Conductivity: The saturated hydraulic conductivity of the natural fine-grained soil shall meet the stated tolerances, when compacted in accordance with requirements established by the CQC Consultant and Contractor on the basis of the soil liner test strip as specified herein.
   4. Other Soil Liner Properties:
      a. The liquid limit shall be at least 25 as measured by ASTM D4318.
      b. The plasticity index shall be at least 10 and less than 30 as measured by ASTM D4318.

C. Bentonite Amended Soil (where applicable):
   1. Hydraulic conductivity of constructed bentonite amended soil shall meet the tolerances when compacted in accordance with requirements established by the CQC Consultant on the basis of test results from the soil liner test strip and the borrow soil characterization study.
   2. Soil used in the bentonite amended soil shall be free from roots, organic matter, debris, particles larger than 3/4 IN, and other deleterious material. All soil used in the bentonite amended soil shall be taken from a borrow area approved by the CQC Consultant and Engineer.
   3. Unless approved otherwise by the CQC Consultant, the soil used in the bentonite amended soil shall meet the following washed sieve gradation:

Sieve Size	Percent Passing by Weight
¾ IN	100
No. 4	55-100
No. 20	45-75
No. 200	10-40

4. Bentonite:
   a. Bentonite shall be free-flowing, powdered, high-swelling, sodium montmorillonite clay (bentonite) free of additives.
   b. Acceptable bentonite manufacturers are:
      1) American Colloid, Co., (800) 637-6654.
      2) Bentonite Corp., (303) 291-2940.
      3) CETCO, (813) 527-0605.
      4) Federal Industrial, (800) 231-3565.
      5) WYO-BEN, (800) 548-7055.
   c. The Contractor may propose a bentonite supplier other than those listed above if it is demonstrated that its use in the amended soil satisfies the requirements of these Specifications.

D. Permeability Test
   1. Laboratory permeability tests (ASTM D-5084) shall be conducted in constant head, triaxial type permeameters. The specimens shall be consolidated under an isotropic effective consolidation stress not to exceed 10 psi and permeated with water under a backpressure of at least 90 pounds per square inch (psi) to achieve saturation of the test specimens. The inflow to and outflow from the specimens shall be monitored with time and the coefficient of permeability calculated for each recorded flow increment. The test shall continue until steady state flow is achieved and relatively constant values of coefficient of permeability are measured.

E. Interface Friction Tests.
   1. Test materials using ASTM D 5321. Section 01060. Special Conditions, paragraph 1.13, outlines the conditions under which this material shall be tested.
   2. This material is part of a system. The system shall meet the requirements before the component material can be deemed acceptable.
   3. The costs associated with this testing shall be included in the Bid price for each material. Any retesting or other additional testing required to meet the Specifications shall be at no additional cost to the Owner.

2.2 SOIL LINER MATERIAL ACCEPTANCE

A. General: All imported, on-site, and processed materials specified in this Section are subject to the following requirements:
   1. All tests necessary for the Contractor to locate and define acceptable sources of materials shall be made by the CQC Consultant. Certification that the material conforms to the Specification requirements along with copies of the test results from a qualified commercial testing laboratory shall be submitted to the CQA Consultant for approval at least 10 days before the material is required for use. All material samples shall be furnished by the Contractor at the Contractor's sole expense.
   2. All samples required in this Section shall be representative and be clearly marked to show the source of the material and the intended use on the project. Sampling of the material source shall be done by the CQC Consultant in accordance with ASTM D75.
   3. Notify the CQA Consultant at least 24 hours prior to sampling so that they may observe the sampling procedures.
   4. Tentative acceptance of the material source shall be based on an inspection of the source by the CQA Consultant and the certified test results of the Borrow Source Characterization Study (BSCS) as submitted by the Contractor to the CQA Consultant. No imported

materials shall be delivered to the site until the proposed source and materials tests have been accepted in writing by the CQA Consultant.

5. Final acceptance of any material will be based on results of tests made on material samples taken from the completed soil liner test strip, combined with the results of the BSCS. If tests conducted by the CQC Consultant or the CQA Consultant indicate that the material does not meet Specification requirements, material placement will be terminated until corrective measures are taken. Material which does not conform to the Specification requirements and is placed in the work shall be removed and replaced at the Contractor's sole expense.
6. Contractor shall be solely responsible for obtaining all permits required to obtain acceptable sources of materials for use in the work.

B. Sampling and testing required herein shall be done at the Contractor's sole expense.

C. Borrow Source Characterization Study:

1. The Contractor will be responsible for all processing and screening of the soil liner material at his own cost to meet the requirements of the Specifications. The Contractor will be responsible for the erosion protection of the stockpile and borrow area during his operation. The Contractor shall coordinate all aspects of this operation with the CQC Consultant, CQA Consultant, and Project Manager.
2. CQC Consultant shall complete a BSCS of natural fine-grained soils or of soil that will be used in bentonite amended soils.
3. Contractor shall conduct tests, including particle size, Atterberg limits, moisture-density, and hydraulic conductivity tests, as necessary to locate an acceptable source of material.
4. Once a potential source of material has been located, the CQC Consultant shall develop and undertake a testing program to demonstrate the acceptability of the proposed material. Certified results of all tests shall be submitted to the CQA Consultant upon completion of tests. Tentative acceptance of the borrow source by the CQA Consultant will be based upon the results of the study. The testing program shall include the following elements, at a minimum:
   a. An excavation plan for the borrow source indicating proposed surface mining limits and depths of samples to be taken for testing.
   b. Test pits for borrow source sampling shall be appropriately spaced to reflect site geomorphology and sampled at depth intervals appropriate to the proposed excavation methods.
   c. A minimum of 12 samples shall be collected and tested for the parameters required as described in the following paragraphs.
5. Test Parameters and Reporting for Natural Fine-Grained Soils: All samples collected from the proposed borrow area for natural fine-grained soils shall be tested for the following parameters:

Parameter	Test Method
Particle Size (sieve plus hydrometer)	ASTM D422
Atterberg Limits	ASTM D4318
Standard Proctor	ASTM D698
Hydraulic Conductivity(1)	ASTM D5084

(1) Hydraulic conductivity tests shall be performed on recompacted samples of the proposed material, compacted according to criteria developed by the CQC Consultant using data from tests conducted in accordance with ASTM D698.

6. Test Parameter for Soil to be Used in Bentonite Amended Soil:
   a. Parameters and reporting for soils to be used in bentonite amended soil shall be the same as for natural fine-grained soil.
   b. Tests required under this paragraph are part of the BSCS. Additional tests on the bentonite amended soil product are required for soil liner acceptance. See 2.1E.

D. Borrow Soils Conformance Testing:
1. Following acceptance of a borrow source for natural fine-grained soils and soils for bentonite amendment, the following tests shall be performed by the CQC Consultant on samples taken from the excavated material using the methods and at the frequencies indicated below:

Test	Test Method	Minimum Frequency
Percent Fines	ASTM D1140	1 per 5,000 cu yd
Atterberg Limits	ASTM D4318	1 per 5,000 cu yd
Standard Proctor	ASTM D698	1 per 10,000 cu yd

2. The CQC Consultant shall conduct tests more often if variation in test results is occurring, or if material appears to depart from Specifications.
3. The CQA Consultant may also conduct independent tests to confirm the accuracy of the CQC testing.
4. If tests indicate material does not meet Specification requirements, Contractor shall terminate material placement until corrective measures are taken.
5. Contractor shall remove and replace material which does not meet Specification requirements at no additional cost to the Owner.

E. Bentonite Amended Soil Conformance Testing (where applicable):
1. Following acceptance of a source for soils to be used in bentonite amended soils, the CQC Consultant shall perform a Design Mix Analysis and submit certifications for the imported bentonite material as described below.
2. Design Mix Analysis:
   a. Collect two of the coarsest samples of the soil taken from the approved borrow area (based on percent retained on #200 sieve). Soil samples for testing shall be at least 100 pounds each.
   b. Trial mix samples shall be prepared by mixing each soil sample with three trial application rates of bentonite. Compact each trial mix sample to a dry density equal to 95 percent relative compaction and at a moisture content within the range of optimum to optimum plus 3 percent (ASTM D-698) for the unamended soil.
   c. Test the hydraulic conductivity of the trial mix samples using ASTM D5084 and report all data to CQA Consultant. Graph measured hydraulic conductivity vs. percent bentonite.
   d. Contractor shall select a minimum bentonite content needed to consistently achieve the required in-place hydraulic conductivity.
3. After mix design and initial testing, CQC Consultant shall conduct tests of the mixed bentonite amended soil, after it has been discharged from the pugmill and before this is placed in the work using the following methods and at the following frequencies.

Test	Method	Minimum Frequency
Standard Proctor	ASTM D698 or ASTM D1557	1 per 10,000 cu yd

4. Bentonite: CQC Consultant shall submit certifications from the supplier of the bentonite material that it meets the requirements specified under PART 2, PRODUCTS.

F. Fine-Grained Material Dewatering, Mixing, and Staging
1. Dewatering of soil liner borrow excavations, if required, shall be solely at the Contractor's expense.
2. Drying, blending, or wetting required to maintain the soil liner soil at a suitable moisture content shall be solely at the Contractor's expense.

2.3 EQUIPMENT

A. Compaction Equipment:

1. The compaction equipment shall be of a suitable type, adequate to obtain the permeability specified, that provides a kneading action, such as a wobble-wheeled roller or a sheepsfoot roller having tines as long as the maximum loose lift thickness to ensure proper lift interface compaction free of voids.
2. The CQC Consultant shall confirm compaction equipment adequacy, and recommend changes if required, based on the soil liner test strip. Such additional equipment will be provided by Contractor at no additional cost.
3. The compaction equipment shall be maintained and operated in a condition that will deliver manufacturer's rated compactive effort.
4. Hand-operated equipment shall be capable of achieving specified soil densities.
5. The finished surface of the final lift shall be rolled with a smooth steel drum roller or rubber-tired roller to eliminate tine or roller marks and provide a smooth, dense surface for geomembrane placement.

B. Moisture Control Equipment:
1. Equipment for applying water shall be of a type and quality adequate for the work, shall not leak, and shall be equipped with a distributor bar or other approved device to assure uniform application.
2. Equipment for mixing and drying out material shall consist of blades, discs, or other equipment defined by the CQC Consultant as approved by the CQA Consultant.
3. Mixing of natural fine-grained soils may also be required to get even distribution of moisture.
4. Soil liner material must not be compacted within 24 hours of the adjustment of water content by the addition of water.

C. Bentonite Amended Soil Mixing Equipment (where applicable):
1. Contractor shall mix, process, and condition the bentonite amended soil in a pugmill prior to placing and compacting the mixture.
2. The pugmill shall have the capability to break up soil clumps and mix material to form a homogeneous blend. The pugmill shall have controls that allow a variable rate of discharge from it, to control the degree of mixing. The pugmill shall have automated controls to control the rate of feed of each material to within an accuracy of 2 percent by weight.
3. The pugmill discharge shall be equipped with a batching bin having a drop outlet for loading hauling vehicles directly from the pugmill. Pugmill shall be positioned to allow direct discharge to hauling vehicles.
4. Contractor shall not store amended soil in a manner or for a length of time that will cause any degradation of the project or amended soil.

PART 3 - EXECUTION

3.1 SOIL LINER TEST STRIP

A. Test Strip Installation:
1. Prior to actual soil liner installation, a soil liner test strip of a dimension no less than 100 FT long by 30 FT wide by 1.5 FT thick shall be constructed by the Contractor over a compacted subgrade within the liner construction site.
2. The soil liner test strip shall be constructed in three 6 IN lifts. The final compacted thickness of each lift shall be a maximum of 6 IN. Prior to placement of successive lifts, the surface of the lift in place shall be scarified or otherwise conditioned to eliminate lift interfaces.
3. The soil liner test strip shall be constructed using the same equipment and construction procedures that are anticipated for use during actual liner installation.
4. During test strip installation, the Contractor in coordination with his CQC Consultant and the CQA Consultant shall determine the field procedures that are best suited for his construction equipment to achieve the requirements specified herein.

5. If the test strip fails to achieve the desired results, the soil material of the strip shall be completely removed, and additional test strip(s) shall be constructed until the requirements are met.
6. The CQC Consultant shall document that the subgrade of the test strip liner is properly compacted to at least 95 percent of the maximum dry density, as determined using the Standard Proctor test (ASTM D-698). Field density tests on the subgrade shall be performed by the CQC Consultant and documented at a minimum of three test locations within the test strip area.
7. At least five field density measurements shall be performed by the CQC Consultant on each lift of the liner test strip. The field density tests shall be conducted using a nuclear gauge (ASTM D-2922) or other method, as approved by the CQA Consultant. Corresponding tests for moisture content to determine dry density shall likewise be performed by using a nuclear gauge (ASTM D-3017), or other approved method. On the test pad, the density measurement if performed by a nuclear gauge shall be verified through performance of one sand cone test (ASTM D-1556) or drive tube test (ASTM D-2937) at a location selected by the CQA Consultant. The moisture content measurement, if performed by a nuclear gauge shall be verified by recovering at least five samples for oven-dry testing (ASTM D-2216) from the test location.
8. A composite sample will be taken from each lift for recompacted lab permeability (ASTM D-5084).
9. Upon completion of the soil liner test strip, the CQC Consultant, as observed by the CQA Consultant, shall measure the thickness of the test strip at a minimum of five random locations.
10. A minimum of five random samples of the liner construction materials delivered to the site during test strip installation shall be tested by the CQC Consultant for moisture content (ASTM D-2216), sieve analyses (ASTM D-421, D-422) and Atterberg limits (ASTM D-4318).
11. The CQC Consultant shall conduct at least one standard Proctor (ASTM D-698) and one modified Proctor (ASTM D-1557) compaction test on bag samples of the test strip material to determine the moisture-density relationships.
12. A minimum of one undisturbed sample shall be taken from each lift of the test strip by the CQC Consultant for laboratory hydraulic conductivity testing. The samples shall be taken within a 2 FT radius of the in-situ density and moisture tests. The CQA Consultant will also conduct at least one confirmatory in-situ hydraulic conductivity testing.
13. The data gathered from the test strip sampling (i.e., field density, moisture, undisturbed samples, and in-situ hydraulic conductivity) shall be used along with the Proctor curve for the soil to develop a range of acceptable moisture and density test values which are likely to be consistent with the required maximum permeability. This range of moisture/density values will be established by the CQC Consultant and the CQA Consultant and will be utilized as a means to establish Pass/Fail Criteria for the remainder of the area to be lined by the subject material.
14. The test strip will be considered acceptable if the measured hydraulic conductivity of the test strip as determined by ASTM D-5084 meets the requirements of the Specifications.
15. If field and laboratory test data indicate that the installed test strip meets the requirements of this Specification, it may be used as part of the liner provided that it is adequately protected by the Installer from drying and equipment damage after installation. The Installer shall scarify the liner material along the edge of the test strip. A minimum 2 FT overlap per lift is required for mixing and compaction between the test strip and the liner.
16. If the test strip fails to meet Specifications, additional mix designs (if bentonite amended) and/or test strips will be constructed until a test strip meets the requirements. No soil liner may be placed until a test strip has been accepted by the CQA Consultant.
17. Upon receipt of the test data from the CQA Consultant, the Project Manager shall inform the Contractor if the test strip can remain in-place as part of the liner.

