NCDENR

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

Dexter R. Matthews, Director | Division of Waste Management | Michael F. Easley, Governor
William G. Ross Jr., Secretary

June 14, 2005

Mark Snyder, P.E.
Project Manager, Closed Sites
Waste Management
2859 Paces Ferry Road, Suite 1600
Atlanta, Georgia 30339

Fac/Permit No. 34-06 | Date 9/19/13 | Doc ID# | DIN

Re: Authorization for Reconstruction of Section of Phase 2 Closure
Permit No. 34-06
Piedmont Landfill
Forsyth County, North Carolina

Dear Mr. Snyder:

The Solid Waste Section (SWS) completed a review of your response dated June 10, 2005, to SWS comments dated May 31, 2005, for the above referenced project. Based on the Design Report, cover letter dated May 12, 2005, and the response to comments and revisions submitted under cover letter dated June 10, 2005, authorization to proceed with construction as provided in the referenced documents is hereby granted with the following conditions:

- Reject and removed material from the existing cover will be stored and managed in a manner that will not cause a wind-blown hazard, odors, litter or other adverse conditions.
- Reject and removed material from the existing cover will be properly disposed, reclaimed or reprocessed within 3 months of certification and SWS acceptance of the reconstruction.
- Waste Management will provide written communication to the SWS of the details for material disposal as soon as practical.
- Waste Management will be responsible for assuring that the reject and removed material from the existing cover will be properly disposed by any party that receives the material.

Please note that the reconstruction is considered to be Post-Closure maintenance activity. Therefore, the initiation date for the Piedmont Landfill Post-Closure period remains October 29, 2004, for a period of 30 years from that date except as may be adjusted as provided in Rule .1627(d)(2) as stated in correspondence from this office dated December 28, 2004.

Thank you for your attention to this matter. Please call me should you have any questions or comments regarding this letter at (919) 508-8504.

Sincerely,

Geoffrey H. Little
Environmental Engineer
Solid Waste Section

c: Mike Loyd, WM
Jim Coffey, DWM
Jim Barber, DWM
Mark Poindexter, DWM
Brent Rockett, DWM
Jason Watkins, DWM
Ethan Brown, DWM

WASTE MANAGEMENT

WASTE MANAGEMENT SOUTHERN GROUP

2859 Paces Ferry Road
Suite 1600
Atlanta, GA 30339
(770) 805-4130

June 10, 2005

Received
JUN 2005
Solid Waste
Section

NC Department of Environment and Natural Resources
Division of Waste Management – Solid Waste Section
1646 Mail Service Center
Raleigh, North Carolina 27699-1646
Attn: Mr. Geoffrey H. Little

Subject: Response to Comments on Proposed Design
Reconstruction of Section of Phase 2 Closure
Piedmont Landfill and Recycling Center, Kernersville, North Carolina
Permit Number 34-06

Dear Mr. Little:

Please find enclosed one (1) original and one (1) copy of revisions to the Design Report – Reconstruction of an Area of Phase 2 Final Closure for the above referenced facility. These revisions have been developed in response to Solid Waste Section comments received June 3, 2005, via your letter dated May 31, 2005, and are being submitted for approval by the North Carolina Department of Environment and Natural Resources (NCDENR).

We have addressed the Solid Waste Section's comments in this transmittal by restating the Section comment in italics and then providing our response. Accordingly, Waste Management of Carolinas, Inc. submits the following responses:

1. *Section 2.2 Description of Proposed Final cover System, Paragraph 2 (p. 3): Please indicate in the drawings the location of the proposed storage area.*

   Response:

   In response to the Section's comment, Drawing 2 of 4 has been revised to show two potential locations for stockpiling material during the reconstruction of the final cover at the Piedmont Landfill. One is the former laydown area located north and west of the landfill gas flares, the other is within the borrow area located north of the landfill. Please replace the existing Drawing 2 of 4 in the Design Report with the revised drawing, enclosed.

2. *Section 2.2 Description of Proposed Final Cover System, Paragraph 2 (p. 3): Statement is presented that existing final cover system protective soil component will be reused. Will the reinforced erosion mat be removed from the sloughed protective cover layer before reuse in the reconstructed protective cover? If not, how will the reinforced erosion mat be incorporated into the vegetative/protective cover?*

Response:

WM does not intend to remove the erosion mat from the sloughed protective soil cover layer prior to its reuse during reconstruction of the final cover. The erosion mat has been exposed to the elements and subject to UV degradation since its installation approximately 9 months ago. The erosion mat will be further degraded during the removal, stockpiling and reuse of the final cover protective cover component to the point where we believe its presence will not complicate the reconstruction effort.

3. *Drawing 4 of 4, Detail 3/3: 8 oz/sy nonwoven geotextile filter and 60-mil thick HDPE A/A Super Gripnet geomembrane liner are not shown in the detail. The geotextile and geomembrane are shown in Detail 1/3.*

Response:

In response to the Section's comment, Drawing 4 of 4 has been revised to show the 8 oz/sy nonwoven geotextile filter and 60-mil thick HDPE A/A Super Gripnet® geomembrane liner in Detail 3/3. Please replace the existing Drawing 4 of 4 in the Design Report with the revised drawing, enclosed.

4. *Appendix C CQA Plan Amendment Section 2.5.1 Trial Seams (p 2-8): Please provide the frequency or determination required for trial seam testing.*

Response:

In response to the Section's comment, Section 2.5.1 of the CQA Plan Amendment was revised to include trial seam testing procedures and frequencies. Please replace the existing pages 2-8 and 2-9 in the existing CQA Plan with the enclosed revised pages 2-8 and 2-9.

5. *Appendix C CQA Plan Amendment Table 2-1 (p 2-14): GRI Test Method GM13 standard specification ASTM D 6693 in place of ASTM D 638 for determining tensile strength. The difference between the tests is testing temperature. Otherwise, the tests do not differ in numeric strength or elongation values.*

Response:

In response to the Section's comment, Table 2-1 of the CQA Plan Amendment has been revised to reference ASTM D 6993 instead of the originally referenced ASTM D 638. Please replace the existing Table 2-1 of the CQA Plan Amendment with the revised table, enclosed.

6. *Please provide details of the means for disposing the waste cover material.*

Response:

Specific details for disposing waste cover material generated during the reconstruction of the final cover at the Piedmont Landfill are not available for inclusion in this response. It is

WM's intent to investigate alternatives for the final disposition of surplus materials generated during the reconstruction effort in a cost effective manner. For instance, initial discussions indicate that the LLDPE geomembrane is a strong candidate for recycle and efforts to utilize this option will continue as the reconstruction effort progresses. Needless to say, any disposition of waste cover materials will be in accordance with applicable State, Federal and Local regulations.

We trust you will find the enclosed revisions satisfactory and look forward to receipt of approval by the Solid Waste Section of the revised Design Report. If you have any questions or require additional information, please contact me at (770) 805-3529.

Sincerely,

Waste Management of Carolinas, Inc.

Mark R. Snyder

Mark R. Snyder, P.E.
Project Manager, Closed Sites

enclosures

cc: Jim Coffee, NCDENR, w/o enclosures
March Smith, WMCI, w/o enclosures

file copy

NCDENR

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

Dexter R. Matthews, Director | Division of Waste Management | Michael F. Easley, Governor
William G. Ross Jr., Secretary

May 31, 2005

Mark Snyder, P.E.
Project Manager, Closed Sites
Waste Management
2859 Paces Ferry Road, Suite 1600
Atlanta, Georgia 30339

Re: Review Comments for Proposed Design
Reconstruction of Section of Phase 2 Closure
Permit No. 34-06
Piedmont Landfill
Forsyth County, North Carolina

Dear Mr. Snyder:

Review of the above referenced submittal dated May 12, 2005, is complete. Below are comments regarding the proposed design the we request you address before construction approval for the project can be granted.

1. Section 2.2 Description of Proposed Final Cover System, Paragraph 2 (p. 3): Please indicate in the drawings the location of the proposed storage area.

2. Section 2.2 Description of Proposed Final Cover System, Paragraph 2 (p. 3): Statement is presented that existing final cover system protective soil component will be reused. Will the reinforced erosion mat be removed from the sloughed protective cover layer before reuse in the reconstructed protective cover? If not, how will the reinforced erosion mat be incorporated into the vegetative/protective cover?

3. Drawing 4 of 4, Detail 3/3: 8 oz/sy nonwoven geotextile filter and 60-mil thick HDPE A/A Super Gripnet geomembrane liner are not shown in the detail. The geotextile and geomembrane are shown in Detail 1/3.

4. Appendix C CQA Plan Amendment Section 2.5.1 Trial Seams (p 2-8): Please provide the frequency or determination required for trial seam testing.

5. Appendix C CQA Plan Amendment Table 2-1 (p 2-14): GRI Test Method GM13 standard specification ASTM D 6693 in place of ASTM D 638 for determining tensile strength. The difference between the tests is testing temperature. Otherwise, the tests do not differ in numeric strength or elongation values.

6. Please provide details of the means for disposing the waste cover material.

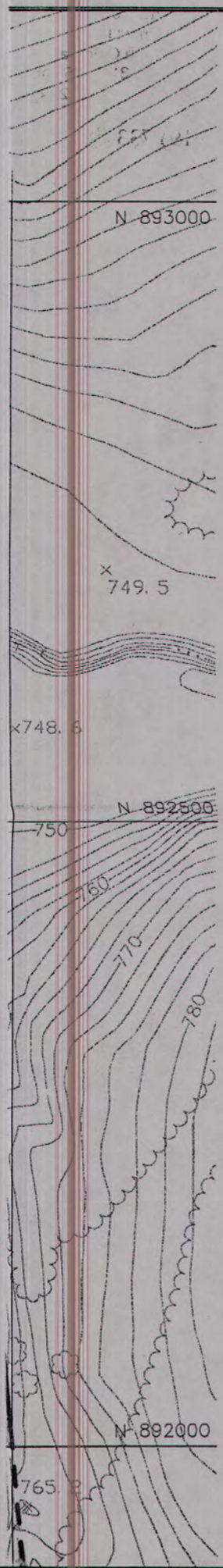
Please call me should you have any questions or comments regarding this letter. Also, please note that our office telephone numbers are changed. You may call me directly at (919) 508-8504. The new number for the

Division of Waste Management is (919) 508-8400. Our fax number is unchanged and remains (919) 733-4810.

Sincerely,

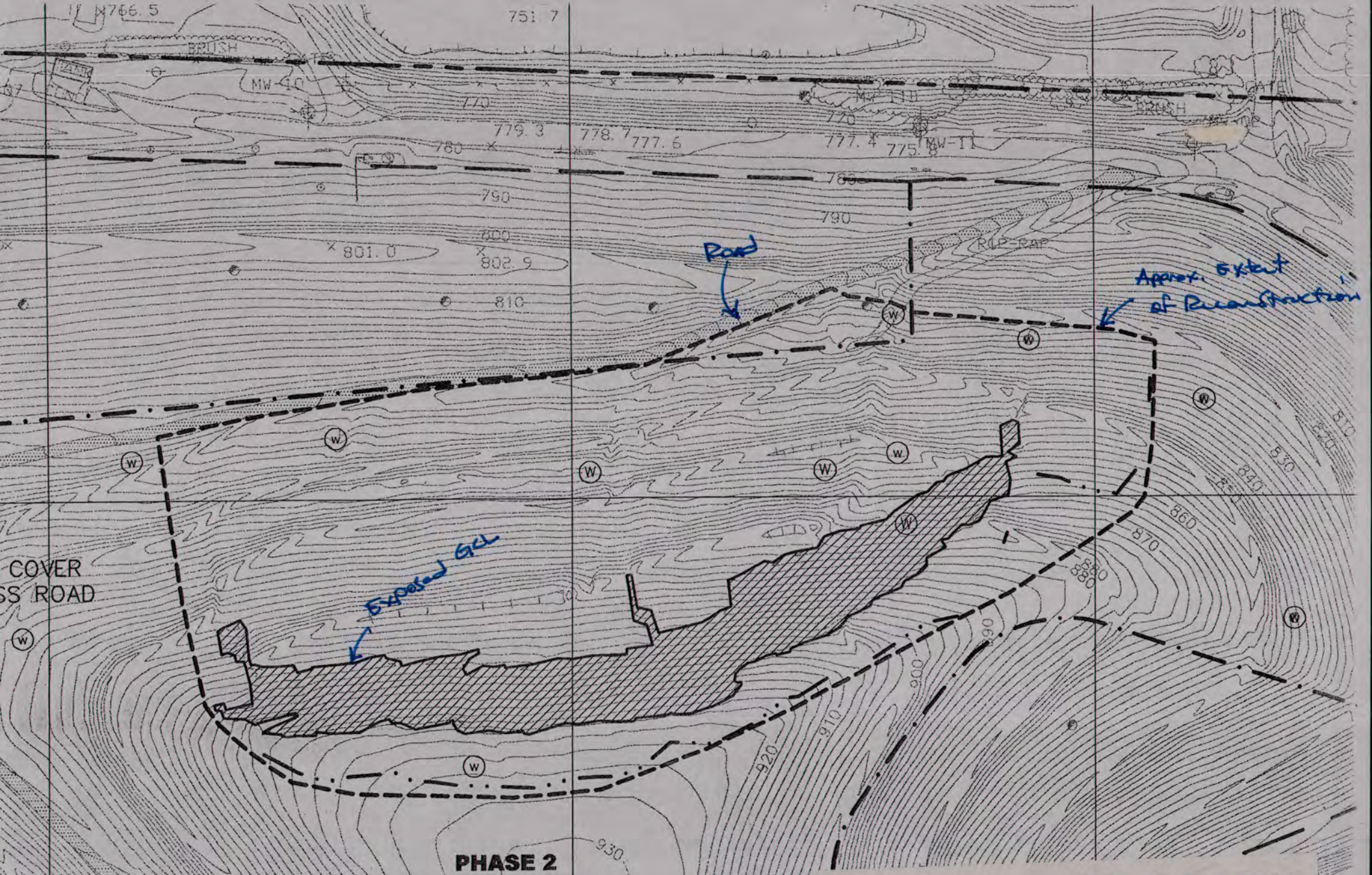
Geoffrey H. Little
Environmental Engineer
Solid Waste Section

c: Mike Loyd, WM
Jim Coffey, DWM
Jim Barber, DWM
Mark Poindexter, DWM
Brent Rockett, DWM
Jason Watkins, DWM



LEGEND

780	CONTOUR OF EXISTING GRADE (FEET, MSL)
	COUNTY BOUNDARY
	FENCE LINE
	PROPERTY LINE
	TREE / BRUSH LINE
	APPROXIMATE LIMIT OF LANDFILL
	PHASE 2 BOUNDARY
	BOUNDARY BETWEEN PHASE 1 AND SOUTHERN/EASTERN SIDESLOPES
	EXISTING FINAL COVER ACCESS ROAD
	TREE
MW-07	EXISTING MONITORING WELL
	APPROXIMATE LIMIT OF FINAL COVER RECONSTRUCTION AREA
	CRACKING IN COVER SOIL
	EXPOSED GCL
	EXISTING GAS WELL
W	GAS WELL WITHIN OR NEAR RECONSTRUCTION AREA



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To J. Watkins & B Rocket	From Graf	
Co./Dept. DENR/SWS	Co. DENR/SWS	
Phone #	Phone # 919-508-8504	
Fax # 336-771-4631	Fax #	

WASTE MANAGEMENT

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May 12, 2005

Received
MAY 2005
Solid Waste Section

NC Department of Environment and Natural Resources
Division of Waste Management – Solid Waste Section
1646 Mail Service Center
Raleigh, North Carolina 27699-1646
Attn: Mr. Geoffrey H. Little

Subject: Request for Approval of Proposed Design
Reconstruction of Section of Phase 2 Closure
Piedmont Landfill and Recycling Center, Kernersville, North Carolina
Permit Number 34-06

Dear Mr. Little:

Please find enclosed one (1) original and one (1) copy of the Design Report – Reconstruction of an Area of Phase 2 Final Closure for the above referenced facility. Appendix C of the Design Report includes the CQA Plan Amendment – Reconstruction of an Area of Phase 2 Closure. The Design Report was developed in response to the January 2005 movement of final cover at the Piedmont Landfill and is being submitted for approval by the North Carolina Department of Environment and Natural Resources (NCDENR) in accordance with the schedule contained in our February 16, 2005, submittal as modified by our requests dated March 8 and April 25, 2005.

As requested by the Section, this submittal complies with the applicable sections of the Solid Waste Rules and also addresses concerns raised in your letter dated April 14, 2005, regarding equivalency of the proposed final cover configuration to the regulatory specified minimum final cover, and the incorporation of drainage berm stresses into design analyses for transmissivity and seismic and slope stability. Not specifically addressed in these documents are your concerns related to the effect of installation on geomembrane asperity and the depth to gas extraction well screens in the area of cover movement.

Based upon the results of laboratory interface shear strength testing of the Agru/America, Inc. (A/A) Super Gripnet product as presented in Attachment 2 of Appendix B2 of the Design Report, degradation of the gemembrane asperity during installation is not expected to occur. Asperity height was measured at the completion of shear strength tests of the A/A product under three (3) separate load configurations representing 2, 5 and 10 feet of soil cover. No degradation of asperity height was observed in geomembrane samples following completion of these tests. It should be noted that the reduction in asperity height as discussed on Page 21 of the Investigation Report was observed in samples of an A/A Micro Drain liner material fabricated using linear low density polyethylene and incorporating "micro spike" texturing. The A/A Super Gripnet product proposed in the reconstruction design is fabricated using high density polyethylene and incorporates a considerably more aggressive "super spike" texturing with an asperity height an order of magnitude greater than that of the Micro Drain liner. It is our opinion that the more

resilient HDPE material, coupled with an aggressive "super spike" texturing, will preclude the occurrence of any degradation of asperity height due to installation and is confirmed by the measurement of asperity height from post shear strength test samples of the A/A Super Gripnet product.

With regard to the depth to screen in gas wells located in the area of concern, a review of historical data was conducted in conjunction with interviews of personnel supervising the installation of wells in that area. Contrary to the assertion made on Page 17 of the Investigation Report that wells in the area of concern were installed with the top of screen 40 feet below the waste surface, it was determined that all but 3 wells constructed in 2004 were actually installed with the top of screen 20 feet below waste surface. The remaining wells (21, 22 and 45) were installed with the top of screen between 20 and 40 feet below the final waste surface. This information, when coupled with the more efficient operation of the gas collection and control system as evidenced through recent wellfield tuning events, indicates that landfill gas is being effectively controlled at the facility. It is our intent to incorporate this information into a later submittal to the Solid Waste Section that addresses the "Observations regarding the Investigative Report" contained on Page 1 of your April 14, 2005, letter.

We trust you will find the enclosed submittals satisfactory and look forward to receipt of approval by the Solid Waste Section of this request. If you have any questions or require additional information, please contact me at (770) 805-3529.

Sincerely,

Waste Management of Carolinas, Inc.

Mark R. Snyder, P.E.
Project Manager, Closed Sites

enclosures

cc: Jim Coffee, NCDENR, w/o enclosures
March Smith, WMCI, w/o enclosures

prepared for

Waste Management of Carolinas, Inc.

2859 Paces Ferry Road, Suite 1600
Atlanta, Georgia 30339

Fac/Perm/Co ID # 34-06
Date 8/8/13
Doc ID#
DIN
Carmen Johnson
9/19/13

DESIGN REPORT

RECONSTRUCTION OF AN AREA OF PHASE 2 FINAL CLOSURE PIEDMONT LANDFILL KERNERSVILLE, NORTH CAROLINA

prepared by

GeoSyntec Consultants

1255 Roberts Boulevard, Suite 200
Kennesaw, Georgia 30144

Project Number: NCP2005.3204

May 2005

Prepared for:

Waste Management of Carolinas, Inc.
2859 Paces Ferry Road, Suite 1600
Atlanta, Georgia 30339

DESIGN REPORT
RECONSTRUCTION OF AN AREA OF PHASE 2 FINAL CLOSURE

PIEDMONT LANDFILL
KERNERSVILLE, NORTH CAROLINA

Received
MAY 2005
Solid Waste Section

Prepared by:

GeoSyntec Consultants
1255 Roberts Boulevard, Suite 200
Kennesaw, Georgia 30144

NORTH CAROLINA PROFESSIONAL SEAL 24769 ENGINEER MAJDI A. OTHMAN

Project Number: NCP2005.3184

May 2005

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Appendix C Technical Specifications and CQA Procedures

1. INTRODUCTION

1.1 Terms of Reference

This report was prepared by GeoSyntec Consultants, Inc. (GeoSyntec) for the Waste Management Piedmont Landfill (PLF) located near Kernersville, North Carolina. The report describes final cover system reconstruction proposed for an area of the Phase 2 closure at PLF that previously underwent downslope movement. The report also summarizes engineering evaluations associated with the proposed final cover system reconstruction. This report was prepared by Drs. Basak Gulec and Majdi A. Othman, P.E., and it was reviewed by Drs. Jay Beech, P.E., and Rudy Bonaparte, P.E., all of GeoSyntec.

1.2 Project Summary

Construction of the PLF final cover system was completed in three phases over the operating life of the facility: Phase 1 Closure; Southern and Eastern Sideslopes Closure; and Phase 2 Closure. The areas closed during each of the three phases of closure construction are shown in Drawing 2 of the Phase 2 final closure reconstruction drawings included in Appendix A. These drawings are hereafter referred to as the Reconstruction Drawings.

Two episodes of downslope movement of a portion of the Phase 2 final cover system occurred within the past ten months. On 28 August 2004, during Phase 2 closure construction, gas-pressure buildup in the landfill induced uplifting and associated downslope movement of an approximately six-acre portion of the final cover system. The portion of the cover system that moved was located on the north-facing slope of the landfill. Subsequently, approximately two and one-half months after the completion of construction (January 2005), an approximately seven-acre portion of the cover system underwent similar downslope movement. It was observed that the location of the January 2005 movement encompassed all but about a one-half acre portion of the area of the August 2004 movement. After the January 2005 movement, the geosynthetic clay liner (GCL) component of the cover system was exposed along the crest of the slope. Within the area of movement, the drainage benches moved down the slope with the protective soil. Drawing 2 of the Reconstruction Drawings depicts conditions of the final cover system after the January 2005 movement.

GeoSyntec conducted a series of field investigations and a laboratory testing program to investigate the January 2005 movement. The results of these investigations were compiled in a report dated March 2005 that was submitted to the North Carolina Department of Environment and Natural Resources (NCDENR). GeoSyntec and WM met with NCDENR on 12 April 2005 to discuss the results of the investigation and to

present recommendations regarding reconstruction of the failed area of the Phase 2 final cover system.

During the meeting with NCDENR, GeoSyntec and WM presented a plan for reconstruction of the portion of the Phase 2 final cover system that had undergone movement. GeoSyntec and WM proposed a redesigned cover system consisting of the following components, from top to bottom:

- 24-inch thick protective/vegetative soil layer;
- 8 oz/yd^2 geotextile filter layer;
- Agru America, Inc. (A/A) Super Gripnet® liner consisting of a 60-mil thick (average; 55-mil thick minimum) high density polyethylene (HDPE) geomembrane with friction spikes on the bottom and drainage studs on top; and
- 10-inch thick compacted soil layer (existing subgrade).

The design calculations and analyses supporting the proposed final cover system are presented in this design report.

1.3 Objectives and Organization of Report

The purpose of this report is to describe the proposed reconstruction of the Phase 2 closure at the PLF and to provide supporting design calculations and analyses. The remainder of this report is organized as follows:

- a description of the final cover system reconstruction is presented in Section 2; and
- results of design analyses performed in support of the proposed final cover system are presented in Section 3.

Three appendices to this report present the followings:

- Appendix A: Design Drawings, Reconstruction of an Area of Phase 2 Closure;
- Appendix B: Design Calculation Packages; and
- Appendix C: Technical Specifications and CQA Procedures.

2. DESCRIPTION OF FINAL COVER SYSTEM RECONSTRUCTION

2.1 Delineation of Reconstruction Area

As part of the investigation of the January 2005 cover system movement, several field investigation activities were undertaken from 21 January to 1 March 2005. The delineation of the area of movement, including delineation of the area of exposed GCL and cracking in the protective cover soil, was initially based on the site reconnaissance conducted on 1 March. The initially-delineated area is shown on Figure 2-4 of the investigation report [GeoSyntec Consultants, 2005]. The delineated area was refined further based on detailed review of available aerial photography and topography (conducted on 20 March 2005) to develop the reconstruction area shown on Drawings 2 and 3 of the Reconstruction Drawings.

As indicated on Drawings 2 and 3, the area of final cover reconstruction (7.5 acres) is designated as the minimum anticipated repair area. If during reconstruction, any signs of distress or movement are observed outside of this delineated area, the reconstruction area will be extended to encompass these distressed areas.

2.2 Description of Proposed Final Cover System

As described in Section 1.2 of this report, the proposed final cover system will include an A/A Super Gripnet® liner, which has two primary functions: (i) the studs located on top of the geomembrane will provide a laterally-transmissive drainage layer to convey water infiltrating through the protective soil layer to a drainage outlet; and (ii) the geomembrane component will act as a barrier to minimize infiltration of water through the cover system. The spikes on the bottom of the geomembrane are designed to improve the interface shear strength between the geomembrane and underlying subgrade in comparison to the interface strength obtained with a smooth geomembrane. Drawing 4 of the Reconstruction Drawings presents the details of the proposed final cover system and the tie-in of the proposed system to the existing final cover system. The technical specifications and construction quality assurance (CQA) requirements of the A/A Super Gripnet® liner are provided in Appendix C of this report.

Prior to placement of the proposed final cover system, the protective soil component of the existing final cover system will be removed and stockpiled in a nearby location for reuse in the new final cover system. Then, the existing geosynthetics (i.e., A/A microdrain liner and GCL) will be removed and stockpiled. The existing 10-inch thick subgrade soil layer will remain in place, but will be smoothed and proof rolled. Upon completion of final cover system reconstruction, side-slope drainage benches will be constructed and connected to existing benches. The locations of the proposed drainage benches are shown on Drawing 3, and the drainage bench details are shown on Drawing 4.

3. DESIGN ANALYSES

3.1 Hydraulic Analysis and Technical Demonstration of Equivalency

3.1.1 Introduction

This section presents the results of hydraulic analyses performed for the proposed final cover system to: (i) estimate the rate of infiltration through the system and demonstrate its equivalency to the regulatory minimum final cover system required by NCDENR; and (ii) evaluate the adequacy of the cover system internal drainage layer to convey infiltration water to the drainage layer outlet without exceeding the free-flow capacity of the layer. The detailed calculations are provided in Appendix B1 of this report.

3.1.2 Method of Analysis

Modeling of the hydraulic performance of the proposed and regulatory minimum final cover systems was performed using the Hydrologic Evaluation of Landfill Performance (HELP) model, version 3.07, developed for USEPA (Schroeder et al., 1994 a,b). The program accepts climatologic, soil, and design data and uses a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, evaporation, soil moisture storage, and lateral drainage.

3.1.3 Material Properties and Assumptions

The HELP model default climatological data for Greensboro, North Carolina, which is located only about 15 miles to the east of the PLF site, was selected to synthetically generate weather data for the PLF site. To more closely model weather data at the site, the default mean monthly precipitation data was adjusted to be consistent with the mean monthly precipitation data obtained for the weather station closest to the site.

The properties of different layers for the proposed final cover system (HELP default material texture number, thickness, porosity, field capacity, wilting points, and saturated hydraulic conductivity) are provided in the calculation package presented in Appendix B1. The proposed final cover soil layers (i.e., protective/vegetative soil and subgrade soil) were modeled as HELP default materials that have the same classification under the Unified Soil Classification System (USCS) as those defined based on laboratory testing of these soils. The A/A Super Gripnet® liner was modeled as two separate layers, a geonet drainage layer and geomembrane barrier layer. The saturated hydraulic conductivity of the geonet drainage layer was selected based on results of transmissivity tests conducted on the proposed final cover system as presented in Appendix B1.

The remaining assumptions and material properties assumed in the infiltration analyses are presented in detail in Appendix B1.

3.1.4 Results of Analyses

Infiltration Rates and Equivalency Demonstration

Peak daily and average annual infiltration rates were estimated to be 2.00×10^{-5} and 7.67×10^{-7} inch/day, respectively for the proposed final cover system, and 3.42×10^{-4} and 8.94×10^{-5} inch/day, respectively for the regulatory minimum final cover system. Average annual head on top of the geomembrane was calculated to be 0.001 and 6.13 inches for the proposed and regulatory minimum final covers, respectively.

Estimated infiltration rates for the proposed final cover system are up to two orders of magnitude less than estimated infiltration rates for the regulatory minimum final cover system. Based on these results, the proposed final cover system performance is predicted to exceed the performance of the regulatory minimum final cover system with respect to infiltration.

Hydraulic Performance of Drainage Layer

The average and maximum heads on top of the geomembrane on the peak day of the modeling period for the proposed final cover system were calculated to be 0.048 and 0.085 inches, respectively. This indicates that the drainage layer has adequate transmissivity to convey infiltration water down the landfill slope to the drainage outlet at the toe of the slope.

3.2 Static and Seismic Veneer Stability of Cover System

3.2.1 Introduction

Static and seismic stability of the proposed final cover system was evaluated in veneer mode (i.e., sliding of the cover system along a weak interface within the cover). The calculations are provided in Appendix B2. The analysis methods, material properties and assumptions, and results are described briefly below.

3.2.2 Methods of Analyses

The finite slope stability analysis method [Giroud, et al., 1995] was used to calculate the factor of safety for static stability of the proposed final cover system. The pseudo-static factor of safety was estimated using the equation of Matasović [1991]. A calculated pseudo-static factor of safety greater than 1.0 suggests that no permanent seismic displacement is expected. A factor of safety less than 1.0, however, suggests

permanent displacement can occur. If the factor of safety was calculated to be less than 1.0, then the seismic displacement would be estimated using the simplified method of Hynes and Franklin [1984]. This method of analysis is consistent with the United States Environmental Protection (USEPA) seismic guidance document [USEPA,1995].

3.2.3 Material Properties and Assumptions

The maximum horizontal acceleration (MHA) at the PLF site was estimated to be 0.11g based on the United States Geological Survey (USGS) seismic hazard map. The corresponding peak horizontal acceleration at the top of the PLF was estimated as 0.21 g, as discussed in Appendix B2 of this report.

For evaluation of stability of the final cover system for the PLF in veneer mode, a slope inclination of 33.3 percent (3H:1V) and a slope length of 340 ft were considered. The thickness of the protective soil above the geosynthetics is designed to be 2 ft. However, two other thicknesses (3 ft and 4 ft) were considered in the analyses to address the potential for the protective soil layer to be constructed thicker than 2 ft.

Compaction and shear strength tests were performed on soil from the PLF site that will be used for the protective/vegetative soil layer of the final cover system. Based on the results of these tests (included in Appendix B2), a total (i.e., moist) unit weight of 120 pounds per cubic foot (pcf) and a total-stress shear strength represented by a cohesion (c) of 100 pounds per square foot (psf) and an internal friction angle (ϕ) of 29° were conservatively assumed for the protective/vegetative soil layer.

Site-specific shear strength testing was performed on prepared samples representing the proposed final cover system (with an A/A Super Gripnet® liner) to evaluate interface shear strength characteristics of the proposed final cover system. The results of this testing are included in Appendix B2. Based on these results, the following total-stress shear strength parameters were conservatively selected for the critical cover system interface (i.e., geomembrane-subgrade interface): peak adhesion (a) and ϕ values of 79 psf and 25°, respectively and large-displacement a and ϕ values of 89 psf and 21.3°, respectively.

The water depth in the drainage layer above the geomembrane was estimated to be 0.048 inches (0.004 ft) based on the HELP analysis performed in the calculation package titled *"Proposed Final Cover System Infiltration Analysis"* presented as Appendix B1 of this report. This value represents the average head in the drainage layer for a peak day of the HELP model simulation.

The stability analyses assume that the gas collection and control system (GCCS) is operated in a manner that prevents the build up of landfill gas beneath the geomembrane. Also, the hydraulic head applied in the drainage layer considers that the drainage

benches, slope drains, and drainage ditch at the toe of the slope are maintained free of debris and vegetation, such that the slope srain outlets and cover system internal drainage layer are free draining.

3.2.4 Results of Analyses

The calculated factors of safety for static stability of the proposed final cover system (in veneer mode) for all of the different conditions analyzed are 1.97 or larger based on peak strength parameters and 1.81 or larger based on large-displacement shear strength parameters. These calculated static factors of safety are considered acceptable.

The calculated pseudo-static factors of safety for the proposed final cover system are greater than 1.0 for both peak and large-displacement shear strength parameters. This indicates that permanent displacement of the proposed final cover system is not anticipated as a result of horizontal accelerations caused by the design earthquake.

3.3 Static and Seismic Slope Stability Analysis Drainage Benches

3.3.1 Introduction

The stability of the drainage benches to be constructed on the proposed final cover system for the PLF reconstruction was evaluated under both static and seismic conditions. These calculations are presented in detail in Appendix B3. The analysis methods, material properties and assumptions, and results are described briefly below.

3.3.2 Methods of Analyses

Static slope stability analyses were performed using the simplified Bishop method of slices [Bishop, 1955] for circular potential slip surfaces, and the simplified Janbu limit equilibrium method [Janbu, 1973] for block potential slip surfaces, both as implemented in the computer program XSTABL® 5.201. Following the simplified Janbu analysis, which was used to randomly search for block failure surfaces, Spencer's method [1967] was used to analyze the most critical surface and refine the estimate of the factor of safety with respect to a block failure.

Seismic stability analysis was performed in accordance with USEPA seismic guidance document [USEPA, 1995] and as summarized in Appendix B3. The analyses were performed using the simplified Bishop method (for circular failure surfaces) and simplified Janbu method (for block failure surfaces) to identify the most critical potential slip surface. Similar to the static stability analysis, the Janbu analysis was then verified using the Spencer's method.

3.3.3 Material Properties and Assumptions

The design MHA at the top of the PLF was estimated to be 0.21g as discussed in Section 3.2.3. The unit weight and internal/interface shear strength properties were based on laboratory test results presented in the calculation package titled *"Static and Seismic Slope Stability Analyses of Proposed Final Cover System (Veneer Mode)"* and summarized in Section 3.2.3 of this design report.

Similar to the veneer stability of the cover system, the drainage bench stability analyses assume that the gas collection and control system (GCCS) is operated in a manner that prevents the build up of landfill gas beneath the geomembrane, and that the drainage benches and slope drains are maintained free of debris and vegetation, such that the slope drain inlets and cover system internal drainage layer are free draining.

3.3.4 Results of Analyses

The calculated factors of safety for static stability of the proposed final cover drainage benches are 1.98 or larger.

The yield accelerations for circular and block failure modes were greater than the design MHA (i.e., 0.21g), indicating the landfill will not undergo permanent displacement during the design earthquake.

4. REFERENCES

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Schroeder. P.R., Dozier, T.S., and Zappi, P.A., McEnroe, B.M., Sjostrom, J.W., and Peyton, R.L. (1994b) "*The Hydrologic Evaluation of Landfill Performance (HELP) Model, Engineering Documentation for Version 3.*" U.S. Environmental Protection Agency, Office of Research and Development Washington, D.C., Report No. EPA/600/R-94/168b.

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[redacted] See End of File for Drawings

Appendix A

Final Cover System Reconstruction Design Drawings

Appendix B
Calculation Packages

Appendix B1
Proposed Final Cover System Infiltration Analysis

GEOSYNTEC CONSULTANTS

COMPUTATION COVER SHEET

Client: WM **Project:** Piedmont Landfill **Project/Proposal #:** NCP2005 **Task #:** ____

TITLE OF COMPUTATIONS PROPOSED FINAL COVER SYSTEM INFILTRATION ANALYSIS

COMPUTATIONS BY:
Signature T. Elkady — DATE 5 May 05
Printed Name and Title: Tamer Elkady, Engineer

ASSUMPTIONS AND PROCEDURES CHECKED BY:
(Peer Reviewer)
Signature Majdi Ahmed Othman — DATE 6 May 05
Printed Name and Title: Majdi Othman, Associate

COMPUTATIONS CHECKED BY:
Signature Majdi Ahmed Othman — DATE 6 May 05
Printed Name and Title: Majdi Othman, Associate

COMPUTATIONS BACKCHECKED BY:
(Originator)
Signature T. Elkady — DATE 6 May 05
Printed Name and Title: Tamer Elkady, Engineer

APPROVED BY:
(PM or Designate)
Signature Majdi Ahmed Othman — DATE 12 May 05
Printed Name and Title: Majdi Othman, Associate

APPROVAL NOTES: ____

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

PROPOSED FINAL COVER SYSTEM INFILTRATION ANALYSIS

INTRODUCTION

The purpose of this calculation package is to calculate the rate of rainfall infiltration through the proposed final cover system for the Piedmont Landfill (PLF). This infiltration rate is compared to a calculated infiltration rate for the regulatory minimum subtitle D final cover system required by the North Carolina Department of Environment and Natural Resources (NCDENR) to demonstrate equivalency of the proposed final cover to the regulatory minimum final cover.

