LETTER OF TRANSMITTAL

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Date: 11/3/00

Sauget Area 1
Dead Creek Sediment and
Soil Removal Action

The following items are:

_X_ Enclosed ____Requested ____ Sent Separately Via:_____

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1	**Response to Comments (Part II) Document**

The above items are submitted:

At your request _X_ For your review For your signature

____ For your files ____ For your action ____ For your information

Comments:

By: Bruce Yare

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Applied Chemistry, Creative Solutions

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November 3, 2000

Kevin Turner-Environmental Scientist, OSC
U. S. Environmental Protection Agency
8588 Rt. 148
Marion, IL 62959

Re: Sauget Sites Area I - May 31, 2000 Unilateral Administrative Order
Docket No. V-W-99-C-554
Dead Creek Sediments & Soils Removal / Containment
- **Time Critical Removal Action Work Plan**
- **Response to Comments - Part II**

Mr. Turner,

On May 31, 2000 the United States Environmental Protection Agency ("U. S. EPA") issued a Unilateral Administrative Order ("Order") to Monsanto Company and Solutia Inc. ("Solutia") requiring removal of soils and sediments from Dead Creek and placement within a containment cell. On June 30, 2000 Solutia submitted for U. S. EPA's approval, a Time Critical Removal Action Work Plan ("TCRAWP") pursuant to the Order. On August 14, 2000, Solutia received your August 10th letter containing U. S. EPA's comments on the TCRAWP, along with additional comments from the Illinois Environmental Protection Agency ("IEPA"), except for Mr. Robert Watson; Illinois Department of Natural Resources ("IDNR"); and the U. S. Fish and Wildlife Service. Mr. Robert Watson's comments were received by Solutia via email on August 31, 2000.

Pursuant to agreements reached in an October 11, 2000 meeting of all parties to discuss the comments on the TCRAWP, Solutia's Response to Comments - Part I was submitted to the Agencies on October 27. The initial response to comments contained responses to all comments from your August 10 letter. This Response to Comments - Part II contains responses to an agreed-to subset of Mr. Watson's comments, including Solutia's "Group 1" responses and all of Mr. Watson's "musts" comments. Solutia's Group 1 responses addressed those comments from Mr. Watson which were agreed-to by Solutia with no further discussion. Mr. Watson's "musts" list of comments were communicated to Solutia at the October 11, 2000 meeting.

All parties agreed that U. S. EPA approval of Response to Comments - Part II would provide sufficient certainty of the containment cell design to allow completion of a Request for Proposal ("RFP") by Solutia. Solutia will begin immediately to prepare the RFP. However, as was stated in the October 11th meeting, Solutia's Response to Comments - Part II must satisfactorily address all Agencies' concerns before the RFP is submitted to the contractors. Therefore, subject to timely U. S. EPA approval of this Response to Comments - Part II submittal, the RFP is tentatively targeted to be issued to prequalified contractors by November 22, 2000. The contractors will be requested to return their bids within a one month period. The bids will then be reviewed by Solutia, a selection made and a contract awarded. This projected schedule would permit contract award by late January / early February timeframe. The selected contractor would then be given approximately one month to be mobilized to the site.

Response to Comments - Part III will contain responses to all remaining comments from Mr. Watson not already addressed in Response to Comments - Parts I & II. Part III will be submitted to U. S. EPA by December 29, 2000.

Sincerely,

D. M. Light
Project Coordinator
Solutia Inc.

cc: (w/enclosure)

Thomas Martin, Esq. - U. S. EPA
Michael McAteer - U. S. EPA
Candy Morin - IEPA
Robert Watson - IEPA
Linda Tape, Esq. - Thompson Coburn

cc: (w/o enclosure)
Bruce Yare - 6S
Mike Foresman - 6S

Time Critical Removal Action Work Plan

Dead Creek Sediment and Soil

Sauget and Cahokia, Illinois

Response to Comments (Part II)

DRAFT

November 3, 2000

Submitted to:

US Environmental Protection Agency
Chicago, Illinois

Submitted by:

Solutia Inc.
St. Louis, Missouri

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INTRODUCTION

On May 31, 2000 USEPA issued a Unilateral Administrative Order (UAO) requiring removal of soils and sediments from Dead Creek and placement of excavated material in an on-site containment cell. Solutia submitted a Time Critical Removal Action Work Plan (TCRAWP), also required by the Order, on June 30, 2000. This Work Plan was organized as follows:

Section 1.0	Introduction
Section 2.0	Site Description
Section 3.0	Sediment Chemical Analyses and Bioassays
Section 4.0	Sediment and Soil Removal Plan
Section 5.0	Sediment Handling, Dewatering and Treatment Plan
Section 6.0	Storm Water Management Plan
Section 7.0	Excavated Area Soil Sampling Plan
Section 8.0	Creek Segment B Liner Installation Plan
Section 9.0	Containment Cell Design Report
Section 10.0	Schedule

On August 14, 2000, Solutia received USEPA's, IEPA's, Illinois Department of Natural Resources' (IDNR), and U. S. Fish and Wildlife Service's (USFWS) comments on the TCRAWP.

Additional IEPA comments on the Containment Cell Design Report were received by Solutia on August 31, 2000. Although IEPA numbered its comments 1 through 87, there were actually 131 comments. Multiple comments were included in a single comment number, e.g. Comment 24 a, b, c, d, e, f and g, resulting a higher comment total than indicated by the comment numeration.

To facilitate preparation of a response to comments document and a containment cell construction bid package, Solutia organized IEPA's August 31, 2000 comments on the Containment Cell Design Report into ten groups:

Group 1	Design, Specifications and CQA Plan Improvements (38 Comments)
Group 2	No Improvement in Design, Specifications and CQA (29 Comments)
Group 3	Design Calculations (25 Comments)
Group 4	Design Report Revisions (13 Comments)
Group 5	Additional Site Characterization (7 Comments)
Group 6	Technically Impracticable (7 Comments)
Group 7	Did Not Understand (5 Comments)
Group 8	Regional/Historical Information (2 Comments)
Group 9	No Response Required (2 Comments)

Group 10 Miscellaneous (3 Comments)

This breakdown, and an action plan for addressing these comments, was sent to USEPA on September 25, 2000. In the action plan, Solutia agreed to incorporate the 38 Group 1 comments into the Design Report immediately and issue a bid package based on the revised document. Group 1 comments included:

1 to 9	10 to19	20 to 29	30 to 39	40 to 49	50 to 59	60 to 69	70 to 79	80 to 87
6	13	24g	32a	40	51	61	74	80
7	14		32b	41	53	62	75	86a
8			32c	42a	54	66	78	86b
			32f	43	55	67		
			33c	48	56	68		
			34a	49	57	69		
			34d		58			

On October 10 and 11, 2000, a meeting of all parties was held to discuss the comments on the TCRAWP. During this meeting, IEPA's list of 60 "must have" comments was communicated to Solutia. These comments are listed below:

1 to 9	10 to19	20 to 29	30 to 39	40 to 49	50 to 59	60 to 69	70 to 79	80 to 87
1	10	20	30	40	50	61	70	80
2	11	21	31	41	51	62	71	81
3	12	24	32	42	52	64	74	82
4	13	28	33	43	53	65	75	84
5	14	29	34	44	54	66	78	86
6	16		39	48	55	67		
7				49	56	68		
8					57	69		
9					58			

As agreed at the October 10 and 11, 2000 meeting, Solutia is responding to the Agencies comments with three submittals. Response to Comments (PartI), which addressed the August 10, 2000 comments, was submitted to the Agency on October 27, 2000. This Response to Comments (Part II) addresses Solutia's Group 1 comments and IEPA's "must have" comments on the Containment Cell Design Report. Response to Comments (Part III), to be submitted by

December 29, 2000, will address the remaining 27 IEPA comments on the Containment Cell Design Report, which include:

1 to 9	10 to19	20 to 29	30 to 39	40 to 49	50 to 59	60 to 69	70 to 79	80 to 87
	15	22	35	45	59	60	72	83
	17	23	36	46		63	73	85
	18	25	37	47			76	87
	19	26	38				77	
		27					79	

GENERAL COMMENTS

1. Response to Comments: The response to these comments needs to include a list of item-by-item responses that indicates how each comment was addressed and where the Design Report was revised in response to each comment.

Response: This Response to Comments (Part II) Document is intended to address this comment. A response is given for each comment along with a commitment to incorporate the response into the Design Report when it is accepted by the Agency.

2. Format of Design Report and Requirements in Exhibit 2: In order to demonstrate that all of the requirements in Exhibit 2 of the UAO are met, the Design Report needs to include a table that clearly cross references the requirements in Exhibit 2 with the various Sections, and appendices in Appendix 7.

Response: The following table will be incorporated into Section 2.0, Introduction, of the Design Report to demonstrate that all of the requirements in UAO Exhibit 2 are addressed.

Exhibit 2	Design Report
1. Design, Construction and Operation Requirements for Containment Cell	
a. Sediment Description	Note 1
b. Liner System	
- Liner System Description	Section 4.1.1 Liner System Description
- Liner System Location Relative to High Water Table	Note 2
- Loads on Liner System	Section 4.3.2 Synthetic Liner Strength
- Liner System Coverage	Section 4.1.4 Lining System Coverage
- Liner System Exposure Prevention	Section 4.1.5 Lining System Exposure

c. Foundation		
- Foundation Description	Section 3.0	Site Characterization
- Subsurface Exploration Data	Section 3.3	Subsurface Conditions
- Laboratory Testing Data	Section 3.2	Geotechnical Testing
d. Engineering Analysis		
- Settlement Potential	Section 4.2.1	Settlement Potential
- Bearing Capacity	Section 4.2.2	Bearing Capacity
- Stability of Landfill Slopes	Section 4.2.3	Cell Slope Stability
- Potential for Excess Hydrostatic or Gas Pressure	Section 4.2.6	Potential Excess Pressure
e. Synthetic Liners		
- General Information	Section 4.3.1	General Information
- Synthetic Liner Compatibility Data	Note 3	
- Synthetic Liner Strength	Section 4.3.2	Synthetic Liner Strength
- Synthetic Liner Bedding	Section 4.3.3	Synthetic Liner Bedding
f. Geocomposite Liner (GCL)		
- Description	Section 4.4.1	General Information
- Material Testing Data		
- GCL Liner Compatibility Data	Note 3	
- GCL Liner Strength	Section 4.4.2	GCL Stength
g. Liner System, Leachate Collection and Detection System		
- System Operation and Design	Section 4.5.1	System Operation & Design
- Equivalent Capacity	Section 4.5.2	Equivalent Capacity
- Grading and Drainage	Section 4.5.3	Grading and Drainage
- Maximum Leachate Head	Section 4.5.4	Maximum Leachate Head
- System Compatibility	Note 3	
- Stability of Drainage Layers	Section 4.5.5	Stability of Drainage Layers
- Strength of Piping	Section 4.5.6	Strength of Piping
- Prevention of Clogging	Section 4.5.7	Prevention of Clogging
h. Liner System, Construction and Maintenance		
1. Material Specifications	Section 6.1.1	Material Specifications
- Synthetic Liner Specifications		
- GCL Liner Specifications		
- Leachate Collection/Detection System		
2. Construction Specifications	Section 6.1.2	Construction Specifications
- Liner System Foundation		
- GCL Liner		
- Synthetic Liner		
- Leachate Collection/Detection System		
i. Construction Quality Control Program	Appendix F and Appendix G	
j. Maintenance Procedures for Leachate Collection/Detection System	Note 4	
k. Liner Repairs During Operation	Specification 02244	
l. Run-off Control Systems		

- Design and Performance	Section 5.5.1	Design and Performance
- Calculation of Peak Flow	Section 5.5.1.1	Calculation of Peak Flow
- Management of Collection and Holding Units	Section 5.5.1.2	Collection & Holding Units
- Construction	Section 5.5.1.3	Construction
- Maintenance	Section 5.5.1.4	Maintenance
- Control of Wind Dispersal	Section 5.6	Control of Wind Dispersal

2. Closure and Post-Closure Requirements
   a. Closure Requirements

1. Closure Plans	Section 5.1	Closure Plans
2. Closure Performance Standards	Section 5.2	Performance Standard
3. Cover Design	Section 5.3	Cover System Description
4. Minimization of Liquid Migration	Section 5.4.2	Minimization of Migration
5. Maintenance Needs	Section 5.4.3	Maintenance Needs
6. Drainage and Erosion	Section 5.4.4	Drainage and Erosion
7. Settlement and Subsidence	Section 5.4.5	Settlement & Subsidence
8. Freeze/Thaw Effects	Section 5.4.6	Freeze/Thaw Effects
b. Post-Closure Requirements	Note 5	
1. Post-Closure Plan		
2. Inspection Plan		
3. Post-Closure Monitoring Plan		
4. Post-Closure Maintenance Plan		
5. Notice in Deed and Certification		

Notes:

1) Time Critical Removal Action Work Plan, Section 3.0 Sediment Chemical Analyses and Bioassays
2) Time Critical Removal Action Work Plan, Section 2.8, Groundwater Levels
3) Compatibility tests are underway and scheduled to be completed in late December 2000.
4) System is designed to minimize maintenance so description of maintenance is needed.
5) Post-closure will be addressed in the O&M Plan which is due 60 days after completion of cell construction.

3. Figures in Appendix 7: If the Figures after 5-6 are redundant/extras, they should be removed from the report. If they refer to specific design issues not shown in the other figures, they need to be specifically referenced in the narrative portion of the design report.

Response: Design drawings will be removed from the Design Report.

4. Previous Excavation of the Site: Section 4.2.1 includes the statement "portions of the site have apparently been previously excavated for borrow material." These excavated areas need to be identified on a scale topographic map of the site. The document needs to indicate if these excavated areas were filled in. If they were backfilled, the fill material

needs to be identified and possibly sampled to determine its chemical and engineering properties.

Response: Paragraph 3 of Section 4.2.1, Settlement Potential, reads as follows:

> "The proposed containment cell will be founded on the existing foundation soils between 397 and 407 ft elevation. The ground surface elevation at the proposed site was apparently about 407 ft. Portions of the site have been previously excavated for borrow fill."

Nothing is known about the excavation history of the site. When writing this paragraph, the author was speculating as to the cause of a slope present on the western edge of the containment cell area. This slope could be natural or it could be man made. For this reason, the last two sentences of this paragraph are speculative and will be removed from the Design Report.

SPECIFIC COMMENTS

Liner System Description

5. Section 4.1.1, Liner System Description: The document needs to identify the manufacturer, product name, and include technical data sheets for all components proposed for use in the bottom, side, and cover systems. Wording which will allow the use of materials from a different manufacturer can also be included in the document provided the alternate material has equivalent, or better, characteristics/properties to the one identified in the Design Report.

Response: Geosynthetic manufacturers and products will be identified in the Design Report. Manufacturers technical data sheets will be included for all geosynthetic components including geomembrane, GCL, geotextile, geonet and geogrid. These cut sheets are included as Attachment 1 of this Response to Comments Document and will be included as Appendix H of the Design Report. Paragraph 1, Section 4.1.1, Description, of the Design Report will be amended as shown below:

> "The bottom liner system for the proposed containment cell will be a multi-component composite lining with leachate collection and leak detection layers. Figure 4-1 shows the proposed configuration of the bottom lining system. A

description of the components is provided below in a bottom to top order. **HDPE membrane will be manufactured by GSE, Serrott or equivalent. Geotextile will be manufactured by Mirafi or equivalent. Geonet and geonet will be manufactured by Tenax or equivalent. GCL will be manufactured by CETCO, GSE, Serrot or equivalent. Manufacturers technical data sheets for these geosynthetics are included in Appendix H."**

6. Section 4.1.1, Liner System Description: A geotextile needs to be placed between the capillary break layer (gravel) and subgrade for the GCL. The geotextile needs to be thick enough (and strong enough) to prevent the six-inch fill layer from being pushed down into the gravel. The document needs to provide the manufacturer, product name, and specifications of this geotextile. It also needs to compare these specifications to the conditions it will be exposed to in the liner system and demonstrate the geotextile will function as intended.

Response - A geotextile will be placed between the capillary break layer and the GCL bedding layer to prevent intrusion of the latter into the former. Strength calculations are included as Attachment 2 of this Response to Comments Document and will be included in Appendix C, Liner System Component Design, of the Design Report. Figures 4-1, 4-2 and 4-8 of the Design Report will include this geotextile. Figures 4-1, 4-2 and 4-8 are in Attachment 3 of this Response to Comments Document. Paragraph 4 of Design Report Section 4.1.1 will be revised as shown below:

> **"After placing a geotextile on top of the capillary break layer**, a 6-inch native fill layer will be pushed and tracked into place over the capillary break layer. ..."

7. Section 4.1.1, Liner System Description: Uncompacted native fill or sand (in the case of the cover system) will not form an adequate subgrade for the GCL. The subgrade under the GCLs in the bottom liner, on the side slopes, and in the cover system all need to be constructed of soils that can be formed into bedding layers capable of supporting and protecting the GCL and other layers in the liner system during the construction process. For more specific requirements regarding the density, moisture, and gradation specifications required for the GCL bedding layer, refer to the comments on the Earthwork Specification 02200 in Appendix E.

Response - A wide range of soils, including sand, can be used as bedding material for geosynthetics. Specification 02200 - Earthwork, included in Attachment 4 of this Response to Comments Document, will be used for the geosynthetic bedding layers in the liner system. It

will also be included in Appendix E, Technical Specifications, of the Design Report. Bedding layer soils will have clods no larger than two inches, will be placed and compacted to 90% Standard Proctor Density and will have a moisture content at or near optimum. Bedding layers will be smooth with no ruts or sharp edges before, during and after installation of the overlying geosynthetic material. They will provide a surface capable of supporting the geosynthetics and other layers in the liner system.

8. Section 4.3.1, Synthetic Liners: The description of the HDPE geomembrane states that it will be smooth (not textured). It is recommended that a textured geomembrane be used to improve the structural stability of the liner systems. If the geomembrane will be textured, the asperity height (height of the textured surface) also needs to be indicated.

Response - Textured geomembrane will be used in liner system construction. Manufacturer's technical data sheets are included in Attachment 1 of this document and they will be included in Appendix H of the Design Report.

9. Section 4.1.1, Synthetic Liners: The design report needs to demonstrate that the 12 inch soil layer in the primary liner system will meet the HDPE geomembrane manufacturer's bedding layer specifications. As part of this demonstration, the design report needs to identify the soil type and grain size distribution of this 12-inch soil layer. This layer should be a clayey soil compacted to at least 95% of the Standard Proctor Density using ASTM D-689 and have a moisture content at or near optimum.

Response - A wide range of soils, including sand, can be used as bedding material for geosynthetics. Specification 02200 - Earthwork, included in Attachment 4 of this Response to Comments Document, will be used for the geosynthetic bedding layers in the liner system. It will also be included in Appendix E, Technical Specifications, of the Design Report. Bedding layer soils will have clods no larger than two inches, will be placed and compacted to 90% Standard Proctor Density and will have a moisture content at or near optimum. Bedding layers will be smooth with no ruts or sharp edges before, during and after installation of the overlying geosynthetic material. They will provide a surface capable of supporting the geosynthetics and other layers in the liner system.

10. Section 4.1.1, Synthetic Liners: The description of the primary liner states that the 12-inch soil layer will not be installed on the side slopes. The design report needs to indicate why the design on the side slopes is different from the bottom liner design and provide justification for this design change. It is recommended that the clay layer in the primary liner system continue up the side slope.

Response - A 12-inch soil layer can not be constructed on the side slopes of the containment cell. Placing sediments directly on the side slope liner does not create a problem unless there are materials present that could puncture the liner system. To insure that the side-slope liner system is not punctured, excavated sediment in contact with the cell side slopes will be screened to remove material larger than 2 inches including sticks, trash and sharp objects. While spreading sediments in the bottom of the cell, a bank of screened sediment will be placed two to three feet high and two to four feet thick at the toe of the slope. This bank of screened sediment will protect the side-slope liner system. When the fill reaches the height of this bank, another one will be constructed of screened sediment at the toe of the slope to protect the side-slope liner system.

Section 5.0 of the Time Critical Removal Action Work Plan will be modified by adding the paragraph shown below. This will ensure that sediments placed against the cell side slopes will not puncture the liner system.

> To insure that the side-slope liner system is not punctured, excavated sediment in contact with the cell side slopes will be screened to remove material larger than 2 inches including sticks, trash and other sharp objects. While spreading sediments in the bottom of the cell, a bank of screened sediment will be placed two to three feet high and two to four feet thick at the toe of the slope. This bank of screened sediment will protect the side-slope liner system. When the fill reaches the height of this bank, another one will be constructed of screened sediment at the toe of the slope to protect the side-slope liner system.

This paragraph will be added at the end of Section 5.0, Sediment Handling, Treatment and Dewatering Plan.

Specification 02225, Section 3.3.F of the Design Report will be modified as shown below. This will ensure that sediments placed against the cell side slopes will not puncture the liner system.

F. Place **screened** sediment **on the** side **slope** lining **to a height of 2 to 3 ft. above the toe of the slope and to a thickness of 2 to 4 ft. Screen these**

sediments to remove materials 2 inches and larger including sticks, trash and other sharp objects.

11. Section 4.1.1, Synthetic Liners: The narrative states (and Figure 4-2 shows) that wastes will be placed directly on top of drainage composite on the side slopes. This is significantly different from the design of the leachate collection system on the bottom liner. The design report needs to indicate why the design of the leachate collection system on the side slopes is different from the bottom liner design and provide justification for this design change. The 6-inch sand protective layer over the geotextile needs to continue up the side slopes.

Response - A 6-inch sand layer can not be constructed on the side slopes of the containment cell. Placing sediments directly on the side slope liner does not create a problem unless there are materials present that could puncture the liner system. To insure that the side-slope liner system is not punctured, excavated sediment in contact with the cell side slopes will be screened to remove material larger than 2 inches including sticks, trash and sharp objects. While spreading sediments in the bottom of the cell, a bank of screened sediment will be placed two to three feet high and two to four feet thick at the toe of the slope. This bank of screened sediment will protect the side-slope liner system. When the fill reaches the height of this bank, another one will be constructed of screened sediment at the toe of the slope to protect the side-slope liner system.

Section 5.0 of the Time Critical Removal Action Work Plan will be modified by adding the paragraph shown below to the end of this section. This will ensure that sediments placed against the cell side slopes will not puncture the liner system.

> To insure that the side-slope liner system is not punctured, excavated sediment in contact with the cell side slopes will be screened to remove material larger than 2 inches including sticks, trash and other sharp objects. While spreading sediments in the bottom of the cell, a bank of screened sediment will be placed two to three feet high and two to four feet thick at the toe of the slope. This bank of screened sediment will protect the side-slope liner system. When the fill reaches the height of this bank, another one will be constructed of screened sediment at the toe of the slope to protect the side-slope liner system.

Specification 02225, Section 3.3.F of the Design Report will be modified as shown below. This will ensure that sediments placed against the cell side slopes will not puncture the liner system.

F. Place **screened** sediment **on the** side **slope** lining **to a height of 2 to 3 ft. above the toe of the slope and to a thickness of 2 to 4 ft. Screen these sediments to remove materials 2 inches and larger including sticks, trash and other sharp objects.**

12. Section 4.1.2, Liner System relative to High Water Table: The report needs to include a geologic cross section that shows the elevations of the landfill, the formations under the unit, and the seasonal fluctuations in the water table.

Response: A geologic section is included in Attachment 5 of this document and will be included as Figure 3.4 of the Design Report.

13. Section 4.1.3, Loads on the Liner System: Calculations supporting the statements and conclusions need to be included in the design report and referenced in the narrative of Section 4.1.3. Each layer in the liner system needs to be considered in the calculations, not just the HDPE geomembrane.

Response - Liner system load calculations are included as Attachment 6 of the Response to Comments Document and will be included in Appendix C, Liner System Component Design, of the Design Report.

14. Section 4.1.4, Figure 4-7, Liner System Anchor Detail: The design report needs to justify the design of the anchor shown in Figure 4-7. The report needs to include estimates of the forces the landfill will exert on the liners, and calculations that show that the anchor will hold the liner in place.

Response - Anchor system design calculations are included as Attachment 7 of the Response to Comments Document and will be included in Appendix C, Liner System Component Design, of the Design Report.

15. Section 4.1.5, Liner System Exposure Prevention: Section 4.1.5 of Appendix 7 in the design report does describe how the liner system (especially the geomembrane layers) will be protected from the wind. This can either be done by placing the soil/sand layers on the geomembrane quickly (e.g. same day) after it is installed, or by temporarily placing sand bags on it.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

16. Section 4.1.5, Liner System Exposure Prevention: Section 4.1.5 of Appendix 7 in the design report needs to discuss the problems associated exposing the GCL to moisture and describe how the GCL will be protected from hydrating before a uniform confining weight (e.g. 6 inches of soil) can be placed on it. Specifically, if the GCL is allowed to hydrate (e.g. swell) without any weight on it, it will lose its structural integrity and need to be replaced. To prevent this problem, the design report needs to indicate that two things will be done. First, each GCL panel (in the bottom, sides, and cover systems) needs to be covered with the geomembrane the same day the GCL is installed to protect it from precipitation and moisture in the air.

    Second, even after the GCL is protected from precipitation by the geomembrane, it will continue to hydrate by drawing moisture from the underlying soil in the subgrade. Therefore, at least 6 inches of soil/sand need to be placed on the GCL to provide uniform confining pressure on it before it is allowed to hydrate beyond 100%. The document needs to provide an estimate of how long it will take the GCL to hydrate to 100% (along with the justifications for this estimate), and show that the construction schedule will be sufficient to insure that adequate confining weight is placed on the GCL within this timeframe.

Response: Specification 02245, Geosynthetic Clay Liner, Section 3.3, Installation, A.7, 8, 9 and 10 require the following:

7. Do not place GCL in the rain or at time of impending rain
8. Do not place GCL in areas of ponded water
9. Replace GCL that is hydrated before placement of overlying geomembrane
10. In general, only deploy GCL that can be covered during that day by geomembrane or a minimum of twelve (12) inches of approved cover soil.

These requirements, already in the specifications, address the first issue raised in Comment 16. As for the second issue, the liner system will be built before 100% hydration of the GCL liner will occur. Technical information on GCL hydration time is included in Attachment 8 of the Response to Comments Document. This information demonstrates that the containment cell will be built before complete GCL hydration occurs.

FOUNDATION

17. Section 3.0, Site Characterization: The proposed location of the containment cell needs to be shown relative to the borings on Figure 3-1.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

18. Section 3.0, Site Characterization: Geologic cross sections from the surface down to the confining layer (bedrock) need to be provided. The location and elevations of the proposed containment cell needs to be shown on these cross sections.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

19. Section 3.0, Site Characterization: Piezometer PZ-1, and the three GB borings, all end in the sand layer (either SM or SP). None of the borings continues to the top of a confining layer (which may be bedrock at this site). The design report needs to characterize the geology from the surface down to the first confining layer. This requirement can be met by either providing a the boring log report for an existing boring near the site that extends down to a confining layer, or by installing an additional boring at the site that extends a confining layer.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

20. Section 3 and Appendix A in Appendix 7, Laboratory Test Data: The following test results and information regarding the soils under the site need to be provided:

    a. Unconfined compression test results (shear strengths) for the upper clay layer, the loose sand layer, and the dense sand layer under the site.

    b. Consolidation test results for the upper clay layer, the loose sand layer, and the dense sand layer under the site.

    c. Hydraulic conductivity test results for all soil strata under the site (the upper clay layer, the silt layer, the loose sand layer, and the dense sand layer).

    d. The ASTM, EPA or other appropriate standard methods used to perform the tests needs to be identified in the document.

Response: Unconfined compressive strength and consolidation tests will be performed on representative samples of the silty clay (CL) and sandy silt (ML) soils found in shallow soils at the containment cell site. In addition, the hydraulic conductivity of these soils will be determined by laboratory testing. ASTM, EPA or other appropriate test methods will be used to perform these tests and the test method will be included with the test results. These test results will be included in Appendix A, Site Characterization, of the Design Report.

Unconfined compressive strength and consolidation tests can not be performed on sand samples. While it is possible to perform laboratory permeability tests on sand samples, the purpose of collecting this information is unclear. Therefore, these tests will not be performed.

ENGINEERING ANALYSES

21. Section 4.2.1, Settlement Potential: The assumptions used to calculate differential settlement are not acceptable. The settlement under the landfill needs to be recalculated considering the following comments:

    a. Density and Soil Strata: The calculations assume a single density for the soil and then assume it is equal to the density of the waste. There are four different soil strata under the site. The calculations need to account for the characteristics of each soil strata and each of the material that is in the liner system. In addition, the calculations need to account for the weight of the gravel or the liner materials. Finally, the actual density (and moisture content) of the sediments needs to be determined and used in the calculations.

    b. Base Elevations: The calculations assume an initial flat surface elevation. However, the narrative states the initial elevation of the site varies by 10 feet. The calculations need to account for the change in elevation across the landfill. This is especially true if the elevation change is because the surface layer (such as the clay) was removed from a portion of the site.

    c. Settlement of Berms: The settlement calculations consider the embankment and fill areas separately. However, the discussion and calculations on differential settlement need to clarify the way the entire landfill is expected to settle during both its construction and later after it is covered. Placement of wastes and the cover system on the interior slopes of the berms could also result in some amount of settlement under the berms. Therefore, the settlement calculations for the embankments need to be provided for the conditions both before, and after, the liner and waste are placed in the landfill. Finally, the design report needs to discuss how settlement of the berm relative to settlement the waste and liner system will impact the stresses placed on the components in the liner system.

    d. Maximum Differential Settlement: The calculations assume an average fill height, that the maximum settlement will occur in the middle of the landfill, and that the settlement at the edge is 2/3 of the settlement in the middle. Differential settlement calculations need to consider the maximum elevation of the landfill, where the maximum settlement is anticipated, and compare this to the location where the least amount of settlement will occur. Figure 5-2 shows the maximum elevation (~ 427') occurs in the southwest quadrant, not the middle of the landfill. The settlement under the maximum elevation needs to be compared to the settlement calculated under the sump area in the northeast corner. This comparison should give not only the maximum differential settlement, but also identify if settlement will negatively impact the bottom slope or leachate collection system.

e. Calculations: The calculations used to estimate the consolidation in the computer model need to be provided with justifications for all assumptions used in the model.

Response: Settlement calculations are included in Attachment 9 of this Response to Comments Document and will be included in Appendix B, Foundation Evaluation, of the Design Report.

22. Section 4.2.2, Bearing Capacity: Section 4.2.2 states that undrained shear strengths were determined for the surficial clays and silts. However, the test results provided in Appendix B show that clay only made up the top 1 inch (of a 6 inch sample) for one of the three unconfined compression tests. Therefore, this section needs to be revised to reflect that the undrained shear strength is only known for the silts under the site. Conversely, additional testing could be done on the surficial clay to determine its undrained shear strength (this is the preferred option).

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

23. Section 4.2.2, Bearing Capacity: Section 4.2.2 needs to provide justification for the statement that the limiting bearing capacity strata was found to be the surficial clays and silts. Part of this justification should include providing the test results from all of the soil strata under the proposed landfill site.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

24. Section 4.2.3, Containment Cell Slope Stability: The narrative in this section is not adequate to demonstrate the containment cell is designed with an adequate factor of safety against slope failure. The following issues need to be addressed:

    a. References to Appendix B: Justifications for the factors of safety discussed in Section 4.2.3 are not provided. If these values are based on the computerized slope stability analyses in Appendix B, the narrative needs to reference this information.

    b. Equations and Calculations: All equations and calculations used in the slope stability analyses need to be provided. If a computer program is used, the equations that the program is based upon, the assumptions used for each run, and a copy of the program all need to be provided.

    c. Soil Strata Assumptions: The soil borings in Appendix A show clay (CL), silt (ML) and loose sand (SM) are present from the ground surface down to approximately 10 feet. However, the total Unit Weight and Saturated Unit Weight were assumed to be the same for each soil type modeled in each computer run in Appendix B. The document needs to justify assigning the same values to different soil types (e.g. provide soil analyses or refer to test results provided elsewhere in the document).

d. Friction Angles: The slope stability evaluation needs to calculate the required interface angle that satisfies the required factor of safety (FS) $\geq$ 1.5 (or as specified in the regulations). This needs to be done for the berms (both interior and exterior slopes), all interfaces in the liner system, and the cover system. When the liner materials are delivered to the site they need to be tested to verify the required friction angles are achieved. In the case of the soils in the liner and berms, once they are compacted, they too need to be tested to verify the required friction angles are achieved.

e. Interface Friction Angle: This section assumes an interface friction angle of 11 degrees between the geonet drainage material and the HDPE liner. The data and justification for this assumption need to be provided.

f. Worst Case Interface: The document needs to include an evaluation of the interface friction angle between all interfaces in the liner (bottom, side, and cover) systems. Part of this evaluation must be the identification, and justification, of the two materials determined to have the worst-case interface friction angle. When an interface involving a GCL is investigated, the evaluation must consider the GCL is hydrated to at least 100% and discuss bentonite migration in the GCL.

g. Laboratory Testing of Liner Materials: The interface friction angles between the various layers in the liner systems (bottom, side, and cover) should be determined in the lab using a shear box (ASTM D5321-92), a large scale direct shear box (ASTM D5321), or a ring shear device (ASTM draft method). If an alternate method is proposed, the document must provide justification for this method.

Response - Factor of safety calculations on the liner system components are included in Attachment 10 of the Response to Comments Document. These calculations will be included in Design Report Appendix C - Liner System Components. Shear box testing (undrained shear strength, ASTM Method D 5321-92) of the GCL/geomembrane interface and the geonet/geomembrane interface will be conducted as part of conformance testing. These tests will be performed 30 days after the Notice to Proceed is sent to the cell construction contractor. A new section, Liner System Shear Box Testing, will be added to the Construction Quality Assurance Manual. It is included in Attachment 11 of the Response to Comments Document. It will also be included in Appendix F, Construction Quality Assurance Manual for Installation of Geosynthetic Components, of the Design Report.

25. Section 4.2.6, Potential for Excess Hydrostatic or Gas Pressure: The design report needs to include calculations demonstrate that the weight of the completed landfill will be greater than the hydrostatic uplift pressure.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

SYNTHETIC LINERS

26. Section 7 Material Compatibility Studies: This section needs to indicate the approximate date the compatibility testing will be concluded and results provided to USEPA and IEPA.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

27. Section 4.3.2, Synthetic Liner Strength: Section 4.3.2 makes a number of statements regarding the strength of the liner that are not justified in the narrative. The narrative needs to provide specific numbers and refer to specific calculations (not just the Appendix) and technical data sheets on the materials in order to justify conclusions such as the following:

    - The synthetic linings in the containment cell will not be subject to significant tensile stresses.
    - The side slope linings will not be overstressed.
    - The longitudinal seams are not expected to be significantly loaded.
    - The strain in the bottom lining due to settlement is well within the elastic limit for the HDPE lining.
    - It appears the bottom linings will not be overstressed.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

28. Appendix C, Calculations on Lining Tensile Strength: The calculations need to be revised as necessary to address the following comments and provide justifications for the assumptions:

    a. The overburden stress should be calculated using maximum thickness over slope in order to determine the worst-case scenario, not the average.

    b. The calculations need to discuss how the liner's anchor figures into the calculation.

    c. The document needs to provide calculations for all materials in the liner system, not just the HDPE geomembrane.

    d. The justification for the interface friction angle between HDPE & HDPE needs to refer to the 1999 edition of Designing with Geosynthetics.

    e. The document needs to calculate the interface friction angles that satisfy the required factor of safety, and then verify these values are not exceeded by testing in the lab (see above comments on slope stability analysis).

    f. The stresses due to settlement do not appear to be addressed in this calculation. As part of this discussion, the document needs to indicate whether the berms or just the gravel and waste are expected to settle (and how much) after the lining materials are installed.

Response - Factor of safety calculations on the liner system components are included in Attachment 10 of the Response to Comments Document. These calculations will be included in Design Report Appendix C - Liner System Components. Shear box testing (undrained shear strength, ASTM Method D 5321-92) of the GCL/geomembrane interface and the geonet/geomembrane interface will be conducted as part of conformance testing. These tests will be performed 30 days after the Notice to Proceed is sent to the cell construction contractor. A new section, Liner System Shear Box Testing, will be added to the Construction Quality Assurance Manual. It is included in Attachment 11 of the Response to Comments Document. It will also be included in Appendix F, Construction Quality Assurance Manual for Installation of Geosynthetic Components, of the Design Report.

29. Section 4.3.3, Synthetic Liner Bedding: Section 4.3.3 did not provide any type of demonstration that sufficient bedding will be provided both above and below the synthetic liners to prevent rupture of the synthetic liner during installation and operation (i.e., thickness and gradation).

Response - A wide range of soils, including sand, can be used as bedding material for geosynthetics. Specification 02200 - Earthwork, included in Attachment 4 of this Response to Comments Document, will be used for the geosynthetic bedding layers in the liner system. It will also be included in Appendix E, Technical Specifications, of the Design Report. Bedding layer soils will have clods no larger than two inches, will be placed and compacted to 90% Standard Proctor Density and will have a moisture content at or near optimum. Bedding layers will be smooth with no ruts or sharp edges before, during and after installation of the overlying geosynthetic material. They will provide a surface capable of supporting the geosynthetics and other layers in the liner system.

GCL Liners

30. Appendix C, GCL Load Calculations: The calculations need to be revised as necessary to address the following comments and provide justifications for the assumptions:

    a. The overburden stress should be calculated using maximum thickness over slope in order to determine the worst-case scenario, not the average.

    b. The calculations need to discuss how the GCL's anchor figures into the calculation.

c. A more detailed description (with calculations as necessary) needs to be provided to justify the statements that the entire downward force (T) must be carried by the internal shear strength of the GCL and that no tension is produced in the GCL.

d. The document needs to describe how the overburden weight is transferred through the layers of the liner system above the GCL. Is the full tensile force (T) from the overburden weight transferred to the GCL, or was this a worst-case assumption?

e. The calculations cite the CETCO Product Manual, Direct Shear Test Data as a source for an interface friction angle between the GCL and soil of 31°. A note on the cover of this data summary clearly states "This data is for informational purposes only and is not intended to replace project specific interface testing, which CETCO emphatically recommends." Therefore, this source for interface friction angles should not be used for design purposes.

f. The document needs to calculate the interface friction angles that satisfy the required factor of safety, and then verify these values are met by testing in the lab (see above comments on slope stability analysis).

g. The stresses due to settlement do not appear to be addressed in this calculation. As part of this discussion, the document needs to indicate whether the berms or just the gravel and waste are expected to settle (and how much) after the lining materials are installed.

Response: GCL load calculations are included in Attachment 12 of this Response to Comments Document and will be included in Appendix C, Liner System Component Design, of the Design Report. Liner system load calculations are in Attachment 6 of the Response to Comments Document. Factor of safety calculations are included in Attachment 10. Interface friction angles are discussed in the Response to Comment 28. Settlement calculations are given in Attachment 9.

31. Section 4.4.2, GCL Strength: Section 4.4.2 in Appendix 7 (page 4-10) states "all tensile stresses will be transferred through the GCL via the internal shear strength to the underlying soil layers." Appendix C also states that no tension is produced in the GCL. However, the Specification for GCLs (02245) in Appendix E states the minimum friction angle for hydrated GCL on a slope is 6°. This is less than the interface friction angles above (11°) and below (31°) the GCL. Therefore, the GCL will not be strong enough to transfer the tensile force to the soils underneath it.

    The conclusions in Section 4.4.2 and the calculations in Appendix C need to be reevaluated and/or additional documentation provided to demonstrate the GCL is strong enough to support the forces exerted on it.

Response: Short term, long term and residual GCL strength calculations are included in Attachment 12 of this Response to Comments Document and will be included in Appendix C, Liner System Component Design, of the Design Report.

LINER SYSTEM, LEACHATE COLLECTION AND DETECTION SYSTEM:

32. Section 4.5, Leachate Collection System: The leachate collection system needs to be revised to include the following features:

    a. The proposal to monitor leachate on a monthly and then annual basis is not adequate to demonstrate that leachate will be removed from the landfill in a timely manner. The leachate collection system needs to include dedicated pumps, sensors, and plumbing to insure that the depth of leachate on top of the primary liner never exceeds one foot. The system pumps need to be automatically actuated by the liquid level in the sump. The system also needs to include a high level alarm to inform Monsanto/Solutia when the liquid level is above the acceptable elevation. The description of the system needs to identify the type of alarm and where the signal will be sent (e.g. the security office at the W.G. Krummrich Plant).

    b. Monsanto/Solutia may want to install an actual sump for the leachate collection system instead of just a gravel layer at the bottom of the slope. A sump at a lower elevation than the primary liner system probably will be necessary in order to meet the requirement to maintaining no more than one foot of leachate on the primary liner, and to accommodate the technical requirements for the pumps.

    c. The elevation view(s) of the collection sump need to show the elevations at which the pump will turn on, turn off, and when the high level alarm will be actuated.

    d. The collection sump should include horizontal perforated pipes to house and protect the suction hoses used to remove leachate.

    e. A description of why a perforated instead of solid pipe will extend from the sump to the surface of the landfill. A perforated pipe should not be used outside of the sump because it could become a conduit for waste sediments to get into the sump and clog it.

    f. Detailed scale drawings (both plan and elevation views) of the leachate collection system and the leachate collection sump need to be provided.

    g. A more detailed description of how liquids will actually be removed from the sump also needs to be provided.

Response - Leachate-collection system design will be modified to include a high-level alarm set to ensure that leachate levels in the leachate collection system are one foot or less. When high level conditions occur, a warning light will be activated at the containment cell and an autodialer

will notify the O&M contractor of the high level condition. A vacuum truck will then be used to remove the leachate for off-site disposal. Operational experience will be used to determine whether it is more cost effective to use a vacuum truck or a permanent pumping system to remove the leachate. Dedicated pumps are not considered necessary at this time because the volume of leachate that will be generated is not known nor can it be estimated. Riser and horizontal collector pipes are sized to allow pump installation in the future.

Leachate collection system design modifications and details are included in Attachment 13. Modifications include a high-level alarm, a collection sump and a horizontal perforated pipe in the sump. These drawings will be included in the Design Report as Figures 4-7 A, B, C, D, E, F, G and H.

33. Section 4.5, Leachate Detection System: The design report needs to address the following comments regarding the leachate detection system:

    a. The design report needs to describe how the detection system will function to detect any leakage through either liner in a timely manner. The proposal to monitor leachate on a monthly and then annual basis is not adequate to make this demonstration. To insure the leachate detection system will detect (and is able to remove) leachate in a timely manner, the system needs to include liquid sensors, level actuated pumps, etc.

    b. The detection sump should include horizontal perforated pipes to house and protect the suction hoses used to remove leachate.

    c. Detailed scale drawings (both plan and elevation views) of the leachate detection system sump need to be provided.

    d. A more detailed description of how liquids will actually be removed from the sump also needs to be provided.

    e. The design report should include some discussion of why the leachate collection, detection, and capillary break sumps are located in separate areas instead of a vertical line.

Response - Section 4.5.4, Maximum Leachate Head, Paragraph 4 will be modified to read:

> The model results show the leachate and leak production rates fall substantially after the cover system is installed over the cell. The leachate and leak production **rates** are essentially zero after the cell water balance has reached

equilibrium. Some leachate production will continue for several months after the cell is covered.

Leachate-detection system design will be modified to include a high-level alarm set to ensure that leachate levels in the leachate detection system are one foot or less. When high level conditions occur, a warning light will be activated at the containment cell and an autodialer will notify the O&M contractor of the high level condition. A vacuum truck will then be used to remove the leachate for off-site disposal. Operational experience will be used to determine whether it is more cost effective to use a vacuum truck or a permanent pumping system to remove the leachate. Dedicated pumps are not considered necessary at this time because the volume of leachate that will be generated is not known nor can it be estimated. Riser and horizontal collector pipes are sized to allow pump installation in the future.

Leachate detection system design modifications and details are included in Attachment 13. Modifications include a high level alarm, a collection sump and a horizontal perforated pipe in the sump. These drawings will be included in the Design Report as Figures 4-7 A, B, C, D, E, F, G and H.

Leachate collection, leachate detection and capillary break sumps are located in a vertical line as shown in the Attachment 13 drawings.

34. Section 4.5, Capillary Break Layer: The design report needs to address the following comments regarding the capillary break layer:

    a. Detailed scale drawings (both plan and elevation views) of the capillary break sump need to be provided.

    b. A more detailed description of how liquids will actually be removed from the sump also needs to be provided.

    c. The capillary break sump should include horizontal perforated pipes to house and protect the suction hoses used to remove leachate.

    d. At a minimum, the capillary break layer needs to include sensors and an alarm to inform Monsanto/Solutia when the liquid level in this layer is above a specified elevation. The narrative needs to identify this elevation, and include justification for it. The description of the system needs to identify the types of sensors and alarm, and where the signal will be sent (e.g. the security office at the W.G. Krummrich Plant).

Response - Capillary break layer design will be modified to include a high-level alarm set to ensure that leachate levels in the capillary break layer are one foot or less. When high level conditions occur, a warning light will be activated at the containment cell and an autodialer will notify the O&M contractor of the high level condition. A vacuum truck will then be used to remove the leachate for off-site disposal. Operational experience will be used to determine whether it is more cost effective to use a vacuum truck or a permanent pumping system to remove the leachate. Dedicated pumps are not considered necessary at this time because the volume of leachate that will be generated is not known nor can it be estimated. Riser and horizontal collector pipes are sized to allow pump installation in the future.

Capillary break layer design modifications and details are included in Attachment 13. Modifications include a high level alarm, a collection sump and a horizontal perforated pipe in the sump. These drawings will be included in the Design Report as Figures 4-7 A, B, C, D, E, F, G and H.

35. Section 4.5.2, Equivalent Capacity: Section 4.5.2 only states that the geonet transmissivity will be greater than 12 inches of sand with a hydraulic conductivity of 1 x 10^{-2} cm/sec. It needs to refer to copies of manufacture's data sheets provided for the geonet, and calculations that demonstrate this statement is correct.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

36. Section 4.5.3, Grading and Drainage: This section needs to include additional detail regarding the grading and drainage for the proposed landfill. Specifically:

    a. The description of the leachate collection system needs to include a demonstration of why perforated pipes are not included as part of the lateral leachate collection system on the bottom of the landfill.

    b. The narrative needs to discuss how the collected leachate will be disposed. Indicate the appropriate permits which will need to be obtained. As a newly generated waste, Monsanto/Solutia will need to determine if it is a hazardous waste. If it is a hazardous waste, storage of it for greater than 90 days is subject to the RCRA storage requirements.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

37. Section 4.5.4, Maximum Leachate Head: This section needs to provide the following information to clarify the conclusions in the document:

    a. Cross sections that identify each of the layers in both HELP models.

    b. Justifications for the assumptions used in the HELP models. For example, when the amount of leachate the sediments will generate is estimated, the report should include lab data from the field and bench/pilot scale tests regarding the moisture content of the sediments and descriptions the physical processes that will be used to dewater them before they are placed in the landfill.

    c. A description of why Layer 6 (waste sediments) is not included in the HELP model for the closed landfill, and why the average head on top of Layer 8 (the primary liner) is indicated to be 0.000 for each year. Thus, it appears the model assumes that all liquids will be squeezed out of the sediments during construction of the landfill, and no precipitation gets through the cover system. The report needs to provide additional discussion and justification for this assumption.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

38. Section 4.5.7 Prevention of Clogging: The following information regarding geotextiles needs to be included in the report:

    a. A sieve analysis of the waste material needs to be performed on both the sediments and the soil used in the primary liner system. This data then needs to be compared to the technical data sheet for the GCL. This is necessary in order to demonstrate the weight and apparent size opening (AOS) of the geotextile(s) is adequate for the design and will not clog.

    b. Describe how clogging would be detected and what cleanup procedures would be used to restore the capacity of the systems.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

LINER SYSTEM, CONSTRUCTION AND MAINTENANCE

39. Testing of Liner Materials: Appendices E, F and G of Appendix 7 need to be revised include testing the liner materials in a shear box to verify the internal and interface friction angles for the materials are sufficient to meet the factor of safety required for the design.

Response: Shear box testing (undrained shear strength, ASTM Method D 5321-92) of the GCL/geomembrane interface and the geonet/geomembrane interface will be conducted as part of conformance testing. These tests will be performed 30 days after the Notice to Proceed is sent to the cell construction contractor. A new section, Liner System Shear Box Testing, will be

added to the Construction Quality Assurance Manual. It is included in Attachment 11 of the Response to Comments Document. It will also be included in Appendix F, Construction Quality Assurance Manual for Installation of Geosynthetic Components, of the Design Report.

40. Specification 01010 Summary of Work; Section 1.3.B.2. Principal Work Items to be Performed by Contractor: This subsection does not include the placement of the soil layer directly below the primary geomembrane liner. It also will need to be revised to include installation of the geotextile this reviewer recommends be placed between the gravel capillary break layer and the GCL bedding layer.

Response - Installation of a soil layer below the primary geomembrane liner and installation of a geotextile on top of the capillary break layer will be added to Specification 01010. The list of principal work items included in Section 1.3.B.2 will be modified as shown below:

- Mobilization to site
- Site preparation to include clear and grub, borrow area development, erosion control, haul road development and stormwater management measures
- Perimeter berm construction
- Construct capillary break ground layer and sump
- Construct tracked in place soil layer
- **Install geotextile**
- Install geosynthetic clay liner
- Secondary geomembrane installation
- Secondary leachate collection system installation including sumps and riser pipes
- **Constructed tracked in place soil layer**
- Install primary geomembrane layer
- ....

A specification for the geotextile placed between the capillary break layer and the GCL bedding layer will be developed and added to the Technical Specifications. It is included inAttachment 14 of this Response to Comments Document and will be added to Specification 02242 of the Design Report.

Stormwater Control

41. Specification 02150, Stormwater Control During Construction; Section 3.2 Groundwater Control: Groundwater in the area of the proposed containment cell may be contaminated with hazardous constituents from other sites in the area such as Site G. Therefore, this subsection needs to specify that collected groundwater will be tested to determine if it contains hazardous constituents, and/or is a hazardous waste. In addition, because it is not acceptable to manage contaminated groundwater the same way as uncontaminated

stormwater, Specification 02150 needs to include procedures for handling groundwater that is determined to be contaminated with hazardous constituents.

Response - Specification 02150, Section 3.2.B will be modified as shown below to indicate that the contractor must test collected groundwater and dispose of it in a manner consistent with the relevant and appropriate regulations:

B. Collected groundwater must be stored and tested by the Contractor to determine if it contains hazardous constituents and/or is a hazardous waste. After testing, the collected groundwater must be disposed in a manner consistent with relevant and appropriate regulations.

This revision will be incorporated verbatim into Section 3.2.B, Groundwater Control, of Specification 02150.

Earthwork

42. Specification 02200, Earthwork, Section 2.3 Fill Material, and Section 3.6, Placement: These specifications need to be revised to address the following comments:

    a. Specification 02200 needs to include separate specifications for the bedding layer that will be placed under the GCL. The same specifications need to be applied to the soil layers under GCLs in the bottom, sides and cover systems because the goal of providing an adequate base for the GCL, and the rest of the liner system, is the same in each case. [Note: Specification 02200 currently does not include/address the layer under the GCL in the cover system.]

    b. In the case of the Compacted Fill, the top 1+ foot on the inside of the berm needs to meet the specification for the GCL bedding layer since this is the soil that will be in contact with the GCL. For the layers under the GCL in bottom liner and the cover system, the entire depth of these layers needs to meet the specification for the GCL bedding layer identified below.

    c. It is not acceptable to simply specify the soil types for the subgrade layers under a GCL as proposed in Section 2.3. The gradation of the soil, density, and moisture content all need to be specified (possibly in Section 3.6) in order to insure the soil will provide an adequate bedding layer for the GCL.

    d. As stated earlier in the comments on Section 4.1.1 regarding the subgrade under the GCL, the subgrade needs to be constructed of a soil that will provide a firm bedding layer that will be rolled smooth. In addition, this bedding layer must be able to retain

these characteristics throughout the construction process. Therefore, it is recommended that the bedding layer under all GCLs be constructed of soil with:

i. 100% of the particles having a maximum dimension not greater than 2 inches,
ii. Not more than 10% of the particles, by weight, having a dimension greater than 0.75 inches,
iii. Not less than 50% of the particles, by weight, passing through the 200 mesh sieve, and
iv. Not less than 25% of the particles, by weight, having a maximum dimension not greater than 0.002 millimeters.