3.2 INSTALLATION

A. The subgrade to be lined shall be smooth and free of vegetation, sticks, roots, foreign objects. and debris. It shall be the responsibility of the Contractor to keep the receiving surfaces in the accepted condition until complete installation of the liner is accomplished.

B. The subgrade shall be proofrolled with a pneumatic tired vehicle of at least 20 tons GVW, making passes across the area as directed by the CQC and/or CQA Consultants. The soil liner shall not be placed over areas deemed unacceptable by either the CQC or CQA Consultants based on proofroll observations or inadequate test results.

C. The soil liner shall be installed in compacted lifts of approximate equal thickness. The material shall be placed consistent with criteria developed from construction of a satisfactory test strip.

D. When particles exceeding ¾ IN are observed at the final lift surface, they shall be removed by the Contractor prior to final rolling of the surface.

E. Equipment shall be used such that bonding of the two lifts will occur. Equipment shall have cleats or other protrusions of such length necessary to completely penetrate into the loose lift. Compaction shall be performed using appropriately heavy, properly ballasted, penetrating foot compactor making a minimum number of passes as approved by the CQC Consultant and CQA Consultant based on the soil liner test strip.

F. If desiccation and crusting of the lift surface occurs prior to placement of the next lift, this area shall be scarified to a minimum depth of 2 IN or until sufficiently moist materials are encountered, whichever is greater. After scarification, the superficial material should be reworked to obtain a moisture content at least 2 percent above optimum moisture content. Alternately, the drier superficial soil may be stripped and mixed with additional moist soil to achieve a moisture content satisfying the project requirements.

G. No frozen material shall be placed.

H. Material shall not be placed on a previous lift which is frozen. Frozen in-place material shall be removed prior to placement of additional soil material.

I. Material which has been subjected to a freeze/thaw cycle(s) shall be disked and recompacted prior to placement of subsequent lifts.

J. During construction, exposed finished lifts of the soil liner material should be sprinkled with water to minimize desiccation, as necessary. The Contractor is responsible to protect the soil liner from rain, drying, desiccation, erosion and freezing. All defective areas shall be repaired by the Contractor to the satisfaction of the CQC Consultant at no extra compensation.

K. At the end of each day's construction activities, completed lifts or sections of the compacted soil liner should be sealed. Common sealing methods include rolling with a rubber tired or smooth-drum roller, backdragging with a bulldozer, or placement of temporary cover soil over the compacted soil liner. The compacted soil liner should be sprinkled with water, as needed.

L. If testing shows that a lift is significantly thicker than 6 IN, the top of the lift will be shaved off so that the lift is approximately 6 IN thick.

3.3 FIELD QUALITY CONTROL AND QUALITY ASSURANCE

A. Refer to the CQA Plan.

B. The following field and laboratory quality control tests shall be performed by the CQC Consultant at no additional expense to the Owner during soil liner construction:

Test	Method	Minimum Frequency	Acceptable Criteria
1. Field Density	ASTM D2937 or ASTM D2937	1/10,000 SF/lift 1/5 D3017 tests	≥ 95% ≥ 95%
	ASTM D3017	1/10,000 SF/lift	≥ 95%
2. Thickness	Surveyor	8 locations/acre	per plans
3. Atterberg Limits	ASTM D4318	1/acre/lift	BSCS Criteria
4. Fines Content	ASTM D1140	1/acre/lift	BSCS Criteria
5. Hydraulic Conductivity	ASTM D5084	1/acre/lift	$\leq 1 \times 10^{-5}$ cm/sec
6. Laboratory Moisture Density Relationship	ASTM D698 or D1557	1/5,000 CY of placed liner material	NA

C. Test methods shall also conform to criteria set forth in Paragraph 3.1, Soil Liner Test Strip.

D. Test frequencies may be modified by the CQA Consultant. If there are indications of declining or failing test results, frequencies may be increased. If hydraulic conductivity test results are well above acceptable, the frequency for Atterberg limit and fine content testing may be waived.

E. The acceptable criteria may be modified by the CQA Consultant if supported by the test strip results and approved by the Engineer.

F. Holes in the compacted soil liner created as a result of destructive testing (eg., thin-walled Shelby tube sampling and nuclear gauge, field density determinations) shall be backfilled and tamped by rod uniformly in 2 IN thick lifts. The backfill material shall be the same liner construction material or hydrated bentonite powder, if approved by the CQA Consultant. On the surface, the backfill material shall extend slightly beyond the holes to make sure that a good tie-in with the surrounding liner is achieved. Repaired areas shall be observed and documented by the CQC Consultant.

G. Give minimum of 24 HR advance notice to CQA Consultant when ready for soil testing and inspection in completed area of the soil liner.

H. For areas not meeting field and laboratory testing criteria, the Contractor shall scarify the full depth of the lift or replace the material as needed. The material shall be reshaped, rewetted as needed, rehomogenized and recompacted to the specified density. Areas not meeting the thickness requirements shall be augmented with additional materials. The added materials shall be reworked with the soil layer to ensure homogeneity and proper bonding. This may be done by scarification of the surface prior to addition of new material. The repaired area shall be properly documented, and field and laboratory quality control testing shall be performed to ensure the repaired liner section meets the requirements specified herein.

I. The Contractor shall pay for all costs associated with corrective work and retesting resulting from failing tests. The CQA Consultant shall be informed immediately of all failing tests.

END OF SECTION

SECTION 02800

GEOSYNTHETIC CLAY LINER (GCL)

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Furnish all labor, material, and equipment to complete installation of the GCL in accordance with the Contract Drawings and these Specifications.
   2. Completely coordinate work with that of other trades.
   3. Although such work is not specifically shown or specified, all supplementary or miscellaneous items, appurtenances, and devices incidental to or necessary for a sound, secure, complete, and compatible installation shall be furnished and installed as part of this work.
   4. Furnish CQC Consultant to monitor the work of GCL Installer and to perform CQC testing in accordance with provisions of the Contract Documents.

B. Related Sections include but are not necessarily limited to:
   1. Section 02220 - Earthwork.
   2. Section 02775 - HDPE Geomembrane Liner.

1.2 QUALITY STANDARDS

A. Referenced Standards:
   1. American Society for Testing and Materials (ASTM).
      a. ASTM D4632, Test Method for Grab Breaking Load and Elongation of Geotextile.
      b. ASTM D4643, Determination of Water Content of Soil by Microwave Oven Method.
      c. ASTM D4833, Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
      d. ASTM D5084, Test Method for Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.
      e. ASTM D5261, Measuring Mass Per Unit Area of Geotextiles.
      f. ASTM D5321, Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.
      g. ASTM D5887, Measurement of Index Flux through Saturated GCL Specimens Using a Flexible Wall Permeameter.
      h. ASTM D5888, Storage and Handling of GCL.
      i. ASTM D5889, Quality Control of GCL.
      j. ASTM D5890, Swell Index Measurement of Clay Mineral Component of GCL.
      k. ASTM D5891, Fluid Loss of Clay Mineral Component of GCL.
      l. ASTM D5993, Measuring Mass Per Unit Area of GCL.
      m. ASTM D6072, Installation of GCL.
   2. Geosynthetic Research Institute (GRI):
      a. GCL-2, Permeability of Geosynthetic Clay Liners.

B. Qualifications:
   1. Manufacturer: The GCL shall be furnished by a manufacturer that has previously produced a minimum of 1,000,000 SF of the material for use in similar projects.

C. CQA Plan Implementation: Construction Quality Assurance documentation for the GCL installation will be performed for the Owner by the CQA Consultant in accordance with the CQA Plan prepared for this project. The work performed under the CQA Plan is paid for by the Owner and is not a part of this contract. The Contractor, CQC Consultant, and GCL Installer, however, should familiarize themselves with the CQA Plan and are responsible for providing reasonable notice of and access to work elements that the CQA Consultant is required by the CQA Plan to overview.

1.3 DEFINITIONS

A. Manufacturer: Manufacturer produces geosynthetic clay liner panels from first quality geotextiles and sodium bentonite. The manufacturer is responsible for producing panels which comply with this Specification. These responsibilities include but are not limited to:
   1. Acceptance of the geotextiles, bentonite, and additives from suppliers/manufacturers and testing of these materials to ensure compliance with the manufacturer's specifications and with this Specification.
   2. Fabrication of the geotextiles and bentonite into GCL panels using mixing and extrusion equipment.
   3. Testing of the GCL to ensure compliance with manufacturer's specification and this Specification.
   4. Shipping of the GCL to fabricator/installer designated facilities.
   5. Certification of the raw materials and finished GCL to comply with this Specification.
   6. Certification of fabricator's and installer's training, experience, and methods for seaming and inspecting GCL installations in compliance with manufacturer's standards and with Quality Assurance requirements of this Specification (Article 1.2).

B. Installer: Installers of GCLs are responsible for storing, handling, fitting, seaming, and testing of GCL panels in the field. These responsibilities include but are not limited to:
   1. Acceptance (in writing) of the GCL rolls from the transporter.
   2. Acceptance (in writing) of the soil material which will serve as a base for the GCL. This acceptance shall precede installation of the GCL, and shall state that the installer has inspected the surface, and reviewed the Specifications for material and placement, and finds all conditions acceptable for placement of GCL liners. The written acceptance shall explicitly state any and all exceptions to acceptance.
   3. Handling, seaming, testing, and repair of GCL liners in compliance with this Specification and with written procedures manuals prepared by the installer or the manufacturer.
   4. Repair or replacement of defects in the GCL as required by the Inspector or the Owner.
   5. Installer and manufacturer may be the same firm.

C. Inspector: Inspectors of GCL liner are responsible for observing field installation of the GCL and providing the manufacturer, installer, and Owner with verbal and written documentation of the compliance of the installation with this Specification and with written procedures manuals prepared by the manufacturer. Inspector's responsibilities include, but are not limited to:
   1. Inspection of material, handling, and field installation of the GCL liner. Inspection of all seams, repair, and test results.
   2. All exceptions to material or installation shall be documented to the Engineer in writing within 48 hours of discovery.

D. Engineer: The Engineer is responsible for design of the geosynthetic liner system.

E. Owner: Owner designates the party responsible for constructing and operating the lined containment system.

1.4 SUBMITTALS

A. Pre-Installation: The Contractor shall submit the following information and material to the CQA Consultant prior to installation of the GCL.
   1. Product Data and Factory Test Results: Published product properties and specifications for the proposed GCL, as well as factory test results of materials certified by the GCL manufacturer, shall be submitted showing conformance with the requirements of these Specifications. In addition, the Contractor shall submit the manufacturer's certification stating that the material is similar to and of the same formulation as that for which test results are submitted, and by which actual usage has been demonstrated to be satisfactory for the intended application.

2. Samples: Samples of the GCL sheeting shall be provided to the CQA Consultant. Samples shall have a width of 6 IN, and a length of 8 IN.
3. Delivery, Storage, and Handling Instructions: The manufacturer's recommendations for delivery, storage, and handling shall be submitted to the CQA Consultant for review.
4. Delivery Date: The CQA Consultant shall be notified of the scheduled delivery date for the materials.
5. Installation Drawings, Procedures, and Schedules: Installation drawings, procedures, and a schedule for carrying out the work shall be provided by the Contractor to the CQA Consultant for review. Procedures addressed by the Contractor shall include but not be limited to material unloading, storage, installation, repair, and protection to be provided in the event of rain. A schedule showing the order of placement, location of panels, seams, and penetrations shall be submitted for the CQA Consultant's review. Submit drawings showing the panel layout, seams, and associated details including pipe penetrations. Following review, these drawings will be used for installation of the GCL. Any deviations from these drawings must be approved by the CQA Consultant.

B. Post-Installation: Upon completion of GCL installation, the Contractor shall submit the following to the CQA Consultant:
1. A certificate stating that the GCL has been installed in accordance with the Plans, Specifications, and the manufacturer's recommendations.
2. Manufacturer's Warranty: The material warranty shall be for defects or failures related to manufacture on a non-prorata basis for five (5) years after date of shipment.
3. GCL Installer's Warranty: The GCL Installer's warranty shall warrant their workmanship to be free of defects on a non-prorata basis for five (5) years after the final acceptance of the Work. This warranty shall include but not be limited to overlapped seams, anchor trenches, attachments to appurtenances, and penetration seals.
4. Record Drawing Information: Record drawings including but not limited to drawings showing the location of all seams, panels, repairs, patches, anchor trenches, pipe penetrations, and other appurtenances, including measurements and dimensions, shall be prepared by the Contractor and submitted to the CQA Consultant following completion of the project.

1.5 PROJECT CONDITIONS

A. The GCL shall not be placed in standing water, high humidity, or while raining. Any material that becomes partially or completely hydrated in the opinion of the CQA Consultant shall be removed and replaced at Contractor's expense.

B. Take necessary precautions to protect underlying soil and geomembrane liners from damage due to any construction activity. Damage to liners shall be repaired at Contractor's expense.