In the remainder of this calculation package, the components of the proposed and regulatory minimum final cover systems are described, and the method of infiltration analysis, parameters used in the analysis, and analysis results are presented.

DESCRIPTION OF PROPOSED AND REGULATORY MINIMUM FINAL COVER SYSTEMS

The components of the proposed final cover consist, from top to bottom, of the following:

- 24-inch thick protective/vegetative soil layer;
- 8 oz/yd^2 geotextile filter;
- Agru America, Inc. (A/A) Super Gripnet® liner consisting of a 60-mil thick (average; 55-mil thick minimum) high density polyethylene (HDPE) geomembrane with friction spikes on the bottom and 0.15-inch thick drainage studs on top; and
- 10-inch thick compacted soil layer (existing subgrade).

Manufacturer's information regarding the 60-mil thick HDPE A/A Super Gripnet® liner is presented in Attachment 1. It is noted that the A/A Super Gripnet® liner has dual functionality. First, the studs located on top of the geomembrane, when combined with a geotextile filter, will provide a drainage layer for water infiltrating through the protective soil layer. Second, the geomembrane component will act as a barrier to minimize infiltration of water through the cover system.

Based on discussion with NCDENR on 12 April 2005, it is the understanding of GeoSyntec that the regulatory minimum subtitle D final cover system consists of the following components (from top to bottom):

- 24-inch thick erosion control/vegetation soil layer;
- 30-mil thick (60-mil thick if HDPE) synthetic liner; and
- 18-inch thick barrier layer with a maximum hydraulic conductivity of 1 $x10^{-5}$ cm/sec.

In the remainder of this calculation package, infiltration analysis method, assumptions, and results are presented, and a conclusion is provided regarding the equivalency (in terms of infiltration) of the proposed final cover to the regulatory minimum final cover.

METHOD OF INFILTRATION ANALYSIS

Modeling of infiltration through the final cover systems was performed using the Hydrologic Evaluation of Landfill Performance (HELP) model, version 3.07, developed for USEPA (Schroeder et al., 1994 a, b).

The HELP program is a quasi two dimensional hydrologic model of water movement across, into, through, and out of landfills. The program accepts climatologic, soil, and design data and uses a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, evaporation, soil moisture storage, and lateral drainage.

ANALYSIS ASSUMPTIONS AND INPUT DATA

The following assumption and input data was used with the HELP program:

Climatic data

- The HELP model user can generate synthetic weather data for select cities within the United States. The HELP model has default climatological data for Greensboro, North Carolina, which is located only about 15 miles to the east of the PLF Site.

Therefore, Greensboro was selected within the HELP model to synthetically generate weather data for the PLF site. However, to more closely model weather data at the PLF site, daily precipitation data from 1933 to 2001 was obtained from the CDROM "*NCDC SUMMARY OF THE DAY*", published by EarthInfo Inc. [EarthInfo, 2002], for a weather station named "Greensboro Piedmont Triad Int" (Weather Station ID: 313630), which is the closest to the PLF site. This daily precipitation data was analyzed to obtain normal mean monthly precipitation data that is more representative of the PLF site than the HELP default data for Greensboro. Therefore, daily precipitation at the PLF was modeled using the synthetic daily weather generation option of HELP for Greensboro, North Carolina, in conjunction with the calculated normal mean monthly precipitation data for the "Greensboro Piedmont Triad Int" weather station. One Hundred (100) one-year precipitation records were synthetically generated. After that, the peak daily rainfall from the precipitation record was manually adjusted from 5.93 to 6.19 in. to model the 25-year, 24-hour storm event (i.e., 6.19 in.). The temperature, relative humidity, and the solar radiation data were modeled for Greensboro, North Carolina using the same option (synthetic daily weather generation) over the 100 one-year modeling period.

- The evaporative zone depth was selected to be the thickness of the protective/vegetative soil layer (i.e., 24 in.).

Final cover data

The following data was used to represent the properties of the different layers for the proposed final cover system:

- Based on testing performed on the protective soil layer material obtained from the PLF site (included in Attachment 2), the protective soil classifies as a silty sand (SM) based on the Unified Soil Classification System (USCS). Non-plastic fines (silt and clay) constitute 22.5% of the material. Accordingly the protective soil layer was modeled as HELP default material texture # 5, which has the following properties:

Thickness:	24 inches
Porosity:	0.457
Field capacity:	0.131

Wilting point:	0.058
Saturated hydraulic conductivity:	1×10^{-3} cm/sec

- The drainage layer of the final cover system was modeled as a material with the following properties (values for HELP default material texture # 34 drainage net were used for porosity, field capacity, and wilting point):

Thickness:	0.145 inches
Porosity:	0.85
Field capacity:	0.01
Wilting point:	0.005
Saturated hydraulic conductivity:	12.2 cm/sec (as discussed below)

GeoSyntec Consultants conducted tests on the proposed A/A Super Gripnet Liner to evaluate its hydraulic transmissivity under different normal stresses and seating times. Two normal stress levels were used. The lower normal stress level (240 psf) represents a thickness of protective soil of about 2 ft above the geosynthetics, which occurs over all areas of the cover system except below the surface-water drainage benches. The higher normal stress level (1,200 psf) represents a protective soil thickness above the geosynthetics of up to 10 ft. Based on the proposed final cover design, the maximum soil thickness above the geosynthetics is about 5 ft and occurs at the drainage benches. Therefore, the transmissivity values measured at the higher normal stress of 1,200 psf are very conservative for the proposed final cover system.

The hydraulic transmissivity results are presented in Attachment 3 and are summarized in Figure 1. Based on these test results, the hydraulic transmissivity for the drainage layer was found to range from approximately 1.16×10^{-3} m^2/sec to 2.19×10^{-3} m^2/sec. For the purpose of this analysis, data from the hydraulic transmissivity testing performed at the higher normal stress level was extrapolated to estimate the hydraulic transmissivity of the drainage layer at the end of the post closure period (i.e., after 30 years) as shown in Figure 1. Based on Figure 1, the long-term hydraulic transmissivity of the drainage layer was conservatively assumed to be 9.00×10^{-4} m^2/sec. Therefore, the saturated hydraulic conductivity was calculated as follows:

$$\text{Saturated hydraulic conductivity} = \frac{9.00 \times 10^{-4}\ m^2/sec \times 10^4\ cm^2/m^2}{0.145\ in \times 2.54\ cm/in}$$
$$= 24.4\ cm/sec$$

Applying an overall reduction factor/factor of safety of 2.0 to the above calculated hydraulic conductivity, results in a calculated design hydraulic conductivity of 12.2 cm/sec. The applied reduction factor/factor of safety of 2.0 is intended to account for unlikely factors such as material variability, clogging, and/or degradation.

- The drainage length was modeled as 495 ft to simulate the largest distance of travel for water in the drainage layer before exiting the final cover system. This drainage length (Figure 2) represents the maximum drainage length measured from the crest to the toe of the slope. It extends along two different slopes with the majority sloping at 3H:1V. Given the limitation of HELP to define the drainage length along combined slopes, the drainage length was assumed to be a combined length of 495 ft along a slope of 3H:1V.

- The 60-mil thick high density polyethylene (HDPE) geomembrane was modeled as a geosynthetic material texture # 35, with a hydraulic conductivity of 2×10^{-13} cm/sec. The geomembrane was assumed to have one hole every acre, with a hole size of 0.16 in^2 in accordance with the recommendations of Giroud and Bonaparte [1989].

- Based on testing performed on the existing subgrade soil obtained from the PLF site (included in Attachment 2), the subgrade soil classifies as a silty sand (SM) based on the Unified Soil Classification System (USCS). The fines (silt and clay) constitute 41.3% of the material and exhibit low plasticity. Accordingly the compacted soil layer was modeled as HELP default material texture # 7, which has the following properties:

Thickness:	10 inches
Porosity:	0.473
Field capacity:	0.222
Wilting point:	0.104
Saturated hydraulic conductivity:	5.2×10^{-4} cm/sec

- Properties of the layers of the regulatory minimum final cover system were assumed to be identical to those assigned for the proposed final cover system except for the soil barrier layer which was modeled as HELP default material texture # 10 (with adjustment of the default hydraulic conductivity value to 1×10^{-5} cm/sec), which has the following properties:

Thickness:	24 inches
Porosity:	0.398
Field capacity:	0.244
Wilting point:	0.136
Saturated hydraulic conductivity:	1×10^{-5} cm/sec

ANALYSES RESULTS

The HELP computer program output files are provided in Attachment 4 for the proposed and minimum regulatory final covers. A summary of the HELP model results is presented in Table 1. From these results, estimated infiltration rates for the proposed final cover system are up to two orders of magnitude less than estimated infiltration rates for the regulatory minimum final cover system.

Table 1 Summary of HELP Model Analysis Results

	Peak daily infiltration rate (inch/day)	Average annual infiltration rate (inch/day)	Average head on top of geomembrane on peak day (inch)
Proposed final cover	2.00×10^{-5}	7.67×10^{-7}	0.048
Minimum Regulatory final cover	3.42×10^{-4}	8.94×10^{-5}	24.0

CONCLUSION

Based on the results of the infiltration analysis conducted herein, equivalency of the proposed final cover system to the regulatory minimum final cover system was demonstrated.

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Schroeder. P.R., Lloyd, C.M., and Zappi, P.A. (1994a) "The Hydrologic Evaluation of Landfill Performance (HELP) Model, User's Guide for Version 3." U.S. Environmental Protection Agency, Office of Research and Development Washington, D.C., Report No. EPA/600/R094/168a.

Schroeder. P.R., Dozier, T.S., and Zappi, P.A., McEnroe, B.M., Sjostrom, J.W., and Peyton, R.L. (1994b) "The Hydrologic Evaluation of Landfill Performance (HELP) Model, Engineering Documentation for Version 3." U.S. Environmental Protection Agency, Office of Research and Development Washington, D.C., Report No. EPA/600/R-94/168b.

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

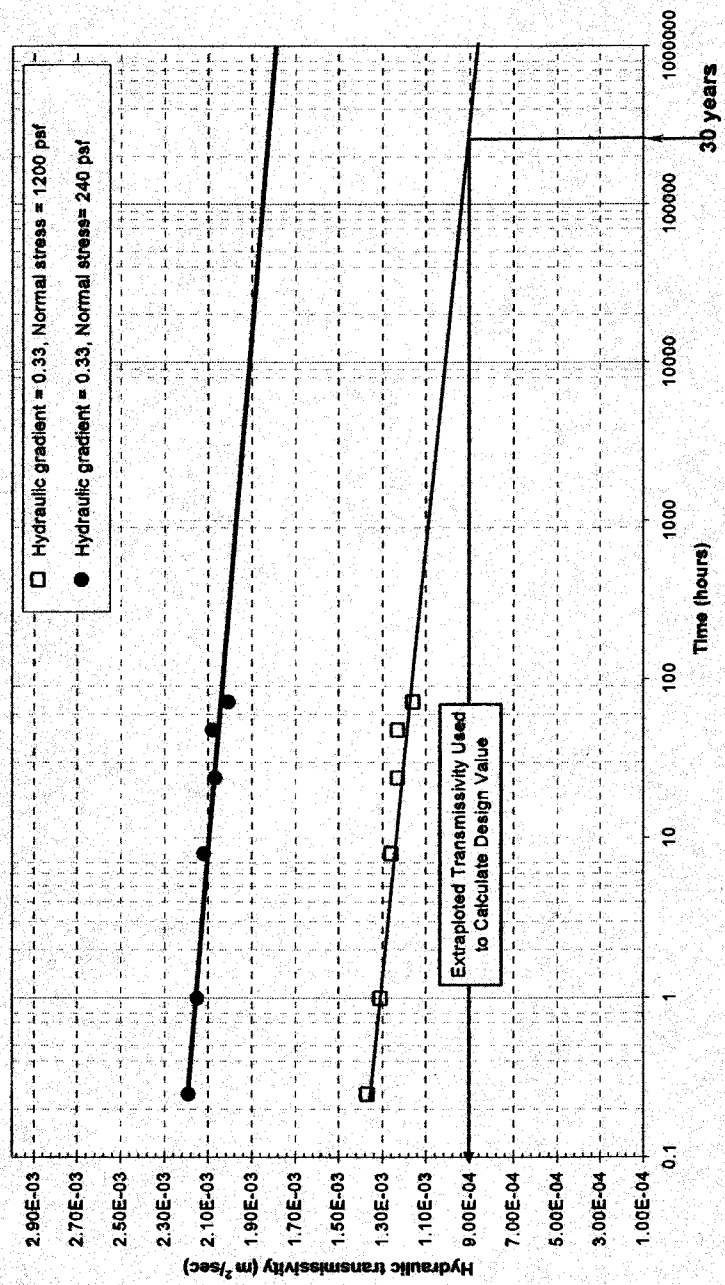

Figure 1: Estimation of the long-term hydraulic transmissivity for the drainage layer of a Super Gripnet® Liner

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

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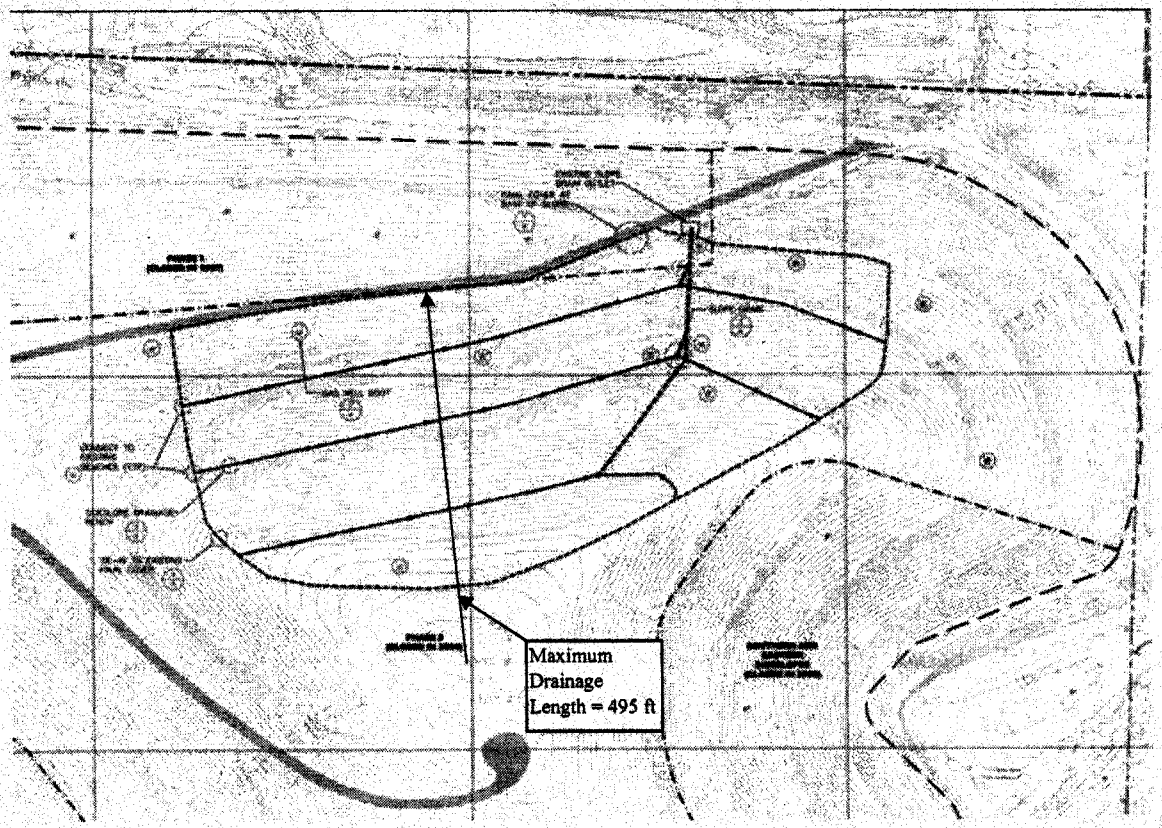


Figure 2. Location of Maximum Drainage Layer Length

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

Attachment 1: Agru America, Inc. Super Gripnet® liner Manufacturer's Fact Sheet

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

AGRU/AMERICA, INC.

SUPER GRIPNET® LINER

Drainage + Anchor Structure Liner

Extruded homogeneously to provide a minimum 60 mil (1.5 mm) containment liner with drainage and anchor structure capability.
These multi-structural products enhance steep composite slope designs with maximum interfacial shear resistance and superior drainage capacity.

Features/Benefits
- Superior interface friction with all soil types and conditions
- Allows steepest possible slopes

Product Data (Minimum Average Roll Values)

Property	Test Method	Values		
Thickness (mils nominal)	ASTM D751	60	80	100
Melt Flow Index (g/10 minutes)	ASTM D1238 - E	.28	.28	.28
Density (g/cm³ min)	ASTM D792 or D1505	.948	.948	.948
Tensile Strength at Yield (lbs/in. width)	ASTM D638 (Modified)	114	152	190
Tensile Strength at Break (lbs/in. width)	Type I Specimen	126	168	210
Elongation at Yield (%)	Gauge length 2 in. break	13	13	13
Elongation at Break (%)	1.3 in. yield, 2 ipm	200	200	200
Tear Resistance (lbs)	ASTM D1004 - Die C	40	53	67
Low Temperature Impact (°F max)	ASTM D746	-103	-103	-103
Dimensional Stability (% change max)	ASTM D1204, 1 hr @ 212°F	±2	±2	±2
Environmental Stress Crack (hrs)	ASTM D1693	1500	1500	1500
Puncture Resistance (lbs)	FTMS 101 - C, Method 2065	75	100	125
Carbon Black Content (%)	ASTM D1603	2 - 3	2 - 3	2 - 3
Carbon Black Dispersion	ASTM D3015	A2	A2	A2

Supply Information (Standard Roll Dimensions)

Thickness		Width		Length		Area		Weight	
mil	mm	ft	m	ft	m	ft²	m²	lbs	kg
60	1.5	22.5	6.86	197	60	4,433	412	2,080	934
80	2.0	22.5	6.86	165	50	3,713	343	1,973	895
100	2.5	22.5	6.86	165	50	3,713	343	2,416	1,096

NOTES: 1) All rolls are wrapped in polyethylene and supplied with two slings. 2) All rolls are fitted with 3.5 inch ID HDPE core. 3) Special roll lengths are available on request. 4) Standard rolls have a diameter of 39 inches (250 mm). 5) A 40 foot standard container will hold 3 rolls. 6) A 48 foot flatbed will hold 14 rolls.

Attachment 2: Subgrade Soil and Protective Soil Laboratory Test Results

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

Subgrade Soil Laboratory Test Results

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

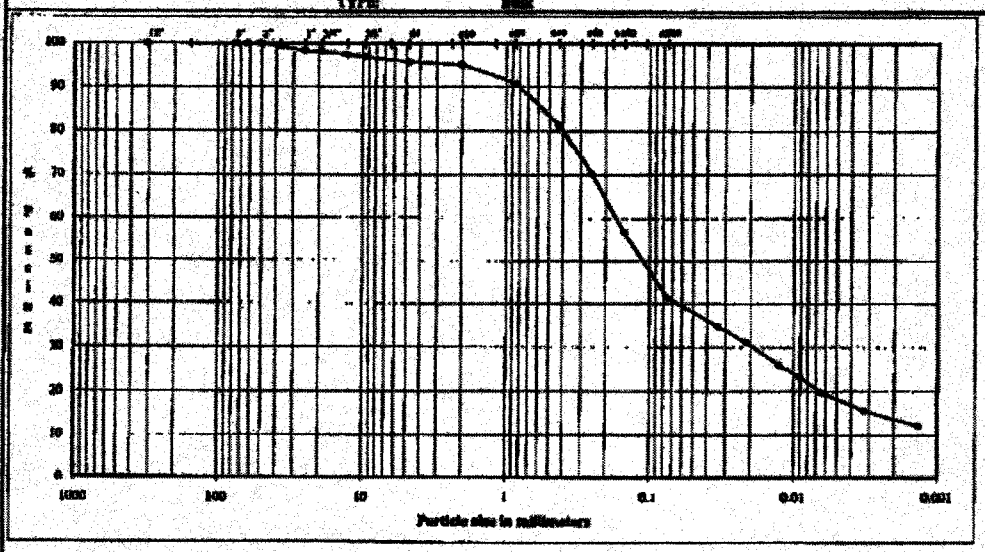
Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

APRIL 2005 053-3012

PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS

ASTM D421, D422, D4318

PROJECT NAME: SGI/2005 LAB TESTING/GA
SAMPLE ID: S11191 - Depth: -
TYPE: Bulk



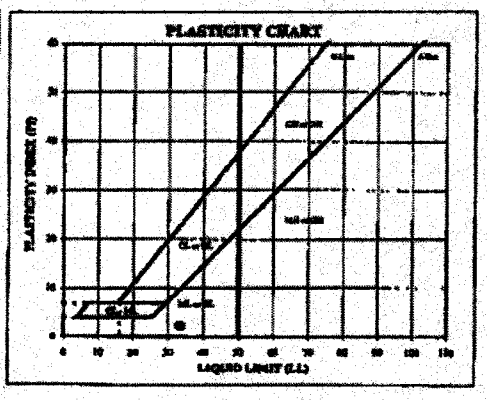
COBBLES	GRAVEL		SAND			FINES
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay

U.S. Standard Sieve Sizes and Numbers

	Particle Size (mm)	% Passing	Classification	Percentage
12.0"	304.8	100.0		
3.0"	75.0	100.0	Cobbles	0.00
2.5"	63.5	100.0		
2.0"	50.0	100.0		
1.5"	37.5	98.2		
1.0"	25.0	98.2		
0.75"	19.0	98.0	Coarse Gravel	2.00
0.50"	12.7	97.4		
0.375"	9.5	96.9		
#4	4.8	95.8	Fine Gravel	2.19
#10	2.00	95.1	Coarse Sand	0.68
#20	0.85	90.9		
#40	0.42	81.4	Medium Sand	13.76
#60	0.25	70.4		
#100	0.15	56.7		
#200	0.075	41.3	Fine Sand	40.04

Hydrometer Analysis

Sand	Silt		
0.034	34.7		
0.022	31.3		
0.013	26.0	Fines Silt or Clay	41.34
0.0091	23.4		
0.0065	20.0		
0.0092	15.4		
0.0014	12.3		



ATTERBERG LIMITS
Method -B (Dry preparation)

SL	LL	PL	PI	LI
16.0	33	31	2	-4.60

DESCRIPTION: Brown, MEDIUM TO FINE SAND, and clayey silt, trace coarse to fine gravel.

USCS: SM

TECH: SD04/TJ
DATE: 04/27/05
CHECK: [illegible]
REVIEW: [illegible]

Golder Associates Inc.

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

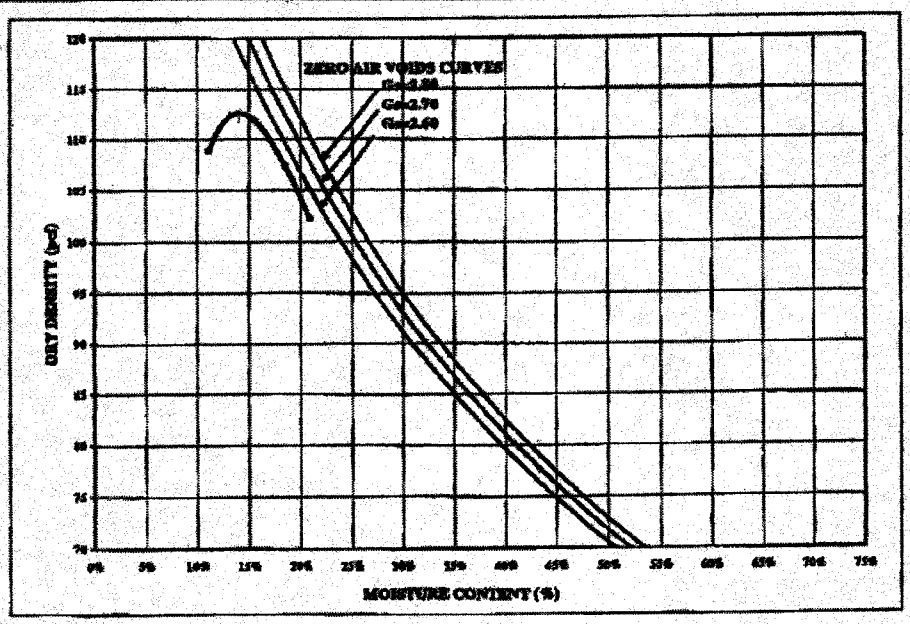
Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

APRIL 2005 053-3012

MOISTURE / DRY DENSITY CURVE
ASTM D 698 Method A

Mechanical	Standard	Wet Method

PROJECT NAME: 05/2005 LAB TESTING/GA
PROJECT NUMBER: 053-3012
SAMPLE ID: 011191 - DEPTH: - SAMPLE TYPE: Bulk



COMPACTION POINTS		
Specimen Number	Dry Density (pcf)	Moisture Content (%)
1	108.8	11.1%
2	111.9	13.3%
3	107.3	18.5%
4	102.3	21.0%

Maximum Dry Density (pcf)	112.6
Optimum Moisture (%)	14.1
Corrected Maximum Dry Density (pcf)	
Corrected Optimum Moisture (%)	
As-Received Moisture Content	14.0%
% Retained on # 4 sieve	4.2%
% Retained on 3/8" sieve	
% Retained on 3/4" sieve	

DESCRIPTION: Brown, MEDIUM TO FINE SAND, and clayey silt, trace coarse to fine gravel.

USCS: SM

CHECK: REVIEW:

Golder Associates Inc.

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

Protective Soil Laboratory Test Results

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

APRIL 2005 [illegible]

PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS
ASTM D422, D422, D4318

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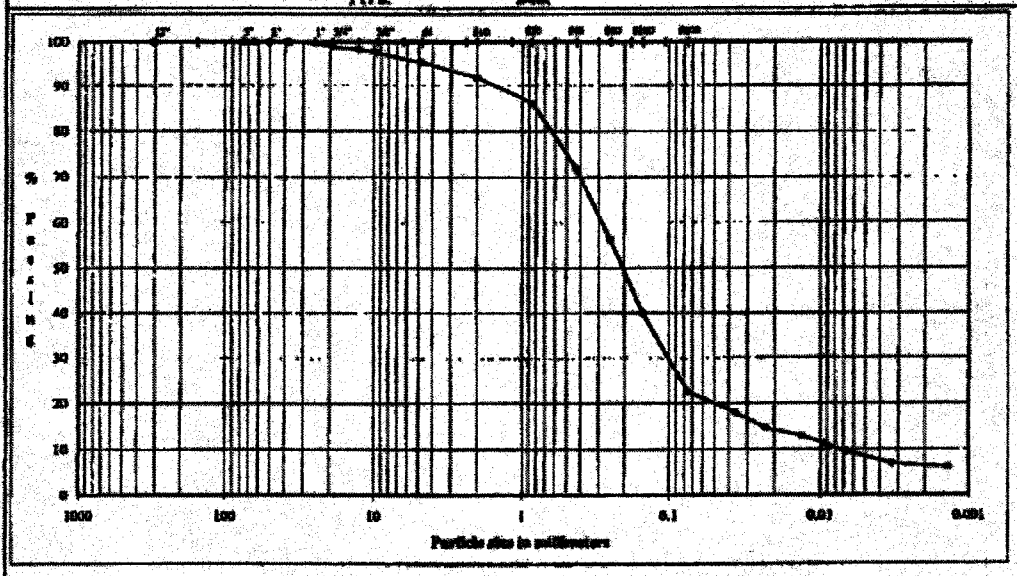
SAMPLE ID: [illegible] Depth: -
TYPE: [illegible]



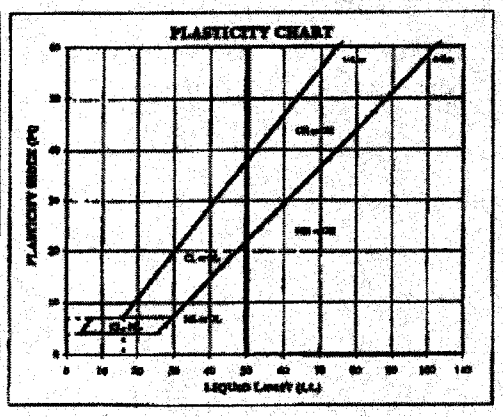
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay
GRAVEL	GRAVEL		SAND			FINES

U.S. Standard Sieve Size and Number

Particle Size (mm)	% Passing	Particle Size Classification	Percentage
12.0"	304.8	100.0	
3.0"	75.0	100.0	Cobbles
2.5"	63.5	100.0	
2.0"	50.0	100.0	
1.5"	37.5	100.0	
1.0"	25.0	99.7	
0.75"	19.0	98.8	Coarse Gravel
0.50"	12.7	98.1	
0.375"	9.5	97.8	
#4	4.8	96.3	Fine Gravel
#10	2.00	92.9	Coarse Sand
#20	0.85	84.1	
#40	0.43	71.3	Medium Sand
#60	0.25	56.4	
#100	0.15	40.1	
#200	0.075	32.5	Fine Sand

Hydrometer Analysis

(mm)	%Finer		
0.036	18.8	Silt or Clay	32.49
0.023	14.6		
0.013	13.9		
0.0094	11.1		
0.0067	8.4		
0.0033	6.9		
0.0016	6.9		



ATTERBERG LIMITS
Method -B (Dry preparation)

PL	LL	PI	SI	LI
14.9	NP	NP	NP	NP

DESCRIPTION: Brown, MEDIUM TO FINE SAND, some slightly silt, trace coarse to fine gravel.

USCS: SM

TECH: [illegible]
DATE: [illegible]
CHECK:
REVIEW: [illegible]

Golder Associates Inc.

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

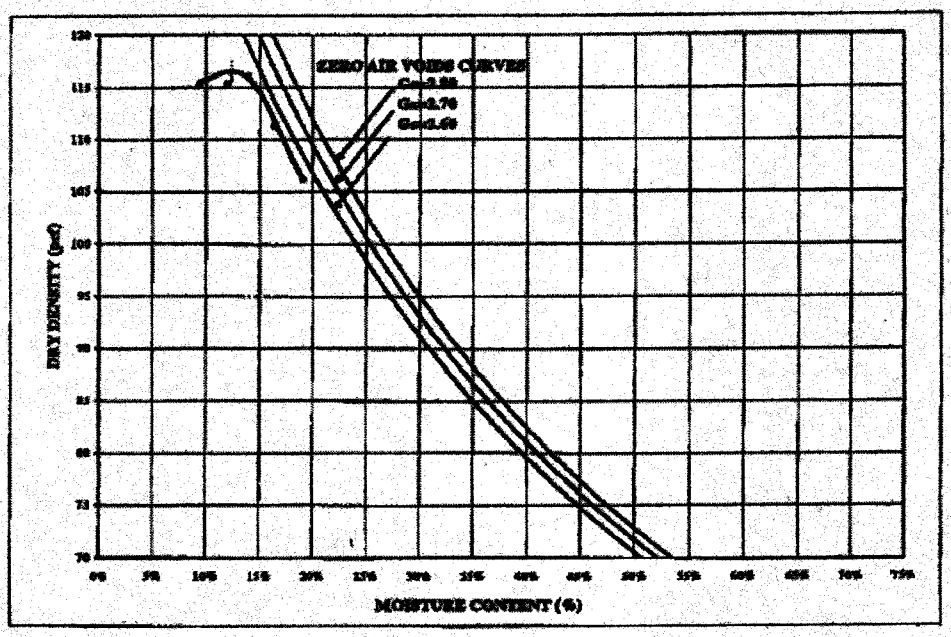
Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

APRIL 2005 053-3012

MOISTURE / DRY DENSITY CURVE
ASTM D 698 Method A

Mechanical	Standard	Wet Method

PROJECT NAME: SGS/2005 LAB TESTING/GA
PROJECT NUMBER: 053-3012
SAMPLE ID: 811194 - DEPTH: - SAMPLE TYPE: Bulk



COMPACTION POINTS		
Specimen Number	Dry Density (pcf)	Moisture Content (%)
1	115.2	9.4%
2	115.4	12.0%
3	116.1	14.0%
4	111.3	16.5%
5	106.1	19.1%

Maximum Dry Density (pcf)	116.7
Optimum Moisture (%)	12.4
Corrected Maximum Dry Density (pcf)	
Corrected Optimum Moisture (%)	
As-Received Moisture Content	16.9%
% Retained on # 4 sieve	4.7%
% Retained on 3/8" sieve	
% Retained on 3/4" sieve	

DESCRIPTION: Brown, MEDIUM TO FINE SAND, some clayey silt, trace coarse to fine gravel.
USCS: SM

CHECK: [illegible]
REVIEW: [illegible]

Golder Associates Inc.

Attachment 3: Agru America, Inc. Super Gripnet® Liner Hydraulic Transmissivity Test Results

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

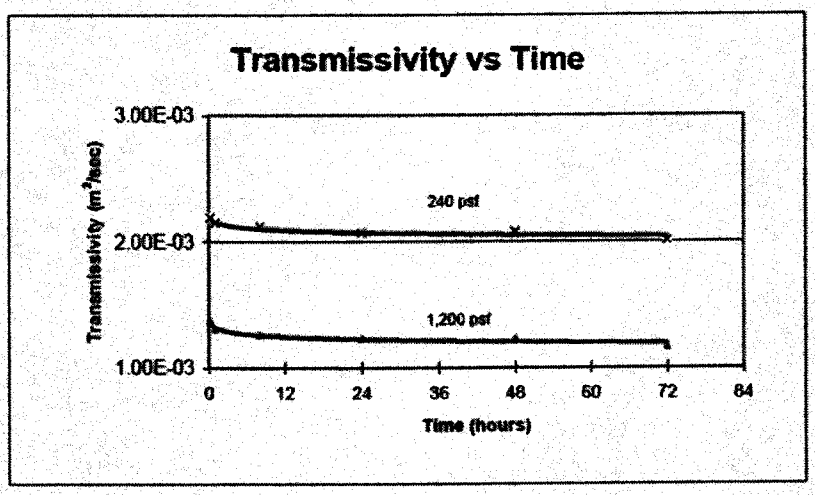
MAY 2005 053-3012

TRANSMISSIVITY TEST RESULTS
ASTM D4716

PROJECT NAME: SGI/2005 LAB TESTING/GA
SAMPLE NUMBER: Agru Super Gripnet

Configuration: Plate/Cover Soil (S11194)/Geotextile/Geomembrane (studs up and spikes removed)/Rubber/Plate
Seating Time (hr): Not Applicable
Gradient: 0.33
Pressure (psf): 1,200 240

Time (Hours)	Specimen 1 Transmissivity (m^2/sec)	Specimen 2 Transmissivity (m^2/sec)
0.25	1.37E-03	2.19E-03
1	1.31E-03	2.15E-03
8	1.26E-03	2.12E-03
24	1.23E-03	2.07E-03
48	1.23E-03	2.08E-03
72	1.16E-03	2.01E-03



	Load:	1,200 Before (in)	1,200 After (in)	240 Before (in)	240 After (in)
Change in height of studs after the 72 hour Transmissivity readings. (Five studs were measured)	1.0	0.155	0.143	0.157	0.148
	2.0	0.154	0.139	0.160	0.149
	3.0	0.159	0.147	0.155	0.145
	4.0	0.157	0.144	0.160	0.149
	5.0	0.151	0.144	0.151	0.148
	Avg:	0.155	0.143	0.157	0.148
	Height Change (%):		8		6

Golder Associates Inc.