The bedding layer under a GCL needs to be compacted to at least 95% of the Standard Proctor Density using ASTM D-689, have a moisture content at or near optimum, and be smooth rolled so that there are no sharp edges or protruding objects in the surface.

All of these specifications need to be included in Specification 02200.

Response - A wide range of soils, including sand, can be used as bedding material for geosynthetics. Specification 02200 - Earthwork, included in Attachment 4 of this Response to Comments Document, will be used for the geosynthetic bedding layers in the liner system. It will also be included in Appendix E, Technical Specifications, of the Design Report. Bedding layer soils will have clods no larger than two inches, will be placed and compacted to 90% Standard Proctor Density and will have a moisture content at or near optimum. Bedding layers will be smooth with no ruts or sharp edges before, during and after installation of the overlying geosynthetic material. They will provide a surface capable of supporting the geosynthetics and other layers in the liner system.

43. Specification 02200, Earthwork, Section 2.3 Fill Material: The specifications for Protective Fill need to be revised to specify the protective fill in contact with the GCL shall not contain dirt clods greater than 2 inches.

Response - A wide range of soils, including sand, can be used as bedding material for geosynthetics. Specification 02200 - Earthwork, included in Attachment 4 of this Response to Comments Document, will be used for the geosynthetic bedding layers in the liner system. It will also be included in Appendix E, Technical Specifications, of the Design Report. Bedding layer soils will have clods no larger than two inches, will be placed and compacted to 90% Standard Proctor Density and will have a moisture content at or near optimum. Bedding layers will be smooth with no ruts or sharp edges before, during and after installation of the overlying geosynthetic material. They will provide a surface capable of supporting the geosynthetics and other layers in the liner system.

44. Specification 02200, Earthwork, Section 2.3 Fill Material: The specifications for each soil layer in the bottom, side, and cover systems need to refer back to the cross section details that describe the relative locations of these layers (e.g. Figures 4-1, 4-2, and 5-2). In addition, the specifications (and the CQAP in Appendix G) need to indicate that the thicknesses shown in the figures are the **compacted** thicknesses of the layer.

Response - Cross-referencing the Design Report, design drawings and the specifications creates the potential for conflicts among the various documents. This is turn creates problems for the Owner and the Contractor. Order of document precedence will be set out in the bid package and will be used to determine which document governs a particular situation. Cross referencing disrupt this order of precedence.

A note will be added to Design Report Figures 4-1, 4-2, 4-7 A, B, C, D, E, F, G and H and 5-2, to indicate that thicknesses are compacted thicknesses. Revised figures are included in Attachment 15 of this Response to Comments Document.

45. Comments on Specification 02200, Earthwork, Section 2.4, Equipment: This section needs to include specifications for the equipment used to smooth roll the soil used for the GCL subgrade.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

46. Specification 02200, Earthwork, Section 3.6, Placement: This section needs to be revised to address the following comments:

    a. Section 3.6.A.4. states that "differences in elevation for materials placed and compacted shall not exceed four feet . . ." Since material should not be placed in lifts in excess of eight (8) inches, this 4 foot difference seems excessive. The basis for a four (4) foot difference needs to be provided, and the specification revised as necessary to clarify its intent.

    b. Section 3.6.B.9. states lift thickness shall be controlled by the contractor through the use of grade stacks. This by itself is not adequate. The maximum depth of a loose lift needs to be specified in the specification. In general, the maximum depth of a loose lift should not be greater than eight (8) inches.

    c. Section 3.6.C.8 states the density of the tracked in place soil shall be no less than 90% of the maximum Standard Proctor dry density. However, other parts of the document state this layer will not be compacted. The portions of the Design Report that discuss this soil layer need to be revised as necessary to insure the document is consistent.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

47. Specification 02200, Earthwork, Section 3.10, Quality Control: Item A.10 requires data to be sealed by a Florida registered P.E. The section needs to be revised to reference an Illinois registered P.E. In addition, URS/Monsanto/Solutia need to review the entire document to insure references to Florida requirements are removed from the document.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

Sediment Material Handling

48. Specification 02225, Sediment Material Handling, Section 3.3, Placing and Spreading Sediments: This specification needs to state that sediments will not be placed in the cell from the top of the berms and/or pushed down the side slopes. This type of filling procedure should be avoided because it can damage the side slope liner system. Sediments (wastes) should only be placed on the bottom of the landfill and pushed toward the side slopes.

Response - Excavated sediments will be transported to the cell by truck. Trucks will use a ramp constructed inside the cell to transport sediments to the bottom of the cell. After the sediment is dumped, a bulldozer or other suitable equipment will be then used to spread the material. Section 3.3, Placing and Spreading Sediments, of Specification 02225, Sediment Material Handling, will be amended to include the following statements:

M. Contractor shall not place sediment in the cell from the top of the berms or by pushing sediment down the side slopes.

N. Contractor will place sediments only on the bottom of the cell and push them toward the side slopes.

These changes will be incorporated into the Design Report verbatim.

Geogrid

49. Specification 02227, Geogrid Reinforcement, Section 2.3, Geogrid: The use of "Geogrids" is not identified in the Figures provided in the Design Report. Details of how and where they will be used on the access ramp and cover need to be provided with the Figures in the Design Report.

Response - Drawings showing geogrid use are included in Attachment 16 of this Response to Comments Document. They will be included in the Design Report as Figures 4-9 and 4-10.

Geomembrane

50. Specification 02244, Geomembrane: The Installation Panel Layout Drawing referenced in Specification 02244 that identifies the placement of the geomembrane panels needs to be provided as part of Design Report.

Response - Panel layout drawings will be prepared by the Contractor and submitted to the Agency 30 days prior to the start of liner installation. This information will also be included in the record drawings for the cell. Preparation of these drawings by the Design Engineer is not appropriate because it removes the Contractor's obligation to install the liner according to the design and specifications.

Specification 02244, Section 1.5, Submittals, will be modified as shown below and incorporated in the Design Report:

F. Installation Panel Layout Drawing identifying placement patterns and seams, both fabricated (if applicable) and field seams, as well as any variance or additional details which deviate from the Drawings. Layout shall be drawn to scale and shall be adequate for use as the construction plan, and shall include information such as dimensions, panel numbering, and installation details. The Engineer shall review all Panel Layout Drawings prior to installation. **Panel Layout Drawings, as prepared by the Contractor and reviewed by the Engineer, shall be submitted to USEPA 30 days prior to liner installation.**

51. Specification 02244, Geomembrane: Specification 02244 needs to be revised to indicate that the HDPE geomembrane will be tested to verify it meets the minimum values for all of the parameters using the test methods and at the frequencies specified in the GRI standard GM13 (Rev. 3, June 28, 2000). Table 1(a) from GM13 that specifies the properties, test methods, minimum values, and frequencies is included as an attachment to these comments. **Note**: The values listed in the tables of GM13 are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

Response - Specification 02244, modified to include the test methods and frequencies in GRI Standard GM13 (Rev. 3, June 28, 2000), is given in Attachment 17 of this Response to Comments Document. It will be incorporated in the Technical Specifications of the Design Report verbatim.

52. Specification 02244, Geomembrane, Section 2.4, Field Seams: Section 2.4 needs to specify that seams will be welded by double tracked fusion welding machines whenever possible. Corners, butt seams and long repairs need to be fusion welded where possible. Extrusion or fusion welding should be used for all other repairs, detail work and patches.

Response - Section 2.4.A, Field Seams, of Specification 02244 will be changed to read as follows and included in the Technical Specifications of the Design Report:

A. Approved processes for seaming are extrusion welding and fusion double seam welding. **Fusion double seam welding will be the primary method for joining long, straight seams. Extrusion welding will be the primary seaming method in areas such as corners, sumps, pipe penetrations, tear repairs and cap strips where fusion double seam welding is not feasible.**

53. Specification 02244, Geomembrane, Section 3.4, Deployment: Section 3.4 needs to specify that geomembrane panels will be deployed on the side slopes the same way the GCL is required to be deployed in Specification 02245, by rolling them down the slope in a controlled manner. Geomembrane panels should not be pulled up the slopes.

Response: Section 3.4.E, Deployment, of Specification 02244 will be rewritten as shown below and included in the Design Report Technical Specifications:

E. Panels shall be oriented perpendicular to the line of the slope crest (i.e., down and not across slope)**, anchored securely and deployed down the slope in a controlled manner. Panels shall not be pulled up the slope.**

GCL

54. Specification 02245, GCL, Section 1.4 Delivery, Storage & Handling: It is recommended that section 1.4 of Specification 002245 be revised to require rolls of GCL to be stored off the ground on pallets from the time of delivery until they are installed.

Response: Section 1.4.B.1, Storage and Protection, of Specification 02245 will be revised as follows and included verbatim in the Technical Specifications of the Design Report:

1. The Contractor shall provide on-site storage area for GCL rolls from time of delivery until installation. **Rolls of GCL will be stored off the ground from time of delivery until they are installed.**

55. Specification 02245, GCL, Section 2.1 Materials: If a "lock-stitched" GCL is the same as one that is "needle-punched," the wording of this specification should be revised to reference a "needle-punched" GCL. If it is different, a copy of the manufacture's product data sheet that describes the process of creating a lock-stitched GCL needs to be provided.

Response: Geosynthetic manufacturers and products will be identified in the Design Report. Manufacturers technical data sheets will be included for all geosynthetic components including geomembrane, GCL, geotextile, geonet and geogrid. These cut sheets are included as Attachment 1 of this Response to Comments Document and will be included as Appendix H of the Design Report.

56. Specification 02245, GCL, Section 2.1 Materials: Table 1 needs to be revised to add the QC properties, tests methods, and testing frequencies specified in ASTM D-5889; Standard Practice for Quality Control of Geosynthetic Clay Liners. The minimum value for each of these additional properties also needs to be provided in the table.

Response - Table 1 of Specification 02245 was modified to include the QC properties, test methods and testing frequencies specified in ASTM D-5889. Minimum values of these additional properties were also added to this table. Table 1 is in Attachment 18 of this Response to Comments and will be included in Specification 02245 of the Design Report.

57. Specification 02245, Section 2.1 Materials: The minimum internal friction angle for hydrated GCL on a slope is identified as 6°. This is less than the interface friction angles above and below the GCL. The specification for the minimum internal friction angle for the GCL should be revised (increased), or additional information provided to justify this proposed minimum value (see earlier comments on Section 4.4.2, GCL Strength).

Response: Short term, long term and residual GCL strength calculations are included in Attachment 12 of this Response to Comments Document and will be included in Appendix C, Liner System Component Design, of the Design Report.

58. Specification 02245, GCL, Section 3.3 Installation: The specifications for overlaps of GCL panels need to state that the panels should be overlapped/layered in such a way that any liquid will run from one panel to the top of the next, rather than underneath it.

Response: Section 3.3.B.2, Overlaps, of Specification 02245 will be amended as shown below to indicate that the GCL layers need to be overlapped so that any liquid will run from one panel to the top of the next. Placing GCL so that liquid from one layer can run underneath a lower layer will be prohibited.

2. In general, no horizontal seams are allowed on side slopes. **Any horizontal seams on side slopes will be overlapped so that liquid will run from the top of the higher panel to the top of the lower panel. GCL shall not be placed so that liquid from a higher panel can run underneath a lower panel.**

59. Specification 02245, GCL, Section 3.4 Anchor Trench: The Figures/details of the liner system show the ends of the liner system laid out horizontally in the berm, not in an anchor trench. The application needs to be revised to consistently identify how the liner system will be anchored. It is recommended that an anchor trench be used to hold the liner system in place.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

60. Specification 02245, GCL: This specification does not include a section on Quality Control.

Response - Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

Geonet

61. Specification 02246, Geonet, Section 2.1: The table of geonet properties needs to be revised to include transmissivity, the test method used to measure this parameter, and the minimum acceptable value. The frequencies for testing each property should also be added to the table.

Response - Geonet transmissivity values, test method and minimum acceptable values were added to Specification 02246. Manufacturers specifications and testing methods were also added to this table. The revised table is included in Attachment 19 of this Response to

Comments Document and will be included verbatim in the Technical Specifications of the Design Report.

It is inappropriate to test this material in the field since it will perform as designed unless damaged. Visual inspection will be used to insure that damaged geonet is not installed. Specification 02246, Section 3.1, Geonet Placement and Handling, will be modified to prohibit the use of damaged geonet as shown below and included in the Technical Specifications:

A. Handle all geonet is such a manner as to ensure it is not damaged in any way. **Damaged geonet shall not be installed. If geonet is damaged during or after installation, it shall be replaced.**

Seeding

62. Specification 02932, Seeding, Section 2.1 Seed Mixture: This section specifies the use of Pensacola Bahia seed and Bermuda grass seed on the cover of the landfill. It is questionable whether these types of grasses are acceptable for use in Illinois. The vegetation specifications for this site should required the seed mixture to conform to Illinois DOT Section 624.07 Seed Mixture Class 1 specifications, and include seeds such as Kentucky Bluegrass, Perennial Ryegrass, Red Top or Creeping Red Fescue, and Ladino or White Dutch Clover.

Response - Specification 02932 was changed to include grass seed mixes appropriate for Illinois, specifically IDOT Section 250 Seed Mixture Class 1. The revised specification is included in Attachment 20 of this Response to Comments Document and will be included in the Technical Specifications section of the Design Report.

Gas Venting System

63. Gas Venting System: Appendix E and Appendix F do not appear to include any specifications for the materials used to vent gasses from the landfill, or the procedures to install these devices through the cover system.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

CONSTRUCTION QUALITY CONTROL PROGRAM:

64. CQA Sampling: Because this landfill will be used to hold fairly high concentrations of PCBs, organic wastes, and heavy metals, it is very important that it is properly constructed.

Therefore, in addition to the confirmation samples collected, analyzed and interpreted by the Construction Manager, the CQA consultant should be responsible for collecting and interpreting his or her own samples from the soils and liner materials used to construct the landfill.

Response - The Construction Manager is not collecting, analyzing and interpreting confirmation samples. Implementation of the CQA Manual, which includes collection, analysis and interpretation of samples from the soils and liner materials used to construct the containment cell, is the responsibility of the CQA Consultant. To ensure that the containment cell is properly constructed, the CQA Consultant will implement the QCA Manual independent of the Construction Manager, Manufacturer and Installer. However, the CQA Consultant will report results to the Construction Manager, Designer and Owner. These reporting relationships are discussed in the response to Comment 65 below.

65. Quality Control or Quality Assurance: The Construction Quality Assurance Programs, and the Specifications to some extent, need to be revised to better define the rolls of the Construction Manager and CQA Consultant:

    a. An organizational chart that graphically describes how construction of the project will be organized needs to be provided.

    b. The CQA Manuals (Appendix E, Section 1.3.1.1 and Appendix G, Section 2.3.1.1) state that the Construction Manager is responsible for the organization and implementation of the quality assurance activities for the project. Thus it appears the Construction Manager is responsible for the CQA officer's duties.

    c. Several sections within the specifications in Appendix E refer to quality assurance and/or quality evaluation. For example, Geonets, Specification 02246 includes sections titled Quality Assurance, Quality Control, and Material Quality Evaluation. As the Construction Manager is responsible for compliance with the requirements in the specification, it appears that the Construction Manager may also be performing Quality Assurance. The wording in the specifications needs to be revised where necessary to clearly state that the Construction Manager only performs Quality Control, not Quality Assurance.

Response - The Construction Manager is responsible for ensuring that the containment cell is built properly. Paragraph 1, Section 1.3.1.1, Responsibilities of Appendix F, Construction Quality Assurance Manual for Installation of Geosynthetic Components for the Sauget Area 1 TSCA Landfill, states the following:

> The Construction Manager is responsible for all construction quality. The Construction Manager is responsible for the organization and implementation of the quality assurance activities for the project.

Section 1.2.4, Geosynthetic Construction Quality Assurance Consultant, of the same document states:

> The Geosynthetic Construction Quality Assurance (CQA) Consultant is a firm independent from the Construction Manager, Manufacturer(s) and Installer that shall be responsible for observing and documenting activities related to the quality assurance of the production and installation of the geosynthetic system on behalf of Solutia.

This clearly obviates the comment:

> "Thus, it appears the Construction Manager is responsible for the CQA officer's duties."

Appendix E, Construction Quality Assurance Manual for Installation of Soil Components of the Lining and Final Cover Systems for the Sauget Area 1 TSCA Landfill include the same language.

To clarify reporting relationships of the CQA Consultant, the project organization chart in Attachment 21 of this Response to Comments Document will be included in Appendix F and Appendix E of the Design Report.

CQAP Installation of Geosynthetic Components Appendix F

66. CQA Manual, Geosynthetics, Appendix F: The CQA Manual for installation of geosynthetic components needs to be revised to reflect earlier comments that have been made regarding the specifications and the properties of the geosynthetic components in the liner systems.

Response - The CQA manual will be revised to incorporate earlier comments on specifications and properties of the geosynthetic components in the liner systems. It will be included in the final version of the Design Report.

67. CQA Manual, Geosynthetics, Appendix F: The CQA Manual for installation of geosynthetic components needs to be revised to include a section on GCLs.

Response - Section 6.0, Geosynthetic Clay Liners, will be added to Appendix F, Construction Quality Assurance Manual for Installation of Geosynthetic Components for the Sauget Area 1 TSCA Landfill. This new section is included as Attachment 22 of this Response to Comments Document.

68. CQA Manual, Geosynthetics, Appendix F: It is recommended that an individual table be created for each geosynthetic component that lists the properties, test name and test method number, test frequency and the acceptable minimum/maximum values for each property.

Response - A table listing the properties, test name and test method, test frequency and acceptable values of each geosynthetic component will be added to Appendix F, Construction Quality Assurance Manual for Installation of Geosynthetic Components for the Sauget Area 1 TSCA Landfill. This table is included as Attachment 23 of this Response to Comments Document.

69. CQA for Subgrade under Geomembranes: Section 2.3 Subgrade Preparation needs to specify quantifiable values for the subgrade. At a minimum, these need to include density, moisture content, maximum depth/height of ruts in the subgrade, and the size of rocks or sharp objects allowed in the top 6 inches of the soil below the geomembrane that are identified in the Specifications.

Response - Section 2.3.1.3, Surface Preparation, will be amended to read as follows:

> The surface to be lined has been rolled, compacted, or handworked so as to be free of irregularities, protrusions, loose soil and abrupt changes in grade. **Bedding layer soils will have clods no larger than two inches, will be placed and compacted to 90% Standard Proctor Density and will have a moisture content at or near optimum. Bedding layers will be smooth with no ruts or sharp edges before, during and after installation of the overlying**

geosynthetic material. They will provide a surface capable of supporting the geosynthetics and other layers in the liner system.

This text will be incorporated verbatim in Section 2.3.1 of Appendix F, Construction Quality Assurance Manual for Installation of Geosynthetic Components for the Sauget Area 1 TSCA Landfill.

70. CQA for Geomembranes relative to GCLs: Section 2.4.4, Method of Deployment needs to be revised to reflect the following comments regarding the placement of geomembrane on a GCL:

    a. Section 2.4.4 needs to specify the method used to deploy the geomembrane will not damage the GCL under the geomembrane (e.g. the heavy equipment used to install the geomembrane will not drive on the GCL, and the geomembrane will be rolled down the side slopes rather than dragged up them).

    b. Deployment (and welding) of geomembrane panels needs to be tied to installation of the GCL panels under the geomembrane. Specifically, the geomembrane needs to be installed the same day that the GCL panels directly under it are installed.

    c. The geomembrane needs to be covered with 6 inches of material before the GCL under it has time to become fully hydrated. When possible, the weight of 6 inches of material should be placed on the GCL the same day the GCL panel is installed. The CQA manual should refer to the calculations (required by these comments) that provide an estimate of the time it will take the GCL to become fully hydrated once it is installed.

Response: Specification 02245, Section 3.3, Installation, requires the following:

A. GCL deployment: Handle GCL in a manner to ensure it is not damaged. At a minimum comply with the following:

1. On slopes, anchor the GCL securely and deploy it down the slope in a controlled manner.
10. In general, only deploy GCL that can be covered during that day by geomembrane or a minimum of 12 inches of approved soil cover.

These requirements are already included in the specifications and there is no apparent need to include them in the CQA Manual. As for the last issue, the liner system will be built before 100% hydration of the GCL liner will occur. Technical information on GCL hydration time is

included in Attachment 8 of this Response to Comments Document. This information demonstrates that the containment cell will be built before complete GCL hydration occurs.

71. Wrinkles in Geomembranes: Both Section 2.4.4, Method of Deployment, and Section 2.8.5, Large Wrinkles need to be revised to address the following comments on wrinkles in geomembranes:

    a. Section 2.4.4 needs to identify a specific, measurable the size of a wrinkle in the geomembrane that is considered unacceptable. Both the width and height need to be specified. Section 2.4.4 needs to state that if a wrinkle is taller than it is wide, or is higher than 3 inches above the subgrade, the geomembrane panel should be readjusted to smooth out the wrinkle before it is welded to the next panel.

    b. There should not be any wrinkles in the geomembrane that is placed on top of the GCL since they can result in uneven pressures on the GCL. This can damage the integrity of the GCL by causing bentonite migration and an increase in the permeability of the GCL.

    c. CQA at the site needs to be capable of insuring that installation process does not result in a wrinkle that is 12 inches high. Section 2.8.5 needs to be revised to reflect that a wrinkle taller than it is wide, or higher than 3 inches above the subgrade, will be repaired.

Response - Section 2.8.5, Large Wrinkles, Paragraph 1, will be revised as indicated below and included in Appendix F:

> When seaming of the geomembrane is completed, and prior to placing overlying materials, the Geosynthetic CQA Consultant shall indicate to the Construction Manager which wrinkles should be cut and reseamed by the Installer. The number of wrinkles to be repaired should be kept to an absolute minimum. Therefore, wrinkles should be located during the coldest part of the installation process, while keeping in mind the forecasted weather to which the uncovered geomembrane may be exposed. **The geomembrane will be inspected for wrinkles every morning by the Geosynthetic CQA Consultant and the results of the inspection will be documented. On completion of geomembrane installation, it will be inspected for wrinkles by the Geosynthetic CAQ Consultant and the Agency and the results of this inspection will be video recorded with a date stamp. Unacceptably large wrinkles will be removed after this final inspection.** Wrinkles are considered

large when the geomembrane can be folded over on itself. Seams produced while repairing wrinkles shall be tested as outlined above.

72. Seaming Geomembranes: Section 2.5.2, Acceptable Seaming Methods: As noted in the comments on the Specifications for geomembranes, this section needs to specify that the CQA consultant is responsible for insuring the use of extrusion welds will be minimized.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

73. Conformance Testing for Geonets: Transmissivity should be included as a conformance test in Section 4.2.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

CQAP Installation of Soil Components Appendix G

74. CQA Manual, Soil Components, Appendix G: The CQA Manual for installation of soil components needs to be revised to include earlier comments regarding the specifications and properties of the soil components in the liner systems. For example, Section 4.2.3 Soil Selection Criteria needs to include a subsection for the bedding layer under the GCL, and additional criteria such as specifications for the grain size distributions need to be provided for the various types of fills.

Response - The CQA manual will be revised to incorporate earlier comments on specifications and properties of the geosynthetic components in the liner systems. It will be included in the final version of the Design Report.

75. CQA Manual, Soil Components, Appendix G: It is recommended that an individual table be created for each soil component that lists the properties, test name and test method number, test frequency and the acceptable minimum/maximum values for each property.

Response - A table listing the properties, test name and test method, test frequency and acceptable values of each soil component will be added to Appendix G, Construction Quality Assurance Manual for Installation of Soil Components of the Liner and Final Cover Systems for the Sauget Area 1 Landfill. This table is included as Attachment 24 of this Response to Comments Document.

76. CQA Manual, Soil Components, Appendix G, Section 4.2.3: The Soil Selection Criteria for each soil component needs to include measurement of the thickness of each soil component.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

77. CQA Manual, Soil Components, Appendix G, Section 4.2.4: The design report needs to identify the sources of the borrow soils on a scale drawing. It also needs to describe how these areas have been used in the past (e.g. agricultural, industrial, residential, etc.).

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

78. CQA Manual, Soil Components, Appendix G, Section 4.2.4: The section titled Earth Fill Material Management needs to identify the parameters, test methods and testing frequencies for which the borrow soils will be analyzed. The minimum number of parameters and test frequencies for evaluating borrow sources are provided in Tables 2-2 and 2-3 of the USEPA Technical Guidance Document titled Quality Assurance and Quality Control for Waste Management Facilities (EPA/600/R-93/182, September 1993). If there is evidence, or it is suspected, that the source area may be contaminated with hazardous constituents, it may be necessary to perform additional tests in order to determine if the soils contain contaminants.

Response - Off-site borrow will be sampled and analyzed for TCL/TAL constituents at a rate of one sample every 5,000 cubic yards. This testing requirement will be incorporated in Section 4.2.4 of the CQA Manual by adding this sentence to the end of the first paragraph:

> As the material is excavated from an approved borrow facility, the CQA Consultant shall confirm that the soils meet the requirements of the Specifications. The CQA consultant will use his/**her** experience with visual/manual soil classification techniques to assess the segregation of soils. The CQA Consultant will note in his/**her** field records changes in odor, texture, apparent moisture, and the depths of which they occur. The CQA Consultant shall confirm that adequate processing, as described in the Specifications, is performed for removal of roots, rocks, rubbish or unsuitable materials, and achieve the specified soil clod size. **Off-site borrow will be sampled and analyzed for TCL/TAL constituents at a rate of one sample every 5,000 cubic yards. Results will be compared to TACO Tier I criteria for commercial/industrial area soils. Soil with concentrations higher than these levels will not be accepted for use in containment cell construction.**

79. CQA Manual, Soil Components, Appendix G, Section 4.3.3: The design report needs to clarify which component in the landfill design it considers the Low Permeability Fill.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

80. CQA Manual, Soil Components, Appendix G, Section 4.3.4: The evaluation of layer bonding states that test pits may be used (emphasis added). This section needs to specify the minimum number of test pits per lift per acre thatwill be used to evaluate the bonding of two lifts.

Response - Paragraph 1 of Section 4.3.4, Evaluation of Layer Bonding, will be rewritten as follows and included verbatim in Appendix G, Construction Quality Assurance Manual for Installation of Soil Components of the Liner and Final Cover Systems for the Sauget Area 1 Landfill:

> **Evaluation of layer bonding will be determined by collecting one Shelby tube sample for every 10,000 square feet of compacted bottom soil. Shelby tubes will only be pushed 8 inches in order to protect the underlying liner system. Samples holes will be filled with bentonite.**
>
> **The CQA Consultant shall confirm that layer bonding between compacted lifts is adequate and that discontinuities do not appear to exist. This will be accomplished by cutting the Shelby tube sample in half longitudinally and visually examining the sample.** The CQA Consultant shall notify the Construction Manager of any layer bonding deemed to be deficient and shall confirm that repairs are performed by the Earthwork Contractor.

81. Test Fill / Construction Proofing Ramp: It is recommended that a test pad be used to evaluate the bonding between the lifts prior to construction of the containment cell. The procedures for constructing and evaluating a test pad are provided in Section 2.10 of the USEPA Technical Guidance Document titled Quality Assurance and Quality Control for Waste Management Facilities (EPA/600/R-93/182, September 1993). Note: This same procedure can also be used to evaluate the soils proposed for use as the bedding layer below the GCL component of the liner.

Response - Shelby tube samples will be used to check bonding between soil layers. Samples will be collected and checked at a frequency of one every 10,000 square feet. With this approach, a test pad is not needed to assure bonding between soil layers.

MAINTENANCE PROCEDURES FOR LEACHATE COLLECTION & DETECTION SYSTEMS

82. Maintenance Procedures for Leachate Collection and Detection Systems: Maintenance of the leachate collection and detection systems needs to be considered when these systems are designed. Therefore, the Design Report needs to describe the anticipated maintenance activities that will be used to assure proper operation of the leachate collection/detection systems throughout the landfill's expected life, and describe how the design of these systems incorporates these maintenance activities. In addition, Exhibit 2 of the UAO included this item as a requirement in the Design Report.

Response - Leachate collection and leachate detection systems were designed to be low maintenance systems. No maintenance is required to ensure that drainage occurs because both systems drain by gravity to their respective collection sumps. Vacuum trucks will be used to remove accumulated liquids from both sumps so no pump maintenance is required. Riser pipes and perforated pipe sections in the collection sumps are large enough to allow pressure washing should fouling occur.

LINER REPAIRS DURING OPERATION

83. Liner Repairs During Operation: The Design Report needs to describe the methods that will be used to repair any damage to the liner, which occurs while the landfill is in operation during placement of the waste (e.g. a dozer ripping the liner). This description needs to address all layers in the liner system.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

RUN-OFF CONTROL SYSTEMS

84. Run-Off Control Systems, Section 5.5: The design of the landfill needs include a run-off control system that is capable of holding the stormwater from a 25 year 24 hour storm after the unit is closed. It is not acceptable discharge the run-off from the closed landfill directly to Dead Creek. A run-off control system for the closed landfill will prevents sediments from washing off of the landfill and into the restored Dead Creek. Also, if the cover system fails, and the run-off becomes contaminated, the run-off control system will prevent the contaminated run-off, sediments and wastes, from entering and contaminating the restored Dead Creek. The description of the run-off control system needs to include the following:

a. Design and Performance: Describe the run-off collection and control system design. Provide calculations demonstrating that the system has sufficient capacity to collect and hold the total run-off volume. Provide a plan view showing the locations of the run-off control system components, along with sufficient drawing details and cross sections. Indicate the fate of the collected run-off.

b. Calculation of Peak Flow: Identify the total run-off volume expected to result from at least a 24-hour, 25-year storm. Describe data sources and methods used to make the peak flow calculation. Provide copies of the calculations and data, including appropriate references.

c. Management of Collection and Holding Units: Describe how collection and holding facilities associated with run-on and run-off control systems will be emptied or otherwise managed expeditiously after storms to maintain system design capacity. Describe the fate of liquids discharged from these systems.

d. Construction: Provide detailed construction and material specifications for the run-off control systems. Include descriptions of the construction quality control program that will be utilized to assure that construction is in accordance with design requirements.

e. Maintenance: Describe any maintenance activities required to assure continued proper operation of the run-off control systems throughout the active life of the unit.

Response - During construction, storm water in the cell will be pumped from the cell and discharged to Dead Creek. After sediment transfer, storm water in the cell will be treated, as required, and discharged to the POTW. Once the cover is installed, sedimentation will be controlled using best management practices. After vegetation is established there is no need to control runoff from the cell. Storm water runoff will be routed to a drainage swale on the north side of the cell that discharges to Dead Creek. Design drawings for this swale, which is designed to handle a 25 year, 24 hour storm, are included in Attachment 25 of this Response to Comments Document. They will be included as Figures 5-1 and 5-6 of the Design Report.

Calculation of Peak Flow:

85. Peak Flow and Design of Drainage Control Structures: The calculations in Appendix D need to be revised to address the following comments regarding the stormwater calculations:

a. The first page of the stormwater control calculations refer to a peak flow of 16 cfs, but then use 8 cfs to calculate depth of flow and velocity. The QTR-55 computer model in indicates the peak flow for a 25 year 24 hour storm is 11 cfs. Therefore, the design calculations should use at least 11 cfs for the flow.

b. The design of the down chute uses a depth of flow of 0.38 inches when the depth of flow in the drainage swale upstream from the chute is indicated to be 0.58 inches. The calculations need to identify how the depth of flow in the down chute was determined.

c. The calculations for sheet flow use the amount of rainfall from a 2 year 24 hour storm. This is not acceptable. The design needs to be based on the rainfall from a 25 year 24 hour storm.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

CLOSURE AND POST-CLOSURE REQUIREMENTS

86. Section 5.4 Cover System Design: As noted in earlier comments regarding the Specifications and liner materials, the cover system design needs address the following comments:

a. The common name, species and variety of the proposed cover crop needs to be provided.

b. Descriptions of GCL and synthetic liner components including chemical properties, strength, thickness and manufacturer's specifications.

c. It is not acceptable to use sand as a bedding layer under the GCL component in the cover system. See earlier comment on bedding layer requirements for a GCL in the bottom liner.

Response - The last sentence of Section 5.4.1, General, will be modified to read:

> The grassing will be with **grass seed mixes appropriate for Illinois, specifically IDOT Section 250 Seed Mixture Class 1.**

Geosynthetic manufacturers and products will be identified in the Design Report. Manufacturers technical data sheets will be included for all geosynthetic components including Geomembrane, GCL, geotextile, geonet and geogrid. These cut sheets are included as Attachment 1 of this Response to Comments Document and will be included as Appendix H of the Design Report.

A wide range of soils, including sand, can be used as bedding material for geosynthetics. Specification 02200 - Earthwork, included in Attachment 4 of this Response to Comments Document, will be used for the geosynthetic bedding layers in the liner system. It will also be

included in Appendix E, Technical Specifications, of the Design Report. Bedding layer soils will have clods no larger than two inches, will be placed and compacted to 90% Standard Proctor Density and will have a moisture content at or near optimum. Bedding layers will be smooth with no ruts or sharp edges before, during and after installation of the overlying geosynthetic material. They will provide a surface capable of supporting the geosynthetics and other layers in the liner system.

POST-CLOSURE REQUIREMENTS

87. Post-Closure Requirements: If the Post-Closure Requirements will be addressed in the O & M Plan, the Design Report needs to state this. Otherwise, they need to be included in the Design Report since they were included in Exhibit 2 of the UAO.

Response: Comment to be addressed in the December 29, 2000 Response to Comments Document (Part III)

ATTACHMENT 1

GEOSYNTHETIC MATERIAL CUT SHEETS

GSE

GSE HD*

HDPE Geomembrane

GSE HD is a high quality, high density polyethylene (HDPE) geomembrane produced from a specially formulated, proprietary virgin polyethylene resin. This polyethylene resin is designed specifically for flexible geomembrane applications. GSE HD contains approximately 97.5% polyethylene, 2.5% carbon black and trace amounts of antioxidants and heat stabilizers; no other additives, fillers or extenders are used. GSE HD has outstanding chemical resistance, mechanical properties, environmental stress crack resistance, dimensional stability and thermal aging characteristics. GSE HD has excellent resistance to UV radiation and is suitable for exposed conditions.

TESTED PROPERTY	TEST METHOD	MINIMUM VALUES				
Thickness, mils (mm)	ASTM D 751/1593/5199	27 (0.68)	36 (0.90)	54 (1.35)	72 (1.80)	90 (2.25)
Density, g/cm^3	ASTM D 792/1505	0.94	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 638, Type IV					
Strength at Break, lb/in-width (N/mm)	Dumbell, 2 ipm	122 (21)	162 (28)	243 (43)	324 (57)	405 (71)
Strength at Yield, lb/in-width (N/mm)		65 (11)	86 (15)	130 (23)	173 (30)	216 (38)
Elongation at Break, %	G.L. 2.5 in (64 mm)	560	560	560	560	560
Elongation at Yield, %	G.L. 1.3 in (33 mm)	13	13	13	13	13
Tear Resistance, lb (N)	ASTM D 1004	22 (98)	30 (133)	45 (200)	60 (267)	75 (334)
Puncture Resistance, lb (N)	FTMS 101, Method 2065	39 (174)	52 (231)	80 (356)	105 (467)	130 (579)
Carbon Black Content, %	ASTM D 1603	2.0	2.0	2.0	2.0	2.0
Environmental Stress Crack Resistance, hr	ASTM D 1693, Cond. B	1500	1500	1500	1500	1500

REFERENCE PROPERTY	TEST METHOD	NOMINAL VALUES				
Thickness, mils (mm)	ASTM D 751/1593/5199	30 (0.75)	40 (1.0)	60 (1.5)	80 (2.0)	100 (2.5)
Roll Length** (approximate), ft (m)		952 (290)	650 (198)	420 (128)	320 (98)	250 (76)
Low Temperature Brittleness, °F (°C)	ASTM D 746, Cond. B	<-107 (<-77)	<-107 (<-77)	<-107 (<-77)	<-107 (<-77)	<-107 (<-77)
Oxidative Induction Time, minutes	ASTM D 3895, 200 °C Pure O_2, 1 atm	100	100	100	100	100
Water Absorption, % wt. change	ASTM D 570	<0.01	<0.01	<0.01	<0.01	<0.01
Moisture Vapor Transmission, g/m^{2}day	ASTM E 96	<0.001	<0.001	<0.001	<0.001	<0.001
Carbon Black Dispersion	ASTM D 3015	A1,A2,B1	A1,A2,B1	A1,A2,B1	A1,A2,B1	A1,A2,B1
Dimensional Stability (each direction), %	ASTM D 1204, 100 °C, 1 hr	±2	±2	±2	±2	±2
Melt Flow Index, g/10 minutes	ASTM D 1238, Cond.190/2.16	≤1.0	≤1.0	≤1.0	≤1.0	≤1.0

GSE HD is available in rolls approximately 22.5 ft (6.9 m) and 34.5 ft (10.5 m) wide and weighing about 2,900 lb (1,315 kg) and 4,400 lb (1,995 kg) respectively. Other material thicknesses are available upon request.

** Roll lengths correspond to the 22.5 ft (6.9 m) wide roll goods.

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GSE

GSE HD* Textured

Textured HDPE Geomembrane

GSE HD Textured is the textured version of GSE HD. It is a high quality, high density polyethylene (HDPE) geomembrane with one or two co-extruded, textured surfaces, and consisting of approximately 97.5% polyethylene, 2.5% carbon black and trace amounts of antioxidants and heat stabilizers; no other additives, fillers or extenders are used. The resin used is a specially formulated, proprietary virgin polyethylene and is designed specifically for flexible geomembrane applications. GSE HD Textured has excellent resistance to UV radiation and is suitable for exposed conditions. This product allows projects with greater slopes to be designed since frictional characteristics are enhanced.

TESTED PROPERTY	TEST METHOD	MINIMUM VALUES				
Thickness, mils (mm)	ASTM D 751/1593/5199	27 (0.68)	36 (0.90)	54 (1.35)	72 (1.80)	90 (2.25)
Density, g/cm^3	ASTM D 792/1505	0.94	0.94	0.94	0.94	0.94
Tensile Properties (each direction)[1]	ASTM D 638, Type IV					
Strength at Break, lb/in-width (N/mm)	Dumbell, 2 ipm	38 (7)	50 (9)	75 (13)	100 (18)	125 (22)
Strength at Yield, lb/in-width (N/mm)		65 (11)	86 (15)	130 (23)	173 (30)	216 (38)
Elongation at Break, %	G.L. = 2.5 in (64 mm)	120	120	120	120	120
Elongation at Yield, %	G.L. = 1.3 in (33 mm)	13	13	13	13	13
Tear Resistance, lb (N)	ASTM D 1004	22 (98)	30 (134)	45 (200)	60 (267)	75 (334)
Puncture Resistance, lb (N)	FTMS 101, Method 2065	38 (169)	52 (231)	80 (356)	105 (467)	130 (579)
Carbon Black Content, %	ASTM D 1603	2.0	2.0	2.0	2.0	2.0
Environmental Stress Crack Resistance[2], hr	ASTM D 1693, Cond. B	1500	1500	1500	1500	1500

REFERENCE PROPERTY	TEST METHOD	NOMINAL VALUES				
Thickness, mils (mm)	ASTM D 751/1593/5199	30 (0.75)	40 (1.0)	60 (1.5)	80 (2.0)	100 (2.5)
Roll Length (approximate), ft (m)		825 (251)	730 (223)	520 (158)	400 (122)	325 (99)
Low Temperature Brittleness, °F (°C)	ASTM D 746, Cond. B	<-107 (<-77)	<-107 (<-77)	<-107 (<-77)	<-107 (<-77)	<-107 (<-77)
Oxidative Induction Time, minutes	ASTM D 3895, 200 °C Pure O_2, 1 atm	100	100	100	100	100
Carbon Black Dispersion	ASTM D 3015	A1,A2,B1	A1,A2,B1	A1,A2,B1	A1,A2,B1	A1,A2,B1
Dimensional Stability (each direction), %	ASTM D 1204, 100 °C, 1 hr	±2	±2	±2	±2	±2
Melt Flow Index, g/10 minutes	ASTM D 1238, Cond.190/2.16	≤1.0	≤1.0	≤1.0	≤1.0	≤1.0

GSE HD Textured is available in rolls approximately 22.5 ft (6.9 m) wide and weighing about 3,700 lb (1,678 kg). Other material thicknesses are available upon request.

[1]The combination of stress concentrations due to coextrusion texture geometry and the small specimen size results in large variation of test results. Therefore, these tensile properties are minimum average values.

[2]Note: ESCR for HD Textured is conducted on representative smooth membrane samples.

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GSE

GSE HyperFrictionFlex*

Textured HyperFlex* HDPE Geomembrane

GSE HyperFrictionFlex is a premium grade, high density polyethylene (HDPE) geomembrane produced from a specially formulated, virgin polyethylene resin, and textured using GSE's patented FrictionFlex® process. The polyethylene resin is designed specifically for flexible geomembrane applications. HyperFlex has outstanding resistance to UV radiation and stress cracking and is therefore highly suited for exposed applications. The FrictionFlex process is the only manufacturing method that provides a textured material without significant reduction of any of the physical properties of the smooth surfaced membrane. No other textured membrane provides an equivalent combination of enhanced slope stability and resistance to containment failure if settlement of the lined structure occurs.

TESTED PROPERTY	TEST METHOD	MINIMUM VALUES			
Thickness, mils (mm)	ASTM D 751/1593/5199	36 (0.90)	54 (1.35)	72 (1.80)	90 (2.25)
Density, g/cm^3	ASTM D 792/1505	0.94	0.94	0.94	0.94
Tensile Properties (each direction)	ASTM D 638, Type IV				
Strength at Break, lb/in-width (N/mm)	Dumbell, 2 ipm	162 (28)	243 (43)	324 (57)	405 (71)
Strength at Yield, lb/in-width (N/mm)		86 (15)	130 (23)	173 (30)	216 (38)
Elongation at Break, %	G.L. = 2.5 in (64 mm)	500	560	560	560
Elongation at Yield, %	G.L. = 1.3 in (33 mm)	13	13	13	13
Tear Resistance, lb (N)	ASTM D 1004	30 (133)	45 (200)	60 (267)	75 (334)
Puncture Resistance, lb (N)	FTMS 101, Method 2065	52 (231)	80 (356)	105 (467)	130 (579)
Carbon Black Content, %	ASTM D 1603	2.0	2.0	2.0	2.0
Environmental Stress Crack Resistance, hr	ASTM D 1693, Cond. B	1500	1500	1500	1500

REFERENCE PROPERTY	TEST METHOD	NOMINAL VALUES			
Thickness, mils (mm)	ASTM D 751/1593/5199	40 (1.0)	60 (1.5)	80 (2.0)	100 (2.5)
Roll Length (approximate), ft (m)		665 (216)	470 (215)	350 (107)	280 (85)
Low Temperature Brittleness, °F (°C)	ASTM D 746, Cond. B	<-107 (<-77)	<-107 (<-77)	<-107 (<-77)	<-107 (<-77)
Oxidative Induction Time, minutes	ASTM D 3895, 200 °C Pure O_2, 1 atm	100	100	100	10
Carbon Black Dispersion	ASTM D 3015	A1,A2,B1	A1,A2,B1	A1,A2,B1	A1,A2,B1
Dimensional Stability (each direction), %	ASTM D 1204, 100 °C, 1 hr	±2	±2	±2	±2
Melt Flow Index, g/10 minutes	ASTM D 1238, Cond.190/2.16	≤1.0	≤1.0	≤1.0	≤1.0

GSE HyperFrictionFlex is available in rolls approximately 22.5 ft (6.9 m) and 24 ft (7.3 m) wide and weighing about 3,500 lb (1,588 kg). Other material thicknesses are available upon request. See the FrictionFlex Application Data Sheet for more information regarding the GSE FrictionFlex texturing process.

** Roll lengths correspond to the 24 ft (7.3 m) wide roll goods.

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GSE HyperNet*
HDPE Geonet

GSE HyperNet products are geosynthetic drainage materials composed of two bonded, overlapping HDPE strands commonly referred to as geonet. HyperNet transmits fluids (liquids and gases) in the plane of the net by creating open channels that allow flow. HyperNet is a premium grade geonet with excellent chemical resistance, mechanical properties and life expectancy.

GSE HyperNet HF*
HDPE High Flow Geonet

GSE HyperNet HF products are manufactured in the same manner as standard GSE HyperNet but are designed specifically for use in situations where high flow and high loads are expected such as in landfill cell designs.

GSE HyperNet CP*
HDPE Capping Geonet

GSE HyperNet CP products are manufactured in the same manner as standard GSE HyperNet but are designed specifically for use in situations where lower normal loads are expected such as in landfill cap designs.

TESTED PROPERTY	TEST METHOD	MINIMUM AVERAGE VALUES[d]		
		HyperNet	HyperNet HF	HyperNet CP
Transmissivity, m^2/sec	ASTM D 4716	1×10^{-3} [a]	2×10^{-3} [a]	1×10^{-3} [b]
Thickness, mil (mm)	ASTM D 5199	200 (5)	250 (6.3)	200 (5)
Density, g/cm^3	ASTM D 1505	0.94	0.94	0.94
Tensile Strength (MD), lb/in (N/mm)	ASTM D 5034/5035	45 (7.9)	55 (9.6)	32 (5.6)
Carbon Black Content, %	ASTM D 1603	2.0	2.0	2.0
Roll Width, ft (m)		14 (4.3)	14 (4.3)	14 (4.3)
Roll Length[c], ft (m)		300 (90)	300 (90)	300 (90)

(a) Gradient of 1.0, normal load of 10,000 psf, water at 70°F between stainless steel plates
(b) Gradient of 1.0, normal load of 4,000 psf, water at 70°F between stainless steel plates
(c) Other roll lengths may be available upon request.
(d) These are typical values and are based on the cumulative results of specimens tested and as determined by GSE Quality Assurance practices.

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Specifications

High Density Polyethylene (HDPE) – DS Textured

Series HTX13

Serrot's HDPE geomembranes are produced from first quality, high molecular weight resins and are manufactured specifically for containment of fluids in hydraulic structures. Serrot geomembranes are durable and have been formulated to be resistant to chemicals, ultraviolet degradation and leaching additives. The series of geomembranes shown below is based on a minimum average thickness value equal to the nominal thickness minus 5%, with the lowest individual of 8 of 10 values equal to the nominal thickness minus 10%, and the lowest individual of 10 values equal to nominal minus 15%.

Property	Test Method	Frequency[1]	HT413	HT613	HT813	HT1013
Thickness (nominal) (mils)			40	60	80	100
Thickness (min. ave.) (mils)	D5994	per roll	38	57	76	95
• Lowest indiv. of 8 of 10 values			36	54	72	90
• Lowest indiv. of 10 values			34	51	68	85
Tensile Properties (min. ave.)	D638 Type IV	50,000 SF				
• Yield Strength (lb/in)	(2 ipm)		84	126	168	210
• Break Strength (lb/in)			60	90	120	150
• Yield Elongation (%)	(1.3" gauge)		12	12	12	12
• Break Elongation (%)	(2.0" gauge)		100	100	100	100
Tear Resistance (min. ave.) (lb)	D1004	50,000 SF	28	42	56	70
Puncture Resistance (min. ave.) (lb)	D4833 FTMS 101/ Method 2065[2]	50,000 SF Certified	60 52	90 78	120 104	150 130
Carbon Black Content (range) (%)	D1603/D4218	50,000 SF	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	D5596	50,000 SF	Note	Note	Note	Note
Density (min. ave.) (g/cc)	D1505/D792	Resin Batch	0.940	0.940	0.940	0.940
Stress Crack Resistance (hr)	D5397 (App.)	Resin Batch	200	200	200	200
Dimensional Stability (max. ave.) (%)	D1204	Resin Batch	±2	±2	±2	±2

[1] Testing frequencies are rounded to the nearest full roll.

[2] FTMS 101 has been replaced with D4833. Value shown for comparison purposes only. Carbon Black Dispersion for 10 different views: all 10 in Categories 1 or 2.

The information contained herein has been compiled by Serrot International, Inc. and is, to the best of our knowledge, true and accurate. This information is offered without warranty. Final determination of suitability for use contemplated is the sole responsibility of the user. This information is subject to change without notice.

HTX13E 12/21/99

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GSE FabriCap*

HDPE Geonet/Geotextile Capping Composite

GSE FabriCap geocomposites typically consist of GSE HyperNet CP with nonwoven polypropylene geotextile fabric heat-bonded to one or both sides. The geotextile serves as a filter to prevent the geonet from clogging while the geonet provides a path for the fluids (liquids and gases). GSE HyperNet CP is manufactured in the same manner as standard GSE HyperNet but is designed specifically for use in situations where lower normal loads are expected such as in landfill cap designs.

TESTED PROPERTY	TEST METHOD	MINIMUM AVERAGE VALUES[e]		
		with 4 oz/yd²	with 6 oz/yd²	with 8 oz/yd²
Transmissivity,[a] m²/sec	ASTM D 4716	1.1×10^{-4}	1.0×10^{-4}	9.0×10^{-5}
Ply Adhesion, lb/in (N/mm)	ASTM D 413 or F 904		*See footnote (b)*	
Roll Width, ft (m)		14 (4.3)	14 (4.3)	14 (4.3)
Roll Length, ft (m)		250 (76.2)	225 (68.6)	200 (60.9)
Net component only [c]				
Transmissivity,[a] m²/sec	ASTM D 4716	1×10^{-3}	1×10^{-3}	1×10^{-3}
Thickness, mil (mm)	ASTM D 5199	200 (5)	200 (5)	200 (5)
Density, g/cm³	ASTM D 1505	0.94	0.94	0.94
Tensile Strength (MD), lb/in (N/mm)	ASTM D 5034/5035	32 (5.6)	32 (5.6)	32 (5.6)
Carbon Black Content, %	ASTM D 1603	2.0	2.0	2.0
Geotextile component only [c,d]		**4 oz/yd²**	**6 oz/yd²**	**8 oz/yd²**
Thickness, mil (mm)	ASTM D 5199	45 (1.1)	60 (1.5)	80 (2.0)
Grab Tensile, lb (N)	ASTM D 4632	100 (445)	150 (665)	200 (890)
Puncture Strength, lb (N)	ASTM D 4833	65 (285)	95 (420)	130 (575)
AOS, US sieve (mm)	ASTM D 4751	70 (0.212)	70 (0.212)	80 (0.180)
Flow Rate, gpm/ft² (lpm/m²)	ASTM D 4491	140 (5700)	110 (4480)	110 (4480)
UV Resistance, % retained	ASTM D 4355 (after 500 hours)	70	70	70

(a) Gradient of 1.0, normal load of 4,000 psf, water at 70°F between stainless steel plates
(b) Greater than the friction angle of the textile to soil
(c) Component properties prior to lamination
(d) Other geotextiles are available and may be provided as agreed upon by GSE. All geotextile property values are as reported by the geotextile supplier.
(e) These are typical values and are based on the cumulative results of specimens tested and as determined by GSE Quality Assurance practices.

This information is provided for reference purposes only and is not intended as a warranty or guarantee. GSE assumes no liability in connection with the use of this information. Check with GSE for current, standard minimum quality assurance procedures.

* GSE and other marks used in this document are trademarks and service marks of GSE Lining Technology, Inc.; certain of which are registered in the United States and other countries.