C. The Contractor shall ensure that adequate dust control methods are in effect to prevent the unnecessary accumulation of dust and dirt on geosynthetic surfaces, which hampers the efficient field seaming of geosynthetic panels.

D. The Contractor shall maintain natural surface water drainage diversions around the work area. The Contractor shall provide for the disposal of water that may collect in the work area, from precipitation falling on the work or from inadequate diversion structures.

PART 2 - PRODUCTS

2.1 MATERIALS

A. General:
1. The GCL shall consist of bentonite encased, front and back, with geotextile. GCL consisting of bentonite backed with geomembrane can be used only if approved by the Project

Manager and Engineer. The materials supplied under these Specifications shall be first quality products designed and manufactured specifically for the purposes of this work.

2. The GCL shall be supplied in rolls which have a minimum width of 12 FT. The roll length shall be maximized to provide the largest manageable sheet for the fewest overlaps. Labels on the roll shall identify the sheet number, date of fabrication, proper direction of unrolling, and minimum recommended overlap. A quality control certificate shall be supplied with each roll.
3. **The GCL shall be reinforced on slopes of 25% or greater with a minimum of 6 feet runout and unreinforced on slopes less than 25%.**
4. The bentonite shall be continuously adhered to both geotextiles to ensure that the bentonite will not be displaced during handling, transportation, storage and installation, including cutting, patching, and fitting around penetrations. The bentonite sealing compound or bentonite granules used to seal penetrations and make repairs shall be made of the same natural sodium bentonite as the GCL and shall be as recommended by the GCL manufacturer. The permeability of the GCL overlap seams shall be equal to or less than the permeability of the body of the GCL sheet.

B. Physical Properties: Physical properties of GCL shall be as shown in Table 1 of this Section. The manufacturer shall certify that materials provided meet these criteria according to ASTM D5889 as modified by this Specification.

TABLE 1: REQUIRED GCL PROPERTIES

GCL PROPERTY	TEST METHOD	VALUE	
		REINFORCED	NONREINFORCED
Maximum Hydraulic Conductivity	ASTM D5084 (@ 30 psi effective stress)	5×10^{-9} cm/s	5×10^{-9} cm/s
Minimum Bentonite Content	ASTM D5993 (@ 0% moisture)	0.75 lb/sf	0.75 lb/sf
Minimum Grab Tensile Strength	ASTM D4632	90 lbs	75 lbs
Minimum Puncture Resistance	ASTM D4833	80 lbs	N/A
Typical Shear Strength	ASTM D5321	500 psf (when hydrated)	50 psf
Minimum Free Swell	ASTM D5890	24 mL	24 mL
Maximum Fluid Loss	ASTM D5891	18 mL	18 mL
Maximum Moisture Content	ASTM D4643	100%	100%

C. Interface Friction Tests.

1. Test this and adjacent materials using ASTM D 5321. Section 01060 Special Conditions paragraph 1.13 outlines the conditions under which this material shall be tested.
2. This material is part of a system. The system shall meet the requirements before the component material can be deemed acceptable.

3. The costs associated with this testing shall be included in the Bid price for each material. Any retesting or other additional testing required to meet the specification shall be at no additional cost to the Owner.

PART 3 - EXECUTION

3.1 CONSTRUCTION

A. Shipping, Handling, and Storage:
1. During periods of shipment and storage, all GCL shall be protected from direct sunlight, water, mud, dirt, dust, and debris. To the extent possible, the GCL shall be maintained wrapped in heavy-duty protective covering until use. GCL delivered to the project site without protective wrapping shall be rejected.
2. The Engineer shall approve the shipping and delivery schedule prior to shipment. The Engineer shall approve the on-site storage area for the GCL. Unloading and storage of GCL shall be the responsibility of the Contractor.
3. GCL that is damaged during shipping, handling, or storage shall be rejected and replaced at Contractor's expense.

B. Installation of GCL:
1. GCL shall be placed to the lines and grades shown on the Contract Drawings. At the time of installation, GCL shall be rejected by the CQA Consultant if it has defects, rips, holes, flaws, evidence of deterioration, or other damage.
2. The surface receiving the GCL shall be prepared to a relatively smooth condition, free of obstructions, excessive depressions, debris, and very soft or loose pockets of soil. This surface shall be approved by the CQA Consultant prior to GCL placement.
3. The GCL shall be placed smooth and free of excessive wrinkles.
4. The GCL shall be installed on sideslopes with vertical seams only.
5. When GCL is placed with upslope and downslope portions, the upslope portion shall be lapped such that it is the upper or exposed surface.
6. The GCL shall not be placed in standing water or while raining. Any material that becomes partially/totally hydrated shall be removed and replaced.
7. The GCL seams shall be laid with a minimum overlap equal to 6 IN or the manufacturer's recommendation, whichever is greater.
8. GCL shall be temporarily secured in a manner approved by the CQA Consultant prior to placement of overlying materials.
9. Any GCL that is torn or punctured shall be repaired or replaced as directed by the CQA Consultant, by the Contractor at no additional cost to the Owner. The repair shall consist of a patch of GCL placed over the failed areas and shall overlap the existing GCL a minimum of 12 IN from any point of the rupture.
10. If in-place GCL is not otherwise protected from hydration due to rainfall, the GCL shall be covered with a minimum of 12 IN of the overlying design material within 12 hours of GCL placement.

3.2 FIELD QUALITY CONTROL

A. The CQA Consultant shall monitor and document the installation of GCL.to ensure that the installation and necessary repairs are made in accordance with these Specifications.

3.3 GCL ACCEPTANCE

A. The GCL Installer shall retain all ownership and responsibility for the GCL until final acceptance by the Owner. The Owner will accept the GCL installation when the installation is finished, all required submittals have been received and approved, and CQC/CQA verification of the adequacy of all field seams and repairs, including associated testing, is complete.

END OF SECTION

Appendix E

CQA PLAN

CONSTRUCTION QUALITY ASSURANCE PLAN

TABLE OF CONTENTS

SECTION 1.0
GENERAL

1.1 INTRODUCTION

This Construction Quality Assurance (CQA) Plan has been prepared to provide the Owner. Engineer, and CQA Consultant the means to govern the construction quality and to satisfy landfill certification requirements under current solid waste management regulations.

More specifically, this CQA Plan addresses the soils and geosynthetics components of the liner and leachate collection/removal (LCR) systems. The liner system, as referenced herein, generally consists of a soil subgrade and a composite liner (consisting of a compacted soil liner and an overlying HDPE geomembrane liner). The LCR system consists of a granular drainage material with perforated collection piping, manholes, and fittings. General references in this Plan to the various components as the "liner or LCR system(s)" are intended to be as described herein.

The CQA Plan is divided into the following sections:

- Section 1.0 General
- Section 2.0 Soil Liner Construction Quality Assurance
- Section 3.0 Geomembrane Liner Construction Quality Assurance
- Section 4.0 LCR Construction Quality Assurance
- Section 5.0 Geotextile Construction Quality Assurance
- Section 6.0 High Density Polyethylene Pipe, Manholes, and Fittings Construction Quality Assurance
- Section 7.0 Geonet Construction Quality Assurance
- Section 8.0 GCL Construction Quality Assurance
- Section 9.0 Surveying Construction Quality Control
- Section 10.0 Construction Quality Assurance Documentation

Information provided in this CQA Plan is based on the North Carolina Solid Waste Management Rules 15A NCAC 13B .1624. Compliance with these rules is a condition of the contract.

1.2 DEFINITIONS RELATING TO CONSTRUCTION QUALITY

1.2.1 Construction Quality Assurance (CQA)

In the context of this Plan, construction quality assurance is defined as a planned and systematic program employed by the Owner to assure conformity of the liner systems, LCR systems, and protective cover system installation with Contract Drawings, and the project specifications. CQA is provided by the CQA Consultant as a representative of the Owner and is independent from the Contractor and all manufacturers. The CQA program is designed to provide adequate confidence that items or services meet contractual and regulatory requirements and will perform satisfactorily in service.

1.2.2 Construction Quality Control (CQC)

Construction Quality Control refers to actions taken by manufacturers, fabricators, installers, or the Contractor to ensure that the materials and the workmanship meet the requirements of this CQA Plan and the project specifications. In the case of the liner and LCR systems, CQC is provided by the Contractor's CQC Agency. In the case of geosynthetic components, material quality control (QC) is provided by the manufacturer's certification and the CQC for the installation of the various geosynthetics is provided by the Contractor's CQC Agency. The manufacturer's specifications and quality control (QC) requirements are included in this CQA Plan by reference only. A complete updated version of each geosynthetic component manufacturer's QC Plan will be incorporated as part of the Contractor's CQC Plan.

1.2.3 CQC/CQA Certification Document

At the completion of construction and prior to placement of waste in the landfill, a certification document will be prepared by the CQA Consultant and be submitted to State Solid Waste Regulators. The certification report will include all QC testing performed by the Geosynthetics Manufacturers, all CQC testing performed by the CQC Agency, or Geosynthetic Installers, and all CQA conformance testing performed by the CQA Consultant.

1.2.4 Discrepancies Between Documents

The CQA Plan is intended to be a supporting document to improve the overall documentation of the Work. The CQA Plan is less specific from the project specifications, and conflicts may exist between the documents. The Contractor is instructed to bring discrepancies to the attention of the Engineer or CQA Consultant for resolution. The Engineer has the sole authority to determine resolution of discrepancies existing within the Contract Documents. Unless otherwise determined by the Engineer, the more stringent requirement shall be the controlling resolution. Reference is made to the project specifications, Section 00700 - General Conditions.

1.3 PARTIES TO CONSTRUCTION QUALITY ASSURANCE

1.3.1 Description of the Parties

The parties to Construction Quality Assurance and Quality Control include the Owner, Project Manager, Engineer, Contractor, Geosynthetics Manufacturer, Geosynthetics Installer, CQA Consultant, Geosynthetics CQA Laboratory, Soils CQA Laboratory, CQC Agency, Geosynthetics CQC Laboratory, and Soils CQC Laboratory. The lines of authority and communications between each of the parties involved in the CQA and CQC are illustrated in Figure 1 (Page 4).

1.3.1.1 Owner

The Owner is the City of Greensboro, who owns and/or is responsible for the facility.

1.3.1.2 Project Manager

The Project Manager is the official representative of the Owner. The Project Manager serves as communications coordinator for the project, initiating the resolution, preconstruction, and construction meetings outlined in Section 1.7. The Project Manager shall also be responsible for proper resolution of all quality issues that arise during construction. The Project Manager is HDR Engineering, Inc. of Charlotte, NC.

1.3.1.3 Engineer

The Engineer is responsible for the engineering design, drawings, plans and project specifications for the liner system and protective cover system. The Engineer is HDR Engineering, Inc. of Charlotte, NC.

1.3.1.4 Contractor

The Contractor is responsible for the construction of the subgrade, construction of the subbase (as applicable), soil liner berms, soil and geomembrane liners, anchor trench excavation and backfill, and for placement of the LCR system. The Contractor is responsible for submittal coordination and the overall CQC on the project.

1.3.1.5 Geosynthetics Manufacturer

The Geosynthetics Manufacturer(s) is(are) responsible for the production of geomembranes, geonets, and geotextiles. The manufacturers are responsible for Quality Control (QC) during manufacture of the geosynthetic components, certification of the properties of the geosynthetic components, and field installation criteria.

1.3.1.6 Geosynthetics Installer

The Geosynthetics Installer(s) is(are) a subcontractor of the Contractor and is(are) responsible for field handling, storing, placing, seaming, protection of (against wind, etc.), and other aspects of the geosynthetics installations, including the geomembranes and geotextiles. The Installer may also be responsible for transportation of these materials to the site, and for the preparation and completion of anchor trenches.

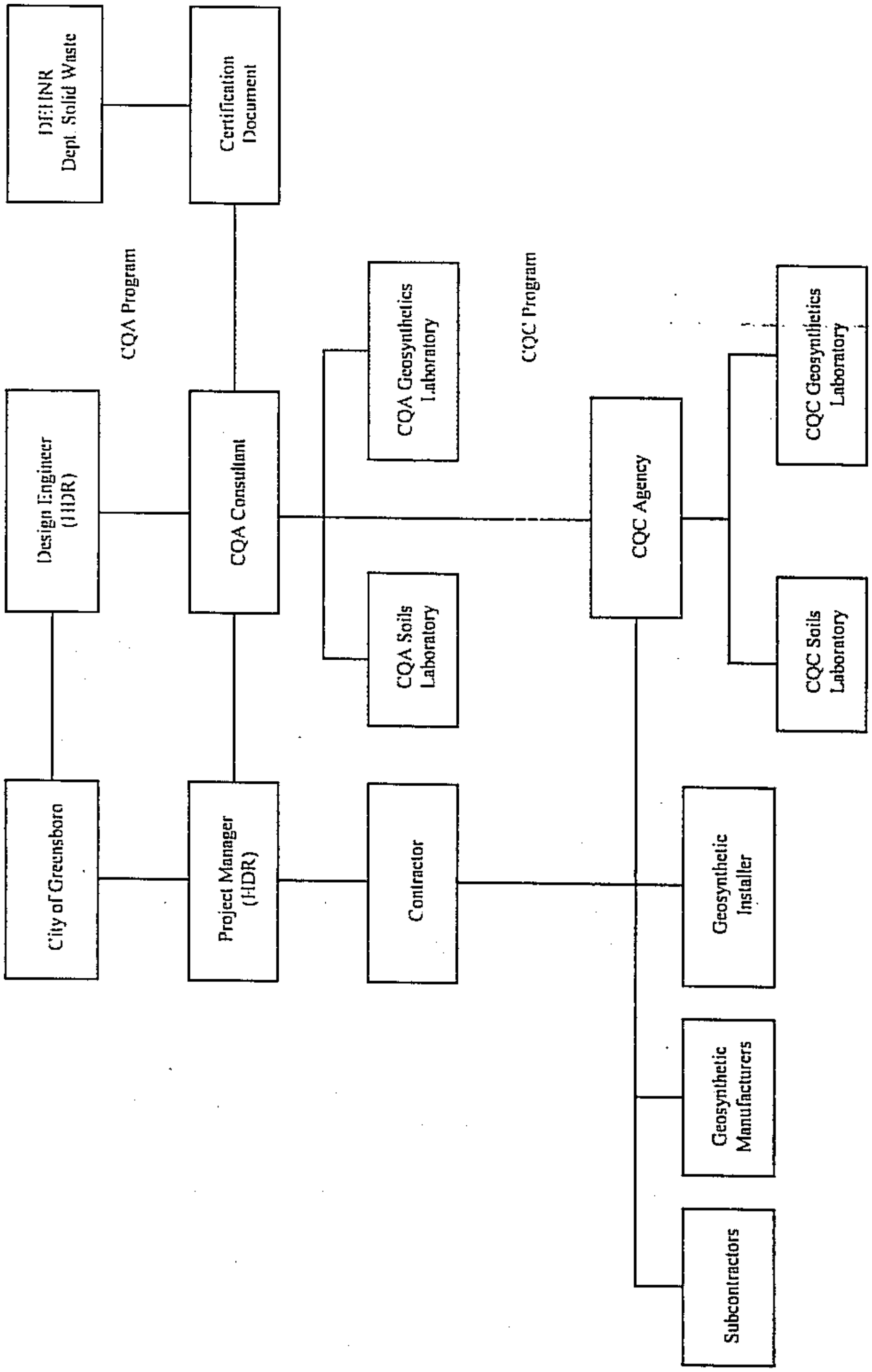


Figure 1 - CQA/CQC Lines of Authority and Communication

1.3.1.7 Construction Quality Assurance Consultant

The CQA Consultant is a representative of the Owner and is responsible for observing, testing, and documenting activities related to the CQC/CQA of the earthworks at the site, and the installation of the geosynthetic components of the liner and leachate collection/removal systems. The CQA Consultant is also responsible for issuing a facility certification report, sealed by a Professional Engineer registered in North Carolina.