Attachment 4: HELP Model Output Files

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

Minimum Regulatory Final Cover System

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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:      C:\HELP\Piedmont\PIED4.D4
TEMPERATURE DATA FILE:        C:\HELP\Piedmont\PIED7.D7
SOLAR RADIATION DATA FILE:    C:\HELP\Piedmont\PIED13.D13
EVAPOTRANSPIRATION DATA:      C:\HELP\Piedmont\PIED11.D11
SOIL AND DESIGN DATA FILE:    C:\HELP\Piedmont\NCDENR.D10
OUTPUT DATA FILE:             C:\HELP\Piedmont\NCDENR.OUT


TIME:  22:38     DATE:   5/ 9/2005


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

     TITLE:  Piedmont LF Final Cover Equivalency Demo-Regulatory Minimum

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


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


                                  LAYER  1
                                  --------

                         TYPE 2 - LATERAL DRAINAGE LAYER
                           MATERIAL TEXTURE NUMBER    5
          THICKNESS                    =     24.00   INCHES
```

```
POROSITY                      =      0.4570 VOL/VOL
FIELD CAPACITY                =      0.1310 VOL/VOL
WILTING POINT                 =      0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.3462 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.100000005000E-02 CM/SEC
SLOPE                         =     33.30   PERCENT
DRAINAGE LENGTH               =    495.0    FEET
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                        LAYER  2
                        --------

            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           =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS      =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY         =  3 - GOOD


                        LAYER  3
                        --------

             TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                     =     18.00   INCHES
POROSITY                      =      0.3980 VOL/VOL
FIELD CAPACITY                =      0.2440 VOL/VOL
WILTING POINT                 =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.3980 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.999999975000E-05 CM/SEC


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

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 33.% AND A SLOPE LENGTH OF 495. FEET.

SCS RUNOFF CURVE NUMBER	=	59.20	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	24.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	8.308	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	10.968	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.392	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	15.472	INCHES
TOTAL INITIAL WATER	=	15.472	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	=	3.50	
START OF GROWING SEASON (JULIAN DATE)	=	90	
END OF GROWING SEASON (JULIAN DATE)	=	305	
EVAPORATIVE ZONE DEPTH	=	24.0	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
3.42	3.24	3.76	3.33	3.48	3.64
4.49	4.15	3.80	2.93	2.78	3.05

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

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
38.20	40.70	48.50	57.90	66.50	73.90
77.30	76.10	69.70	58.70	48.70	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 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.37	3.33	4.01	3.18	3.31	3.56
	4.64	4.29	3.99	2.87	2.86	2.88
STD. DEVIATIONS	1.70	1.68	1.87	1.51	1.72	1.89
	2.11	2.17	2.61	1.86	1.71	1.80
RUNOFF						
TOTALS	0.009	0.096	0.033	0.000	0.006	0.000
	0.000	0.000	0.005	0.000	0.002	0.024
STD. DEVIATIONS	0.049	0.531	0.246	0.000	0.043	0.001
	0.003	0.001	0.035	0.002	0.015	0.168
EVAPOTRANSPIRATION						
TOTALS	1.240	1.585	2.414	2.637	5.008	4.898
	4.381	4.008	2.664	1.259	1.035	1.011

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

STD. DEVIATIONS	0.232	0.304	0.516	0.682	0.575	1.472
	1.650	1.340	1.052	0.351	0.186	0.179

LATERAL DRAINAGE COLLECTED FROM LAYER 1

TOTALS	1.5742	1.5764	1.7111	1.3044	0.9529	0.2036
	0.0629	0.0794	0.1894	0.4467	0.7581	1.1126
STD. DEVIATIONS	1.1547	0.9214	0.9084	0.6714	0.4823	0.2317
	0.1524	0.2247	0.3873	0.7374	0.9022	0.9450

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.0046	0.0046	0.0053	0.0046	0.0037	0.0009
	0.0003	0.0003	0.0007	0.0016	0.0025	0.0036
STD. DEVIATIONS	0.0021	0.0015	0.0013	0.0011	0.0011	0.0010
	0.0006	0.0009	0.0013	0.0019	0.0022	0.0022

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	10.1625	11.3535	11.7188	10.5646	8.0580	1.9483
	0.5795	0.7091	1.6068	3.3956	5.5468	7.9462
STD. DEVIATIONS	4.8395	3.7621	3.0941	2.7101	2.5497	2.1449
	1.3799	1.9124	2.9136	4.3005	5.0978	5.0093

****

****

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	42.28	(6.642)	153482.2	100.00
RUNOFF	0.175	(0.5982)	634.86	0.414
EVAPOTRANSPIRATION	32.139	(3.4042)	116664.97	76.012

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

LATERAL DRAINAGE COLLECTED FROM LAYER 1	9.97171	(3.72192)	36197.297	23.58403
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.03262	(0.00864)	118.426	0.07716
AVERAGE HEAD ON TOP OF LAYER 2	6.132	(1.656)		
CHANGE IN WATER STORAGE	-0.037	(2.2690)	-133.36	-0.087

****
****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.19	22469.701
RUNOFF	2.103	7632.0811
DRAINAGE COLLECTED FROM LAYER 1	0.23203	842.27100
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.000342	1.24148
AVERAGE HEAD ON TOP OF LAYER 2	24.000	
MAXIMUM HEAD ON TOP OF LAYER 2	44.794	
LOCATION OF MAXIMUM HEAD IN LAYER 1 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	4.40	15981.2402

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4570

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0580

*** 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.

****

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

****

FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	4.6347	0.1931
2	0.0000	0.0000
3	7.1640	0.3980
SNOW WATER	0.000	

****
****

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

Proposed Final Cover System

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

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


PRECIPITATION DATA FILE:     C:\HELP307\piedmont\PIED4.D4
TEMPERATURE DATA FILE:       C:\HELP307\piedmont\PIED7.D7
SOLAR RADIATION DATA FILE:   C:\HELP307\piedmont\PIED13.D13
EVAPOTRANSPIRATION DATA:     C:\HELP307\piedmont\PIED11.D11
SOIL AND DESIGN DATA FILE:   C:\HELP307\piedmont\proposed.D10
OUTPUT DATA FILE:            c:\help307\piedmont\proposed.OUT


TIME:  15:36     DATE:   5/10/2005


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

     TITLE:  Piedmont LF final Cover Equivalency Demo- Proposed Cover

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


     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   5
          THICKNESS                  =      24.00   INCHES
```

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

```
POROSITY                      =      0.4570 VOL/VOL
FIELD CAPACITY                =      0.1310 VOL/VOL
WILTING POINT                 =      0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.1717 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.100000005000E-02 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                        LAYER  2
                        --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                     =      0.14   INCHES
POROSITY                      =      0.8500 VOL/VOL
FIELD CAPACITY                =      0.0100 VOL/VOL
WILTING POINT                 =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.0229 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =   12.1999998000     CM/SEC
SLOPE                         =     33.30   PERCENT
DRAINAGE LENGTH               =    495.0    FEET


                        LAYER  3
                        --------

              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           =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS      =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY         =  3 - GOOD


                        LAYER  4
                        --------
```

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

```
                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER   7
THICKNESS                    =     10.00   INCHES
POROSITY                     =      0.4730 VOL/VOL
FIELD CAPACITY               =      0.2220 VOL/VOL
WILTING POINT                =      0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4730 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.520000001000E-03 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 33.% AND A SLOPE LENGTH OF 495. FEET.

```
SCS RUNOFF CURVE NUMBER              =     58.00
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =      1.000  ACRES
EVAPORATIVE ZONE DEPTH               =     24.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      4.122  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =     10.968  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      1.392  INCHES
INITIAL SNOW WATER                   =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =      8.855  INCHES
TOTAL INITIAL WATER                  =      8.855  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                   =   3.50
START OF GROWING SEASON (JULIAN DATE)     =     90
END OF GROWING SEASON (JULIAN DATE)       =    305
EVAPORATIVE ZONE DEPTH                    =  24.0  INCHES
AVERAGE ANNUAL WIND SPEED                 =   7.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY     =  66.00 %
```

Written by: Tamer Y. Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 05 /6 (YY MM DD)

Client: WM Project: Piedmont LF Project/Proposal No.: NCP2005-3204 Task No: 01

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
3.42	3.24	3.76	3.33	3.48	3.64
4.49	4.15	3.80	2.93	2.78	3.05

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
38.20	40.70	48.50	57.90	66.50	73.90
77.30	76.10	69.70	58.70	48.70	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 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.37	3.33	4.01	3.18	3.31	3.56
	4.64	4.29	3.99	2.87	2.86	2.88

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STD. DEVIATIONS	1.70	1.68	1.87	1.51	1.72	1.89
	2.11	2.17	2.61	1.86	1.71	1.80

RUNOFF

TOTALS	0.001	0.053	0.004	0.000	0.000	0.000
	0.000	0.000	0.003	0.000	0.000	0.002
STD. DEVIATIONS	0.007	0.353	0.026	0.000	0.002	0.000
	0.001	0.000	0.026	0.000	0.004	0.012

EVAPOTRANSPIRATION

TOTALS	0.783	1.041	1.773	2.240	3.659	2.119
	2.620	2.374	1.870	1.044	0.773	0.596
STD. DEVIATIONS	0.283	0.308	0.480	0.426	1.140	1.315
	1.356	1.164	1.034	0.458	0.262	0.237

LATERAL DRAINAGE COLLECTED FROM LAYER 2

TOTALS	2.2649	2.2931	2.2870	1.3755	1.3660	1.5067
	1.9273	1.7530	1.6031	1.4138	1.6291	1.9191
STD. DEVIATIONS	1.4632	1.4228	1.3705	1.0943	0.9176	0.7386
	0.8595	0.8254	1.0337	1.0541	1.2327	1.1818

PERCOLATION/LEAKAGE THROUGH LAYER 4

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 3

AVERAGES	0.0017	0.0019	0.0018	0.0011	0.0011	0.0012
	0.0015	0.0014	0.0013	0.0011	0.0013	0.0015
STD. DEVIATIONS	0.0011	0.0012	0.0011	0.0009	0.0007	0.0006
	0.0007	0.0006	0.0008	0.0008	0.0010	0.0009

****

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	42.28	(6.642)	153482.2	100.00
RUNOFF	0.063	(0.3542)	227.99	0.149
EVAPOTRANSPIRATION	20.893	(3.9330)	75843.25	49.415
LATERAL DRAINAGE COLLECTED FROM LAYER 2	21.33861	(4.18768)	77459.156	50.46784
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00028	(0.00005)	1.031	0.00067
AVERAGE HEAD ON TOP OF LAYER 3	0.001	(0.000)		
CHANGE IN WATER STORAGE	-0.014	(1.3330)	-49.22	-0.032

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.19	22469.701
RUNOFF	1.772	6431.3174
DRAINAGE COLLECTED FROM LAYER 2	1.99322	7235.39307
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000020	0.07378
AVERAGE HEAD ON TOP OF LAYER 3	0.048	
MAXIMUM HEAD ON TOP OF LAYER 3	0.226	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	4.40	15981.2402

Recalculation of Havg & Hmax using Giroud's equation [Giroud, 1995]

please see next page.

Giroud, J.P and Houlihan, M.F. (1995) "Design of Leachate Collection Layers," Proceeding Sardinia 95, Fifth International Landfill Symposium, Cagliari, Italy

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MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3361

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0580

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

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

****

****

FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	2.7671	0.1153
2	0.0019	0.0132
3	0.0000	0.0000
4	4.7300	0.4730
SNOW WATER	0.000	

****
****

$$\lambda = \frac{q_i k}{\tan^2\beta} = \frac{1.9225\times10^{-6}/0.4}{\tan^2 18.4} = 4.34\times10^{-5}$$

$q_i = 1.99322$ in/day $= 1.9225\times10^{-6}$ ft/s

$k = 12.2$ cm/s $= 0.4$ ft/s.

$L = 495$ ft

$$J = 1 - 0.12\exp\left[-\left[\log\left[\frac{8}{5}\lambda\right]^{5/8}\right]^2\right] = 1 - 0.12\exp\left[-\log\left[\frac{8}{5}\times4.34\times10^{-5}\right]^{5/8}\right]^2$$

$$= 0.99986016$$

$$T_{max} = L\,J\,\frac{\sqrt{1+4\lambda}-1}{2}\,\frac{\tan\beta}{\cos\beta} = 495\times0.99986\,\frac{\sqrt{1+4(4.34\times10^{-5})}}{2}\cdot\frac{\tan18.4}{\cos18.4}$$

$$= 0.0215\times\frac{\tan18.4}{\cos18.4} = 7.53\times10^{-3}\text{ ft}$$

$\frac{T_{avg}}{T_{max}} = f(\lambda) \Rightarrow \lambda = 4.34\times10^{-5} \Rightarrow \frac{T_{avg}}{T_{max}} = 0.5$ from table 3. $T_{avg} = 3.765\times10^{-3}$ ft

$h_{avg} = T_{avg}\cdot\cos\beta = 3.765\times10^{-3}\times\cos18.4 = 3.57\times10^{-3}$ ft $= 0.043$ inches ✓ same O.K. as HELL

$h_{max} = T_{max}\cdot\cos\beta = 7.53\times10^{-3}\times\cos18.4 = 7.145\times10^{-3}$ ft $=$ **0.086 inches**

Appendix B2
Static and Seismic Slope Stability Analyses of Proposed Final Cover System

GEOSYNTEC CONSULTANTS

COMPUTATION COVER SHEET

Client: WM **Project:** Piedmont Landfill **Project/Proposal #:** NCP2005 **Task #:** ____

TITLE OF COMPUTATIONS STATIC AND SEISMIC SLOPE STABILITY ANALYSES OF PROPOSED FINAL COVER SYSTEM (VENEER MODE)

COMPUTATIONS BY:
Signature T. Elkady — DATE 5 May 2005
Printed Name and Title: Tamer Elkady, Engineer

ASSUMPTIONS AND PROCEDURES CHECKED BY:
(Peer Reviewer)
Signature Majdi Ahmed Othman — DATE 6 May 2005
Printed Name and Title: Majdi Othman, Associate

COMPUTATIONS CHECKED BY:
Signature Majdi Ahmed Othman — DATE 6 May 05
Printed Name and Title: Majdi Othman, Associate

COMPUTATIONS BACKCHECKED BY:
(Originator)
Signature T. Elkady — DATE 6 May 2005
Printed Name and Title: Tamer Elkady, Engineer

APPROVED BY:
(PM or Designate)
Signature Majdi Ahmed Othman — DATE 12 May 05
Printed Name and Title: Majdi Othman, Associate

APPROVAL NOTES: ____

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

Written by: Tamer Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 5 /6 (YY MM DD)

Client: WMI Project: Piedmont LF Project/Proposal No.: NCP2005 Task No: 3204

STATIC AND SEISMIC SLOPE STABILITY ANALYSES OF PROPOSED FINAL COVER SYSTEM (VENEER MODE)

PURPOSE

The purpose of the analyses presented in this calculation package is to evaluate static and seismic stability of the proposed final cover system for the Piedmont Landfill (PLF), which includes an Agru America, Inc. (A/A) Super Gripnet® Liner, in veneer mode (i.e., sliding of the cover system along a weak interface within the cover).

METHOD OF ANALYSES

Static Stability Analysis:

Static slope stability of a landfill final cover system can be analyzed assuming infinite slope conditions or finite slope conditions. The infinite slope stability analysis method considers a slope of infinite length whereby the driving and resisting forces occur only along or parallel to an interface (i.e., slip plane). The finite slope stability analysis method considers a slope of finite length and additionally takes into account soil strength above a slip plane, primarily as a toe-buttressing effect. Since the final cover slopes at the PLF are relatively short, the finite slope stability analysis method is appropriate.

The finite slope stability factor of safety equation, as formulated by Giroud, et al. [1995], is:

$$FS = \left[\frac{\gamma_t(t-t_w)+\gamma_b t_w}{\gamma_t(t-t_w)+\gamma_{sat} t_w}\right]\frac{\tan\delta}{\tan\beta} + \frac{a/\sin\beta}{\gamma_t(t-t_w)+\gamma_{sat} t_w}$$
$$+\left[\frac{\gamma_t(t-t^*_w)+\gamma_b t^*_w}{\gamma_t(t-t_w)+\gamma_{sat} t_w}\right]\left[\frac{\tan\phi/(2\sin\beta\cos^2\beta)}{1-\tan\beta\tan\phi}\right]\frac{t}{h}$$
$$+\left[\frac{1}{\gamma_t(t-t_w)+\gamma_{sat} t_w}\right]\left[\frac{1/(\sin\beta\cos\beta)}{1-\tan\beta\tan\phi}\right]\frac{ct}{h} \qquad (1)$$

where:
- FS = factor of safety;
- δ = interface friction angle;
- a = apparent interface adhesion;
- ϕ = soil internal friction angle;

c = apparent soil cohesion;
γ_t = moist soil unit weight;
γ_b = buoyant soil unit weight;
γ_{sat} = saturated soil unit weight;
t = depth of cover soil above critical interface;
t_w = water depth above critical interface;
t_w^* = water depth at slope toe;
β = slope inclination; and
h = vertical height of slope.

It is noted that while the above equation is specifically for an interface above a geomembrane, or similar layers, it can also be applied to interfaces below the geomembrane by changing the coefficient of the first term, (i.e., the coefficient of $\tan\delta / \tan\beta$) to 1.0. The slope geometry, which is used to derive the above equation, is shown in Figure 1.

Seismic Stability Analysis:

A pseudo-static slope stability analysis is performed for the A/A final cover system. The pseudo-static factor of safety is estimated by performing an infinite slope stability analysis using Equation 2 [Matasović, 1991]:

$$FS = \frac{c/(\gamma z \cos^2\beta) + \tan\phi\ [1 - \gamma_w (z - d_w)/(\gamma z)] - k_s \tan\beta \tan\phi}{k_s + \tan\beta} \qquad (2)$$

where: FS = factor of safety;
k_s = peak average horizontal acceleration as a fraction of gravity;
γ = unit weight of slope material(s) in pcf;
γ_w = unit weight of water in pcf;
c = cohesion in psf;
β = slope angle in degrees;
ϕ = angle of internal friction on the assumed failure surface in degrees;
z = depth to the assumed failure surface in ft; and
d_w = depth to the water table (assumed parallel to the slope) in ft.

The peak horizontal acceleration at the top of the PLF is estimated using a chart (Figure 2) developed by Idriss [1990], as presented by Kavazanjian and Matasović [1994].

A calculated factor of safety greater than 1.0 suggests that no permanent seismic deformation is expected. A factor of safety less than 1.0, however, suggests permanent deformation can occur. The amount of seismic displacement can be computed based on k_s and the yield acceleration, K_y. The yield acceleration is the horizontal acceleration which results in a pseudo-static factor of safety of 1.0. The yield acceleration may be calculated using Equation 3 [Matasović, 1991]:

$$K_y = \frac{c/(\gamma \bullet z \bullet \cos^2 \beta) + \tan \phi\,[1 - \gamma_w (z - d_w)/(\gamma \bullet z)] - \tan \beta}{1 + \tan \beta \tan \phi} \qquad (3)$$

The seismic displacement, corresponding to the computed K_y/k_s ratio, is estimated using the results presented by Hynes and Franklin [1984] and the "modified mean + one standard deviation curve" developed by GeoSyntec as presented in Figure 3. The "modified mean + one standard deviation curve" considers data associated with only large earthquakes, and therefore, is more conservative to use. This procedure is consistent with those given in the USEPA guidance document [USEPA, 1995].

PERFORMANCE CRITERIA

The target FS for the static stability analysis using peak and residual shear strength values are 1.5 and 1.2, respectively. For seismic analysis, the permanent deformation is considered acceptable if it is less than 6 to 12 in.

DESIGN PEAK GROUND ACCELERATION

The maximum horizontal acceleration (MHA) at the PLF site was assumed to be the maximum expected horizontal acceleration depicted on a seismic hazard map, with a 90 percent or greater probability that the acceleration will not be exceeded in 250 years. Therefore, the MHA was selected to be 0.11g based on the United States Geological Survey (USGS) seismic map (Figure 4). Based on this value, the corresponding peak horizontal acceleration at the top of the PLF may be estimated using Figure 2 as 0.21 g.

FINAL COVER SYSTEM DATA

The components of the proposed final cover consist, from top to bottom, of the following:

- a 24-inch thick protective/vegetative soil layer;
- an 8 oz/yd^2 geotextile filter;
- an Agru America, Inc. (A/A) Super Gripnet® liner consisting of a 60-mil thick (average; 55-mil thick minimum) high density polyethylene (HDPE) geomembrane with friction spikes on the bottom and 0.15-inch thick drainage studs on top; and
- a 10-inch thick compacted soil layer (existing subgrade).

For evaluation of the stability of the proposed final cover system for the PLF in veneer mode, a slope of 33.3 percent (3H:1V) and a length of 340 ft were considered, which correspond to the maximum slope inclination and length in the reconstruction area. The thickness of the protective soil above the geosynthetics is designed to be 2 ft. However, to address the potential for the protective soil layer to be constructed thicker than 2 ft, two other thickness are considered in the analyses presented herein, specifically 3 ft and 4 ft.

Compaction and shear strength tests were performed on soil from the PLF site that will be used for the protective/vegetative soil layer of the final cover system. The results of these tests are included in Attachment 1. Based on the compaction test performed, the soil has a maximum dry unit weight of 116.7 pcf and optimum water content of 12.4% based on the standard Proctor effort. It is assumed that the soil will be compacted in the field to a water content of about 3% wet of optimum (i.e., about 15.4%) and a dry unit weight at about 90% of the maximum dry unit weight (i.e., 105 pcf). This combination of water content and dry unit weight results in a total (i.e., wet) unit weight of about 120 pcf. Therefore, for the analyses presented in this calculation package, a total unit weight of 120 pcf is assumed. The shear strength tests indicated that the protective/vegetative soil has peak shear strength represented by a cohesion (c) of 80 psf and a friction angle (ϕ) of 37°, and a large displacement shear strength represented by a c of 100 psf and a ϕ of 29°. To be conservative, the lower (large-displacement) shear strength values will be used.

GeoSyntec performed site-specific shear strength tests on prepared samples representing the proposed final cover system (with an A/A Super Gripnet® Liner) to evaluate interfacial shear strength characteristics of the proposed final cover system. The test configuration included an A/A Super Gripnet® Liner sandwiched between other

components of the proposed final cover system. Specifically, the test configuration consisted, from top to bottom, of: (i) protective soil; (ii) 8 oz/yd^2 geotextile; (iii) A/A Super Gripnet® Liner; and (iv) compacted subgrade soil. The results of this testing are included in Attachment 2. As shown in Attachment 2, the samples of the proposed final cover system exhibited peak c and ϕ values of 90 psf and 27° and large-displacement c and ϕ values of 100 psf and 23°. To apply a level of conservatism, the interface shear strength values used for the analyses will represent 90 percent of the laboratory-measured interface shear strengths. These shear strengths correspond to peak c and ϕ values of 79 psf and 25° and large-displacement c and ϕ values of 89 psf and 21.3°.

The water depth in the drainage layer above the geomembrane (t_w) was calculated using the HELP model [Schroeder, 1994] in the calculation package titled "Proposed Final Cover System Infiltration Analysis". As discussed in that calculation package, the drainage length considered in the HELP model was 495 feet, which accounts for the continuity of the final cover drainage layer extending from the crest to the toe of the north-facing slope of the PLF (i.e ., the reconstruction area). This drainage length extends along two different slopes with approximately 340 feet at a 3H:1V slope. Therefore, the 340 feet long is considered in this calculation package. Based on the HELP analysis results, the average water depth on a peak day was estimated to be 0.048 inches (0.004 ft).

RESULTS AND CONCLUSIONS

The equation used to evaluate static stability of the final cover in veneer mode (i.e., Equation 1) was coded in an Excel® spreadsheet and is presented herein as Tables 1 and 2. Table 1 presents the analysis results considering 90 percent of peak interface shear strength and for different protective/vegetative cover thicknesses. Similarly, Table 2 presents the analysis results considering 90 percent of large-displacement interface shear strength and for different protective/vegetative cover thicknesses. As shown in Tables 1 and 2, all of the calculated factors of safety exceed the target factors of safety, and therefore, are acceptable. A summary of calculated static factors of safety is presented in the table below.

Calculated Static Factors of Safety

Protective Soil Thickness (ft)	Interface Shear Strength Parameters	
	Peak	Large displacement
2.0	2.49	2.39
3.0	2.14	2.00
4.0	1.97	1.81

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Client: WMI Project: Piedmont LF Project/Proposal No.: NCP2005 Task No: 3204

Pseudo-static analyses are performed to evaluate the seismic stability of the final cover in veneer mode. Results of the pseudo-static analyses are presented in Table 3 and summarized in the table below. The calculated pseudo-static factors of safety for the proposed final cover system are greater than one for peak and large-displacement strength values. Even when the protective soil thickness is assumed to be thicker than 2 ft (up to 4 ft), the calculated pseudo-static factors of safety are still larger than one. This indicates that permanent deformation of the proposed final cover system is not anticipated as a result of horizontal accelerations caused by the design earthquake. This meets the performance criteria for seismic stability of less than 6 to 12 in.

Calculated Pseudo-static Factors of Safety

Protective Soil Thickness (ft)	Interface Shear Strength Parameters	
	Peak	Large displacement
2.0	1.47	1.43
3.0	1.25	1.17
4.0	1.13	1.05

For the analyses presented herein, the following assumptions were made:

(i) the existing landfill gas extraction system at the site is operating in a manner that precludes positive gas pressure buildup on the underside of the proposed final cover; and

(ii) materials used for the protective/vegetative cover soil are similar to those used in site-specific laboratory tests attached to this package. If other materials from onsite or offsite borrow sources are used, it is recommended that site-specific testing be performed to verify that the selected material(s) meet the requirements for the stability of the final cover system.

Based on the analyses presented in this calculation package, the proposed final cover system for the PLF meets the performance criteria with respect to static and seismic stability in a veneer mode.

REFERENCES

Giroud, J.P., Bachus, R.C., and Bonaparte, R., "Influence of Water Flow on the Stability of Geosynthetic-Soil Layered Systems on Slopes," *Geosynthetics International*, Vol. 2, No. 6, 1995, pp. 1149-1180.

Hynes, M.E., and Franklin, A.G., "Rationalizing the Seismic Coefficient Method," *Miscellaneous Paper GL - 84 - 13,* U.S. Army Engineer Waterways Experiment Station, Vickburg, MS, 1984, pp. 34.

Idriss, I. M., "Response of Soft Soil Sites During Earthquakes," *Seed Memorial Symposium Proceedings,* Vol. 2, BiTech Publications, Berkeley, CA 1990.

Kavazanjian, E., Jr., and Matasović, N., "Seismic Analysis of Solid waste Landfills" Accepted for publication, Proceedings, GeoEnvironment 2000, Geotechnical Special Publication, ASCE, New York, NY, 1994.

Matasović, N., "Selection of Method for Seismic Slope Stability Analysis," *Proceedings of the 2nd International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics,* Vol. 2, St. Louis, 1991, pp. 1057-62.

Schroeder, P. R., N. M., Lloyd, C. M. and Zappi, P.A. (1994) "The Hydrologic Evaluation of Landfill Performance (HELP) Model: User's Guide for Version 3," EPA/600/R-94/168a, September 1994, U. S. Environmental Protection Agency Office of Research and Development, Washington, D.C.

USEPA, "*RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities*", Office of Research and Development, EPA/600/R-95/051, April 1995.

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Client: WMI Project: Piedmont LF Project/Proposal No.: NCP2005 Task No: 3204

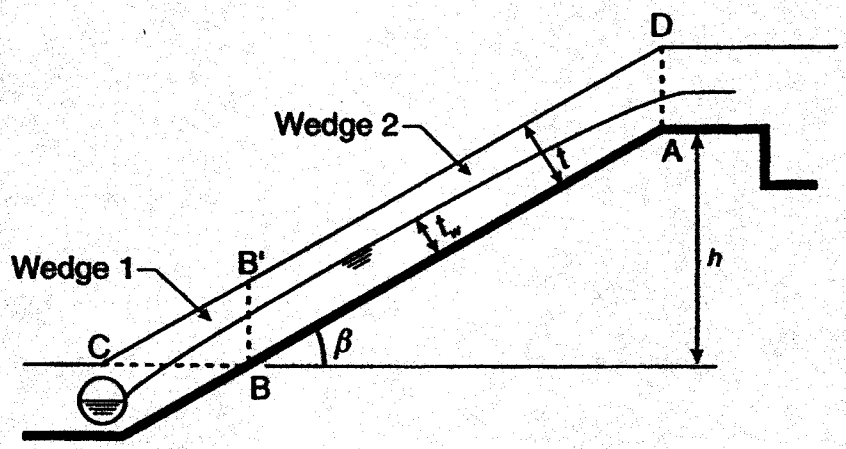

Figure 1. Slope Geometry Used to Derive the Finite Slope Stability Equation.

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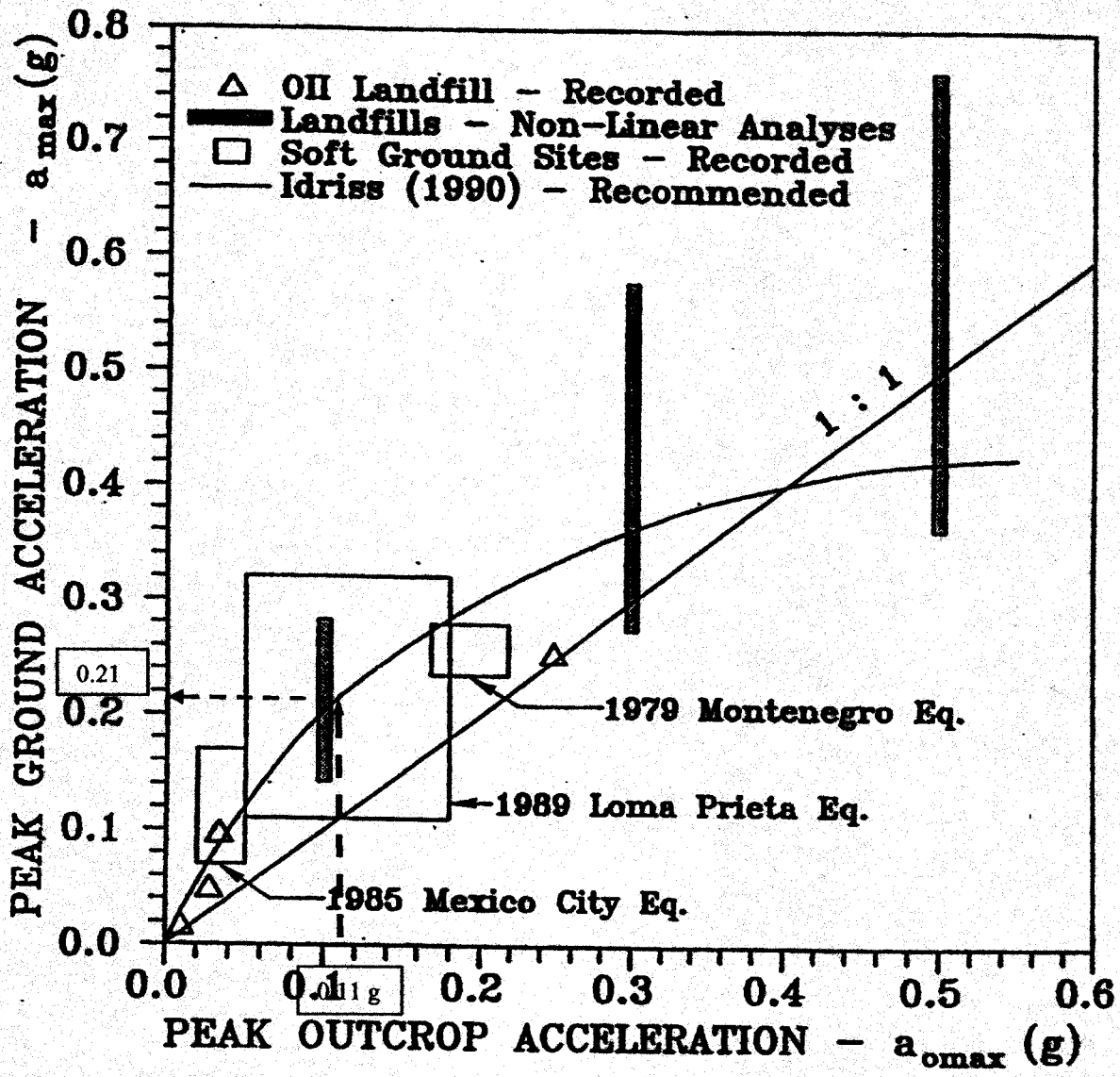

Observed Variations of Peak Horizontal Accelerations on Soft Soil and MSW Sites in Comparison to Rock Sites (Kavazanjian and Matasović, 1994).