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Represented by:

*For environmental lining solutions...the world comes to GSE.**

A Gundle/SLT Environmental, Inc. Company

Product Specification - Structural Geogrid UX160020SB

TensarEarthTechnologies,Inc.reservestherighttochange its product specifications at any time. It is the responsibility of the specifier and purchaser to ensure that product specifications used for design and procurement purposes are current and consistent with the products used in each instance. Please contact Tensar Earth Technologies, Inc. at 800-836-7271 for assistance.

The structural geogrid shall be an integrally formed grid structure manufactured of a stress resistant high density polyethylene material with molecular weight and molecular characteristics which impart: (a) high resistance to loss of load capacity or structural integrity when the geogrid is subjected to mechanical stress in installation; (b) high resistance to deformation when the geogrid is subjected to applied force in use; and (c) high resistance to loss of load capacity or structural integrity when the geogrid is subjected to long-term environmental stress.

The structural geogrid shall accept applied force in use by positive mechanical interlock (i.e. by direct mechanical keying) with: (a) compacted soil or construction fill materials; (b) contiguous sections of itself when overlapped and embedded in compacted soil or construction fill materials; and (c) rigid mechanical connectors such as bodkins, pins or hooks. The structural geogrid shall possess sufficient cross sectional profile to present a substantial abutment interface to compacted soil or particulate construction fill materials and to resist movement relative to such materials when subject to applied force. The structural geogrid shall possess sufficient true initial modulus to cause applied force to be transferred to the geogrid at low strain levels without material deformation of the reinforced structure. The structural geogrid shall possess complete continuity of all properties throughout its structure and shall be suitable for reinforcement of compacted soil or particulate construction fill materials to improve their long term stability in structural load bearing applications such as earth retention systems. The structural geogrid shall otherwise have the following characteristics:

Product Type - **Integrally Formed Structural Geogrid**

Load Transfer Mechanism - **Positive Mechanical Interlock**

Product Properties	**Units**	**MD Values[1]**
Load Capacity		
· True Initial Modulus in Use[2]	kN/m (lb/ft)	1787.3 (122,500)
· Long-Term Allowable Load In Sands, Silts & Clay[3]	kN/m (lb/ft)	41.7 (2,857)
· Long-Term Allowable Load In Well Graded Sand[3]	kN/m (lb/ft)	41.7 (2,857)
· Long-Term Allowable Load in Aggregate[3]	kN/m (lb/ft)	37.4 (2,564)
Integrity of Product Structure		
· Junction Strength[4]	kN/m (lb/ft)	100.8 (6,908)
· Flexural Stiffness[5]	x1,000 mg-cm	6,600

Durability

·Resistance to Installation Damage[6]	%SC/%SW/%GP	95/95/85
·Resistance to Long-Term Degradation[7]	%	100

Dimensions and Delivery

The structural geogrid shall be delivered to the jobsite in roll form with each roll individually identified and nominally measuring 1.3 meters (4.26 feet) in width and 61.0 meters (200 feet) in length. A typical truckload quantity is 216 rolls. On special request, the structural geogrid may also be custom cut to specific lengths or widths to suit site specific engineering designs.

Notes

1. Unless indicated otherwise, values shown are minimum average roll values determined in accordance with ASTM D-4759. Brief descriptions of test procedures are given in the following notes. Complete descriptions of test procedures are available on request from Tensar Earth Technologies, Inc.
2. True resistance to elongation when initially subjected to a load measured via GRI-GG1 (tested at 10 percent per minute based on the greater of 2 aperture or 8-inch [200 millimeter] gauge length) without deforming test materials under load before measuring such resistance or employing "secant" or "offset" tangent methods of measurement so as to overstate tensile properties.
3. True strength available for resisting force in long-term load bearing applications is determined by reducing ultimate tensile strength by state-of-practice factors for installation damage, degradation in use, product integrity limitations and long-term product deformation per GRI-GG4.
4. Load transfer capability measured via GRI-GG2.
5. Resistance to bending force measured via ASTM D-1388, Option A, using specimen dimensions of 864 millimeters in length by 1 aperture in width.
6. Resistance to loss of load capacity or structural integrity when subjected to mechanical stress in installation measured via ASTM D-5818 in a clayey sand (SC), a well graded sand (SW) and crushed stone classified as a poorly graded gravel with a maximum 2 inch particle size (GP).
7. Resistance to loss of load capacity or structural integrity when subjected to chemically aggressive environments measured via EPA 9090 immersion testing.

Tensar Earth Technologies, Inc.
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Atlanta, Georgia 30328-5363
(800) 836-7271

Date: June 1, 1999

This product specification supersedes all prior specifications for the product described above and is not applicable to any products shipped to jobsite prior to June 1, 1999.

SERROT INTERNATIONAL, INC.

[Up]

BENTOFIX®

Thermal Lock "NSL" Geosynthetic Clay Liner	FIX - 501 NSL

· Technical Bulletin ·

Bentofix Thermal Lock "NSL" is a needlepunch reinforced GCL comprised of a uniform layer of granular sodium bentonite encapsulated between a slit-film woven and a virgin staple fiber nonwoven geotextile. The needlepunched fibers are thermally fused to the woven geotextile to enhance the reinforcing bond.

Geotextile Properties	Test Method	Minimum Test Frequency	Value - English	Value - SI
Cap Nonwoven Mass/Unit Area	ASTM D 5261	1/200,000 sq. ft (1/20,000 sq. m)	6.0 oz./yd^2 MARV	200 g / m^2 MARV
Woven Scrim Mass/Unit Area	ASTM D 5261	1/200,000 sq. ft (1/20,000 sq. m)	3.1 oz./yd^2 MARV	105 g / m^2 MARV
Bentonite Properties				
Swell Index	ASTM D 5890	1/100,000 lbs. (50,000 kg)	24 ml / 2g min.	24 ml / 2g min.
Moisture Content	ASTM D 4643	1/100,000 lbs. (50,000 kg)	12 % max.	12 % max.
Fluid Loss	ASTM D 5891	1/100,000 lbs. (50,000 kg)	18 ml max.	18 ml max.
Finished GCL Properties				
Bentonite Mass Per Unit Area[1]	ASTM D 5993	1/40,000 sq. ft (1/4,000 sq. m)	0.75 lb. / sq. ft MARV	3.66 kg / m^2 MARV
Grab Strength[2]	ASTM D 4632	1/40,000 sq. ft (1/4,000 sq. m)	95 lbs MARV	422 N MARV
Grab Elongation[2]	ASTM D 4632	1/40,000 sq. ft (1/4,000 sq. m)	100 % Typical	100 % Typical
Peel Strength[3]	ASTM D 4632	1/40,000 sq. ft (1/4,000 sq. m)	15 lbs. min.	66 N
Permeability[4]	ASTM D 5084	1/100,000 sq. ft (1/10,000 sq. m)	5 x 10^{-9} cm/sec max	5 x 10^{-9} cm/sec max
Index Flux[4]	ASTM D 5887	1/Week	1 x 10^{-8} m^3/m^2/sec max	1 x 10^{-8} m^3/m^2/sec max

Internal Shear Strength[5]	ASTM D 6243	Periodic	500 psf Typical	24 kPa Typical
Dimensions				
Width x Length	nominal	Every Roll	15.5 x 150 ft	4.7 x 45.72 m
Area per Roll	nominal	Every Roll	2325 ft^2	216 m^2
Packaged Weight	typical	Every Roll	2160 lbs	980 kg

NOTES:

[1]. Oven-dried measurement. Equates to .084 lb when indexed to a 12% moisture content.
[2]. Measured at maximum peak, in the weakest principal direction.
[3]. Modified to use a 4-inch wide grip. The maximum peak of five specimens averaged.
[4]. De-Aired Tap Water @ 5 psi maximum effective confining stress and 2 psi head.
[5]. Typical peak value for specimen hydrated for 24 hr. and sheared under a 200 psf normal stress.

Information regarding the physical properties of Bentofix Thermal Lock products, including the information contained in this specification sheet, is, to the best of our knowledge, information and belief, representative of Bentofix Thermal Lock products. All information, data, suggestions, opinions and recommendations are offered without guarantee or warranty of any kind. The final determination as to the appropriateness or suitability of any Bentofix product in any particular application rests with the user and is the user's sole responsibility. All rights are reserved to alter, change or modify the Bentofix products and product specifications at any time without notice. Please check with your sales or technical representative to assure that specifications are current. Bentofix is a registered trademark of Naue Fasertechnik, GmbH. (May-99 Bentofix NSL99)

BFNSL - 0599

Web Site Development: cb3.com
This page was last modified: Sunday, November 07, 1999

TENAX **CE**

Type: **450 - 600 - 750 - 900**

Geonets

TENAX **CE** geonets are high profile rhomboidal shaped mesh structures made by two sets of overlaid intersecting strands. The intersecting strands form overlaid sets of continuous deep channels which provide high flow capacity. These geonets are used in waste disposal and general civil engineering projects, where a high flow capacity is required.

TENAX **CE** geonets are manufactured from extrusion of High Density Polyethylene (HDPE), black in color; they are inert to chemical and biological conditions normally occurring in soil. Moreover they are treated with special additives to resist UV degradation.

TENAX **CE** geonets are available in a wide range of thicknesses and widths, so as to satisfy any design and installation need.

Typical applications

Load distribution, site leveling and mechanical protection of the geomembrane; drainage of the accidental leaks below primary; leachate and rain water collection above primary geomembrane; mechanical protection of the geomembranes when in contact with waste-materials and/or soil; drainage of liquids and gases present in the soil above and/or below the capping geomembrane.

PHYSICAL CHARACTERISTICS		**CE 450**	**CE 600**	**CE 750**	**CE 900**	**notes**
STRUCTURE		2 strands	2 strands	2 strands	2 strands	
POLYMER TYPE		HDPE	HDPE	HDPE	HDPE	
U.V. STABILIZER		carbon black	carbon black	carbon black	carbon black	
FOAMING AGENT		NO	NO	NO	NO	

DIMENSIONAL CHARACTERISTICS	**UNIT**	**CE 450**	**CE 600**	**CE 750**	**CE 900**	**notes**
THICKNESS at 20 kPa	mm	4.0	4.5	5.0	5.5	a,c
THICKNESS at 200 kPa	mm	3.8	4.2	4.8	5.2	a,c
UNIT WEIGHT	g/m²	450	600	750	900	a,d
ROLL WIDTH	m	2.3	2.3	2.3	2.3	a,g
ROLL LENGTH	m	100	50	50	50	a
ROLL DIAMETER	m	0.78	0.56	0.58	0.62	a
ROLL VOLUME	m³	1.41	0.73	0.79	0.89	a
ROLL GROSS WEIGHT	kg	103.5	69.0	86.3	103.5	a

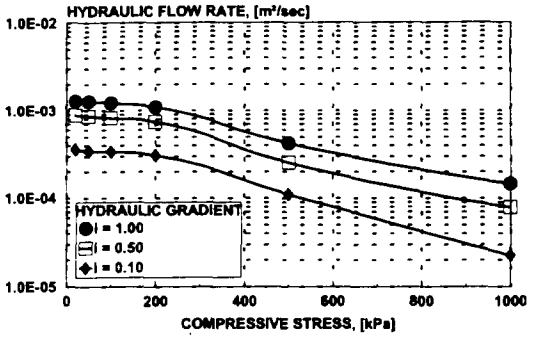
TECHNICAL CHARACTERISTICS	**UNIT**	**CE 450**	**CE 600**	**CE 750**	**CE 900**	**notes**
HYDRAULIC FLOW RATE						
i=1 σv = 20 kPa	m²/ sec	1.18 E-03	1.39 E-03	1.41 E-03	1.44 E-03	a,b,e
i=1 σv = 100 kPa	m²/ sec	1.11 E-03	1.31 E-03	1.33 E-03	1.36 E-03	a,b,e
i=1 σv = 200 kPa	m²/ sec	1.00 E-03	1.24 E-03	1.26 E-03	1.28 E-03	a,b,e
i=1 σv = 500 kPa	m²/ sec	3.84 E-04	7.61 E-04	9.26 E-04	1.09 E-03	a,b,e
TENSILE STRENGTH	kN / m	4.0	5.0	7.0	9.0	a,b,f
ELONGATION AT PEAK	%	80	30	30	30	a,b,f

NOTES:
a) Typical values
b) Longitudinal direction
c) ISO 9863
d) ISO 9864
e) ASTM D4716
f) ISO 10319
g) Upon request available 3.8 m wide

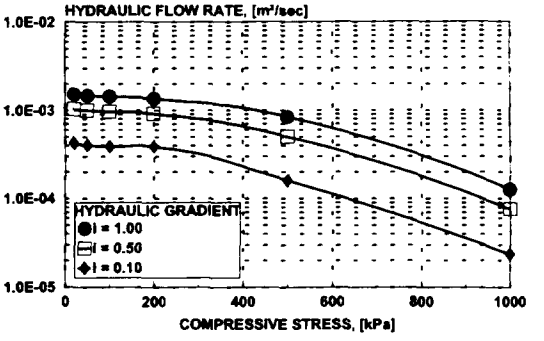
TENAX®
Man, Technology, Environment.

Typical Hydraulic Characteristics

TENAX CE 450



TENAX CE 600



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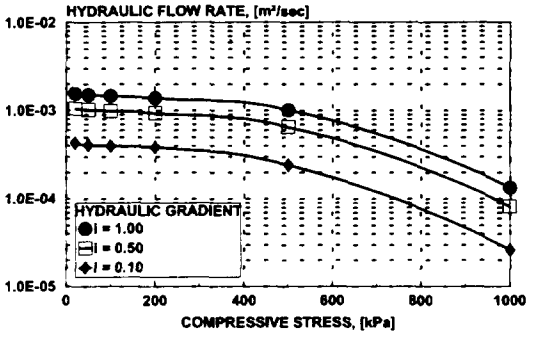

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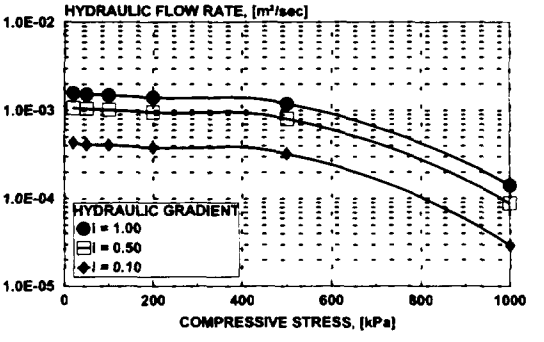

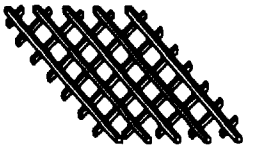

TENAX CE

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TENAX®
Man, Technology, Environment.

TENAX **CE**

Type: **1000**

Geonet

TENAX **CE** geonets are high profile rhomboidal shaped mesh structures made by two sets of overlaid intersecting strands. The intersecting strands form overlaid sets of continuous deep channels which provide high flow capacity. These geonets are used in waste disposal and general civil engineering projects, where a high flow capacity is required.

TENAX **CE** geonets are manufactured from extrusion of High Density Polyethylene (HDPE), black in color; they are inert to chemical and biological conditions normally occurring in soil. Moreover they are treated with special additives to resist UV degradation.

TENAX **CE** geonets are available in a wide range of thicknesses and widths, so as to satisfy any design and installation need.

The TENAX **CE 1000** geonet is ideal for mechanical protection of the geomembrane. Its structure, having a small mesh, high unit weight and cover properties, avoid the damages of the waterproofing geomembranes due to sharp objects and concentrated loads.

Typical applications

Load distribution, site leveling and mechanical protection of the geomembrane; drainage of the accidental leaks below primary; leachate and rain water collection above primary geomembrane; mechanical protection of the geomembranes when in contact with waste-materials and/or soil; drainage of liquids and gases present in the soil above and/or below the capping geomembrane.

PHYSICAL CHARACTERISTICS	TEST METHOD	UNIT	CE 1000	notes
STRUCTURE			2 strands	
POLYMER TYPE			HDPE	
U.V.STABILIZER			carbon black	
FOAMING AGENT			NO	

DIMENSIONAL CHARACTERISTICS	TEST METHOD	UNIT	CE 1000	notes
THICKNESS at 20 kPa	ISO 9863	mm	4.0	a
THICKNESS at 200 kPa	ISO 9863	mm	3.8	a
UNIT WEIGHT	ISO 9864	g/m²	1000	a
MD APERTURE SIZE		mm	5.0	a,b
TD APERTURE SIZE		mm	5.0	a,c
ROLL WIDTH		m	2.0	a
ROLL LENGTH		m	25	a
ROLL DIAMETER		m	0.39	a
ROLL VOLUME		m³	0.31	a
ROLL GROSS WEIGHT		kg	50.0	a

TECHNICAL CHARACTERISTICS	TEST METHOD	UNIT	CE 1000	notes
HYDRAULIC FLOW RATE				
i = 1.00 σv = 20 kPa	ASTM D4716	m²/s	1.09 E-03	a,b
i = 1.00 σv = 100 kPa	ASTM D4716	m²/s	1.04 E-03	a,b
i = 1.00 σv = 200 kPa	ASTM D4716	m²/s	9.81 E-04	a,b
i = 1.00 σv = 500 kPa	ASTM D4716	m²/s	4.12 E-04	a,b
TENSILE STRENGTH	ISO 10319	kN/m	8.5	a,b
ELONGATION AT PEAK	ISO 10319	%	40	a,b
RESIDUAL THICKNESS at 100 kPa	ASTM D1621	%	> 95	a
RESIDUAL THICKNESS at 500 kPa	ASTM D1621	%	> 70	a

NOTES:

a) Typical values
b) Machine direction (MD)
c) Transversal direction (TD)

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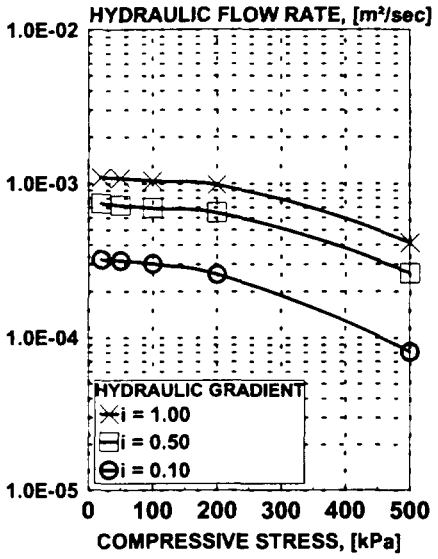
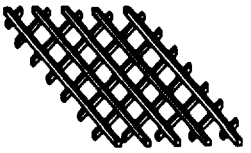
Typical Hydraulic Characteristics

TENAX CE 1000





TENAX CE

The TENAX Laboratory has been created in 1980 and has been continuously improved with the purpose of assuring unequalled technical development of the products and accurate Quality Control.

The TENAX Laboratory can perform mechanical, hydraulic and durability tests, according to the most important international standards like ISO, CEN, ASTM, DIN, BSI, UNI.

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Man, Technology, Environment.

Bentomat® DN Certified Properties

Bentomat "DN" is a reinforced GCL consisting of a layer of sodium bentonite between two geotextiles, which are needlepunched together.

MATERIAL PROPERTY	TEST METHOD	TEST FREQUENCY, ft^2 (m^2)	CERTIFIED VALUES
Bentonite Swell Index[1]	ASTM D 5890	1 per 50 tons	24 mL/2g min.
Bentonite Fluid Loss[1]	ASTM D 5891	1 per 50 tons	18 mL max.
Bentonite Mass/Area[2]	ASTM D 5993	40,000 ft^2 (4,000 m^2)	0.75 lb/ft^2 (3.6 kg/m^2)
GCL Grab Strength[3]	ASTM D 4632	200,000 ft^2 (20,000 m^2)	150 lbs (400 N)
GCL Peel Strength[3]	ASTM D 4632	40,000 ft^2 (4,000 m^2)	15 lbs (65 N)
GCL Index Flux[4]	ASTM D 5887	Weekly	1×10^{-8} $m^3/m^2/sec$
GCL Permeability[4]	ASTM D 5084	Weekly	5×10^{-9} cm/sec
GCL Hydrated Internal Shear Strength[5]	ASTM D 5321	Periodic	500 psf (24 kPa) typical

Notes:

1 Bentonite property tests performed at CETCO's bentonite processing facility before shipment to CETCO's GCL production facilities.

2 Bentonite mass/area reported at 0 percent moisture content.

3 All tensile testing is performed in the machine direction, with results as minimum average roll values unless otherwise indicated.

4 Index flux and permeability testing with deaired distilled/deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. Reported value is equivalent to 925 gal/acre/day. This flux value is equivalent to a permeability of 5×10^{-9}cm/sec for typical GCL thickness. This flux value should not be used for equivalency calculations unless the gradients used represent field conditions. A flux test using gradients that represent field conditions must be performed to determine equivalency. The last 20 weekly values prior the end of the production date of the supplied GCL may be provided.

5 Peak value measured at 200 psf (10 kPa) normal stress. Site-specific materials, GCL products, and test conditions must be used to verify internal and interface strength of the proposed design.

1500 West Shure Drive Arlington Heights, Illinois 60004 [800] 527.9948 tel [847] 392.5800 fax [847] 577.5571

CETCO
COLLOID ENVIRONMENTAL TECHNOLOGIES COMPANY
Lining Technologies www.cetco.com

Bentomat® DN Panel and Roll Specifications

STANDARD PANEL SPECIFICATIONS

Panel Dimensions*.....**14** ft. (**4.3** m) wide; **150** ft. (**45.7** m) long
Total Panel Area.....**2,100** sq. ft. (**195** sq. m)
Effective Area.....**1,998** sq. ft. (**185** sq. m)
{Assumes 6-in. (150 mm) edge overlap and 2-ft. (600 mm) end overlap}

STANDARD ROLL SPECIFICATIONS

Dimensions.....**16** ft. (**4.88** m) wide w/ core; **24** in. (**610** mm) diameter
Nominal Weight.....**2,600** lbs. (**1,180** kg)
Core Size (I.D.).....**4** in. (**100** mm) I.D. Inner core plug measures **2.5** in. (**63** mm)
Packaging.....**8**-mil (**0.2** mm) U.V.-resistant polyethylene sleeve

STANDARD SHIPPING SPECIFICATIONS

Shipment Size.....**15** rolls per truckload or container load
Granular Bentonite.....**50**-lb. (**23** kg) bags

UNLOADING AND HANDLING EQUIPMENT

Core Pipe and Spreader Bar.....**18** ft. (**5.5** m) long, **2.5** in. (**63** mm) Nominal Pipe Size, XXH
OR: Solid steel pipe
OR: Stinger attachment for forklift
Chains or Straps.....**2** required; each approximately **12** ft. (**3.7** m) long
Equipment.....Front end loader or forklift (typical)

* Custom lengths/widths available

The information and data contained herein are believed to be accurate and reliable. CETCO makes no warranty of any kind and accepts no responsibility for the results obtained through application of this information.

1500 West Shure Drive Arlington Heights, Illinois 60004 [800] 527.9948 tel [847] 392.5800 fax [847] 577.5571

Bentomat® ST Certified Properties

Bentomat "ST" is a reinforced GCL consisting of a layer of sodium bentonite between woven and non-woven geotextiles, which are needlepunched together.

MATERIAL PROPERTY	TEST METHOD	TEST FREQUENCY, ft^2 (m^2)	CERTIFIED VALUES
Bentonite Swell Index[1]	ASTM D 5890	1 per 50 tons	24 mL/2g min.
Bentonite Fluid Loss[1]	ASTM D 5891	1 per 50 tons	18 mL max.
Bentonite Mass/Area[2]	ASTM D 5993	40,000 ft^2 (4,000 m^2)	0.75 lb/ft^2 (3.6 kg/m^2)
GCL Grab Strength[3]	ASTM D 4632	200,000 ft^2 (20,000 m^2)	90 lbs (400 N)
GCL Peel Strength[3]	ASTM D 4632	40,000 ft^2 (4,000 m^2)	15 lbs (65 N)
GCL Index Flux[4]	ASTM D 5887	Weekly	1×10^{-8} $m^3/m^2/sec$
GCL Permeability[4]	ASTM D 5084	Weekly	5×10^{-9} cm/sec
GCL Hydrated Internal Shear Strength[5]	ASTM D 5321	Periodic	500 psf (24 kPa) typical

Notes:

1 Bentonite property tests performed at CETCO's bentonite processing facility before shipment to CETCO's GCL production facilities.

2 Bentonite mass/area reported at 0 percent moisture content.

3 All tensile testing is performed in the machine direction, with results as minimum average roll values unless otherwise indicated.

4 Index flux and permeability testing with deaired distilled/deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. Reported value is equivalent to 925 gal/acre/day. This flux value is equivalent to a permeability of 5×10^{-9}cm/sec for typical GCL thickness. This flux value should not be used for equivalency calculations unless the gradients used represent field conditions. A flux test using gradients that represent field conditions must be performed to determine equivalency. The last 20 weekly values prior the end of the production date of the supplied GCL may be provided.

5 Peak value measured at 200 psf (10 kPa) normal stress. Site-specific materials, GCL products, and test conditions must be used to verify internal and interface strength of the proposed design.

1500 West Shure Drive Arlington Heights, Illinois 60004 [800] 527.9948 tel [847] 392.5800 fax [847] 577.5571

Bentomat® ST Panel and Roll Specifications

STANDARD PANEL SPECIFICATIONS

Panel Dimensions*.....**15** ft. (**4.6** m) wide; **150** ft. (**45.7** m) long
Total Panel Area.....**2,250** sq. ft. (**209** sq. m)
Effective Area.....**2,145** sq. ft. (**200** sq. m)
{Assumes 6-in. (150 mm) edge overlap and 2-ft. (600 mm) end overlap}

STANDARD ROLL SPECIFICATIONS

Dimensions.....**16** ft. (**4.88** m) wide w/ core; **24** in. (**610** mm) diameter
Nominal Weight.....**2,700** lbs. (**1,225** kg)
Core Size (I.D.).....**4** in. (**100** mm) I.D. Inner core plug measures **2.5** in. (**63** mm)
Packaging.....**8**-mil (**0.2** mm) U.V.-resistant polyethylene sleeve

STANDARD SHIPPING SPECIFICATIONS

Shipment Size.....**15** rolls per truckload or container load
Granular Bentonite.....**50**-lb. (**23** kg) bags

UNLOADING AND HANDLING EQUIPMENT

Core Pipe and Spreader Bar.....**18** ft. (**5.5** m) long, **2.5** in. (**63** mm) Nominal Pipe Size, XXH
OR: Solid steel pipe
OR: Stinger attachment for forklift
Chains or Straps.....**2** required; each approximately **12** ft. (**3.7** m) long
Equipment.....Front end loader or forklift (typical)

* Custom lengths/widths available

The information and data contained herein are believed to be accurate and reliable. CETCO makes no warranty of any kind and accepts no *responsibility for the results obtained through application of this information.*

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Bentomat® CL Certified Properties

Bentomat "CL" is a reinforced GCL consisting of a layer of sodium bentonite between two geotextiles, which are needlepunched together and laminated to a thin flexible membrane liner.

MATERIAL PROPERTY	TEST METHOD	TEST FREQUENCY, ft^2 (m^2)	CERTIFIED VALUES
Bentonite Swell Index[1]	ASTM D 5890	1 per 50 tons	24 mL/2g min.
Bentonite Fluid Loss[1]	ASTM D 5891	1 per 50 tons	18 mL max.
Bentonite Mass/Area[2]	ASTM D 5993	40,000 ft^2 (4,000 m^2)	0.75 lb/ft^2 (3.6 kg/m^2)
GCL Grab Strength[3]	ASTM D 4632	200,000 ft^2 (20,000 m^2)	120 lbs (530 N)
GCL Peel Strength[3]	ASTM D 4632	40,000 ft^2 (4,000 m^2)	15 lbs (65 N)
GCL Index Flux[4]	ASTM D 5887 or E 96	Weekly	1×10^{-9} $m^3/m^2/sec$
GCL Hydraulic Conductivity[4]	ASTM D 5084 or E 96	Weekly	5×10^{-10} cm/sec
GCL Hydrated Internal Shear Strength[5]	ASTM D 5321	Periodic	500 psf (24 kPa) typical

Notes:

1 Bentonite property tests performed at CETCO's bentonite processing facility before shipment to CETCO's GCL production facilities.

2 Bentonite mass/area reported at 0 percent moisture content.

3 All tensile testing is performed in the machine direction, with results as minimum average roll values unless otherwise indicated.

4 ASTM D5887 Index flux and ASTM D5084 hydraulic conductivity testing with deaired distilled/deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. Reported value is equivalent to 95 gal/acre/day. This flux value is equivalent to a permeability of 5×10^{-10} cm/sec for typical GCL thickness. Alternatively, hydraulic conductivity can be determined by performing water vapor transmissivity testing (ASTM E 96) on the membrane side of the GCL and use conversion outlined by Koerner (1994). This flux value should not be used for equivalency calculations unless the gradients used represent field conditions. A flux test using gradients that represent field conditions must be performed to determine equivalency. The last 20 weekly values prior the end of the production date of the supplied GCL may be provided.

5 Peak value measured at 200 psf (10 kPa) normal stress. Site-specific materials, GCL products, and test conditions must be used to verify internal and interface strength of the proposed design.

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Bentomat® CL Panel and Roll Specifications

STANDARD PANEL SPECIFICATIONS

Panel Dimensions*.....**14.5** ft. (**4.4** m) wide; **150** ft. (**45.7** m) long
Total Panel Area.....**2,175** sq. ft. (**202** sq. m)
Effective Area.....**2,072** sq. ft. (**192.5** sq. m)
{Assumes 6-in. (150 mm) edge overlap and 2-ft. (600 mm) end overlap}

STANDARD ROLL SPECIFICATIONS

Dimensions.....**16** ft. (**4.88** m) wide w/ core; **24** in. (**610** mm) diameter
Nominal Weight.....**2,700** lbs. (**1,225** kg)
Core Size (I.D.).....**4** in. (**100** mm) I.D. Inner core plug measures **2.5** in. (**63** mm)
Packaging.....**8**-mil (**0.2** mm) U.V.-resistant polyethylene sleeve

STANDARD SHIPPING SPECIFICATIONS

Shipment Size.....**15** rolls per truckload or container load
Granular Bentonite.....**50**-lb. (**23** kg) bags

UNLOADING AND HANDLING EQUIPMENT

Core Pipe and Spreader Bar.....**18** ft. (**5.5** m) long, **2.5** in. (**63** mm) Nominal Pipe Size, XXH
OR: Solid steel pipe
OR: Stinger attachment for forklift
Chains or Straps.....**2** required; each approximately **12** ft. (**3.7** m) long
Equipment.....Front end loader or forklift (typical)

* Custom lengths/widths available

The information and data contained herein are believed to be accurate and reliable. CETCO makes no warranty of any kind and accepts no responsibility for the results obtained through application of this information.

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Claymax® 200R Certified Properties

Claymax "200R" is an unreinforced GCL consisting of a layer of sodium bentonite between two woven geotextiles, which are continuously adhered together.

MATERIAL PROPERTY	TEST METHOD	TEST FREQUENCY, ft^2 (m^2)	CERTIFIED VALUES
Bentonite Swell Index[1]	ASTM D 5890	1 per 50 tons	24 mL/2g min.
Bentonite Fluid Loss[1]	ASTM D 5891	1 per 50 tons	18 mL max.
Bentonite Mass/Area[2]	ASTM D 5993	40,000 ft^2 (4,000 m^2)	0.75 lb/ft^2 (3.6 kg/m^2)
GCL Grab Strength[3]	ASTM D 4632	200,000 ft^2 (20,000 m^2)	150 lbs (660 N)
GCL Peel Strength	ASTM D 4632	N/A	N/A
GCL Index Flux[4]	ASTM D 5887	Weekly	1×10^{-8} $m^3/m^2/sec$
GCL Permeability[4]	ASTM D 5084	Weekly	5×10^{-9} cm/s
GCL Hydrated Internal Shear Strength[5]	ASTM D 5321	Periodic	50 psf (2.4 kPa) typical

Notes:

1 Bentonite property tests performed at CETCO's bentonite processing facility before shipment to CETCO's GCL production facilities.

2 Bentonite mass/area reported at 0 percent moisture content.

3 All tensile testing is performed in the machine direction, with results as minimum average roll values unless otherwise indicated.

4 Index flux and permeability testing with deaired distilled/deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. Reported value is equivalent to 925 gal/acre/day. This flux value is equivalent to a permeability of 5×10^{-9}cm/sec for typical GCL thickness. This flux value should not be used for equivalency calculations unless the gradients used represent field conditions. A flux test using gradients that represent field conditions must be performed to determine equivalency. The last 20 weekly values prior the end of the production date of the supplied GCL may be provided.

5 Peak value measured at 200 psf (10 kPa) normal stress. Site-specific materials, GCL products, and test conditions must be used to verify internal and interface strength of the proposed design.

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Claymax® 200R Panel and Roll Specifications

STANDARD PANEL SPECIFICATIONS

Panel Dimensions*.....**13.8** ft. (**4.2** m) wide; **150** ft. (**45.7** m) long

Total Panel Area.....**2,075** sq. ft. (**193** sq. m)

Effective Area.....**1,973** sq. ft. (**183** sq. m)

{Assumes 6-in. (150 mm) edge overlap and 2-ft. (600 mm) end overlap}

STANDARD ROLL SPECIFICATIONS

Dimensions.....**14.5** ft. (**4.4** m) wide w/ core; **20** in. (**510** mm) diameter

Nominal Weight.....**2,600** lbs. (**1,180** kg)

Core Size.....**4** in. (**100** mm) I.D. Inner core plug measures 2.5 in. (**63** mm)

Packaging.....**8**-mil (**0.2** mm) U.V.-resistant polyethylene sleeve

STANDARD SHIPPING SPECIFICATIONS

Shipment Size.....**15** rolls per truckload

UNLOADING AND HANDLING EQUIPMENT

Core Pipe and Spreader Bar.....**16** ft. (**4.3** m) long, **3.5** in. (**89** mm) O.D., XXH

OR: Solid steel pipe

OR: Stinger attachment for forklift

Chains or Straps.....**2** required; each approximately **12** ft. (**3.7** m) long

Equipment.....Front end loader or forklift (typical)

* Custom lengths/widths available

The information and data contained herein are believed to be accurate and reliable. CETCO makes no warranty of any kind and accepts no responsibility for the results obtained through application of this information.

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CETCO
COLLOID ENVIRONMENTAL TECHNOLOGIES COMPANY
Lining Technologies www.cetco.com

Claymax® 600CL Certified Properties

Claymax "600CL" is an unreinforced GCL consisting of a layer of sodium bentonite between a geotextile and a laminate comprised of a geotextile and a polyethylene membrane, which are continuously adhered together.

MATERIAL PROPERTY	TEST METHOD	TEST FREQUENCY, ft^2 (m^2)	CERTIFIED VALUES
Bentonite Swell Index[1]	ASTM D 5890	1 per 50 tons	24 mL/2g min.
Bentonite Fluid Loss[1]	ASTM D 5891	1 per 50 tons	18 mL max.
Bentonite Mass/Area[2]	ASTM D 5993	40,000 ft^2 (4,000 m^2)	0.75 lb/ft^2 (3.6 kg/m^2)
GCL Grab Strength[3]	ASTM D 4632	200,000 ft^2 (20,000 m^2)	75 lbs (330 N)
GCL Peel Strength	ASTM D 4632	N/A	N/A
GCL Index Flux[4]	ASTM D 5887 or E96	Weekly	1×10^{-9} $m^3/m^2/sec$
GCL Permeability[4]	ASTM D 5084 or E96	Weekly	5×10^{-10} cm/s
GCL Hydrated Internal Shear Strength[5]	ASTM D 5321	Periodic	50 psf (2.4 kPa) typical

Notes:

1 Bentonite property tests performed at CETCO's bentonite processing facility before shipment to CETCO's GCL production facilities.

2 Bentonite mass/area reported at 0 percent moisture content, the GCL industry standard.

3 All tensile testing is performed in the machine direction, with results as minimum average roll values unless otherwise indicated.

4 Index flux and permeability testing with deaired distilled/deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. Reported value is equivalent to 95 gal/acre/day. This flux value is equivalent to a permeability of 5×10^{-10} cm/sec for typical GCL thickness. Alternatively, hydraulic conductivity can be determined by performing water vapor transmissivity testing (ASTM E96) on the membrane side of the GCL and use conversion outlined by Koerner (1994). This flux value should not be used for equivalency calculations unless the gradients used represent field conditions. A flux test using gradients that represent field conditions must be performed to determine equivalency. The last 20 weekly values prior to the end of the production date of the supplied GCL may be provided.

5 Peak value measured at 200 psf (10 kPa) normal stress. Site-specific materials, GCL products, and test conditions must be used to verify internal and interface strength of the proposed design.

1500 West Shure Drive Arlington Heights, Illinois 60004 [800] 527.9948 tel [847] 392.5800 fax [847] 577.5571

Claymax® 600CL Panel and Roll Specifications

STANDARD PANEL SPECIFICATIONS

Panel Dimensions*.....**13.8** ft. (**4.2** m) wide; **150** ft. (**45.7** m) long
Total Panel Area.....**2,075** sq. ft. (**193** sq. m)
Effective Area.....**1,973** sq. ft. (**183** sq. m)
{Assumes 6-in. (150 mm) edge overlap and 2-ft. (600 mm) end overlap}

STANDARD ROLL SPECIFICATIONS

Dimensions.....**14.5** ft. (**4.4** m) wide w/ core; **20** in. (**510** mm) diameter
Nominal Weight.....**2,700** lbs. (**1,225** kg)
Core Size.....**4** in. (**100** mm) I.D. Inner core plug measures 2.5 in. (**63** mm)
Packaging.....**8**-mil (**0.2** mm) U.V.-resistant polyethylene sleeve

STANDARD SHIPPING SPECIFICATIONS

Shipment Size.....**15** rolls per truckload

UNLOADING AND HANDLING EQUIPMENT

Core Pipe and Spreader Bar.....**16** ft. (**4.3** m) long, **3.5** in. (**89** mm) O.D., XXH
OR: Solid steel pipe
OR: Stinger attachment for forklift
Chains or Straps.....**2** required; each approximately **12** ft. (**3.7** m) long
Equipment.....Front end loader or forklift (typical)

* Custom lengths/widths available

The information and data contained herein are believed to be accurate and reliable. CETCO makes no warranty of any kind and accepts no responsibility for the results obtained through application of this information.

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ATTACHMENT 2

GEOTEXTILE STRENGTH CALCULATIONS

URS Greiner Woodward Clyde

Page ___ of ___

Job: Solutia Sauget | Project No. C10000405 1.00 | Sheet 1 of 4

Description: Gravel Layer Separator Fabric Design | Computed by: M. Brungard | Date: 10/18/00

Checked by: C. Reed | Date: 11/2/00

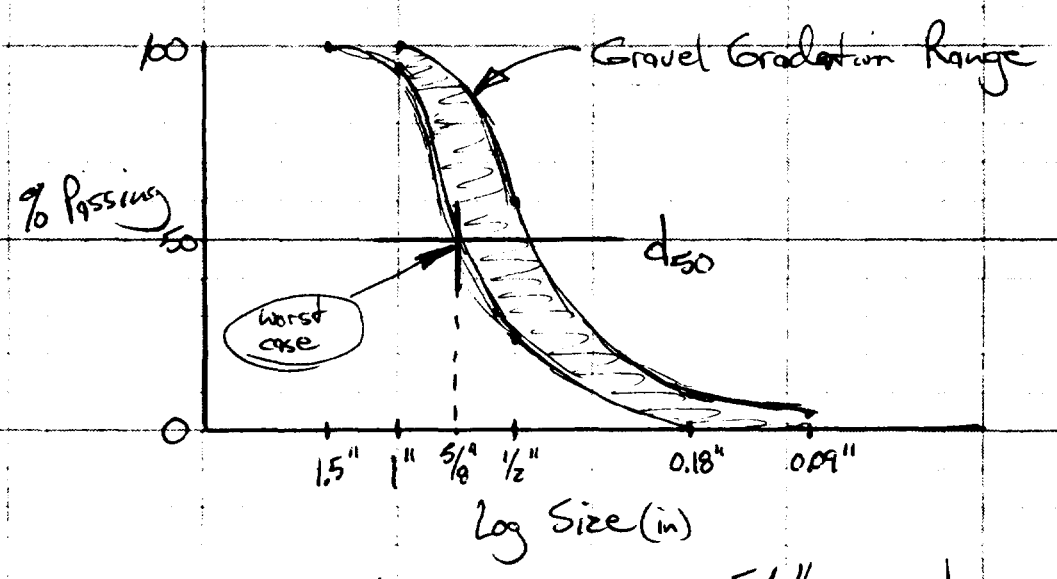
Reference

Purpose: Determine requirements for a geotextile separator fabric located between the gravel layer and overlying GCL bedding soil layer beneath the proposed landfill cell.

Assumptions: The gravel fill material will have the following gradation as shown in Section 02200 of the Technical Specifications.

Size	% Passing
1.5"	100
1.0"	95-100
0.5"	25-60
No.4 (0.18")	0-10
No.8 (0.09")	0-5

The gradation is graphically described below



Assume Avg. Stone Size = 5/8" = d_{50}

Burst Resistance

Applicable Eqns: $T_{req'd} = \frac{1}{2} p' d_v [f(\varepsilon)]$

and $F.S. = \frac{60.6\, p_{test}}{p' d_a}$

where: p' = applied pressure (say 100 psi)

p_{Test} = Mullen Burst test pressure

$d_v = 0.33\, d_a$

$d_a = d_{50} = 5/8"$

* The applied pressure (100psi) is very conservative since it assumes high pressure truck tires & reduction due to spreading of the loading through the soil layer.

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Gravel Layer Separator Fabric Design
Project No. C100004051.00
Computed by: M. Brungard
Checked by: C. Reed
Page ___ of ___
Sheet 2 of 4
Date 10/18/00
Date 11/2/00
Reference

Assume the F.S. = 2.0 — this has units of (mm)

$$2.0 = \frac{60.6\ p_{test}}{(100\,psi)\,(5/8'')} \rightarrow 15.8\ mm$$

$$2.0 = \frac{60.6\ \cancel{mm}\ p_{test}}{(100\,psi)\,(15.8\ \cancel{mm})}$$

$$\underline{52.4\ psi = p_{test}} \quad (min) \quad \text{Mullen Burst Str.}$$

Tensile Strength

Applicable Eqn: $T_{req} = p'(d_v)^2[f(\varepsilon)]$

where: p' = applied pressure (100 psi)
$d_v = 0.33\ d_a$
$d_a = d_{50} = 5/8'' = 15.8\ mm$
$f(\varepsilon)$ = strain function → 0.52 (assumed)

$$T_{req} = 100\,psi\left(\frac{5/8''}{3}\right)^2 0.52$$

$$= \underline{\cancel{20.5}\ lbs} \qquad \underline{2.25\ lbs} \quad (MB)\ 11/2/00$$

use F.S = 2.0

$$T_{allow} = 2.0 \times T_{req}$$

$$= 2.0 \times \cancel{20.5}\ 2.25\ lbs$$

$$= \underline{\cancel{40.6}\ 4.5\ lbs} \quad (MB)\ 11/2/00 \quad \text{Ult. Grab Strength}$$

Tear Strength (Puncture)

Applicable Eqn: $F_{req} = p' d_a^2 S_1 S_2 S_3$

where: p' = applied pressure (100 psi)
$d_a = d_{50} = 5/8'' = 15.8\ mm$
S_1 = protrusion factor = 0.4
S_2 = scale factor = 0.5
S_3 = shape factor = 0.6

URS Greiner Woodward Clyde

Job Solutia Sauget
Description Gravel Layer Separator Fabric Design

Project No. C10000 4051.00
Computed by M. Brungard
Checked by C. Reed

Page ___ of ___
Sheet 3 of 4
Date 10/8/00
Date 11/2/00
Reference

$$F_{req} = 100\,psi\,(5/8'')^2\,0.4(0.5)\,0.6$$
$$= \underline{4.7\ lbs}$$

A fabric with 10 lbs puncture strength provides a F.S. of over 2.0.

Summary The separator fabric between the gravel & GCL bedding layer should have the following minimum properties:

Mullen Burst (ASTM D 3786) = 53 psi
Grab Strength (ASTM D 4632) = ~~41~~ lbs 5 lbs MB 11/2/00
Puncture Strength (ASTM D 4833) = 10 lbs

A technical data sheet for an example geotextile product meeting these requirements is attached

The Mirafi 135N product has:

Mullen Burst = 145 psi
Grab Strength = 80 lbs
Puncture Strength = 40 lbs

All the material values greatly exceed the required values. This is one of the lightest fabrics available.

Reference: Designing with Geosynthetics, Koerner, 4th Ed, 1999. pg. 151 – 158.

Solutio Sauger
Gravel Layer Separator Fabric Design

4 of 4
M. Brungard
10/18/00

TC Mirafi _____ *TECHNICAL DATA SHEET*

Mirafi 135N

Mirafi 135N is a nonwoven geotextile composed of polypropylene fibers, which are formed into a stable network such that the fibers retain their relative position. 135N is inert to biological degradation and resists naturally encountered chemicals, alkalis, and acids.

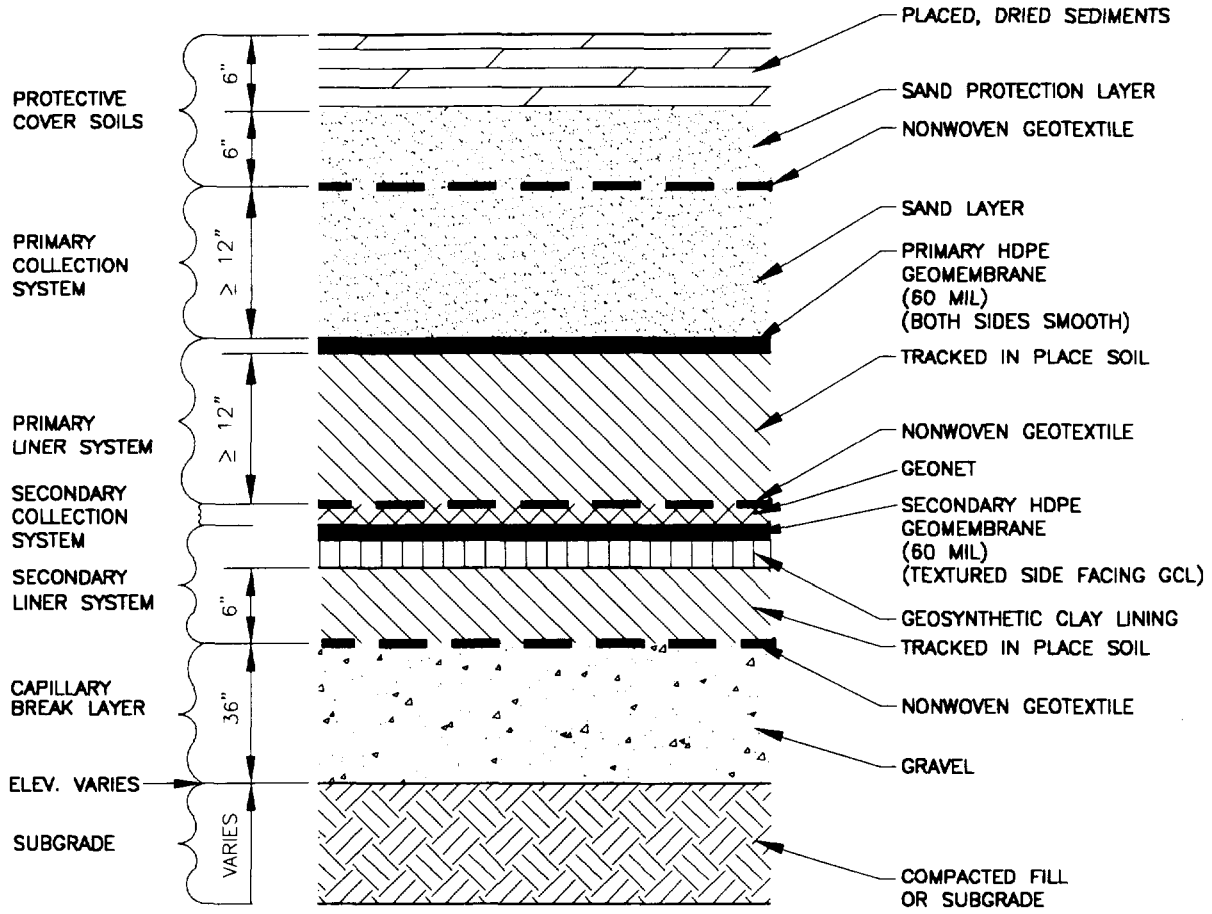
Mechanical Properties	Test Method	Unit	Minimum Average Roll Value	
			MD	CD
Grab Tensile Strength	ASTM D 4632	kN (lbs)	0.36 (80)	0.36 (80)
Grab Tensile Elongation	ASTM D 4632	%	50	50
Trapezoid Tear Strength	ASTM D 4533	kN (lbs)	0.13 (30)	0.13 (30)
Mullen Burst Strength	ASTM D 3786	kPa (psi)	1000 (145)	
Puncture Strength	ASTM D 4833	kN (lbs)	0.17 (40)	
Apparent Opening Size (AOS)	ASTM D 4751	mm (U.S. Sieve)	0.300 (50)	
Permittivity	ASTM D 4491	sec^{-1}	2.1	
Permeability	ASTM D 4491	cm/sec	0.23	
Flow Rate	ASTM D 4491	$l/min/m^2$ ($gal/min/ft^2$)	6336 (155)	
UV Resistance (at 500 hours)	ASTM D 4355	% strength retained	70	

Physical Properties	Test Method	Unit	Typical Value	
Weight	ASTM D 5261	g/m^2 (oz/yd^2)	110 (3.2)	
Thickness	ASTM D 5199	mm (mils)	1.0 (40)	
Roll Dimensions (width x length)	--	m (ft)	3.8 x 110 (12.5 x 360)	4.5 x 110 (15 x 360)
Roll Area	--	m^2 (yd^2)	418 (500)	502 (600)
Estimated Roll Weight	--	kg (lb)	55 (121)	65 (144)

DISCLAIMER: TC Mirafi warrants our products to be free from defects in material and workmanship when delivered to TC Mirafi's customers and that our products meet our published specifications. Contact your local TC Mirafi Representative for detailed product specification and warranty information.

ATTACHMENT 3

REPORT FIGURE REVISIONS



A BOTTOM LINER SYSTEM DETAIL

C1.4 | C1.6

N.T.S.