1.3.1.8 Geosynthetics Construction Quality Assurance Laboratory

The Geosynthetics CQA Laboratory is a party, independent from the Owner, that is responsible for conducting tests on conformance samples of geosynthetics used in the liner and LCR systems. The Geosynthetics CQA Laboratory service cannot be provided by any party involved with the manufacture, fabrication, or installation of any of the geosynthetic components.

1.3.1.9 Soils Construction Quality Assurance Laboratory

The Soils Construction Quality Assurance Laboratory is a party, independent from the Owner, that is responsible for conducting geotechnical tests on conformance samples of soils used in the liner system. The Soils CQA Laboratory service cannot be provided by any party involved with the Contractor.

1.3.1.10 Construction Quality Control Agency

The CQC Agency is a representative of the Contractor and is responsible for the earthwork and soil liner quality control sampling and testing. The term CQC Agency shall be used to designate the Engineer in charge of the quality control work. The personnel of the CQC Agency also includes Quality Control Monitors who are also located at the site for construction observation and monitoring. The CQC Agency is responsible for the timely conveyance of CQC testing results to the CQA Agency.

1.3.1.11 Geosynthetics Construction Quality Control Laboratory

The Geosynthetics CQC Laboratory is a party, independent from the Contractor, that is responsible for conducting tests on conformance samples of geosynthetics used in the liner and LCR systems.

1.3.1.12 Soils Construction Quality Control Laboratory

The Soils Construction Quality Control Laboratory is a party, independent from the Contractor, that is responsible for conducting geotechnical tests on conformance samples of soils used in the liner system.

1.3.2 Qualifications of the Parties

The following qualifications are required of all parties involved with the manufacture, fabrication, installation, transportation, and CQC/CQA of all materials for the liner and LCR systems. Where applicable, these qualifications must be submitted by the Contractor to the Project Manager for review and approval.

1.3.2.1 Contractor

Qualifications of the Contractor are specific to the construction contract and independent of this CQA Plan.

1.3.2.2 Geosynthetics Manufacturers

Each Geosynthetics Manufacturer must satisfy the qualifications presented in the project specifications and must be prequalified and approved by the Project Manager.

The physical properties of each geosynthetic product must be certified by the geosynthetics manufacturer. The properties certified must include, at a minimum, those identified in the project specifications. Manufacturers certification must be approved by the CQA Consultant before the product is used.

1.3.2.3 Geosynthetic Installer(s)

The Geosynthetic Installer(s) will be trained and qualified to install the geosynthetics components of the liner system. Each Geosynthetics Installer must meet the requirements of the project specifications and be approved by the Project Manager. The Geomembrane Installer must be approved by the Geomembrane Manufacturer.

1.3.2.4 Construction Quality Assurance Consultant

The CQA Consultant will act as the Owner's CQA Representative and will report to the Project Manager. The CQA Consultant will perform conformance testing to satisfy the requirements of this CQA Plan, will observe the CQC work performed by the CQC Agency, and will prepare the certification document incorporating both CQA and CQC test data. The CQA Consultant will have experience in the CQC/CQA aspects of landfill liner system construction and soils testing, and be familiar with ASTM and other related industry standards. The activities of the CQA Consultant will be performed under the supervision of a Registered Professional Engineer.

1.3.2.5 Construction Quality Control Agency

The CQC Agency will be a party, independent from the Contractor. The CQC Agency will be experienced with soils, including soil liners, and geosynthetics, including geomembranes, geonets, and geotextiles. The CQC Agency will satisfy the requirements of the project specifications and be approved by the Project Manager. The activities of the CQC Agency will be performed under the supervision of a Registered Professional Engineer.

1.3.2.6 Geosynthetics Construction Quality Control Laboratory

The Geosynthetics CQC Laboratory is a subcontractor of the CQC Agency and will have experience in testing geosynthetics and be familiar with ASTM, NSF, and other applicable test standards. The Geosynthetics CQC Laboratory will be capable of providing test results within 24 hours or a reasonable time after, as agreed to at the outset of the project, receipt of samples, and will maintain that standard throughout the installation.

1.4 SCOPE OF CONSTRUCTION QUALITY ASSURANCE PLAN

The scope of this CQA Plan includes the CQA of the soils and geosynthetic components of the liner and LCR systems for the subject facility. The CQA for the selection, evaluation, and placement of the soils is included in the scope. This document is intended to be used in concert with the CQC requirements presented in the project specifications.

1.5 UNITS

In this CQA Plan, all properties and dimensions are expressed in U.S. units.

1.6 REFERENCES

The CQA Plan includes references to the most recent version of the test procedures of the American Society of Testing and Materials (ASTM), the Federal Test Method Standards (FTMS), the "Standards for Flexible Membrane Liners" of the National Sanitation Foundation (NSF), and the "Geosynthetic Research Institute" (GRI).

1.7 SITE AND PROJECT CONTROL

To guarantee a high degree of quality during installation, clear, open channels of communication are essential. To that end, meetings are critical.

1.7.1 CQA/CQC Resolution Meeting

Prior to field mobilization by the Contractor, a Resolution Meeting will be held. This meeting will include all parties then involved, including the Project Manager, the CQA Consultant, the Engineer, the Contractor, and the CQC Agency.

The purpose of this meeting is to begin planning for coordination of tasks, anticipate any problems which might cause difficulties and delays in construction, and, above all, review the CQA and CQC Plans to all of the parties involved. It is very important that the rules regarding testing, repair, etc., be known and accepted by all.

This meeting should include all of the following activities:

- communicate to all parties any relevant documents;
- review critical design details of the project;
- review the seam layout drawing provided by the Geomembrane/Geosynthetic Installer.
- review the site-specific CQA and CQC Plans;
- make any appropriate modifications to the CQA and CQC Plans to ensure that they specify all testing activities that are necessary;
- reach a consensus on the CQA/CQC quality control procedures, especially on methods for determining acceptability of the soils and geosynthetics;
- review the proposed liner system and protective cover system;
- decide the number of spare seaming units for geomembranes to be maintained on site by the Geomembrane/Geosynthetic Installer (this number depends on the number of seaming crews and on the type of seaming equipment);
- select testing equipment and review protocols for testing and placement of general earthwork materials;
- confirm methods for the soil liner material selection testing, acceptable zone determinations, and test strip installation;
- confirm the methods for documenting and reporting, and for distributing documents and reports; and
- confirm the lines of authority and communication.

The meeting will be documented by the Project Manager and minutes will be transmitted to all parties.

1.7.2 CQA/CQC Preconstruction Meeting

A Preconstruction Meeting will be held at the site prior to placement of the geomembrane liner. At a minimum, the meeting will be attended by the Project

Manager, Engineer, the CQA Consultant, the Contractor, the CQC Agency, and the Geosynthetic/Geomembrane Installation Superintendent.

Specific topics considered for this meeting include:

- make any appropriate modifications to the CQA and CQC Plans;
- review the responsibilities of each party;
- review lines of authority and communication;
- review methods for documenting and reporting, and for distributing documents and reports;
- establish protocols for testing;
- establish protocols for handling deficiencies, repairs, and retesting;
- review the time schedule for all operations;
- establish rules for writing on the geomembrane, i.e., who is authorized to write, what can be written, and in which color;
- outline procedures for packaging and storing archive samples;
- review panel layout and numbering systems for panels and seams;
- establish procedures for use of the extrusion seaming apparatus, if applicable;
- establish procedures for use of the fusion seaming apparatus, if applicable;
- finalize field cutout sample sizes;
- review seam testing procedures;
- review repair procedures; and
- establish soil stockpiling locations (if any).

The meeting will be documented by the Project Manager and minutes will be transmitted to all parties. The Resolution Meeting and the Preconstruction Meeting may be held as one meeting or separate meetings, depending on the direction of the Project Manager.

1.7.3 Daily and Weekly CQA/CQC Progress Meetings

A weekly progress meeting will be held between the Project Manager, the CQA Consultant, the Contractor, the CQC Agency, the Geosynthetic/Geomembrane Installation Superintendent, and representatives from any other involved parties. This meeting will discuss current progress, planned activities for the next week, and any new business or revisions to the work. The CQA Consultant will log any problems, decisions, or questions arising at this meeting in his daily report. Any matter requiring action which is raised in this meeting will be reported to the appropriate parties.

A daily meeting will be held between the CQA Consultant, the CQC Agency, the Geosynthetic/ Geomembrane Installation Superintendent, and representatives from any other involved parties. This meeting will discuss current progress, planned activities for the next shift, and any new business or revisions to the work. The CQA Consultant will log any problems, decisions, or questions arising at this meeting in his daily report. Any matter requiring action which is raised in this meeting will be reported to the appropriated parties.

Meeting frequency will depend on the schedule of the project and the mutual agreement of all parties involved.

1.7.4 Problem or Work Deficiency Meetings

A special meeting will be held when and if a problem or deficiency is present or likely to occur. At a minimum, the meeting will be attended by all interested parties, the Contractor, the Project Manager, and the CQA Consultant. If the problem requires a design modification, the Engineer should also be present. The purpose of the meeting is to define and resolve the problem or work deficiency as follows:

- define and discuss the problem or deficiency;
- review alternative solutions; and
- implement an action plan to resolve the problem or deficiency.

The meeting will be documented by the Project Manager and minutes will be transmitted to affected parties.

SECTION 2.0
SOIL LINER CONSTRUCTION QUALITY ASSURANCE

2.1 INTRODUCTION

This section of the CQA Plan addresses the soil components of the liner system. and outlines the soils CQA program to be implemented with regard to materials confirmation. laboratory and field confirmation test requirements. overview and interfacing with the Contractor's CQC Program, and resolution of problems.

2.2 EARTHWORK CONSTRUCTION

2.2.1 Subgrade

The subgrade material below the controlled fill will be prepared by the Contractor prior to the placement of fill. The CQC Agency will provide density testing of the pre-fill subgrade at the frequency specified in the project specifications. The CQA Consultant will observe the proofroll by the Contractor, review the density test data provided by the CQC Agency, and provide verification that the pre-fill subgrade is acceptable. The CQA Consultant may conduct confirmation density testing as deemed appropriate.

2.2.2 Structural/Controlled Fill

The Contractor shall place fill in accordance with the project specifications. The CQC Agency shall provide testing of the controlled fill material in accordance with the project specifications. The CQA Consultant will provide confirmation testing of the controlled fill as deemed appropriate.

2.3 SOIL LINER SYSTEM

2.3.1 Soil Liner Subgrade

Testing will be conducted by the CQC Agency as observed by the CQA Consultant. The subgrade material below the subbase is composed of controlled fill and in situ soils. The surface of the subgrade will be prepared prior to the construction of the subbase. The CQA Consultant will visually examine the surface of the subgrade to verify that any potentially deleterious materials have been removed.

2.3.2 Soil Liner Material

The soil liner material shall be placed and compacted in accordance with the project specifications. The CQC Agency shall conduct field density and moisture tests at the frequency presented in the project specifications. In addition to the required CQC tests, the CQA Consultant shall provide conformance tests at a frequency of approximately 10 percent of the required CQC tests. Additional CQA conformance testing may be performed at the discretion of the CQA Consultant.

Hydraulic Conductivity, Atterberg Limits, and Percent-Fines testing of the soil liner material shall be performed by the CQC Agency in accordance with the project specifications. Additional CQA conformance testing may be performed at the discretion of the CQA Consultant.

Thickness measurement shall be conducted in accordance with the project specifications by the CQC Agency and observed by the CQA Consultant.

2.4 SOILS TESTING

2.4.1 Test Methods

All testing used to evaluate the suitability or conformance of soils materials will be carried out in accordance with the project specifications.

2.4.2 Soils Testing Requirements

The soil CQC testing must comply with the minimum frequencies presented in the project specifications. The frequency of CQA testing required will be determined by the CQA Consultant in light of the potential variability of materials and the acceptance/failure rate of the CQC testing.

2.5 SOILS CONSTRUCTION QUALITY ASSURANCE

CQA will be performed on all soil components of the liner construction. CQA evaluation will consist of: (1) monitoring the work and observing the CQC testing; and (2) performing laboratory and field conformance tests. Laboratory CQA conformance tests will be conducted on samples taken at the borrow source, stockpile, and during the course of the work prior to construction. Field CQA conformance tests will be conducted during the course of the work.