Figure 2

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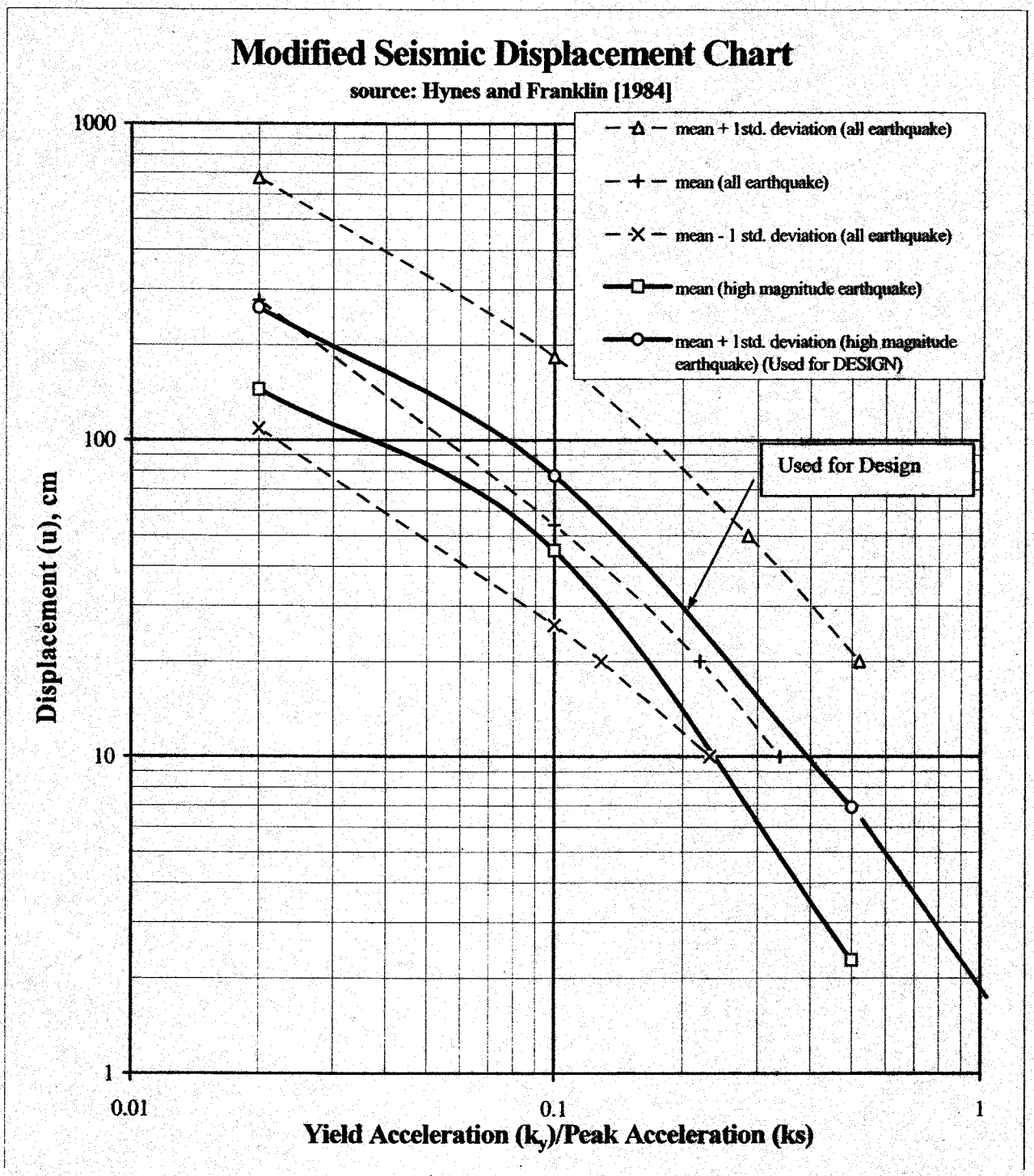

Figure 3

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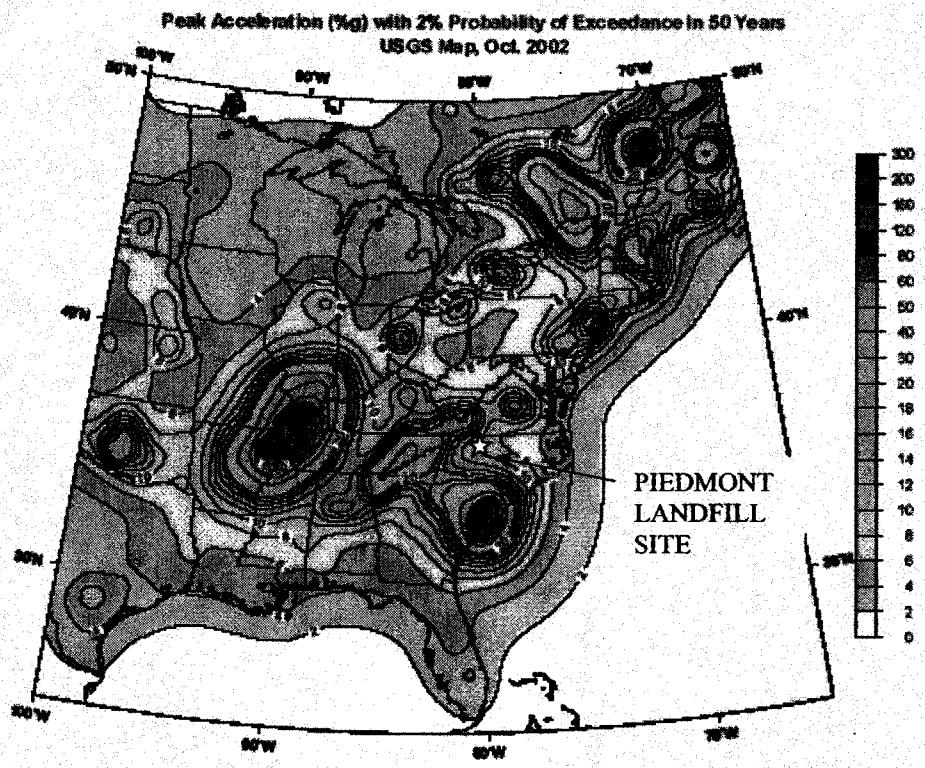
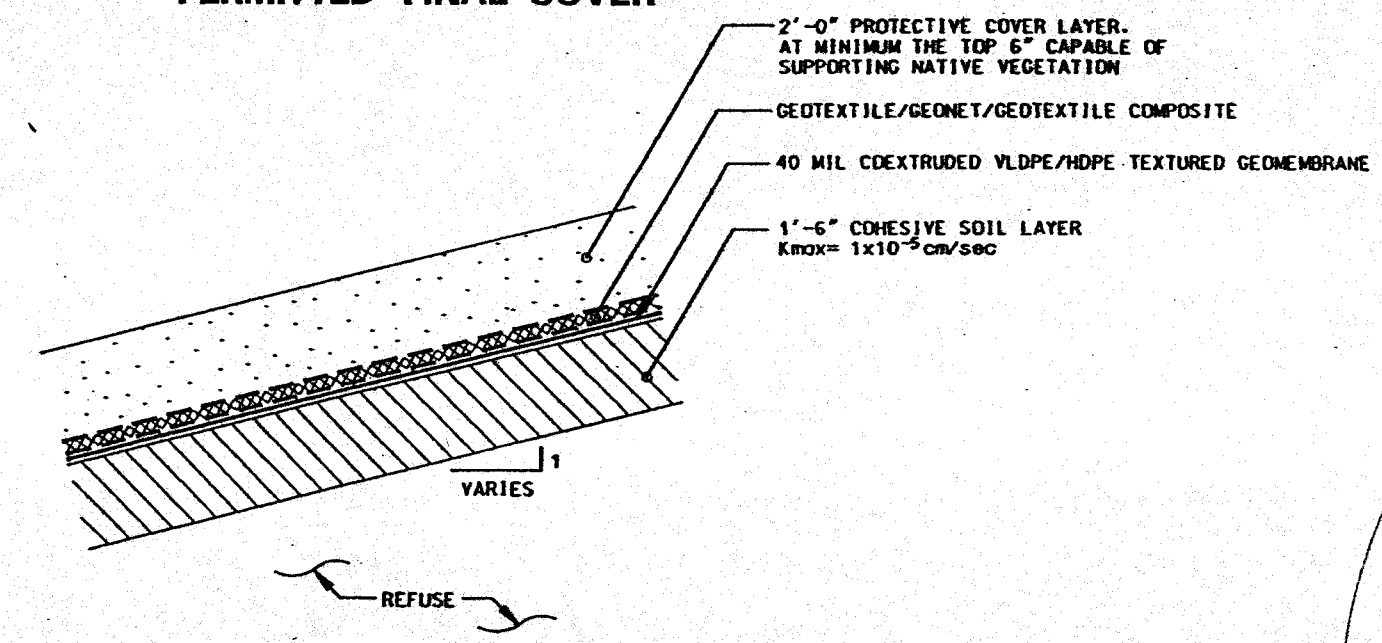


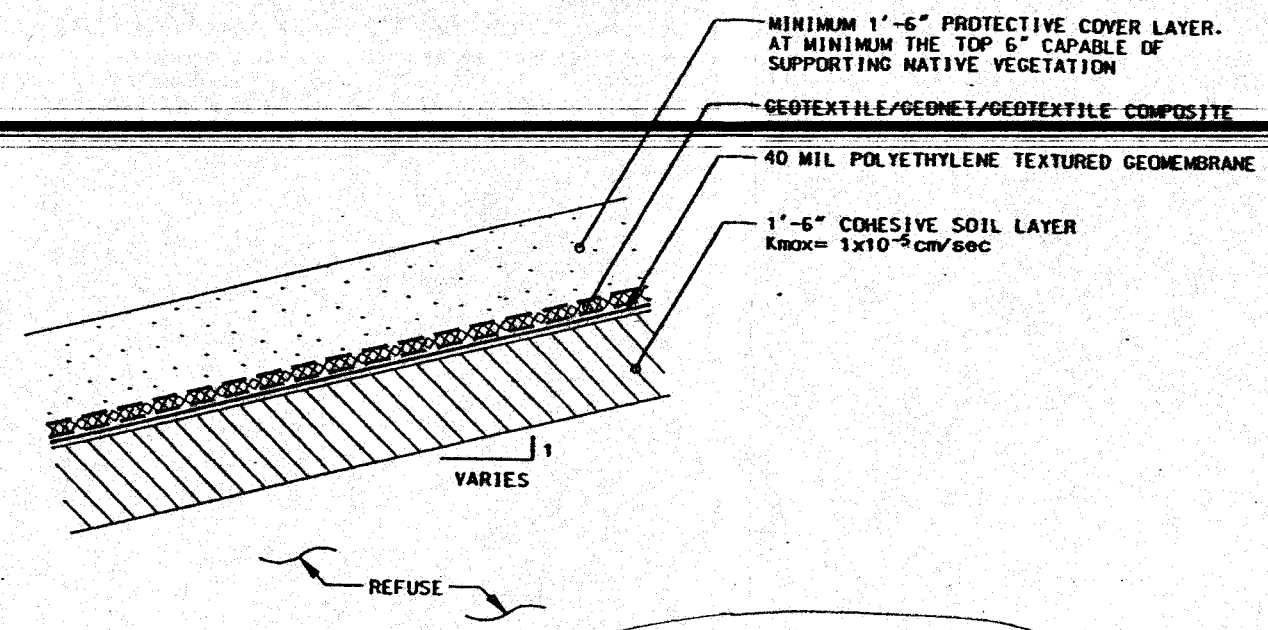
Note: 2% probability in 50 years is equal to 10 % probability in 250 years

Figure 4

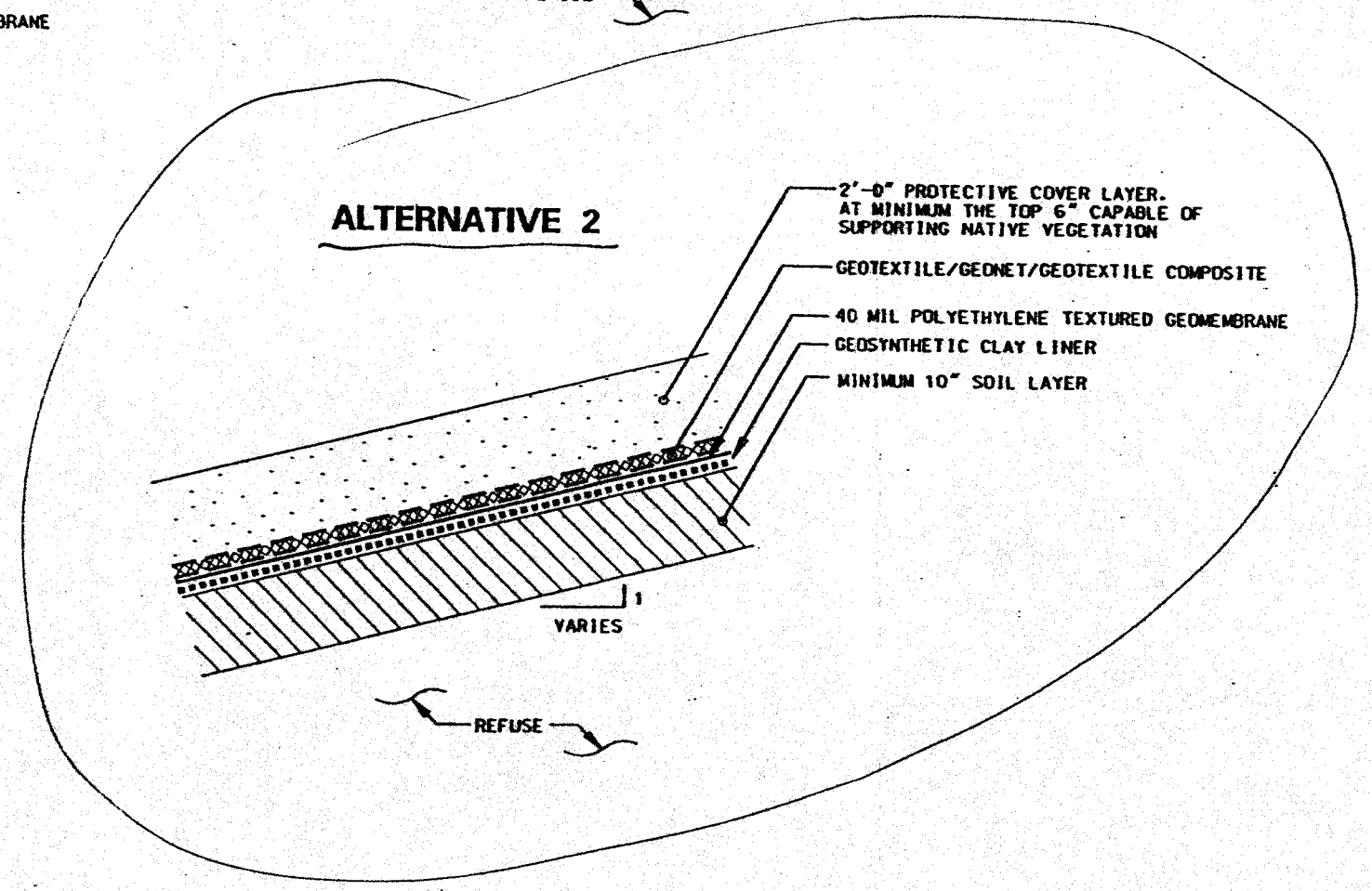
PERMITTED FINAL COVER



ALTERNATIVE 1



ALTERNATIVE 2



RUST ENVIRONMENT & INFRASTRUCTURE

FIGURE 1
FINAL COVER DETAILS

PIEDMONT LANDFILL AND RECYCLING CENTER
KERNERSVILLE, FORSYTH COUNTY, NORTH CAROLINA

722FGR1.DGN

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Table 1. Piedmont Landfill Final Cover Veneer Stability

Finite Slope Equation [Giroud et al., 1995]

Assuming 90% of Peak Interface Shear Strength.

Protective soil thickness = 2.0 feet

FS Above GEOMEMBRANE		
Input Parameters:		
γ_t (Unit wt of soil):	120	pcf
γ_{sat} (Saturated unit wt of soil):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water thickness):	0.004	ft
t* (water thickness at slope toe):	0.004	ft
δ (weakest interface friction angle):	25.0	deg
ϕ (friction angle of soil):	29	deg
a (interface adhesion)	79.0	psf
c (cohesion of soil above geomembrane)	100	psf
T (Tension in Geosynthetics)	0	psf
h (height of slope):	113.33	ft
t (thickness of soil layer)	2.0	ft
β (slope angle)	18.4	deg
FS	2.49	

FS Below GEOMEMBRANE		
Input Parameters:		
γ_t (Unit wt of soil):	120	pcf
γ_{sat} (Saturated unit wt of soil):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water thickness):	0.004	ft
t* (water thickness at slope toe):	0.004	ft
δ (weakest interface friction angle):	25.0	deg
ϕ (friction angle of soil):	29	deg
a (interface adhesion)	79.0	psf
c (cohesion of soil above geomembrane)	100	psf
T (Tension in Geosynthetics)	0	psf
h (height of slope):	113.33	ft
t (thickness of soil layer)	2.0	ft
β (slope angle)	18.4	deg
FS	2.49	

Protective soil thickness = 3.0 feet

FS Above GEOMEMBRANE		
Input Parameters:		
γ_t (Unit wt of soil):	120	pcf
γ_{sat} (Saturated unit wt of soil):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water thickness):	0.004	ft
t* (water thickness at slope toe):	0.004	ft
δ (weakest interface friction angle):	25.0	deg
ϕ (friction angle of soil):	29	deg
a (interface adhesion)	79.0	psf
c (cohesion of soil above geomembrane)	100	psf
T (Tension in Geosynthetics)	0	psf
h (height of slope):	113.33	ft
t (thickness of soil layer)	3.0	ft
β (slope angle)	18.4	deg
FS	2.14	

FS Below GEOMEMBRANE		
Input Parameters:		
γ_t (Unit wt of soil):	120	pcf
γ_{sat} (Saturated unit wt of soil):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water thickness):	0.004	ft
t* (water thickness at slope toe):	0.004	ft
δ (weakest interface friction angle):	25.0	deg
ϕ (friction angle of soil):	29	deg
a (interface adhesion)	79.0	psf
c (cohesion of soil above geomembrane)	100	psf
T (Tension in Geosynthetics)	0	psf
h (height of slope):	113.33	ft
t (thickness of soil layer)	3.0	ft
β (slope angle)	18.4	deg
FS	2.14	

Protective soil thickness = 4.0 feet

FS Above GEOMEMBRANE		
Input Parameters:		
γ_t (Unit wt of soil):	120	pcf
γ_{sat} (Saturated unit wt of soil):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water thickness):	0.004	ft
t* (water thickness at slope toe):	0.004	ft
δ (weakest interface friction angle):	25.0	deg
ϕ (friction angle of soil):	29	deg
a (interface adhesion)	79.0	psf
c (cohesion of soil above geomembrane)	100	psf
T (Tension in Geosynthetics)	0	psf
h (height of slope):	113.33	ft
t (thickness of soil layer)	4.0	ft
β (slope angle)	18.4	deg
FS	1.97	

FS Below GEOMEMBRANE		
Input Parameters:		
γ_t (Unit wt of soil):	120	pcf
γ_{sat} (Saturated unit wt of soil):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water thickness):	0.004	ft
t* (water thickness at slope toe):	0.004	ft
δ (weakest interface friction angle):	25.0	deg
ϕ (friction angle of soil):	29	deg
a (interface adhesion)	79.0	psf
c (cohesion of soil above geomembrane)	100	psf
T (Tension in Geosynthetics)	0	psf
h (height of slope):	113.33	ft
t (thickness of soil layer)	4.0	ft
β (slope angle)	18.4	deg
FS	1.97	

Written by: Tamer Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 5 /6 (YY MM DD)

Client: WMI Project: Piedmont LF Project/Proposal No.: NCP2005 Task No: 3204

Table 2. Piedmont Landfill Final Cover Veneer Stability

Finite Slope Equation [Giroud et al., 1995]

Assuming 90% of Large-Displacement Interface Shear Strength.

Protective soil thickness = 2.0 feet

FS Above GEOMEMBRANE		
Input Parameters:		
γ_t (Unit wt of soil):	120	pcf
γ_{sat} (Saturated unit wt of soil):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water thickness):	0.004	ft
t* (water thickness at slope toe):	0.004	ft
δ (weakest interface friction angle):	21.3	deg
ϕ (friction angle of soil):	29	deg
a (interface adhesion)	89.0	psf
c (cohesion of soil above geomembrane)	100	psf
T (Tension in Geosynthetics)	0	psf
h (height of slope):	113.33	ft
t (thickness of soil layer)	2.0	ft
β (slope angle)	18.4	deg
FS	2.39	

FS Below GEOMEMBRANE		
Input Parameters:		
γ_t (Unit wt of soil):	120	pcf
γ_{sat} (Saturated unit wt of soil):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water thickness):	0.004	ft
t* (water thickness at slope toe):	0.004	ft
δ (weakest interface friction angle):	21.3	deg
ϕ (friction angle of soil):	29	deg
a (interface adhesion)	89.0	psf
c (cohesion of soil above geomembrane)	100	psf
T (Tension in Geosynthetics)	0	psf
h (height of slope):	113.33	ft
t (thickness of soil layer)	2.0	ft
β (slope angle)	18.4	deg
FS	2.39	

Protective soil thickness = 3.0 feet

FS Above GEOMEMBRANE		
Input Parameters:		
γ_t (Unit wt of soil):	120	pcf
γ_{sat} (Saturated unit wt of soil):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water thickness):	0.004	ft
t* (water thickness at slope toe):	0.004	ft
δ (weakest interface friction angle):	21.3	deg
ϕ (friction angle of soil):	29	deg
a (interface adhesion)	89.0	psf
c (cohesion of soil above geomembrane)	100	psf
T (Tension in Geosynthetics)	0	psf
h (height of slope):	113.33	ft
t (thickness of soil layer)	3.0	ft
β (slope angle)	18.4	deg
FS	2.00	

FS Below GEOMEMBRANE		
Input Parameters:		
γ_t (Unit wt of soil):	120	pcf
γ_{sat} (Saturated unit wt of soil):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water thickness):	0.004	ft
t* (water thickness at slope toe):	0.004	ft
δ (weakest interface friction angle):	21.3	deg
ϕ (friction angle of soil):	29	deg
a (interface adhesion)	89.0	psf
c (cohesion of soil above geomembrane)	100	psf
T (Tension in Geosynthetics)	0	psf
h (height of slope):	113.33	ft
t (thickness of soil layer)	3.0	ft
β (slope angle)	18.4	deg
FS	2.00	

Protective soil thickness = 4.0 feet

FS Above GEOMEMBRANE		
Input Parameters:		
γ_t (Unit wt of soil):	120	pcf
γ_{sat} (Saturated unit wt of soil):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water thickness):	0.004	ft
t* (water thickness at slope toe):	0.004	ft
δ (weakest interface friction angle):	21.3	deg
ϕ (friction angle of soil):	29	deg
a (interface adhesion)	89.0	psf
c (cohesion of soil above geomembrane)	100	psf
T (Tension in Geosynthetics)	0	psf
h (height of slope):	113.33	ft
t (thickness of soil layer)	4.0	ft
β (slope angle)	18.4	deg
FS	1.81	

FS Below GEOMEMBRANE		
Input Parameters:		
γ_t (Unit wt of soil):	120	pcf
γ_{sat} (Saturated unit wt of soil):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water thickness):	0.004	ft
t* (water thickness at slope toe):	0.004	ft
δ (weakest interface friction angle):	21.3	deg
ϕ (friction angle of soil):	29	deg
a (interface adhesion)	89.0	psf
c (cohesion of soil above geomembrane)	100	psf
T (Tension in Geosynthetics)	0	psf
h (height of slope):	113.33	ft
t (thickness of soil layer)	4.0	ft
β (slope angle)	18.4	deg
FS	1.81	

Written by: Tamer Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 5 /6 (YY MM DD)

Client: WMI Project: Piedmont LF Project/Proposal No.: NCP7005 Task No: 3204

Table 3. Seismic Analysis Using 90% of Peak and Large-Displacement Interface/Internal Shear Strength.

Protective soil thickness = 2.0 feet

Calculation of Factor of Safety and Yield Acceleration
For Infinite Slope Conditions
Using Equation from Matasovic [1991]

$$FS=\frac{\left(\frac{c}{\gamma z\cos^2\beta}+\tan\delta\left(1-\frac{\gamma_w(z-d_w)}{\gamma z}\right)-K_s\tan\beta\tan\delta\right)}{Ks+\tan\beta}$$

$$k_y=\frac{\left(\frac{c}{\gamma z\cos^2\beta}+\tan\delta\left(1-\frac{\gamma_w(z-d_w)}{\gamma z}\right)-\tan\beta\right)}{1+\tan\beta\tan\delta}$$

Where:
k_y = yield acceleration, g.;
γ = unit weight of soil cover, pcf;
γ_w = unit weight of water, pcf;
c = cohesion along the assumed failure surface, psf;
ϕ = friction angle along the assumed failure surface, degrees;
β = slope angle, degrees;
z = depth of the assumed failure surface, ft; and
d_w = depth of water surface (assumed parallel to the slope), ft.
k_s = peak average horizontal acceleration for potential slide mass, g. = a_{max}

Input parameters:			ϕ (degrees)	c (psf)	FS	k_y (g)	k_y/a_{max}
γ, pcf	*120*						
z, ft	*2.000*	Peak	25.0	79.0	1.470	0.431	2.05
β, degrees	*18.43*	Large-displacement	21.3	89.0	1.425	0.414	1.97
γ_w, pcf	*62.4*						
d_w, ft	*1.9960*						
k_s, g	*0.21*						

Protective soil thickness = 3.0 feet

Calculation of Factor of Safety and Yield Acceleration
For Infinite Slope Conditions
Using Equation from Matasovic [1991]

$$FS=\frac{\left(\frac{c}{\gamma z\cos^2\beta}+\tan\delta\left(1-\frac{\gamma_w(z-d_w)}{\gamma z}\right)-K_s\tan\beta\tan\delta\right)}{Ks+\tan\beta}$$

$$k_y=\frac{\left(\frac{c}{\gamma z\cos^2\beta}+\tan\delta\left(1-\frac{\gamma_w(z-d_w)}{\gamma z}\right)-\tan\beta\right)}{1+\tan\beta\tan\delta}$$

Where:
ky = yield acceleration, g.;
γ = unit weight of soil cover, pcf;
γ_w = unit weight of water, pcf;
c = cohesion along the assumed failure surface, psf;
ϕ = friction angle along the assumed failure surface, degrees;
β = slope angle, degrees;
z = depth of the assumed failure surface, ft; and
d_w = depth of water surface (assumed parallel to the slope), ft.
k_s = peak average horizontal acceleration for potential slide mass, g. = a_{max}

Input parameters:			ϕ (degrees)	c (psf)	FS	ky (g)	ky/a_{max}
γ, pcf	*120*						
z, ft	*3.000*	Peak	25.0	79.0	1.246	0.326	1.55
β, degrees	*18.43*	Large-displ	21.3	89.0	1.172	0.293	1.39
γ_w, pcf	*62.4*						
d_w, ft	*2.9960*						
k_s, g	*0.21*						

Protective soil thickness = 4.0 feet

Calculation of Factor of Safety and Yield Acceleration
For Infinite Slope Conditions
Using Equation from Matasovic [1991]

$$FS=\frac{\left(\frac{c}{\gamma z\cos^2\beta}+\tan\delta\left(1-\frac{\gamma_w(z-d_w)}{\gamma z}\right)-K_s\tan\beta\tan\delta\right)}{Ks+\tan\beta}$$

$$k_y=\frac{\left(\frac{c}{\gamma z\cos^2\beta}+\tan\delta\left(1-\frac{\gamma_w(z-d_w)}{\gamma z}\right)-\tan\beta\right)}{1+\tan\beta\tan\delta}$$

Where:
ky = yield acceleration, g.;
γ = unit weight of soil cover, pcf;
γ_w = unit weight of water, pcf;
c = cohesion along the assumed failure surface, psf;
ϕ = friction angle along the assumed failure surface, degrees;
β = slope angle, degrees;
z = depth of the assumed failure surface, ft; and
d_w = depth of water surface (assumed parallel to the slope), ft.
k_s = peak average horizontal acceleration for potential slide mass, g. = a_{max}

Input parameters:			ϕ (degrees)	c (psf)	FS	ky (g)	ky/a_{max}
γ, pcf	*120*						
z, ft	*4.000*	Peak	25.0	79.0	1.134	0.273	1.30
β, degrees	*18.43*	Large-displ	21.3	89.0	1.046	0.232	1.11
γ_w, pcf	*62.4*						
d_w, ft	*3.9960*						
k_s, g	*0.21*						

Written by: Tamer Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 5 /6 (YY MM DD)

Client: WMI Project: Piedmont LF Project/Proposal No.: NCP2005 Task No: 3204

ATTACHMENT 1

RESULTS OF COMPACTION AND SHEAR STRENGTH TESTING ON FINAL COVER PROTECTIVE/VEGETATIVE SOIL

Written by: Tamer Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 5 /6 (YY MM DD)

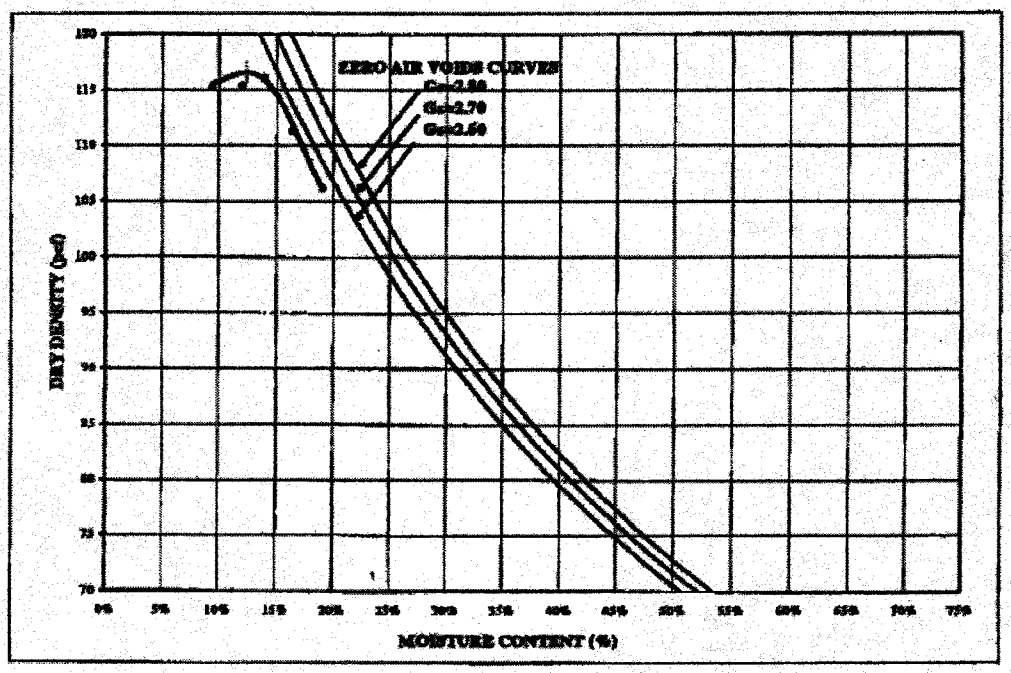
Client: WMI Project: Piedmont LF Project/Proposal No.: NCP2005 Task No: 3204

APRIL 2005 053-3012

MOISTURE / DRY DENSITY CURVE
ASTM D 698 Method A

Mechanical	Standard	Wet Method

PROJECT NAME: SGE2005 LAB TESTING/GA
PROJECT NUMBER: 053-3012
SAMPLE ID: 811194 DEPTH: - SAMPLE TYPE: Bulk



COMPACTION POINTS		
Specimen Number	Dry Density (pcf)	Moisture Content (%)
1	115.2	9.4%
2	115.4	12.0%
3	116.1	14.0%
4	111.3	16.5%
5	106.1	19.1%

Maximum Dry Density (pcf)	116.7
Optimum Moisture (%)	13.6
Corrected Maximum Dry Density (pcf)	
Corrected Optimum Moisture (%)	
As-Received Moisture Content	16.9%
% Retained on # 4 sieve	6.7%
% Retained on 3/8" sieve	
% Retained on 3/4" sieve	

DESCRIPTION: Brown, MEDIUM TO FINE SAND, some clayey silt, trace coarse to fine gravel.

USCS: SM

CHECK:
REVIEW:

Golder Associates Inc.

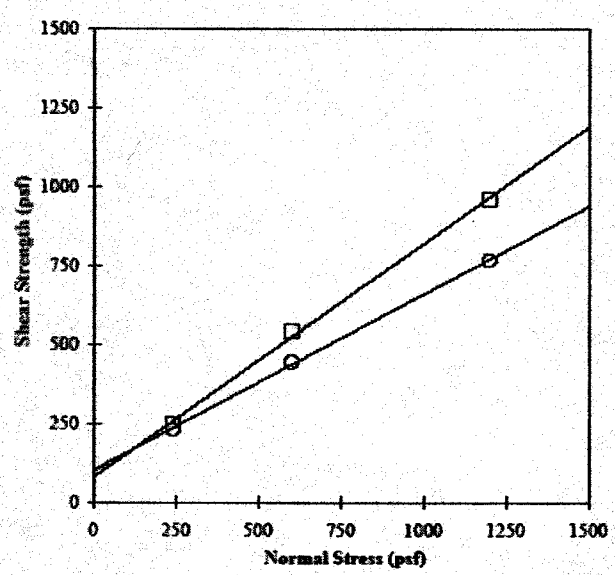
Written by: Tamer Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 5 /6 (YY MM DD)

Client: WMI Project: Piedmont LF Project/Proposal No.: NCP2005 Task No: 3204

SGI TESTING SERVICES, LLC

INTERNAL DIRECT SHEAR TESTING (ASTM D 5321)
GEOSYNTEC CONSULTANTS - WMI/PIEDMONT LANDFILL

Test Series No. 8:
internal strength of Protective Soil Cover (TP-1B) under as-placed moisture conditions



Test Conditions:

Shear Box Size (in x in):	12 x 12
Shear Area (sq. ft.):	1
Upper Box:	90% standard Proctor at +3% above OMC
Lower Box:	90% standard Proctor at +3 % above OMC
Soaking Stress (psf):	N/A
Soaking Time (hour)	N/A
Consolid. Stress (psf):	N/A
Consolidation Time (hour)	N/A
Shear Rate (in/min):	0.04

Normal Stress (psf)	Peak Load (lb)	Large Displ Load (lb)	Peak Strength (psf)	Large Displ Strength (psf)	Shear Strength Parameters: Peak Friction Angle (degree)	Peak Cohesion (psf)	Large Displacement Friction Angle (degree)	Large Displacement Cohesion (psf)
240	245	230	245	230	37	80	29	100
600	542	444	542	444				
1200	961	768	961	768				

Note: Shear failure occurred within the Protective Soil Cover material during each test series.

Project No.: SGI5011
File Name:SGI5011-8

Written by: Tamer Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 5 /6 (YY MM DD)

Client: WMI Project: Piedmont LF Project/Proposal No.: NCP2005 Task No: 3204

ATTACHMENT 2

RESULTS OF LABORATORY INTERFACE SHEAR STRENGTH TESTING ON PROPOSED FINAL COVER SYSTEM

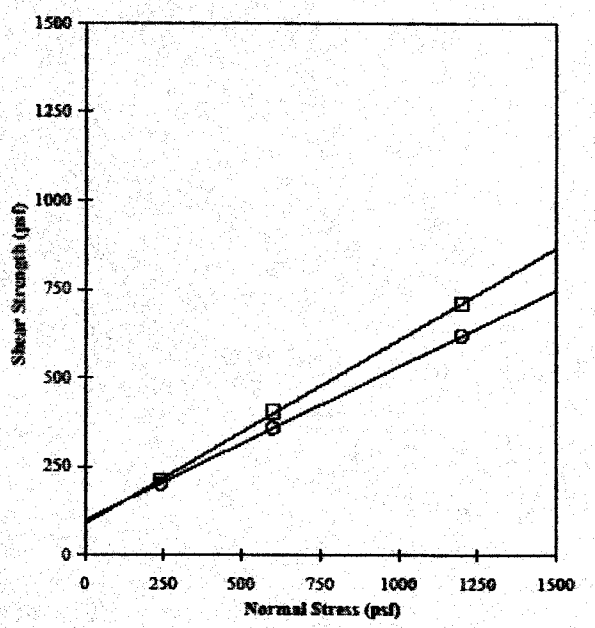
Written by: Tamer Elkady Date: 05 /5 /6 (YY MM DD) Reviewed by: Majdi Othman Date: 05/ 5 /6 (YY MM DD)

Client: WMI Project: Piedmont LF Project/Proposal No.: NCP2005 Task No: 3204

SGI TESTING SERVICES, LLC

INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)
GEOSYNTEC CONSULTANTS - WMI/PIEDMONT LANDFILL

Test Series No. 9:
Protective Soil Cover (TP-1B) against 8 oz. Nonwoven geotextile against the cyclinder side of 60-mil Agru SuperGripNet HDPE geomembrane (Roll No. 341769-04) against Foundation soil (TP-1B) under wetted conditions



Test Conditions:

Shear Box Size (in x in):	12 x 12
Shear Area (sq. ft.):	1
Upper Box:	90% standard Proctor at +3% above OMC
Lower Box:	90% standard Proctor at +3 % above OMC
Soaking Stress (psf):	N/A
Soaking Time (hour)	N/A
Consolid. Stress (psf):	N/A
Consolidation Time (hour)	N/A
Shear Rate (in/min):	0.04

ASPERITY HEIGHT (MILS)

Reading	Initial Value	240 psf	600 psf	1200 psf
1	206.5	204	208.5	211.5
2	199.5	207.5	202.7	209.5
3	204.5	190.8	191.2	190.5
4	190.0	199	190	191.9
5	191.9	207	201.5	200
avg	198.6	201.5	198.8	200.7

Normal Stress (psf)	Peak Load (lb)	Large Displ Load (lb)	Peak Strength (psf)	Large Displ Strength (psf)	Shear Strength Parameters: Peak Friction Angle (degree)	Peak Adhesion (psf)	Large Displacement Friction Angle (degree)	Large Displacement Adhesion (psf)
240	209	202	209	202	27	90	23	100
600	404	359	404	359				
1200	708	618	708	618				

Note: Shear failure occurred between the spikes side of geomembrane and the foundation soil during each test.

Project No.: SGI5011
File Name:SGI5011-9

Appendix B3
Static and Seismic Slope Stability Analyses of Final Cover System Drainage Benches

GEOSYNTEC CONSULTANTS

COMPUTATION COVER SHEET

Client: WM **Project:** Piedmont Landfill **Project/Proposal #:** NCP2005 **Task #:** ____

TITLE OF COMPUTATIONS FINAL COVER DRAINAGE BENCH STABILITY ANALYSES

COMPUTATIONS BY:
Signature: Basak Gulec — DATE: 5 May 05
Printed Name and Title: Basak Gulec, Senior Staff Engineer

ASSUMPTIONS AND PROCEDURES CHECKED BY:
(Peer Reviewer)
Signature: Majdi Ahmed Othman — DATE: 6 May 05
Printed Name and Title: Majdi Othman, Associate

COMPUTATIONS CHECKED BY:
Signature: Majdi Ahmed Othman — DATE: 6 May 05
Printed Name and Title: Majdi Othman, Associate

COMPUTATIONS BACKCHECKED BY:
(Originator)
Signature: Basak Gulec — DATE: 6 May 05
Printed Name and Title: Basak Gulec, Senior Staff Engineer

APPROVED BY:
(PM or Designate)
Signature: Majdi Ahmed Othman — DATE: 12 May 05
Printed Name and Title: Majdi Othman, Associate

APPROVAL NOTES: ____

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

Written by: Basak Gulec Date: 05/06/05 Reviewed by: Majdi Othman Date: 05/06/05

Client: WM Project: Piedmont Landfill Project/Proposal No.: NCP2005 Task No.: 3204

FINAL COVER DRAINAGE BENCH SLOPE STABILITY ANALYSES

PURPOSE

The purpose of this calculation package is to evaluate stability of the final cover drainage bench in the proposed closure reconstruction area of Phase 2 of the Piedmont Landfill. The stability of the drainage bench was evaluated under both static and seismic conditions. Figure 1 shows a detail of the final cover drainage bench.