NOTES

1. NOT FOR CONSTRUCTION
2. LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

PREPARED FOR: SOLUTIA	Drawn: R. HAYDEN	PROJECT NAME: SOLUTIA INC. SAUGET AREA 1	FIGURE 4-1
URSGWC JOB NUMBER: C100003899.00	Design: M. BRUNGARD		
URS Greiner Woodward Clyde, A Division of URS Corporation, 7650 W. Courtney Campbell Causeway, Tampa, Florida 33607-1462, Tel: 813.286.1711 Fax: 813.287.8591	Checked: G. WANTLAND	DRAWING TITLE: BOTTOM LINER SYSTEM DETAIL	
	Date: OCT. 30, 2000		

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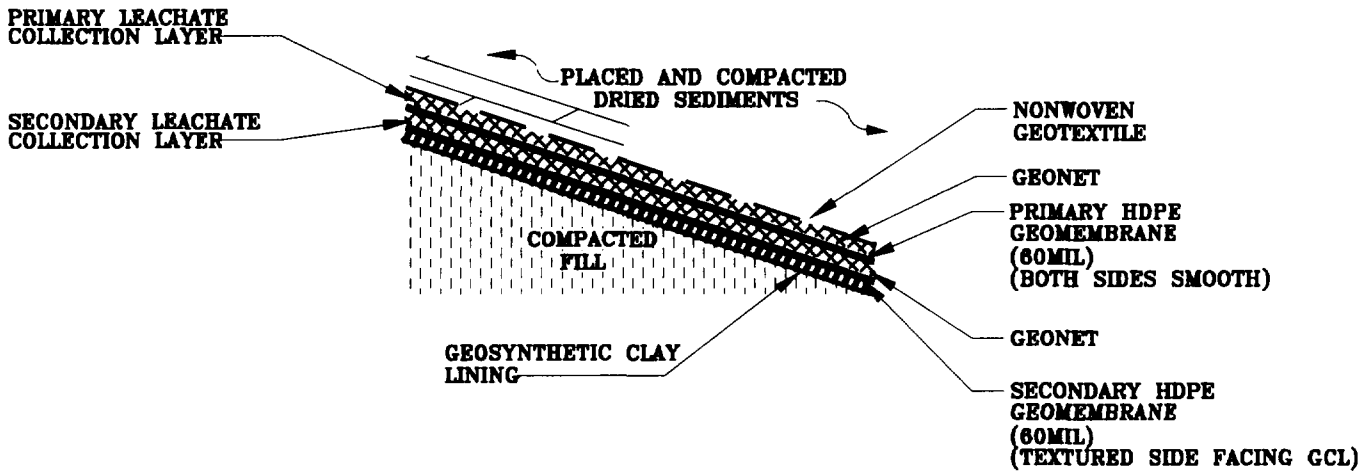

G

C1.4 | C1.6

SIDE SLOPE LINER SYSTEM DETAIL

N.T.S

NOT FOR CONSTRUCTION

PREPARED FOR: SOLUTIA INC.	Drawn: R. HAYDEN	PROJECT NAME: SOLUTIA INC. SAUGET AREA 1	FIGURE 4-2
URSGWC JOB NUMBER: C100004051.00	Design: M. BRUNGARD		
URS Greiner Woodward Clyde, A Division of URS Corporation, 7650 W. Courtney Campbell Causeway, Tampa, Florida 33607-1462, Tel: 813.286.1711 Fax: 813.287.8591	Checked: G. WANTLAND	DRAWING TITLE: SIDE SLOPE LINER SYSTEM DETAIL	
	Date: OCT. 30, 2000		

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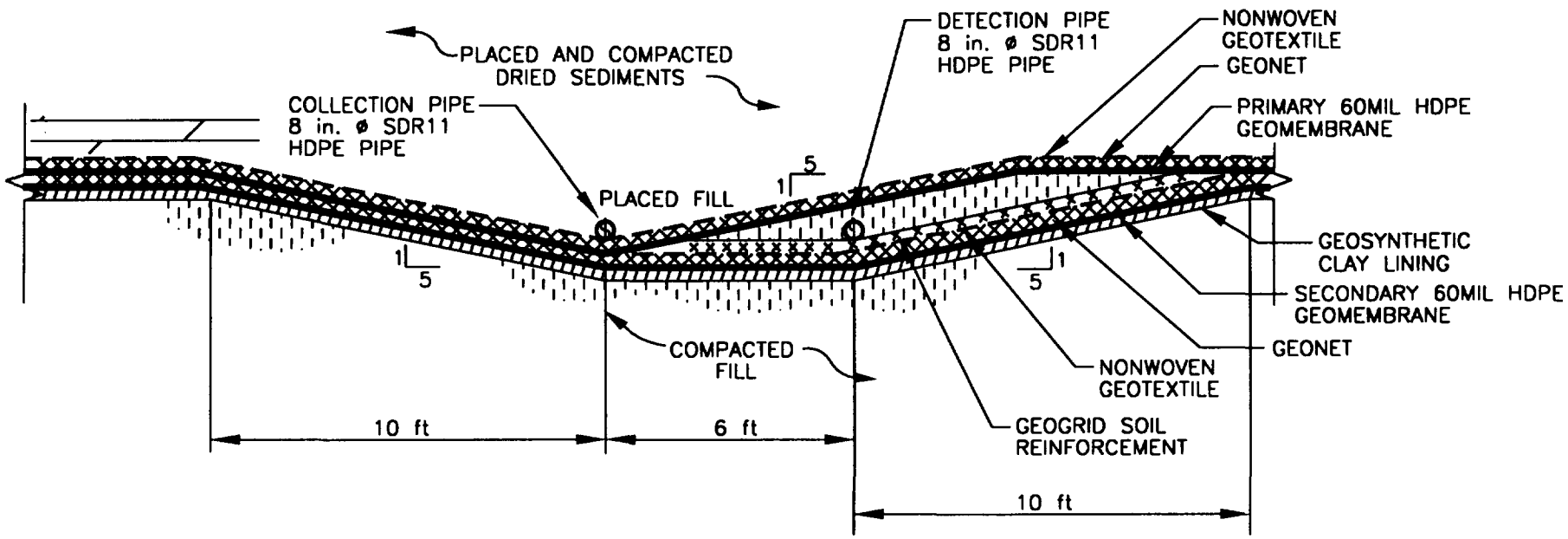


LEACHATE COLLECTION SYSTEM RISER PIPE DETAIL

C
C1.2 | C1.6

NTS

NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC. SAUGET AREA 1 CAHOKIA, ILLINOIS	URS Greiner Woodward Clyde 7650 WEST COURTNEY CAMPBELL CSWY. TAMPA, FLORIDA 33607-1462 TEL: 813.286.1711 FAX: 813.287.8591			LEACHATE COLLECTION LAYER OUTLET PIPE SECTION	PROJECT NUMBER C10000405.00
	SCALE NTS	DRAWN BY: CRH CHECKED BY:	DATE: 10/23/00 DATE:		FIGURE NUMBER 4-8
	LINER DETAILS_MOD1.dwg - Layout Fig4-8				

ATTACHMENT 4

REVISED SPECIFICATION 02200

SECTION 02200

EARTHWORK

PART 1 GENERAL

1.1 SECTION INCLUDES

A. This section describes general earthwork requirements for site preparation, perimeter berms, insitu soil compaction, soil protection, sand drainage layer, gravel fill, vegetative cover soil, and related activities. This section does not include sediment handling and placement.

1.2 REFERENCES

A. ASTM D75 - Practice for Sampling Aggregates.

B. ASTM C136 - Method for Sieve Analysis of Fine and Coarse Aggregates.

C. ASTM D422 - Method for Particle-Size Analysis of Soils.

D. ASTM D698 - Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3).

E. ASTM D1556 - Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.

F. ASTM D2167 - Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method.

G. ASTM D2216 - Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures.

H. ASTM D2434 - Test Method for Permeability of Granular Soils.

I. ASTM D2487 - Classification of Soils for Engineering Purposes.

J. ASTM D2922 - Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth).

K. ASTM D2937 - Test Method for Density of Soil in Place by the Drive Cylinder Method.

L. ASTM D3017 - Test Method for Moisture Content of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth).

M. ASTM D4318 - Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

N. ASTM D1140 - Test Method for Amount of Material in Soils Finer than the No. 200 Sieve.

O. ASTM D5084 - Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Perimeter.

1.3 DEFINITIONS

A. Well-Graded: A mixture of particle sizes that has no specific concentration, or lack thereof, of one or more sizes. A material type that, when compacted, produces a strong and relatively incompressible soil mass.

B. Coverage: One coverage is defined as the requirement of successive trips of a piece of compaction equipment, which by means of sufficient overlap, will ensure that all areas of the layer being compacted have been subjected to one pass of the compaction equipment.

C. Optimum Moisture Content: The maximum moisture content that will result when plotted against the dry unit weight of a soil when subjected to the ASTM D698 compaction test.

D. Percent Compaction: The percent compaction in-place shall be calculated as the ratio (in percent) of the in-place dry density to the estimated maximum dry density, in accordance with ASTM D698, of the representative fill material at the location of the in-place density test.

E. Proof Rolling: Rolling a surface with a minimum of 3 passes with approved compaction equipment for the purpose of detecting soft or loose areas.

F. On-Site Soils: On-site soils are defined as the insitu material located within the footprint of the liner system and the perimeter berms.

G. Borrow Soils: borrow soils are defined as material transferred to the footprint area from a remote location.

H. Unsuitable Materials: All soil materials that contain waste, debris, roots, organic matter, frozen matter, stone or rock with any dimension greater than 1-inch, or any other material that are determined by the Construction Manager to be unsuitable for stable, compacted backfill purposes. Approved on-site borrow soils are suitable fill.

I. Borrow Areas: Borrow areas are those locations approved by the Construction Manager for procurement, excavation and use of materials for Construction of the Perimeter Containment Levee, Final Cover or landfill soil components. Borrow areas do not include "on-site soils" as defined herein.

J. Fine-Grained Soils: Fined grained soils are defined as those materials which pass a 200 sieve in accordance with the guidelines established in ASTM C136.

1.4 TESTING

A. The Contractor will retain the services of a QC testing laboratory that has been approved by Construction Manager to perform tests as specified herein. At a minimum, the Contractor shall be responsible for providing QC for the following:

1. Compliance testing for materials provided from onsite and offsite sources.

2. QC testing and inspection during construction.

B. The Contractor shall inspect and verify all earthwork operations are in conformance with this specification and the contract documents. Moisture/density relationships for the various fill materials will be established as part of the QC program. Field density tests, sample selection, and construction observations will be performed in sufficient numbers and in such locations to verify that the specified density is being achieved.

C. The Contractor shall inform the Construction Manager prior to conducting all field tests to allow oversight. No additional fill placement shall be permitted in areas that have not met the specified fill placement criteria.

1.5 SUBMITTALS

A. Construction Plan

The Contractor shall submit a construction plan identifying the procedures and methods to be used. The plan shall be approved by the Construction Manager prior to any earthwork activities. The construction plan shall, at a minimum, include the following:

1. Proposed material source(s) and proposed method(s) of sampling.

2. Proposed soil processing, placement, compaction, and moisture control equipment, including equipment catalog with weight, dimensions, and operating data for all equipment.
3. Proposed locations of soil processing and moisture control.

4. Proposed methods for soil processing and moisture control.

5. Proposed work schedule.

6. Proposed method of protecting Work, to include temporary drainage measures.

7. Proposed QC Personnel. All QC personnel shall demonstrate specific experience of at least 2 years in the areas in which they will be performing QC inspections.

8. Proposed professional engineer registered in Illinois with no less than 5 years experience in the performance and evaluation of geotechnical laboratory tests on constructed materials.

9. Proposed land surveyor licensed in the State of Illinois.

10. Proposed excavation, stockpiling, regrading and staging plan describing handling and transport of borrow materials.

11. Proposed proof rolling method and equipment for each subgrade condition.

B. Contractor shall submit results of prequalification test data on each material source to the Construction Manager for approval prior to procurement, excavation, transport, stockpiling or use.

C. Contractor shall submit results of all field and laboratory prequalification and quality control data to the Construction Manager within 1 work day of receipt.

D. Contractor shall submit the results of all observations and documentation generated by its quality control personnel the next work day.

E. Contractor shall submit results of all field surveys and documentation to the Construction Manager. Copies of surveyor field data, books and notes shall be submitted within 1 work day of generation. Copies of survey information signed and sealed by a Florida licensed surveyor shall be submitted within 1 work day of receipt.

1.6 PROTECTION

A. All streets, roads, grading, structures, utilities and other improvements not specifically designated to be cleared, removed, stripped or altered as a part of the work shall be protected from damage throughout the construction period. Any damage caused by the Contractor, his employees, agents, or any lower tiered subcontractors shall be immediately repaired to the original condition and to the satisfaction of the Construction Manager at no additional cost to the Owner.

B. Traffic Control

1. Keep all roads, sidewalks, and parking areas that are not part of this project usable at all times.

2. The Contractor shall provide all necessary barricades, lights, signs, signals, etc., for the protection of the workers and the public, as established by the Occupational Safety and Health Administration (OSHA) Construction Safety and Health Regulation 29 CFR, Part 1926, Subpart G, Signs, Signals and Barricades, and in Subpart P- Excavations, trenching and shoring, and IDOT Standard Specifications for Highway Construction, latest edition.

C. Existing Utilities

1. The Contractor is solely responsible for identification of all utilities, both known and unknown.

2. Known existing utilities are indicated on the Plans. The Contractor shall hand excavate areas within 6 feet (ft) of existing utilities. Any requested variance from the hand excavation requirement shall be submitted in writing to the Construction Manager.

3. Actual locations of all existing utilities within the work area shall be located by the Contractor by hand excavation and indicated on the As-Built drawings.

4. After the actual locations and routing of the existing utilities have been found to be accurately determined through this hand excavation, and after approval from the Construction Manager, the Contractor may begin excavation using machinery in a manner acceptable to the Construction Manager.

5. After excavation by machinery has begun, the Contractor shall be fully responsible for all utilities that were found through hand excavation and/or which were indicated on the Drawings.

6. Any existing utility indicated on the Drawings that is damaged by the Contractor shall be immediately repaired to its previous undamaged condition at no additional cost to the Owner.

7. Notify the Construction Manager immediately of any encountered utilities not shown on the Drawings.

8. Obtain approval from the Construction Manager before backfilling in areas of known utilities. Utility warning tape (provided by the Contractor) shall be placed 12 inches above existing or newly installed utilities.

D. Monitoring Wells

1. Contractor shall be solely responsible for identification of all groundwater monitoring wells.

2. Known groundwater monitoring wells are indicated on the Plans. Contractor shall not operate machinery, excavate, mound soil or otherwise disturb the ground surface around a monitoring well without the concurrence of the Construction Manager.

3. Contractor shall be solely responsible for the protection and usability of the monitoring wells during the work.

4. If the Contractor damages a monitoring well during the performance of the work, the Contractor shall immediately notify the Construction Manager of the damage.

5. If the Owner subsequently determines that the damaged monitoring well no longer performs satisfactorily, the Owner will have the well repaired, replaced or abandoned by a qualified well installer and will recover any resulting cost from the Contractor.

6. Repair , replacement or abandonment procedures shall be those required by the Northwest Water Management District. Repair, replacement and/or abandonment procedures shall include all fees and documentation required by the Water Management District.

1.7 REGULATORY REQUIREMENTS

A. Permits

Obtain and comply with all appropriate local, state, and federal permits and licenses required for performing the work.

PART 2 PRODUCTS

2.1 ON-SITE SOILS

A. Soils in the vicinity of the Landfill contain a limited amount of organic and inorganic constituents. Excavation and removal of onsite or surrounding soils is not permitted unless approved by the Construction Manager.

B. Pockets, lenses or layers of material differing in texture, gradation, moisture or density from the surrounding material shall be identified and removed with the concurrence of the Construction Manger. Removed materials shall be replaced with

Compacted Fill in accordance with the requirements of the Specifications. Removed materials shall be disposed in the manner and location designated by the Construction Manager.

2.2 BORROW SOURCES

A. Borrow sources do not exist within the property boundary of the proposed landfill for use on this project.

B. Borrow sources may not be available within the Plant boundaries for the Drainage Material or the Vegetated Cover Fill.

C. Offsite Sources

1. Contractor shall be responsible for locating sources of borrow material from offsite sources sufficient to complete the work. The Contractor shall obtain representative samples of the proposed source for laboratory testing. Results of the testing along with representative samples of the proposed material shall be submitted to the Construction Manager for approval prior to procurement, excavation, transport stockpiling or use.

2. Contractor use of other borrow sources shall only be with the written approval of the Construction Manager. Unless otherwise directed by the Construction Manager all material shall conform to the requirements of the Specifications.

2.3 FILL MATERIAL

A. Compacted Fill

1. Compacted Fill shall consist of random granular or cohesive materials obtained from approved on-site or off-site borrow areas. Compacted Fill will contain a minimum of 5 percent by dry weight of material passing the U.S. No. 200 Sieve and be free of lenses, pockets or layers of material differing in texture, gradation, and moisture from surrounding material. Compacted Fill shall consist of soil types meeting the following classifications of ASTM D2487:

2. The maximum clod size for Compacted Fill shall be 4 inches in any dimension. Oversize material shall be removed or reworked to conform to these requirements. Non-uniform material shall be removed or reworked to conform to these requirements.

B. Tracked In-place Fill

1. Tracked In-place Fill shall consist of poorly graded granular or cohesive fill obtained from approved borrow areas. Tracked In-place Fill shall be free from lenses, pockets or layers of material differing in texture, gradation, and moisture from surrounding material.

2. Tracked In-place Fill shall consist of soils types meeting the following classifications of ASTM D2487:

Silty to Clayey Sands	SC, SP, SP-SM, SC-SM
Silty Sands	SM, SP
Clayey Silts to Silty Clays	SC-SM, SM-SC, CL
Silty Sandy Clays	CL
Combinations of the above	

3. The maximum clod size for Tracked In-place Fill shall be 2 inches in any dimension. Oversize material shall be removed or reworked to conform to these requirements. Non-uniform material shall be removed or reworked to conform to these requirements.

C. Drainage Material

1. Drainage material shall consist of siliceous, non-carbonate, non-angular sound sand or gravel obtained from approved borrow sources. Drainage material will contain a maximum of 10 percent by dry weight of material passing the U.S. No. 100 Sieve and be free of lenses, pockets or layers of material differing in texture, gradation and moisture from the surrounding material.

2. Sand drainage material shall consist of soil types meeting the following classifications of ASTM D2487:

Slightly Silty Sands	SM, SP-SM, SW-SM
Well Graded to Poorly Graded Sands	SP, SW

Sand drainage material shall conform to the following ASTM C33 requirements for fine aggregates:

Sieve Size	Percent Passing by Weight
3/8 inch	100
No. 4	95 – 100
No. 8	80 – 100
No. 16	50 – 85
No. 30	25 – 60
No. 50	10 – 30
No. 100	0 – 10

Sand drainage material shall have a laboratory measured permeability of $\geq 1 \times 10^{-3}$ cm/sec.

3. Gravel drainage material shall consist of soil types meeting the following classifications of ASTM D2487.

Sandy Gravel to Sandy Silty Gravel	GW-GM, GP-GM
Well Graded to Poorly Graded Gravel	GW, GP

Gravel drainage material shall conform to the following ASTM C33 requirements for coarse aggregates:

Sieve Size	Percent Passing by Weight
1.5 inch	100
1 inch	95 – 100
½ inch	25 – 60
No. 4	0 – 10
No. 8	0 – 5

Gravel drainage material shall have a laboratory measured permeability of ≥ 1 cm/sec.

D. Protection Layer

1. Protection Layer shall consist of granular or fine-grained materials obtained from approved borrow areas, or other sources as approved by the Construction Manager. Protection Layer will be used to construct the protective soil layer placed directly on the Primary Collection System. Protection Layer shall consist of soil types meeting the following classifications:

Silty to Clayey Sands	SC, SP, SP-SM, SC-SM
Poor to Well Graded Sands	SP, SW
Sandy to Silty Clays	SM-SC
Creek Sediments	

2. Protection Layer shall be free of rocks, sticks, roots deleterious or unsuitable materials. Maximum clod size for protective fill shall be 2 inches in any dimension. Oversize material shall be removed or reworked to conform to these requirements. Non-uniform material shall be removed or reworked to conform to these requirements.

E. Vegetated Cover Fill

1. Vegetated Cover Fill shall consist of granular material obtained from approved borrow areas. Vegetated Cover Fill will contain a maximum of 15 percent by dry weight of material passing the U.S. No. 200 Sieve and be free from lenses, pockets or layers of material differing in texture, gradation, and moisture from surrounding material. The Vegetated Cover Fill shall have a laboratory measured permeability $\geq 1 \times 10^{-3}$ cm/sec. Vegetated Cover Fill shall consist of soil types meeting the following classifications of ASTM D2487:

Silty Sands	SM
Clayey Sands	SC, CL-SC
Silty to Clayey Sand	SP-SM, SP-SC, SC-SM
Topsoil	
Combinations of the above	

2. The maximum clod size for vegetated cover shall be 2 inches in any dimension. Oversize material shall be removed or reworked to conform to these requirements. Non-uniform material shall be removed or reworked to conform to these requirements.

3. Vegetated Cover Fill shall conform to the following gradation requirements:

Sieve Size	**Percent Passing by Weight**
No. 16	100
No. 30	90 – 100
No. 50	60 – 100
No. 100	25 – 80
No. 200	5 – 40

2.4 EQUIPMENT

1. All equipment and tools used in the performance of this work are subject to the approval of the Construction Manager before work is started.

2. Contractor shall provide compaction equipment appropriate for the material types to obtain the densities specified. At a minimum "footed" rollers are expected for compaction of fine-grained soils or cohesive fills. Smooth drum rollers or hand compaction methods may be appropriate for granular drainage material sands and gravels.

3. Contractor shall provide hand-operated compaction equipment in areas closer than 2 ft from pipes or other appurtenant structures to obtain the densities specified.
4. Contractor shall operate and maintain compaction equipment in accordance with the manufacturer's instructions and recommendations. If inadequate densities are obtained, provide larger and/or different type equipment at no cost to the Owner.

5. Contractor shall provide equipment for applying water of a type and quality adequate for the Work, free of leaks and equipped with a distributor bar or other approved device to ensure uniform application.

6. Contractor shall provide equipment for mixing and drying out material, such as blades, discs, or other approved equipment.

7. Contractor shall sufficiently weigh the compaction equipment such that the feet fully penetrate the loose lift during initial compaction.

8. Contractors mixing and blending equipment shall fully penetrate loose lifts during mixing to achieve a uniform material.

PART 3 EXECUTION

3.1 WATER CONTROL

A. Contractor shall furnish, install, maintain and operate all equipment and materials needed to prevent, control and remove surface water within or adjacent to the area of work in accordance with the approved Stormwater Control Plan identified in Section 02150 of these Specifications.

B. Contractor shall furnish, install, maintain, and operate all equipment and materials to prevent ground water from flowing into excavations or onto work areas or areas designated to receive fill as necessary or as required by the Construction Manager.

3.2 CLEARING AND GRUBBING - LANDFILL FOOPRINT AREA

A. Contractor shall remove vegetation including snags, brush, and rubbish occurring in the areas of the work.

B. Roots, brush, rotten wood, and other refuse collected by the Contractor from the clearing and grubbing operations shall be disposed by the Contractor at the designated location shown on the Drawings.

3.3 SUBGRADE PREPARATION

A. General

1. Contractor shall proof roll footprint areas as shown on the Plans to identify soft or spongy areas.

2. Contractor shall remove soft or spongy areas and replace with Compacted Fill. Low spots and depressions shall be backfilled to achieve a uniform grade.

3. Contractor shall spread out excavated subgrade soils for drying and blending with onsite soils within the footprint of the landfill unless Contractor's written request for options are approved.

B. Perimeter Berms and Liner System Footprint

1. Contractor shall disc, harrow and breakup subgrade soils to a depth of 8 inches within the perimeter berm and liner system footprint.

2. Contractor shall prepare subgrade soils to meet the requirements of Compacted Fill.

3. Soils not meeting the requirements of Compacted Fill shall be removed and replaced by the Contractor.

4. Contractor shall adjust in-place soils moisture content to be no less than 2 percent below optimum and no more than 3 percent above optimum as determined by ASTM D698.

5. Contractor shall compact insitu soils to not less than 95 percent of the laboratory maximum Standard Proctor dry density (ASTM D698). Any single in-place density test falling below 90 percent compaction level shall be classified as a failing test and the area of materials represented by the failing test shall be re-processed by the Contractor until 95 percent or greater compaction is achieved. Areas represented by in-place density test results falling between 90 and 95

percent maximum Standard Proctor dry density may be accepted if both of the following conditions are met:

(a) The test result is not more than 1 in 5 successive tests in the range of 90 to 95 percent maximum density.

(b) Total number of in-place density tests falling in the range of 90 to 95 percent maximum dry density is less than 10 percent of the total number of in-place density tests completed at that time.

Areas represented by unacceptable tests with compactions between 90 and 95 percent shall be reprocessed by the Contractor until 95 percent or greater maximum dry density is achieved.

3.4 SURFACE PREPARATION

A. The compacted surface of any layer of fill which is too wet or too dry for bonding to the next layer of material shall be dried or moistened by the Contractor and compacted before the next layer is placed.

B. Contractor shall scarify the foundation so that the surface materials will bond and compact with the first layer of fill.

C. Contractor shall place all fill to conform to the grades and cross-sections shown on the Plans.

3.5 EXCAVATION

A. All excavation shall comply with the requirements of OSHA 29 CFR Part 1926.

B. Limits

1. Contractor shall excavate to lines, grades, and dimensions, as shown on the Plans.

2. Contractor shall minimize excavation beyond limits shown unless otherwise approved in writing by the Construction Manager.

3. Contractor shall design and use sloping, sheeting, shoring and bracing as necessary to protect existing structures from damage.

4. Contractor shall grade the surface of overexcavated areas by creating a smooth transition to adjoining areas, and slope to drain.

5. Overexcavated areas shall be backfilled and compacted by the Contractor in accordance with these specifications at no expense to the Owner unless additional excavation was previously approved by the Construction Manager.

C. At the conclusion of each days work, Contractor shall backfill, barricade or adequately fence and protect all trenches and/or excavations in accordance with the Owner's EH&S Requirements.

3.6 PLACEMENT

A. General

1. Contractor shall construct the soil components of the lining and final cover system using suitable fill materials as specified.

2. Contractor shall construct soil components to the lines and grades shown on the Plans.

3. Contractor shall construct each layer of each zone in a continuous and nearly horizontal layer for the full width at the elevation of the layer unless otherwise required by the Specifications or Plans.

4. Contractor shall place and compact all materials to prevent constructed discontinuities in the fill or segregated areas of the work. Differences in elevation for material placed and compacted shall not exceed four (4) ft unless otherwise approved in writing by the Construction Manager.

5. Special care shall be taken by the Contractor to ensure bonding of new fill to constructed segments previously placed by benching in 2 ft horizontally into the existing fill for each 1-ft vertical placement. This requirement shall not apply to construction interfaces between side slopes and bottom materials.

6. Contractor shall moisten or aerate, scarify, and work with harrows, discs, or other suitable equipment in such a manner to reduce the clod size of material being placed to the requirements given. Blend all material to be free from lenses, pockets, or layers of material differing in texture, gradation, and moisture from surrounding materials and to depths that provide a bonding surface with the new material.

7. Soils with excess moisture shall be sufficiently dried to meet the specified compaction requirements.

8. Contractor may at his option add moisture to the borrow area.

B. Compacted Fill

1. Prior to placing any new fill, the Contractor shall scarify the foundation upon which new fill is to be placed. Where the proposed fills overlie unsuitable materials, such materials shall be removed by the Contractor.

2. Contractor shall ensure the uniform moisture distribution of the Compacted Fill.

3. Materials too dry for compaction may be pre-wetted in the borrow areas by the Contractor. Supplemental water, if required, may be added by the Contractor to the material after placement and prior to compaction by uniform sprinkling and shall be mixed uniformly using discs.

4. Contractor shall conduct borrow and placing operations to assure product uniformity.

5. The material shall be placed by the Contractor in maximum 12-inch thick (loose) lifts.

6. The placement moisture content for Compacted Fill zone materials shall be between 2 percent below and 3 percent above optimum moisture content (ASTM D698).

7. Compacted Fill shall be compacted by the Contractor to not less than 95 percent of the laboratory maximum Standard Proctor dry density (ASTM D698). Any single in-place density test falling below 90 percent compaction level shall be classified as a failing test and the area of materials represented by the failing test shall be be-processed by the Contractor until 95 percent compaction is achieved. Areas represented by in-place density test results falling between 90 and 95 percent maximum Standard Proctor dry density may be accepted if both of the following conditions are met:

   (a) The test result is not more than 1 in 5 successive tests in the range of 90 to 95 percent maximum density.

   (b) The total number of in-place density tests falling between 90 to 95 percent maximum dry density is less than 10 percent of the total number of in-place density tests completed at that time.

   Areas represented by unacceptable tests with compactions between 90 and 95 percent shall be reprocessed by the Contractor until 95 percent or greater maximum dry density is achieved.

8. The Contractor shall route all construction equipment in a manner that ensures uniform compaction of each lift.

9. Lift thickness shall be controlled by the Contractor through the use of temporary grade stakes.

10. If the compacted surface of any completed lift of fill is too wet or too dry for placement of the subsequent lift, it shall be dried back or moistened, and then scarified before the next lift of fill is placed. Contractor shall remove grade stakes from the fill prior to compacting that lift.

11. Contractor shall protect and maintain a smooth finished surface on the embankment prior to seeding with vegetative cover.

12. Erosion gullies, rills or other surface discontinuity developing on the exterior face of the embankment shall be repaired by the Contractor immediately.

13. Erosion features which average 2 inches deep or less shall be repaired by the Contractor by reblading and compacting the surface.

14. Erosion features which average greater than 6 inches deep shall be removed by the Contractor and replaced using procedures acceptable to the Construction Manager.

C. Tracked In-place Fill

1. Tracked In-place Fill shall be placed by the Contractor to the lines and grades shown in the Plans.

2. Soil material shall conform to the material requirements of these Specifications for Tracked In-place Fill.

3. The Contractor shall place the first lift of Tracked In-place Fill over the geosynthetic material (i.e., geomembrane liner) in a uniform loose lift no less than 12 inches thick by track-mounted earthmoving equipment. All fill shall be "rolled" into place such that fill placement shall not "gouge" or displace the lower materials.

4. The first lift of the Tracked In-place Fill will be inspected and tested. If the in-place density and moisture content meet the requirements of the Specifications, either all or a portion of the first lift will be accepted.

5. Prior to placement of subsequent lifts, the Contractor shall sufficiently roughen the area to a depth of approximately 2 inches. Fill moisture content shall be modified as necessary to provide a suitable bond with the next lift.

6. Contractor shall spread subsequent fill in uniform lifts not exceeding 9 inches in loose thickness before compaction.

7. Contractor shall adjust moisture content as required to maintain the range specified. Moisture content adjustment shall be accomplished by aerating and discing when too wet or by adding water and mixing by discing or blading when too dry. The addition of water to the clay fill shall utilize thorough mixing to achieve a uniform moisture content distribution within the Low Permeability Fill.

8. Contractor shall compact Tracked In-place Fill to no less than 90 percent of the laboratory maximum Standard Proctor dry density as per ASTM D698.

9. The placement moisture content shall be optimum or above optimum moisture content as determined by ASTM D698.

10. Contractor shall not permit equipment to travel directly on geosynthetic material.

D. Drainage Material

1. Contractor shall place Drainage Materials to the lines and grades shown in the Plans.

2. Drainage Material shall conform to the material requirements for Sand Drainage or Gravel Drainage Material or Capillary Break Layer in these Specifications.

3. Contractor shall prevent soils from adjacent zones being tracked or mixed with Drainage Material Fill.

4. Contractor shall loosely dump and "roll" Sand Drainage Material into place without sliding or gouging underlying material.

5. Contractor shall place Sand Drainage Material in uniform horizontal lifts no less than 12 inches thick prior to compaction.

6. Contractor shall compact Sand Drainage layer to 50 percent relative density.

7. Contractor shall place Gravel Drainage Fill in uniform lifts. Contractor shall not dump gravel on geosynthetic materials.

8. Contractor shall not permit equipment to travel directly on geosynthetic material.

E. Protection Layer

1. Contractor shall place Protection Layer to the lines and grades shown in the Plans.

2. Protection Layer shall conform to the requirements of these Specifications.

3. Contractor shall place Protection Layer in uniform loose lifts. Contractor shall "roll" Protection Layer into place without gouging underlying materials.

4. Protection Layer shall be walked into place using track-mounted equipment.

5. Contractor shall not permit equipment to travel directly on geosynthetic material.

F. Vegetated Cover Fill

1. Contractor shall place Vegetated Cover to the lines and grades shown on the Plans.

2. Contractor shall place first lift of Vegetated Cover in uniform horizontal lifts of 12 inches.

3. Contractor shall "roll" Vegetated Cover Fill into place without gouging underlying layers using tracked equipment with ground pressures less than 5 psi.

4. Each lift of Vegetated Cover Fill shall be compacted by the Contractor with no less than 3 coverages using tracked equipment.

5. Contractor shall not permit equipment to directly travel across geosynthetic material.

3.7 PREPARATION FOR GEOSYNTHETIC MATERIAL PLACEMENT

A. Contractor shall trim all surfaces and areas to receive geosynthetic materials to achieve a smooth uniform grade, free from sharp edges, ruts or discontinuities.

B. Contractor shall condition the upper six inches of surface soil in all areas to receive geosynthetic materials with water as necessary to achieve a moisture content of approximately optimum as determined by ASTM D 698.

C. Contractor shall smooth drum roll all areas after moisture conditioning is complete. Soft or spongy areas of fill shall be removed at the direction of the Construction Manager and replaced in accordance with the requirements of these specifications at no cost to the Owner.

D. Contractor shall certify to the Construction Manager that all areas to receive geosynthetic materials area free from sharp edges, ruts or discontinuities.

E. Prior to releasing an area for geosynthetic placement, the Construction Manager or his designee will inspect the area for conformance to these specifications. Contractor shall rework areas that that are deemed not acceptable by the Construction Manager until acceptance is achieved.

3.8 MAINTENANCE

A. During work interruption(s) Contractor shall be solely responsible for preventing moisture loss from compacted materials.

B. Contractor shall remove and replace or recondition materials that have dried below the specified moisture range for that fill classification.

C. Contractor shall replace dried soils using material and procedures in accordance with these Specifications.

D. Temporary covers may be used to prevent moisture loss.

E. Desiccation Cracks

1. Desiccation cracks within the compacted material shall be repaired immediately by the Contractor.

2. Contractor shall repair shall desiccation cracks (less than 2 inches in depth) by discing or rotary tilling the fill to produce clods that are no greater than 2 inches. Moisture content of the fill shall be properly adjusted to within the range specified. Fill shall be thoroughly mixed to achieve a uniform moisture content distribution and compacted to the specified value.

3. Contractor shall repair deep desiccation cracks (greater than 2 inches in depth) by removing the fill from the compacted layer to a depth of 1.5 times the average depth of desiccation crack. Contractor shall replace and recompact fill into the excavated area meeting the requirements of the Specifications.

3.9 CONSTRUCTION TOLERANCE

A. Survey Precision

1. Contractor shall provide survey control for all earthwork placement, compaction, excavation and grading and as otherwise directed by the Construction Manager.

2. Contractor shall perform surveys of the work to ± 0.1 ft vertically and ± 0.25 ft horizontally.

B. Surface Tolerance

1. Contractor shall construct finished subgrades, compacted surfaces and drainage material layers from -0.0 to +0.1 ft.

2. Contractor shall provide constructed work with variations in final grade ≤ 0.25 ft above minimum thickness vertically between any two points located within 100 ft in any direction with the exception of designated changes in grade.

3.10 SURVEY CONTROL DATA

A. Survey data shall be collected as specified below or as otherwise directed by the Construction Manager.

B. Subgrade

1. Contractor shall collect survey data at points a maximum of 50 ft apart beneath the lining system footprint.
2. Contractor shall collect survey data at points 100 ft apart on the centerline of the perimeter berm.
3. Contractor shall collect survey data for the outside toe of the perimeter berm at the same frequency as the measurements of the centerline.

C. Perimeter Berm

1. Contractor shall collect survey data at points 100 ft apart. Survey data points shall at a minimum be on the centerline of the perimeter berm, the outside toe and the inside toe of the lift.
2. Contractor shall collect survey data on every third lift of the perimeter berm starting with the finished surface of the first lift.

D. Tracked In-place Fill

1. Contractor shall collect survey data at points 50 ft apart and no less than 6 points per grade.
2. Contractor shall collect survey data of the following surfaces:
   - the finished layer to receive Tracked In-place Fill
   - the compacted surface of the first lift of Tracked In-place Fill
   - the final constructed surface of Tracked In-place Fill

E. Drainage Material

1. Contractor shall collect survey data at the following locations:
   - the finished layer to receive the drainage material
   - locations, widths, grades and elevations of gravel drains and sumps

- the top and bottom of each drainage layer

2. Contractor shall collect survey data at points no further than 25 ft apart and no less than 6 points per grade.

F. Protection Layer

1. Contractor shall collect survey data at points 100 ft apart and no less than 6 points per grade.

2. Contractor shall collect survey data on the finished surface to receive the Protection Layer and on the top of the Protection Layer.

G. Vegetated Cover

1. Contractor shall collect survey data at points 100 ft apart and no less than 6 points per grade.

2. Contractor shall collect survey data on the finished surface to receive the Vegetated Cover and on the top of the Vegetated Cover Layer.

3.11 QUALITY CONTROL

A. General

1. Tests and analysis of fill materials will be performed by the Contractor's approved QC personnel and Testing Laboratory.

2. Field inspection and testing will be performed by the Contractor.

3. The test frequency option which results in the greatest number of tests shall be used by the Contractor.

4. If the Construction Manager suspects the accuracy of the Nuclear Density gauge based on the review of QA test comparisons, the Contractor shall be responsible for proposing corrective actions to be taken to resolve discrepancies. The Construction Manager must approve the proposed corrective action before any further testing with the Nuclear Density gauge is accepted.

5. If the Contractor's in-place density test fails due to moisture content, re-test in the same area. If the second test fails, remove or rework area defined by surrounding tests meeting the Specifications.

6. All perforations due to density test probe, sample tubes, or test pit excavation shall be backfilled by the Contractor. All perforations shall be backfilled with

material similar to that of the layer. Backfill shall be recompacted using methods and procedures specified. Contractor may use a powdered bentonite backfill as an option.

7. One point compaction tests shall be performed by the Contractor whenever a change in material is observed or suspected, as directed by the Construction Manager and no less than once per day per material type.

8. Contractor may use one point compaction data for calculation of maximum Standard Proctor dry density until a laboratory generated moisture density curve is developed. Contractor may continue placement at his own risk.

9. If placed and compacted material does not meet the requirements of these Specifications based on the laboratory generated moisture density curve, the Contractor shall remove or rework all such material to meet these requirements at no additional cost to the Owner.

10. Contractor shall submit all preconstruction and construction quality control data with a cover letter signed and sealed by a Illinois registered professional engineer indicating the requirements of the Specifications have been achieved and the data as presented is representative of the material tested.

B. Preconstruction Material Quality Evaluation

1. The Contractor shall perform material quality evaluations on all proposed borrow sources for approval by the Construction Manager prior to procurement, excavating, transport, stockpiling or use.

2. Compacted Fill testing requirements:

• ASTM D2216	1 per source
• ASTM D4318	1 per source
• ASTM D1140	1 per source
• ASTM D698	1 per source
• ASTM D5084	1 per source

3. Tracked In-place Fill testing requirements:

• ASTM D2216	1 per source
• ASTM D4318	1 per source
• ASTM D1140	1 per source
• ASTM D698	1 per source

4. Drainage Material testing requirements for each sand and gravel source:

• ASTM D2216	1 per source per type
• ASTM D422	1 per source per type
• ASTM D2434	1 per source per type

5. Protection Layer testing requirements:

• ASTM D2216	1 per source
• ASTM D1140 or D422	1 per source
• ASTM D698	1 per source

6. Vegetated Cover Fill testing requirements:

• ASTM D2216	1 per source
• ASTM D4318	1 per source
• ASTM D1140	1 per source
• ASTM D5084	1 per source

C. Construction Material Quality Evaluation

1. Laboratory testing shall be performed by the Contractor's QC personnel on each source throughout the performance of construction.

2. Compacted Fill testing requirements for each borrow source used:

• ASTM D2216	1 per 20,000 yds^3
• ASTM D4318	1 per 20,000 yds^3
• ASTM D1140	1 per 20,000 yds^3
• ASTM D698	1 per 20,000 yds^3
• ASTM D5084	1 per 50,000 yds^3

3. Tracked In-place Fill testing requirements for each borrow source used:

• ASTM D2216	1 per 10,000 yds^3
• ASTM D4318	1 per 10,000 yds^3
• ASTM D1140	1 per 10,000 yds^3
• ASTM D698	1 per 20,000 yds^3

4. Drainage Material testing requirements for each sand and gravel source:

• ASTM D2216	1 per 10,000 yds^3
• ASTM D422	1 per 10,000 yds^3
• ASTM D2434	1 per 10,000 yds^3

5. Protection Layer testing requirements for each material source:

• ASTM D2216	1 per 50,000 yds^3
• ASTM D1140 or D422	1 per 50,000 yds^3
• ASTM D698	1 per 50,000 yds^3

6. Vegetated Cover testing requirements for each material source:

• ASTM D2216	1 per 20,000 yds^3
• ASTM D4318	1 per 10,000 yds^3
• ASTM D1140 or D422	1 per 10,000 yds^3
• ASTM D5084	1 per 20,000 yds^3

D. Constructed Material Quality Control

1. Compacted Fill

In-place density ASTM D2922 ASTM D3017	1 per 2,000 yd^3 placed and compacted
In-place density verification ASTM D2937 ASTM D2216	1 per 15,000 yd^3 placed and compacted

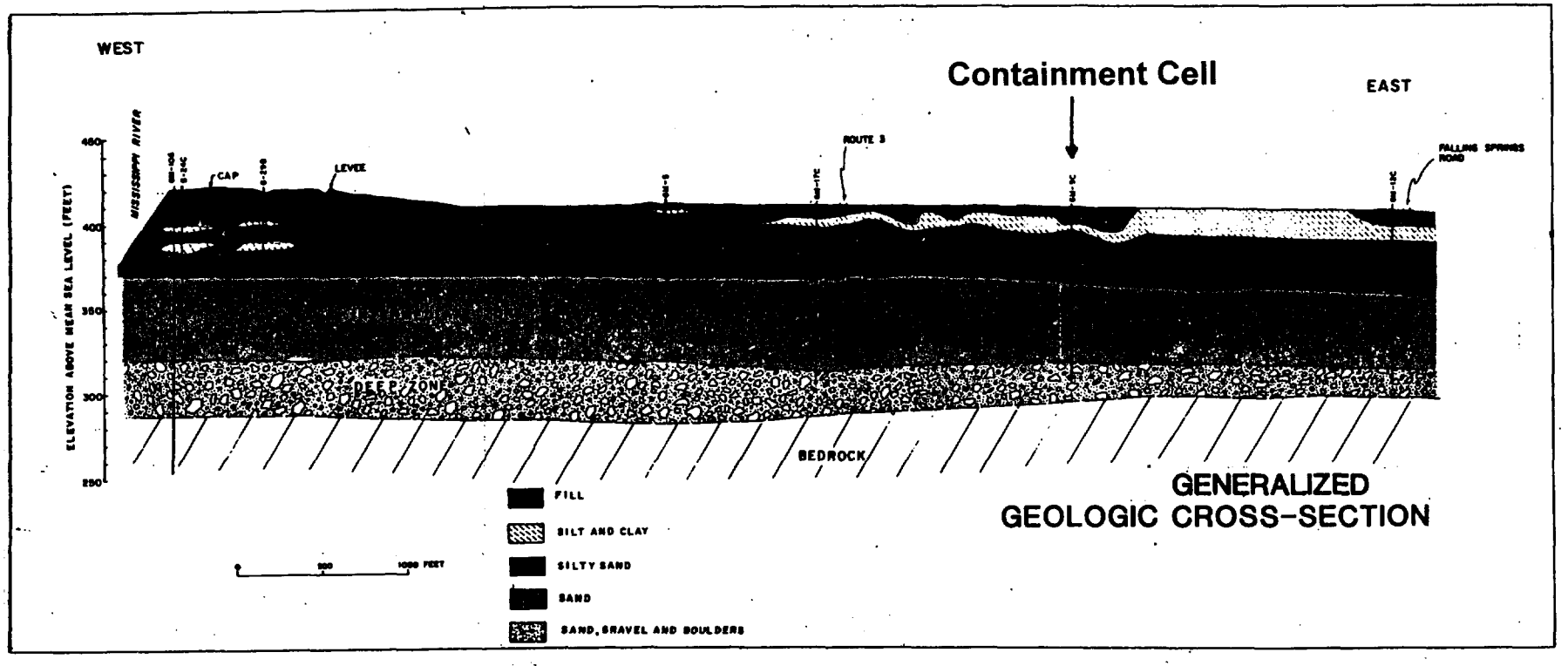
2. Tracked In-place Fill

In-place density ASTM D2922 ASTM D3017	1 per 15,000 ft^2 placed and compacted with a minimum of 6 per lift
In-place density verification ASTM D2937 ASTM D2216	1 per 2,000 yd^3 placed and compacted with a minimum of 1 per lift

END OF SECTION 02200

ATTACHMENT 5

GEOLOGIC CROSS SECTION



Regional Groundwater Levels Historical Highs

Well	Elevation (ft., msl)
GM-106	404.5
B-24C	405.1
B-29C	401.4
GM-5	397.0
GM-17C	398.2
GM-9C	399.4
GM-12C	400.3

Recent Groundwater Levels In Containment Cell Vicinity

Date	Highest (ft., msl)	Lowest (ft., msl)
3Q99	399.0	395.4
4Q99	397.7	392.6
1Q00	396.6	390.8

Containment Cell Elevations

	Highest (ft., msl)	Lowest (ft., msl)
Foundation	405.2	396.5
Secondary Geomembrane	408.7	400.0
Primary Geomembrane	409.7	402.0

ATTACHMENT 6

LINER SYSTEM LOADINGS CALCULATION

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Lining System Tensile Stresses

Project No. CI 0000 4051.00
Computed by: M. Brungard
Checked by: R. Hayden

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Purpose: Evaluate the stresses in all components of the lining system due to waste placement.

Assumptions: The Lining system stability analysis performed by M. Brungard dated 10/19/00 proved that the lining system is stable when the soil placement on the slopes is limited and equipment is not allowed to operate on the slopes. As the cell is filled, the factor of safety for slope stability increases substantially. Downslope movement is significantly limited ~~after the~~ as the cell is filled.

Stresses During Filling

Evaluate the stresses imposed on the lining system components due to the limited soil layer placed on the side slopes during filling.

The lining system stability analysis determined that the interface friction between the primary geonet & primary lining is about:

$$(8500 \text{ lbs/ft}_{\text{eqpt.}} + 3600 \text{ lbs/ft}_{\text{soil}}) \cos 18.4^\circ \tan 8^\circ = \underline{1613 \text{ lbs/ft}}$$

The yield stress for HDPE is about 2800 psi. This is about 2016 lbs/ft for 60-mil sheet. The applied tensile stress should be keep below this limit by proper anchor trench design. The anchorage should not provide any more resistance than this.

From phone conversation w/ Eric Reed of GSE Lining Technologies regarding typical interface friction values

Some of the stresses due to the soil layer loading are transferred to the lower lining system components. Since the interface friction values for the GCL/Textured HDPE and GCL/Soil interfaces are known to be at least 100% greater than the Geonet/Smooth HDPE value (16° compared to 8°), the loads in the lining system will produce tension only in the HDPE primary lining. The Secondary HDPE lining and GCL will transfer any loading through those layers into the subgrade. The GCL internal shear strength is at least 500 psf.

The minimum vertical loading required to exceed the GCL's 500 psf internal shear strength is shown on the next page.

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Lining System Tensile Stresses

Project No. C10000405.00
Computed by: M. Brungard
Checked by: R. Haydon

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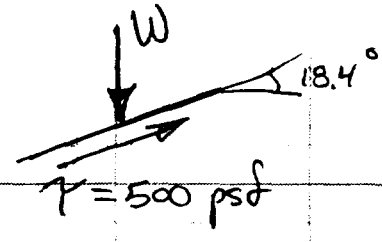

Assume a worst case condition by using an interface friction value of 30° for the GCL / Textured HDPE interface. This is the highest value reported in the Bentomat Direct Shear Testing Summary dated 6/00. Most values are in the 20° to 25° range.

$$\tau = W \cos 18.4 \tan 30^\circ = 500 \text{ psf}$$

$$W = \frac{500 \text{ psf}}{\cos 18.4 \tan 30} = \underline{912 \text{ psf}}$$

In this worst case, the waste depth would be about $\frac{912 \text{ psf}}{120 \text{ pcf}}$ = 7.5 feet.

This depth of fill is specifically prohibited by the waste filling plan. The only time that this fill depth will occur is in the filled cell areas. The factor of safety for slope stability approaches infinity since the resisting force of the waste fill far exceeds the driving force in this case.

The internal shear strength of the GCL cannot be exceeded under the proposed filling plan that limits the height of wastes on the side slopes to no more than 4 feet above the level of fill within the waste cell.

* The results above show that the secondary membrane & GCL cannot be placed into tension by the proposed loads. All tensile loads will be absorbed by the primary membrane, when any exist.

The total loading on the primary membrane is calculated on the following page.

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Lining System Tensile Stresses

Project No. C100004051.00
Computed by: M. Brungard
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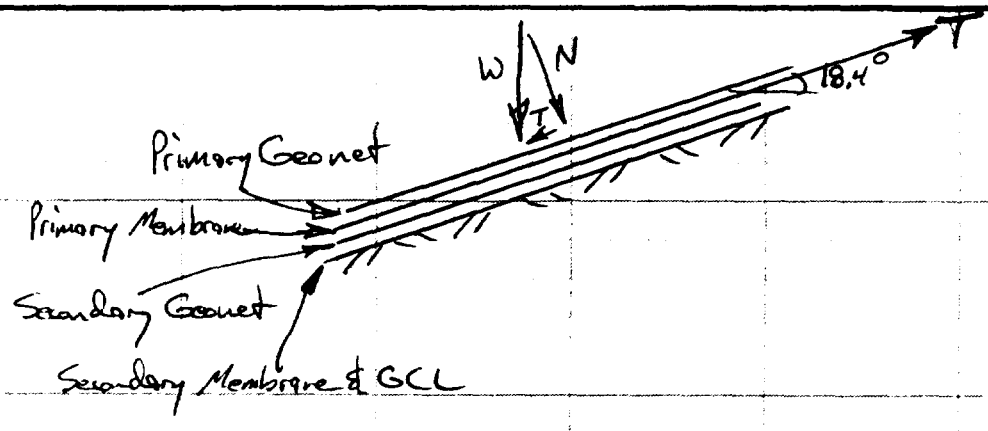


The range of interface friction values for a Geonet/Smooth HDPE interface are 8° to 12°.

The interface friction between the waste material and the geotextile-faced primary geonet is likely to be at least 75% of the waste material's frictional or cohesive strength. This is substantially higher than the 8° to 12° estimated for the geonet/smooth HDPE interface, therefore no slippage will be assumed between the waste & primary geonet.

Evaluate (2) cases, 1) primary interface @ 12°, secondary interface @ 8°

2) primary interface @ 12°, secondary interface @ 12°

1) Stress transmitted by primary geonet =

$$= (8500 \text{ lbs/ft} + 3600 \text{ lbs/ft}) \cos 18.4^\circ \tan 12^\circ$$
$$= \underline{2440 \text{ lbs/ft}}$$

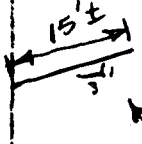
Stress transmitted by secondary geonet to secondary membrane/GCL

$$= (8500 \text{ lbs/ft} + 3600 \text{ lbs/ft}) \cos 18.4^\circ \tan 8^\circ$$
$$= \underline{1613 \text{ lbs/ft}}$$

Tension in Primary membrane

$$2440 \text{ lbs/ft} - 1613 \text{ lbs/ft} = \underline{\underline{827 \text{ lbs/ft}}}$$

Stress on Secondary membrane/GCL



$$\underline{1613 \text{ lbs/ft}} \qquad \frac{1613 \text{ lbs/ft}}{15'} = \boxed{107 \text{ psf} < 500 \text{ psf}}$$

OK

The length of the soil prism used in this analysis is 15'

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Lining System Tensile Stresses

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2) Stress transmitted by Primary Geonet = 2440 lbs/ft

Stress transmitted by Secondary geonet to secondary membrane & GCL = 2440 lbs/ft

Tension in Primary Membrane = 2440 - 2440 = 0 lbs/ft

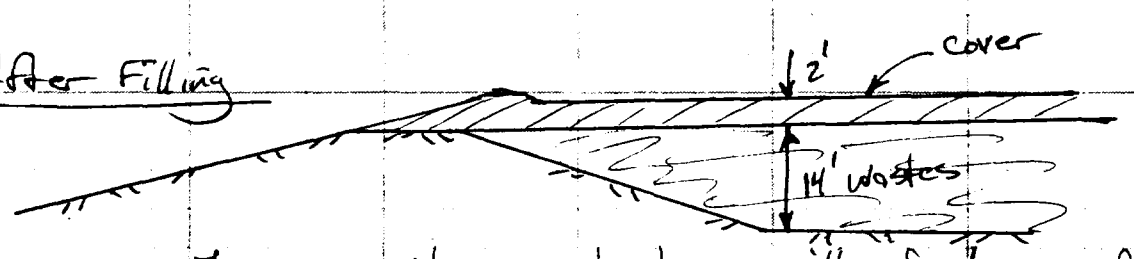
Stress on Secondary Membrane/GCL = 2440 lbs/ft

Stress distributed over contact area = $\frac{2440 \text{ lbs/ft}}{15'}$ = 162 psf

OK

162 << 500 psf limit for GCL internal strength

Stresses After Filling



The cover soils are to be a silty or clayey sand material. The moist unit weight is assumed to be 120 pcf, which is conservative for the material.