2.5.1 Monitoring

The CQA Consultant shall monitor and document the construction of all soil components. Monitoring the construction work for the subbase soil, and the soil component of the liner system, includes the following:

- observing CQC testing to determine the water content and other physical properties of the subbase and soil component of the liner system during compaction and compilation of the data;

- monitoring the loose thickness of lifts as placed;

- monitoring the action of the compaction and/or heavy hauling equipment on the construction surface (i.e., penetration, pumping, cracking, etc.); and

- monitoring the number of passes used to compact each lift.

2.5.2 Construction Quality Assurance Judgmental Testing

During construction, the frequency of conformance testing may be increased at the discretion of the CQA Consultant when visual observations of construction performance indicate a potential problem. Additional testing for suspected areas will be considered when:

- the rollers slip during rolling operation;

- the lift thickness is greater than specified;

- the fill material is at an improper moisture content;

- fewer than the specified number of roller passes are made;

- dirt-clogged rollers are used to compact the material;

- the rollers may not have used optimum ballast;

- the fill materials differ substantially from those specified; or

- the degree of compaction is doubtful.

2.5.3 Perforations in Soil Liner

Perforations that must be filled will include, but not be limited to, the following:

- nuclear density test probe locations;

- permeability sampling locations; and/or

- thickness checks.

Unless otherwise noted, or as directed by the Project Manager, all perforations of the subbase by probes or sample tubes will be backfilled in accordance with project specifications. The CQA Consultant will observe and confirm that adequate procedures are being employed.

2.5.4 Deficiencies

If a defect is discovered in the earthwork product, the CQC Agency will immediately determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQC Agency will determine the extent of the deficient area by additional tests, observations, a review of records, or other appropriate means. If the defect is related to adverse site conditions, such as overly wet soils or surface desiccation, the CQC Agency will define the limits and nature of the defect.

2.5.5.1 Notification

After determining the extent and nature of a defect, the CQC Agency will notify the Project Manager, the CQA Consultant, and Contractor and schedule appropriate retests when the work deficiency is corrected. The CQA Consultant shall observe all retests on defects.

2.5.5.2 Repairs and Retesting

The Contractor will correct the deficiency to the satisfaction of the CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQC Agency will develop and present to the Project Manager and CQA Consultant suggested solutions for approval.

All retests recommended by the CQC Agency must verify that the defect has been corrected before any additional work is performed by the Contractor in the area of the deficiency. The CQA Consultant will verify that all installation requirements are met and that all submittals are provided.

2.5.5.3 Penalties

Refer to Specification Section 02775.

SECTION 3.0
GEOMEMBRANE LINER
CONSTRUCTION QUALITY ASSURANCE

3.1 GEOMEMBRANE MANUFACTURER'S CERTIFICATION, AND CQA CONFORMANCE TESTING

3.1.1 Geomembrane Manufacturer's Certification

Compliance testing will be performed by the Geomembrane Manufacturer to demonstrate that the product meets the manufacturers' quality control and conformance test minimum standards for geomembrane specifications and exceeds the project specifications. Additional testing will be performed by the CQA Consultant for purposes of conformance evaluation. If the results of the Geomembrane Manufacturer's and the CQA Consultant's testing differ, the testing will be repeated by the CQA Consultant's laboratory, and the Geomembrane Manufacturer will be allowed to monitor this testing. The results of this latter series of tests will prevail, provided that the applicable test methods have been followed.

3.1.1.1 Raw Material

Prior to the installation of any geomembrane material, the Geomembrane Manufacturer will provide the CQA Consultant and the CQC Agency with the following information as a bound document with the individual sections clearly identified:

- the origin (Resin Supplier's name and resin production plant), identification (brand name, number), and production date of the resin;
- a copy of the quality control certificates issued by the Resin Supplier;
- reports on the tests conducted by the Geomembrane Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the project; and
- a statement that the percentage of reclaimed polymer added to the resin is in accordance with the project specifications.

The CQA Consultant will review these documents and report any discrepancies with the above requirements to the Project Manager.

3.1.1.2 Geomembrane Manufacturing

Prior to the installation, the Geomembrane Manufacturer will provide the Contractor and the CQA Consultant with the following:

- a properties sheet including, at a minimum, all specified properties, measured using test methods indicated in the project technical specifications, or equivalent;
- the sampling procedure ~~and results of testing;~~ and
- a certification that property values given in the properties sheet are minimum average roll values and are guaranteed by the Geomembrane Manufacturer.

The CQA Consultant will review these documents and verify that:

- the reported property values certified by the Geomembrane Manufacturer meet all of the project technical specifications;
- the measurements of properties by the Geomembrane Manufacturer are properly documented and that the test methods used are acceptable; and
- Report any discrepancies with the above requirements to the Project Manager.

3.1.1.3 Rolls and Sheets

Prior to shipment, the Geomembrane Manufacturer will provide the CQA Consultant and the CQC Agency with a quality control certificate for each roll (HDPE geomembrane) or sheet (non-HDPE geomembrane) of geomembrane provided. The quality control certificate will be signed by a responsible party employed by the Geomembrane Manufacturer, such as the Production Manager. The quality control certificate will include:

- roll numbers and identification; and
- sampling procedures and results of quality control tests -- as a minimum, results will be given for thickness, tensile characteristics and tear resistance, evaluated in accordance with the methods indicated in the project specifications or equivalent methods approved by the Engineer.

The quality control certificate will be bound and included as part of the report required in Section 3.1.1.1.

The CQA Consultant will:

- verify that the quality control certificates have been provided at the specified frequency and that each certificate identified the rolls or sheets related to it;

- review the quality control certificates and verify that the certified roll or sheet properties meet the project technical specifications; and

- report any discrepancies with the above requirements to the Project Manager.

3.2 GEOMEMBRANE INSTALLATION

3.2.1 Transportation, Handling, and Storage

3.2.1.1 <u>Transportation and Handling</u>

The CQA Consultant will verify that:

- handling equipment used on the site is adequate, meets manufacturer's recommendations, and does not pose any risk of damage to the geomembrane; and

- the Geomembrane Installer's personnel handle the geomembranes with care.

Upon delivery at the site, the CQA Consultant will conduct a surface observation of all rolls and sheets for defects and damage. This examination will be conducted without unrolling rolls or unfolding sheets unless defects or damages are found or suspected. The CQA Consultant will indicate to the Project Manager:

- any rolls or sheets, or portions thereof, that should be rejected and removed from the site because they have severe flaws; and

- any rolls or sheets that have minor repairable flaws.

Refer to ASTM D4873 for detailed methods.

3.2.1.2 Storage

The CQA Consultant will document that the Contractor's storage of the geomembrane provides adequate protection against moisture, dirt, shock, and other sources of damage or contamination.

3.2.2 Earthwork

3.2.2.1 Surface Preparation

The CQC Agency and the Geomembrane Installer will certify in writing that the surface on which the geomembrane will be installed meets line and grade, and the surface preparation requirements of the project specifications. The certificate of acceptance will be given by the CQC Agency to the CQA Consultant prior to commencement of geomembrane installation in the area under consideration. The CQA Consultant will give a copy of this certificate to the Project Manager.

To ensure a timely covering of the soil liner surface, the Project Manager may allow subgrade acceptance in areas as small as one acre. After the supporting soil has been accepted by the Geomembrane Installer, it will be the Geomembrane Installer's responsibility to indicate to the Project Manager of any change in the supporting soil condition that may require repair work. If the CQA Consultant concurs with the Geomembrane Installer, then the Project Manager will ensure that the supporting soil is repaired.

3.2.2.2 Anchorage System

The CQA Consultant will verify that anchor trenches have been constructed and backfilled according to project specifications and design drawings.

3.2.3 Geomembrane Placement

3.2.3.1 Field Panel Identification

The CQA Consultant will document that the Geomembrane Installer labels each field panel with an "identification code" (number or letter-number consistent with the layout plan) agreed upon by the CQC Agency, Geomembrane Installer, and CQA Consultant at the CQA/CQC Preconstruction Meeting, Section 1.7.2.

The Geomembrane Installer will establish a table or chart showing correspondence between roll numbers and field panel identification codes. This documentation shall be submitted to the CQC Agency and CQA Consultant weekly for review and verification. The field panel identification code will be used for all quality control and quality assurance records.

3.2.3.2 Field Panel Placement

3.2.3.2.1 Location

The CQA Consultant will verify that field panels are installed at the location indicated in the Geomembrane Installer's layout plan, as approved or modified in Section 3.2.3.1.

3.2.3.2.2 Installation Schedule

The CQA Consultant will evaluate every change in the schedule proposed by the Geomembrane Installer and advise the Project Manger on the acceptability of that change. The CQA Consultant will verify that the condition of the supporting soil has not changed detrimentally during installation.

The CQA Consultant will record the identification code, location, and date of installation of each field panel.

3.2.3.2.3 Placement of Geomembrane

The CQA Consultant will verify that project specification related restrictions on placement of geomembrane are fulfilled. Additionally, the CQA Consultant will verify that the supporting soil has not been damaged by weather conditions.

The CQA Consultant will inform the Project Manager if the above conditions are not fulfilled.

3.2.3.2.4 Damage

The CQA Consultant will visually observe each panel, after placement and prior to seaming, for damage. The CQA Consultant will advise the Project Manager which panels, or portion of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels which have been rejected will be marked and their removal from the work area recorded by the CQA Consultant. Repairs will be made according to procedures described in the project specifications.

As a minimum, the CQA Consultant will document that:

- the panel is placed in such a manner that it is unlikely to be damaged; and
- any tears, punctures, holes, thin spots, etc., are either marked by the Geomembrane Installer for repair or the panel is rejected.

3.2.4 Field Seaming

3.2.4.1 Seam Layout

The Geomembrane Installer will provide the CQA Consultant with a seam layout drawing, i.e., a drawing of the facility to be lined showing all expected seams. The CQA Consultant and Engineer will review the seam layout drawing and verify that it is consistent with the accepted state of practice and this CQA Plan. In addition, no panels not specifically shown on the seam layout drawing may be used without the Project Manager's prior approval.

A seam numbering system compatible with the panel numbering system will be agreed upon at the Resolution and/or Preconstruction Meeting, Section 1.7. An on-going written record of the seams and repair areas shall be maintained by the Geomembrane Installer with weekly review by the CQA Consultant.

3.2.4.2 Requirements of Personnel

The Geomembrane Installer will provide the CQA Consultant with a list of proposed seaming personnel and their experience records. This document will be reviewed by the Project Manager and the CQA Consultant for compliance with project specifications.

3.2.4.3 Seaming Equipment and Products

Field seaming processes must comply with project specifications. Proposed alternate processes will be documented and submitted to the CQA Consultant for his approval. Only seaming apparatus which have been specifically approved by make and model will be used. The CQA Consultant will submit all documentation to the Engineer for his concurrence.

3.2.4.4 Nondestructive Seam Continuity Testing

The Geomembrane Installer will nondestructively test all field seams over their full length using test methods approved by the project specifications. The CQA Consultant shall periodically observe the nondestructive testing to ensure conformance with this CQA Plan and the project specifications.

For approximately 10% of the noncomplying tests, the CQA Consultant will:

- observe continuity testing of the repaired areas performed by the Geomembrane Installer;

- confirm the record location, date, test unit number, name of tester, and compile the record of testing provided by the Geomembrane Installer;

- provide a walkthrough inspection of all impacted seam areas and verify that the areas have been tested in accordance with the CQA Plan and project specifications; and

- verify that the Geomembrane Installer has marked repair areas with the appropriate color-coded marking pencil.

3.2.4.5 Destructive Seam Testing

Destructive seam tests will be performed by the CQC Agency at locations and a frequency in accordance with the project specifications. The CQA Consultant will perform conformance tests on a minimum of 10% of the CQC destructive seam test samples obtained. Additional destructive seam tests may be required at the CQA Consultant's discretion. Selection of such locations may be prompted by suspicion of contamination, excessive grinding, offcenter and/or offset seams, or any other potential cause of imperfect seaming.

3.2.4.5.1 Geosynthetics Construction Quality Assurance Laboratory Testing

Destructive test samples will be packaged and shipped by the CQA Consultant in a manner that will not damage the test sample. The Project Manager will be responsible for storing the archive samples. These procedures will be fully outlined at the Resolution Meeting, Section 1.7. Test samples will be tested by the Geosynthetics CQA Laboratory.

Conformance testing will include "Seam Strength" and "Peel Adhesion" (ASTM D638 using one-inch strips and a strain rate of two inches per minute) in accordance with ASTM D4437 and project specifications. All geomembrane destructive test samples that fail to meet project specifications shall be saved and sent to the CQA Consultant for observation.

The Geosynthetics CQA Laboratory will provide preliminary test results no more than 24 hours after they receive the samples. The CQA Consultant will review laboratory test results as soon as they become available.

3.2.4.5.2 Defining Extent of Destructive Seam Test Failure

All defective seam test failures must be bounded by seam tests from which destructive samples passing laboratory tests have been taken. The CQA Consultant will document repair actions taken in conjunction with all destructive seam test failures.

3.2.5 Defects and Repairs

All seams and nonseam areas of the geomembrane will be examined by the CQC Agency for identification of defects, holes, blisters, undispersed raw materials. and any sign of contamination by foreign matter. Each suspected location. both in seam and nonseam areas, will be nondestructively tested using methods in accordance with the project specifications. Each location which fails the nondestructive testing will be marked by the CQC Agency and repaired by the Geomembrane Installer. Repair procedures will be in accordance with project specifications or procedures agreed to by the Project Manager in the preconstruction meeting. The CQA Consultant will observe all repair procedures and advise the Project Manager of any problems.

3.2.6 Backfilling of Anchor Trench

Anchor trenches will be will be backfilled and compacted as outlined in the project specifications. The CQA Consultant will review the backfilling operation and advise the Project Manager of any problems.

3.2.7 Liner System Acceptance

The Geomembrane Installer and the Geosynthetic Manufacturers will retain all ownership and responsibility for the geosynthetics in the landfill cell until acceptance by the Owner.