METHODS OF ANALYSES AND DESIGN CRITERIA

Static Stability Analysis

Static slope stability analyses were performed using the simplified Bishop method of slices [Bishop, 1955] for circular failure surfaces, and the simplified Janbu [Janbu, 1973] limit equilibrium slope stability analysis methods for block failure surfaces, both as implemented in the computer program XSTABL® 5.201 [Sharma, 1994]. The program was used to generate potential slip surfaces and calculate the factor of safety for each of these surfaces. XSTABL identifies the slip surface with the lowest factor of safety. Information required for the analyses include the geometry of the drainage bench, and the material properties of the final cover system.

For block failure surfaces, the simplified Janbu method was used to randomly search failure surfaces. This method allows a large number of surfaces to be quickly generated and evaluated with respect to factor of safety, and for the most critical surface to be identified. It does not, however, entirely satisfy force and moment equilibrium. For this reason, a more rigorous analysis method [Spencer, 1967] was applied to the critical surface found by the Janbu search. Spencer's method satisfies vertical and horizontal force equilibrium and moment equilibrium.

Minimum acceptable static slope stability factors of safety for cover systems depend on project-specific conditions and uncertainties. When cover systems include strain-softening components or interfaces, differing minimum factors of safety are often applied for peak strength analysis and analysis based on residual (large-displacement) strength. In addition, several additional factors typically influence selection of the minimum acceptable factor of safety for static slope stability including reliability of laboratory test methods, similarity between laboratory testing conditions and field conditions, reliability of method of slope stability analysis used, construction procedures and quality control and assurance, and consequences of slope failure. General guidance on selecting factors of

safety for slope stability analysis can be found in USACOE (1970), Mitchell and Mitchell (1992), and Duncan (1992). For the PLF cover drainage benches, a minimum design factor of safety of 1.5 is applied for peak strength analysis and a minimum design factor of safety of 1.2 is applied for residual (large-displacement) strength.

Seismic Stability Analysis

Seismic stability analysis was performed in accordance with United States Environmental Protection (USEPA) seismic guidance document [USEPA, 1995] as follows:

1. The computer program XSTABL was used to perform a pseudo-static equilibrium analysis of the analyzed cross section. The analysis used the simplified Janbu method to identify the most critical slip surface, which was then verified using Spencer's method. The value of the horizontal acceleration was adjusted until the factor of safety was calculated as 1.0. The horizontal acceleration, which results in a pseudo-static factor of safety of 1.0 is termed the yield acceleration (k_y) as it represents the smallest horizontal acceleration which may cause materials located along the failure surface to experience permanent displacement.
2. The yield acceleration was compared to the design maximum horizontal acceleration (MHA). The design MHA was assumed to be 0.21g as discussed in the calculation package titled "*Static and Seismic Slope Stability Analyses of Proposed Final Cover System*". If k_y is greater than MHA, then the landfill will not likely undergo permanent displacement. If k_y is less than MHA, then the landfill will likely undergo permanent displacement, and in this case, a displacement analysis is performed as described in step 3 below.
3. The seismic displacement, corresponding to the computed ky/MHA ratio, is estimated using the results presented in Hynes and Franklin [1984] and the "modified mean + one standard deviation curve" developed by GeoSyntec Consultants as presented in Figure 2. The Hynes and Franklin relationships shown in Figure 2 were based on analyses performed using the Newmark [1965] method of seismic deformation analysis and several hundred recorded time histories for earthquakes from around the world as well as six synthetic time histories, representing earthquakes up to 7.7 in magnitude. The modified relationships shown in Figure 2 were developed based on the data generated by the Hynes and Franklin analyses related only to earthquakes of magnitude 7 to 7.7.

According to the USEPA [1995] guidance document, landfill containment systems are expected to remain operable if the permanent seismic deformations are less than 6 to 12 in. Larger permanent seismic deformations may be acceptable for final cover systems for which deformations are readily observable and damage is repairable. For the PLF final cover drainage benches, the permanent displacement will be considered acceptable if it is less than 6 to 12 in.

SUMMARY OF ANALYSES PERFORMED

A summary of the analyses performed is presented below.

Analysis Mode	Consider Bench Has Water?	Peak or Residual Shear Strength [1]	Potential Slip Surface Analyzed
Circular Failure Mode	Yes	N/A	Circular surface within the final cover soil
Circular Failure Mode with Seismic Load	No	N/A	Circular surface within the final cover soil
Waste Block Mode	Yes	Peak	Block surface along geosynthetics/soil barrier interface
Waste Block Mode	Yes	Residual	Block surface along geosynthetics/soil barrier interface
Waste Block Mode With Seismic Load	No	Peak	Block surface along geosynthetics/soil barrier interface

[1] "Peak" refers to using the peak interface shear strength and "Residual" refers to using the residual interface shear strength, measured from the site-specific testing.

MATERIAL PROPERTIES

Summary of the material properties used in the analyses is presented below.

Material	γ (pcf)	c or a (psf)	ϕ or δ (°)
Protective/Vegetative Soil Layer (1,2)	120	100	29
Foundation Soil Layer	120	0	30
Peak Interface Shear Strength (1,3)	-	90	27
Residual Interface Shear Strength (1,3)	-	100	23

[1] The internal/interface shear strength properties presented in this table are based on laboratory test results presented in the calculation package titled "*Static and Seismic Slope Stability Analyses of Proposed Final Cover System*".

[2] To be conservative, residual internal shear strength properties are used for the protective/vegetative soil layer in the stability analysis.

[3] The interface shear strength laboratory test results are presented in the table. These interface shear strength values are based on a single data set. To be conservative and account for material variability, the interface shear strength values used for the analyses will represent 90 percent of the laboratory-measured interface shear strengths. These shear strengths correspond to peak c and ϕ values of 79 and 25° and large-displacement c and ϕ values of 89 and 21.3°.

Similar to the veneer stability of the cover system, the drainage bench stability analyses assume that the gas collection and control system (GCCS) is operated in a manner that prevents the build up of landfill gas beneath the geomembrane, and that the drainage benches and slope drains are maintained free of debris and vegetation, such that the drainage layer is free draining.

RESULTS

The results of the final cover drainage bench static and seismic stability analyses are summarized in Tables 1 and 2, respectively. Associated XSTABL output files are presented in Attachment 1.

Table 1. Summary of Static Stability Analyses Results.

Analysis Mode	Run	Consider Bench Has Water?	Peak or Residual Shear Strength	Minimum Calculated FS	Target FS	Acceptable (?)
Circular Failure Mode	B_C1_1	Yes	N/A	2.16	1.50	Yes
Waste Block Mode	B_WB1SP	Yes	Peak	2.11	1.50	Yes
Waste Block Mode	B_WB2SP	Yes	Residual	1.98	1.20	Yes

Table 2. Summary of Seismic Stability Analyses Results.

Analysis Mode	Run	Consider Bench Has Water?	Peak or Residual Shear Strength	Yield Acceleration	Design Peak Acceleration	Displacement (in)	Acceptable (?)
Circular Failure Mode	B_C1_S	No	N/A	0. 430g	0.21g	0	Yes
Waste Block Mode	B_WB1SSP	No	Peak	0.480g	0.21g	0	Yes

SUMMARY AND CONCLUSIONS

Stability of the final cover drainage benches was evaluated in this calculation package. Based on the results of the analyses presented herein, the static and seismic bench stability is adequate.

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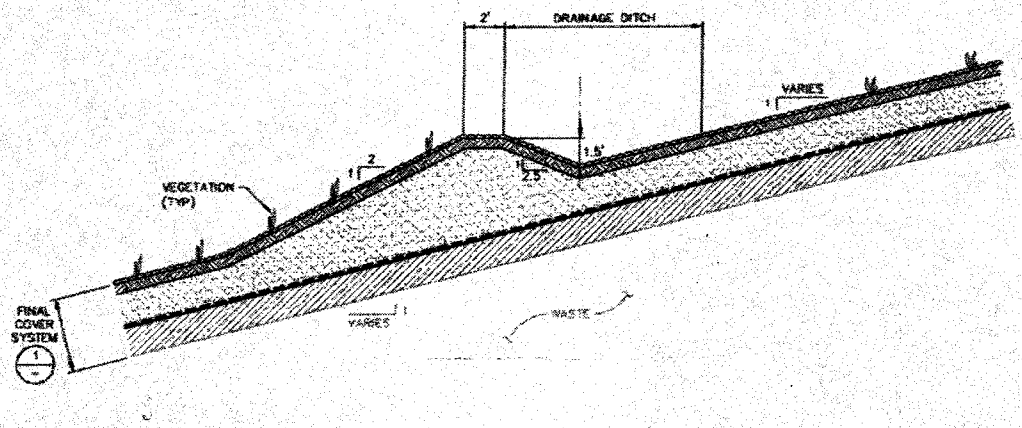

Figure 1. Final Cover Drainage Bench Detail.

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Client: WM Project: Piedmont Landfill Project/Proposal No.: NCP2005 Task No.: 3204

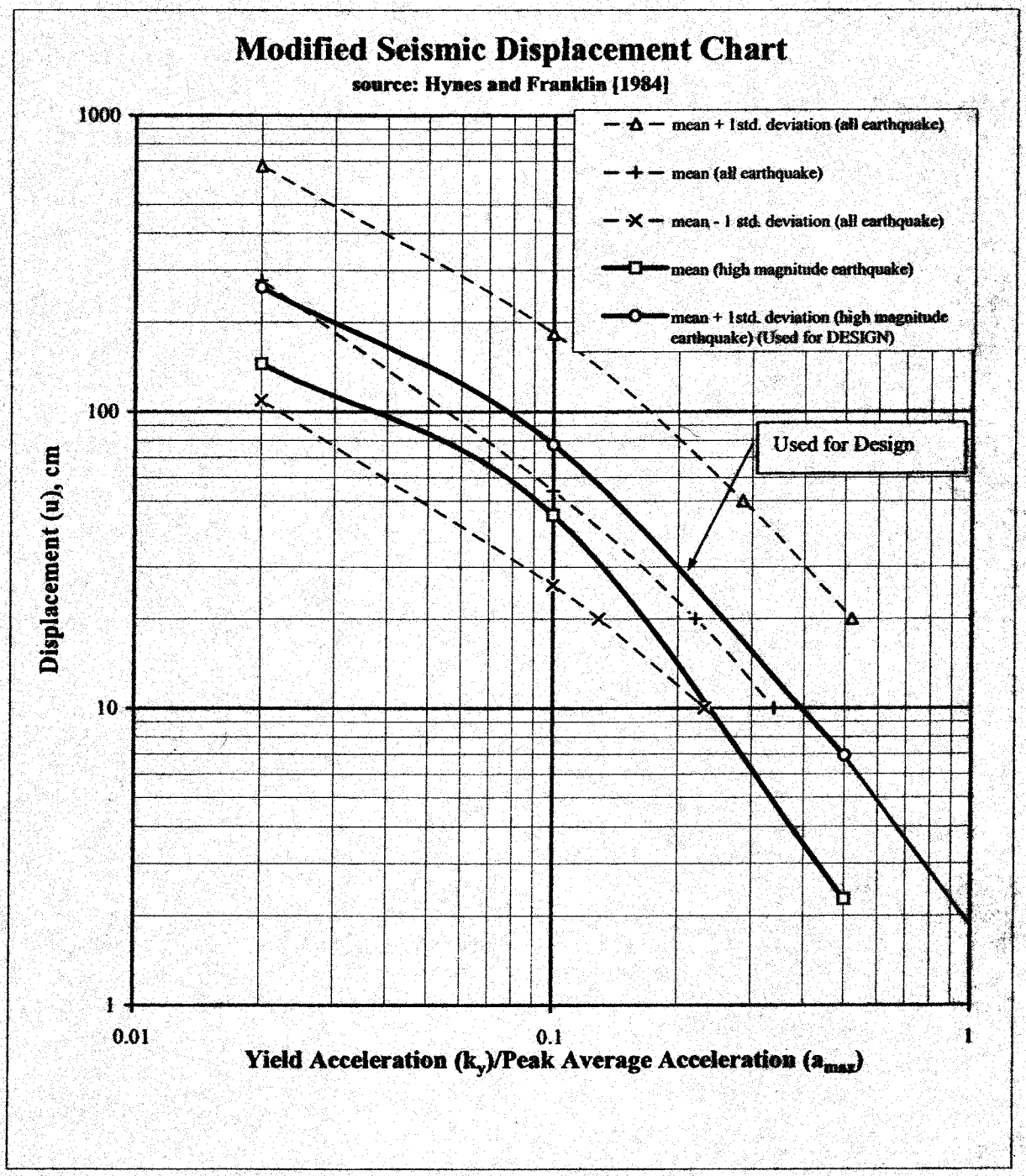


Figure 2. Seismic Displacement versus Yield Acceleration/Peak Average Acceleration Ratio.

ATTACHMENT 1

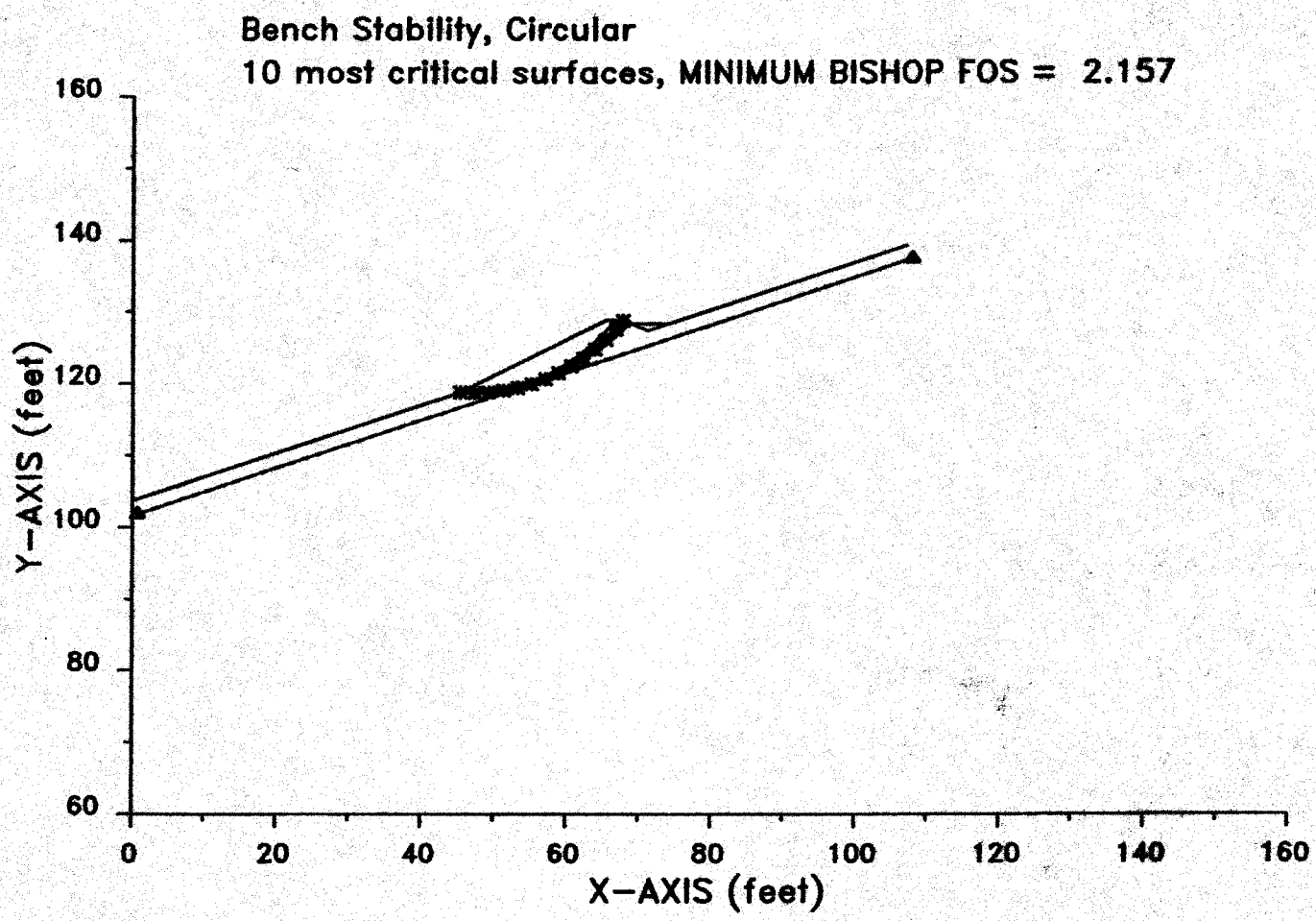
XSTABL OUTPUT

STATIC STABILITY ANALYSES

Written by: Basak Gulec Date: 05/06/05 Reviewed by: Majdi Othman Date: 05/06/05

Client: WM Project: Piedmont Landfill Project/Proposal No.: NCP2005 Task No.: 3204

B_C1_1 5-10-** 17:13



Written by: Basak Gulec Date: 05/06/05 Reviewed by: Majdi Othman Date: 05/06/05

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XSTABL File: B_CI_1 5-10-** 17:13

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```

Problem Description : Bench Stability, Circular

SEGMENT BOUNDARY COORDINATES
---

6 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.1	103.7	45.0	118.6	1
2	45.0	118.6	65.5	128.9	1
3	65.5	128.9	67.5	128.9	1
4	67.5	128.9	68.7	128.4	1
5	68.7	128.4	74.2	128.4	3
6	74.2	128.4	107.1	139.3	1

3 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	68.7	128.4	71.2	127.4	1
2	71.2	127.4	74.2	128.4	1
3	.7	101.8	107.9	137.5	2

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	120.0	120.0	100.0	29.00	.000	.0	0
2	120.0	120.0	.0	30.00	.000	.0	0
3	62.4	62.4	.1	.10	.000	.0	0

BOUNDARIES THAT LIMIT SURFACE GENERATION HAVE BEEN SPECIFIED

```
  LOWER limiting boundary of  1 segments:

Segment      x-left      y-left      x-right     y-right
  No.         (ft)        (ft)        (ft)        (ft)

   1            .7       101.8       107.9       137.5


A critical failure surface searching method, using a random
technique for generating CIRCULAR surfaces has been specified.


 1600 trial surfaces will be generated and analyzed.


  40 Surfaces initiate from each of  40 points equally spaced
along the ground surface between  x =      45.0 ft
                                  and  x =      57.0 ft


Each surface terminates between   x =      57.0 ft
                                  and  x =      75.0 ft


Unless further limitations were imposed, the minimum elevation
at which a surface extends is  y =        .0 ft


* * * * *  DEFAULT SEGMENT LENGTH SELECTED BY XSTABL  * * * * *

    2.0 ft line segments define each trial failure surface.


---------------------
ANGULAR RESTRICTIONS
---------------------

  The first segment of each failure surface will be inclined
  within the angular range defined by :

          Lower angular limit :=   -45.0 degrees
          Upper angular limit :=  (slope angle - 5.0) degrees


***********************************************************************
    --  WARNING  --  WARNING  --  WARNING  --  WARNING  --  (# 48)
***********************************************************************
Negative effective stresses were calculated at the base of a slice.
This warning is usually reported for cases where slices have low self
weight and a relatively high "c" shear strength parameter.  In such
cases, this effect can only be eliminated by reducing the "c" value.
***********************************************************************

    ------------------------------------------------------------
    USER SELECTED option to maintain strength greater than zero
    ------------------------------------------------------------


    ************************************************************
    **     Factor of safety calculation for surface #  1293   **
    **     failed to converge within FIFTY iterations         **
    **                                                        **
    **    The last calculated value of the FOS was  22.0480   **
    **    This will be ignored for final summary of results   **
    ************************************************************
```

```
Circular surface (FOS= 22.0480) is defined by: xcenter =     52.96
ycenter =    131.07   Init. Pt. =     54.85   Seg. Length =   2.00
-----------------------------------------------------------------
```

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED BISHOP METHOD * * * * *

The most critical circular failure surface
is specified by 14 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	45.31	118.75
2	47.31	118.69
3	49.30	118.78
4	51.29	119.02
5	53.25	119.42
6	55.18	119.96
7	57.05	120.65
8	58.87	121.48
9	60.62	122.45
10	62.29	123.55
11	63.88	124.77
12	65.36	126.11
13	66.74	127.56
14	67.74	128.80

**** Simplified BISHOP FOS = 2.157 ****

```
*******************************************************************
**                                                               **
**  Out of the   1600 surfaces generated and analyzed by XSTABL, **
**        1 surfaces were found to have MISLEADING FOS values.   **
**                                                               **
*******************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : Bench Stability, Circular

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	2.157	47.13	144.79	26.10	45.31	67.74	1.707E+05
2.	2.182	45.97	150.15	31.40	45.31	68.65	2.117E+05
3.	2.183	45.80	149.08	30.33	45.31	68.17	1.940E+05
4.	2.189	45.57	150.74	31.98	45.31	68.53	2.099E+05
5.	2.192	45.53	149.10	30.35	45.31	67.98	1.884E+05
6.	2.197	45.02	148.68	30.08	45.00	67.63	1.821E+05
7.	2.200	45.96	148.91	30.00	45.62	68.08	1.852E+05
8.	2.211	45.55	151.28	32.37	45.62	68.51	2.054E+05
9.	2.213	44.63	152.27	33.52	45.31	68.31	2.081E+05
10.	2.218	45.67	145.05	26.46	45.00	66.60	1.508E+05

* * * END OF FILE * * *

Written by: Basak Gulec Date: 05/06/05 Reviewed by: Majdi Othman Date: 05/06/05

Client: WM Project: Piedmont Landfill Project/Proposal No.: NCP2005 Task No.: 3204

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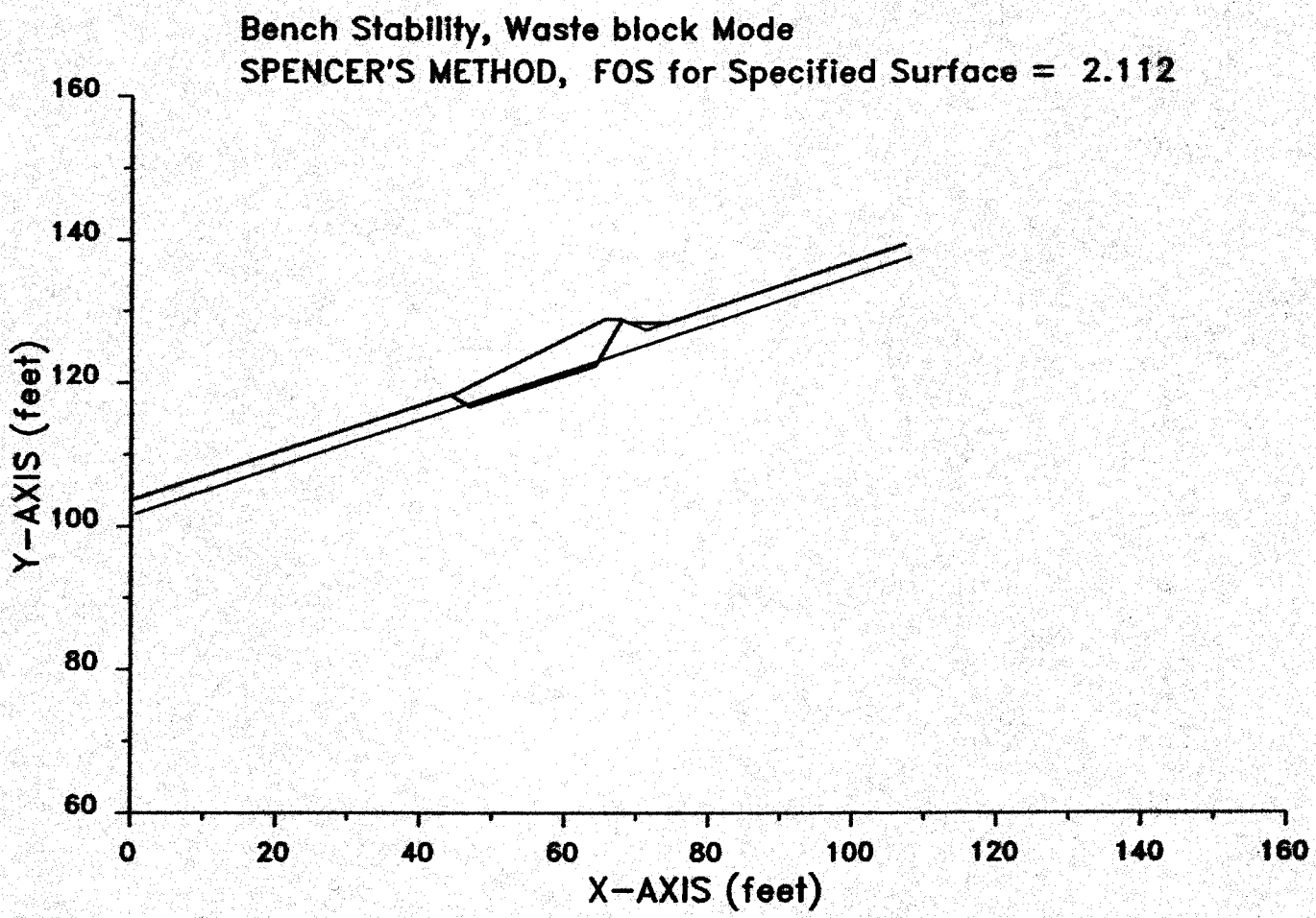

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```

Problem Description : Bench Stability, Waste block Mode

SEGMENT BOUNDARY COORDINATES

6 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.1	103.7	45.0	118.6	1
2	45.0	118.6	65.5	128.9	1
3	65.5	128.9	67.5	128.9	1
4	67.5	128.9	68.7	128.4	1
5	68.7	128.4	74.2	128.4	3
6	74.2	128.4	107.1	139.3	1

3 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	68.7	128.4	71.2	127.4	1
2	71.2	127.4	74.2	128.4	1
3	.7	101.8	107.9	137.5	2

ISOTROPIC Soil Parameters

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	120.0	120.0	100.0	29.00	.000	.0	0
2	120.0	120.0	79.0	25.00	.000	.0	0
3	62.4	62.4	.1	.10	.000	.0	0

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by

the following 6 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	44.10	118.30
2	46.32	116.99
3	46.81	116.68
4	64.05	122.35
5	64.49	123.04
6	67.85	128.75

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	44.55	118.04	.42	.90	-30.57	18.36	45.
2	45.66	117.38	1.55	1.32	-30.57	26.68	246.
3	46.57	116.83	2.55	.49	-32.32	26.68	150.
4	55.43	119.51	4.33	17.24	18.21	26.68	8948.
5	64.27	122.70	5.59	.44	57.48	26.68	297.
6	65.00	123.90	4.75	1.01	59.54	26.68	574.
7	66.50	126.46	2.44	2.00	59.54	.00	586.
8	67.68	128.46	.37	.35	59.54	-22.62	16.

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	18.3616	2.1037	2.2343
3	18.7508	2.1118	2.1037
4	18.7369	2.1115	2.1118

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	169.0	100.0	29.00	0.	0.	0.	.00
2	414.5	100.0	29.00	0.	0.	0.	.00
3	600.1	79.0	25.00	0.	0.	0.	.00
4	468.3	79.0	25.00	0.	0.	0.	.00
5	346.2	79.0	25.00	0.	0.	0.	.00
6	261.1	100.0	29.00	0.	0.	0.	.00
7	118.1	100.0	29.00	0.	0.	0.	.00
8	-10.3	100.0	29.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	44.55	169.0	49.8	.0	91.7

2	45.66	414.5	186.2	.0	156.2
3	46.57	600.1	306.2	.0	169.9
4	55.43	468.3	519.1	.0	140.8
5	64.27	346.2	670.3	.0	113.9
6	65.00	261.1	569.5	.0	115.9
7	66.50	118.1	293.0	.0	78.4
8	67.68	-10.3	44.5	.0	44.6

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	45.00	18.74	182.	.42	.83	.504
2	46.32	18.74	741.	.87	2.27	.381
3	46.81	18.74	1025.	1.04	2.83	.366
4	64.05	18.74	785.	1.55	5.82	.267
5	64.49	18.74	585.	1.45	5.35	.271
6	65.50	18.74	236.	1.21	4.14	.291
7	67.50	18.74	-23.	.24	.74	.322
8	67.85	.00	0.	-.05	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 379.82 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 127.07 (psf)

Total Length of failure surface = 28.75 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 2.112

Total shear strength available along specified failure surface = 771.49E+01 lb

****
For the specified surface, the analysis computed the following:

Negative (tensile) Normal Effective Force = 0 slices
Negative (tensile) Interslice Force = 1 slices
Unreasonable Location of Interslice Force = 0 slices

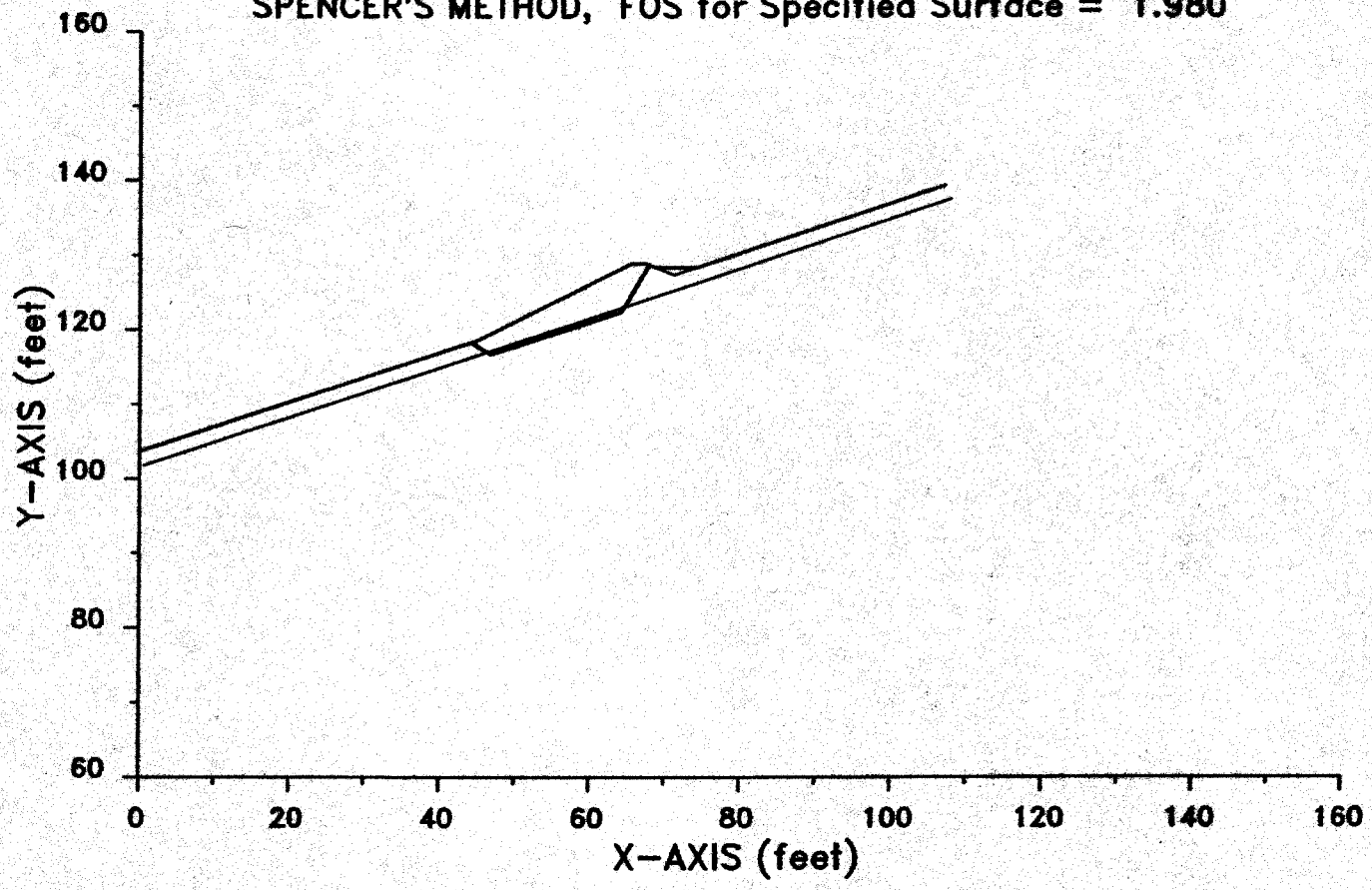
In view of these errors, the computed FOS may be UNREASONABLE!
****

Written by: Basak Gulec Date: 05/06/05 Reviewed by: Majdi Othman Date: 05/06/05

Client: WM Project: Piedmont Landfill Project/Proposal No.: NCP2005 Task No.: 3204

B_WB2SP 5-10-** 17:03

Bench Stability, Waste block Mode
SPENCER'S METHOD, FOS for Specified Surface = 1.980



XSTABL File: B_WB2SP 5-10-** 17:03

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```

Problem Description : Bench Stability, Waste block Mode

SEGMENT BOUNDARY COORDINATES
---

6 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.1	103.7	45.0	118.6	1
2	45.0	118.6	65.5	128.9	1
3	65.5	128.9	67.5	128.9	1
4	67.5	128.9	68.7	128.4	1
5	68.7	128.4	74.2	128.4	3
6	74.2	128.4	107.1	139.3	1

3 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	68.7	128.4	71.2	127.4	1
2	71.2	127.4	74.2	128.4	1
3	.7	101.8	107.9	137.5	2

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	120.0	120.0	100.0	29.00	.000	.0	0
2	120.0	120.0	89.0	21.30	.000	.0	0
3	62.4	62.4	.1	.10	.000	.0	0

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by

the following 6 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	44.12	118.31
2	46.34	117.00
3	46.81	116.68
4	64.05	122.35
5	64.53	123.06
6	67.88	128.74

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	44.56	118.05	.41	.88	-30.51	18.36	43.
2	45.67	117.39	1.54	1.34	-30.51	26.68	248.
3	46.58	116.84	2.55	.47	-34.25	26.68	144.
4	55.43	119.51	4.33	17.24	18.21	26.68	8948.
5	64.29	122.71	5.59	.48	55.94	26.68	322.
6	65.01	123.88	4.77	.97	59.48	26.68	556.
7	66.50	126.40	2.50	2.00	59.48	.00	600.
8	67.69	128.42	.40	.38	59.48	-22.62	18.

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	17.9415	1.9735	2.1110
3	18.2999	-----	1.9735
3	18.1207	1.9771	-----
4	18.2889	1.9805	1.9771
5	18.2838	1.9804	1.9805

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	173.5	100.0	29.00	0.	0.	0.	.00
2	422.5	100.0	29.00	0.	0.	0.	.00
3	610.6	89.0	21.30	0.	0.	0.	.00
4	468.4	89.0	21.30	0.	0.	0.	.00
5	360.8	89.0	21.30	0.	0.	0.	.00
6	259.4	100.0	29.00	0.	0.	0.	.00
7	118.9	100.0	29.00	0.	0.	0.	.00
8	-10.7	100.0	29.00	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)

1	44.56	173.5	48.6	.0	99.1
2	45.67	422.5	185.1	.0	168.8
3	46.58	610.6	306.2	.0	165.1
4	55.43	468.4	519.1	.0	137.2
5	64.29	360.8	670.4	.0	116.0
6	65.01	259.4	572.8	.0	123.1
7	66.50	118.9	299.9	.0	83.8
8	67.69	-10.7	48.2	.0	47.5

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	45.00	18.28	187.	.40	.81	.499
2	46.34	18.28	776.	.86	2.27	.379
3	46.81	18.28	1063.	1.04	2.83	.367
4	64.05	18.28	757.	1.49	5.82	.256
5	64.53	18.28	546.	1.41	5.35	.263
6	65.50	18.28	222.	1.17	4.19	.280
7	67.50	18.28	-26.	.26	.80	.323
8	67.88	.00	0.	.97	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 380.78 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 126.85 (psf)

Total Length of failure surface = 28.75 feet

For the single specified surface and the assumed angle of the interslice forces, the SPENCER'S (1973) procedure gives a

FACTOR OF SAFETY = 1.980

Total shear strength available along specified failure surface = 722.14E+01 lb

****
For the specified surface, the analysis computed the following:

Negative (tensile) Normal Effective Force = 0 slices
Negative (tensile) Interslice Force = 1 slices
Unreasonable Location of Interslice Force = 0 slices

In view of these errors, the computed FOS may be UNREASONABLE!
****

SEISMIC STABILITY ANALYSES

Written by: Basak Gulec Date: 05/06/05 Reviewed by: Majdi Othman Date: 05/06/05

Client: WM Project: Piedmont Landfill Project/Proposal No.: NCP2005 Task No.: 3204

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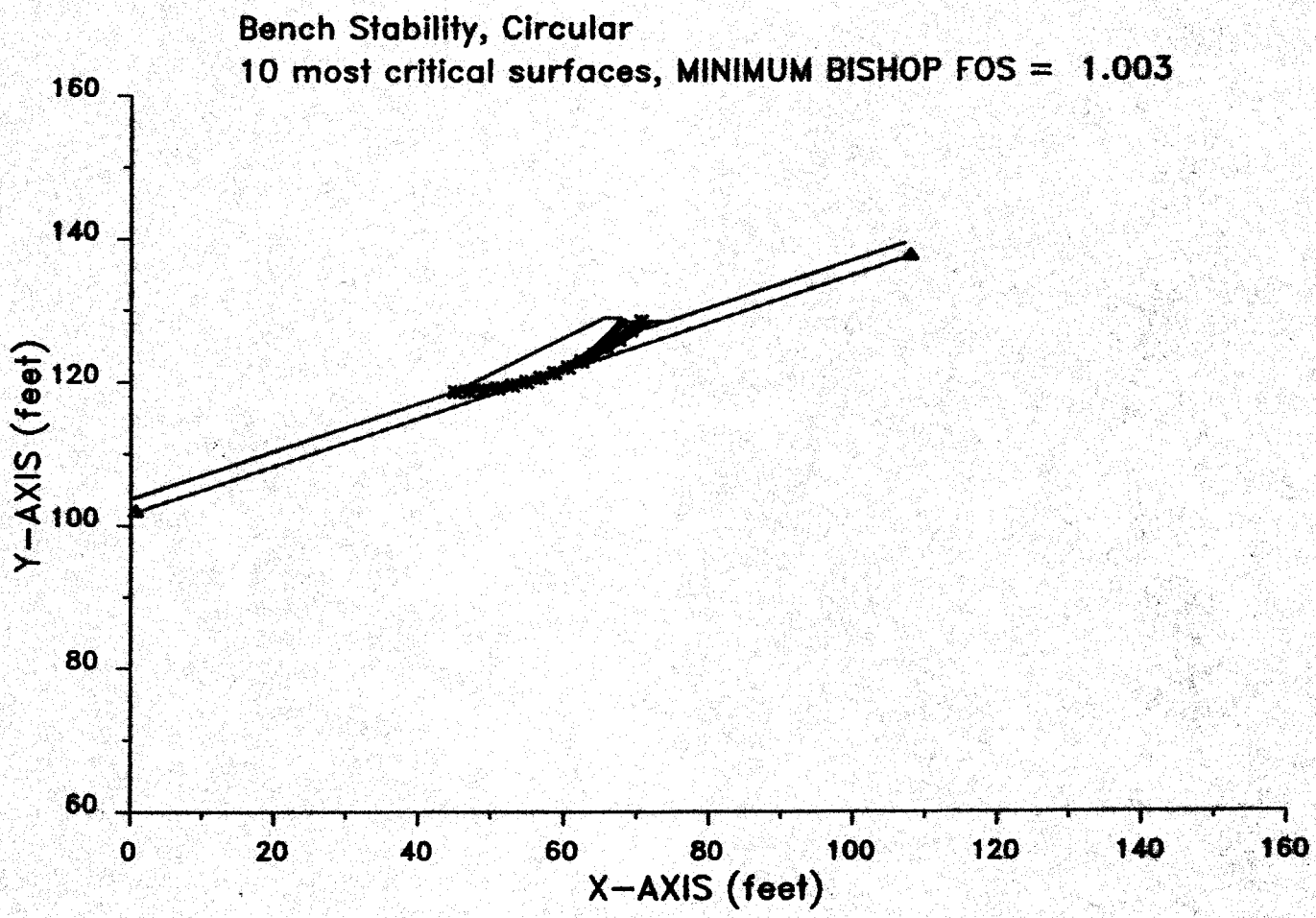

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*              using the                *
*           Method of Slices            *
*                                       *
*        Copyright (C) 1992 Ä 96        *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
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*****************************************
```

Problem Description : Bench Stability, Circular

SEGMENT BOUNDARY COORDINATES
---

6 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.1	103.7	45.0	118.6	1
2	45.0	118.6	65.5	128.9	1
3	65.5	128.9	67.5	128.9	1
4	67.5	128.9	68.7	128.4	1
5	68.7	128.4	74.2	128.4	3
6	74.2	128.4	107.1	139.3	1

3 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	68.7	128.4	71.2	127.4	1
2	71.2	127.4	74.2	128.4	1
3	.7	101.8	107.9	137.5	2

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	120.0	120.0	100.0	29.00	.000	.0	0
2	120.0	120.0	.0	30.00	.000	.0	0
3	62.4	62.4	.1	.10	.000	.0	0

A horizontal earthquake loading coefficient
of .430 has been assigned

A vertical earthquake loading coefficient

of .000 has been assigned

BOUNDARIES THAT LIMIT SURFACE GENERATION HAVE BEEN SPECIFIED

LOWER limiting boundary of 1 segments:

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)
1	.7	101.8	107.9	137.5

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

1600 trial surfaces will be generated and analyzed.