The waste material is expected to be a very silty or clayey material. Typical wet unit weights for these materials are between 90 and 110 pcf. This analysis will use 115 pcf to be conservative.

Max. Overburden Stress @ toe of slope

$(14' \times 115 \text{ pcf}) + (2' \times 120 \text{ pcf}) = 1850 \text{ psf}$

The waste material is expected to consolidate slightly after placement. Evaluate the downslope movement of the wastes due to consolidation.

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Lining System Tensile Stresses

Project No. C100004051.00
Computed by: M. Brungard
Checked by: R. Haydon

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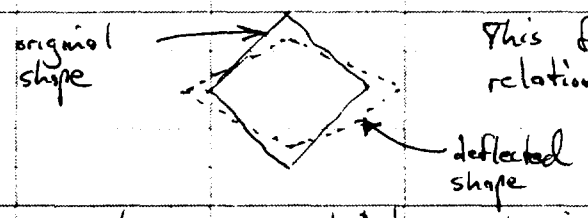
For any tensile stress to be applied to the lining, the soil on the slope would have to move downslope. That means that a horizontal strain in the soil mass would occur.

Poisson's ratio is a measure of the horizontal & vertical strain relationship: $\mu = \frac{\varepsilon_{horizontal}}{\varepsilon_{vertical}}$

For various soils, the Poisson's ratio falls in the range of 0.2 to 0.4.



This figure shows the relationship for Poisson's ratio

In the case above, consolidation strain would translate to a lateral movement opposing any downslope movement. Additionally, consolidation theory assumes no lateral spreading. The poisson ratio & consolidation theory both give evidence that lateral movement ~~due~~ downslope due to consolidation is not likely.

Evaluate the state of horizontal stresses in the waste and compare to the driving force of the soil wedge on the side slope

The minimum horizontal stress expected within the wastes can be estimated using the "at-rest" pressure coefficient $(K_o) = \sigma_h' / \sigma_v'$

empirical correlation $= K_o = (1 - \sin\phi)$ where ϕ = soil friction angle

At the toe of slope location, $\sigma_v' \approx$ 1850 psf (from pg 4)

The soil friction angle (ϕ) could range from 0° (undrained) to about 30° (drained)

That shows that K_o ranges from 1.0 to 0.5

Therefore, σ_h ranges from 1850 to 925 psf.

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Lining System Tensile Stresses

Project No. C/00004051.00
Computed by: M. Brungard
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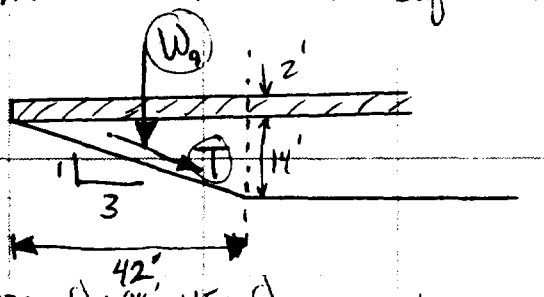
The driving force at the toe of slope is calculated below:



$$W_a = \frac{(2' \times 120 pcf) + (2 \times 120 pcf) + (14' \times 115 pcf)}{2} \times 42'$$

$$= 1045 psf \times 42'$$

$$= \underline{43{,}890 \text{ lbs}}$$

$$T = W_a \sin \beta \qquad \beta = 18.4^\circ \text{ for 3:1 slope}$$

$$= 43{,}890 \sin 18.4$$

$$= \underline{13854 \text{ lbs}}$$

The wedge acts on an interface measuring 16' x 1' (unit width)

$$\text{Soil Wedge Lateral Pressure} = \frac{13854 \text{ lbs}}{16 \text{ ft}^2} = \underline{\underline{865 \text{ psf}}}$$

The analysis above neglects any interface friction and also the improvement in the K_o due to waste compaction.

Both of these factors would further improve the conditions. Including the interface friction reduces the lateral pressure. Compaction improves the K_o factor by the following relationship

$$K_{o\,compacted} = K_{o(nc)} \times \sqrt{OCR}$$

where: nc = stands for normally consolidated (uncompacted)
OCR = overconsolidation ratio

Construction compaction routinely achieves OCR's of 2 to 4. This results in the K_o increasing by a factor of 1.5 to 2.

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Lining System Tensile Stresses

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Summary:

The analyses using either a stress or strain approach indicate that no appreciable movement of the soil mass on the cell slopes will occur.

This shows that consolidation or other conditions will not create additional lining tension once the wastes are in place within the cell.

The lining system components will only endure normal stresses due to the overburden loading. No shear stresses will be created in the lining system after cell filling is complete.

ATTACHMENT 7

ANCHOR SYSTEM CALCULATION

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Lining System Anchorage Design

Project No. C100004051.00
Computed by: M. Brungard
Checked by: R. Haydon

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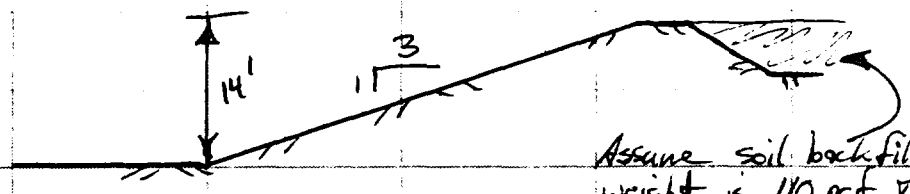
Purpose: Design the anchorage details for the lining system components. Design the anchorage to pull out of the trench before reaching the HDPE yield stress.

Configuration: The lining system will use 60-mil HDPE membranes w/ geonets and GCL components.

The max slope height is 14 feet. The slope angle is 3 to 1. The max. slope length is 44 feet.



Assume soil backfill unit weight is 110 pcf. This is typical for moist clays & silts.

Allowable Tension in Lining:

The max. allowable stress in the HDPE linings is 2,800 psi to stay in the elastic range of the material.

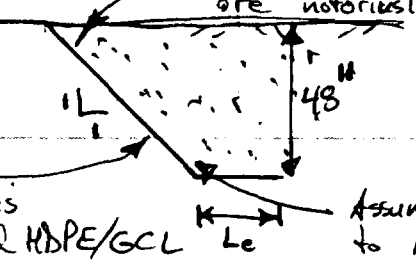
For 60-mil lining, the max. force in the lining is:

$$2800\,psi \times 0.060'' = 168\ lbs/in$$
$$= \underline{\underline{2016\ lbs/ft}} = (T)$$

Anchor Design:

Secondary Lining Tension (T)

Use a 45° downslope, since 90° trenches are notoriously difficult to maintain in good condition prior to backfilling.



Assume $\delta = 16°$ on this side due to Textured HDPE/GCL interface.

Assume $\delta = 8°$ on this side due to HDPE/Geonet interface

$$T = 2016\ lbs/ft = \sqrt{2}\,(4')\,\frac{110\,pcf\,(4')}{2}\left(\cos 45° \tan 8° + \cos 45° \tan 16°\right)$$
$$+ \left(L_e(110\,pcf)\,4'(\tan 16° + \tan 8°)\right)$$
$$= 376\ lbs/ft + 188(L_e)$$

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Lining System Anchorage Design

Project No. C10004051.00
Computed by: M. Brungard
Checked by: R. Hayden

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Date 10/25/00
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$$2016 \text{ lbs/ft} = 376 \text{ lbs/ft} + 188 (L_e)$$

$$1640 = 188 (L_e)$$

$$\underline{8.7'} = (L_e)$$ This is too long.

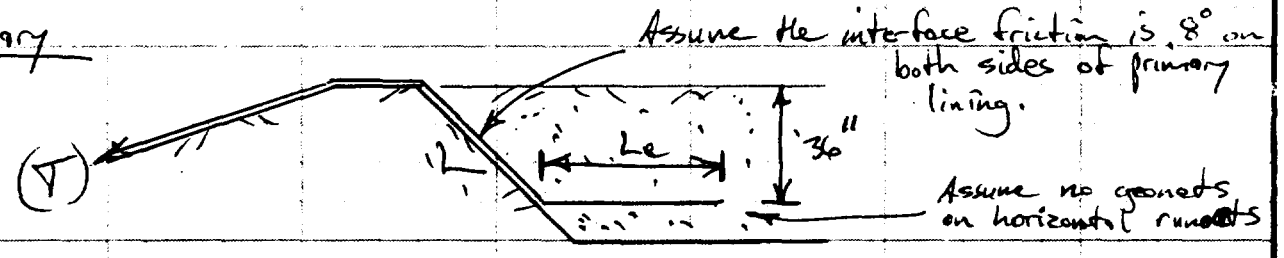
Assume that the Geonet & GCL do not extend onto the horizontal portion of the lining. The interface friction angle between a smooth HDPE and a clay soil is assumed to have a typical value of 16° (from Interface Friction Analyses, Schlegel Lining, 1987).

$$2016 \text{ lbs/ft} = 376 \text{ lbs/ft} + (L_e)\, 110 \text{ pcf} (4') (\tan 16° \times 2)$$

$$1640 = 252 (L_e)$$

$$\underline{6.5' = (L_e)}$$ (OK)

Primary



$$T = 2016 \text{ lbs/ft} = \sqrt{2}\,(3') \frac{110 \text{ pcf} (3')}{2} \cos 45° \tan 8° \times (2 \text{ sides}) +$$

$$L_e (110 \text{ pcf}) 3' \tan 17° \times (2 \text{ sides})$$

$$2016 = 139 \text{ lbs/ft} + 201 (L_e) \text{ lbs/ft}$$

$$1877 = 201 (L_e)$$

$$\underline{9.3' = L_e}$$ (ok)

Summary: The secondary lining will not be subjected to the proposed tensile forces. The textured HDPE/GCL will absorb & transmit the forces into the underlying ground. The primary lining ~~will~~ can undergo the proposed lining tension and it is therefore more important in this analysis. The (L_e) lengths shown in these analyses are the <u>maximum</u> lengths. Shorter runout lengths are permissible.

determined in Lining Tensile Stress calcs by M. Brungard 10/20/00

ATTACHMENT 8

TECHNICAL INFORMATION ON GCLs

96-4 Bonaparte, R., Othman, M.A., Rad, N.S., Swan, R.H., and Vander Linde, D.L., "Evaluation of Various Aspects of GCL Performance", Appendix F in *Report of 1995 Workshop on Geosynthetic Clay Liners*, D.E. Daniel and H.B. Scranton authors, EPA/600/R-96/149, USEPA National Risk Management Research Laboratory, Cincinnati, 1996, pp. F1-F34.

EVALUATION OF VARIOUS ASPECTS OF GCL PERFORMANCE

by

R. Bonaparte[1], M.A. Othman[1], N.R. Rad[1], R.H. Swan[1], and D.L. Vander Linde[1]

INTRODUCTION

The purpose of this paper is to briefly present the results of various activities that have recently been undertaken by the authors on the subject of geosynthetic clay liner (GCL) testing and performance evaluation. The subjects that are addressed are:

- field hydraulic performance of composite liners containing GCLs;
- drained shear strength of hydrated GCLs at high normal stress;
- interface shear strength between unhydrated GCLs and textured geomembranes at high normal stress;
- hydration of GCLs adjacent to soil layers; and
- causes of failure of a landfill cover system containing a GCL.

FIELD PERFORMANCE OF COMPOSITE LINERS CONTAINING GCLs

Sources of Flow in LDS of Double-Liner System

A double liner system consists of top and bottom liners with a leakage detection system (LDS) between the two liners. If the double-liner system is used in a landfill, it will also contain a leachate collection and removal system (LCRS) above the top liner. As part of an ongoing research investigation for the United States Environmental Protection Agency (USEPA), the authors have collected data

[1]GeoSyntec Consultants, 1100 Lake Hearn Drive, Atlanta, Georgia 30342

on the rates of liquid flow into the sumps of LCRSs and LDSs for a wide variety of double-lined waste management units located throughout the United States. Comparison of the rates of flow into the LCRS and LDS of a unit can be used to quantify the performance of the top liner (in terms of the ability to impede advective transport of liquid through the liner). In essence, the LDS serves as a large lysimeter (i.e., collection pan) below the top liner.

To make the evaluation, consideration must be given to the potential sources of liquid in the LDS. Gross et al. [1990] described the potential sources of LDS flow, which are (Figure 1): (i) leakage through the top liner; (ii) drainage of water (mostly rainwater) that infiltrates the leakage detection layer during construction but does not drain to the LDS sump until after start of facility operation ("construction water"); (iii) water expelled from the LDS layer as a result of compression under the weight of the waste ("compression water"); (iv) water expelled from any clay component of the top liner as a result of clay consolidation under the weight of the waste ("consolidation water"); and (v) for a waste management unit with its base located below the water table, groundwater infiltration through the bottom liner ("infiltration water").

Gross et al. [1990] and Bonaparte and Gross [1990] presented the following five-step approach for evaluating the sources of LDS liquid at a specific waste management unit.

- Identify the potential sources of flow for the unit based on double-liner system design, climatic and hydrogeologic setting, and unit operating history.
- Calculate flow rates from each potential source.
- Calculate the time frame for flow from each potential source.
- Evaluate the potential sources of flow by comparing measured flow rates to calculated flow rates at specific points in time.
- Compare LCRS and LDS chemical constituent data to further establish the likely source(s) of liquid.

Bonaparte and Gross [1990, 1993] used this five-step approach to evaluate the sources of LDS flow for 93 waste management units. Under a contract to the USEPA Risk Reduction Research Laboratory, the authors are currently performing this evaluation using new data from the facilities in the Bonaparte and Gross studies, as well as data from a significant number of additional waste management units not included in the original studies. Preliminary results for waste management units with composite top liners containing GCLs are presented below.

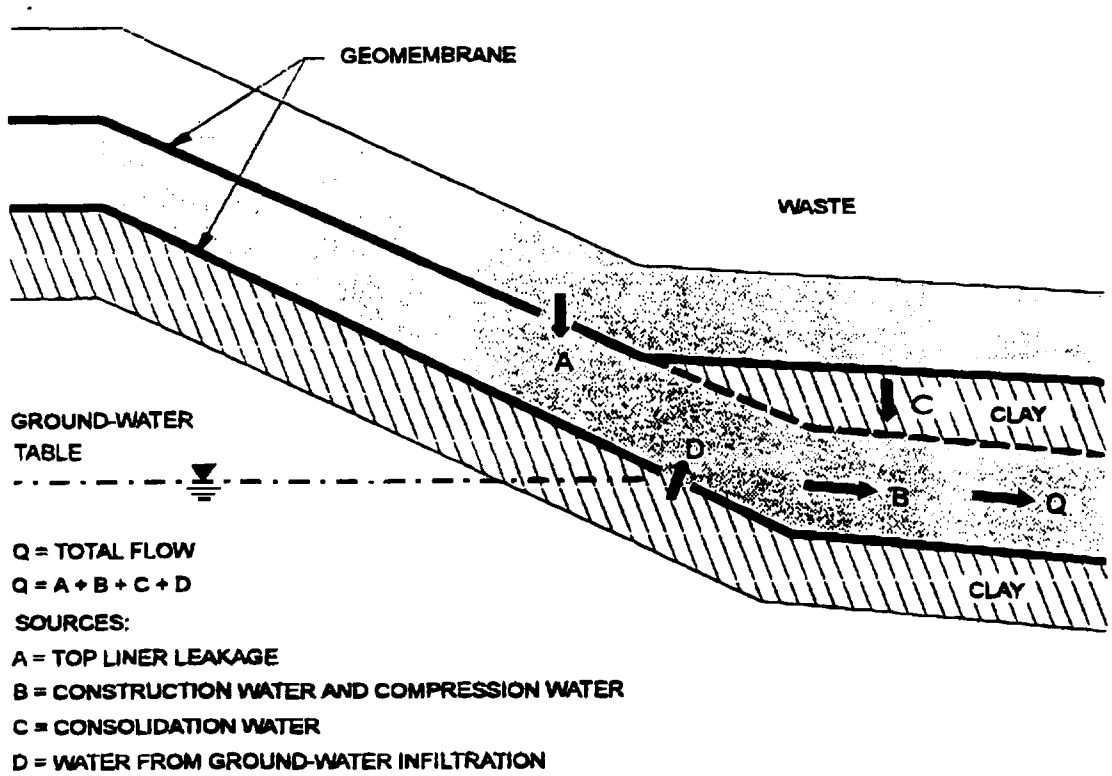


Figure 1. Sources of flow from leak detection layers.

LCRS and LDS Flow Data

Flow rate data have been collected for 26 waste management units containing composite top liners consisting of a geomembrane overlying a GCL. The 26 units are located at six different landfill sites. Descriptions of the components of the liner systems used at these facilities are presented in Table 1 and flow rate data for the LCRSs and LDSs in the units are presented in Table 2. Average daily flow rates were calculated for both systems on a monthly basis by dividing the total amount of liquid extracted from the system during the month by the number of days in the month and the area of the waste management unit. Flow rates are reported in units of liter/hectare/day (lphd). The volume of flow used in the calculation was typically obtained from the landfill operator, with flow measurements most often measured using accumulating flow meters. The reported flow volumes should be considered approximate.

Table 1. Description of landfill liner system components.

Landfill Identification	LCRS		Composite Top Liner		LDS		Bottom Liner		
	Material	Thickness (mm)	HDPE Geomembrane Thickness (mm)	GCL Thickness (mm)	Material	Thickness (mm)	HDPE Geomembrane Thickness (mm)	Layer 2	
								Material	Thickness (mm)
A	Sand	600	1.5	13	Sand	300	1.5	Clay	200
B	Sand	600	2.0	13	Sand	450	2.0	Clay	300
C	Sand	450	1.5	13	Sand	300	1.5	GCL	13
D	Sand	600	1.5	13	GT/GN[1]	5	1.5	N/A	N/A
E	Sand	600	1.5	13	GT/GN	5	1.5	Clay	900
F	GN	5	1.5	13	GT/GN	5	1.0	GCL	13

Notes: [1] GT = Geotextile, GN = Geonet.
[2] All material thicknesses are nominal values.

Table 2. Summary of flow data for the LCRS and LDS of units with composite top liners containing GCLs.

Cell No.	Cell Area	End of Cell Const. (month-year)	Start of Waste Placem. (month-year)	End of Final Closure (month-year)	Initial Period of Operation[1]					Active Period of Operation[2]					Post Closure Period[3]				
					Time Period	LCRS Flow[4]		LDS Flow		Time Period	LCRS Flow		LDS Flow		Time Period	LCRS Flow		LDS Flow	
						Avg.	Peak	Avg.	Peak		Avg.	Peak	Avg.	Peak		Avg.	Peak	Avg.	Peak
	(hectare)				(months)	(lphd)	(lphd)	(lphd)	(lphd)	(months)	(lphd)	(lphd)	(lphd)	(lphd)	(months)	(lphd)	(lphd)	(lphd)	(lphd)
A1	2.0	7-88	7-88	2-91	1-2	16,718	19,738	0.0	0.0	3-32	561	2,384	0.0	0.0	33-83	65	103	0.0	0.0
A2	2.0	7-88	7-88	2-91	1-5	15,521	58,671	15.0	44.9	6-32	281	570	1.9	20.6	33-83	178	421	0.0	0.0
A3	1.7	8-88	9-88	4-93	1-5	3,366	7,985	34.6	150.5	6-56	290	1,075	3.7	46.8	57-81	206	458	0.9	9.4
A4	1.7	8-88	9-88	4-93	1-12	2,534	12,688	101.0	860.2	13-56	75	187	0.9	13.1	57-81	47	84	0.0	0.0
A5	2.8	9-88	10-88		1-11	1,084	3,394	37.4	91.6	12-80	56	187	1.9	37.4					
A6	3.9	11-88	12-88		1-9	3,759	7,171	53.3	92.6	10-80	168	655	0.0	0.0					
A7	2.6	1-89	2-89		1-10	5,376	12,155	33.7	46.8	11-76	234	851	1.9	9.4					
A8	3.8	7-89	7-89		1-14	4,881	21,038	47.7	188.9	15-71	439	1,384	0.0	0.0					
A9	3.3	12-89	12-89		1-9	1,047	3,478	0.9	7.5	10-65	37	159	0.0	0.0					
A10	3.9	2-90	7-90		1-7	2,786	13,698	0.0	0.0	8-59	374	645	0.0	0.0					
A11	3.0	2-90	2-90		1-16	4,675	14,586	0.0	0.0	17-64	150	337	0.0	0.0					
A12	4.0	10-90	10-90		1-18	2,945	8,836	0.0	0.0	19-56	655	1,905	0.0	0.0					
A13	3.0	1-91	1-91		1-32	3,740	14,343	0.0	0.0	33-53	281	486	0.0	0.0					
A14	2.8	4-91	4-91		1-11	2,777	6,582	0.0	0.0	12-38	281	449	0.0	0.0					
A15	2.8	5-92	5-92		1-12	5,573	11,809	0.0	0.0	13-37	299	561	0.0	0.0					
A16	4.5	1-93	1-93		1-22	4,675	17,756	0.0	0.0	23-29	206	393	0.0	0.0					
B1	3.6	5-93	8-93		1-10	3,273	12,155	177.7	822.8	11-17	393	1,403	2.8	15.0					
C1	2.4	4-93	5-93		1-12	6,358	20,570	130.9	523.6										
C2	2.4	7-93	8-93		1-10	3,553	7,480	289.9	514.3										
D1	4.0	12-90	2-91		1-23			11.2	24.3	24-47			0.9	3.7					
D2	2.4	12-92	1-93		1-24	4,208	11,688	0.9	14.0										
D3	2.8	12-92	1-93		1-13	3,179	8,228	0.0	0.0	14-24	187	309	0.0	0.9					
E1	3.8	9-92	12-92		3-23	3,890		1.9	22.4										
F1	1.3	7-94	10-94		1-9	6,330	12,052	0.0	0.0										
F2	1.0	7-94	8-94		1-11	9,967	21,729	4.7											
F3	1.0	7-94	8-94		1-11	11,248	31,313	11.2											

Notes:

(1) "Initial Period of Operation" represents period after waste placement has started and only a few lifts of waste and daily cover have been placed in the cell (i.e., no intermediate cover).

(2) "Active Period of Operation" represents period when waste thickness in cell is significant and/or an effective intermediate cover is placed on the waste.

(3) "Post Closure Period" represents period after final cover system has been placed on the entire cell.

(4) Flow rates are given in liter/hectare/day.

Figure 2 shows LCRS and LDS average daily flow rate data for a municipal solid waste management unit, located in Pennsylvania, that was active for 56 months. Subsequently, a final cover system containing a geomembrane was placed over the entire unit. Flow data for the 56-month operational period and a 25-month post closure period were obtained and analyzed. As Figure 2 shows, flow rates in both systems were highest immediately after the start of waste placement and thereafter decreased with time. During the first twelve months of operation, the average rate of flow into the LCRS sump decreased from 12,700 to 180 lphd. After that time, the LCRS flow rate stabilized and during the following 44 months, the rate of flow into the LCRS sump varied between 10 and 170 lphd. After final closure, the flow rate decreased even further, to between 10 and 80 lphd.

As illustrated in Figure 2, waste management unit development can be divided into three distinct periods. During the first period, herein referred to as the "initial period of operation", LCRS flow rates may be relatively high. High flows during this period are attributed to the occurrence of rainfall into a unit that initially contains little waste. To the extent rainfall occurs during this period, it will find its way rapidly into the LCRS. Obviously, the amount of LCRS flow during this period is highly dependent on climate. A lag exists between the time liquid first enters the LCRS and when it flows into the LCRS sump. The magnitude of the lag is largely dependent on the hydraulic characteristics (i.e., the length and slope of the LCRS and the hydraulic conductivity of the LCRS drainage material). Most available data indicate a decreasing LCRS flow rate with time during the initial period of operation. During the second period, referred to herein as the "active period of operation", the rate of flow into the LCRS continues to decreases and eventually stabilizes. This occurs as the amount of waste in the unit increases and as daily and intermediate layers of cover soil are placed. This trend in flow rates is also dependent on the type of waste but is likely representative of the trends observed at most new landfills, excluding those that accept sludges or other high moisture content wastes. During the "post closure period", the final cover system further reduces infiltration of rainwater into the waste, resulting in a further reduction in LCRS flow. Final covers containing geomembranes can, if functioning properly, virtually eliminate rainwater infiltration.

LDS flow rates for the waste management unit in Figure 2 were highest (860 lphd) at the beginning of operations and decreased in the following few months, becoming very low (i.e., less than 10 lphd) within approximately 15 months after the start of unit operation. The decrease in LDS flow with time is expected because: (i) flow rates in the LCRS during this time period decreased, and therefore, the potential for leakage through the top liner also decreased; (ii) most construction water initially present in the LDS flowed to the LDS sump in the first few weeks to months of unit operation; and (iii) the volume of compression and consolidation water for this waste management unit should be very small.

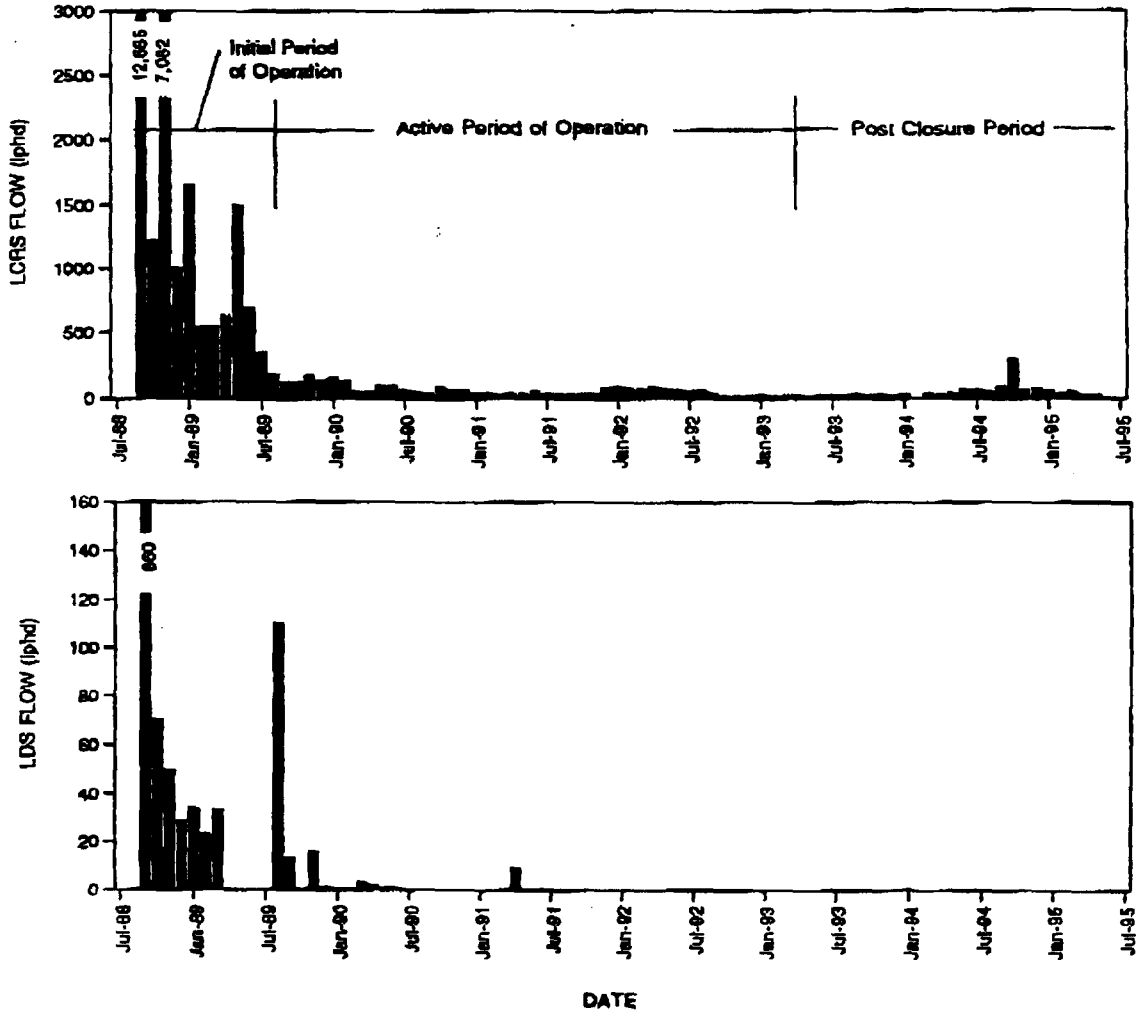


Figure 2. LCRS and LDS flow rates at a modern MSW landfill in Pennsylvania.

Table 2 summarizes LCRS and LDS flow data for the 26 waste management units containing GCLs in their composite top liners. Average and peak flow rates are reported for the three time periods described above. Table 2 shows that between the initial and active periods of operation, LCRS flow rates decreased one to two orders of magnitude and LDS flow rates decreased one to three orders of magnitude. Reported peak LCRS flow rates were up to 5 times the average, while peak LDS flow rates were up to 20 times the average. Table 3 presents the mean values of average and peak flows for the database.

Table 3. Mean values of flow for the data in Table 2 (Note: m = mean value; σ = standard deviation; values are in liter/hectare/day).

LCRS	Number of Units	Average Flow Rate		Peak Flow Rate	
		m	σ	m	σ
Initial Period of Operation	25	5,350	3,968	14,964	11,342
Active Period of Operation	18	276	165	752	590
Post-Closure Period	4	124	-	266	-

LDS	Number of Units	Average Flow Rate		Peak Flow Rate	
		m	σ	m	σ
Initial Period of Operation	26	36.6	68.5	141.8	259.9
Active Period of Operation	19	0.7	1.1	7.7	13.7
Post-Closure Period	4	0.2	-	2.3	-

Top Liner Hydraulic Efficiency

Table 4 summarizes calculated "apparent" efficiencies for the composite top liners of the 26 waste management units presented in Table 2. Liner apparent efficiency, AE, is calculated using the following equation:

AE (%) = (1 - LDS Flow Rate / LCRS Flow Rate) x 100 (Equation 1)

Table 4. "Apparent" efficiencies of composite liners containing GCLs[1].

Cells with Sand LDS				Cells with GT/GN LDS	
Cell No.	Initial Period of Operation (%)	Active Period of Operation (%)	Post-Closure Period (%)	Cell No.	Initial Period of Operation (%)
A1	100.00	100.00	100.00	D1	99.98
A2	99.90	99.33	100.00	D2	100.00
A3	98.97	98.71	99.55	E1	99.95
A4	96.01	98.75	100.00	F1	100.00
A5	97.23	97.50		F2	99.95
A6	98.58	100.00		F3	99.90
A7	99.37	99.20			
A8	99.02	100.00			
A9	99.91	100.00			
A10	100.00	100.00			
A11	100.00	100.00			
A12	100.00	100.00			
A13	100.00	100.00			
A14	100.00	100.00			
A15	100.00	100.00			
A16	100.00	100.00			
B1	94.57	99.29			
C1	97.94				
C2	91.84				
Number	19	17	4	Number	6
Range	91.84 - 100.00	97.5 - 100.00	99.55 - 100.00	Range	99.90 - 100.00
Mean	98.60	99.58	99.89	Mean	99.96
Median	99.90	100.00	100.00	Median	99.97

Notes: [1] Apparent Efficiency = (1 - LDS Flow / LCRS Flow) x 100 %

This liner efficiency is referred to as "apparent" because, as described above, flow into the LDS sump may be attributed to sources other than top liner leakage (Figure 1). If the only source of flow into the LDS sump is top liner leakage, then Equation 1 provides the "true" liner efficiency. Liner efficiency provides a measure of the effectiveness of a particular liner in limiting or preventing advective transport across the liner.

Table 4 presents calculated AE values for waste management units with sand LDSs (Landfills A, B, and C). For these units, the apparent efficiency is lowest during the initial period of operation (AE_m = 98.6 percent; where AE_m = mean apparent efficiency) and increases significantly thereafter (AE_m = 99.58 percent during the active period of operation and AE_m = 99.96 percent during the post closure period). The lower AE_m during the initial period of operation can be attributed to LDS flow from construction water. For units A, B, and C, calculated AE values during the active period of operation and the post-closure period may provide a reasonably accurate indication of true liner efficiency for the conditions at these units during the monitoring periods. It should be noted, however, that the true efficiency of a liner is not constant but rather a function of the hydraulic head in the LCRS and size of the area over which LCRS flow is occurring (the area is larger at high flow rates compared to low flow rates).

Table 4 also presents calculated AE values for waste management units with geonet LDSs (Landfills D, E, and F). The available data are limited to the initial period of unit operation. As shown in Table 4, AE_m for the six units with geonet LDSs is 99.96 percent. This value is much higher than the AE_m of liners of cells with sand LDSs for the same facility operational period (i.e., 98.60 percent). This higher efficiency can be attributed to the differences in liquid storage capacity and hydraulic transmissivity between sand and geonet drainage materials. A granular drainage layer can store a much larger volume of construction water and releases this water more slowly during the initial period of operation than does a geonet drainage layer. This suggests that, during the initial period of operation, the main source of flow in a sand LDS underlying a composite top liner containing a GCL is construction water.

Conclusions on Field Performance of Composite Liners Containing GCLs

From Table 2, LDS flows attributable to top liner leakage very from 0 to 50 lphd, with most values being less than about 2 lphd. These flow rates are very low. The data shown in Table 4 suggest that the true hydraulic efficiency of a composite liner incorporating a GCL may be greater than 99.90 percent. A liner with this efficiency, when appropriately used as part of an overall liner system, can provide a very high degree of liquid containment capability.

SHEAR STRENGTH OF HYDRATED GCLs

Overview

For a recent project, the authors were concerned with the long-term drained shear strength of hydrated GCLs at normal stresses in the range of 240 to 720 kPa. Drained shear strengths are applicable to long-term design and the range of considered normal stresses is applicable to conditions in a liner system at the base of a landfill. A testing program to evaluate the long-term drained shear strength of GCLs was undertaken and this program is ongoing. To develop interim values for preliminary design, the authors reviewed and analyzed available data from the technical literature on the consolidated-drained (CD) shear strength of GCLs. The findings of this review are presented below.

Required Deformation Rates to Achieve CD Conditions

To achieve consolidated drained (CD) test conditions, direct shear tests must be carried out at a very slow rate of shear displacement. The required displacement rate can be estimated using the well-known time-to-failure equation specified in American Society of Testing and Materials (ASTM) standard test method D 3080:

$$t_f = 50\ t_{50} \qquad \text{(Equation 2)}$$

where: t_f = total elapsed time to failure(s); and t_{50} = time required for the test specimen to achieve 50 percent primary consolidation under the specified normal stress, or increment(s) thereof. Using t_f from consolidation tests and an estimated failure displacement δ_t, the required shear displacement rate, d_r, can be calculated using the equation:

$$d_r = \delta_t \,/\, t_f \qquad \text{(Equation 3)}$$

Shan [1993] performed one-dimensional consolidation tests on the GCL products Claymax®, Gundseal®, Bentomat®, and Bentofix®. He evaluated t_f values for each product. The results of his evaluation are provided in Figure 3. With reference to this figure, at normal stresses in the range of 240 to 720 kPa, t_f values are in the range of about 100 to 400 hours. If it is assumed that a displacement of 25 mm is needed to achieve peak shear stress conditions, a required shear displacement rate of 0.05 to 0.25 mm/s is calculated. Only test results conducted at shear displacement rates that satisfy Equations 2 and 3 and the data from Shan [1993] should be considered to represent CD conditions. Test results at faster rates will yield lower shear strengths as a result of positive pore pressure development during the shearing phase of the test.

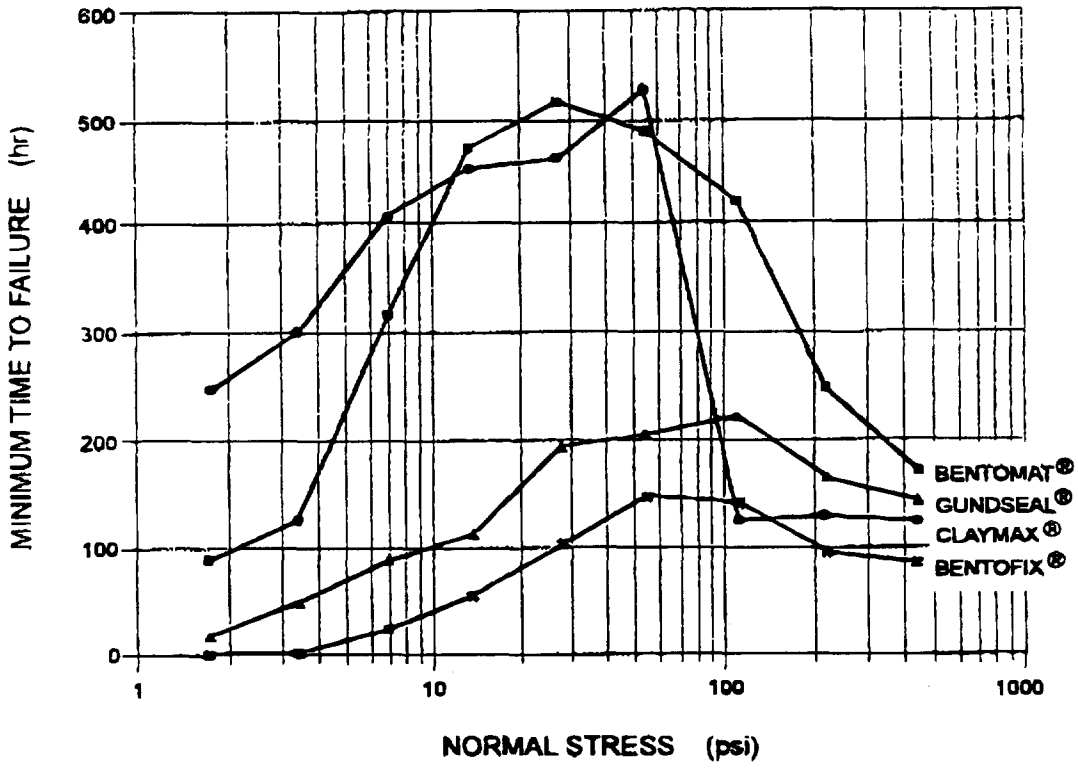


Figure 3. Relationship between time to failure of GCLs in direct shear tests and normal stress (from Shan, 1993; Note: 1 psi = 6.9 kPa).

It is noted that direct shear tests on GCLs are often performed in general accordance with the standard test method ASTM D 5321 ("*Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method*"). This method provides the following guidelines for selecting shear displacement rates for tests involving soils:

> "*11.6 Apply the shear force using a constant rate of displacement that is slow enough to dissipate soil pore pressures, as described in Method D 3080 (Note 9). If excess pore pressures are not anticipated, and in the absence of a material specification, apply the shear force at a rate of 1 mm/min (0.04 in./min).*"

The foregoing requirement calls for performing direct shear tests involving soils at a shear displacement rate in conformance with ASTM D 3080 if pore pressures are anticipated. For the soil component of GCLs (i.e., sodium montmorillonite), significant pore pressures will certainly be generated if the GCL is sheared at rates faster than those satisfying Equations 2 and 3. Interestingly, however, most test data available in the published literature were generated at the default shear displacement rate of 0.017 mm/s. Data generated at the default shear displacement rate are considered to reflect "undrained" or "partially-drained," and not "fully-drained," conditions.

Review of Available Information for Unreinforced GCLs

For purposes of shear strength characterization, two different categories of GCL can be considered: GCLs that do not contain internal reinforcement (hereafter referred to as unreinforced GCLs) and those that do (hereafter referred to as reinforced GCLs). Published information relevant to the CD shear strengths of unreinforced GCLs is very limited. The available information is summarized below.

- Daniel and Shan [1991] and Shan and Daniel [1991] reported CD direct shear test results for the GCL product Claymax®. Tests were performed using 60-mm diameter specimens and a shear deformation rate of 5 x 10^{-6} mm/s. Test results have been interpreted herein in terms of "peak (p)" and "large-displacement (ld)" normalized shear strengths. Peak displacements in these tests were 0.5 to 5 mm with the largest displacement corresponding to the lowest normal stress; the reported "ld" shear strengths correspond to shear displacements of approximately 6 to 9 mm. Results from the tests are as follows:

σ_n (kPa)	$(\tau/\sigma_n)_p$	ϕ_p	$(\tau/\sigma_n)_{ld}$	ϕ_{ld}
34	0.236	13.3°	0.236	13.3°
69	0.238	13.4°	0.209	11.8°
100	0.194	11.0°	0.165	9.4°
140	0.178	10.1°	0.137	7.8°

where: σ_n = normal stress on the shear plane at failure (kPa); τ = shear stress on the shear plane at failure (kPa); and ϕ = secant friction angle (dimensionless), calculated as the inverse tangent of τ/σ_n. It is noted that ϕ should also be interpreted as a measure of normalized shear strength and not as a "true" indication of internal friction. This data interpretation is illustrated in Figures 4 and 5.

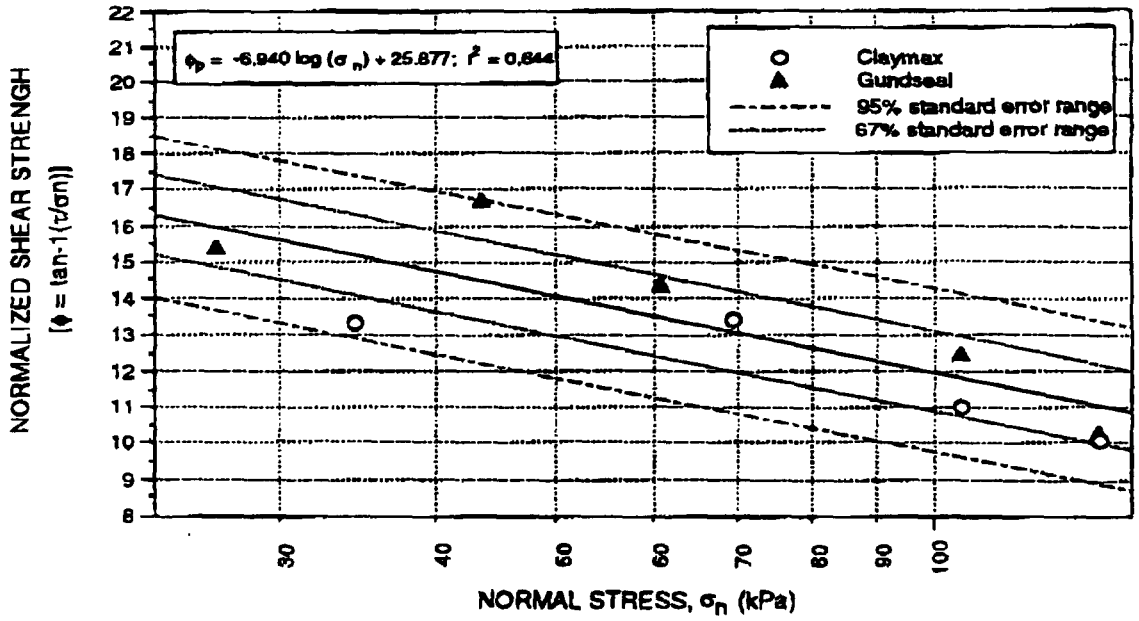


Figure 4. Log-linear regression analysis for peak CD conditions.

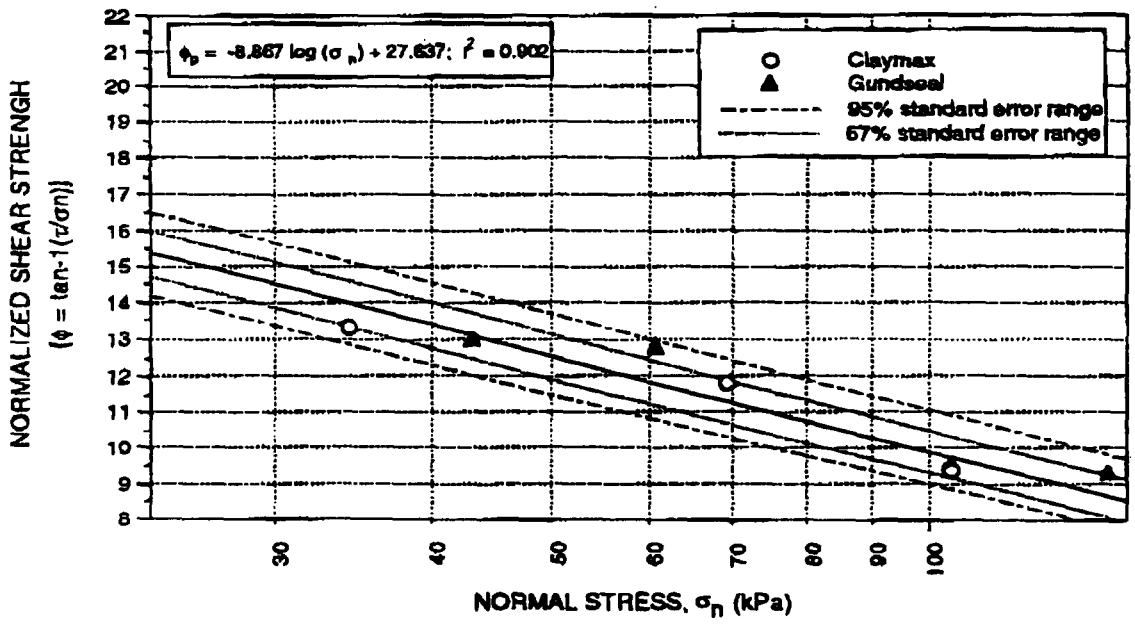


Figure 5. Log-linear regression analysis for large-displacement CD conditions.

- Daniel and Shan [1991], Daniel et al. [1993], and Shan [1993] reported direct shear CD test results for the GCL product Gundseal®. Tests were performed using 60-mm diameter specimens and a shear deformation rate of 5 x 10^{-6} mm/s. Test results have been interpreted herein in terms of peak and large-displacement normalized shear strengths. Typical peak displacements in these tests were 2 to 4 mm with the largest displacement corresponding to the lowest normal stress; the reported "ld" shear strengths correspond to shear displacements of approximately 9 to 12 mm. Results from the tests are as follows:

σ_n (kPa)	$(\tau/\sigma_n)_p$	ϕ_p	$(\tau/\sigma_n)_{ld}$	ϕ_{ld}
27	0.275	15.4°	-	-
44	0.300	16.7°	0.231	13.0°
61	0.256	14.4°	0.227	12.8°
100	0.223	12.6°	0.169	9.6°
140	0.181	10.3°	0.164	9.3°

The direct shear test results from Daniel and Shan are plotted in Figures 4 and 5 for "peak" and "large displacement" shearing conditions, respectively. Regression equations were developed to describe the test results. It is interesting to note the lesser amount of scatter in the results for the large-displacement shearing conditions compared to the peak shearing conditions.

The test results in Figures 4 and 5 only cover the stress range between 24 and 144 kPa. Even at these relatively low normal stresses, GCL CD shear strengths exhibit significant normal stress dependency. A basis is needed for extrapolating this stress dependency to higher normal stress. This basis was derived from published information from the soil mechanics literature on the shear strength of sodium montmorillonite. This information is summarized below.

- Mesri and Olson [1970] and Olson [1974] reported the results of constant rate-of-strain CD and consolidated-undrained (with pore pressure measurement) triaxial compression tests on homionic sodium montmorillonite consolidated from a slurry (Figure 6); approximate effective-stress normalized shear strengths and secant friction angles derived from the tests are as follows:

σ_n (kPa)	(τ/σ_n)	ϕ
72	0.21	12°
170	0.14	8°
340	0.10	6°
530	0.07	4°

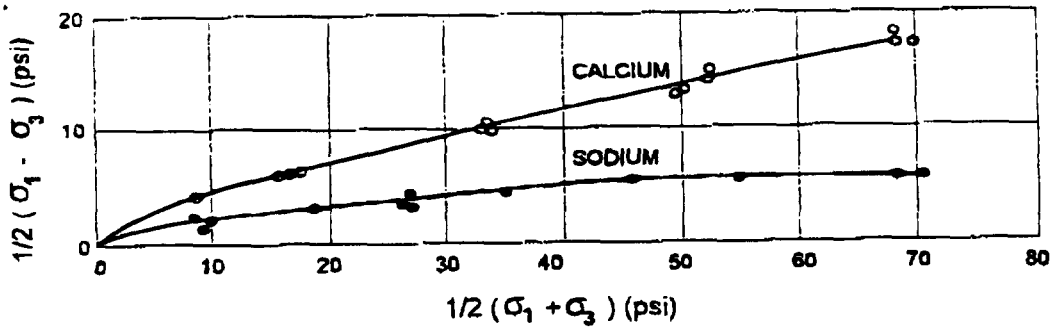


Figure 6. Effective-stress failure envelopes for calcium and sodium montmorillonite from CD and CU triaxial tests (from Mesri and Olson, 1970; Note: 1 psi = 6.9 kPa).

- Mitchell [1993] presented residual shear strength data for montmorillonite from Kenney [1967] and Chattopadhyay [1972]. Inspection of the residual shear strength data shown in Figure 7 reveals several significant points:

  - the residual friction angle exhibits significant stress dependency over a wide range of normal stress; stated differently the residual failure envelope is curved over a wide range of normal stress;

  - there may exist a normal stress above which the residual friction angle is independent of normal stress; based on Figure 7, this normal stress may be on the order of 480 kPa for sodium montmorillonite; and

  - the residual friction angle of montmorillonite is dependent on the dominant exchangeable cation and the soil pore chemistry; the smallest measured residual friction angle given in Figure 7 is 3° for homionic sodium montmorillonite in distilled water.

The GCL regression lines from Figures 4 and 5 are plotted along with the Mesri and Olson [1970] data in Figure 8. Reasonable agreement is observed between the Mesri and Olson data and the extrapolated regression lines for the unreinforced GCL. Also shown on this figure are the residual shear strengths for sodium montmorillonite developed by Kenney [1967] and Chattopadhyay [1972] as reported by Mitchell [1993]. These latter results further support the extrapolations presented in Figure 8.