The geomembrane component of the liner system will be accepted by the Owner when:

- the installation is finished;
- verification of the adequacy of all seams and repairs, including associated testing, is complete;
- CQC Agency provides the CQA Consultant and Project Manager with a final copy of the nondestructive test documentation, repair information. and as-built drawings.
- CQA Consultant furnishes the Project Manager with certification that the geomembrane was installed in accordance with the Geosynthetic Manufacturer's recommendations as well as the Plans and project specifications;
- all documentation of installation is completed including the CQA Consultant's final report; and
- certification by the CQA Consultant, including Record Drawing(s),

sealed by a Professional Engineer registered in the state in which the project is located, has been received by the Project Manger.

The CQA Consultant will certify that the installation has proceeded in accordance with this CQA Plan and the project specifications for the project except as noted to the Project Manager.

3.2.8 Materials in Contact with Geomembranes

The quality assurance procedures indicated in this Subsection are only intended to assure that the installation of these materials does not damage the geomembrane. Although protective geosynthetics and geotextiles have been incorporated into the liner system, all reasonable measures to protect the geomembrane and provide additional quality assurance procedures are necessary to assure that systems built with these materials will be constructed to ensure proper performance.

3.2.8.1 Soils

Prior to placement, the CQA Consultant will visually confirm that all soil materials to be placed against the geomembrane comply with project specifications. The Geomembrane Installer will provide the CQA Consultant a written surface acceptance certificate in accordance with Section 3.2. 1. All soil materials shall be placed and compacted in accordance with project specifications.

3.2.8.2 Sumps and Appurtenances

The CQA Consultant will verify that:

- installation of the geomembrane in appurtenance areas, and connection of the geomembrane to appurtenances have been made according to the project specifications;

- extreme care is taken while seaming around appurtenances since neither nondestructive nor destructive testing may be feasible in these areas;

- the geomembrane has not been visibly damaged while making connections to appurtenances;

- The installation of the geomembrane shall be exercised so as not to damage sumps; and

- the CQA Consultant will inform the Project Manager if the above conditions are not fulfilled.

SECTION 4.0
LCR CONSTRUCTION QUALITY ASSURANCE

4.1 INTRODUCTION

This section of the CQA plan addresses the sand and gravel drains, and the soil buffer layer of the LCR system. By reference to Sections 5.0 and 6.0 of this CQA Plan, this section also addresses the perforated plastic pipes and geotextile filters and cushions that are included in the LCR system. This section outlines the CQA program to be implemented with regard to materials confirmation, laboratory and field test requirements, overview and interfacing with the Contractor's CQC Program, and resolution of problems.

4.2 GRANULAR LEACHATE COLLECTION SYSTEM

4.2.1 Protective Cover (Leachate Collection Layer) Material

The LCR layer shall be placed and compacted in accordance with the project specifications. The CQC Agency will provide gradation and density testing of the granular material at the frequency specified in the project specifications. The CQA Consultant will observe that placement of the granular material is done in a manner to protect the geomembrane, and review the gradation and density test data provided by the CQC Agency. The CQA Consultant may conduct confirmation gradation and density testing as deemed appropriate.

4.2.2 Sump and LCR Pipe Drain Material

The drain material placed in the sumps and surrounding the LCR drainage pipe shall be placed in accordance with the project specifications. The CQC Agency will provide gradation and mineralogical testing of the gravel material at the frequency specified in the project specifications. The CQA Consultant will observe that placement of the gravel is done in a manner to protect the geomembrane and plastic pipe and review the gradation and density test data provided by the CQC Agency. The CQA Consultant may conduct confirmation gradation and additional testing as deemed appropriate.

4.3 RELATED MATERIALS

4.3.1 Geotextile Cushion and Filter Material

The geotextile cushion placed beneath the gravel drain material, and the geotextile filter placed between the sand drainage layer and the soil buffer layer shall be placed in accordance with project specifications. The CQA program for these materials is presented in Section 5.0 of this CQA Plan.

4.3.2 High Density Polyethylene (HDPE) Pipe Material

The perforated HDPE pipe placed within the gravel drain material shall be placed in accordance with project specifications. The CQA program for this material is presented in Section 6.0 of this CQA Plan.

4.3.3 Soil Buffer Layer Material

The soil buffer layer material shall be placed and compacted in accordance with project specifications. The CQC Agency will provide classification testing of the material at the frequency specified in the project specifications. The CQA Consultant will observe that the placement of the soil buffer is done in a manner to protect the filter geotextile and review the classification data provided by the CQC Agency. The CQA Consultant may conduct confirmation classification testing as deemed appropriate.

4.4 MATERIALS TESTING

4.4.1 Test Methods

All testing used to evaluate the suitability or conformance of LCR materials will be carried out in accordance with the project specifications.

4.4.2 Material Testing Requirements

The material CQC testing must comply with the minimum frequencies presented in the project specifications. The frequency of CQA testing will be determined by the CQA Consultant in light of the potential variability of the materials and the acceptance/failure rate of the CQC testing.

4.5 LCR CONSTRUCTION QUALITY ASSURANCE

CQA will be performed on all components of the LCR system construction. CQA evaluation will consist of: (1) monitoring the work and observing the CQC testing, and (2) performing laboratory and field conformance tests. Laboratory CQA conformance tests will be conducted on samples taken at the borrow source, stockpile, and during the course of work prior to construction. Field conformance tests will be conducted during the course of the work.

4.5.1 Monitoring

The CQA Consultant shall monitor and document the construction of all LCR components. Monitoring the construction work for the natural materials of the LCR system includes the following:

- reviewing CQC testing for gradation and other physical properties of the natural materials and compilation of the data;

- monitoring the minimum vertical buffer maintained between field equipment and the geomembrane; and

- monitoring the placement of the natural materials does not fold or damage the geomembrane in any way.

4.5.2 Deficiencies

If a defect is discovered in the earthwork product, the CQC Agency will immediately determine the extent and nature of the defect and report it to the CQA Consultant. If the defect is indicated by an unsatisfactory test result, the CQC Agency will determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the CQA Consultant deems appropriate.

4.5.2.1 Notification

After determining the extent and nature of a defect, the CQC Agency will notify the Project Manager and Contractor and schedule appropriate retests when the work deficiency is corrected. The CQA Consultant shall observe all retests on defects.

4.5.2.2 Repairs and Retesting

The Contractor will correct the deficiency to the satisfaction of the CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQC Agency will develop and present to the Project Manager suggested solutions for his approval.

All retests recommended by the CQC Agency must verify that the defect has been corrected before any additional work is performed by the Contractor in the area of the deficiency. The CQA Consultant will verify that all installation requirements are met and that all submittals are provided.

4.5.2.3 Penalties

Refer to Specification Section 02775.

SECTION 5.0
GEOTEXTILE MATERIAL AND INSTALLATION QUALITY ASSURANCE

5.1 MANUFACTURING

The Contractor will provide the CQA Consultant with a list of guaranteed minimum average roll value" properties (as defined by the Federal Highway Administration), for the type of geotextile to be delivered. The Contractor will also provide the CQA Consultant with a written certification from the Geotextile Manufacturer that the materials actually delivered have "minimum average roll value" properties which meet or exceed all property values guaranteed for that type of geotextile.

The CQA Consultant will examine all manufacturer certifications to ensure that the property values listed on the certifications meet or exceed those specified for the particular type of geotextile. Any deviations will be reported to the Project Manager.

The inspection methods, handling techniques, and property values identified in this section for the filter geotextile shall also apply to geotextile portion of the geocomposite drain which will be heat bonded to the geonet (see Section 7.0 for more detail).

5.2 LABELING

The Geotextile Manufacturer will identify all rolls of geotextile in conformance with the project specifications. The CQA Consultant will examine rolls upon delivery and any deviation from the above requirements will be reported to the Project Manager.

5.3 SHIPMENT AND STORAGE

During shipment and storage, the geotextile will be protected as required by manufacturer's recommendations and the project specifications. The CQA Consultant will observe rolls upon delivery at the site and any deviation from the above requirements will be reported to the Project Manager.

5.4 HANDLING AND PLACEMENT

The Geosynthetic Installer will handle all geotextiles in such a manner as required by the project specifications. Any noncompliance will be noted by the CQA Consultant and reported to the Project Manager.

5.5 SEAMS AND OVERLAPS

All geotextiles will be seamed or overlapped in accordance with project specifications or as approved by the CQA Consultant and Engineer.

5.6 REPAIR

Any holes or tears in the geotextile will be repaired in accordance with the project specifications. The CQA Consultant will observe any repair and note any noncompliance with the above requirements and report them to the Project Manager.

5.7 PLACEMENT AND MATERIALS

All soil materials located on top of a geotextile shall be placed in accordance with the project specifications. Any noncompliance will be noted by the CQA Consultant and reported to the Project Manager.

SECTION 6.0

HIGH DENSITY POLYETHYLENE MANHOLES, PIPE AND FITTINGS CONSTRUCTION QUALITY ASSURANCE

6.1 MATERIAL REQUIREMENTS

All HDPE manholes, pipe, and fittings shall be produced in accordance with the project specifications.

6.2 MANUFACTURER

Prior to the installation of HDPE manholes or pipes, the Manufacturer will provide to the Contractor and the CQA Consultant the following:

- a properties sheet including, at a minimum, all specified properties, measured using test methods indicated in the project technical specifications;
- a list of quantities and descriptions of materials other than the base resin which comprise the pipe;
- the sampling procedure and results of testing; and
- a certification by the HDPE Pipe Manufacturer that values given in the properties sheet are minimum values and are guaranteed by the HDPE Pipe Manufacturer.

The CQA Consultant will review these documents and verify that:

- the property values certified by the HDPE Pipe Manufacturer meet all of the project technical specifications; and
- the measurements of properties by the HDPE Pipe Manufacturer are properly documented and that the test methods used are acceptable.
- Report any discrepancies with the above requirements to the Project Manager.

6.2.1 Verification and Identification

Prior to shipment, the Contractor will provide the Project Manager and the CQA Consultant with a quality control certification for each lot/batch of HDPE pipe provided. The quality control certificate will be signed by a responsible party employed by the HDPE Pipe Manufacturer, such as the Production Manger. The quality control certificate will include:

- lot/batch number and identification; and

- sampling procedures and results of quality control tests.

The CQA Consultant will:

- verify that the quality control certificates have been provided at the specified frequency for all lots/batches of pipe, and that each certificate identifies the pipe lot/batch related to it; and

- review the quality control certificates and verify that the certified properties meet the project technical specifications.

6.3 NONDESTRUCTIVE TESTING

6.3.1 Nondestructive Testing of Joints and Penetrations

All nonperforated HDPE joints and where the piping system penetrates the geomembrane must be nondestructively tested. Pipe joints will be tested using the pressure test as provided in the project technical specifications. Other nondestructive test methods may be used only when:

- the Geosynthetic Installer can prove its effectiveness;

- the method is approved by the Pipe Manufacturer; and

- the method is approved by the Engineer.

The Project Manager and the CQA Consultant will verify the effectiveness and validity of the alternative test method.

The CQA Consultant will report any nonconformance of testing methods to the Project Manager.

SECTION 7.0
HDPE GEONET CONSTRUCTION QUALITY ASSURANCE

7.1 MATERIAL REQUIREMENTS

All HDPE geonet shall be produced in accordance with the project specifications.

7.2 MANUFACTURING

The Geonet Manufacturer will provide the Contractor and the CQC Agency with a written certification, signed by a responsible party, that the geonets actually delivered have properties which meet or exceed the guaranteed properties.

The CQA Consultant will examine all manufacturer's certifications to ensure that the property values listed on the certifications meet or exceed the project specifications. Any deviations will be reported to the Project Manager.

7.3 LABELING

The Geonet Manufacturer will identify all rolls of geonet in accordance with project specifications. The CQA Consultant will examine rolls upon delivery and any deviation from the above requirements will be reported to the Project Manager.

7.4 SHIPMENT AND STORAGE

Geonet cleanliness is essential to its performance; therefore, the shipping and storage of geonet must be in accordance with the project specifications. The CQA Consultant will examine rolls upon delivery and any deviation from the above requirements will be reported to the Project Manager.

The CQA Consultant will verify that geonets are free of dirt and dust just before installation. The CQA Consultant will report the outcome of this verification to the Project Manager; and, if the geonets are judged dirty or dusty, they will be washed by the Geonet Installer prior to installation.

Washing operations will be observed by the CQA Consultant and improper washing operations will be reported to the Project Manager.

7.5 HANDLING AND PLACEMENT

The Geonet Installer will handle all geonets in a manner in accordance with the project specifications. The CQA Consultant will note any noncompliance and report it to the Project Manager.

7.6 STACKING AND JOINING

When several layers of geonets are stacked, care should be taken to ensure that stacked geonets are placed in the same direction. A stacked geonet will never be laid in perpendicular directions to the underlying geonet (unless otherwise specified by the Engineer). The CQA Consultant will observe the stacking of geonets and will note any noncompliance and report it to the Project Manager.

Adjacent geonets will be joined according to construction drawings and project specifications. The CQA Consultant will note any noncompliance and report it to the Project Manager.

7.7 REPAIR

Any holes or tears in the geonet will be repaired in accordance with project specifications. The CQA Consultant will observe any repair, note any noncompliance with the above requirements, and report them to the Project Manager.

7.8 PLACEMENT OF SOIL MATERIALS

All soil materials placed over the geonet should be placed in accordance with project specifications so as to ensure:

- the geonet and underlying geomembrane are not damaged;
- minimal slippage of the geonet on the underlying geomembrane occurs; and
- no excess tensile stresses occur in the geonet.

Any noncompliance will be noted by the CQA Consultant and reported to the Project Manager.

SECTION 8.0
GEOSYNTHETIC CLAY LINER (GCL) MATERIAL AND
INSTALLATION QUALITY ASSURANCE

8.1 MANUFACTURING

The Contractor will provide the CQA Consultant with a list of guaranteed "minimum average roll value" properties (as defined by the Federal Highway Administration) for the GCL to be delivered. The Contractor will also provide the CQA Consultant with a written certification from the GCL Manufacturer that the materials actually delivered have "minimum average roll value" properties which meet or exceed all property values guaranteed for the GCL.