40 Surfaces initiate from each of 40 points equally spaced along the ground surface between x = 45.0 ft
and x = 57.0 ft

Each surface terminates between x = 57.0 ft
and x = 75.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

2.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

****
-- WARNING -- WARNING -- WARNING -- WARNING -- (# 48)
****
Negative effective stresses were calculated at the base of a slice. This warning is usually reported for cases where slices have low self weight and a relatively high "c" shear strength parameter. In such cases, this effect can only be eliminated by reducing the "c" value.
****

USER SELECTED option to maintain strength greater than zero

Written by: Basak Gulec Date: 05/06/05 Reviewed by: Majdi Othman Date: 05/06/05

Client: WM Project: Piedmont Landfill Project/Proposal No.: NCP2005 Task No.: 3204

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED BISHOP METHOD * * * * *

The most critical circular failure surface
is specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	45.00	118.60
2	47.00	118.68
3	48.99	118.85
4	50.97	119.13
5	52.94	119.51
6	54.88	119.99
7	56.79	120.56
8	58.68	121.23
9	60.53	122.00
10	62.33	122.85
11	64.09	123.80
12	65.81	124.84
13	67.46	125.96
14	69.06	127.16
15	70.55	128.40

**** Simplified BISHOP FOS = 1.003 ****

The following is a summary of the TEN most critical surfaces

Problem Description : Bench Stability, Circular

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	1.003	44.48	158.15	39.56	45.00	70.55	2.667E+05
2.	1.014	44.65	161.87	42.97	45.62	71.60	2.937E+05
3.	1.015	45.97	150.15	31.40	45.31	68.65	1.906E+05
4.	1.016	44.21	164.78	45.89	45.62	72.17	3.209E+05
5.	1.016	47.55	151.48	32.29	46.23	70.12	2.094E+05
6.	1.021	45.57	150.74	31.98	45.31	68.53	1.890E+05
7.	1.025	47.13	144.79	26.10	45.31	67.74	1.535E+05
8.	1.026	47.76	150.03	30.68	46.54	69.50	1.869E+05
9.	1.027	45.80	149.08	30.33	45.31	68.17	1.745E+05
10.	1.028	46.77	155.25	35.88	46.54	70.56	2.253E+05

* * * END OF FILE * * *

Written by: Basak Gulec Date: 05/06/05 Reviewed by: Majdi Othman Date: 05/06/05

Client: WM Project: Piedmont Landfill Project/Proposal No.: NCP2005 Task No.: 3204

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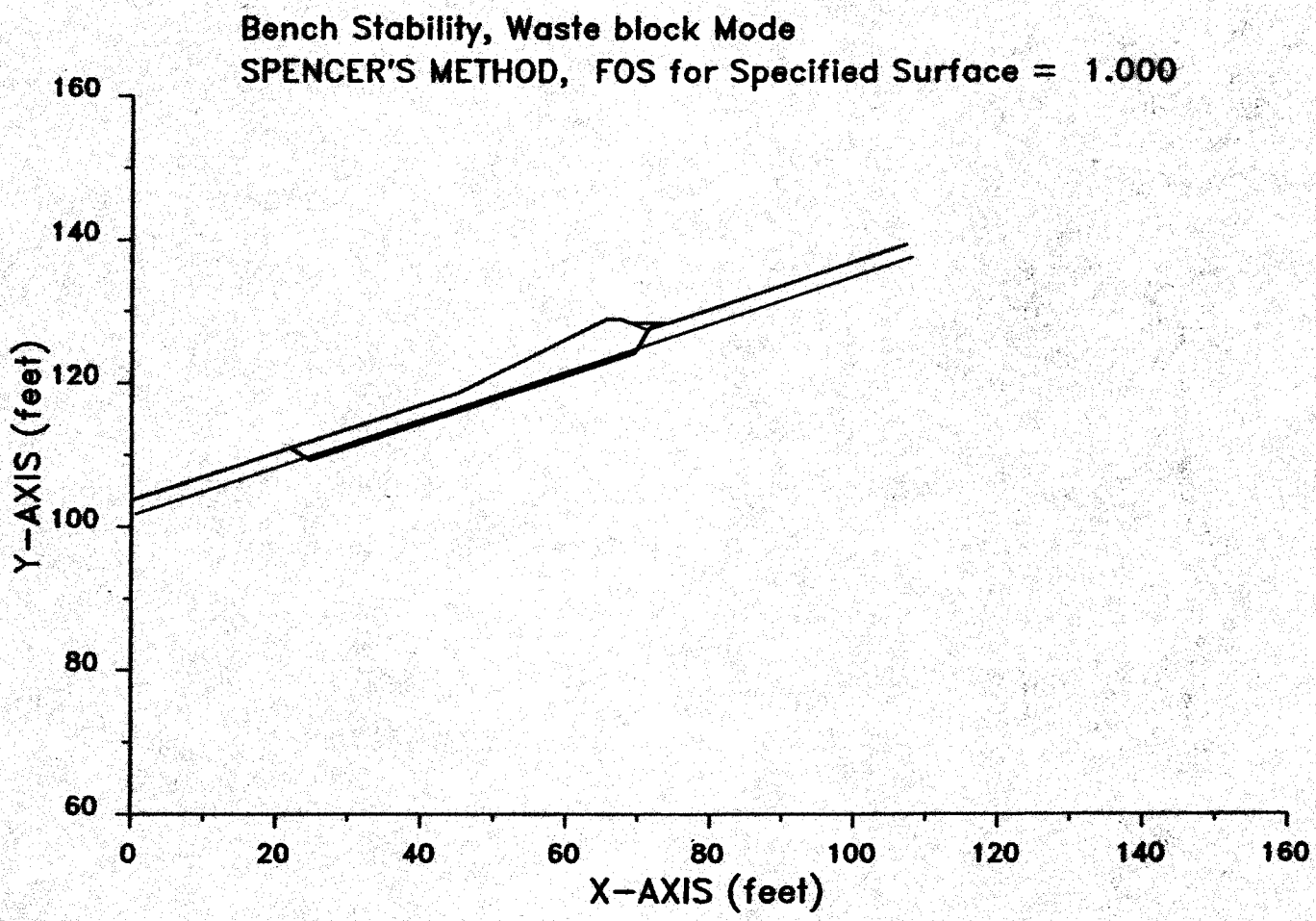

Written by: Basak Gulec Date: 05/06/05 Reviewed by: Majdi Othman Date: 05/06/05

Client: WM Project: Piedmont Landfill Project/Proposal No.: NCP2005 Task No.: 3204

XSTABL File: B_WB1SSP 5-10-** 17:07

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*              using the                *
*           Method of Slices            *
*                                       *
*        Copyright (C) 1992 Ä 96        *
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*****************************************
```

Problem Description : Bench Stability, Waste block Mode

SEGMENT BOUNDARY COORDINATES
---

6 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.1	103.7	45.0	118.6	1
2	45.0	118.6	65.5	128.9	1
3	65.5	128.9	67.5	128.9	1
4	67.5	128.9	68.7	128.4	1
5	68.7	128.4	74.2	128.4	3
6	74.2	128.4	107.1	139.3	1

3 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	68.7	128.4	71.2	127.4	1
2	71.2	127.4	74.2	128.4	1
3	.7	101.8	107.9	137.5	2

ISOTROPIC Soil Parameters
---

3 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	120.0	120.0	100.0	29.00	.000	.0	0
2	120.0	120.0	79.0	25.00	.000	.0	0
3	62.4	62.4	.1	.10	.000	.0	0

A horizontal earthquake loading coefficient
of .480 has been assigned

A vertical earthquake loading coefficient

of .000 has been assigned

A SINGLE FAILURE SURFACE HAS BEEN SPECIFIED FOR ANALYSIS

Trial failure surface specified by
the following 7 coordinate points :

Point No.	x-surf (ft)	y-surf (ft)
1	21.89	110.93
2	24.14	109.61
3	24.67	109.26
4	69.36	124.14
5	69.79	124.81
6	71.34	127.45
7	72.29	128.40

****
SELECTED METHOD OF ANALYSIS: Spencer (1973)
****

****
SUMMARY OF INDIVIDUAL SLICE INFORMATION
****

Slice	x-base (ft)	y-base (ft)	height (ft)	width (ft)	alpha	beta	weight (lb)
1	23.02	110.27	1.04	2.25	-30.42	18.36	280.
2	24.41	109.43	2.33	.53	-33.44	18.36	147.
3	34.83	112.64	2.58	20.33	18.42	18.36	6300.
4	55.25	119.44	4.31	20.50	18.42	26.68	10598.
5	66.50	123.19	5.71	2.00	18.42	.00	1371.
6	68.10	123.72	4.93	1.20	18.42	-22.62	710.
7	69.03	124.03	4.37	.66	18.42	.00	341.
8	69.57	124.47	3.93	.43	57.31	.00	194.
9	70.49	126.01	2.39	1.41	59.58	.00	346.
10	71.27	127.33	1.07	.14	59.58	.00	10.
11	71.82	127.92	.47	.95	45.00	.00	28.

ITERATIONS FOR SPENCER'S METHOD

Iter #	Theta	FOS_force	FOS_moment
2	26.0987	1.0496	.9247
3	22.9494	-----	1.0496
3	24.5240	1.0137	-----
4	23.5814	.9946	1.0137
5	23.9837	-----	.9946
5	23.7825	.9986	-----
6	23.8962	1.0008	.9986
7	23.8717	1.0005	1.0008

SLICE INFORMATION ... continued :

Slice	Sigma (psf)	c-value (psf)	phi	U-base (lb)	U-top (lb)	P-top (lb)	Delta
1	1183.1	100.0	29.00	0.	0.	0.	.00
2	1587.7	79.0	25.00	0.	0.	0.	.00

3	230.5	79.0	25.00	0.	0.	0.	.00
4	379.3	79.0	25.00	0.	0.	0.	.00
5	500.3	79.0	25.00	0.	0.	0.	.00
6	432.9	79.0	25.00	0.	0.	0.	.00
7	379.2	79.0	25.00	0.	0.	0.	.00
8	120.8	79.0	25.00	0.	0.	0.	.00
9	27.4	100.0	29.00	0.	0.	0.	.00
10	-28.2	100.0	29.00	0.	0.	0.	.00
11	18.3	.1	.10	0.	0.	0.	.00

SPENCER'S (1973) - TOTAL Stresses at center of slice base

Slice #	Base x-coord (ft)	Normal Stress (psf)	Vertical Stress (psf)	Pore Water Pressure (psf)	Shear Stress (psf)
1	23.02	1183.1	124.3	.0	755.5
2	24.41	1587.7	279.9	.0	819.0
3	34.83	230.5	309.9	.0	186.4
4	55.25	379.3	517.0	.0	255.7
5	66.50	500.3	685.5	.0	312.2
6	68.10	432.9	591.5	.0	280.7
7	69.03	379.2	516.8	.0	255.7
8	69.57	120.8	450.8	.0	135.3
9	70.49	27.4	245.4	.0	115.1
10	71.27	-28.2	72.1	.0	84.3
11	71.82	18.3	29.6	.0	.1

SPENCER'S (1973) - Magnitude & Location of Interslice Forces

Slice #	Right x-coord (ft)	Force Angle (degrees)	Interslice Force (lb)	Force Height (ft)	Boundary Height (ft)	Height Ratio
1	24.14	23.87	3427.	1.14	2.07	.549
2	24.67	23.87	4424.	1.38	2.59	.530
3	45.00	23.87	3555.	3.00	2.57	1.168
4	65.50	23.87	894.	4.12	6.05	.681
5	67.50	23.87	493.	3.62	5.38	.673
6	68.70	23.87	300.	3.08	4.48	.688
7	69.36	23.87	214.	2.61	4.26	.614
8	69.79	23.87	87.	3.32	3.59	.924
9	71.20	23.87	11.	1.14	1.19	.958
10	71.34	23.87	26.	.37	.95	.395
11	72.29	.00	-7.	-.07	.00	.000

AVERAGE VALUES ALONG FAILURE SURFACE

Total Normal Stress = 347.14 (psf)
Pore Water Pressure = .00 (psf)
Shear Stress = 245.79 (psf)

Total Length of failure surface = 55.55 feet

```
For the single specified surface and the assumed angle
of the interslice forces, the SPENCER'S (1973)
procedure gives a

          FACTOR OF SAFETY =   1.000

Total shear strength available
along specified failure surface =  136.60E+02   lb

*****************************************************************
 For the specified surface, the analysis computed the following:

Negative (tensile) Normal Effective Force =  1 slices
Negative (tensile) Interslice Force       =  0 slices
Unreasonable Location of Interslice Force =  1 slices