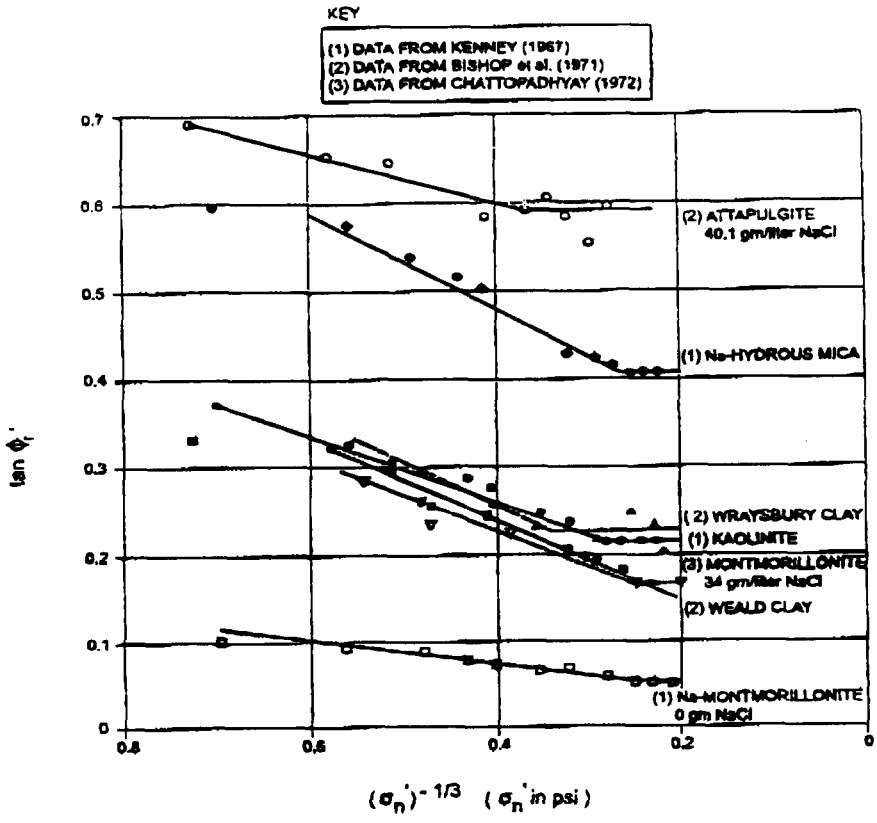


Figure 7. Residual effective-stress friction angles for clay minerals (from Mitchell, 1993; Note: 1 psi = 6.9 kPa).

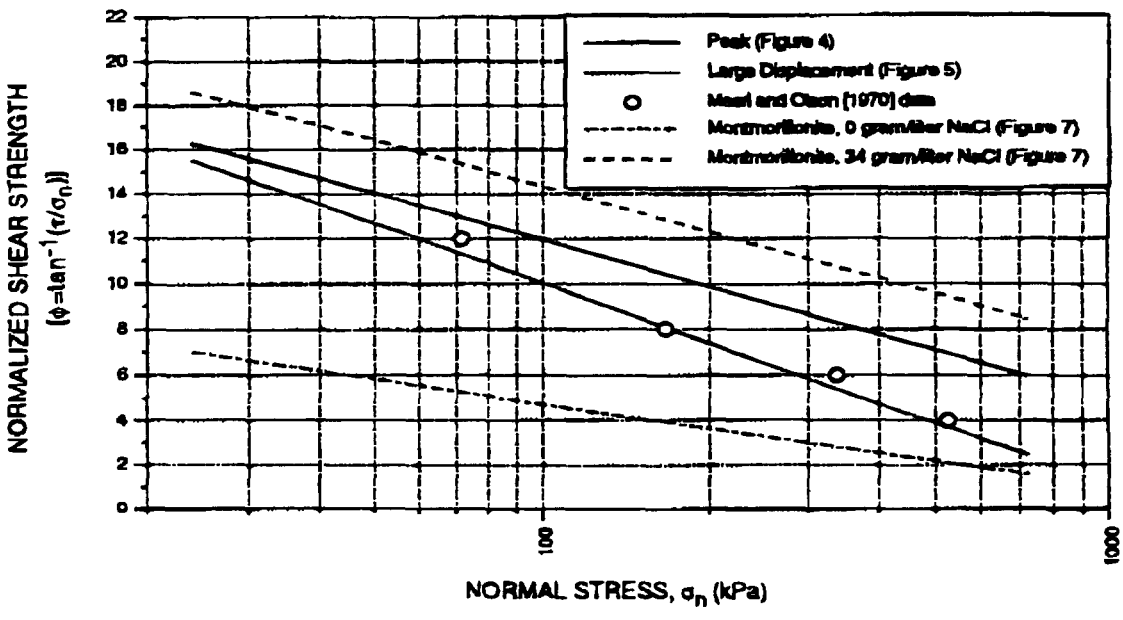


Figure 8. Comparison on montmorillonite shear strength data and GCL log-linear regression lines.

Review of Available Information for Reinforced GCLs

The authors were unable to find any information in the published technical literature on the CD shear strengths of reinforced GCLs at high normal stress. A few CD tests performed at low normal stress have been reported by Daniel and Shan [1991] for the product Bentomat®. These results cannot be extrapolated to higher normal stress, however, due to the current limited understanding of the effect of reinforcing fibers on the shear displacement-shear resistance-normal stress relationship for this type of material.

The authors have performed a limited number of consolidated-quick (CQ) direct shear tests on reinforced GCLs at normal stresses in the range of interest. Quick tests were performed at a displacement rate of 0.016 mm/s. While not "truly undrained" due to the lack of boundary drainage control in the direct shear test, the specimens in these tests will only undergo very limited pore pressure dissipation during the shear phase of the test due to the high rate of shear displacement. Due to these pore pressures, CQ tests at a given consolidation stress will result in lower GCL shear strengths than obtained from true CD tests at the same normal stress. CQ tests may therefore be considered to provide a lower bound of the CD shear strength of reinforced GCLs.

The results of the CQ direct shear tests on reinforced GCLs indicate relatively high peak shear strengths followed by a significant degree of shear softening (i.e., post peak decrease in shearing resistance). A typical test result is illustrated in Figure 9. Normalized peak and large displacement shear strengths, and the ratio of the two (ψ) for a normal stress of 480 kPa are given below:

	ϕ_p	ϕ_{ld}	τ_{ld}/τ_p
Bentomat®	29°	10°(↓)	0.32
Bentofix®	31°	16°(↓)	0.48
Claymax® 500SP	13°	6°(↓)	0.45

In the above table the downward arrow (↓) indicates that the GCL shearing resistance was decreasing at the end of the test (i.e., at a shear displacement of 40 to 50 mm). The ψ values reported above are low, generally in the range of 0.3 to 0.5. In contrast, ψ values for the CD direct shear tests on unreinforced GCLs were higher, typically in the range of 0.7 to 1.0. The ϕ_{ld} values reported above are somewhat larger than those obtained for the unreinforced GCLs. However, as noted above, observation of the shear force-displacement plots for the tests indicates that the shear stresses applied to the sample were decreasing at the ends of the tests, which typically occurred at a displacement of 40 to 50 mm. This observation, coupled with observations of the tested samples, that the GCL reinforcing fibers and stitching were still partially intact at the time the test was terminated, suggests that residual CD and CQ shear strengths of reinforced

GCLs may not be much larger than those of unreinforced GCLs. Clearly, testing is required to establish the large-displacement, high normal stress behavior of these materials, and to identify differences in product behavior based on differences in montmorillonite properties and reinforcing characteristics.

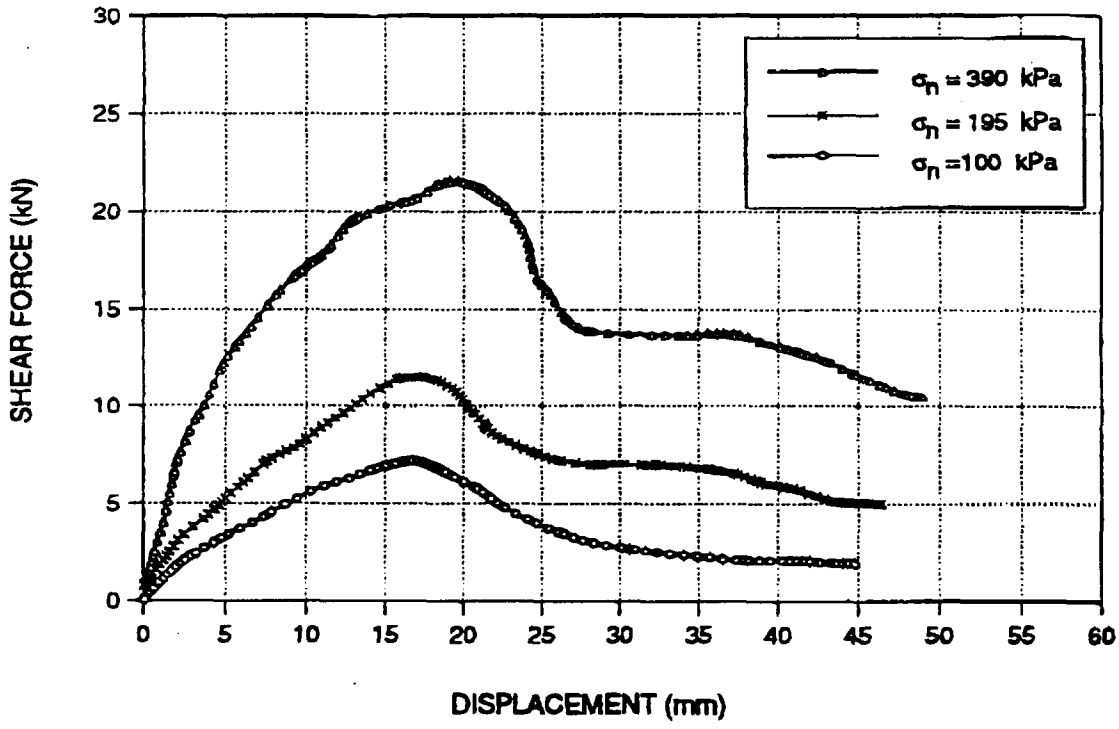


Figure 9. Results of CQ direct shear tests on reinforced Bentofix GCL.

Interim Design Values

Unreinforced GCLs: Based on the information presented in Figure 8, the authors used the following interim guidelines for performing liner system stability analyses for long-term drained conditions, for potential slip surfaces that involve internal shearing of unreinforced GCLs. These guidelines further assume that the GCL will hydrate through adsorption of water from an adjacent subgrade soil layer.

- Slope stability analyses are performed using: (i) peak internal GCL shear strengths and a minimum slope-stability factor of safety of 1.5; and (ii) large-displacement internal GCL shear strengths and a minimum slope-stability factor of safety of 1.15.

- Using the regression equation presented in Figure 4, peak normalized shear strengths are:

σ_n (kPa)	$(\tau/\sigma_n)_p$	ϕ_p
96	0.214	12.1°
240	0.157	8.9°
480	0.114	6.5°
720	0.106	6.1°

- Using the regression equation presented in Figure 5, large-displacement normalized shear strengths are:

σ_n (kPa)	$(\tau/\sigma_n)_{ld}$	ϕ_{ld}
96	0.178	10.1°
240	0.116	6.6°
480	0.070	4.0°
720	0.052	3.0°

For the large displacement strengths, a minimum friction angle cutoff of 3° was assumed based on the test results reported by Mitchell [1993], presented in Figure 7.

The normalized shear strengths given above are relatively low, and their use may be viewed by some as overconservative. This view should be tempered with the realization that the large-displacement GCL shear strengths reported in the technical literature do not represent true residual minimums (due to the limited displacement of the direct shear apparatus) and no allowance has been made for the possible effects of drained creep of the GCL under working stress conditions. Furthermore, the available CD direct shear test results for unreinforced GCLs correlate well with the triaxial compression test results for sodium montmorillonite from Mesri and Olson [1970] and Olson [1974] (Figure 6). Finally, it is noted that the foregoing approach, which utilizes a smaller slope stability factor of safety with the large displacement shear strengths than the factor of safety used with the peak shear strengths, is similar to the approaches advocated by Byrne [1994] and Stark and Poeppel [1994].

Reinforced GCLs: Recognizing the lack of data on the CD strength of reinforced GCLs at high normal stress, the complex behavior and high degree of shear-softening exhibited by these products, the authors utilized the same factors of safety and GCL long-term shear strengths for reinforced GCLs as for unreinforced GCLs. It is recognized that this assumption is conservative. However, given the limitations with respect to the available reinforced GCL test data (e.g., the technical literature does not contain any "true" CD direct shear test

results for reinforced GCLs at high normal stress) and the other factors discussed above, the authors believe the assumption was prudent.

SHEAR STRENGTH OF GCL-GEOMEMBRANE INTERFACES

Direct Shear Testing Program

For a project located in the desert of southeastern California, the authors performed 14 interface direct shear tests on unhydrated GCL-textured HDPE geomembrane interfaces. The tests were performed in a 300 mm x 300 mm shear box following procedures in general accordance with ASTM D 5321. Three different GCLs were tested. The geomembrane used in the tests was from a single roll of material and samples were selected based on visual observation of a consistent degree of texturing. The tests were carried out in a manner that allowed shearing either at the GCL interface or internally within the GCL bentonite layer. Tests were carried out at normal stresses ranging between approximately 350 and 1,920 kPa. Sliding in the tests consistently occurred at the interface and not within the GCL. Thus, the test results correlate to interface failures and at the same time provide conservative lower bound unhydrated shear strengths for the tested GCLs under the project testing conditions.

Typical test results are presented in Figure 10 and summarized in Table 5. The tests correspond to two shearing rates, namely 0.016 mm/s and 0.0007 mm/s. Interface friction angles obtained from the tests at the slower shearing rate are 1° to 2° lower than interface friction angles obtained from tests at the higher shearing rate. The test results also reveal an interface shear strength stress-dependency with secant interface friction angles 5° to 10° lower at 1,920 kPa than at 350 kPa. The interfaces exhibited only minor amounts of shear softening (typically less than 1 to 2°) at test displacements of up to about 50 mm.

Comment on Results

The foregoing interface direct shear test results illustrate the ranges of shear strengths obtained and several of the factors that affect this strength including normal stress, displacement rate, and magnitude of displacement.

The authors note that they have observed relatively wide variances in the degree of texturing of geomembranes, even from a given manufacturer. The degree of texturing significantly influences the interface shear strength. Thus, the strength values reported above should not be considered appropriate for design. Interface shear strengths for design should be established on a project-specific basis and construction-phase quality control testing should be used to establish that materials delivered to the construction site can achieve the interface strengths established during design.

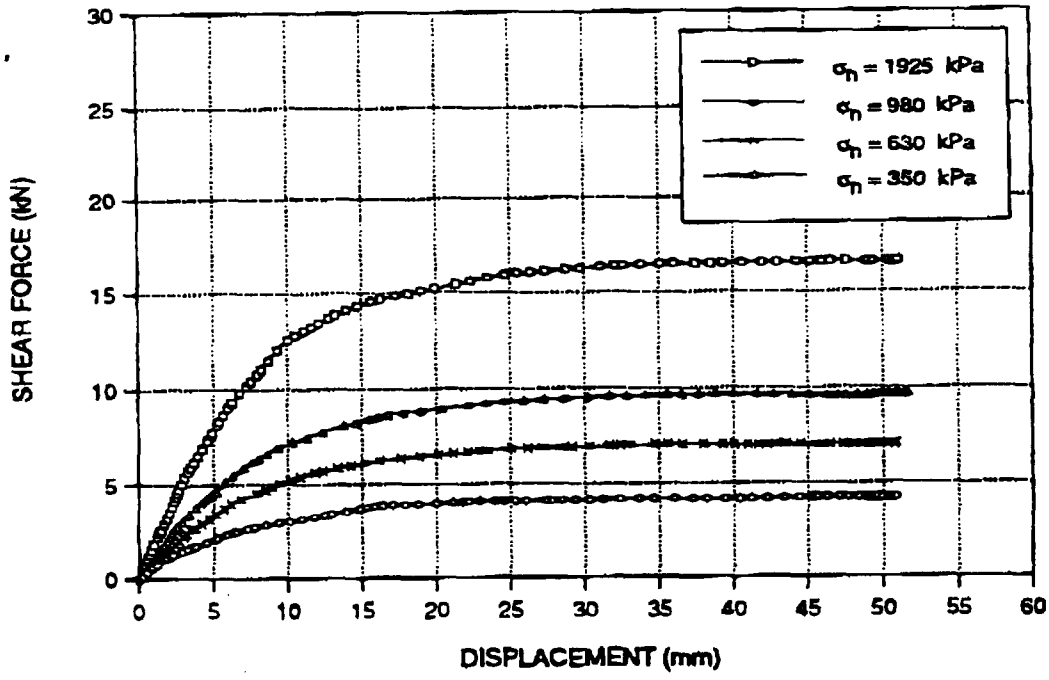


Figure 10. Results of direct shear tests on unhydrated Bentofix GCL-textured HDPE geomembrane interface.

HYDRATION OF GCLs ADJACENT TO SOIL LAYERS

Overview of Testing Program

The authors conducted an extensive laboratory testing program to evaluate the potential for hydration of GCLs placed against a compacted subgrade soil layer. Hydration tests were performed on three different GCL products to evaluate the effects of: (i) test duration (i.e., hydration time); (ii) soil initial water content; (iii) thickness of soil layer; and (iv) overburden pressure. Three commercially-available GCL products, namely, Claymax®, Bentomat®, and Bentofix® were used in the testing program. The soil used in the testing program was obtained from the USEPA GCL Field Test Site at the ELDA-RDF facility in Cincinnati, Ohio. This material is classified as low plasticity clay (CL) based on the Unified Soil Classification System (USCS). Tests were performed on two different soil samples and consistent results were obtained between samples. The results reported herein were obtained from tests on a sample with 99 percent of the soil passing the U.S. No. 200 standard sieve and 33 percent smaller than 2 μm (clay fraction). The liquid limit of the soil is 41 and the plasticity index is 19. The soil has an optimum moisture content (OMC) of 20 percent and a maximum dry unit weight of 16.7 kN/m^3 based on the standard Proctor compaction method (ASTM D 698).

Table 5. Direct shear test results of textured 80-mil HDPE geomembrane/unhydrated GCL interfaces[1].

Test Number	Type of GCL	Normal Stress (kPa)	Displacement Rate (mm/s)	Large Displacement Secant Friction Angle[2] (ϕ_{ld}°)
1	Bentomat GCL (nonwoven side)	350	0.016	24°
2	Bentomat GCL (nonwoven side)	620	0.016	24°
3	Bentomat GCL (nonwoven side)	960	0.016	23°
4	Bentomat GCL (nonwoven side)	960	0.0007	22°
5	Bentomat GCL (nonwoven side)	1,920	0.016	19°
6	Bentomat GCL (nonwoven side)	1,920	0.0007	17°
7	Bentofix GCL (nonwoven side)	350	0.016	28°
8	Bentofix GCL (nonwoven side)	620	0.016	26°
9	Bentofix GCL (nonwoven side)	960	0.016	23°
10	Bentofix GCL (nonwoven side)	1,920	0.016	21°
11	Gundseal GCL (bentonite granules side)	350	0.016	34°
12	Gundseal GCL (bentonite granules side)	620	0.016	29°
13	Gundseal GCL (bentonite granules side)	960	0.016	27°
14	Gundseal GCL (bentonite granules side)	1,920	0.016	24°

Notes: (1) The tests were performed using unhydrated GCLs and in a manner that allowed shearing at the geomembrane/GCL interface, as well as within the GCL bentonite layer.
(2) Final displacements in the tests were in the range of 25 to 50 mm.

TOTAL P.24

Testing Apparatus and Procedure

Figure 11 shows the apparatus specially designed to conduct the GCL hydration tests. The apparatus consists of a polypropylene mold 75 mm in diameter and 150 mm in height. A geomembrane/GCL/soil composite specimen is placed in the mold and covered with two layers of a thin vapor barrier. A loading platen is placed on the specimen for application of overburden pressure.

To process the soil, it was first passed through a U.S. No. 4 standard sieve. The soil was then moisture conditioned to achieve the desired moisture content. The moist soil was placed in the mold in a loose condition and statically compressed to 50-mm thick lifts. The soil was compacted to a dry unit weight equal to approximately 90 percent of the maximum dry unit weight based on the standard Proctor method (ASTM D 698). Two soil lifts were used giving a total thickness of 100 mm. The GCL and geomembrane specimens were carefully trimmed from the same sheets. The initial moisture content of the GCL was measured by taking a small sample from the same GCL sheet and measuring its weight before and after oven drying. The initial moisture content of the GCLs varied between 15 and 20 percent.

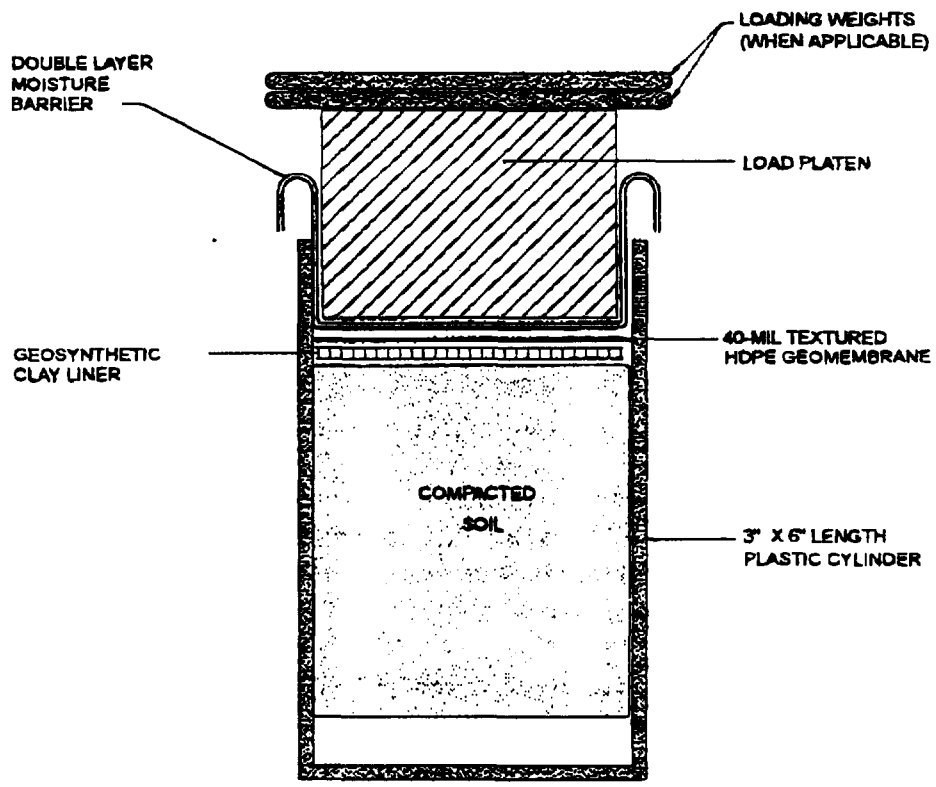


Figure 11. Simplified diagram of GCL hydration test set-up.

The GCL and geomembrane were placed on the soil and covered with the vapor barrier. The side of the GCL placed against the soil was woven in the case of Claymax® and nonwoven for Bentomat® and Bentofix®. Overburden pressure of 10 kPa was applied on the composite specimen utilizing standard weights which were placed on the loading platen. The entire apparatus was then placed in a temperature and humidity controlled room for the desired hydration time period. At the end of the hydration period, the test specimen was removed and the water content of the GCL and soil were measured. The final moisture content of the GCL was measured by weighing the entire GCL specimen before and after oven drying. The final moisture content of the soil was measured as the average water content of three samples obtained from the top, middle, and bottom of the soil specimen.

Testing Conditions and Results

As previously described, test conditions were varied to evaluate the effects of several factors on the hydration of GCLs. To evaluate the effect of test duration, tests were performed where the GCL was in contact with the soil for 5, 25, and 75 days. Soil specimens were compacted to initial moisture contents equal to OMC, 4 percentage points dry of OMC, and 4 percentage points wet of OMC to evaluate the effect of soil initial moisture content on GCL hydration.

Figures 12, 13, and 14 present the results of the hydration tests for the GCL products Claymax®, Bentomat®, and Bentofix®, respectively. These figures show that the moisture content of all three GCLs increased significantly as a result of contact with compacted subgrade soil. The increase in GCL water content was significant after only five days of hydration. With increasing time, GCL water content continued to increase at a decreasing rate. For most tests, GCL water content reached a maximum value after about 25 days of soil contact and for some of the tests water content continued to increase even after 75 days of hydration. It is interesting to note that all three GCL products showed relatively similar behavior. Increases in water content were comparable for the three GCL products despite differences in GCL fabric (i.e., woven vs. nonwoven) and types of bentonite clay used to manufacture the GCLs.

Figures 12, 13, and 14 illustrate the influence of soil subgrade initial moisture content on the hydration of GCLs. From these figures, it is evident that the moisture content of the GCL for any particular hydration time increases as the initial moisture content of the soil increases. These figures also show that a small increase in soil initial moisture content can have a significant impact on GCL moisture content. For example, after 75 days of hydration, the moisture content of Claymax® was approximately 16 percent higher when the initial moisture content of the soil was equal to OMC than when it was 4 percentage points drier than OMC. This behavior is expected because more water is available in the soil for the GCL to hydrate.

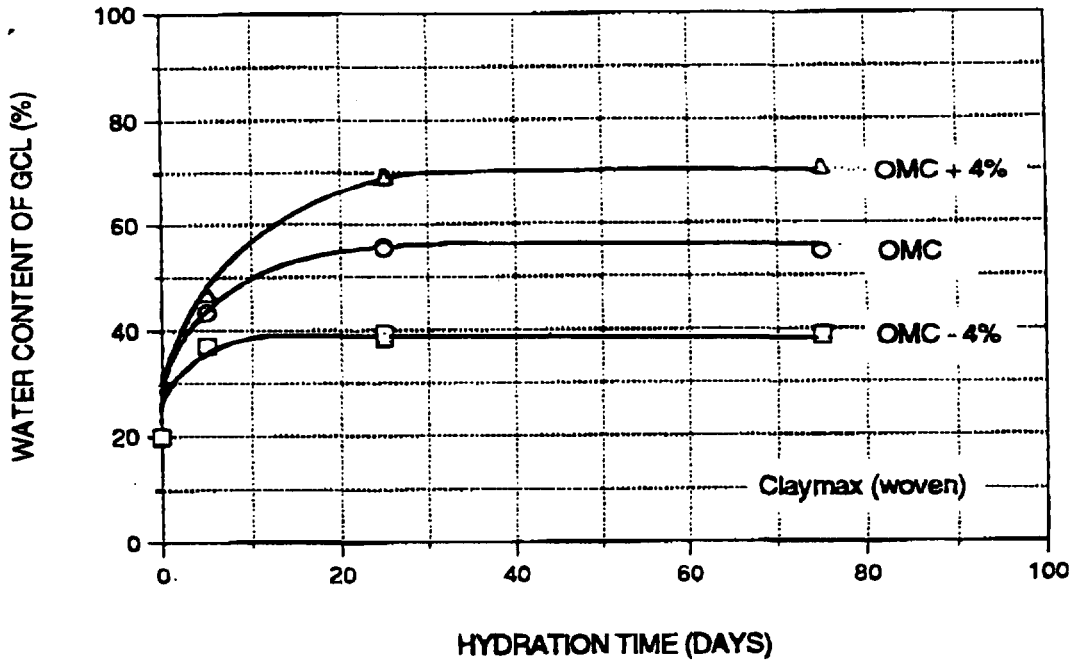


Figure 12. Increase in GCL moisture content due to contact with compacted subgrade soil: Claymax® with woven geotextile against soil.

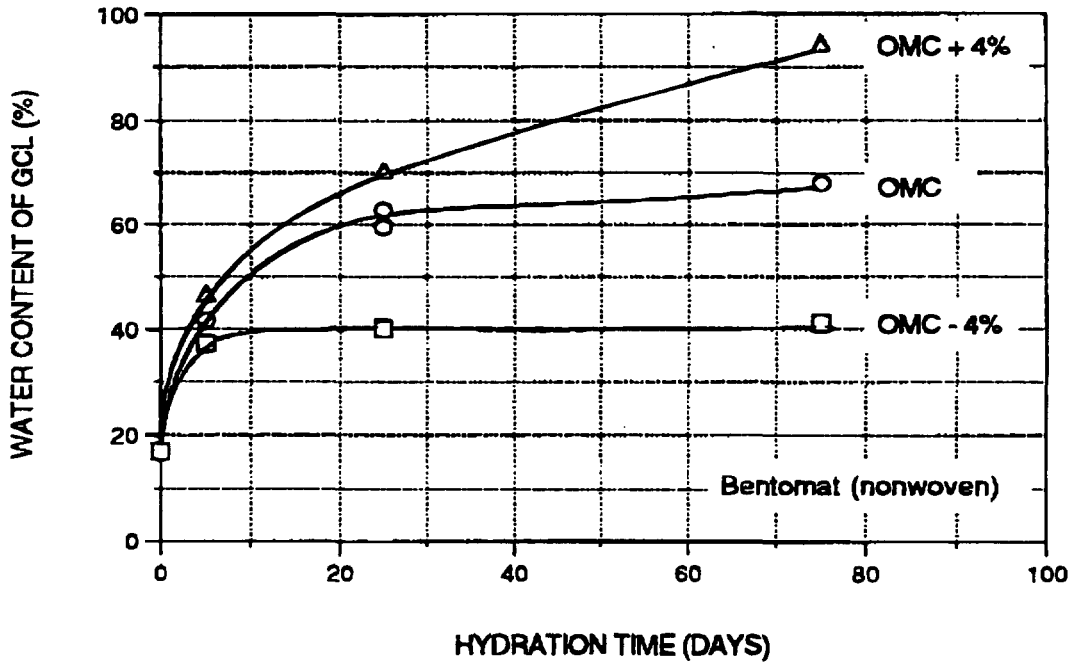


Figure 13. Increase in GCL moisture content due to contact with compacted subgrade soil: Bentomat® with nonwoven geotextile against soil.

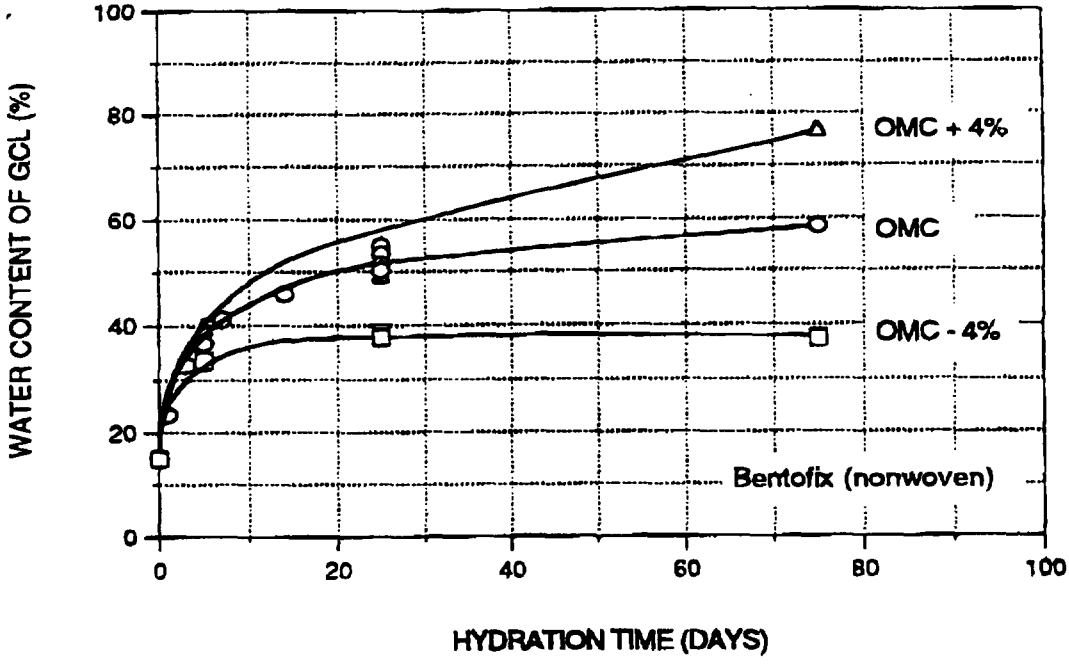


Figure 14. Increase in GCL moisture content due to contact with compacted subgrade soil: Bentofix® with nonwoven geotextile against soil.

The examination of the curves shown in Figures 12, 13, and 14 shows that the time required for the GCL to reach its final moisture content is less in the case of a dry soil than in the case of a wet soil. At the lowest soil initial moisture content tested, GCL moisture content ceased to increase after about 5 to 25 days. At the highest initial moisture content tested, the Bentomat® and Bentofix® GCLs continued to increase in moisture content after 75 days of hydration.

To evaluate the effect of soil layer thickness, specimens were prepared using 50, 100, 150, and 200 mm of soil thickness. Soil initial moisture content was 20 percent and dry unit weight was 14.9 kN/m^3 for all specimens. Figure 15 shows the results of hydration tests for the Bentofix® GCL after 25 days of hydration. The GCL moisture content increased with the increase of the soil layer thickness. However, it appears that only a small change in moisture content increase occurs for thicknesses greater than 100 mm.

The effect of overburden pressure on GCL hydration is illustrated in Figure 16 for the Bentofix® GCL. As shown in this figure, overburden pressure in the range of 5 to 390 kPa did not significantly affect the rate of GCL hydration during the 25-day test duration.

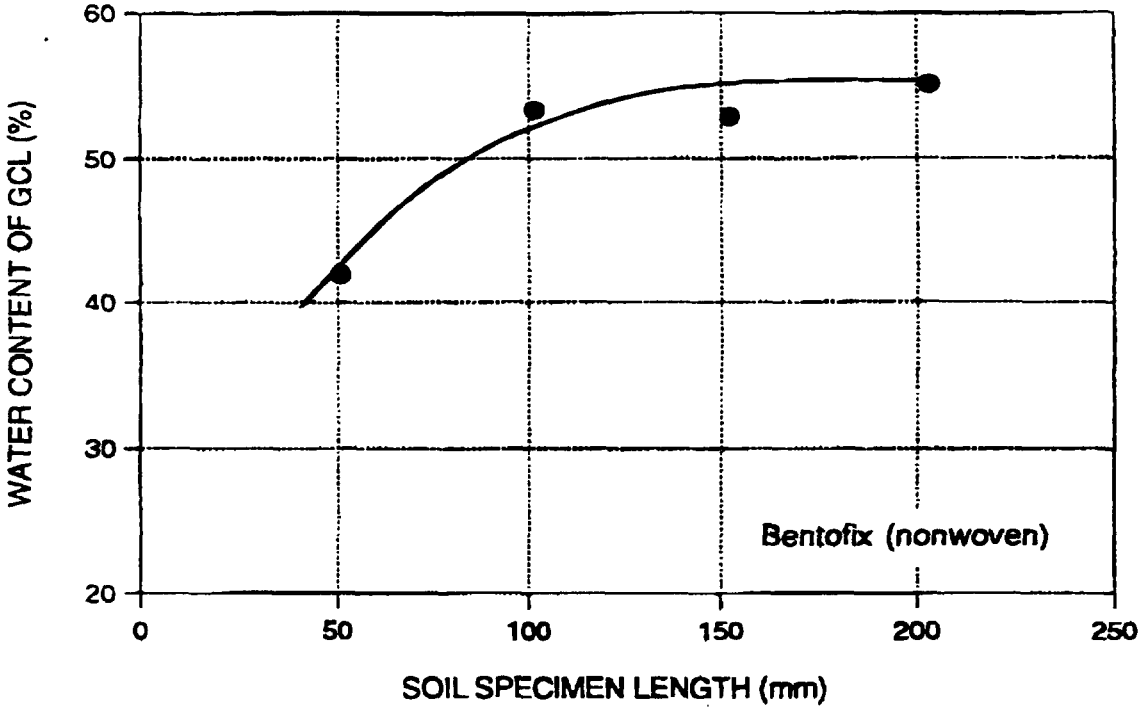


Figure 15. Influence of subgrade soil layer thickness on GCL moisture content.

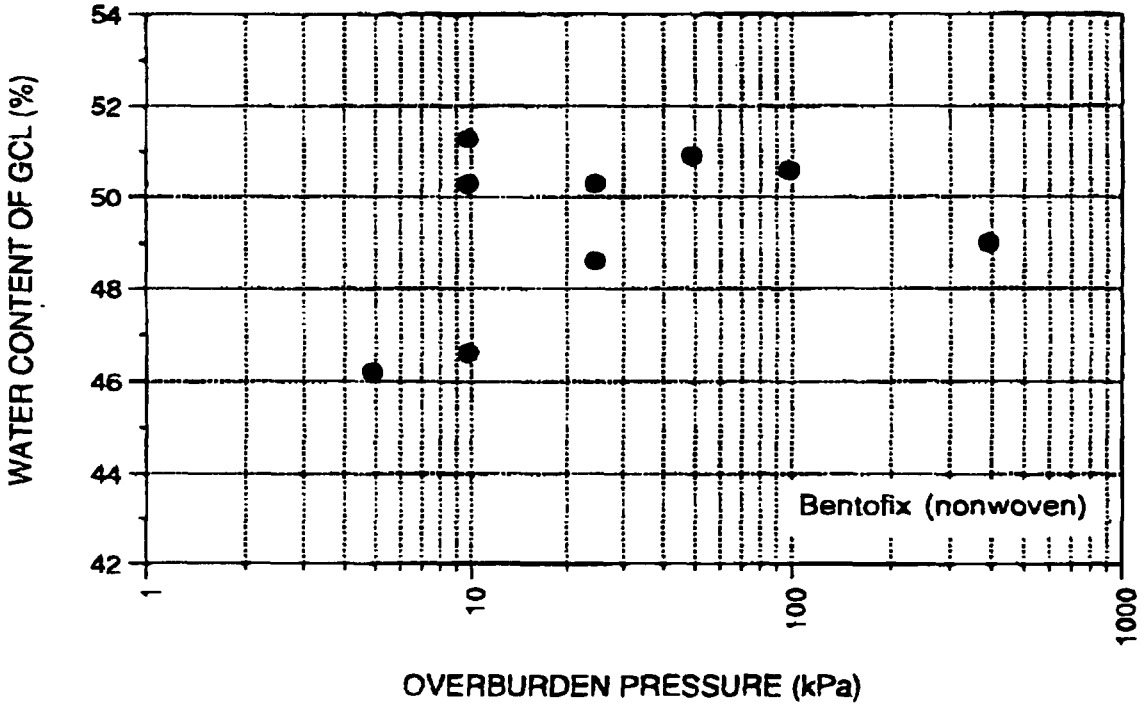


Figure 16. Influence of overburden pressure on the increase in GCL moisture content.

Summary

From the testing program results described above, the following can be concluded:

- GCLs will hydrate when placed in contact with subgrade soils compacted within the range of moisture contents typically found in earthwork construction specifications; this conclusion is consistent with data provided by Daniel et al. [1993]; even for the driest soil (compacted 4 percentage points dry of OMC), GCL moisture contents consistently increased from an initial value in the range of 15 to 20 percent up to about 40 percent within a 100-day period; it should thus be anticipated that GCLs placed even against relatively dry compacted subgrades will undergo substantial hydration;

- given that Daniel et al. [1993] have shown that long-term GCL shear strengths are insensitive to water content for water contents above about 50 percent, stability analyses involving GCLs placed in contact with compacted subgrade soils should be based on hydrated GCL shear strengths;

- significant increases in GCL moisture contents may occur within a few days of GCL contact with a moist soil; the rate of GCL hydration is initially highest and then decreases with increasing time;

- within the range of conditions tested a higher soil moisture content results in a higher GCL moisture content;

- larger soil layer thickness results in a larger increase in GCL moisture content, however, for soil layer thicknesses greater than 100 mm only insignificant increases were observed with increasing soil layer thickness;

- overburden pressure within the range tested (i.e., 5 to 390 kPa) did not influence the hydration process; and

- differences between GCL products tested (i.e., type of bentonite clay and fabric) did not seem to significantly affect the test results.

FAILURE OF LANDFILL COVER SYSTEM CONTAINING A GCL

Description of Cover System

The authors recently investigated the failure of a cover system for a municipal solid waste landfill near Atlanta, Georgia. The failure is described in more detail by Vander Linde et al. [1995]. The cover system was constructed in the fall of 1994 on 3H:1V (horizontal:vertical) side slopes to a maximum height above surrounding ground of approximately 18 m. The cover system consisted of, from top to bottom:

- 300-mm thick layer of final cover soil which is classified as silty sand containing approximately 40 percent fines based on ASTM D 2487, and which has a hydraulic conductivity in the range of 10^{-4} to 10^{-3} cm/s;
- stitch-bonded reinforced GCL; and
- 150- to 300-mm thick layer of intermediate cover soil which served as a foundation for the overlying final cover components.

Failure of System

During the winter of 1995, the cover system experienced several episodes of downslope movement. The first major episode occurred approximately one month after the completion of construction; the movement occurred after a three-day period in which 58 mm of rain fell at the site. The next major episode occurred six weeks later, after two days of inclement weather generated about 41 mm of rainfall at the site. Total downslope movements exceeded 1 m at some locations. The observed failure mechanism was sliding of the final cover soil on top of the GCL.

Analysis of Failure

The episodes of downslope movement both followed periods of extended rainfall at the site. A slope stability back-analysis of the cover system was performed which accounted for the influence of rainfall-induced seepage forces on cover system factor of safety against downslope sliding. The back-analysis involved two steps:

- estimating seepage forces within the cover soil using several different calculation methods and parameter values; and
- calculating the resulting slope stability factors of safety for the range of estimated seepage forces.

The evaluation of seepage forces involved calculating the water build-up (i.e., hydraulic head) within the final cover soil on top of the GCL. Head was calculated using a methodology developed by Giroud and Houlihan [1995] and checked using the United States Environmental Protection Agency (USEPA) Hydrologic Evaluation of Landfill Performance (HELP) computer program Version 3.03 [USEPA, 1994a, 1994b]. The values of head calculated using these approaches ranged from 150 mm to the full thickness of the cover soil layer, 300 mm.

Calculations to obtain slope stability factors of safety were performed using the equations presented by Giroud et al. [1995a, 1995b]. An important input to the equations is the shear strength of the interface between the cover soil and GCL. Tests to evaluate the shear strength of this interface had not been carried out as part of the original design. For the back-analysis of the failure, a range of friction angles (20° to 26°) was considered for the cover soil-GCL interface; this range likely brackets the actual interface strength and includes the value of 24° originally assumed by the design engineer. Calculations were performed and the following results were obtained:

Interface Friction Angle (degrees)	Factor of Safety (FS) vs. Hydraulic Head 0 mm	100 mm	200 mm
20°	1.09	0.84	0.60
24°	1.35	1.04	0.73
26°	1.47	1.13	0.80

These calculation results demonstrate the significant impact of seepage forces on the stability of the final cover soil. Even with the largest assumed interface strength, only 140 mm of head buildup is required to decrease the slope stability factor of safety to less than 1.0. Interface shear strength tests performed after the completion of the back analyses resulted in peak and large-displacement secant friction angles for the GCL-cover soil interface, at the applicable normal stress, of 23° and 21°, respectively.

Summary

The primary factor contributing to the observed final cover soil movements was the build-up of seepage forces in the final cover soil during periods of heavy rain. Seepage forces were not accounted for in the design. If seepage forces had been accounted for, the potential for instability likely would have been identified during preparation of the design. The development of seepage forces in cover soils is typically minimized by the inclusion of a drainage layer above the low-permeability barrier component of the cover (in this case, the GCL). A secondary factor contributing to the movements was a final cover soil-GCL interface shear strength lower than assumed in the design. An interface friction

angle of 24° was assumed by the design engineer, based on information provided by the GCL manufacturer. The actual project-specific interface shear strength was closer to 21°. This result highlights the fact that actual interface strengths can only be assessed by project-specific testing; such testing was not performed for the project.

ACKNOWLEDGEMENTS

The authors would like to thank Mr. Robert R. Landreth and Mr. David A. Carson of the U.S. Environmental Protection Agency, Risk Reduction Research Laboratory for their support in the evaluation of double-liner system performance.

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ATTACHMENT 9

SETTLEMENT CALCULATION

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Landfill Settlement Calculations
Project No. C10004051.00
Computed by: M. Brungard
Checked by: R. Haydon
Page ___ of ___
Sheet 1 of 8
Date 11/3/00
Date 11/3/00
Reference

Purpose: These calculations are enhanced versions of the general settlement calculated for the landfill in calculations dated 5/4/00 by M. Brungard titled "Settlement Potential". These calculations will explain the selection of soil properties, existing ground elevations, settlement of individual landfill components during construction, maximum differential settlement and the justification for the consolidation settlement model.

Soil Properties:

Limited boring and laboratory information for the site are available at this time. The 4 borings at the site show that sandy silt extends to about EL 390 with a thin veneer of clay at ground surface. Silty sand was found below EL 390. Geologic estimates for the depth to rubble or bedrock were taken from experience in this region. EL 290 was assumed as the top of non-compressible bedrock or rubble. No borings extended this deep.

The soil density for the foundation soils is calculated in relation to the SPT blow count at each depth interval. The methodology is taken from: Schmertmann (1978), Guidelines for Cone Penetration Test, Performance & Design, Federal Highway Administration. The methodology has been computerized and used to create the results attached.

The waste and fill soil density are conservatively estimated at 125 pcf (moist). Textbook estimates for various soil types show that this is equivalent to a moist, dense well graded soil.

Ground Surface:

The regional topography indicates that the region is generally flat. It can be assumed that low portions of the site have been previously level with the surrounding ground and therefore have been prestressed by that over burden weight. Use EL. 407 as the current ground level. Because the low areas of the site are assumed to be prestressed, it is not necessary to consider the actual ground surface elevation changes at the site.

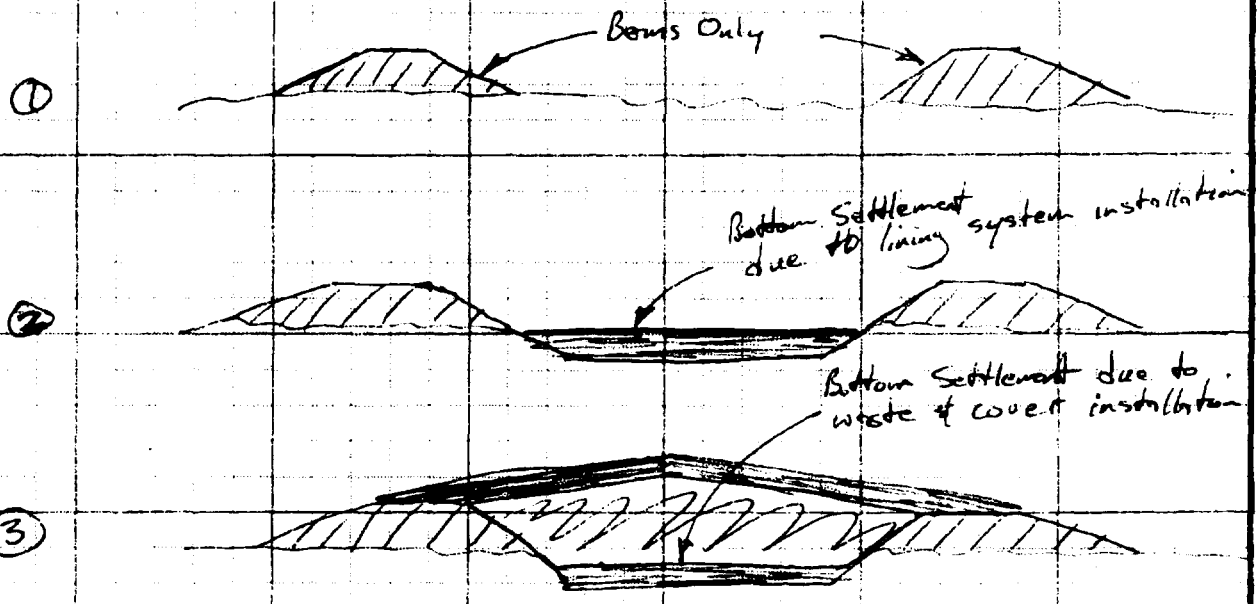
The water table was estimated at EL. 397' from piezometer readings at the site. (10' depth)

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Landfill Settlement Calculations
Project No. C10004051.00
Computed by: M. Brungard
Checked by: R. Hayden
Page ___ of ___
Sheet 2 of 8
Date 11/3/00
Date 11/3/00
Reference

The elastic settlement characteristics for each soil layer in the subsurface profile is correlated to the SPT blow counts from the borings. That information is calculated within the computer program.

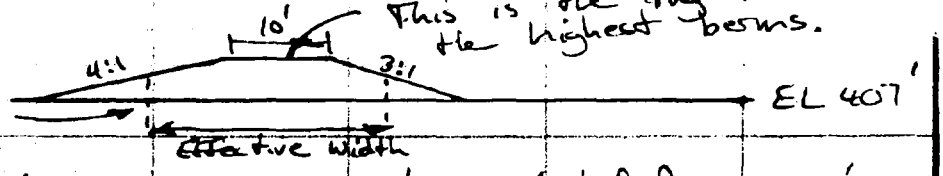
Settlement: The settlement of the landfill components will be estimated in a sequential manner. The sequence is divided into 3 configurations as shown below



The computerized Schmertmann settlement analysis does not include settlements due to clay or silt consolidation. These settlements will be added & calculated by hand.

Berm Settlement

Use EL 420' for top of Berm. This is the avg elevation for the highest berms.



Assume effective width extends to center of slopes.

$\Delta H = 420 - 407 = 13'$

Applied Pressure $= 13' \times 125\,pcf = \underline{1625\,psf}$

Effective Width $= \left(\frac{13'}{2} \times 3\right) + 10' + \left(\frac{13'}{2} \times 4\right) = \underline{55.5'}$ say $\underline{56'}$

Sent By: URS; 18505741313; 3 Nov'00 4:53PM; Job 937;Page 3/9

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Landfill Settlement Calculations
Project No. C10000405.00
Computed by: M. Brungard
Checked by: R. Hayden
Page ___ of ___
Sheet 3 of 8
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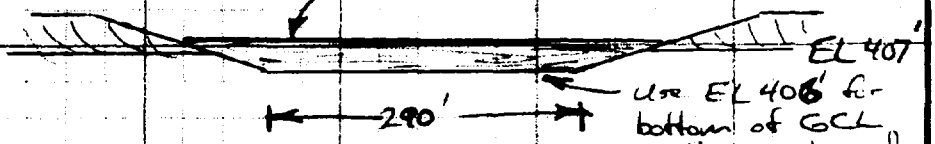
Date 11/3/00
Reference

Berm Settlement = 2.99 say 3" (see attached sheet)

Use EL 409' for top of Primary Collection at the center of the cell.

Bottom Settlement:



Use EL 406' for bottom of GCL at the center of the cell.

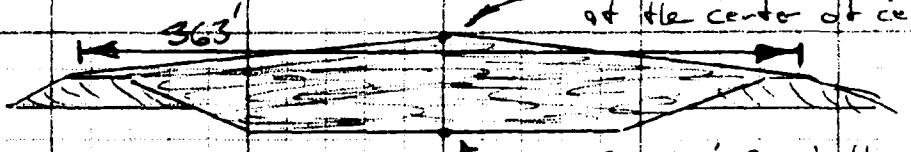
$\Delta H = 409' - 406' = 3'$

Applied Pressure = 3' × 125 pcf = 375 psf

Bottom Settlement = 0.29" say 0.3" (see attached sheet)

Final Filled Bottom Settlement:

Use EL 422 for top of cover at the center of cell.



Use EL 406' for bottom of GCL at the center of cell.

$\Delta H = 422' - 406' = 16'$

Applied Pressure = 16' × 125 pcf = 2000 psf ← highly conservative since this is the peak, not average

Assume the effective width & length are 400'

Bottom Settlement = 2.34" (see attached sheet.)