The CQA Consultant will examine all manufacturer certifications to determine if the property values listed on the certifications meet or exceed those specified for the GCL. Any deviations will be reported to the Engineer.

8.2 LABELING

The GCL Manufacturer will identify all rolls of GCL in conformance with the project specifications. The CQA Consultant will examine rolls upon delivery and any deviation from the above requirements will be reported to the Engineer.

8.3 SHIPMENT AND STORAGE

During shipment and storage, the GCL will be protected as required by the project specifications. The CQA Consultant will observe rolls upon delivery at the site and any deviation from the above requirements will be reported to the Engineer.

8.4 HANDLING AND PLACEMENT

The Geosynthetic Installer will handle the GCL in such a manner as required by the project specifications. Any noncompliance will be noted by the CQA Consultant and reported to the Engineer.

8.5 SEAMS AND OVERLAPS

The GCL will be seamed or overlapped in accordance with project specifications or as approved by the CQA Consultant and Engineer.

8.6 REPAIR

Any holes or tears in the GCL will be repaired in accordance with the project specifications. The CQA Consultant will observe any repair and note any noncompliance with the above requirements and report them to the Engineer.

8.7 PLACEMENT AND MATERIALS

All soil materials located on top of the GCL shall be placed in accordance with the project specifications. Any noncompliance will be noted by the CQA Consultant and reported to the Engineer.

SECTION 9.0
SURVEYING CONSTRUCTION QUALITY CONTROL

9.1 INTRODUCTION

Surveying of lines and grades is conducted on an ongoing basis during construction of the component liner and leachate collection systems. Close CQC of the surveying is absolutely essential to ensure that slopes are properly constructed. The surveying conducted at the site shall be performed by the Contractor.

9.2 SURVEY CONTROL

Permanent benchmarks and baseline control points are to be established for the site at locations convenient for daily tie-in. The vertical and horizontal controls for this benchmark will be established within normal land surveying standards.

9.3 SURVEYING PERSONNEL

The Contractor's survey crew will consist of a Senior Surveyor, and as many Surveying CQC Monitors as are required to satisfactorily undertake the requirements for the work. All Surveying CQC personnel will be experienced in the provision of these services, including detailed, accurate documentation.

All surveying will be performed under the direct supervision of a Registered Professional Engineer (PE) or Licensed Land Surveyor (PLS) licensed in the state in which the project is located. The Licensed Land Surveyor may be the Senior Surveyor.

9.4 PRECISION AND ACCURACY

A wide variety of survey equipment is available to meet the requirements of this project. The survey instruments used for this work should be sufficiently precise and accurate to meet the needs of the project. All survey instruments should be capable of reading to a precision of 0.01 foot and with a setting accuracy of 20 seconds. (5.6×10^{-3} degrees).

9.5 LINES AND GRADES

The following surfaces shall be surveyed to verify the lines and grades achieved during construction. The survey should at least include (as deemed appropriate by the Engineer and CQA Consultant):

- one or more construction baselines;
- a working grid with a sufficient number of benchmarks;

- surface of the subgrade;
- all existing structures;
- surface of the soil liner component;
- invert elevation of and location of leachate collection/header and force main piping at each lateral intersection and endpoint, and every 50 feet between the intersections and endpoints;
- inverts of sumps and manholes;
- surface of the leachate collection layer (protective cover);
- elevations of and locations of subcell berms;
- top/toe of all perimeter berms, roads, and channels;
- location of edge of liner, tie-in seam to adjacent existing liner system (as applicable);
- corners/intersections of all geosynthetic rolls or panels; and
- location of anchor trenches.
- All areas outside of the landfill unit graded under this contract.

Laser planes are highly recommended for achieving the correct lines and grades during construction of each surface.

9.6 FREQUENCY AND SPACING

All surveying will be carried out immediately upon completion of a given installation to facilitate progress and avoid delaying commencement of the next installation. In addition, spot checks, as determined by the Senior Surveyor, CQA Consultant, or Project Manager, during construction may be necessary to assist the Contractor in complying with the required grades.

The following spacings and locations will be provided by the CQC Surveyor, as a minimum, for survey points:

- surfaces with slopes less than 10 percent will be surveyed on a square grid not wider than 100 feet;

SECTION 10.0
CONSTRUCTION QUALITY ASSURANCE DOCUMENTATION

10.1 DOCUMENTATION

An effective CQA plan depends largely on recognition of all construction activities that should be monitored and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The CQA Consultant will document that all quality assurance requirements have been addressed and satisfied.

This CQA plan integrates the testing and inspection performed by the CQC Agency in accordance with the project specifications with the CQA overview and conformance testing performed by the CQA Consultant, in accordance with this CQA Plan.

The CQA Consultant will provide the Project Manager with the CQC Agency's daily and weekly reports including signed descriptive remarks, data sheets, and logs to verify that all CQC monitoring activities have been carried out. The CQA Consultant will also provide the Project manager with a weekly report summarizing CQA activities and identifying potential quality assurance problems. The CQA Consultant will also maintain at the job site a complete file of Plans, Reports, project specifications, a CQA Plan, checklists, test procedures, daily logs, and other pertinent documents.

10.2 RECORDKEEPING

The CQC Agency's reporting procedures will include preparation of a daily report which, at a minimum, will consist of: a) field notes, including memoranda of meetings and/or discussions with the Contractor; b) observation logs and testing data sheets; and c) construction problem and solution data sheets. The daily report must be completed at the end of each CQC Agency's shift, prior to leaving the site. This information will be submitted weekly to and reviewed by the CQA Consultant.

The CQC Agency's weekly reports must summarize the major events that occurred during that week. Critical problems that occur shall be communicated verbally to the Project Manager or CQA Consultant immediately as well as being included in the weekly reports. The CQC Agency's weekly report must be submitted to the CQA Consultant no later than the Monday following the week reported.

The CQA Consultant's weekly report must summarize the CQC Agency's weekly and daily reports, CQA conformance testing activities, construction problems that occurred, and the resolution of construction problems. The CQA Consultant's weekly report should identify all potential or actual compliance problems outstanding. The CQA Consultant's weekly report must be submitted to the Project Manager on the Wednesday following the week reported.

10.2.1 Memorandum of Discussion with CQC Agency or Geosynthetic Installer

A report will be prepared summarizing each discussion between the CQA Consultant and the CQC Agency or Geosynthetic Installer. At a minimum, the report will include the following information:

- date, project name, location, and other identification;
- name of parties to discussion at the time;
- relevant subject matter or issues;
- activities planned and schedule; and
- signature of the CQA Consultant.

10.2.2 CQA Observation Logs and Testing Data Sheets

CQA observation logs and conformance testing data sheets will be prepared by the CQA Consultant on a weekly basis. At a minimum, these logs and data sheets will include the following information:

- an identifying sheet number for cross referencing and document control;
- date, project name, location, and other identification;
- data on weather conditions;
- a reduced-scale Site Plan showing all proposed work areas and test locations;
- descriptions and locations of ongoing construction;
- descriptions and specific locations of areas, or units, of work being tested and/or observed and documented;
- locations where tests and samples were taken;
- a summary of test results;
- calibrations or recalibrations of test equipment, and actions taken as a result of recalibration;

- off-site materials received, including quality verification documentation;
- decisions made regarding acceptance of units of work, and/or corrective actions to be taken in instances of substandard quality; and
- the CQA Consultant's signature.

10.2.3 CQA Construction Problem and Solution Data Sheets

CQA sheets describing special construction situations will be cross-referenced with specific CQA observation logs and testing data sheets, and must include the following information, where available:

- an identifying sheet number for cross referencing and document control;
- a detailed description of the situation or deficiency;
- the location and probable cause of the situation or deficiency;
- how and when the situation or deficiency was found or located;
- documentation of the response to the situation or deficiency;
- final results of any responses;
- any measures taken to prevent a similar situation from occurring in the future; and
- the signature of the CQA Consultant, and signature of the Project Manager indicating concurrence if required by this CQA Plan.

The Project Manager will be made aware of any significant recurring non-conformance with the project specifications. The Project Manager will then determine the cause of the non-conformance and recommend appropriate changes in procedures or specification. When this type of evaluation is made, the results will be documented, and any revision to procedures or project specifications will be approved by the Owner and Engineer.

10.3 CQA PHOTOGRAPHIC REPORTING DATA SHEETS

Photographic reporting data sheets, where used, will be cross-referenced with CQA observation logs and testing data sheets and/or CQA construction problem and solution data sheets. Photographs shall be taken at regular intervals during the construction process and in all areas deemed critical.

These photographs will serve as a pictorial record of work progress, problems, and mitigation activities. The basic file will contain color prints; negatives will also be stored in a separate file in chronological order. These records will be presented to the Project Manager upon completion of the project.

In lieu of photographic documentation, videotaping may be used to record work progress, problems, and mitigation activities. The Project Manager may require that a portion of the documentation be recorded by photographic means in conjunction with video taping.

10.4 DESIGN AND/OR PROJECT TECHNICAL SPECIFICATION CHANGES

Design and/or project specification changes may be required during construction. In such cases, the CQA Consultant will notify the Project Manager and the Engineer. The Project Manager will then notify the appropriate agency, if necessary.

Design and/or project specification changes will be made only with the written agreement of the Project Manager and the Engineer, and will take the form of an addendum to the project specifications. All design changes shall include a detail (if necessary) and state which detail it replaces in the plans.

10.5 CQA PROGRESS REPORTS

The CQA Consultant will prepare a summary progress report each week, or at time intervals established at the pre-construction meeting. As a minimum, this report will include the following information;

- a unique identifying sheet number for cross-referencing and document control;
- the date, project name, location, and other information;
- a summary of work activities during progress reporting period;
- a summary of construction situations, deficiencies, and/or defects occurring during the progress reporting period;
- summary of all test results, failures and retests, and

- signature of the CQA Consultant.

10.6 SIGNATURE AND FINAL REPORT

At the completion of each major construction activity at the landfill unit, the CQA Consultant will certify all required forms, observation logs, field and laboratory testing data sheets including sample location plans, construction problems and solution data sheets. The CQA Consultant will also provide a final report which will certify that the work has been performed in compliance with the plans and project technical specifications, and that the supporting documents provide the necessary information.

The CQA Consultant will also provide summaries of all the data listed above with the report. The Record Drawings will include scale drawings depicting the location of the construction and details pertaining to the extent of construction (e.g., depths, plan dimensions, elevations, soil component thicknesses, etc.). All surveying and base maps required for development of the Record Drawings will be done by the Construction Surveyor. These documents will be certified by the Contractor and CQC Agency and delivered to the CQA Consultant and included as part of the CQA documentation (Certification) report.

It may be necessary to prepare interim certifications, as allowed by the regulatory agency to expedite completion and review.

10.7 STORAGE OF RECORDS

All handwritten data sheet originals, especially those containing signatures, will be stored by the Project Manager in a safe repository on site. Other reports may be stored by any standard method which will allow for easy access. All written documents will become property of the Owner.

Appendix F

DEED TO SUBSTATION PROPERTY

4620-1479
3-142-502-43

North Carolina - Guilford County
The certificate (s) of

092944

[signatures]

A Notary (Notaries) Public is (are) certified to be correct. This instrument and this certificate are duly registered at the date and time shown herein.

KATHERINE LEE PAYNE, REGISTER OF DEEDS

[signature]

Assistant/Deputy Register of Deeds

RECORDED
KATHERINE LEE PAYNE
REGISTER OF DEEDS
GUILFORD COUNTY, NC

BOOK: 4620
PAGE(S): 1479 TO 1486

12/10/1997 11:16:18

12/10/1997		
1 DEEDS	92944	$6.00
7 DEEDS ADDN PGS		$14.00
1 PROBATE FEE		$2.00
1 EXCISE TAX STAMP		$24.00

Excise Tax $24.00 | Recording Time, Book and Page

Tax Lot No.: 3-142-502-43 Parcel Identifier No. ____
Verified by ____ County on the ____ day of ____, 19__
by ____

Mail after recording to City of Greensboro Property Management PO Box 3136 Greensboro, NC 27402

This instrument was prepared by Parker, Poe, Adams & Bernstein L.L.P. [DU020-65502]

Brief Description For The Index:

NORTH CAROLINA NON-WARRANTY DEED

THIS DEED made this 10th day of December, 1997, by and between

GRANTOR	GRANTEE
DUKE ENERGY CORPORATION, formerly DUKE POWER COMPANY, a North Carolina corporation, formerly a New Jersey Corporation	CITY OF GREENSBORO Post Office Box 3136 Greensboro, NC 27402-3136 Attn: Property Management

Enter in appropriate block for each party: name, address, and, if appropriate, character of entity, e.g. corporation or partnership.

The designation Grantor and Grantee as used herein shall include said parties, their heirs, successors and assigns, and shall include singular, plural, masculine, feminine or neuter as required by context.

WITNESSETH, that Grantor, for valuable consideration paid by Grantee, the receipt of which is hereby acknowledged, has and by these presents does grant, bargain, sell and convey unto Grantee in fee simple, subject to the reservations in favor of Grantor set forth herein, all that certain lot or parcel of land situated in the City of Greensboro, Gilmer Township, Guilford County, North Carolina and more particularly described as follows:

See Exhibit A, attached hereto and incorporated by reference herein (the "Property")

Grantor reserves unto itself, its successors and assigns, the Easement set forth and defined on Exhibit B and the Utility Equipment and Improvements described on Exhibit B, which Exhibit B is attached hereto and incorporated herein by reference.

Grantee joins in this deed to agree to the covenants of Grantee contained herein

STATE OF NORTH CAROLINA 12/10/1997 24.00 Real Estate Excise Tax Guilford County

001479

PPAB-CHI/231649.1

4620-1480

The property hereinabove described was acquired by Grantor by instrument recorded in Deed Book 1848 Page 189 in the Office of the Register of Deeds, Guilford County, North Carolina

A map showing the above described property is recorded in Plat Book —, —.