 In view of these errors, the computed FOS may be UNREASONABLE!
*****************************************************************
```

Appendix C

Technical Specifications and CQA Procedures

Prepared for:

Waste Management of Carolinas, Inc.
2859 Paces Ferry Road
Suite 1600
Atlanta, Georgia 30339

CQA PLAN AMENDMENT RECONSTRUCTION OF AN AREA OF PHASE 2 CLOSURE

PIEDMONT LANDFILL KERNERSVILLE, NORTH CAROLINA

Prepared by:

GeoSyntec Consultants
1255 Roberts Boulevard, Suite 200
Kennesaw, Georgia 30144

NORTH CAROLINA PROFESSIONAL SEAL 24769 ENGINEER MAJDI A. OTHMAN

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1. INTRODUCTION

1.1 Purpose of CQA Plan Amendment

The current construction quality assurance (CQA) plan for the final cover systems of the Piedmont Landfill (PLF) was prepared by Rust Environment and Infrastructure, of Greenville, South Carolina, and is dated July 1996. The CQA plan was implemented in 2004 for the construction of the Phase 2 Closure. This CQA Plan Amendment (Amendment) was prepared by GeoSyntec Consultants, Inc. (GeoSyntec) to establish the quality-assurance monitoring and documentation procedures that shall be used for the reconstruction for an area of the Phase 2 closure that underwent downslope movement in January 2005. In particular, the purpose of this Amendment is to address the CQA procedures for those components of the reconstruction final cover system that are not addressed in the current CQA Plan.

1.2 Focus and Organization of CQA Plan Amendment

The final cover system that will be used for the Phase 2 closure reconstruction consists of the following components, from top to bottom:

- 24-inch thick protective/vegetative soil layer;
- 8 oz/yd^2 geotextile filter layer;
- Agru America, Inc. (A/A) Super Gripnet® liner consisting of a 60-mil thick high density polyethylene (HDPE) geomembrane with friction spikes on the bottom and drainage studs on top; and
- 10-inch thick compacted soil layer (existing subgrade).

The A/A Super Gripnet® liner (referred to hereafter as geomembrane) and the geotextile filter are unique to this final cover system (i.e., are not components of the previously permitted final cover systems), and therefore, are not included in the current CQA Plan. Therefore, the remainder of this Amendment is organized to present the CQA procedures for these two geosynthetic materials. The CQA procedures for the soil components of the final cover system will remain as described in the current CQA Plan.

The remainder of this Amendment is organized as follows:

- the geomembrane CQA procedures are presented in Section 2; and
- the geotextile filter CQA procedures are described in Section 3.

2. A/A SUPER GRIPNET® LINER (GEOMEMBRANE)

2.1 Overview

This section of the QA/QC Plan presents the CQA procedures to be implemented with regard to the geomembrane component of the cover system. The following activities are discussed in the remainder of this section:

- Pre-Construction Qualifying of Material Sources;
- Material Conformance Testing;
- Field Evaluation/Monitoring of Construction Techniques;
- Field Testing of Work Product; and
- Deficiencies, Problems, and Repairs.

2.2 Pre-Construction Qualifying of Material Sources

Prior to installation of any geomembrane, the manufacturer or Geosynthetics Installer shall provide the CQA project manager (CQAPM) with Manufacturer's certification statements and quality control information, including the following:

- Written certification, signed by a responsible party employed by the Manufacturer. The Manufacturer shall guarantee the minimum average roll values (95 percent lower confidence limit) are met for physical, mechanical, and environmental properties corresponding to the test procedures for the required geomembrane properties.
- Quality control certificates with test results, signed by a responsible party employed by the Manufacturer. Each quality control certificate shall include date, roll identification numbers, testing procedures, and results of quality control tests performed using the methods specified and at the required frequencies.

- Certification statement from the resin supplier stating that the resin properties are met for the specified test procedures and properties listed in the Specifications.

- Copies of dated quality control certificates issued by the resin supplier for each resin lot used in geomembrane production for the following properties:

  - Resin Density (ASTM D 1505); and

  - Melt Flow Index (ASTM D 1238).

The CQAPM shall examine all geomembrane manufacturers' certifications to verify that the property values listed on the certifications meet or exceed the project specifications and that proper and complete documentation has been provided for all geomembrane to be used at the site.

2.3 Material Conformance Testing

Conformance sampling of geomembrane rolls may be performed either at the manufacturing plant or upon delivery of the rolls to the site, as requested by Owner. The laboratory test methods to be used for CQA conformance testing of the geomembrane are given in Table 2-1.

Any nonconformance of the material's physical properties will be reported to the Owner's Representative and to the Manufacturer. The following procedure will apply whenever a geomembrane material sample fails a conformance test:

- The manufacturer will be required to replace all of the rolls of material within the batch from which the sample that is not in conformance with the specifications was obtained. The material must be replaced with material that meets the requirements of the specifications.

- Alternatively, if the manufacturer, the owner, and the CQA Certifying Engineer (CQACE) all agree, CQA personnel may obtain additional conformance samples from the closest numerical roll on both sides of the roll from which the failing sample was obtained. These two samples must pass the conformance tests. If either of these samples fails to meet the requirements, samples will be

collected from the five numerically closest untested rolls on both sides of the failed sample and tested by the CQA Testing Laboratory. These ten samples must pass the conformance tests. If any of these samples fail, a sample from every roll of the applicable geosynthetic material on site and a sample from every roll that is subsequently delivered from the manufacturer must be conformance tested by the CQA Testing Laboratory.

During conformance testing, CQA personnel may also verify that the manufacturer has identified all rolls of geosynthetic material with the following information:

- name of manufacturer;
- product identification;
- lot number;
- batch number;
- roll number; and
- roll dimensions.

2.4 Field Evaluation/Monitoring of Construction Techniques

2.4.1 CQACE Site Inspections

The CQACE shall inspect deployment and installation of the geomembrane during key events.

2.4.2 Proposed Panel Layout

Prior to construction, CQA personnel and the Owner's Representative shall review the proposed panel layout plan submitted by the Geosynthetics Installer. The purpose of the review shall be to become familiar with the proposed orientation of the panels, the general installation sequencing, the quantities of materials needed for the job, and to assess whether the proposed installation is in accordance with the specifications.

2.4.3 Transportation, Handling, and Storage

During unloading and storage, the geomembrane material shall be handled to minimize damage. The geomembrane shall also be stored in a manner that minimizes damage. CQA personnel shall inspect the geomembrane rolls prior to use. Any damaged rolls shall be repaired or replaced.

2.4.4 Field Panel Identification

Each field panel shall be given an identification code. The field panel identification code shall be used for all quality assurance/quality control records.

2.4.5 Field Panel Placement

CQA personnel shall monitor field panel placement and verify that field panels are installed at the location indicated in the Geosynthetics Installer's proposed panel layout plan. CQA personnel shall record the field panel identification code, manufacturers roll number, location, date of installation, and dimensions of each field panel. CQA personnel shall label each panel in the field with its panel identification number using a semi-permanent marker (e.g., paint stick).

Prior to deployment of the geomembrane, the Contractor shall smooth and proof roll the soil subgrade. Any rock particles larger than 3/8 inch in size shall be removed from the soil subgrade surface. The QA personnel shall observe the work area, and shall verify that the top of compacted soil subgrade (i.e., surface on which geomembrane shall be deployed) has been appropriately prepared and fully approved. It is the responsibility of CQA personnel to provide subgrade acceptance forms to the Geosynthetics Installer and verify that they have been signed by CQA personnel, the Geosynthetics Installer, and the Owner's Representative prior to deployment.

CQA personnel shall monitor geomembrane deployment and verify compliance with the following:

- ambient temperatures are within the limits required by the Specifications, and wind is not excessive;

- any equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons or other means;
- the prepared surface underlying the geomembrane has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement, without excessive moisture (e.g., dew, ponding, etc.);
- all personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane;
- the method used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil;
- the method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels);
- adequate temporary loading and/or anchoring (e.g., sand bags, tires) has been placed to prevent uplift by wind; and
- direct contact with the geomembrane is minimized in areas where excessive traffic may be expected (e.g., the geomembrane is protected by geotextiles, extra geomembrane, or other suitable materials).

CQA personnel shall observe the geomembrane panels, after placement and prior to seaming, for damage, and shall advise the Contractor which panels, or portions of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels which have been rejected shall be marked and their removal from the work area shall be recorded by CQA personnel.

2.4.6 Field Panel Seaming

2.4.6.1 Panel Layout

To the extent practical, horizontal seams on the side slopes should be avoided. If avoiding horizontal seams is not practical, then the horizontal seams shall be discontinuous (i.e., staggered) between adjacent panels. In corners and odd-shaped geometric locations, the number of seams should be minimized. No horizontal seam

should be less than 5 ft beyond the toe of the slope, or areas of potential stress concentrations, unless otherwise authorized by the CQACE. A seam numbering system compatible with the field panel identification numbering system shall be utilized.

2.4.6.2 Seaming Equipment and Products

Extrusion Weld Process

CQA personnel shall perform the following activities during the extrusion welding process:

- verify and document that the extrusion-welding apparatus is permanently marked with an identification number;
- verify that the extrusion-welding apparatus is equipped with gauges giving the temperature in the apparatus and at the nozzle;
- verify that the extrudate is comprised of the same resin as the geomembrane sheeting;
- monitor extrudate temperatures, ambient temperatures, and geomembrane sheet temperatures at appropriate intervals;
- verify that a suitable number of spare operable seaming apparatus are maintained on site;
- verify that the extruder is purged prior to beginning a seam until all heat-degraded extrudate has been removed from the barrel;
- confirm that the electric generator is placed on a smooth base such that no damage occurs to the geomembrane; and
- confirm that a smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage.

Fusion Process

CQA personnel shall perform the following activities during the fusion welding process:

- verify and document that the fusion-welding apparatus is a self-propelled device and that it is permanently marked with an identification number;
- verify that the fusion-welding apparatus is equipped with gauges giving the applicable temperatures and welding speed;
- verify that a suitable number of spare operable seaming apparatus are maintained on site;
- confirm that the electric generator is placed on a smooth base such that no damage occurs to the geomembrane;
- confirm that, for cross seams, the edge of the cross seam is ground to a smooth incline (top and bottom) prior to welding;
- verify that a smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and
- verify that a movable protective layer is used, as necessary, directly below each overlap of geomembrane that is to be seamed to prevent build-up of moisture between the sheets.

2.4.6.3 Seam Preparation

CQA personnel shall monitor that:

- weather conditions for seaming are within the limits required by the Specifications, unless authorized by the CQACE;
- prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material;

- seams are adequately overlapped;
- if seam overlap grinding is required, the process is completed according to the geomembrane manufacturer's instructions prior to the seaming operation, and in a way that does not damage the geomembrane;
- the grind depth shall not exceed 10 percent of the geomembrane thickness;
- grinding marks shall not appear beyond 0.25 inches of the extrudate after it is placed; and
- seams are aligned with the fewest possible number of wrinkles and "fishmouths".

2.4.6.4 Overlapping and Temporary Bonding

CQA personnel shall monitor that:

- the panels of geomembrane have a finished overlap of adequate width in accordance with the Specifications;
- no solvent or adhesive is used; and
- the procedure used to temporarily bond adjacent panels together does not damage the geomembrane; in particular, the temperature of hot air at the nozzle of any spot welding apparatus is controlled such that the geomembrane is not damaged.

2.5 Field Testing of Work Product

2.5.1 Trial Seams

CQA personnel shall observe and document the Contractor's trial seam testing procedures and verify that they are in accordance with the Specifications. CQA personnel shall document identification numbers of trial seam samples and record results. Each sample shall also be marked with the date, time, machine temperature(s) and setting(s), number of seaming unit, and name of seaming technician.

Trial seams shall be made prior to production seaming by all seamers and by all equipment to be used during production seaming. Trial seams shall be made on fragment pieces of geomembrane to verify that seaming conditions are adequate. Such

trial seams shall be made at the beginning of each seaming period, and at least once each four (4) hours, for each seaming apparatus used that day. Also, each seamer shall make at least one trial seam each day. The trial seam sample shall be at least 5 feet long by 1 foot wide (after seaming) with the seam centered lengthwise. Four specimens, each 1.0 inch wide, shall be cut from the trial seam sample by the Geosynthetic Installer. The specimens shall be tested in peel (both tracks for fusion welds), using an electronic readout field tensiometer, and the specimen shall fail by film tear bond (FTB) (i.e., failure in the parent material) rather than in the seam. Testing using the field tensiometer shall be performed in accordance with ASTM D 6392, at a strain rate of 2 in./min. Ideally, the samples shall be conditioned at 73°F at a relative humidity of 50 percent for two hours prior to testing. If test conditions vary from this requirement, then a 1-inch wide specimen of the parent geomembrane (no weld) shall be tested in the same manner as the seam specimens to determine the break strength at this condition. At no time shall the specimens be soaked in water.

2.5.2 Nondestructive Seam Testing

Nondestructive field seam testing shall be performed on all seams by the Contractor to check the continuity of seams. During the Contractor's nondestructive testing of field seams, CQA personnel shall confirm that seams are tested over their full length using either the vacuum test (for any seam type) or the air pressure test (for double fusion seams only). CQA personnel shall also monitor nondestructive testing and document the results, including at a minimum the following information:

- test location;
- date;
- test unit number;
- name of tester; and
- results of all testing.

CQA personnel shall notify the Contractor of any required repairs. Any required seam repairs identified as a result of failed nondestructive seam testing shall be made by the Contractor in accordance with the Specifications, and CQA personnel shall:

- observe the repair procedures;
- observe the retesting procedures; and
- document the results with the same information as above for the initial test.

- seams are adequately overlapped;
- if seam overlap grinding is required, the process is completed according to the geomembrane manufacturer's instructions prior to the seaming operation, and in a way that does not damage the geomembrane;
- the grind depth shall not exceed 10 percent of the geomembrane thickness;
- grinding marks shall not appear beyond 0.25 inches of the extrudate after it is placed; and
- seams are aligned with the fewest possible number of wrinkles and "fishmouths".

2.4.6.4 Overlapping and Temporary Bonding

CQA personnel shall monitor that:

- the panels of geomembrane have a finished overlap of adequate width in accordance with the Specifications;
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- the procedure used to temporarily bond adjacent panels together does not damage the geomembrane; in particular, the temperature of hot air at the nozzle of any spot welding apparatus is controlled such that the geomembrane is not damaged.

2.5 Field Testing of Work Product

2.5.1 Trial Seams

Trial seam testing shall be performed by the Contractor. CQA personnel shall observe and document the Contractor's trial seam testing procedures and verify that they are in accordance with the Specifications. CQA personnel shall document identification numbers of trial seam samples and record results. Each sample shall also

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be marked with the date, time, machine temperature(s) and setting(s), number of seaming unit, and name of seaming technician.

2.5.2 Nondestructive Seam Testing

Nondestructive field seam testing shall be performed on all seams by the Contractor to check the continuity of seams. During the Contractor's nondestructive testing of field seams, CQA personnel shall confirm that seams are tested over their full length using either the vacuum test (for any seam type) or the air pressure test (for double fusion seams only). CQA personnel shall also monitor nondestructive testing and document the results, including at a minimum the following information:

- test location;
- date;
- test unit number;
- name of tester; and
- results of all testing.

CQA personnel shall notify the Contractor of any required repairs. Any required seam repairs identified as a result of failed nondestructive seam testing shall be made by the Contractor in accordance with the Specifications, and CQA personnel shall:

- observe the repair procedures;
- observe the retesting procedures; and
- document the results with the same information as above for the initial test.

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2.5.3 Destructive Testing

2.5.3.1 Location and Frequency

CQA personnel shall select all destructive seam test sample locations in order to accomplish the sampling and testing frequencies given in Table 2-2. Sample locations shall be established by CQA personnel according to the guidelines given below.

- Test locations shall be determined during seaming at CQA personnel's discretion. Selection of such locations may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential cause of imperfect welding.

- The Geosynthetics Installer shall not be informed in advance of the locations where the seam samples will be taken.

2.5.3.2 Sampling Procedures

The Geosynthetics Installer shall cut the destructive samples at the locations designated by CQA personnel, under observation of the CQA personnel when possible. CQA personnel shall mark each sample accordingly and record the sample location on a Seam and Panel Repair Location Log. At a given sampling location, two types of samples shall be taken: (i) field test samples; and (ii) laboratory test samples. A minimum of two field samples (i.e., test strips) should be taken for field testing. Each of these test strips should be 1 in. wide by 12 in. long, with the seam centered parallel to the width. The distance between these two specimens should be 42 in. If both specimens pass the field test described in this Section, a second full laboratory destructive sample shall be taken for testing by the CQA Geosynthetics Testing Laboratory, as follows:

- The full destructive sample should be located between the two field test strips. The sample should be 12 in. wide by 42 in. long with the seam centered lengthwise. The sample shall be cut into three parts and distributed as follows:

  - one 12 in. by 12 in. portion retained by the Geosynthetics Installer;

  - one 12 in. by 12 in. portion archived by CQA personnel; and

- the remaining 12 in. by 18 in. portion should be forwarded immediately by CQA personnel to the CQA Geosynthetics Testing Laboratory.

All holes in the geomembrane resulting from destructive seam test sampling shall be immediately repaired by the Geosynthetics Installer in accordance with repair procedures described in Section 2.6. The continuity of the new seams in the repaired area shall be nondestructively tested, followed by the CQA procedures described in Section 2.5.2.

2.5.3.3 Field Testing

The test strips shall be tested for peel adhesion in the field by the Geosynthetics Installer, using a gauged tensiometer. CQA personnel shall observe all field tests and mark all samples and portions with their number. CQA personnel shall also document using the appropriate standardized field forms: the date, number of seaming unit, seaming technician identification, destructive sampling, and pass or fail description.

2.5.3.4 Laboratory Testing

Destructive test samples shall be tested by the Geosynthetics Testing Laboratory. The testing procedures are given in Table 2-2. Results shall be reviewed by CQA personnel as soon as they become available. The CQACE and Owner's Representative shall be notified of any inconsistencies or nonconformances.

2.5.3.5 Procedures for Destructive Test Failure

The following procedures shall apply whenever a sample fails a destructive test, whether that test was conducted in the field or by the Geosynthetics Testing Laboratory. CQA personnel shall monitor that the Geosynthetics Installer follows one of two options between points judged by CQA personnel to represent conditions of the failed seam (e.g., a tie-in seam or a seam made by the apparatus and/or operator used in the failing seam):

- The Geosynthetics Installer may reconstruct the entire seam (e.g., remove the old seam and reseam) between any two passed destructive test locations.

- The Geosynthetics Installer may trace the welding path to an intermediate location a minimum of 10 ft from the point of the failed test in each direction and take a small sample for an additional field testing in accordance with the destructive test procedure at each location. If these additional isolation samples pass the field test, then full laboratory samples are taken at both locations. If these laboratory samples meet the specified strength criteria, then the seam is reconstructed between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed.

Failed seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken or the entire seam is reconstructed and retested. In cases exceeding 150 ft of reconstructed seam, a sample taken from the zone in which the seam has been reconstructed must pass destructive testing. Repairs shall be made in accordance with this Section. CQA personnel shall document all actions taken in conjunction with destructive test failures.

2.6 Deficiencies, Problems, and Repairs

2.6.1 Inspection for Defects

All seams and non-seam areas of the geomembrane shall be examined by CQA personnel for identification of defects, holes, blisters, undispersed raw materials and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane should be clean at the time of examination.

2.6.2 Repair Procedures

Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, must be repaired by the Geosynthetics Installer. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be agreed upon between the Geosynthetics Installer, the CQACE, and the Owner's Representative.

In addition, the following conditions shall be monitored by CQA personnel:

- surfaces of the geomembrane which are to be repaired shall be abraded no more than one hour prior to the repair;
- all surfaces must be clean and dry at the time of the repair;
- all seaming equipment used in repairing procedures must be approved;
- the repair procedures, materials, and techniques are those approved by CQA personnel in advance of the specific repair;
- patches or caps should extend at least 6 in. beyond the edge of the defect, and all corners of patches should be rounded with a radius of at least 3 in.; and
- the geomembrane below large caps should be appropriately cut to avoid water or gas collection between the two sheets.

2.6.3 Verification of Repairs

Each repair shall be numbered, logged, and non-destructively tested using approved methods. Repairs which pass the non-destructive test shall be taken as an indication of an adequate repair. Large caps may be of sufficient extent to require destructive test sampling, at the discretion of CQA personnel or as specified in Table 2-2. CQA personnel shall observe all non-destructive testing of repairs and shall record the number of each repair, date, and test outcome.

TABLE 2-1

MATERIAL CONFORMANCE TESTING REQUIREMENTS FOR AGRU AMERICA, INC. 60-MIL HDPE SUPER GRIPNET® LINER (GEOMEMBRANE)

PROPERTY	QUALIFIER	UNITS	VALUES	TEST METHOD	TESTING FREQUENCY
Thickness	Nominal minimum	Mil Mil	60 55	ASTM D1777 or ASTM D5994	1 test/roll
Asperity Height	Nominal	Mil	195	GSI DM-12	1 test/roll
Density	minimum	g/cm^3	0.940	ASTM D1505/D792	1 test/resin lot
Minimum Tensile Properties 1. Tensile Strength at Yield 2. Tensile Strength at Break 3. Elongation at Yield 4. Elongation at Break	 minimum minimum minimum minimum	 lb/in. lb/in. Percent Percent	 90 100 10 100	ASTM D 6693	1 test/50,000 ft^2
Tear Resistance	minimum	Lbs	35	ASTM D1004 Die C	1 test/50,000 ft^2
Puncture Resistance	minimum	Lbs	60	ASTM D4833	1 test/50,000 ft^2
Low Temperature Impact	maximum	Deg. F	-60	ASTM D 746	Certification
Carbon Black Content	Range	Percent	2 to 3	ASTM D 1603	1 test/50,000 ft^2
Carbon Black Dispersion	N/A	Category	1 or 2	ASTM D5596	1 test/50,000 ft^2
Dimensional Stability	maximum change	Percent	±2	ASTM D 1204 (1 hr. @ 212°F)	Certification
Environmental Stress Crack	minimum	Hours	200	ASTM D5397	1 test/100,000 ft^2
Melt Flow Index	maximum	g/10 minutes	1.0	ASTM D 1238 Condition E	Certification
Drainage Stud Thickness	nominal	Mil	150		Certification
Drainage Studs distribution	nominal	Studs/ft^2	450		Certification
Transmissivity	minimum	m^2/s	1.3×10^{-3}	ASTM D4716(1)	1 test/200,000 ft^2

Note:

(1) Transmissivity measured using water at 20°C with a gradient of 0.33, under a vertical stress of 1200 psf after 1 hour. Test configuration from top to bottom: Protective soil layer/geotextile filter/Agru America, Inc. Super Gripnet liner.

Tensile ~~Bar~~ Test Δ

D6693 replaced D638

TABLE 2-1

MATERIAL CONFORMANCE TESTING REQUIREMENTS FOR AGRU AMERICA, INC. 60-MIL HDPE SUPER GRIPNET® LINER (GEOMEMBRANE)

PROPERTY	QUALIFIER	UNITS	VALUES	TEST METHOD	TESTING FREQUENCY
Thickness	Nominal minimum	Mil Mil	60 55	ASTM D1777 or ASTM D5994	1 test/roll
Asperity Height	Nominal	Mil	195	GSI DM-12	1 test/roll
Density	minimum	g/cm^3	0.940	ASTM D1505/D792	1 test/resin lot
Minimum Tensile Properties				ASTM D 638/639 Type IV-2 IPM	1 test/50,000 ft^2
1. Tensile Strength at Yield	minimum	lb/in.	90		
2. Tensile Strength at Break	minimum	lb/in.	100		
3. Elongation at Yield	minimum	Percent	10		
4. Elongation at Break	minimum	Percent	100		
Tear Resistance	minimum	Lbs	35	ASTM D1004 Die C	1 test/50,000 ft^2
Puncture Resistance	minimum	Lbs	60	ASTM D4833	1 test/50,000 ft^2
Low Temperature Impact	maximum	Deg. F	-60	ASTM D 746	Certification
Carbon Black Content	Range	Percent	2 to 3	ASTM D 1603	1 test/50,000 ft^2
Carbon Black Dispersion	N/A	Category	1 or 2	ASTM D5596	1 test/50,000 ft^2
Dimensional Stability	maximum change	Percent	±2	ASTM D 1204 (1 hr. @ 212°F)	Certification
Environmental Stress Crack	minimum	Hours	200	ASTM D5397	1 test/100,000 ft^2
Melt Flow Index	maximum	g/10 minutes	1.0	ASTM D 1238 Condition E	Certification
Drainage Stud Thickness	nominal	Mil	150		Certification
Drainage Studs distribution	nominal	Studs/ft^2	450		Certification
Transmissivity	minimum	m^2/s	1.3×10^{-3}	ASTM D4716(1)	1 test/200,000 ft^2

Note:

(1) Transmissivity measured using water at 20°C with a gradient of 0.33, under a vertical stress of 1200 psf after 1 hour. Test configuration from top to bottom: Protective soil layer/geotextile filter/Agru America, Inc. Super Gripnet liner.

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TABLE 2-2

FIELD TESTING REQUIREMENTS FOR AGRU AMERICA, INC. 60-MIL HDPE SUPER GRIPNET® LINER (GEOMEMBRANE) SEAMS

PROPERTY	QUALIFIER	UNITS	VALUES	TEST METHOD	TESTING FREQUENCY
Peel Adhesion	minimum	lb/in	80 (Fusion) 70 (Extrusion)	ASTM D 6392[1]	1 per 500 ft of seam
Shear Strength at Yield Point (i.e., Bonded Seam Strength)	minimum	lb/in	65 (Fusion) 55 (Extrusion)	ASTM D 6392[1]	1 per 500 ft of seam
Vacuum Testing Welded Seams				By Geosynthetics Installer	100 percent of extrusion seams
Air Pressure Testing Welded Seams				By Geosynthetics Installer	100 percent of fusion seams

Notes:

1. For peel adhesion, seam separation shall not extend more than 10 percent into the seam interface. Testing shall be discontinued when the sample has visually yielded.
2. For shear tests, the sheet shall yield before failure of the seam.

3. 8 OZ/YD^2 NON-WOVEN GEOTEXTILE FILTER

3.1 Overview

This section addresses the CQA procedures to be implemented with regard to the 8 oz/yd^2 geotextile filter (geotextile) to be placed directly above the A/A Super Gripnet® geomembrane liner. The following CQA activities are discussed in this section:

- Pre-Construction Qualifying of Material Sources;
- Material Conformance Testing;
- Field Evaluation/Monitoring of Construction Techniques; and
- Deficiencies, Problems, and Repairs.

3.2 Pre-Construction Qualifying of Material Sources

Prior to installation of the geotextile, the Geosynthetics Manufacturer or Geosynthetics Installer shall provide the CQAPM with manufacturer's certification statements and quality control information, including the following:

- Written certification, signed by a responsible party employed by the Manufacturer. The Manufacturer shall guarantee the minimum average roll values (95 percent lower confidence limit) are met for physical, mechanical, and environmental properties corresponding to the test procedures for the required material properties.
- Quality control certificates with test results, signed by a responsible party employed by the Manufacturer. Each quality control certificate shall include date, roll identification numbers, testing procedures, and results of quality control tests performed using the methods specified and at the required frequencies.

The CQAPM shall examine the manufacturer's certifications to verify that the property values listed on the certifications meet or exceed the specifications, and that

proper and complete documentation has been provided by the Manufacturer for the geotextile to be used at the site.

3.3 Material Conformance Testing

Conformance sampling of geotextile rolls may be performed either at the manufacturing plant or upon delivery of the rolls to the site. The laboratory test methods to be used for CQA conformance testing of the geotextile component of the cover system are given in Table 3-1.

Any nonconformance of the material's physical properties will be reported to the Owner's Representative and to the Manufacturer. The following procedure will apply whenever a geotextile material sample fails a conformance test:

- The manufacturer will be required to replace all of the rolls of material within the batch from which the sample that is not in conformance with the specifications was obtained. The material must be replaced with material that meets the requirements of the specifications.

- Alternatively, if the manufacturer, the owner, and the CQA Certifying Engineer (CQACE) all agree, CQA personnel may obtain additional conformance samples from the closest numerical roll on both sides of the roll from which the failing sample was obtained. These two samples must pass the conformance tests. If either of these samples fails to meet the requirements, samples will be collected from the five numerically closest untested rolls on both sides of the failed sample and tested by the CQA Testing Laboratory. These ten samples must pass the conformance tests. If any of these samples fail, a sample from every roll of the applicable geosynthetic material on site and a sample from every roll that is subsequently delivered from the manufacturer must be conformance tested by the CQA Testing Laboratory.

During conformance testing, CQA personnel may also verify that the manufacturer has identified all rolls of geosynthetic material with the following information:

- name of manufacturer;

- product identification;

- lot number;
- batch number;
- roll number; and
- roll dimensions.

3.4 Field Evaluation/Monitoring of Construction Techniques

During unloading and storage, the geotextile shall be handled to minimize damage. The geotextile shall also be stored in a manner that minimizes damage. CQA personnel shall inspect the geotextile rolls prior to use. Any damaged rolls shall be repaired or replaced.

The Geosynthetics Installer/Contractor shall be required to handle all geotextiles in such a manner as to ensure the materials are not damaged in any way. CQA personnel shall verify compliance with the following:

- immediately prior to geotextile placement, the underlying surface must be free of sharp protrusions or other obstructions that could potentially damage the material;
- in the presence of wind, the geosynthetics are weighted with sandbags (or equivalent ballast weight approved by CQA personnel), and that sandbags remain until replaced with an overlying layer;
- geotextiles are kept continually under slight tension to minimize the presence of wrinkles, and if necessary, the material is positioned by hand after being unrolled to minimize wrinkles;
- a visual examination of the material is carried out over the entire surface, after installation, to verify that no potentially harmful foreign objects, such as needles or tools, are present; and

- the geotextiles are not left exposed for longer than the maximum allowable period (as recommended by the Manufacturer) after placement unless a longer exposure period is approved by the CQACE and the Owner's Representative.

CQA personnel shall verify that, where required, geotextile components are continuously sewn, that geotextile components are overlapped a minimum of 6 inches prior to seaming, and that sewing is performed using polymeric thread and stitching type.

CQA personnel shall verify that the Contractor places all soil and aggregate materials on top of geotextiles in such a manner as to verify the following:

- the geotextile and underlying materials are not damaged;
- wrinkles are minimized; and
- excess tensile stresses are not produced in the geosynthetics.

3.5 Deficiencies, Problems, and Repairs

CQA personnel shall report to the Geosynthetics Installer/Contractor any deficiencies in surface on which the geosynthetic components will be placed, and shall not allow deployment until the underlying material is improved to the satisfaction of CQA personnel and in accordance with the Specifications.

CQA personnel shall verify that any holes or tears in the geosynthetics materials are repaired in accordance with the Specifications and manufacturer's recommendations. The extent of deficiencies shall be evaluated by observations, a review of records, or other means deemed appropriate by the CQACE.

The Geosynthetics Installer/Contractor shall correct the deficiency to the satisfaction of CQA personnel and the Owner's Representative. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then CQA personnel shall develop and present to the CQACE and the Owner's Representative suggested alternative solutions for approval. All retests or subsequent re-evaluations recommended by CQA personnel must verify that the deficiency has

been corrected before any additional work is performed by the Contractor in the area of the deficiency.

TABLE 3-1

MATERIAL CONFORMANCE TESTING REQUIREMENTS FOR 8 OZ/YD^2 NON-WOVEN GEOTEXTILE FILTER

PROPERTY	QUALIFIER	UNITS	VALUES	TEST METHOD	TESTING FREQUENCY
Mass Per Unit Area	nominal	oz/sq-yd	8	ASTM D5261	Note 1
Grab Tensile Strength	minimum	lbs	190	ASTM D4632	Note 1
Permittivity	minimum	sec^{-1}	0.90	ASTM D4491	Certification
Puncture Strength	minimum	lbs	110	ASTM D4833	Note 1
Burst Strength	minimum	psi	400	ASTM D3786, Method 4	Note 1
Trapezoidal Tear Strength	minimum	lbs	80	ASTM D4533	Note 1
Apparent Opening Size	minimum	sieve size	70	ASTM D4751	Certification

Notes:

(1) Testing shall be performed in accordance with manufacturer's recommendations or every 100,000 ft^2, whichever is more frequent.

CONSTRUCTION QUALITY ASSURANCE PLAN
FINAL COVER SYSTEMS

PIEDMONT LANDFILL AND RECYCLING CENTER
KERNERSVILLE, NORTH CAROLINA

JULY 1996

NORTH CAROLINA PROFESSIONAL SEAL 20443 ENGINEER PATRICK J. FLOOD

7-12-96

RUST ENVIRONMENT & INFRASTRUCTURE
P.O. BOX 24000
GREENVILLE, SOUTH CAROLINA 29616

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1.0 INTRODUCTION

Waste Management of Carolinas, Inc. (WMCI) currently owns and operates the Piedmont Landfill and Recycling Center (PLFRC) located at 9900 Freeman Road in Kernersville, North Carolina. The landfill facility operates under permit 34-06 and was originally permitted in 1989. The permit was renewed in 1994. The landfill facility is approximately 108 acres in Forsyth County and borders Guilford County. This Final Cover CQA Plan applies to the entire landfill unit.

This document only applies to the final cover system at PLFRC. Two alternative final cover designs are being proposed and are defined as follows:

Alternative 1: From the refuse, there shall be 1.5 feet of compacted cohesive soil with a specified maximum hydraulic conductivity of $1x10^{-5}$ cm/sec, 40 mil polyethylene textured geomembrane, a composite drainage layer consisting of geotextile/geonet/geotextile, and a minimum of 1.5 feet of protective cover with a minimum of the top 6 inches capable of supporting native vegetation.

Alternative 2: From the refuse, there shall be a minimum of 10 inches of compacted soil, geosynthetic clay liner (GCL), 40 mil polyethylene textured geomembrane, a composite drainage layer consisting of geotextile/geonet/geotextile, and 2 feet of protective cover with a minimum of the top 6 inches capable of supporting native vegetation.

Drawings of Alternative 1 and Alternative 2 are shown in Figure 1 at the end of the text.

The purpose of this document is to define the scope and procedures used to verify that the construction performed meets the project requirements. This document also details the formal procedures and test methods utilized to ensure conformance of construction to plans, specifications, or other criteria established for the project. The CQA Plan outlined herein will encompass the following elements on the PLFRC project:

a. Pre-Construction Testing
b. Compacted Soil Liner

c. Geomembrane Liner
d. Geosynthetic Clay Liner
e. Geocomposite Drainage Layer
f. Protective Cover/Vegetative Support Layer
g. Documentation Report

This Final Cover CQA Plan details the necessary information and guidance to verify that the final cover system is constructed in compliance with permitted plans and State regulations and guidance. The specified quality assurance testing and measures, along with the required testing frequencies, are also provided herein. Also detailed in this plan are the organization and minimum qualifications of the CQA personnel as well as the minimum standards for construction, testing, and documentation to assure quality construction

2.0 PROJECT QUALITY ASSURANCE/QUALITY CONTROL TEAM

Prior to starting construction activities, a preconstruction meeting will be held to discuss project details, including construction management organization, team member duties, and reporting requirements.