* less Bottom Settlement above = 0.3

2.04" say 2"

Consolidation Settlement:

The consolidation settlement for the landfill will be calculated using a correlation with the liquid limit for the surficial clays & silts. No other consolidation information is available for the site. LL = 40 for silts observed in borings

For normally consolidated clays, the Compression Index correlation is:

Terzaghi & Peck (1967) $C_c = 0.009\,(LL - 10)$ where LL = liquid limit

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Landfill Settlement Calculations

Project No. C100004051.00
Computed by: M. Brungard
Checked by: R. Hayden

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Date 11/3/00
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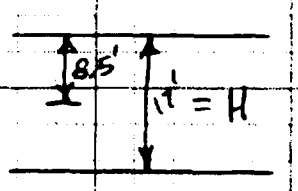
Reference

Berm

$\Delta H = 407' - 390' = \underline{17'}$

$C_c = (40-10)0.009 = \underline{0.27}$

assume $e_0 = 0.6$



Stress at center of layer = 8.5' × 125 pcf = 1062 psf = σ_{vo}'

Berm Applied Pressure = 1625 psf

$$\text{Settlement} = C_c \frac{H}{1+e_0} \log \frac{\sigma_{vo}' + \Delta\sigma_v'}{\sigma_{vo}'}$$

$$= 0.27 \frac{17'}{1+0.6} \log \frac{1062+1625}{1062}$$

$$= \underline{1.15 \text{ feet}} \times \underline{13.8 \text{ inches}}$$

Typical coefficient of consolidation $C_v = 5 \times 10^{-3}$ cm²/sec for normally consolidated material w/ LL = 30

5×10^{-3} cm²/sec = $\underline{0.46 \text{ ft}^2/\text{day}}$

$$\text{Consolidation time } (t) = \frac{H^2}{C_v} T$$

for 50% consolidation $T = 0.2$
90% consolidation $T = 0.85$

$$t_{50} = \frac{(17')^2}{0.46 \frac{ft^2}{day}} \cdot 0.2 = \underline{125 \text{ days}} \rightarrow \underline{7''} \text{ settlement}$$

$$t_{90} = \frac{(17)^2}{0.46} \times 0.85 = \underline{534 \text{ days}} \rightarrow \underline{12''} \text{ settlement}$$

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Landfill Settlement Calculation
Project No. C10000405.00
Computed by: M. Brungard
Checked by: R. Hayden
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Sheet 5 of 8
Date 11/3/00
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Bottom

$\Delta H = 406' - 390' = 16'$

Filled Cell Applied Pressure = 2000 psf

Stress at center of Silt = 8' × 125 pcf = 1000 psf

$$\text{Settlement} = 0.27 \frac{16'}{1+0.10} \log \frac{1000+2000}{1000}$$

$= 1.28$ feet $= 15.5$ inches

Consolidation Time (t)

$$t_{50} = \frac{(16)^2}{0.46\ ft^2/day} \cdot 0.2 = 111 \text{ days} \rightarrow 8''$$

$$t_{90} = \frac{(16)^2}{0.46\ ft^2/day} \cdot 0.85 = 473 \text{ days} \rightarrow 14''$$

Total Settlements:

	Elastic	Consolidation	Total
Berm	3"	13.8"	16.8"
Bottom	2.4"	15.5"	17.9"

Edge to Center Differential Δ = 1.1"

Summary:

This analysis confirms that differential settlement for the landfill will be small and lining system distress should not occur due to settlement. Due to the stress distributions and large depth of influence for the landfill stresses, the use of the averaged maximum stress used in this analysis is appropriate.

Solutia Sauget 11/3/00 M. Brungard

Berm Settlement

DATE: 11/ 3/2000
TIME: 15: 0:53

FILE NAME: boringc.txt
DESCRIPTION: Solutia Sauget Boring Corrected Average

FOOTING PROPERTIES	
Width	56.00 FT
Length	300.00 FT
Depth	0.00 FT
Total Pressure	1625.00 PSF

GENERAL INFORMATION	
Groundwater Depth	10.00 FT
Qc/N Ratio	4.00

SUBSURFACE INFORMATION AND LAYER SETTLEMENTS BY SCHMERTMANN'S METHOD

LAYER BOTTOM DEPTH (FT)	DUTCH CONE Qc (TSF)	USCS	UNDRAIN STRNGTH Su (PSF)	UNIT WEIGHT (PCF)	COMP. SLOPE C	RECOMP. SLOPE Cr	CONS. RATIO OCR	SETTLE-MENT (IN)
5.00	44			119.50				0.09
10.00	36			118.50				0.14
15.00	32			55.60				0.19
20.00	52			58.23				0.14
25.00	76			61.98				0.11
30.00	76			61.98				0.12
35.00	104			64.10				0.10
40.00	48			57.60				0.24
45.00	40			56.60				0.31
50.00	80			62.60				0.15
55.00	224			70.40				0.05
65.00	96			63.60				0.22
75.00	72			61.35				0.27
120.00	72			61.35				0.86

Total Settlement 2.99

Solutia Sauget 11/3/00 M. Bringgold 7 of 8

Bottom Settlement

DATE: 11/ 3/2000
TIME: 15: 6:50

FILE NAME: boringc.txt
DESCRIPTION: Solutia Sauget Boring Corrected Average

FOOTING PROPERTIES		GENERAL INFORMATION	
Width	290.00 FT	Groundwater Depth	10.00 FT
Length	290.00 FT	Qc/N Ratio	4.00
Depth	1.00 FT		
Total Pressure	375.00 PSF		

SUBSURFACE INFORMATION AND LAYER SETTLEMENTS BY SCHMERTMANN'S METHOD

LAYER BOTTOM DEPTH (FT)	DUTCH CONE Qc (TSF)	USCS	UNDRAIN STRNGTH Su (PSF)	UNIT WEIGHT (PCF)	COMP. SLOPE C	RECOMP. SLOPE Cr	CONS. RATIO OCR	SETTLE-MENT (IN)
5.00	44			119.50				0.01
10.00	36			118.50				0.01
15.00	32			55.60				0.01
20.00	52			58.23				0.01
25.00	76			61.98				0.01
30.00	76			61.98				0.01
35.00	104			64.10				0.01
40.00	48			57.60				0.01
45.00	40			56.60				0.02
50.00	80			62.60				0.01
55.00	224			70.40				0.00
65.00	96			63.60				0.02
75.00	72			61.35				0.03
120.00	72			61.35				0.15

Total Settlement 0.29

Solutia Sauget 11/3/00 M. Brungard 8 of 8

Bottom Settlement (Cell Filled)

DATE: 11/ 3/2000
TIME: 15:16:20

FILE NAME: boringc.txt
DESCRIPTION: Solutia Sauget Boring Corrected Average

FOOTING PROPERTIES

Width	400.00	FT
Length	400.00	FT
Depth	1.00	FT
Total Pressure	2000.00	PSF

GENERAL INFORMATION

Groundwater Depth	10.00	FT
Qc/N Ratio	4.00	

SUBSURFACE INFORMATION AND LAYER SETTLEMENTS BY SCHMERTMANN'S METHOD

LAYER BOTTOM DEPTH (FT)	DUTCH CONE Qc (TSF)	USCS	UNDRAIN STRNGTH Su (PSF)	UNIT WEIGHT (PCF)	COMP. SLOPE C	RECOMP. SLOPE Cr	CONS. RATIO OCR	SETTLE-MENT (IN)
5.00	44			119.50				0.06
10.00	36			118.50				0.09
15.00	32			55.60				0.11
20.00	52			58.23				0.08
25.00	76			61.98				0.06
30.00	76			61.98				0.06
35.00	104			64.10				0.05
40.00	48			57.60				0.11
45.00	40			56.60				0.14
50.00	80			62.60				0.07
55.00	224			70.40				0.03
65.00	96			63.60				0.14
75.00	72			61.35				0.20
120.00	72			61.35				1.14

Total Settlement 2.34

ATTACHMENT 10

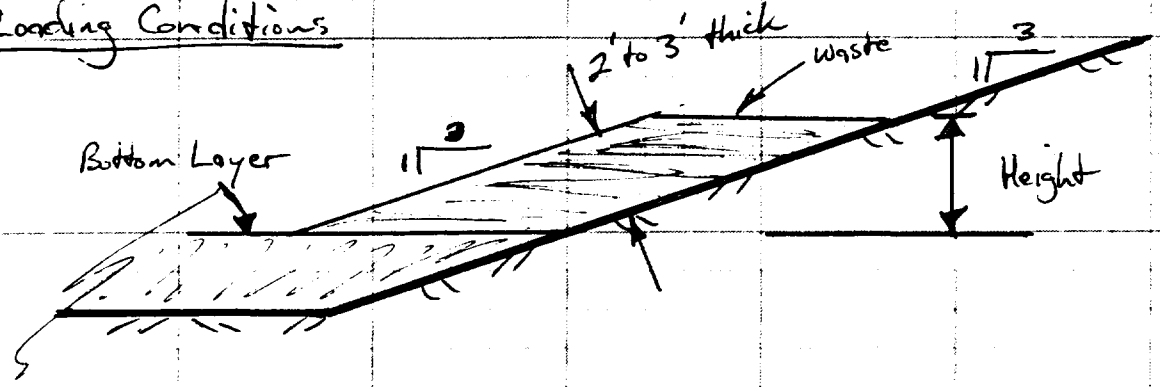
LINER SYSTEM STABILITY CALCULATION

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Lining System Stability Analysis
Project No. C100004051.00
Computed by: M. Brungard
Checked by: R. Hampton
Page ___ of ___
Sheet 1 of 6
Date 10/19/00
Date 10/25/00
Reference

Purpose: Evaluate the stability of all lining system components under the expected loading conditions.

Loading Conditions



Estimated Waste Strength

The actual strength of the wastes is currently unknown, but can be back-calculated from the requirements that the waste fill be "trafficable". The waste must be strong enough to support wheel loads.

The tire pressures commonly prescribed for light to medium-duty wheeled front end loaders was taken from a John Deere 544 maintenance sheet. The tire pressures range from 25 to 55 psi depending on tire size.

Using bearing capacity theory, the undrained shear strength can be estimated.

Applicable Eqn: $\sigma = cN_c$

where: c = undrained shear strength
$N_c = 5.14$ for undrained loading, $\phi = 0°$
σ = Ultimate Bearing Capacity

Using the lowest tire pressure will result in the lower strength value. Set tire pressure to bearing capacity

$$25 \text{ psi} = c(5.14) \longrightarrow c = 4.86 \text{ psi} = 700 \text{ psf}$$

Using the higher tire pressure shows the soil strength would need to be:

$$55\,psi = c(5.14) \longrightarrow c = 10.7\,psi = \underline{1540\,psf}$$

A small factor of safety is needed for the strengths above to account for the tractive forces to power the loader. Say 1.4 for the F.S., so min. strength is 1,000 psf and the strength may range up to 2,200 psf

Using the lower strength value will provide the most conservative slope stability results.

Slope Stability

Assume a block of soil is placed on the slope as shown on page 1. Vary the fill height & equipment loading to determine when failure occurs.

Actual Interface Friction values are not available for the analysis, since the construction contractor will be responsible for material acquisition. Conservative values taken from manufacturers literature will be used as the minimum acceptable interface friction values. These values will be used in this analysis.

Assumed Interface Friction Values

Geonet to Smooth HDPE = 12°
Geonet to Textured HDPE = 8°
} from phone conversation w/ Eric Read of GSE Lining Technology.
GCL to Textured HDPE = 16° – from Bentomat Direct Shear Testing Summary dated 6/00

Use the 8° value for all geonet/HDPE interfaces.

Use 8° for δ since it is the lowest interface value

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Lining System Stability Analysis

Project No. C10000 4051.00
Computed by: M. Brungard
Checked by: R. Hayes

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Date 10/19/00
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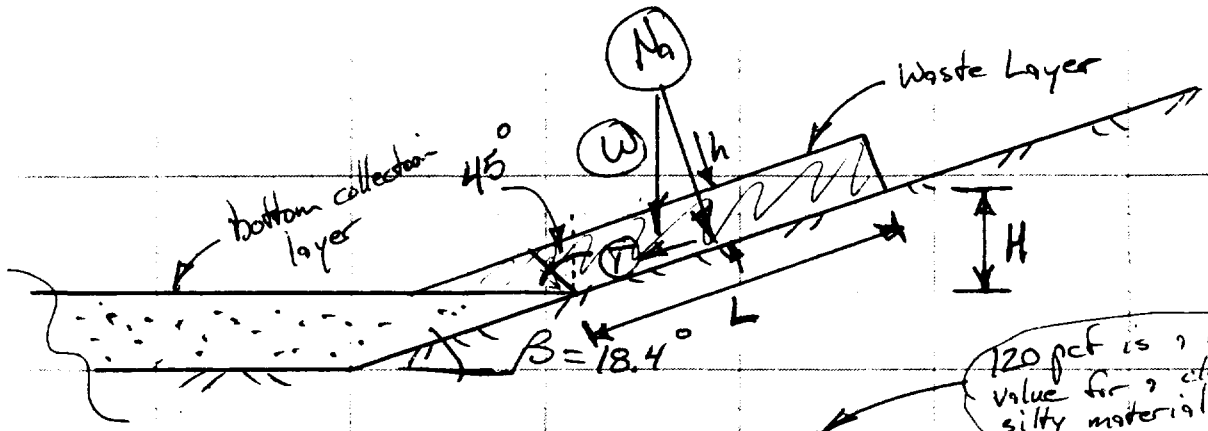
Reference



120 pcf is a high value for a clayey or silty material

$N_a = W\cos\beta$ $\qquad$ $W = hL\gamma$ + Equipment Load

$T = W\sin\beta$ (driving force)

Since the waste material is assumed to fail under undrained conditions, $\phi = 0°$

For $\phi = 0°$, the passive wedge failure angle is $45° + \phi/2 = 45°$ from vertical. The length of the passive failure surface is $h/\cos(45° - 18.4°)$.

The resisting forces are: $N_a \tan\delta$ interface friction

and $c(h/\cos(45-18.4))$ passive wedge

Disregard the friction contribution for passive wedge resistance

where: δ = interface friction angle
c = waste material cohesion.

$$F.S. = \frac{\text{resisting forces}}{\text{driving forces}} = \frac{N_a \tan\delta + c(h/\cos(45-18.4))}{W\sin\beta}$$

evaluate $h = 2'$, $L = 15'$, Eqpt. = 0 lbs

$N_a = hL\gamma\cos\beta = 2'(15')\,120\text{pcf}\,(\cos 18.4) = 3415$ lbs/ft
$T = hL\gamma\sin\beta = 2'(15')\,120\text{pcf}\,(\sin 18.4) = 1136$ lbs/ft
ok $\rightarrow$ $h/\cos(45-18.4) = 2'/\cos 26.6° = 2.22'$

$$F.S. = \frac{3415\tan 8° + 1000\text{ psf}\,(2.22')}{1136} = \frac{2700}{1136} = 2.37$$

OK

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: Lining System Stability Analysis

Project No. CI 00004051.00
Computed by: M. Brungard
Checked by: K. Hayden

Page ___ of ___
Sheet 4 of 6
Date 10/19/00
Date 10/26/00
Reference

if the equipment load is increased to 10,000 lbs/ft, the F.S. is

$$\frac{(10000+3600)\cos 18.4 \tan 8 + 1000\,psf\,(2.22')}{(10000+3600)\sin 18.4} = \frac{4033\ lbs/ft}{4292\ lbs/ft} = 0.94$$

Fails

the max equipment loading is 8500 lbs/ft for F.S. = 1.0

Assuming the equipment width is 8' → the total equipment weight is 68,000 lbs

evaluate $h = 3'$, $L = 15'$, $Eqpt = 0$ lbs/ft

$$F.S. = \frac{5400\cos 18.4 \tan 8 + 1000\,psf\,(3.33')}{5400 \sin 18.4} = \frac{4050\ lbs/ft}{1704\ lbs/ft} =$$

$= 2.37$ OK

This result indicates the F.S. is insensitive to layer thickness

evaluate $h = 2'$, $L = 25'$, $Eqpt = 0$ lbs/ft

$$F.S. = \frac{6000\cos 18.4 \tan 8 + 1000\,psf\,(2.22')}{6000 \sin 18.4} = \frac{3020\ lbs/ft}{1893\ lbs/ft}$$

$= 1.59$ OK

This result indicates that the F.S. is sensitive to layer length up the slope. Considering the length, equipment would have to be on the slope to place fill. Check

The max equipment loading is about 6,250 lbs/ft or ≈ 50,000 lbs

* This is marginal, especially if dynamic loadings are added. The layer length cannot be extended up the slope.

URS Greiner Woodward Clyde

Page ___ of ___

Job: Solutia Sauget | Project No. C100004051.00 | Sheet 5 of 6

Description: Lining System Stability Analysis | Computed by: M. Brungard | Date: 10/19/00

Checked by: R. Hayden | Date: 10/25/00

Reference

Evaluate the effect of having the waste strength lower than predicted. The waste pushed onto the side slopes may be slightly looser than the wastes placed on the bottom areas.

Assume $c = 500$ psf

evaluate: $h = 2'$, $L = 15'$, $E_{qpt} = 0$ lbs/ft

$$\frac{3600 \cos 18.4^\circ \tan 8^\circ + 500(2.22')}{3600 \sin 18.4} = \frac{1590 \text{ lb/ft}}{1136 \text{ lb/ft}} = 1.40$$

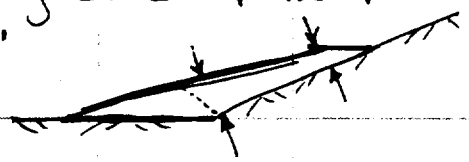
OK

the max. equipment load is about 2800 lbs/ft

or 22,400 lbs

The result above shows that even poorly placed wastes will be stable when placed less than about 5 feet (vertically) or 15 feet (horizontally) up the slope. The actual limit of placement will probably be less than this. The specification for waste placement should prohibit equipment operation on the slope's waste veneer. This will ensure stable slope conditions.

Since the passive wedge resistance is directly proportional to the layer thickness, the F.S. will increase further if the base thickness is greater than the thickness at the top of the layer.



Summary

By using operational constraints during construction, the lining system stability will be maintained. Incrementally raising the wastes on the slopes will ensure that no lining system movement will occur.

Since the lowest interface friction values are on either side of the primary lining, the GCL/HDPE interface will not be stressed.

Access into the cell will be via 6:1 reinforced ramps that are designed to prevent the lining system being loaded in tension.

Sauget Lining System Stability Analysis

6 of 6

10/19/00

TIRE PRESSURES

844G, 544G TC

Tire Size	Type	Ply Rating	Operating Pressure* kPa	bar	psi
14 x 24	G2	10	300	3.8	55
15.5 x 25	L2	12	380	3.8	55
15.5R x 25	L2 or L3 Equiv	(1) Star	**Front 415	4.1	60
			**Rear 205	2.0	30
			Rear, alternate 310	3.1	45
17.5 x 25	L2	12	345	3.4	50
17.5 x 25	L3	12	345	3.4	50
17.5R x 25	L2 or L3 Equiv	(1) Star	**Front 345	3.4	50
			**Rear 170	1.7	25
			Rear, alternate 275	2.8	40
20.5 x 25	L2	12	275	2.8	40
20.5 x 25	L3	12	275	2.8	40
20.5 x 25	L3	16	345	3.4	50
20.5R x 25	L2 or L3 Equiv	(1) Star	**Front 205	2.0	30
			**Rear 170	1.7	25
			Rear, alternate 205	2.0	30
23.1 x 26	LS-2	10	140	1.4	20
28L x 26	LS-2	14	170	1.7	25

*Shipping pressure may vary from operating pressure.

**These radial tire pressures are recommended for optimum traction and tire wear under typical conditions. If a higher rear tire pressure is used, it should not exceed the alternate pressure listed.

TX,55,JC240 -10-29NOV94

To Martin
From Jim

244 H

4. Turn on air supply. Stand to front or rear of tire when you add air to tire.

Tire Size	Type	Ply Rating	Cold Tire kPa	Inflation (bar)	Pressure (psi)
17.5/65 - 20	L2	10	200-230	(2-2.3)	29-34

ATTACHMENT 11

CQA MANUAL SHEAR BOX TESTING

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the Geosynthetic CQA Consultant based on a review of all roll information including quality control documentation manufacturing records.

2.2.2 Liner System Shear Box Testing

Prior to acceptance by the Geosynthetic CQA Consultant or the Construction Manager, the Contractor shall submit information documenting the interface friction values of the selected geosynthetics.

The Construction Manager will review the documentation for conformance with the requirements of the design. This conformance test shall be performed in accordance with the requirements of the Specification.

2.2.3 Test Results

All conformance test results shall be reviewed and by the Geosynthetic CQA Consultant prior to the deployment of the geomembrane. The Geosynthetic CQA Consultant shall examine all results from laboratory conformance testing and shall report any nonconformance to the Construction Manager. The Geosynthetic CQA Consultant shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications. Based upon the recommendation of the Geosynthetic CQA Consultant, the Construction Manager shall accept or reject the geomembrane.

If the Manufacturer has reason to believe that failing tests may be the result of Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different Solutia approved Geosynthetic QALs at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to approval of the Construction Manager.

If a test result is in nonconformance, all material from the lot represented by the failed test should be considered out of specification and rejected. Alternatively, at the option of the Construction Manager, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specifications (note that this procedure is valid only when rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

ATTACHMENT 12

GCL LOAD CALCULATION

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: GCL Loading Calculations

Project No. C10004051.00
Computed by: M. Brungard
Checked by: R. Hayton

Page ___ of ___
Sheet 1 of 6
Date 11/2/00
Date 11/3/00
Reference

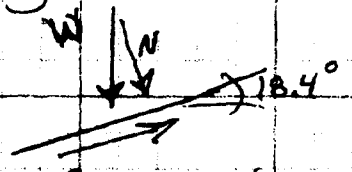
Purpose: Calculate the loading placed on the Geosynthetic Clay Lining (GCL) and evaluate the stability & stresses on the GCL.

Stresses During Filling:

Similar calculations were performed by M. Brungard on 10/27/00 titled "Lining System Tensile Stresses". Those calculations

A worst case evaluation of the allowable loads on the GCL was calculated by assuming a weight of soil was able to transmit the lateral loading via a 30° interface friction between the secondary HDPE lining and GCL. This assumes a textured HDPE lining.

The internal shear stress of 500 psf for the GCL was the limiting value in the equation.



$\tau = 500$ psf

$\tau = W \cos 18.4° \tan 30°$

$500 \text{ psf} = W \cos 18.4° \tan 30°$

$W = \underline{912 \text{ psf}}$

This is equivalent to about 7.5 feet of fill

$\frac{912 \text{ psf}}{120 \text{ pcf}} = \underline{7.5'}$

This fill height is specifically prohibited by the waste filling plan.

The interface friction between the GCL and underlying soil is unknown, but a worst case value has been selected from a set of 23 testing results published by Cetco in June '00. The general minimum value from these tests was about 15°. This is for residual strength.

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: GCL Loading Calculations

Project No. C100041051.00
Computed by: M. Brungardt
Checked by: R. Hayden

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Date 11/2/00
Date 11/3/00
Reference

The maximum fill height when the GCL/soil interface controls is:

Driving Force = $W \sin 18.4^\circ (L)$

Resisting Force = $W \cos 18.4 \tan 15 (L)$ + Tension in GCL

set Driving Force = Resisting Force i.e. F.S. = 1.0

$W \sin 18.4 (L) = W \cos 18.4 \tan 15 (L)$ + Tension

$W (0.315)(L) = W (0.949)(0.268)(L)$ + Tension

$W (0.060)(L) =$ Tension

The minimum tensile strength for GCL materials are 90 lbs/ft (Bentomat ST)

$$W = \frac{\text{Tension}}{0.060(L)} = \frac{90 \text{ lbs/ft}}{0.060(L)} = 1500 \text{ lbs/ft}$$

The filling plan limits the fill height to about 5' and (L) is therefore about 3 × 5' = 15'

$$W = \frac{1500 \text{ lb/ft}}{15'} = 100 \text{ lbs/ft}^2$$

This is equivalent to about $\frac{100 \text{ psf}}{120 \text{ pcf}} = 0.83'$

not much

The maximum tensile strength for GCL materials are 150 lbs/ft (Bentomat DN)

$$W = \frac{150 \text{ lbs/ft}}{0.060(15)} = 166 \text{ psf}$$

This is equivalent to about $\frac{166 \text{ psf}}{120 \text{ pcf}} = 1.4'$

still not much

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: GCL Loading Calculations
Project No. C10000405.00
Computed by: M. Brungard
Checked by: R. Hayden
Page ___ of ___
Sheet 3 of 6
Date 11/2/00
Date 11/3/00
Reference

Stresses during Filling Summary:

The analysis shows that the GCL will not withstand much tension from the soil loading when the soil load is assumed to fully act on the secondary HDPE lining and GCL. Using the higher strength GCL product does not improve the situation much.

Fortunately, the combination of the passive soil wedge resistance and the limiting interface friction between the overlying geonets on either HDPE lining prevents the driving force from being applied to the GCL/soil interface. The contribution of the passive soil wedge was demonstrated in the "Lining System Stability Analysis" by M. Brungard dated 10/19/00.

The passive wedge contribution is quantified in the following equation

$$P = c\left(h / \cos(45^\circ - 18.4^\circ)\right) \quad \text{assumes } \phi = 0^\circ \text{ (undrained)}$$

where: c = waste undrained shear strength (psf)
h = thickness of waste veneer (ft)

For equipment trafficability on the waste mass, the waste's undrained shear strength must be at least 700 psf. (Taken from "Lining System Stability Analysis")

The referenced calculation also proved that the waste veneer thickness does not appreciably affect the slope stability. Assume (h) = 3 feet thick.

If $h = 3'$, then $w = h \times 120$ pcf = 360 psf (assumed moist unit weight for wastes)

Driving Force = $(w)\sin 18.4\,(L)$ = 360 psf $(\sin 18.4)$ 15' = 1705 lbs/ft

Resisting Force = $(w)\cos 18.4\,(L)\tan 15^\circ$ + Tension + $c\left(\frac{h}{\cos(45-18.4)}\right)$

= 360 psf $\cos 18.4\,(15')\tan 15^\circ$ + Tension + $700\left(\frac{3}{\cos 26.6}\right)$

= 1373 lbs/ft + Tension + 2348 lbs/ft

= 3721 lbs/ft + Tension

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Job: Solutia Sauget
Description: GCL Loading Calculations
Project No. C100004051.00
Computed by: M. Brungard
Checked by: R. Hayden
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Sheet 4 of 6
Date 11/2/00
Date 11/3/00
Reference

Setting Driving Force = Resisting Force

1705 lbs/ft = 3721 lbs/ft + Tension

-2016 lbs/ft = Tension

The negative result shows that no tension will be produced in the GCL.

* The GCL will not be loaded by the limited waste filling procedures.

GCL Anchorage:

Since the GCL will not be loaded in tension, the GCL anchorage is not critical. Any amount of embedment within the anchor trench will be sufficient. The minimum GCL/soil interface friction value will be set high enough to equal the max. friction expected for the Geonet/HDPE interface.

Stresses After Filling:

The "Lining System Tensile Stresses" calculations by M. Brungard dated 10/20/00 proved that the waste mass cannot move down the cell slopes after the cell is filled. The compacted wastes will not laterally deflect or allow lateral movement. The slope stability for the waste mass over the slopes approaches infinity as the cell is filled. The driving force is much less than the resisting force.

Minimum GCL Interface Friction:

As shown above, the limited waste filling and filled cell both produce no stresses on the lining system. To limit the possibility of GCL movement during an inadvertant over-stress during filling, the GCL interface friction values must be greater than the maximum interface friction for any of the overlying lining components. The maximum interface friction for Geonet to Smooth HDPE is about 16° per Eric Reed of GSE Lining Technologies.

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: GCL Loading Calculations
Project No. C100004051.00
Computed by: M. Brungard
Checked by: R. Hayden
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Sheet 5 of 6
Date 11/2/00
Date 11/3/00

Reference

Based on 16° maximum interface friction, the minimum HDPE/GCL or GCL/soil must be greater than this value.

$$\text{Soil/GCL } \delta_{min} = \underline{\underline{16^\circ}}$$

The HDPE/GCL will require a textured interface.

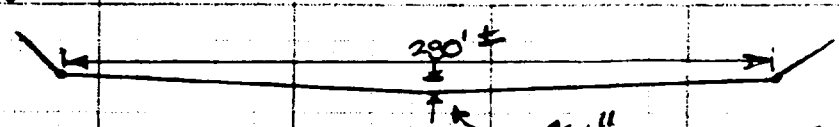
Information provided by Cetco dated 6/00 with 64 testing results for Hydrated GCL w/ textured HDPE lining, shows that 10° to 15° (peak) was the minimum interface friction observed. Most values were 20° to 25° (peak). The tests show that the "normal" test stress levels were frequently over 50 psi. The maximum normal stress for this landfill is about 17 psi assuming 20' of soil or waste at 125 pcf.

Interface friction testing at lower normal stress ranges will provide higher friction values. The 10° to 15° (peak) results above are not applicable to this landfill configuration. The interface friction testing should not exceed a normal stress of about 20 psi in order to better model the landfill conditions expected.

It appears that a HDPE/GCL interface friction of at least $\underline{\underline{16^\circ}}$ should be achievable.

$$\text{HDPE/GCL } \delta_{min} = \underline{\underline{16^\circ}}$$

Settlement Loading: The settlement calculations for the landfill show that the magnitude is small and differential settlement is low. The strain in the lining system components was estimated as:



$$H = \sqrt{140^2 + \left(\tfrac{1}{12}\right)^2} = 140.00002 \qquad \varepsilon = \frac{0.00002}{140} \approx 1.7^{-7}$$

URS Greiner Woodward Clyde

Job: Solutia Sauget
Description: GCL Loading Calculations
Project No. 10000 4051.00
Computed by: M. Brunyard
Checked by: [illegible]
Page ___ of ___
Sheet 6 of 6
Date: 11/2/00
Date: 11/3/00

Reference

The strain in the GCL of 1.7×10^{-7} is insignificant since the GCL components are reported to have strains of 20 percent or more at rupture. The GCL will not be strained or stressed due to settlement.

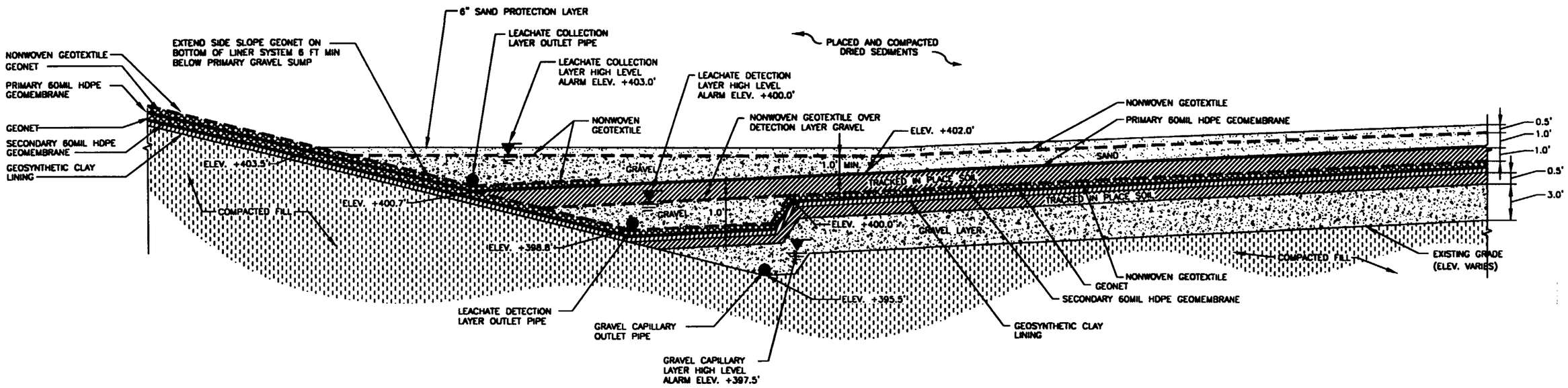
Stresses After Filling Summary:

The calculations show that the GCL will not be stressed after filling provided that the minimum interface friction values of 16° are provided. The preconstruction material testing will have to prove this minimum value, for both the HDPE/GCL & GCL/Soil interfaces.

The settlement magnitude is very limited for this facility and the resulting strain in the GCL is insignificant compared to the strain capacity of any GCL component. No stresses due to settlement are anticipated.

ATTACHMENT 13

LEACHATE COLLECTION SYSTEM DRAWINGS



A COLLECTION SUMP SECTION

NTS

NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

REV	DESCRIPTION OF REVISION	BY	DATE

DESIGNED BY: M. BRUNDARD
DRAWN BY: G. BRADFORD
CHECKED BY: G. WANTLAND
PROJECT MANAGER: G. WANTLAND
DATE: MAY 19, 2000

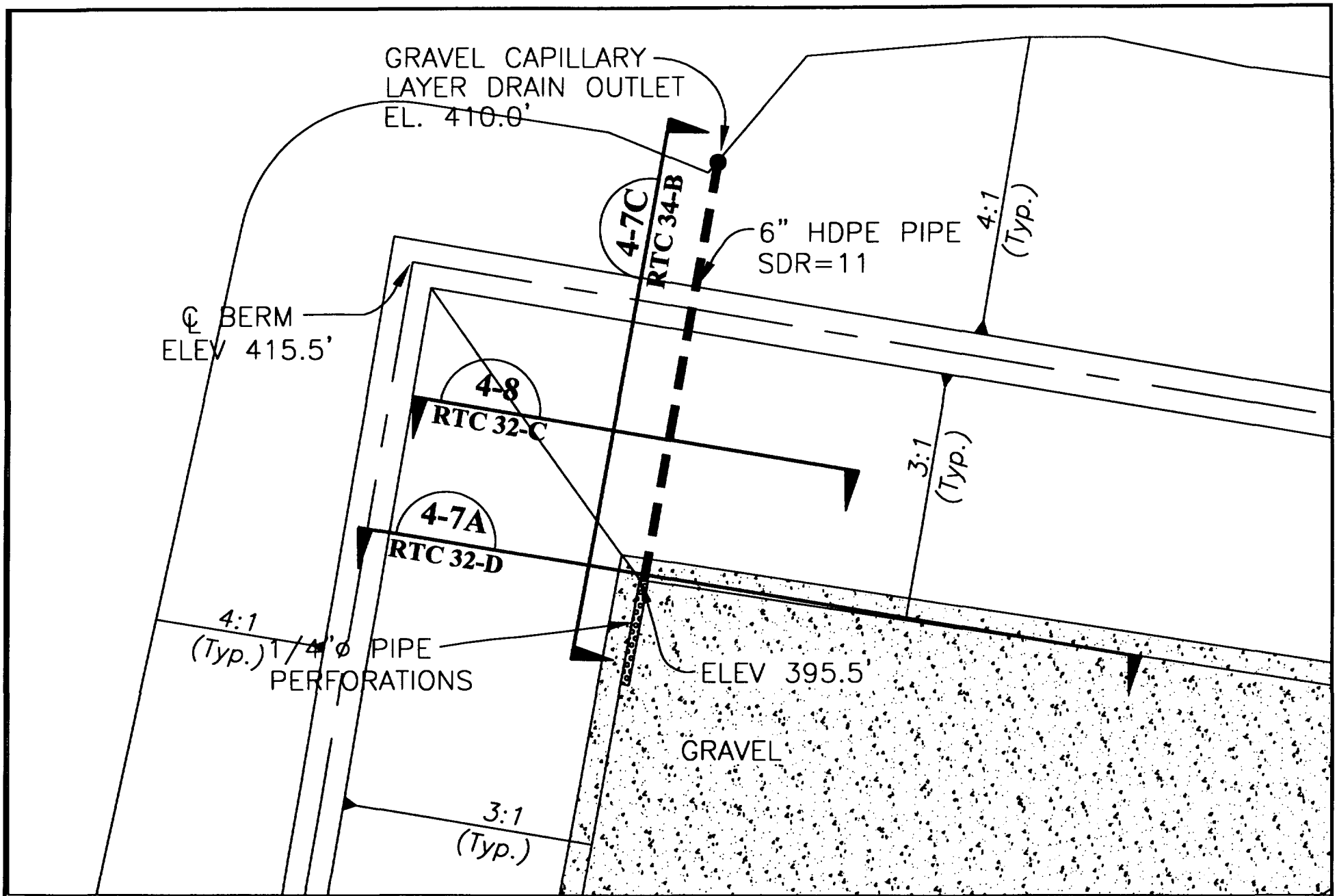
URS Greiner Woodward Clyde
7650 WEST COURTNEY CAMPBELL CSWY.
TAMPA, FLORIDA 33607-1462
TEL: 813.286.1711 FAX: 813.287.8591

SOLUTIA INC.
SAUGET AREA 1
CAHOKIA, ILLINOIS

COLLECTION SUMP SECTION

PROJECT NUMBER
C100003899.00

FIGURE
4-7A



NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC.
SAUGET AREA 1
CAHOKIA, ILLINOIS

URS Greiner Woodward Clyde
7650 WEST COURTNEY CAMPBELL CSWY.
TAMPA, FLORIDA 33607-1462
TEL: 813.286.1711 FAX: 813.287.8591

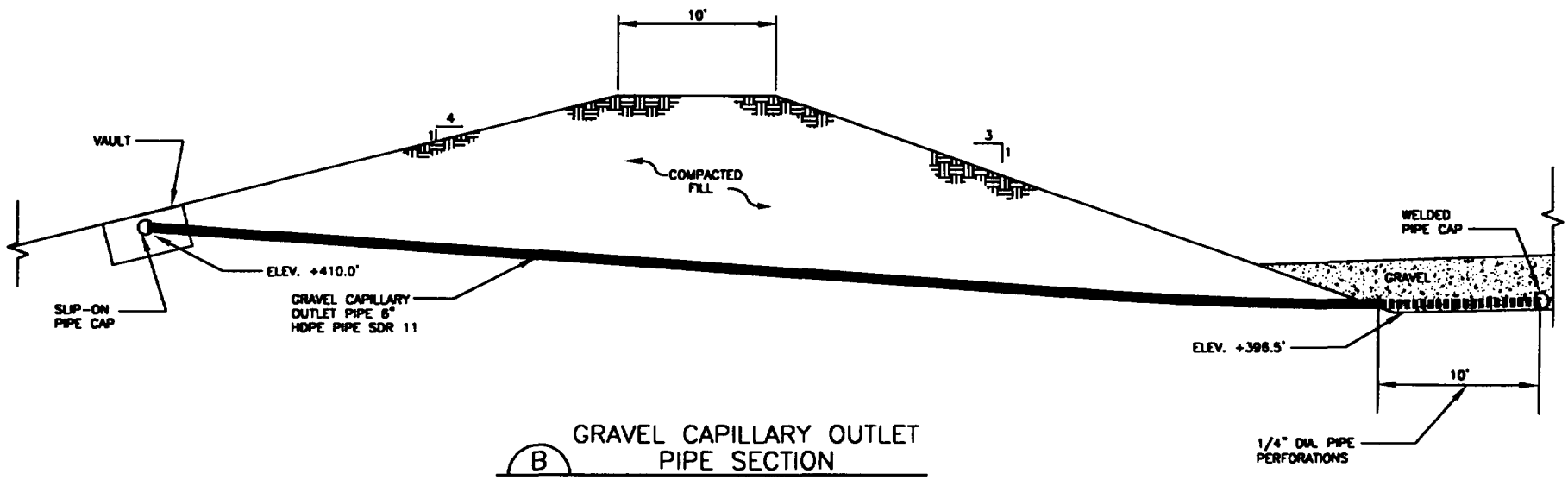
SCALE	DRAWN BY: CRH	DATE: 10/23/00
NTS	CHECKED BY:	DATE:

GRAVEL_PIPE_PLAN.dwg - Layout Fig4-7B

GRAVEL CAPILLARY LAYER
DRAIN OUTLET PLAN

PROJECT NUMBER
C10000405.00

FIGURE NUMBER
4-7B



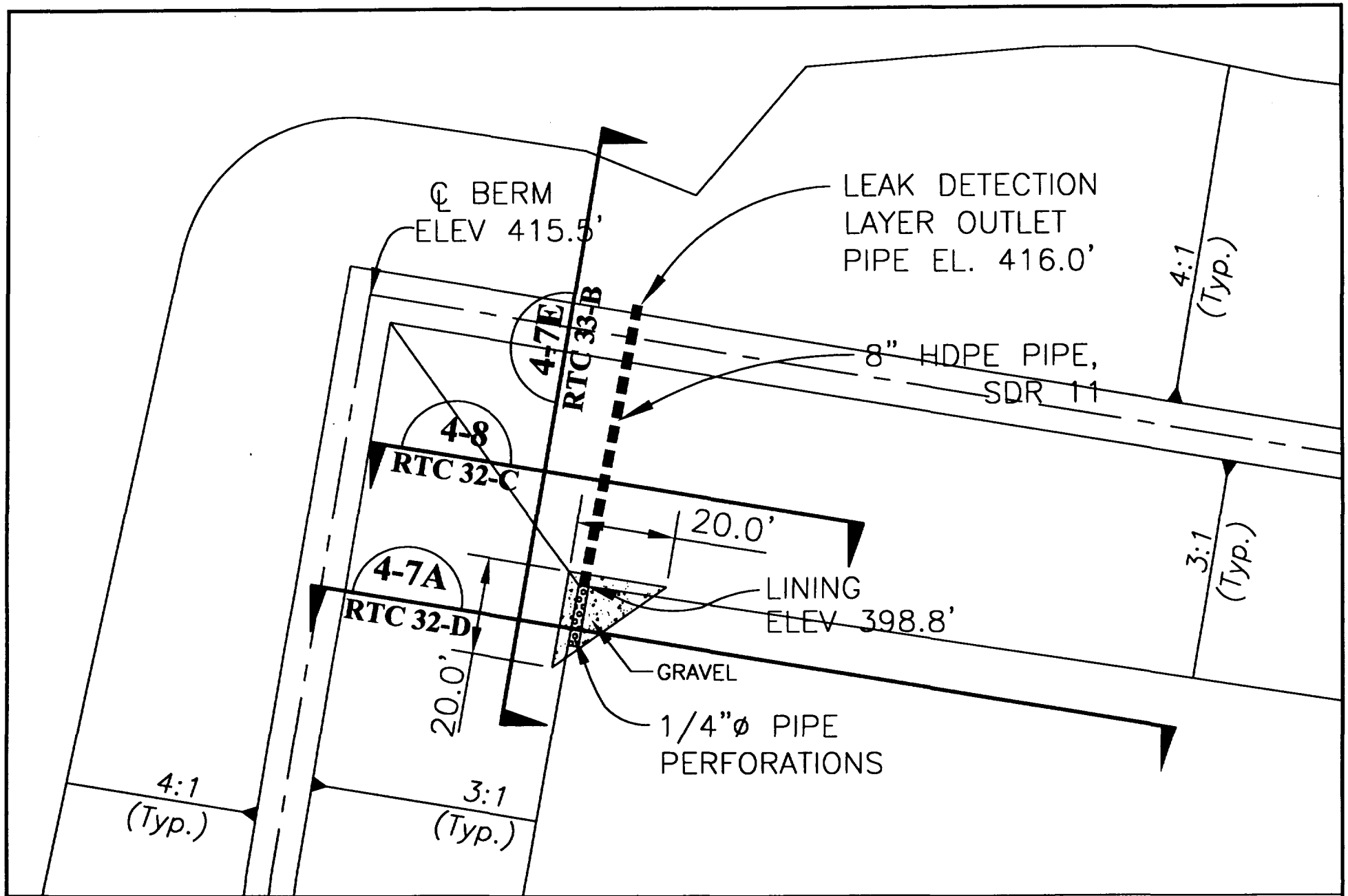
B GRAVEL CAPILLARY OUTLET PIPE SECTION

NTS

NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC. SAUGET AREA 1 CAHOKIA, ILLINOIS	URS Greiner Woodward Clyde 7650 WEST COURTNEY CAMPBELL CSWY. TAMPA, FLORIDA 33607-1462 TEL: 813.286.1711 FAX: 813.287.8591			GRAVEL LAYER CAPILLARY OUTLET PIPE SECTION	PROJECT NUMBER C10000405.00
	SCALE NTS	DRAWN BY: CRH CHECKED BY:	DATE: 10/23/00 DATE:		FIGURE NUMBER 4-7C
	LINER DETAILS_MOD1.dwg - Layout Fig4-7C				



NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC.
SAUGET AREA 1
CAHOKIA, ILLINOIS

URS Greiner Woodward Clyde
7650 WEST COURTNEY CAMPBELL CSWY.
TAMPA, FLORIDA 33607-1462
TEL: 813.286.1711 FAX: 813.287.8581

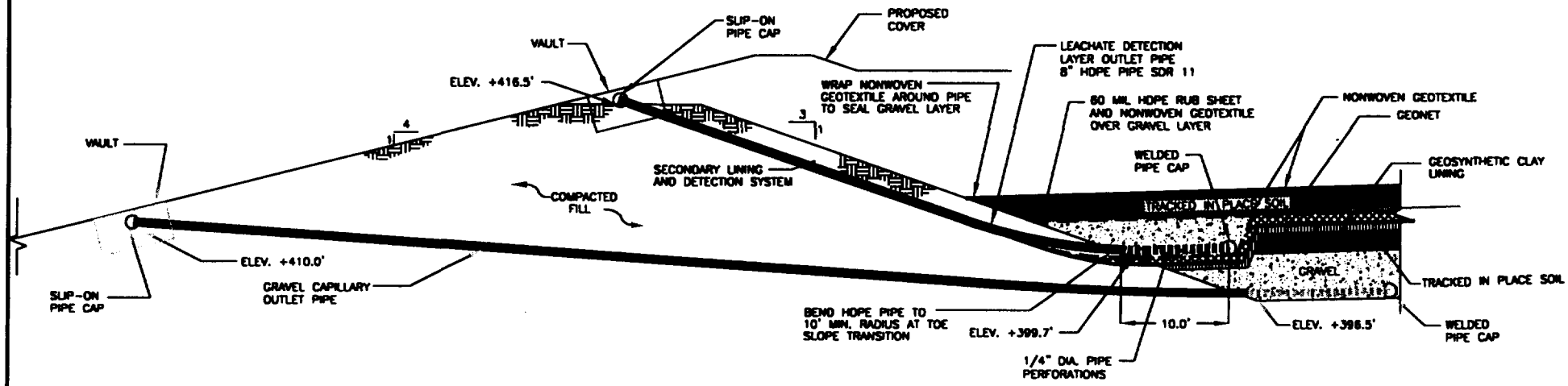
SCALE	DRAWN BY: CRH	DATE: 10/23/00
NTS	CHECKED BY:	DATE:

DETECTION_PIPE_PLAN.dwg – Layout Fig4-7D

LEACHATE DETECTION LAYER
OUTLET PIPE PLAN

PROJECT NUMBER
C10000405100

FIGURE NUMBER
4-7D



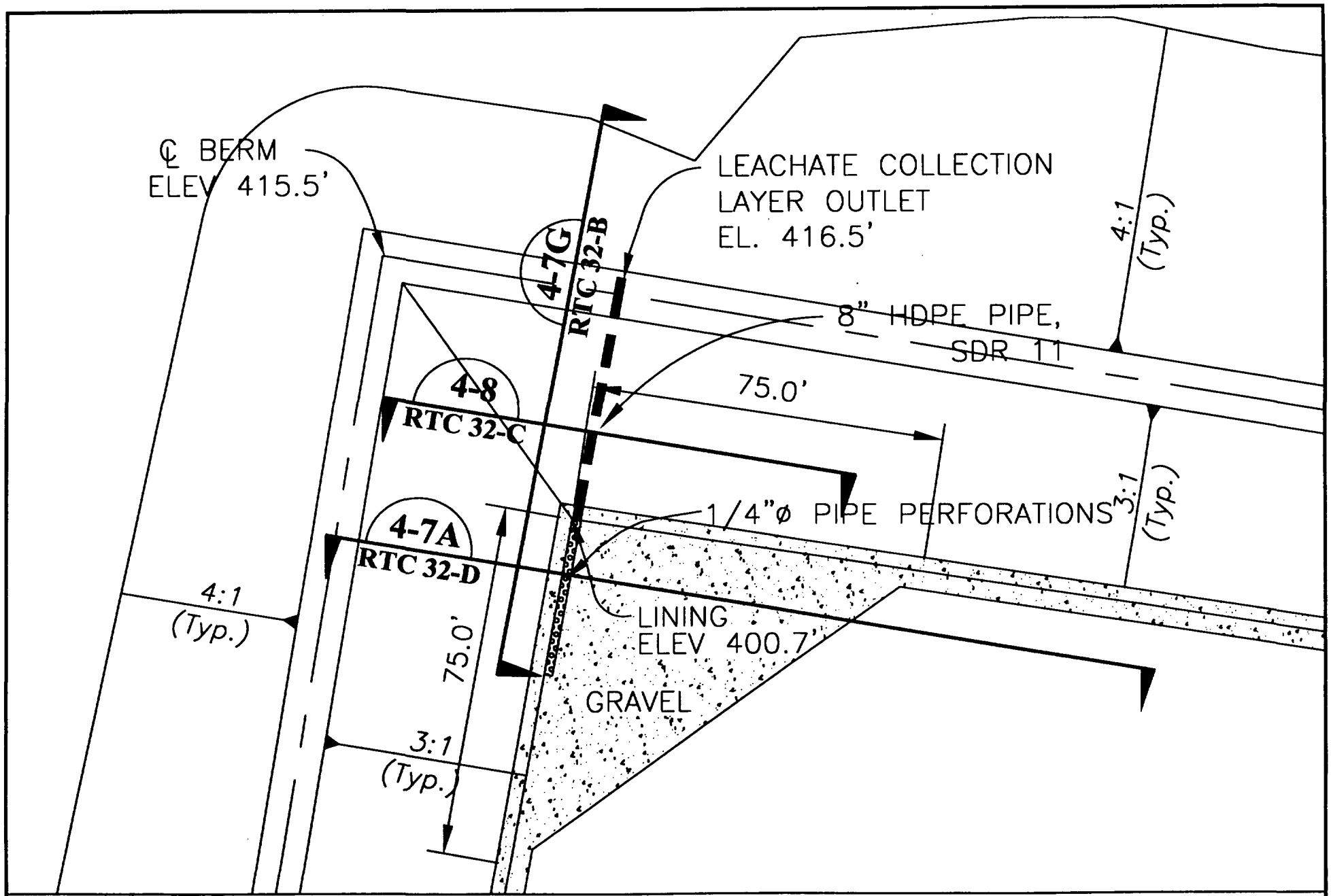
B LEACHATE DETECTION LAYER PIPE SECTION

NTS

NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC. SAUGET AREA 1 CAHOKIA, ILLINOIS	**URS Greiner Woodward Clyde** 7650 WEST COURTNEY CAMPBELL CSWY. TAMPA, FLORIDA 33607-1462 TEL: 813.286.1711 FAX: 813.287.8581			LEACHATE DETECTION LAYER OUTLET PIPE SECTION	PROJECT NUMBER C10000405.00
	SCALE NTS	DRAWN BY: CRH	DATE: 10/23/00		FIGURE NUMBER 4-7E
		CHECKED BY:	DATE:		
	LINER DETAILS_MOD1.dwg - Layout Fig4-7E				



NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC.
SAUGET AREA 1
CAHOKIA, ILLINOIS

URS Greiner Woodward Clyde
7650 WEST COURTNEY CAMPBELL CSWY.
TAMPA, FLORIDA 33607-1462
TEL: 813.286.1711 FAX: 813.287.8591

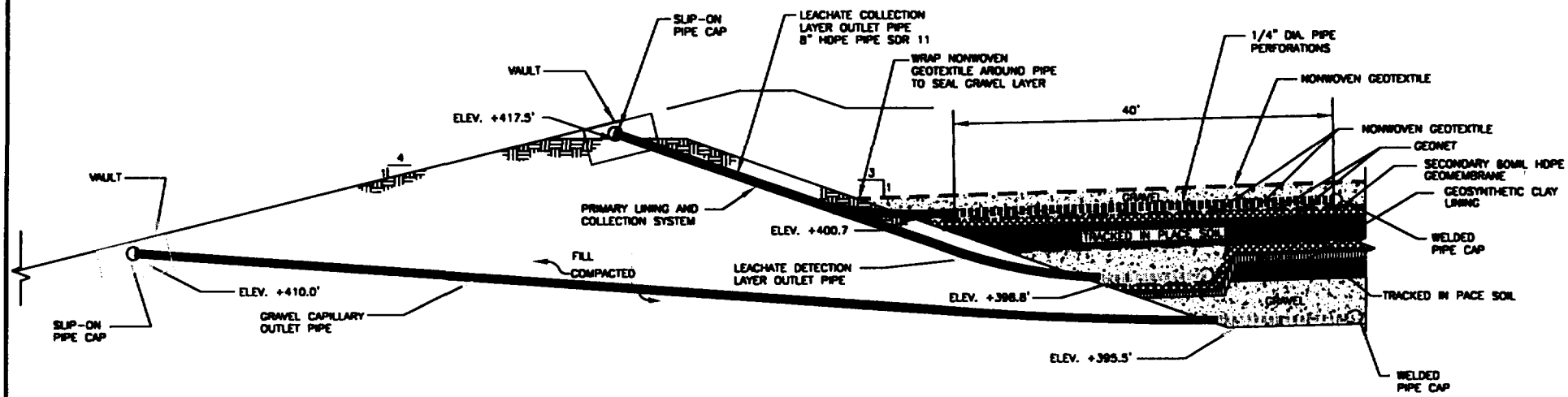
SCALE	DRAWN BY: CRH	DATE: 10/23/00
NTS	CHECKED BY:	DATE:

COLLECTION_PIPE_PLAN.dwg – Layout Fig4-7F

LEACHATE COLLECTION LAYER
OUTLET PIPE PLAN

PROJECT NUMBER
C100004051.00

FIGURE NUMBER
4-7F



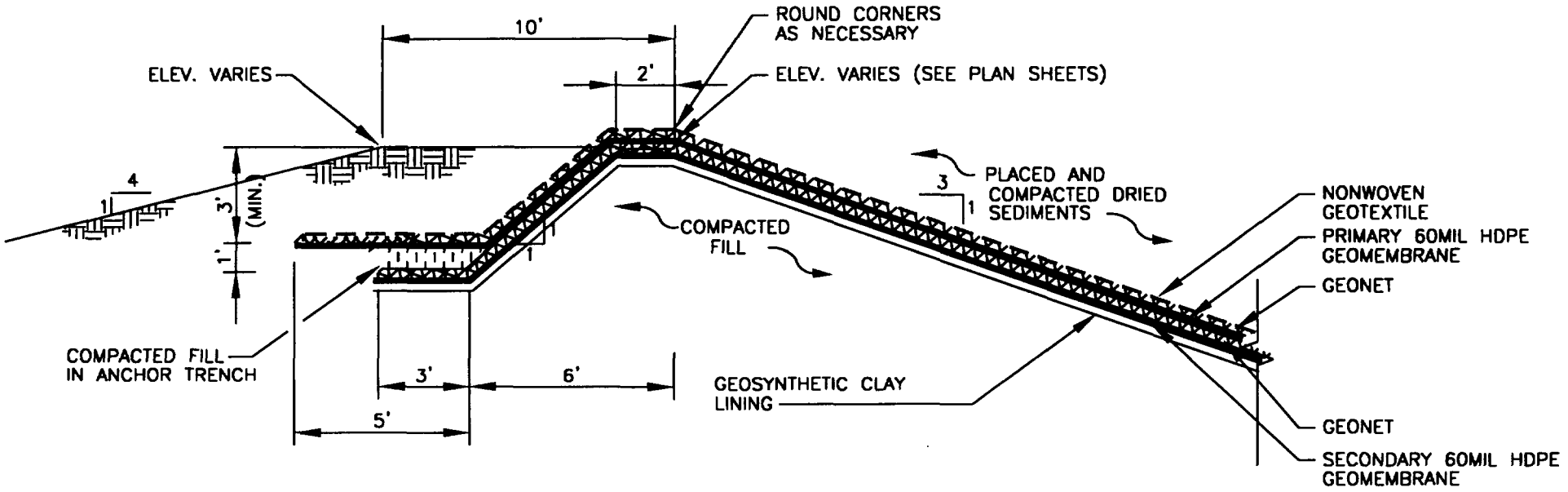
B LEACHATE COLLECTION LAYER PIPE SECTION

NTS

NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC. SAUGET AREA 1 CAHOKIA, ILLINOIS	**URS Greiner Woodward Clyde** 7650 WEST COURTNEY CAMPBELL CSWY. TAMPA, FLORIDA 33607-1462 TEL: 813.286.1711 FAX: 813.287.8591			LEACHATE COLLECTION LAYER OUTLET PIPE SECTION	PROJECT NUMBER C100004051.00
	SCALE NTS	DRAWN BY: CRH CHECKED BY:	DATE: 10/23/00 DATE:		FIGURE NUMBER 4-7G
	LINER DETAILS_MOD1.dwg - Layout Fig4-7G				



D PRIMARY LINER SYSTEM ANCHOR DETAIL

APPROX. SCALE: 1" = 5'

NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC. SAUGET AREA 1 CAHOKIA, ILLINOIS	URS Greiner Woodward Clyde 7650 WEST COURTNEY CAMPBELL CSWY. TAMPA, FLORIDA 33607-1462 TEL: 813.286.1711 FAX: 813.287.8591			PRIMARY LINER SYSTEM ANCHOR DETAIL	PROJECT NUMBER C10000405.00
	SCALE NTS	DRAWN BY: CRH CHECKED BY:	DATE: 10/23/00 DATE:		FIGURE NUMBER 4-7H
	LINER DETAILS_MOD1.dwg - Layout Fig4-7H				

ATTACHMENT 14

REVISED SPECIFICATION 02242

SECTION 02242

GEOTEXTILE

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Storage, handling, and installation of geotextile.