TO HAVE AND TO HOLD the aforesaid lot or parcel of land and all privileges and appurtenances thereto belonging to the Grantee in fee simple, subject to the reservations in favor of Grantor set forth herein.

The Grantor makes no warranty, express or implied, as to title to the Property hereinabove described.

IN WITNESS WHEREOF, the Grantor has hereunto set his hand and seal, or if corporate, has caused this instrument to be signed in its corporate name by its duly authorized officers and its seal to be hereunto affixed by authority of its Board of Directors, the day and year first above written.

DUKE ENERGY CORPORATION,
formerly, DUKE POWER COMPANY
(Corporate Name)

By: Larry G. Bost
GEN. MGR. FACILITY AND ~~President~~ REAL ESTATE SERVICES

ATTEST:
[signature]
ASST. Secretary (Corporate Seal)

CITY OF GREENSBORO (SEAL)

By: Carolyn [signature] (SEAL)
Mayor

ATTEST:
Barbara E. Johnson (SEAL)
Deputy City Clerk (Corporate Seal)

APPROVED AS TO FORM AND LEGALITY
[signature]

SEE ATTACHED NOTARY ACKNOWLEDGMENT PAGES

STATE OF NORTH CAROLINA
COUNTY OF Guilford

I, Kathryn A. Kimble, a Notary Public for the above State and County, hereby certify that Barbara E. Johnson personally came before me this day and acknowledged that she/he is __________ Secretary of __________, a __________ corporation, and that by authority duly given and as the acts of said corporation, the foregoing instrument was signed in its name by its __________ President, sealed with its corporate seal and attested by him/her as its Assistant Secretary.

WITNESS my hand and official seal, this the 10th day of December, 1997.

____
Notary Public

My Commission Expires __________

[NOTARY SEAL]

The foregoing Certificate(s) of __________

is/are certified to be correct. This instrument and this certificate are duly registered at the date and time and in the Book and Page shown on the first page hereof.

__________ REGISTER OF DEEDS FOR __________ COUNTY

By __________ __________ Deputy/Assistant - Register of Deeds

001480

4620-1481

NOTARY ACKNOWLEDGMENT PAGE

STATE OF NORTH CAROLINA

COUNTY OF Mecklenburg

I, Keith E. Jacobs, Notary Public of said County and State, do hereby certify that Carol D. Denton personally appeared before me this day and acknowledged that he/she is Asst Secretary of Duke Energy Corporation, formerly Duke Power Company, a North Carolina corporation, formerly a New Jersey corporation, Grantor, and that by authority duly given and as the act of the corporation, the foregoing instrument was signed in its name by its ________ ~~President/Chairman~~, sealed with its corporate seal, and attested by ~~himself~~/herself as its Asst Secretary. Gen. Mgr. Facility & Real Estate Svcs

Witness my hand and official seal, this 10TH day of October, 1997.

Keith E. Jacobs
Notary Public

My Commission Expires: June 6, 1998

[NOTARY STAMP/SEAL]

NOTARY PUBLIC

184100

STATE OF NORTH CAROLINA

COUNTY OF GUILFORD

I, Kathryn R. Kimble, Notary Public of said County and State, do hereby certify that Barbara E. Johnson personally appeared before me this day and acknowledged that ~~he~~/she is Deputy City Clerk of the City of Greensboro, a municipal corporation, Grantee, and that by authority duly given and as the act of the municipal corporation, the foregoing instrument was signed in its name by its Mayor, sealed with its corporate seal, and attested by ~~himself~~/herself as its Deputy City Clerk.

Witness my hand and official seal, this 10th day of December, 1997.

Kathryn R. Kimble
Notary Public

My Commission Expires: April 14, 2002

[NOTARY STAMP/SEAL]

KATHRYN R. KIMBLE NOTARY PUBLIC GUILFORD COUNTY, N.C.

ASSISTANT SECRETARY CERTIFICATE

I, Carol D. Denton, Assistant Secretary of Duke Energy Corporation, do hereby certify that the following is a true and correct excerpt of a Resolution adopted February 27, 1995, by the Management Committee of the Board of Directors of Duke Energy Corporation, and that said quoted Resolution has not been rescinded or amended.

FURTHER RESOLVED, that effective October 17, 1994, the General Manager of the Real Estate Division be and hereby is authorized to execute any contract, lease, deed, or other instrument relating to real property without further action or approval by the Board of Directors or this Committee when deemed by said General Manager to be necessary or desirable in the operation of the Company's business, subject, however, to a monetary limit of $1,500,000.00 consideration or value in any single transaction, and to execute such documents in any such transaction which is approved by a resolution of this Committee.

FURTHER RESOLVED, That the Secretary or any Assistant Secretary be and hereby is authorized to attest and affix the corporate seal to any contracts, leases, deeds, or other instruments executed under authority of this resolution and may execute any certificate that may be required to certify the incumbency and authority of the officer or manager executing such documents.

I further certify that on October 13, 1997, Larry G. Best was the General Manager, Facility and Real Estate Services, hereby by reason of holding said position and pursuant to the above quoted Management Committee's Resolution, had full authority to represent and act on behalf of Duke Energy Corporation with respect to the conveyance of 1.162 acres of land in Gilmer Township, Guilford County, North Carolina, and to execute on behalf of Duke Energy Corporation all documents and instruments relating in any way thereto.

WITNESS my hand and seal of said Company this 13 day of October, 1997.

SEAL

Carol D. Denton

Assistant Secretary

001482

-4670- 1483

Exhibit A
to North Carolina Non Warranty Deed from
Duke Energy Corporation
to
City of Greensboro

All that tract or parcel of land in the County of Guilford and State of North Carolina, in Gilmer Township, adjoining the lands of others and bounded as follows:

BEGINNING at the center of the Duke Power right-of-way, a corner with James H. Neal and the Tract he sold to the City of Greensboro, and running thence with his line South 09-14-30 East 56.85 feet to the City's southwest corner; thence with their south line South 88-39 East 401.68 feet to an iron pipe; thence with Mildred F. Lewis' west line North 02-28 East 149.49 feet to a point on the north line of Duke Power's right-of-way; thence with the line of the right-of-way south 84-02-20 West 425.87 feet to a point; thence South 09-14-30 East 40.07 feet to the point of BEGINNING containing 1.162 acres and being all of the property conveyed to Grantor by the City of Greensboro, North Carolina by deed recorded in the Office of Register of Deeds of Guilford County, North Carolina in Book 1848, Page 189.

For further reference see Drawing PW3644 on file with the City of Greensboro, Engineering and Inspections Department.

001483

Exhibit B
to North Carolina Non Warranty Deed from
Duke Energy Corporation
to
City of Greensboro

Grantee is the owner and operator of a municipal solid waste facility on Grantee's adjacent land ("Grantee's Adjacent Land"). Grantor is executing the deed at Grantee's request to accommodate Grantee in meeting legal requirements imposed on the operation of the municipal solid waste facility. Grantor operates an electric substation upon the Property and must reserve the rights, privileges and easements contained herein for its benefit in order to continue to operate the electric substation. In consideration of the foregoing and other valuable consideration, the parties agree as follows:

1. Easement. Grantor reserves unto itself, its successors and assigns, a permanent exclusive right, privilege and easement over, upon, across and under the Property (the "Easement") (during the pendency of which Grantor shall have the exclusive right to enter upon and use the Property) for the construction, maintenance, operation, repair, affixing, removal, replacement and use of aboveground, surface level and underground electric or natural gas apparatus, towers, poles, wires, conduits, appliances, pipes, lines, culverts, electric or natural gas equipment, transformers, substations, fencing, telecommunications equipment, personal property, fixtures and other related improvements (whether or not affixed to the Property) now or hereafter placed upon the Property (all of which is collectively called the "Utility Equipment and Improvements") used or useful in the production, transmitting and/or distribution of electricity and/or natural gas and/or the operation of telecommunication system(s) for so long as Grantor needs or desires to use the Property for such purposes. Grantor reserves unto itself, its successors and assigns, all right, title and interest in and to the Utility Equipment and Improvements including the right to remove any or all of the Utility Equipment and Improvements at any time. Grantor may terminate this Easement at any time upon written notice to Grantee.

2. Use. Grantor shall use and occupy the Property for the purposes set forth above and no other purposes except with the mutual written consent of the parties hereto. In no event shall the Property or any part thereof be used for any purpose constituting a nuisance or in any manner which is in violation of present or future laws or government regulations.

3. Maintenance. Grantor shall, at its own expense, keep the Property and all the Utility Equipment and Improvements thereon in good and safe condition and shall make all necessary repairs and replacements to the Property.

4. Indemnification. Grantor shall indemnify Grantee and save it harmless from and against any and all claims, actions, damages, liability and expense, including attorneys fees in connection with the loss of life, personal injury and/or damage to property from or out of any occurrence in, upon or at the Property or the occupancy or use by Grantor of the Property or any part thereof, or occasioned wholly or in part by any act or omission of Grantor, its agents, contractors, employees, invitees, visitors, or servants. Likewise, Grantee shall indemnify Grantor and save it harmless from and against any and all claims, actions, damages, liability and expense, including attorneys fees, including but not limited to, any claims under CERCLA, in connection with the loss of life, personal injury and/or damage to property, including, but not limited to, damage to the Property, from or out of any occurrence in, upon, under or at Grantee's Adjacent Land or the occupancy or use by Grantee of the Grantee's Adjacent Land or any part thereof, or occasioned wholly or in part by any act or omission of Grantee, its agents, contractors, employees, invitees, visitors, or servants. In case either party without fault on its part, is made a party to any litigation commenced by or against the other party, then the other party shall protect and hold harmless and shall pay all cost, expenses and reasonable attorney's fees incurred or paid by the party without fault in connection with such litigation. Each party shall also pay all cost, expenses

001484

and reasonable attorney's fees that may be incurred by the other party in successfully enforcing the covenants and agreements in this deed.

5. Environment. Grantor agrees not to discharge, or allow to be discharged upon the Property, any regulared contaminant in the environment, soil or ground water of the Easement. In the event of any such discharge of contamination either, accidentally or intentionally, Grantor shall immediately report the discharge to the Grantee and other proper authorities as required by law and the affected land shall be remediated, either actively or passively as allowed, by Grantor in accordance with applicable law. Grantee agrees not to discharge, or allow to be discharged on the Easement from Grantee's Adjacent Land or from the Property, any contaminant in the environment, soil or ground water. In the event of any such discharge or contamination either, accidentally or intentionally, Grantee shall immediately report the discharge to Grantor and other proper authorities as required by law and the affected land shall be remediated, either actively or passively as allowed, by Grantee in accordance with applicable law.

6. As Is. Except as specifically provided herein, the Property is sold AS IS without covenant, representation or warranty of any kind, including without limitation, the environmental condition of the Property. Grantee acknowledges that Grantee has had ample opportunity to inspect and has inspected the Property and has determined the condition of the Property. Grantee has satisfied itself that the condition of the Property, including without limitation, the environmental condition of the Property is satisfactory to Grantee. The Property is conclusively presumed to be without environmental contamination as of the date of this deed and Grantee shall indemnify and save Grantor harmless from and against any and all claims, actions, damages, liability and expense, including reasonable attorneys fees, in connection with the past, present and/or future presence of any hazardous waste, hazardous substances and/or other waste or contamination (including groundwater contamination) on the Property, except as specifically provided herein. Grantor represents, as of the date of this deed, that Grantor neither knows of, nor has been advised of, any legal or administrative proceedings, claims or alleged claims, violations or alleged violations, infractions or alleged infractions of any law, rules or regulations relating to the environmental condition of the Property and Grantor has no knowledge that any hazardous wastes or hazardous substances have been brought upon and/or discharged upon the Property by Grantor. Grantor shall indemnify and hold Grantee harmless from and against any and all claims, actions, damages, liability and expense, including reasonable attorneys fee in connection with any past, present or future hazardous waste or hazardous substance as to which it is established by clear and convincing evidence was brought upon and/or discharged upon the Property by Grantor.

001485

7. Notices. All notices required hereunder shall be in writing by registered mail, to the following addresses:

Duke Energy Corporation
422 South Church Street
Charlotte, North Carolina 28242
Attn: W. Wallace Gregory, Jr.

City of Greensboro
Post Office Box 3136
Greensboro, North Carolina 27402-3136
Attn: Property Management

8. Entire Agreement. This deed contains the entire agreement and understanding between the parties as to the Property and the Easement. There are no oral understandings, terms, or conditions, and neither party has relied upon any representation, express or implied, not contained in this deed. All prior understandings, terms, and conditions are deemed merged in this deed. This deed shall not be changed orally, but only upon an agreement in writing and signed by the party against whom enforcement or any waiver, change, modification, or discharge is sought.

9. Binding Effect. The rights and obligations contained in this deed shall inure to the benefit and be binding upon the parties, their successors and assigns.

001486

Appendix G

VOLUME CALCULATIONS

New gboro project to replace corrupted

Project: gboro99 Wed Oct 06 17:05:33 1999

Site Volume Table: Unadjusted

Cut yards	Fill yards	Net yards	Method
Site: cell123			
Stratum: vol13 123-r 321f			
0	6660855	6660855 (F)	End area
0	6524601	6524601 (F)	Prismoidal
Stratum: vol17 123-r cell3			
15	5573814	5573800 (F)	Prismoidal
15	5494280	5494265 (F)	End area
Stratum: vol15 b11-6 123-r			
25849	16221	9627 (C)	End area
25642	16075	9568 (C)	Prismoidal
Stratum: vol18 123-r 4-1			
136	5644843	5644707 (F)	End area
188	5643476	5643288 (F)	Prismoidal
Stratum: vol19 b11-6 cell3			
0	5569602	5569602 (F)	Prismoidal
0	5571030	5571030 (F)	End area

avg 5,643,998 Permit Mod

avg. 5,570,316 CPA

73,682 ⇒ 1.3% increase in gross volume

123-r = Permit Modification Base grades

4-1 = " " Final grades (4:1)

~~B-11-6~~

B11-6 = Basegrades in Construction Permit Application (CPA)

Cell 3 = 4:1 Final grades in " " "

This Permit Modification is a 1.3% increase in gross volume (Final vs. base grades)