2.1 PROJECT TEAM RESPONSIBILITIES

The project team responsible for implementing the CQA Plan shall be technically accountable to the site owner or designated owner representatives. The CQA project team shall consist of a Quality Assurance Project Manager (CQAPM), Certifying Engineer (CE), Senior Site Quality Assurance (SSQA) Manager, and, if required, an appropriate number of technicians to accomplish the work plan. The CQA team shall use sound engineering judgement when determining what additional procedures, other than those outlined in this plan, may be required in order to further assure the construction quality. The CQA team shall operate independently of the designated owner representatives' quality control team. All designated owner representatives shall be responsible for submitting the procedures and results of their quality control program to the CQAPM for review, approval, and documentation.

2.2 CONSTRUCTION QUALITY ASSURANCE PROJECT MANAGER (CQAPM)

The CQAPM shall have experience managing geotechnical engineering, earthwork, and geosynthetics testing for CQA programs. The CQAPM shall be knowledgeable of permit requirements and design plans for the project. The CQAPM is responsible for ensuring that the flow of information between the SSQA Manager and CE is presented to the site owner and designated owner representatives for problem resolutions. If a construction procedure does not meet the design requirements, a resolution meeting will be called and all parties must agree on the action needed to bring the construction within the design requirements.

The CQAPM will visit the site to inspect and document the work activities periodically during the duration of the project. The CQAPM shall be responsible for the overall administration of the quality assurance procedures and for the control of construction quality control documents. The CQAPM shall be responsible for oversight and coordination of the CQA program (CE, SSQA Manager and CQA technicians), surveying, and testing laboratories. The CQAPM, CE, and SSQA Manager shall have frequent dialogue on project status.

2.3 CERTIFYING ENGINEER (CE)

The CE shall be a professional engineer registered in the State of North Carolina with experience performing geotechnical engineering and earthwork testing for other CQA programs. The CE shall have extensive knowledge of the design plans and CQA documents for the project and is responsible (in conjunction with the CQAPM) for informing the contractor or owner of any portion of the work or construction procedures that does not meet the design plans and CQA documents. The CE and the CQAPM may be the same individual.

The CE will periodically visit the site to examine the work to ensure that the design plans and CQA documents are being met. The CE shall also review field and laboratory test data as well as field reports to ensure design specification compliance. Any item requiring attention or approval shall be attended to promptly by the CE and CQAPM. The CE shall be responsible for certification of the final construction as being in conformance with the design plans and CQA documents. Final certification of any element of the project shall be based on conformance to the design plans and CQA documents, conformance to the plan as well as sound engineering judgement; CE shall have the ultimate responsibility for approving and disapproving any element of the project based on the above mentioned factors.

2.4 SENIOR SITE QUALITY ASSURANCE MANAGER (SSQA)

The SSQA Manager is the primary on-site representative of the CQA team. The SSQA Manager is responsible for performing or assuring performance of the sampling and testing required for implementation of this CQA plan. The SSQA Manager shall be selected by the CQAPM and CE and is accountable to the CQAPM. The SSQA Manager shall be familiar with the tests, processes, and materials involved in the construction of compacted cohesive soil, geomembrane liners, and other construction elements. The SSQA Manager shall be proficient in conducting laboratory tests, nuclear density and moisture content tests and visual soil classification; he should also be familiar with geomembrane liner testing and processes.

The SSQA Manager shall monitor all appropriate construction operations. He shall oversee sampling and field testing mandated in this plan, design plans, and specifications. The SSQA Manager shall log site operations together with the test results and submit them once a week to the CQAPM for

review and distribution. Any non-compliance item shall be documented and reported to the CQAPM immediately. If necessary, the CQAPM or CE shall assume the duties and responsibilities of the SSQA Manager.

2.5 QUALITY ASSURANCE TECHNICIANS

If required, Quality Assurance technicians may assist the SSQA Manager in performance of his duties. CQA technician(s) shall report directly to the SSQA Manager. All test results shall be forwarded daily to the SSQA Manager to be included in the weekly report.

3.0 DOCUMENTATION PROCEDURES

3.1 STANDARD REPORTING PROCEDURES

The SSQA Manager and/or the CQA Technicians shall issue reports of construction activities. These reports shall include, as a minimum, the following information:

1. An identifying sheet number for cross-referencing and documentation control.
2. Date, project name, location, and other identification.
3. Weather conditions.
4. Problems encountered and resolutions.
5. Descriptions and locations of ongoing construction.
6. Equipment and personnel in work area, including subcontractors.
7. Descriptions and specific locations of areas, or units, of work being tested and/or observed and documented.
8. Locations where samples were taken.
9. A summary of test results, failures, and retests.
10. Observations of the following operations for geosynthetics, as stipulated in this Final Cover CQA Plan:
    a. Material delivery
    b. Unloading and on-site storage and transport
    c. Sampling for conformance testing
    d. Deployment operations
    e. Jointing/seaming operations
    f. Conditions of panel before and after placement
    g. Visual inspection of walkovers
    h. Repair locations

3.1.1 Applicable Forms

The SSQA Manager will utilize forms appropriate to the type of information being recorded or transmitted. These forms will include Daily Field Reports, Weekly Progress Reports, and various soil test data reporting forms. In addition, various geosynthetic information and test data forms will be used. Other forms will be used as necessary.

3.2 PROBLEM/DEFICIENCY/IDENTIFICATION AND CORRECTIVE ACTION

The SSQA Manager is required to inform the General Contractor and/or the Geosynthetic Contractor, or their representatives, in a timely manner, of any difference between the interpretation of the plans and specifications by the contractors and the SSQA Manager. In addition, any actual or suspect work deficiencies shall be brought to the owner's representative's attention.

3.3 PLAN MODIFICATIONS

Design or specification changes shall be made only with written approval of the owner's representative and the Design Engineer. The CQAPM shall promptly document the information necessary whenever any approved changes are made in the field that deviate from the initial design or permit. This documentation shall be included in the Construction Documentation Report.

3.4 PHOTOGRAPHIC DOCUMENTATION

Photographs shall be taken to document observations, problems, or deficiencies, or work in progress. Photograph logs will include the date, location, direction of view, time of day, and description of activity. Photographs will be filed in chronological order in a permanent protective file by the SSQA Manager. One set of prints and negatives shall be turned over to the site owner at the conclusion of the project.

3.5 FINAL CONSTRUCTION DOCUMENTATION REPORT

After the completion of final cover construction, the SSQA Manager shall prepare a final documentation report covering the installation and testing of the complete final cover system. This report shall certify that construction of the final cover system has been constructed in substantial conformance with the design plans, permit, and this Final Cover CQA Plan. A copy of this report shall be issued to the site owner following completion of the protective/vegetative layer and project surveying.

3.5.1 Report Contents

The final documentation report shall include a narrative describing the construction activities and

schedule as well as summarizing soil and geosynthetic test results. Also, the report shall contain a section presenting a certification of closure construction. This certification section shall be signed and sealed by the CE.

CQA testing data generated during construction shall be included in appendices to the report. Also included will be copies of the Construction Meeting Minutes, Design Modifications, and Record Drawings.

3.5.2 List of Record Drawings

At a minimum, the documentation report will include the following Record Drawings:

1. Top of Compacted Cohesive Soil
2. Top of Protective/Vegetative Soil Layer
3. Geomembrane Perimeter Location

Record Drawings shall be prepared and sealed by a surveyor registered to practice in the State of North Carolina.

4.0 COMPACTED COHESIVE SOIL FOR ALTERNATIVE 1

4.1 PRECONSTRUCTION SAMPLING AND TESTING

Preconstruction sampling and testing will be conducted to determine the properties and suitability of soils for construction of the compacted cohesive soil cap. These requirements will be conducted according to Table 1.

The compacted cohesive soil shall be constructed in accordance with the following specifications, except where required differently by the design plans and specifications.

a. Compaction as necessary to meet the required permeability.
b. Allowable moisture content greater than or equal to optimum as determined by standard Proctor (ASTM D 698) and as necessary to meet specified permeability.
c. Required soil hydraulic conductivity of 1.0×10^{-5} cm/sec as determined by ASTM D 5084. (This is not required under the GCL for Alternative 2.)
d. Maximum compacted lift thickness of 6 inches or depth of sheepsfoot, whichever is less.
e. Minimum compacted cohesive soil lift thickness of 1.5 feet. (Minimum soil lift thickness of 10 inches if GCL is used.)
f. Not placed below temperatures of 32 degrees F; unless material temperature is demonstrated as above freezing.

4.2 CONSTRUCTION MONITORING

Quality control of the compacted cohesive soil shall consist of monitoring the work as soil construction procedures. Laboratory and field testing shall be performed in conjunction to ensure that compacted cohesive material conformance and construction performance specifications are achieved.

1) Monitoring and Observations

The SSQA Manager will monitor and test the compacted cohesive soil during construction to ensure performance specifications are achieved. The CE will visit the site periodically as construction progress warrants. Such visits will be frequent enough so that he is fully

knowledgeable of the construction methods and performance so that he can determine that quality control monitoring and testing activities are adequate to meet the terms and intent of this document.

Observations shall include, but not be limited to, the following:

a. Classification, moisture content and distribution, particle size, and other physical properties of the soil during placement and compaction.
b. Type and level of compactive effort, including roller type and weight, drum size and foot length, and number of passes.
c. Action of compaction equipment on soil surface (i.e. foot penetration, rolling, pumping, or shearing).
d. Maximum clod size and breakdown of soil structure.
e. Method of bonding lifts together for fill locations.
f. Removal of stones, roots or other foreign materials which may damage overlying geosynthetic components or adversely affect compaction, lift bonding, and in-place testing/sampling.
g. Repair of areas where damage due to excess moisture, insufficient moisture, or freezing may have occurred.

2) Construction Testing

During compacted cohesive soil construction, the minimum testing and sampling program shown in Table 1 shall be conducted to ensure that adequate compaction and material conformance are being achieved.

4.3 POST-CONSTRUCTION CARE OF THE COMPACTED COHESIVE SOIL

The constructed cohesive soil shall be protected from desiccation and frost damage. Conversely, the area shall be kept free of standing water by adequately grading and/or water removal. Damage caused by rain shall be repaired, and if the lift must be reworked, then appropriate retesting shall be performed.

5.0 GEOSYNTHETICS

This section presents general procedures, quality control and quality assurance testing requirements for the geosynthetic components used in construction. The geosynthetic liner system for this project may include the following components:

a. Geonet with a double-sided heat bonded non-woven geotextile
b. 40- mil textured geomembrane - Presently CoverSeal™ will be used, although an equivalent textured polyethylene geomembrane may be substituted in the future
c. Geosynthetic Clay Liner

5.1 PRE-INSTALLATION MATERIAL EVALUATION

Prior to the installation of any geosynthetic layer (geomembrane or geocomposite), the manufacturer or installer shall provide the CQAPM with quality control certificates signed by an acceptable responsible party employed by the manufacturer. Each quality control certificate shall include roll identification numbers, testing procedures, and results of quality control tests. The quality control tests shall be performed in accordance with project-specific testing methods and subject to the following testing frequency. The quality control testing may be performed in the manufacturing plant. The CQAPM shall review the test results prior to acceptance to ensure that the certified minimum properties meet the project specifications. Results shall be given for the tests presented below. Details on acceptance criteria are presented on Table 2.

Geocomposite

1 per 40,000 ft^2	• Mass Per Unit Area (ASTM D 3776) • Thickness (ASTM D 1777) • Geotextile-Geonet Adhesion (ASTM D 413)

Geosynthetic Clay Liner

1 per 10,000 ft^2	• Moisture Content (ASTM D 4643) • Mass Per Unit Area (ASTM D 3776)
(1 per 100,000 ft^2)	• Hydraulic Conductivity (GRI GCL-2)

Geomembrane

1 per 100,000 ft^2	• Density (ASTM D 1505)
	• Carbon Black Content (ASTM D 1603)
	• Thickness (ASTM D 5199)
	• Tensile Properties (ASTM D 638)
(1 per 250,000 ft^2)	• Multi-Axial Tensile Elongation (GRI GM-4)

1) Handling and Storage of Geosynthetics

Geosynthetics are usually shipped in rolls and shall be marked to show the following minimum information. Manufacturer's certificates should be cross-referenced to rolls delivered on site.

a. Name of manufacturer/fabricator
b. Product type
c. Product thickness
d. Manufacturing batch code or roll number
e. Date of manufacture
f. Physical dimensions (length and width)

The SSQA Manager or the CQA technicians shall inspect the geosynthetic material. The material shall be inspected for any damages from punctures, tears, blocking, and crumpling during preparation for shipment or unloading. The shipment should be rejected if the product is not consistent with what was originally approved.

5.2 CONFORMANCE TESTING

The manufacturer's quality control certificates will be used to show conformance to the project specifications. The quality control certificates shall be submitted to SSQA Manager for review, comment, and inclusion into the final report.

The CQAPM or his field staff shall ensure that geomembrane property values guaranteed by the manufacturer in its specifications are met.

5.3 GEOMEMBRANE INSTALLATION

1) Liner Subgrade Preparation and Acceptance

Prior to the installation of the geomembrane, the liner subgrade shall be checked for irregularities, protrusions, debris, stones, standing water, and abrupt changes in grade. The soil liner surface shall be prepared by rolling with a smooth-drum roller or hand-worked to minimize the surface roughness and to flatten protruding soil or rock particles prior to geomembrane deployment. Loose rocks/stones which could damage the geomembrane shall be removed. Excessive voids, dimples or pit marks shall be filled in with a similar soil mixture. The surface shall not exhibit excessive desiccation or pumping prior to geomembrane deployment. Written acceptance of the subgrade is required from both the geomembrane's installer and the SSQA Manager prior to deployment.

2) Geomembrane Deployment

The geomembrane shall be installed in direct and uniform contact with the compacted cohesive soil or GCL and shall not be placed during inclement weather. Seaming should not take place when ambient temperatures are below 40°F or above 104°F unless trial seams reveal acceptable results at lower/higher temperatures. In general, no support equipment shall be allowed on the geomembrane. Personnel working on the geomembrane shall not smoke, wear damaging shoes, or engage in any other activity likely to damage the geomembrane. Only those sections of the geomembrane that are to be placed and seamed in one day should be unrolled.

3) Panel Marking

For this project, liner markings shall be color coded. Any spray paint used must be environmentally safe and be water-based. Writing on the liner shall be strictly limited to documentation purposes only.

4) Panel Installation

In general, seams should be oriented parallel to the line of maximum slope, i.e., oriented up and down, not across the slope. In corners and odd-shaped geometric locations, the number of field seams should be minimized. When horizontal seams are necessary, adjacent seams shall be staggered horizontally, with the up slope panel overlapping the lower panel ("shingling"). Avoid locating panel intersections closer than 5 feet to the toe of the slope. Objects such as leachate collection sump risers, cleanout riser pipes, and gas vents which will penetrate the cover shall be booted as necessary to prevent infiltration of water or migration of landfill gas.

Panels shall have a minimum four inches finished overlap. Field seaming shall only be performed by the method or methods approved by the manufacturer, either by extrusion welding or double-tracked fusion welding. Fishmouths or wrinkles at the seam overlap shall be cut along the ridge of the wrinkle in order to achieve a flat overlap and the cut shall be seamed and/or patched. Patches shall extend at least 6" beyond the cut in all directions. Seams shall extend to the outside edge of panels placed in the anchor trench.

Panel layout and field seams shall be given an identification code, mapped and logged to record relevant installation information. Minor, superficial scars that are extruded will not receive a repair number. All butt seams, inner cell tie-ins, perimeter envelope seams shall be treated as one seam and have continuous stationing.

5.4 GEOMEMBRANE INSTALLATION QUALITY CONTROL

The SSQA Manager or the CQA technicians will visually monitor sheet quality and periodic seaming procedures during installation. The installer is responsible for providing and documenting quality control testing of the installed material in accordance with the drawings and specifications.

The installer's QC technicians shall monitor and document the following installation and testing operations and provide a copy to the SSQA Manager or CE for review:

a. Trial Seams
b. Panel Placement
c. Panel Seaming

d. Nondestructive Testing
e. Destructive Seam Testing
f. Test Failures and Repairs

Refer to Table 3 for minimum acceptable values for peel and shear testing.

5.5 GEOSYNTHETIC CLAY LINER INSTALLATION

During shipment and storage, the GCL shall be protected from ultraviolet light exposure, precipitation, excessive humidity, puncture, cutting, or any other damaging conditions. GCL rolls shall be stored away from wet ground and be covered with a watertight tarp or under a roof to protect the stored rolls from hydration. The roll wrappings shall be removed shortly before deployment.

The SSQA Manager shall observe rolls prior to deployment at the site and report any deviations from the above requirements to the CQA PM and the Site Engineer.

The SSQA Manager shall review the GCL panel deployment progress and advise the CQAPM on its conformance with the actual field conditions. The SSQA Manager shall verify that the Installer handles the GCL material in such a manner as to ensure that it is not damaged, and the following are complied with:

1. On slopes, the GCL rolls shall be securely anchored and the GCL material then deployed down the slope in such a manner as to keep the GCL panel in tension.
2. The GCL should be installed with the proper side of the material facing upward. The proper orientation of the material should be specified by the project specifications.
3. The Installer shall take any necessary precautions to prevent damage to the underlying soil during placement of the GCL.
4. During placement of the GCL, care shall be taken not to entrap beneath the GCL any stones, excessive dust or moisture that could damage the GCL.

5. After installation, a visual examination of the GCL shall be carried out over the entire surface to ensure that no potentially harmful foreign objects damaged areas are present.
6. Excess loss of bentonite on edges during deployment should be minimized.

No more GCL material should be deployed during one working day than can be covered by the end of that day. Exceptions to this requirement may occur if dry weather is forecast for several consecutive days. GCL deployment shall not be undertaken during precipitation or when there is an immediate threat of precipitation. Adjacent GCL panels shall be joined according to project plans and specifications and meet the following requirements:

1. Edge seam overlaps shall be a minimum of 6 inches.
2. Roll end seam overlaps shall be a minimum of 12 inches.
3. End to end seams on slopes shall be minimized. If they are required, the SSQA Manager shall contact the Design Engineer to verify the method used to attach the GCLs has adequate tensile strength.

Any portion of the GCL exhibiting flaws shall be repaired. Prior to acceptance of the installed GCL, the Installer shall locate and repair damaged areas of the liner as directed by the SSQA Manager. Defects or damage can be identified by either rips or tears in the GCL, delamination of the geotextiles, or premature hydration.

Rips or tears in the GCL shall be covered by another piece of material meeting the project specifications. The material shall extend over the entire damaged area with a minimum six inch overlap in all directions. Addition of bentonite to patches shall be in accordance with the project specifications.

Where the GCL has been exposed to moisture prior to placement of overlying material, the material shall be removed and replaced with material meeting the project specifications.

5.6 GEOCOMPOSITE INSTALLATION

The installer shall handle all geocomposite in such a manner as to ensure that it is not damaged in any way. During placement of geocomposite, care shall be taken not to entrap dirt or excessive dust in

the geonet that could cause clogging of the drainage system, and/or stones that could damage the adjacent geomembrane. If dirt or excessive dust is entrapped in the geocomposite, it should be cleaned prior to placement of the next material on top of it. In this regard, care shall be taken with the handling of sandbags, to prevent puncturing the sandbag.

Geocomposite seams and overlaps must, at a minimum, meet the following requirements:

a. Adjacent rolls shall be overlapped by at least 4 inches.
b. The geonet overlaps shall be tied with plastic fasteners. Tying devices shall be white or yellow for easy inspection. Metallic devices are not allowed.
c. Tying shall be every 5 feet along the length at the adjacent rolls and every 6 inches along end-to-end seams.
d. In the corners of the sideslopes, where overlaps between perpendicular geocomposite strips are required, an extra layer of geocomposite shall be unrolled along the slope, on top of the previously installed geocomposite, from top to bottom of the slope.

The geotextile portion of the geocomposite shall be continuously sewn. Spot sewing is not allowed. Any sewing shall be done using thread with chemical and ultraviolet light resistance properties equal to or exceeding those of the geotextile. The color of the sewing thread shall contrast the background color of the geotextile. Sewing shall be done using machinery and stitch types specified in the project specifications or as approved in writing by the owner's representative and the CE.

5.7 GEOCOMPOSITE REPAIRS

Any holes or tears in the geocomposite shall be repaired using the following two procedures.

a. On sideslopes, a patch made from the same geocomposite shall be thermally bonded into place in accordance with the project specifications. Should any tear exceed 10% of the width of the roll, that roll shall be removed from the slope and replaced.

b. On non-sideslope areas, a patch made from the same geocomposite shall be thermally bonded into place with a minimum of 12 inches overlap in all directions. Care shall be taken to remove any soil or other material which may have penetrated the torn geocomposite.

6.0 PROTECTIVE\VEGETATIVE COVER

A minimum of 18 inches will be placed on Alternative 1, and 24 inches will be placed over the GCL (Alternative 2). The protective and vegetative cover system is installed to protect the components of the lining system and help minimize erosion by supporting vegetative growth. The top 6 inches of the protective layer will be capable of supporting vegetative growth. Before the protective or vegetative cover is placed over the geomembrane, all destructive and nondestructive testing must be completed and approved by the CQAPM.

1) Preconstruction Material Evaluation

Materials selected for use in the protective/vegetative cover system shall be verified by the SSQA Manager to comply with the design plans for the project. Materials for the vegetative layer and protective cover layer shall be selected to meet the performance requirements specified in the design which should include requirements for particle size. Representative samples of the protective\vegetative layers shall be obtained and tested in accordance with the following schedule:

Preconstruction Material Testing for Protective/Vegetative Materials		
Test	**Method**	**Frequency**
Particle-Size Analysis	**ASTM D 422**	**1/source**

2) Construction Conformance Testing

Protective cover materials selected for use shall be tested at regular intervals for minimum thickness verifications. Minimum testing frequency shall be one thickness measurement per acre.

Placement of protective cover materials over geosynthetic liners shall generally not proceed at ambient temperatures below 32°F or above 104°F, but should be conducted at the coolest part of the day to minimize the development of wrinkles or folding of the geosynthetic materials. A minimum of one foot of material is required between low ground pressure dozers and the geomembrane. Greater material thickness must be maintained above the geomembrane to support heavier spreading

equipment and hauling vehicles. In such cases, a minimum thickness of two feet of protective cover shall be used unless otherwise specified in the design. The vegetative layer or protective cover does not necessarily require compaction control. The firmness of the vegetative cover varies with the type of vegetation specified for the cover. Care shall be exercised in placement so as not to shift or damage the underlying geosynthetic layers. The overall thickness of protective/vegetative cover materials shall be verified by either survey methods or careful excavations with thickness measurements.

TABLE 1

QA Testing Frequencies and Criteria for Compacted Cohesive Soil

Pre-Construction Qualification		
Test	**ASTM Method**	**Quantity**
Atterberg Limits	D4318	1 per source
Compaction	D698	1 per source
Particle Size	D1140	1 per source
Moisture Content	D2216	1 per source
Permeability	D5084	1 per source
Construction Testing		
Atterberg Limits	D4318	1/5,000 yd^3
Compaction	D698	1/5,000 yd^3
Particle Size	D1140	1/5,000 yd^3
Moisture Content	D2216	1/5,000 yd^3
Permeability	D5084	1/5,000 yd^3
Nuclear Density/Moisture	D2922	1/lift/10,000 ft^2
Testing Criteria		
Classification	CL, CH, SC, ML, MH, CL-ML	
Particle Size	Maximum size 4 inches	
Organics	PT, OH, OL not suitable for fill	

TABLE 2

QA Testing Frequencies and Criteria For Geosynthetic Clay Liner (Manufacturer's Data)

Test Name	Test Method	Frequency	Specified Value
Moisture Content (Bentonite)	ASTM D 4643	1/10,000 ft^2	10 percent max.
Mass per Unit Area	ASTM D 3776	1/10,000 ft^2	1.06 lbs/ft^2 min.
Hydraulic Conductivity	GRI GCL-2	1/100,000 ft^2	$1x10^{-9}$ cm/sec max.

TABLE 3

Minimum Peel and Shear Testing Values

40-mil Coverseal				
Geomembrane Seams				
Property	**Qualifier**	**Unit**	**Specified Value**	**Test Method**
Bonded Seam Strength	Min.	lb/in	35	ASTM D 4437*
Peel Adhesion:				
Fusion	Min.	lb/in	30	ASTM D 4437*
Extrusion	Min.	lb/in	25	ASTM D 4437*

*Note: Test Methods Modified

Coverseal		
Test Method Modifications		
Property	**Test Method**	**Modifications**
Tensile Properties	ASTM D 638	Type IV Die. ASTM D 638 test specimen shall be used. The Grip separation shall be 2.5 inches. This test does not require the use of extensometers. The rate of grip separation will be 2 inches per minute. A gauge length of 1.3 inches for yield values, and 2.0 inches for break values shall be used to calculate percent elongation from grip movement.
Bonded Seam Strength and Peel Adhesion	ASTM D 4437	For shear tests, the sheet shall yield before failure of the seam. For peel adhesion, seam separation shall not extend more than 10% into the seam. For either test, testing shall be discontinued when the sample has visually yielded.

APPENDIX B

COVERSEAL MANUFACTURER'S SPECIFICATIONS

40 mil *FRICTION SEAL CS* GEOMEMBRANE
QUALITY CONTROL SPECIFICATIONS

FRICTION SEAL CS, National Seal Company's advanced textured polyethylene geomembrane is manufactured by attaching a friction surface to NSC's high quality *CoverSeal* geomembrane. The Friction surface is made from high molecular weight polyethylene resins compounded specifically for use in NSC geomembranes. The resins have been formulated to provide chemical and ultraviolet resistance for final cover applications. NSC produces *FRICTION SEAL CS* with a textured surface on one or both sides of the parent sheet.

The following properties, considered to be the most applicable for final cover applications, are tested every 100,000 ft^2 of geomembrane. Multi-axial tensile elongation is tested every 250,000 ft^2.

SHEET PROPERTIES	METHOD	UNITS	MINIMUM[1]
Thickness	ASTM D5199		
Average		mils	40.0
Individual		mils	36.0
Density[2]	ASTM D 1505	g/cm^3	0.92 - 0.94
Carbon Black Content[2]	ASTM D 1603	percent	2.0 - 3.5
Tensile Properties[3]	ASTM D 638		
Stress at Break		psi	2300
Strain at Break	2.0" gage length	percent	300
	2.5" gage length (NSF)	percent	240
Multi-axial elongation	GRI, GM-4	percent	30

1 Except where noted, this value represents the minimum acceptable test value for a roll.

2 Testing performed on base sheet.

3 Stress and strength values are normalized to the nominal base sheet thickness. NSC certifies properties based on values calculated using nominal thickness only. Stress values calculated using actual product thickness is not guaranteed due to the lack of industry accepted thickness test procedures for friction sheet.

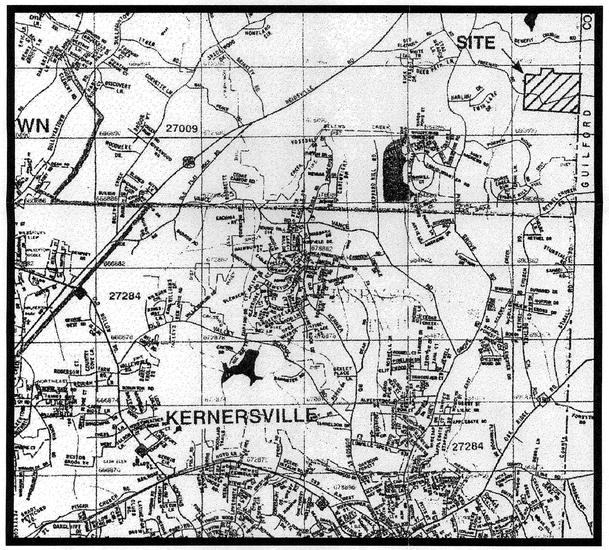
STANDARD ROLL DIMENSIONS

Width 15 feet Weight 3,000 lbs

This information contained herein has been compiled by National Seal Company and is, to the best of our knowledge, true and accurate. All suggestions and recommendations are offered without guarantee. Final determination of suitability for use based on any information provided, is the sole responsibility of the user. There is not implied or expressed warranty of merchantability of fitness of the product for the contemplated use.

NSC reserves the right to update the information contained herein in accordance with technological advances in the material properties.

DESIGN DRAWINGS
RECONSTRUCTION OF AN AREA OF PHASE 2 FINAL CLOSURE
PIEDMONT LANDFILL
KERNERSVILLE, NORTH CAROLINA
MAY 2005



NO SCALE

LOCATION MAP

LIST OF DRAWINGS

DRAWING NO.	DESCRIPTION
1	COVER SHEET
2	EXISTING SITE CONDITIONS
3	SURFACE WATER DRAINAGE PLAN
4	MISCELLANEOUS DETAILS

DETAIL IDENTIFICATION LEGEND

2 / 16 — Detail Number; Sheet on which above detail is presented

Detail Number — 2 / 5 — Sheet on which above detail was first referenced

DETAIL
TITLE OF DETAIL
SCALE: 1" = 1'
DWG: DETLEGEND

Example: Detail Number 2 presented on Sheet No. 16 was referenced for the first time from Sheet No. 5.

Note: Above system also applies to section identifications.

PREPARED FOR:

WASTE MANAGEMENT OF CAROLINAS, INC.

2859 PACES FERRY ROAD
SUITE 1600
ATLANTA, GEORGIA 30339

PREPARED BY:

GEOSYNTEC CONSULTANTS

1255 ROBERTS BLVD, SUITE 200
KENNESAW, GEORGIA 30144
(678) 202-9500

MARK	DATE	REVISION	BY	APPROVED
–	--	--	–	–

GEOSYNTEC CONSULTANTS
1255 ROBERTS BOULEVARD, SUITE 200
KENNESAW, GEORGIA 30144-3694

WASTE MANAGEMENT OF CAROLINAS, INC.

PROJECT: PIEDMONT LANDFILL

TITLE: COVER SHEET

Received MAY 2005 Solid Waste Section

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SIGNATURE

12 May 2005
DATE

NORTH CAROLINA PROFESSIONAL SEAL 24769 ENGINEER MAJID A. OTHMAN

SEAL

DATE:	MAY 2005	SCALE:	AS SHOWN
DESIGN BY:	TYE/BG	JOB NO.:	NCP2005-3204
DRAWN BY:	JJA	FILE NO:	3204-A001
CHECKED BY:	TYE /BG	REVISION NO:	–
REVIEWED BY:	MAO	DRAWING NO:	1 OF 4
APPROVED BY:	MAO		

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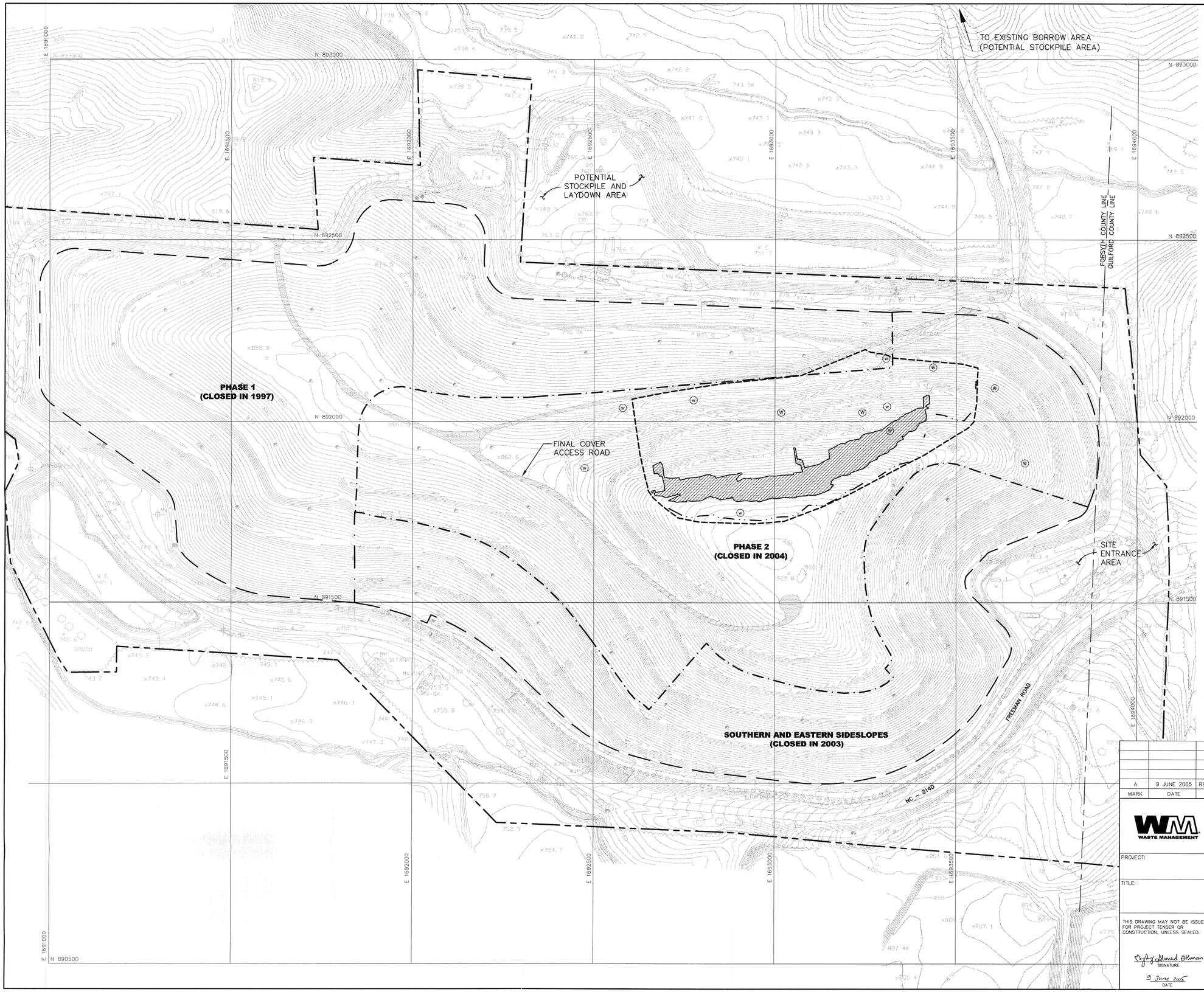

LEGEND

- 780 — CONTOUR OF EXISTING GRADE (FEET, MSL)
- COUNTY BOUNDARY
- FENCE LINE
- PROPERTY LINE
- TREE / BRUSH LINE
- APPROXIMATE LIMIT OF LANDFILL
- PHASE 2 BOUNDARY
- BOUNDARY BETWEEN PHASE 1 AND SOUTHERN/EASTERN SIDESLOPES
- EXISTING FINAL COVER ACCESS ROAD
- TREE
- MW-07 — EXISTING MONITORING WELL
- APPROXIMATE LIMIT OF FINAL COVER RECONSTRUCTION AREA
- CRACKING IN COVER SOIL
- EXPOSED GCL
- EXISTING GAS WELL
- W — GAS WELL WITHIN OR NEAR RECONSTRUCTION AREA

Received
JUN 2005
Solid Waste Section

NOTES:

1. TOPOGRAPHIC MAP IS FROM AERIAL PHOTOGRAPHY DATED 20 MARCH 2005 PROVIDED IN AN ELECTRONIC FILE BY AIR SURVEY PHOTOGRAMMETRIC MAPPING SERVICES OF DULLES, VIRGINIA, AND COMPILED BY PHOTO-GRAMMETRIC METHODS.
2. GRID BASED ON NORTH CAROLINA STATE PLANE COORDINATE SYSTEM, NAD 1927.
3. VERTICAL DATUM BASED ON NGS MEAN SEA LEVEL.

120 60 0 120 240
SCALE IN FEET

MARK	DATE	REVISION	BY	APPROVED
A	9 JUNE 2005	RESPONSE TO NCDENR COMMENTS	TYE	MAO

WASTE MANAGEMENT

GEOSYNTEC CONSULTANTS
1255 ROBERTS BOULEVARD, SUITE 200
KENNESAW, GEORGIA 30144-3694

WASTE MANAGEMENT OF CAROLINAS, INC.

PROJECT: PIEDMONT LANDFILL

TITLE: EXISTING SITE CONDITIONS

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

9 June 2005
DATE

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 24769 MAJID A. OTHMAN
SEAL

DATE:	MAY 2005	SCALE:	1" = 120'
DESIGN BY:	BG	JOB NO.:	NCP2005-3204
DRAWN BY:	JJA	FILE NO:	3204-A002
CHECKED BY:	TYE/BG	REVISION NO:	A
REVIEWED BY:	MAO	DRAWING NO:	2 OF 4
APPROVED BY:	MAO		

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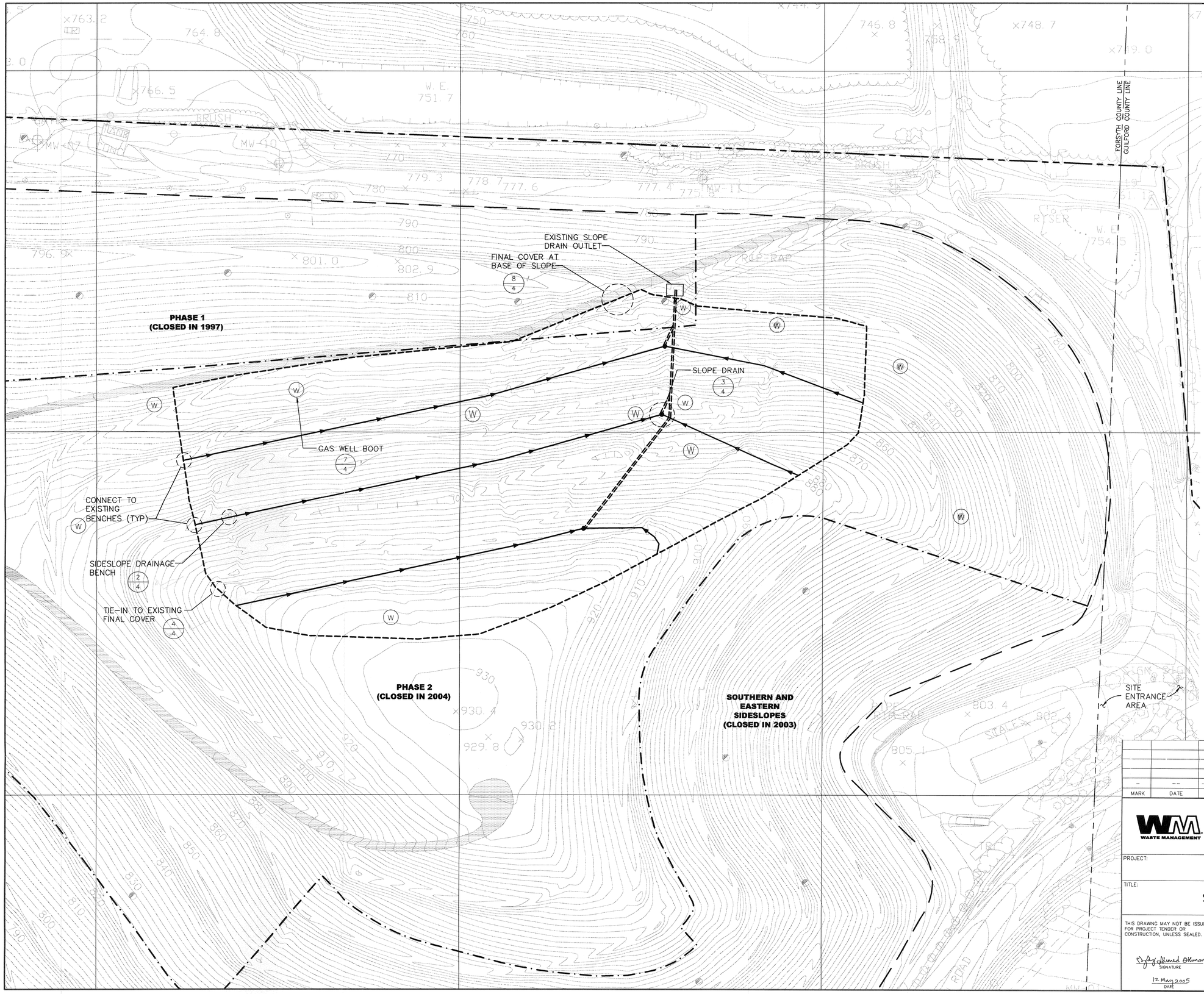

LEGEND

- 780 — CONTOUR OF EXISTING GRADE (FEET, MSL)
- COUNTY BOUNDARY
- FENCE LINE
- PROPERTY LINE
- TREE / BRUSH LINE
- APPROXIMATE LIMIT OF LANDFILL
- PHASE 2 BOUNDARY
- EXISTING FINAL COVER ACCESS ROAD
- TREE
- MW-07 — EXISTING MONITORING WELL
- APPROXIMATE LIMIT OF FINAL COVER RECONSTRUCTION AREA (NOTE 4)
- EXISTING GAS WELL
- W — GAS WELL WITHIN OR NEAR RECONSTRUCTION AREA
- SLOPE DRAIN PIPE
- SIDE SLOPE DRAINAGE BENCH (NOTE 5)

NOTES:

1. TOPOGRAPHIC MAP IS FROM AERIAL PHOTOGRAPHY DATED 20 MARCH 2005 PROVIDED IN AN ELECTRONIC FILE BY AIR SURVEY PHOTOGRAMMETRIC MAPPING SERVICES OF DULLES, VIRGINIA, AND COMPILED BY PHOTO-GRAMMETRIC METHODS.
2. GRID BASED ON NORTH CAROLINA STATE PLANE COORDINATE SYSTEM, NAD 1927.
3. VERTICAL DATUM BASED ON NGS MEAN SEA LEVEL.
4. THE AREA DELINEATED AS THE AREA OF FINAL COVER RECONSTRUCTION IS SHOWN AS THE MINIMUM ANTICIPATED REPAIR AREA. IF DURING RECONSTRUCTION, SIGNS OF DISTRESS FROM PAST MOVEMENT ARE OBSERVED, THE RECONSTRUCTION AREA SHALL BE EXTENDED TO ENCOMPASS THESE AREAS.
5. THE LOCATIONS OF PROPOSED BENCHES ARE APPROXIMATE. BASED ON ACTUAL FIELD CONDITIONS, THE BENCHES SHALL (i) CONNECT THE EXISTING BENCHES TO THE SLOPE DRAIN AND (ii) BE BUILT WITH A MINIMUM LONGITUDINAL SLOPE OF 3 PERCENT.

60 30 0 60 120
SCALE IN FEET

MARK	DATE	REVISION	BY	APPROVED
–	--	--	–	–

WASTE MANAGEMENT

GEOSYNTEC CONSULTANTS
1255 ROBERTS BOULEVARD, SUITE 200
KENNESAW, GEORGIA 30144-3694

WASTE MANAGEMENT OF CAROLINAS, INC.

PROJECT:
PIEDMONT LANDFILL

TITLE:
SURFACE WATER DRAINAGE PLAN

Received MAY 2005 Solid Waste Section

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SIGNATURE

12 May 2005
DATE

NORTH CAROLINA PROFESSIONAL SEAL 24769 ENGINEER MAHMOUD A. OTHMAN
SEAL

DATE:	MAY 2005	SCALE:	1" = 60'
DESIGN BY:	BG	JOB NO.:	NCP2005-3204
DRAWN BY:	JJA	FILE NO:	3204-A003
CHECKED BY:	TYE	REVISION NO:	–
REVIEWED BY:	MAO	DRAWING NO:	3 OF 4
APPROVED BY:	MAO		

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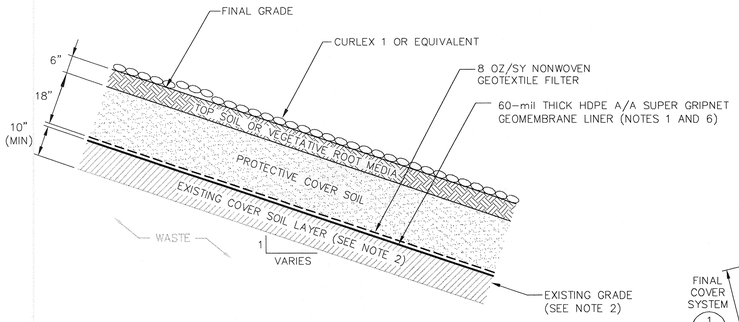
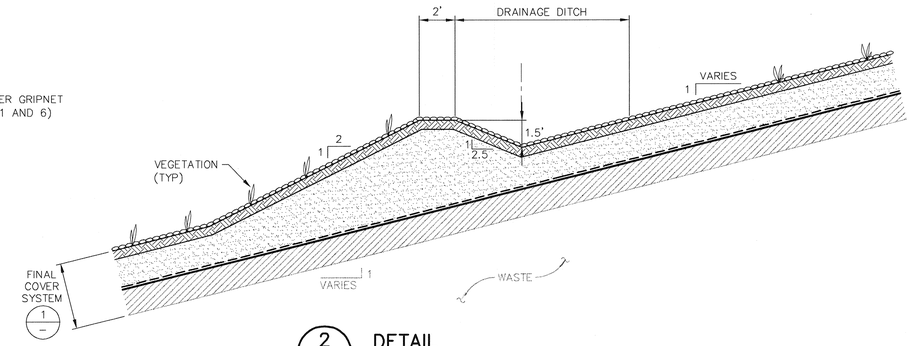
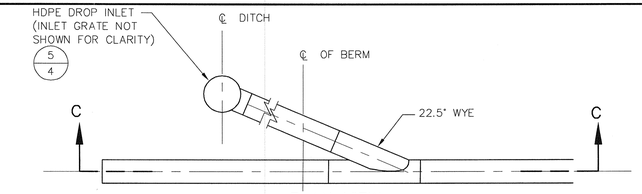


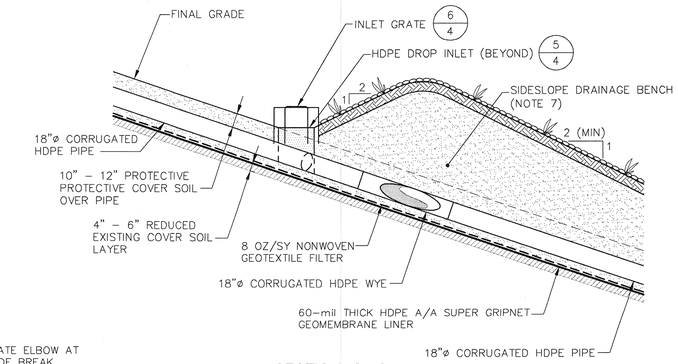
1/3 DETAIL
FINAL COVER SYSTEM USED FOR EXISTING COVER RECONSTRUCTION
SCALE: 1" = 2'



2/3 DETAIL
SIDE SLOPE DRAINAGE BENCH
SCALE: 1" = 4'

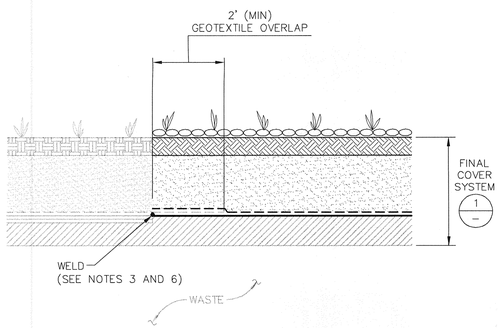


PLAN VIEW

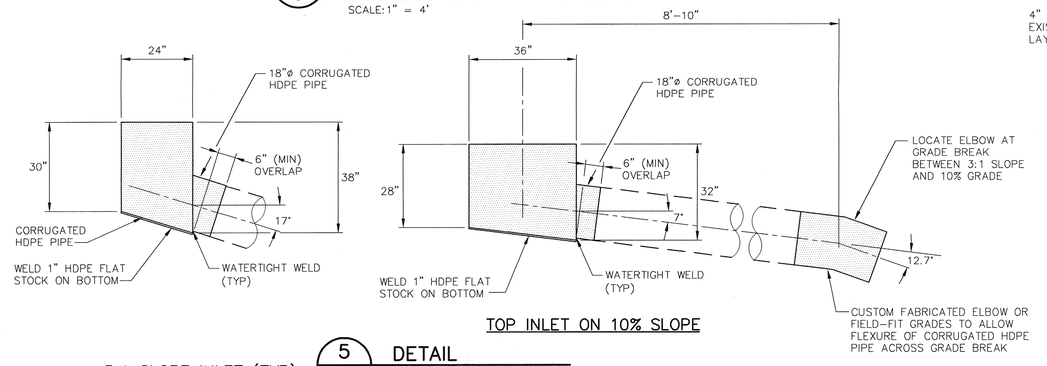


SECTION C–C

3/3 DETAIL
SLOPE DRAIN
SCALE: 1" = 4'
(SEE NOTES 7, 8, 9, AND 10)



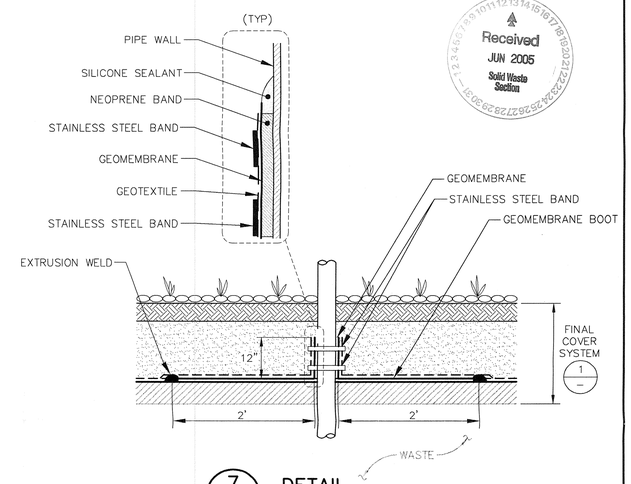
4/3 DETAIL
TIE–IN TO EXISTING FINAL COVER
SCALE: 1" = 2'
(SEE NOTE 1)



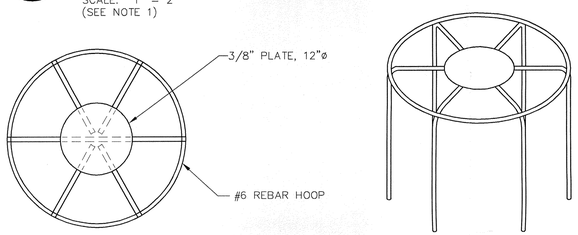
3:1 SLOPE INLET (TYP)

TOP INLET ON 10% SLOPE

5/4 DETAIL
HDPE DROP INLET
SCALE: 1" = 2'

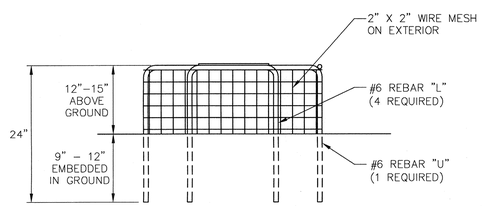


7/3 DETAIL
GAS WELL BOOT
SCALE: NTS



PLAN VIEW

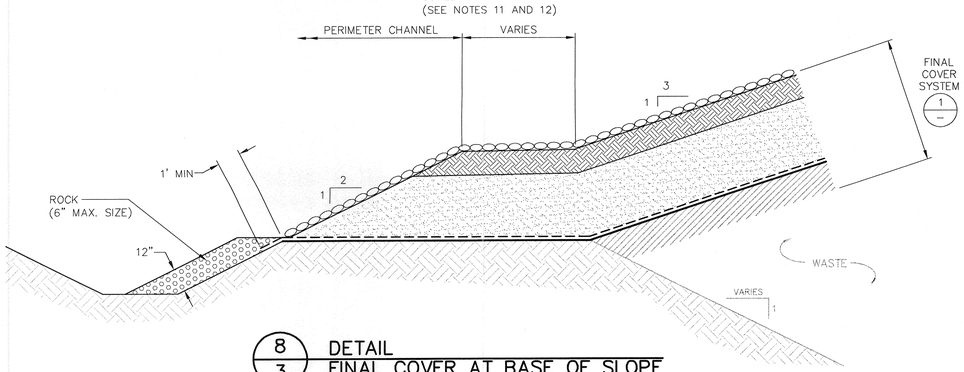
ISOMETRIC



ELEVATION

NO SCALE

6/4 DETAIL
INLET GRATE
SCALE: 1" = 1'
(SEE NOTES 11 AND 12)



8/3 DETAIL
FINAL COVER AT BASE OF SLOPE
SCALE: 3'

NOTES:

1. THE GEOMEMBRANE LINER SHALL BE 60–MIL THICK HDPE SUPER GRIPNET LINER MANUFACTURED BY AGRU/AMERICA, INC. THE SUPER GRIPNET LINER ACTS BOTH AS A GEOMEMBRANE LINER AND A DRAINAGE LAYER.
2. THE MINIMUM ACCEPTABLE THICKNESS OF THE EXISTING COVER SOIL LAYER IS TEN INCHES, EXCEPT BELOW SLOPE DRAIN PIPES AS DISCUSSED IN NOTE 10. THE CONTRACTOR SHALL ADD ADDITIONAL COVER SOIL IF NECESSARY TO MEET THE REQUIRED THICKNESS IN AREAS IMPACTED THROUGH THE REMOVAL OF OVERLYING DAMAGED GEOSYNTHETICS. THE CONTRACTOR SHALL SMOOTH AND PROOF ROLL THE LAYER PRIOR TO THE INSTALLATION OF OVERLYING GEOSYNTHETICS.
3. EXTRUSION OR FUSION WELD AT CONTRACTOR'S DISCRETION. EXTRUSION WELDING REQUIRES 2–FOOT MINIMUM OVERLAP.
4. RIPRAP SHALL HAVE D_{50} = 6" AND D_{MAX} = 12". RIPRAP LINING FOR THE DRAINAGE BENCH SHALL BE PROVIDED TO A DISTANCE OF 10 FEET FROM THE PIPE DRAIN INLETS.
5. DETAILS ARE SHOWN TO THE SCALE NOTED, EXCEPT FOR THE GEOSYNTHETICS WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
6. INTEGRATED DRAINAGE CORE OF THE GEOMEMBRANE SHALL BE REMOVED FROM HDPE GEOMEMBRANE TO ALLOW EXTRUSION WELDING OF PE GEOMEMBRANE FLAP.
7. SHIFT BERM OUT AT INLET BY AMOUNT EQUAL TO INLET DIAMETER D.
8. PROVIDE GRAVEL DROP INLET PROTECTION 1 FOOT HIGH BOTH SIDES.
9. PIPE SHALL BE ADS CORRUGATED HDPE OR EQUIVALENT. ALL COUPLINGS SHALL BE WATERTIGHT AND PROVIDE A CONTINUOUS FLOW CHANNEL.
10. IN AREAS WHERE SLOPE DRAIN PIPES WILL BE INSTALLED, THE EXISTING COVER SOIL LAYER AND PROTECTIVE COVER SOIL WILL BE REDUCED TO ALLOW FOR THE EMBEDMENT OF THE PIPE. THE EXISTING COVER SOIL SHALL BE REDUCED BY 4 TO 6 INCHES AND THE PROTECTIVE COVER SOIL SHALL BE REDUCED TO 10 TO 12 INCHES.
11. WELD ALL REBAR TO BOTTOM OF PLATE AND TO HOOP.
12. SECURE WIRE MESH TO HOOP AND LEGS WITH NON–CORRODIBLE TIES.
13. DETAILS 3, 5, AND 6 ARE OBTAINED FROM PERMIT DRAWING SET PREPARED BY ECOLOGIC IN 1997.

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JUN 2005
Solid Waste Section

MARK	DATE	REVISION	BY	APPROVED
A	9 JUNE 2005	RESPONSE TO NCDENR COMMENTS	TYE	MAO

GEOSYNTEC CONSULTANTS
1255 ROBERTS BOULEVARD, SUITE 200
KENNESAW, GEORGIA 30144–3694

WASTE MANAGEMENT

WASTE MANAGEMENT OF CAROLINAS, INC.

PROJECT: PIEDMONT LANDFILL

TITLE: MISCELLANEOUS DETAILS

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

9 June 2005
DATE

NORTH CAROLINA PROFESSIONAL SEAL 24769 ENGINEER WALID A. OTHMAN

SEAL

DATE:	MAY 2005	SCALE:	AS SHOWN
DESIGN BY:	BG	JOB NO.:	NCP2005–3204
DRAWN BY:	JJA	FILE NO:	3204–A004
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REVIEWED BY:	MAO	DRAWING NO:	4 OF 4
APPROVED BY:	MAO		

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