1.2 REFERENCES

A. ASTM D1117 - Methods of Testing Nonwoven Fabrics.

B. ASTM D5199 - Method for Measuring Thickness of Textile Materials.

C. ASTM D5261 - Test Method for Mass Per Unit Area (Weight) of Nonwoven Fabric.

D. ASTM D3786 - Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method.

E. ASTM D4439 - Terminology for Geosynthetics.

F. ASTM D4491 - Test Methods for Water Permeability of Geotextiles by Permittivity.

G. ASTM D4533 - Test Method for Trapezoid Tearing Strength of Geotextiles.

H. ASTM D4632 - Test Methods for Breaking Load and Elongation of Geotextiles (Grab Method).

I. ASTM D4751 - Test Method for Determining Apparent Opening Size of a Geotextile.

J. ASTM D4833 - Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products.

K. ASTM D4873 - Standard Guide for Identification, Storage and Handling of Geotextiles.

1.3 SUBMITTALS

A. General

1. Contractor shall submit qualification information on the Manufacturer, Installer and Geosynthetic Testing Laboratory.

2. Contractor shall submit prequalification data on each geosynthetic material to the Construction Manager for approval prior to procurement, transport, stockpiling or use.

3. Contractor shall submit results of all quality control data and information to the Construction Manager within 1 work day of receipt.

4. Contractor shall submit all observations and documentation generated by its quality control personnel daily for the current day's activities.

5. Contractor shall submit results of all field surveys and documentation within 1 day of generation including copies of data, field books and notes. Copies of survey information signed and sealed by an Illinois licensed surveyor shall be submitted within 1 day of receipt.

B. Manufacturer

The Manufacturer shall submit the following prior to installing geosynthetics:

1. A list of material properties including certified test results attached to samples of the proposed geosynthetic material.

2. The origin and identification of the resin used to manufacture the product.

3. Submit all quality control documentation required by these Specifications prior to installation.

C. Installer

The Installer shall submit the following prior to installation:

1. Resume of superintendent to be assigned to the project including dates/duration of employment.

2. A list of personnel to be performing field seaming operations with pertinent experience information.

3. All geosynthetic quality control certificates.

D. Contractor shall submit all material and workmanship warranties for the geotextile installation.

1.4 TESTING

A. Contractor shall retain the services of an independent testing laboratory. At a minimum, Contractor shall be responsible for providing the following quality control information:

1. Compliance testing for installed geosynthetics.

2. Quality control testing during construction.

B. The Contractor shall inspect and ensure all work is in conformance with these Specifications.

C. Contractor shall inform the Construction Manager prior to conducting all quality control testing to allow oversight.

D. Contractor shall submit all quality control data (both pre-construction and construction) with a cover letter signed and sealed by a Illinois registered professional engineer indicating the requirements of the Specifications were achieved and the data is representative of the material tested.

PART 2 PRODUCTS

2.1 GENERAL

A. Contractor shall furnish materials whose "Minimum Average Roll Values" (MARV), as defined by the Federal Highway Administration (FHWA), meet or exceed the criteria listed below.

B. Products shall be comprised of polymeric yarns of fibers oriented into a stable network which retains its relative structure during handling, placement and long-term service.

2.2 GEOTEXTILE

A. For filtration, cushion, separation and protection purposes, the geotextile shall consist of staple fiber needle-punched, nonwoven, polypropylene fabric where shown on the Drawings. The following minimum fabric properties are required:

GEOTEXTILE PROPERTIES			
Property	**Standard**	**MARV**	**Units**
Mass per Area	ASTM D 5261	16	oz/yd^2
Grab Strength	ASTM D 4632	380	lbs
Elongation	ASTM D 4632	60	%
AOS	ASTM D 4751	100	U.S. Sieve
Permittivity	ASTM D 4491	0.7	sec^{-1}
Trapezoidal Tear Strength	ASTM D 4533	145	lbs
Burst Strength	ASTM D 3786	750	psi
Puncture Strength	ASTM D 4833	240	lbs

2.3 MANUFACTURERS

A. Synthetic Industries

B. Approved Equal

PART 3 EXECUTION

3.1 INSTALLATION

A. Geotextile storage, handling and installation shall be the responsibility of the Contractor. Any damaged or unacceptable material shall be replaced at no additional cost to the Owner. During shipment and storage, the geotextile shall be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions. To that effect, geotextile rolls shall be shipped and stored in relatively opaque and watertight wrappings.

B. Geotextile rolls shall be handled in such a way that they are not damaged.

C. Geotextile shall be securely anchored and then rolled in such a manner as to continually keep the geotextile sheet in tension.

D. Geotextile shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during placement and shall remain until replaced with cover material.

E. If white colored geotextile is used, precautions shall be taken against "snow blindness" of personnel.

F. Contractor shall take any necessary precautions to prevent damage to underlying layers during placement of the geotextile.

G. Geotextile shall not be exposed to precipitation prior to being installed. Wrappings protecting geotextile rolls shall be removed less than one hour prior to unrolling the geotextile. After the wrapping has been removed, the geotextile shall not be exposed to direct sunlight for more than 15 days (unless otherwise approved by the Construction Manager).

H. Contractor shall seam geotextile rolls by either overlapping, sewing or other methods approved by the Construction Manager.

I. At a minimum, the Contractor shall use the following seaming techniques at the specified locations:

Location	Method of Seaming
• Side Slopes of Lining System	Sewn
• Over Primary Collection System	Sewn
• Fabric Wrapped Around Sumps and Gravel Drain	Overlapped or sewn
• Beneath Tracked-in-Place Soil	Sewn
• Above Capillary Break Layer	Sewn
• Beneath Cover System Geomembrane	Overlapped or sewn
• Above Cover System Geomembrane	Sewn
• Slopes Steeper Than 10 Percent	Sewn
• Slopes Flatter Than 10 Percent	Overlapped or sewn

J. The geotextile seams not sewn shall be overlapped a minimum of 6 inches.

K. Geotextile seams designated as requiring to be sewn shall be continuously sewn with polymeric thread.

1. The thread shall be capable of supplying a seam strength efficiency of 80 percent of the required tensile strength utilizing a Type 401 two-thread chain stitch with a "J" seam.

2. The seam shall have 8 stitches per inch and the stitches shall be a minimum of 2 inches from the fabric edge.

L. Contractor shall pay particular attention at seams such that no soil material is inadvertently inserted beneath the geotextile.

M. Material placement shall be in the direction of the overlap.

N. Soil materials over the geotextile shall be placed in a manner such that the geotextile is not damaged, minimal slippage of the geotextile or underlying layers occurs, and no excess tensile stresses are present in the geotextile.

O. No construction equipment with ground pressure greater than 5 psi shall operate on slopes.

3.2 REPAIRS

A. Holes or tears in the fabric shall be repaired as follows: A fabric patch made from the same geotextile shall be placed over the hole or tear and sewn to the underlying geotextile. Provide a minimum overlap of 24 inches in all directions. Should any tear exceed 10 percent of the width of the roll, that section of the roll shall be removed and replaced.

3.3 QUALITY CONTROL

A. Visual inspections of shipment and storage activities shall be made by the Construction Manager to assure that the fabric has been protected from ultraviolet light exposure, precipitation or other inundation, and dirt, dust, puncture, cutting or any other damaging or deleterious conditions.

B. Contractor shall designate each roll with a roll number (identification code) which is consistent with the layout plan. The rolls shall be positioned on the site as shown on the approved layout drawings. Instructions on boxes or wrapping containing the geotextile materials shall be followed to assure that rolls are unrolled in the proper direction.

3.4 MATERIAL QUALITY EVALUATION

A. Contractor shall submit an affidavit and/or quality control certificate signed by the manufacturer certifying that the geosynthetic rolls meet or exceed specified requirements to the Construction Manager for approval prior to deployment.

B. Preinstallation material quality evaluation testing shall be performed as follows:

• ASTM D5261	4 per roll
• ASTM D4632	1 per 50,000 ft^2
• ASTM D4751	1 per 50,000 ft^2
• ASTM D4491	1 per 50,000 ft^2
• ASTM D4533	1 per 50,000 ft^2
• ASTM D3786	1 per 100,000 ft^2
• ASTM D4833	1 per 100,000 ft^2

C. Conformance Testing

1. Samples shall be obtained at a frequency of one sample per 50,000 square feet.

2. The Contractor shall obtain samples and forward them to a laboratory designated by the Construction Manager.

3. Tests shall be performed to determine mass per Area (ASTM D5261), Permittivity (ASTM D4491), and Tensile Strength (ASTM D4632).

4. The sample shall be across the entire width of the roll excluding the first three (3) feet (ft), and shall be cut three (3) ft long by width roll.

5. Samples shall be 3 ft long by roll width. Machine direction shall be marked on sample with an arrow.

3.5 PLACEMENT OF EARTHEN MATERIALS OVER GEOTEXTILE

A. The Contractor shall place all earthen materials located on top of geotextile in such a manner as to ensure:

1. No damage of geotextile.

2. Minimal slippage of geotextile on underlying layers.

3. No excess tensile stresses in geotextile.

B. Place materials over geotextile by pushing material out over geotextile ahead of equipment in 12-inch thick minimum lifts.

C. On sideslopes, earthen material placement shall begin at toe of slope and proceed upslope to top of slope.

D. Equipment used to place earthen material over the geotextile shall have a maximum contact pressure of 5 lbs/sq inch on earthen material.

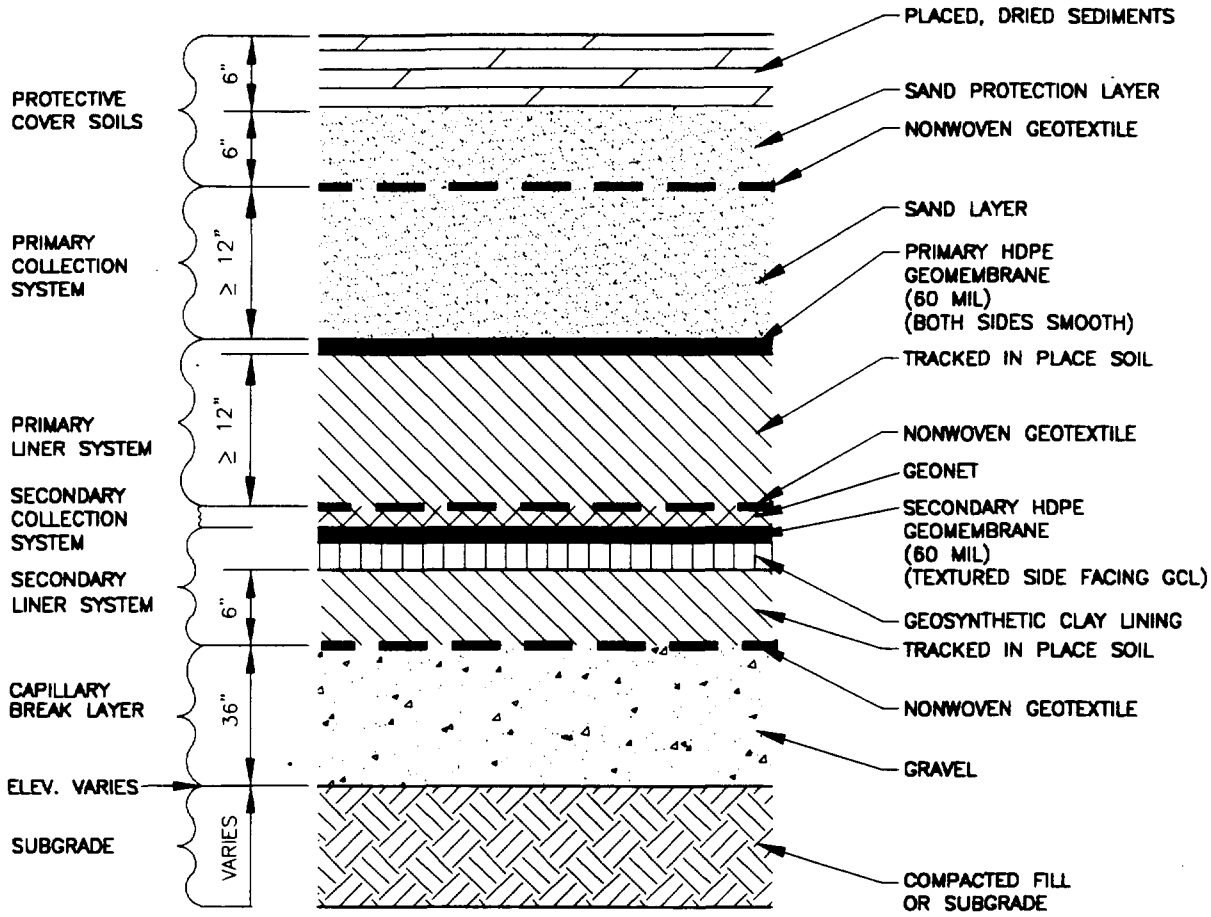
E. Thickness of earthen material over geotextile shall be 12 inches or more before equipment used to place earthen material shall be permitted to cross areas where geotextile has been installed.

F. Thickness of cover material over the top geotextile shall be 2 ft before vehicles with contact pressure greater than 8 lbs/sq inch shall be permitted to cross areas where geotextile has been installed.

END OF SECTION 02242

ATTACHMENT 15

REVISED REPORT FIGURES



A BOTTOM LINER SYSTEM DETAIL

C1.4 | C1.6

N.T.S.

NOTES

1. NOT FOR CONSTRUCTION
2. LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

PREPARED FOR: SOLUTIA	Drawn: R. HAYDEN	PROJECT NAME: SOLUTIA INC. SAUGET AREA 1	FIGURE 4-1
URSGWC JOB NUMBER: C100003899.00	Design: M. BRUNGARD		
URS Greiner Woodward Clyde, A Division of URS Corporation, 7650 W. Courtney Campbell Causeway, Tampa, Florida 33607-1462, Tel: 813.286.1711 Fax: 813.287.8591	Checked: G. WANTLAND	DRAWING TITLE: BOTTOM LINER SYSTEM DETAIL	
	Date: OCT. 30, 2000		

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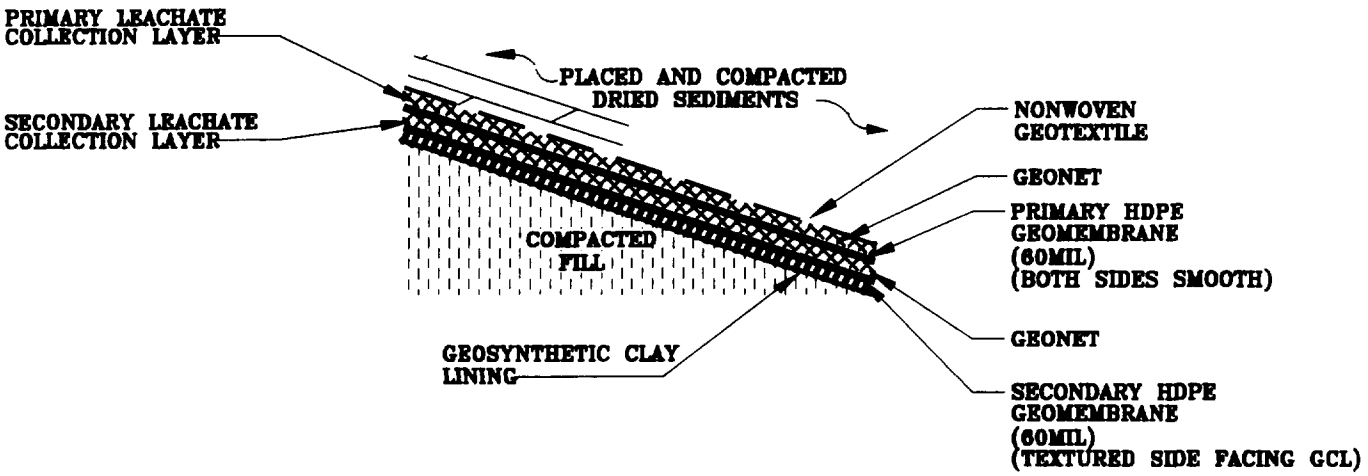

G

C1.4 | C1.6

SIDE SLOPE LINER SYSTEM DETAIL

N.T.S

NOT FOR CONSTRUCTION

PREPARED FOR: SOLUTIA INC.	Drawn: R. HAYDEN	PROJECT NAME: SOLUTIA INC. SAUGET AREA 1	FIGURE 4-2
URSGWC JOB NUMBER: C100004051.00	Design: M. BRUNGARD		
URS Greiner Woodward Clyde, A Division of URS Corporation, 7650 W. Courtney Campbell Causeway, Tampa, Florida 33607-1462, Tel: 813.286.1711 Fax: 813.287.8591	Checked: G. WANTLAND	DRAWING TITLE: SIDE SLOPE LINER SYSTEM DETAIL	
	Date: OCT. 30, 2000		

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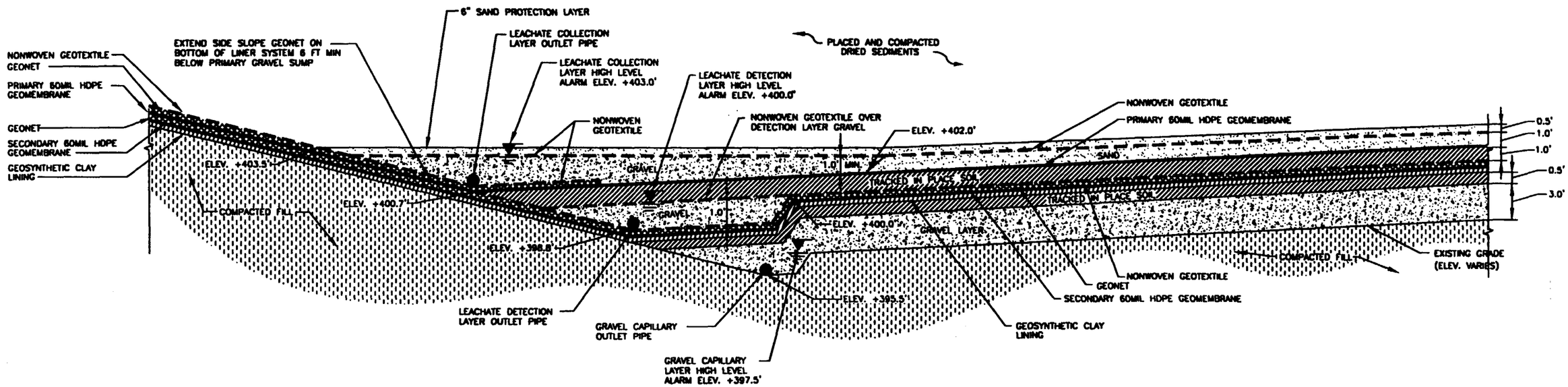


A COLLECTION SUMP SECTION

NTS

NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

REV	DESCRIPTION OF REVISION	BY	DATE

DESIGNED BY: M. BRUNBARD
DRAWN BY: G. BRADFORD
CHECKED BY: G. WANTLAND
PROJECT MANAGER: G. WANTLAND
DATE: MAY 19, 2000

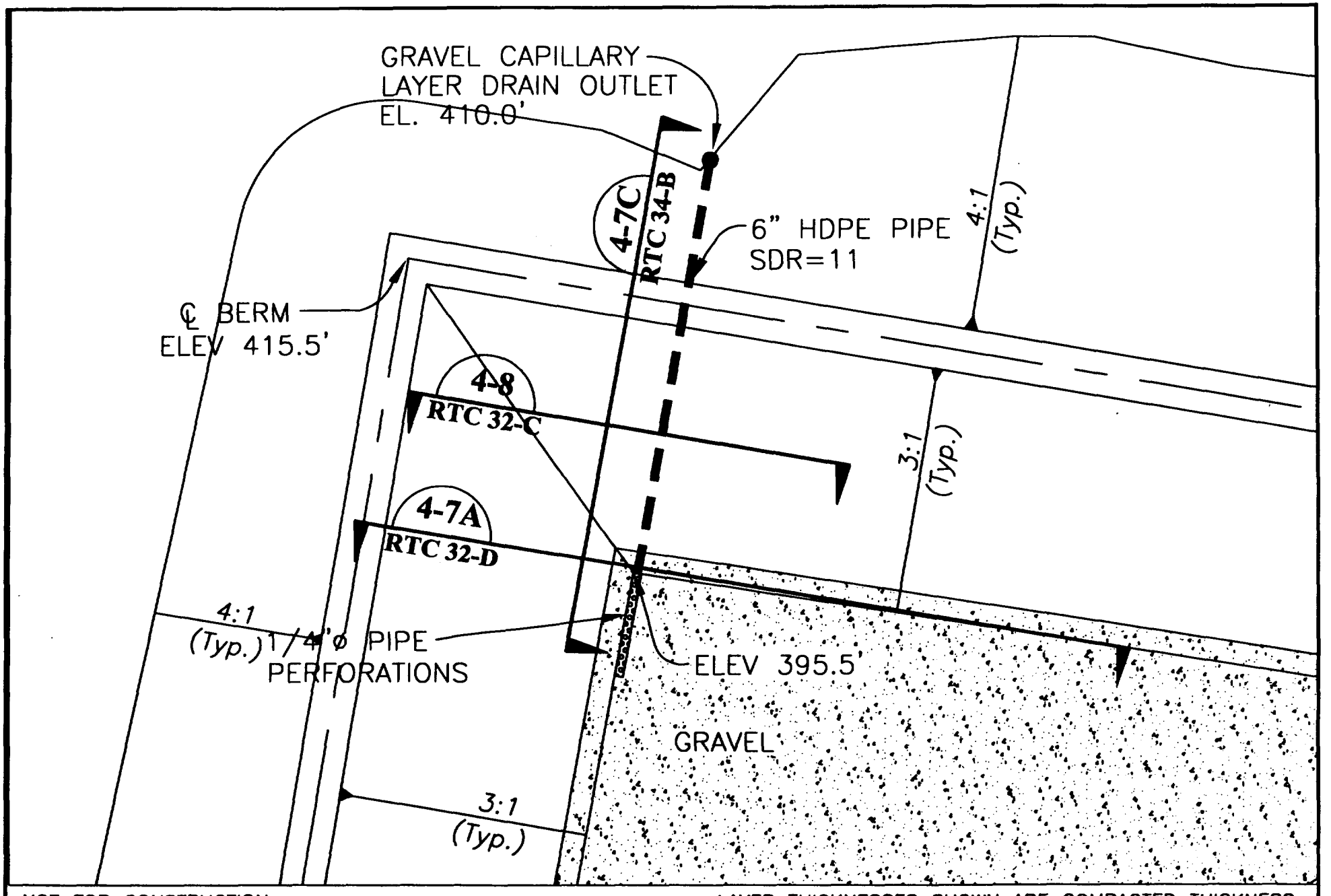
URS Greiner Woodward Clyde
7650 WEST COURTNEY CAMPBELL CSWY.
TAMPA, FLORIDA 33607-1462
TEL: 813.286.1711 FAX: 813.287.8591

SOLUTIA INC.
SAUGET AREA 1
CAHOKIA, ILLINOIS

COLLECTION SUMP SECTION

PROJECT NUMBER C100003899.00

FIGURE 4-7A



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LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC.
SAUGET AREA 1
CAHOKIA, ILLINOIS

URS Greiner Woodward Clyde
7650 WEST COURTNEY CAMPBELL CSWY.
TAMPA, FLORIDA 33607-1462
TEL: 813.286.1711 FAX: 813.287.8591

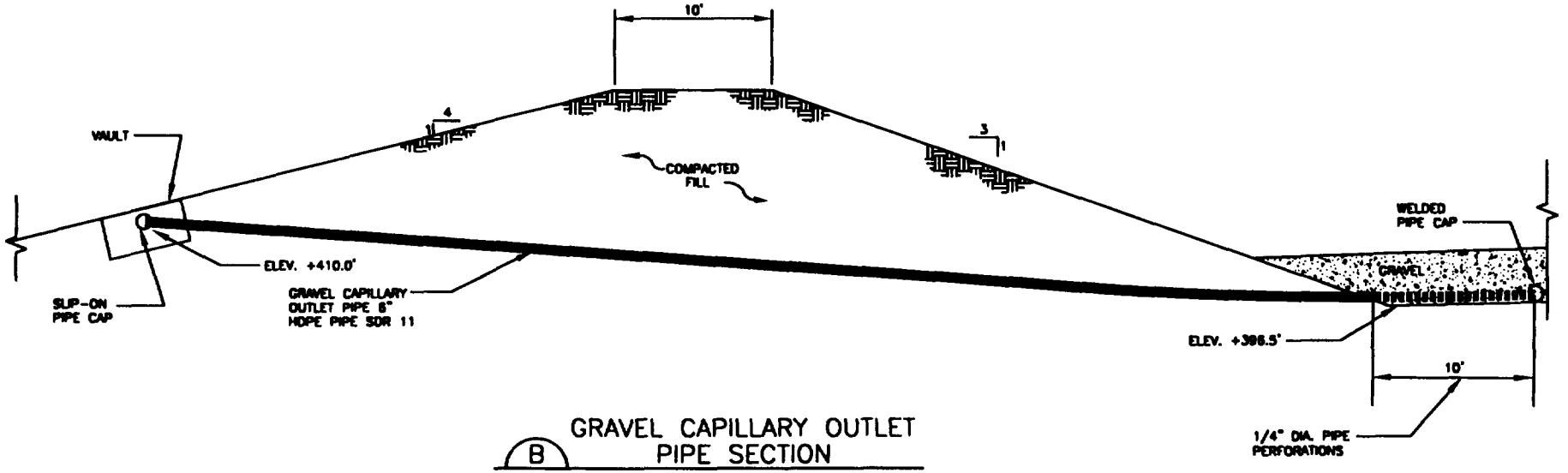
SCALE	DRAWN BY: CRH	DATE: 10/23/00
NTS	CHECKED BY:	DATE:

GRAVEL_PIPE_PLAN.dwg - Layout Fig4-7B

GRAVEL CAPILLARY LAYER
DRAIN OUTLET PLAN

PROJECT NUMBER
C10000405L00

FIGURE NUMBER
4-7B



B GRAVEL CAPILLARY OUTLET PIPE SECTION

NTS

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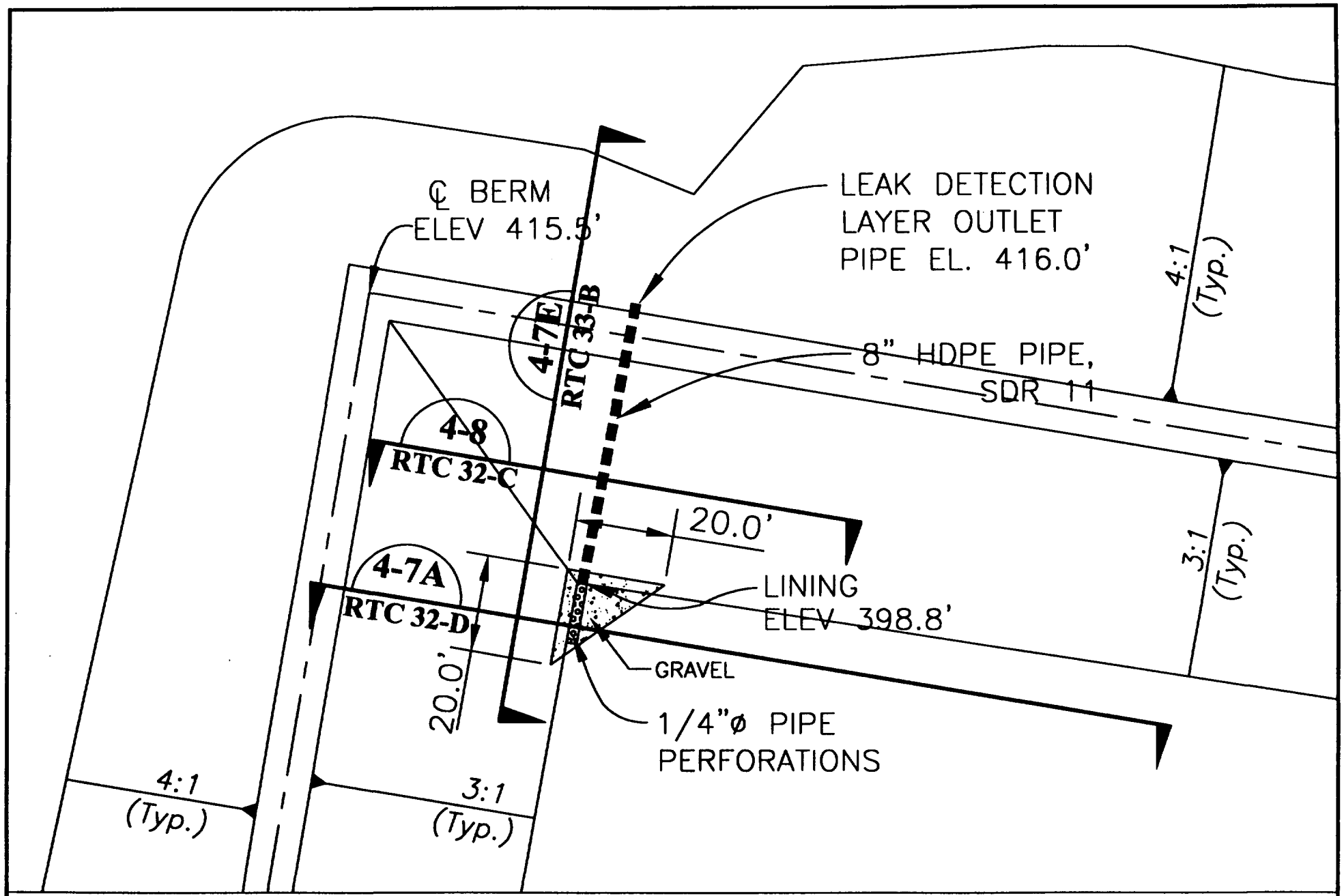
LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC. SAUGET AREA 1 CAHOKIA, ILLINOIS	**URS Greiner Woodward Clyde** 7650 WEST COURTNEY CAMPBELL CSWY. TAMPA, FLORIDA 33607-1462 TEL: 813.286.1711 FAX: 813.287.8591			GRAVEL LAYER CAPILLARY OUTLET PIPE SECTION
	SCALE NTS	DRAWN BY: CRH CHECKED BY:	DATE: 10/23/00 DATE:	
	LINER DETAILS_MOD1.dwg - Layout Fig4-7C			

PROJECT NUMBER
C10000405L00

FIGURE NUMBER
4-7C



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LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC.
SAUGET AREA 1
CAHOKIA, ILLINOIS

URS Greiner Woodward Clyde
7650 WEST COURTNEY CAMPBELL CSWY.
TAMPA, FLORIDA 33607-1462
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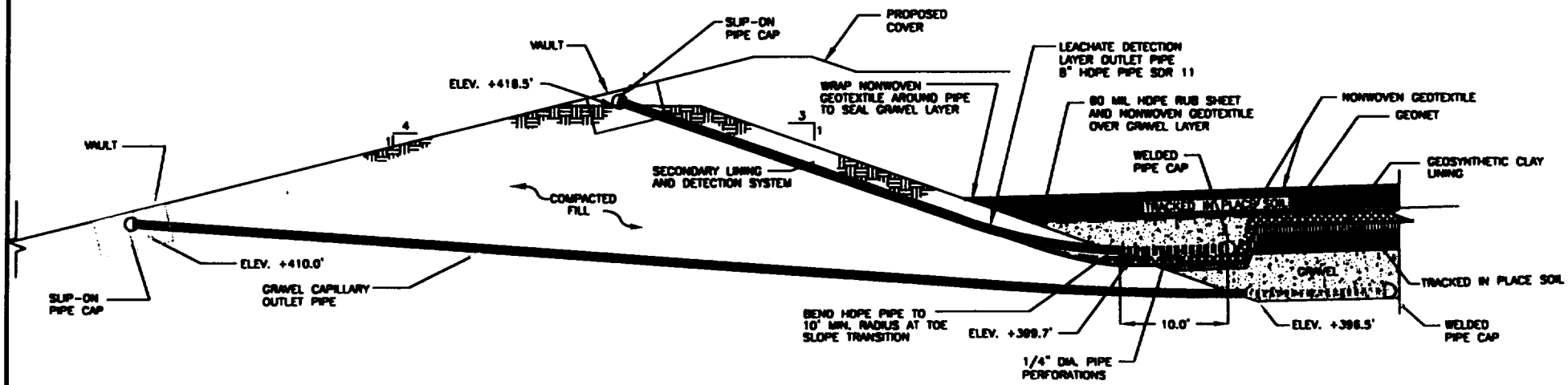
SCALE	DRAWN BY: CRH	DATE: 10/23/00
NTS	CHECKED BY:	DATE:

DETECTION_PIPE_PLAN.dwg – Layout Fig4-7D

LEACHATE DETECTION LAYER
OUTLET PIPE PLAN

PROJECT NUMBER
C10000405L00

FIGURE NUMBER
4-7D



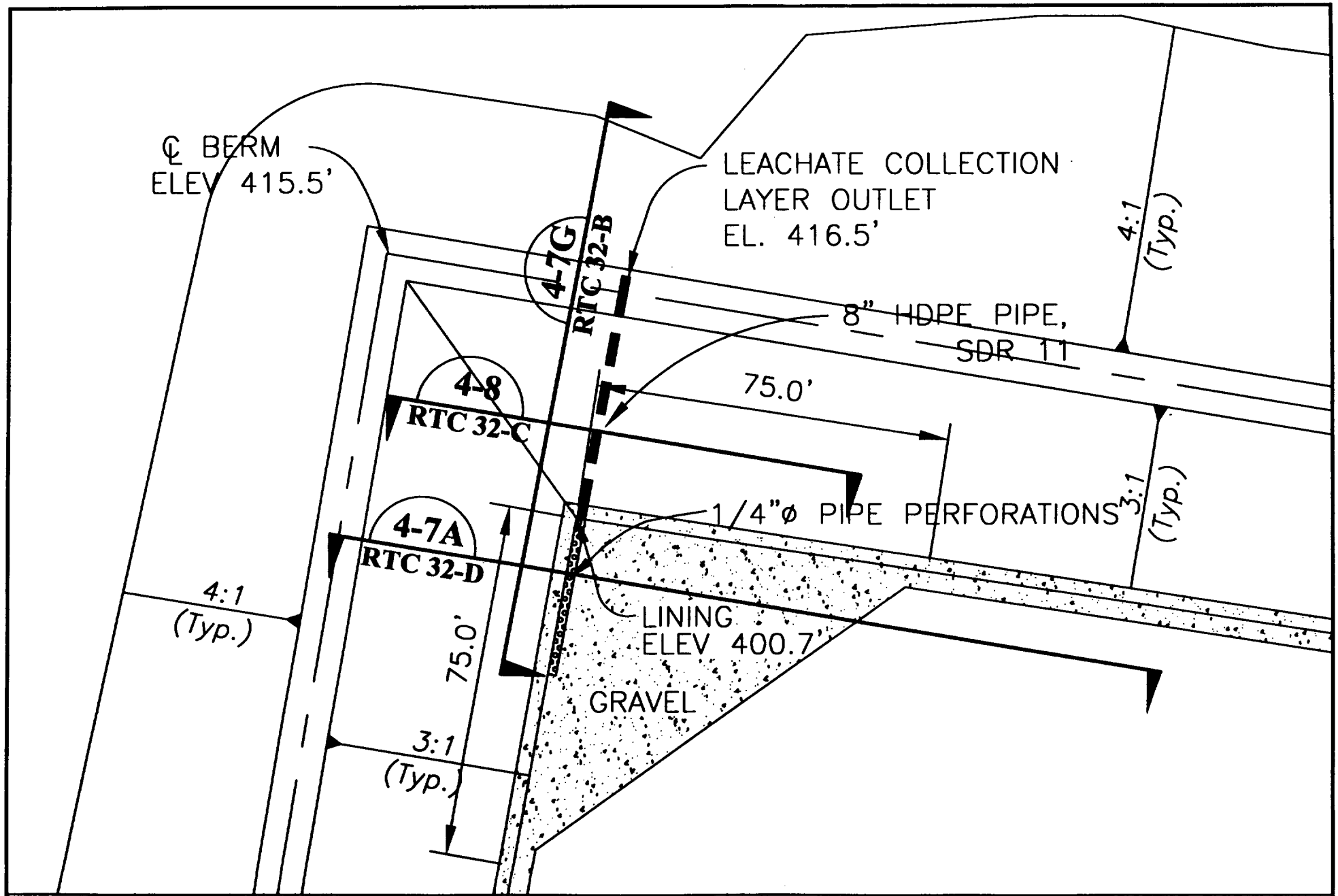
B LEACHATE DETECTION LAYER PIPE SECTION

NTS

NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC. SAUGET AREA 1 CAHOKIA, ILLINOIS	URS Greiner Woodward Clyde 7650 WEST COURTNEY CAMPBELL CSWY. TAMPA, FLORIDA 33607-1462 TEL: 813.286.1711 FAX: 813.287.8581			LEACHATE DETECTION LAYER OUTLET PIPE SECTION
	SCALE NTS	DRAWN BY: CRH	DATE: 10/23/00	PROJECT NUMBER C10000405L00
		CHECKED BY:	DATE:	FIGURE NUMBER 4-7E
	LINER DETAILS_MOD1.dwg - Layout Fig4-7E			



NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC.
SAUGET AREA 1
CAHOKIA, ILLINOIS

URS Greiner Woodward Clyde
7650 WEST COURTNEY CAMPBELL CSWY.
TAMPA, FLORIDA 33607-1462
TEL: 813.286.1711 FAX: 813.287.8591

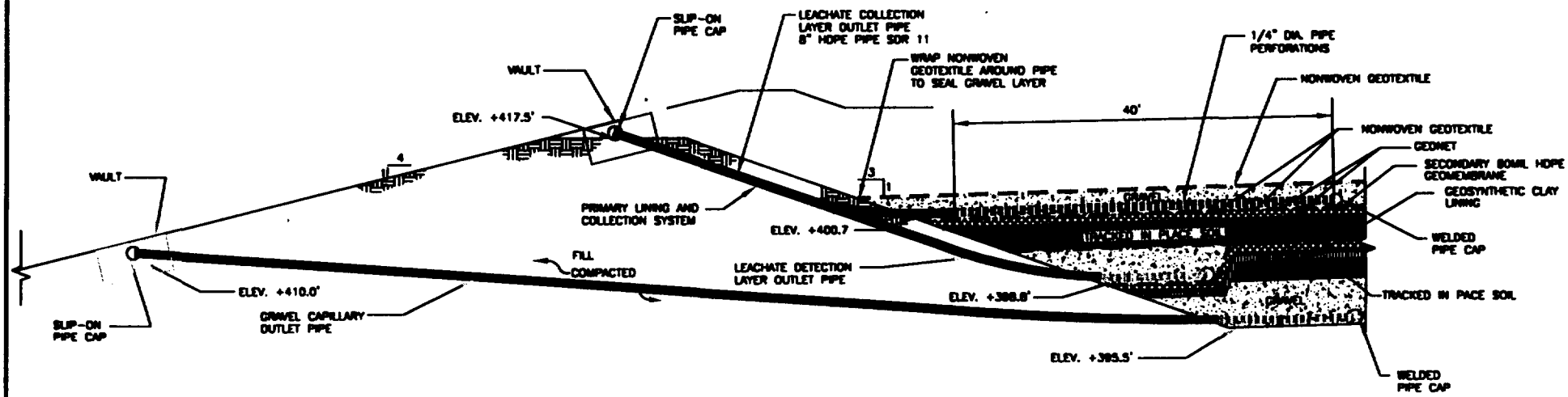
SCALE	DRAWN BY: CRH	DATE: 10/23/00
NTS	CHECKED BY:	DATE:

COLLECTION_PIPE_PLAN.dwg - Layout Fig4-7F

LEACHATE COLLECTION LAYER
OUTLET PIPE PLAN

PROJECT NUMBER
C10000405100

FIGURE NUMBER
4-7F



B LEACHATE COLLECTION LAYER PIPE SECTION

NTS

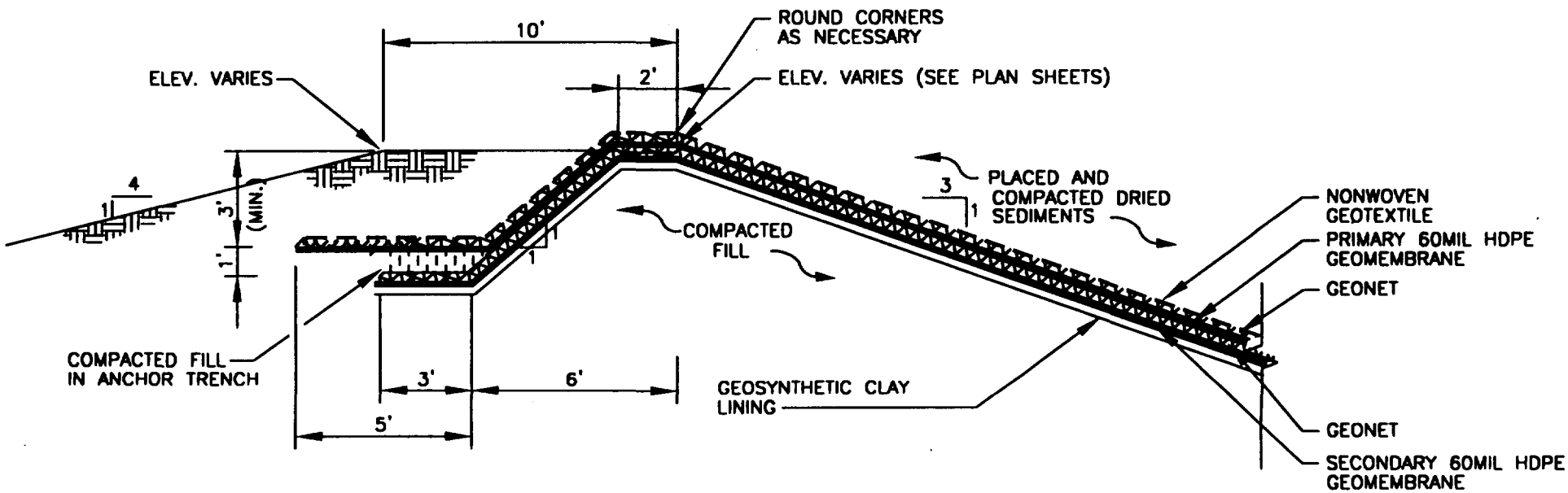
NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC. SAUGET AREA 1 CAHOKIA, ILLINOIS	URS Greiner Woodward Clyde 7650 WEST COURTNEY CAMPBELL CSWY. TAMPA, FLORIDA 33607-1462 TEL: 813.286.1711 FAX: 813.287.8591			LEACHATE COLLECTION LAYER OUTLET PIPE SECTION
	SCALE NTS	DRAWN BY: CRH CHECKED BY:	DATE: 10/23/00 DATE:	
	LINER DETAILS_MOD1.dwg – Layout Fig4-7G			

PROJECT NUMBER
C100004051.00

FIGURE NUMBER
4-7G



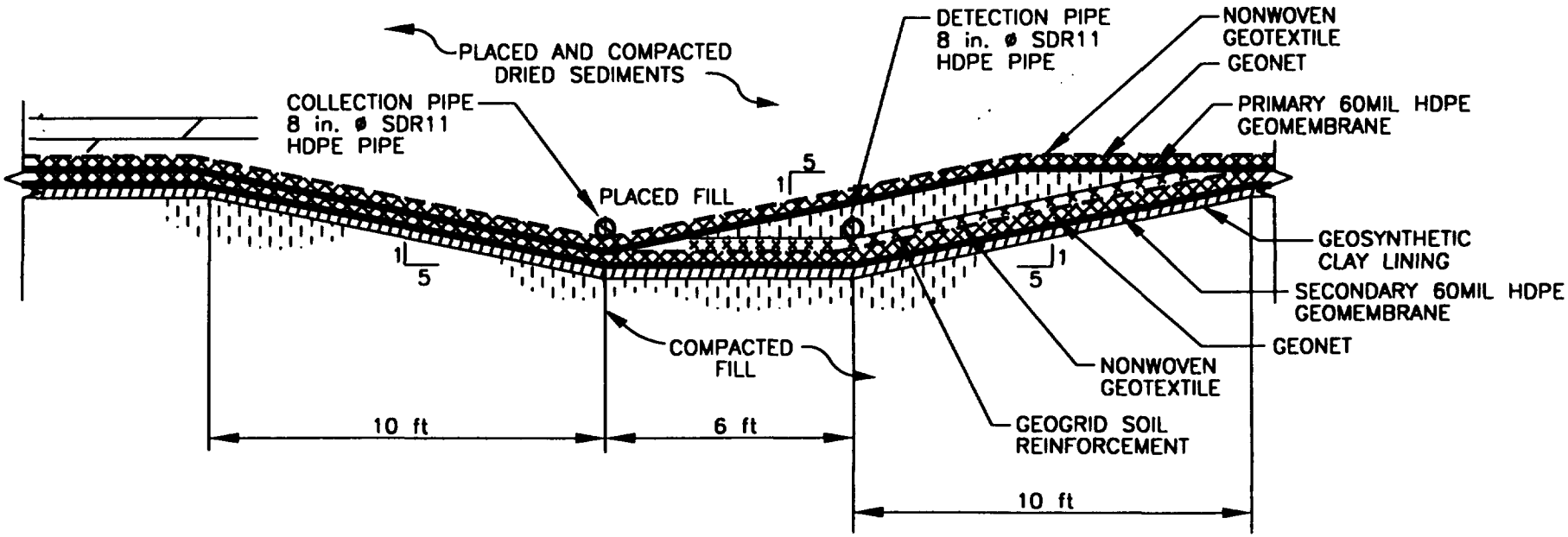
D PRIMARY LINER SYSTEM ANCHOR DETAIL

APPROX. SCALE: 1" = 5'

NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC. SAUGET AREA 1 CAHOKIA, ILLINOIS	URS Greiner Woodward Clyde 7650 WEST COURTNEY CAMPBELL CSWY. TAMPA, FLORIDA 33607-1462 TEL: 813.286.1711 FAX: 813.287.8591			PRIMARY LINER SYSTEM ANCHOR DETAIL
	SCALE NTS	DRAWN BY: CRH	DATE: 10/23/00	PROJECT NUMBER C10000405L00
		CHECKED BY:	DATE:	FIGURE NUMBER 4-7H
	LINER DETAILS_MOD1.dwg - Layout Fig4-7H			



LEACHATE COLLECTION SYSTEM RISER PIPE DETAIL

C
C1.2 | C1.6

NTS

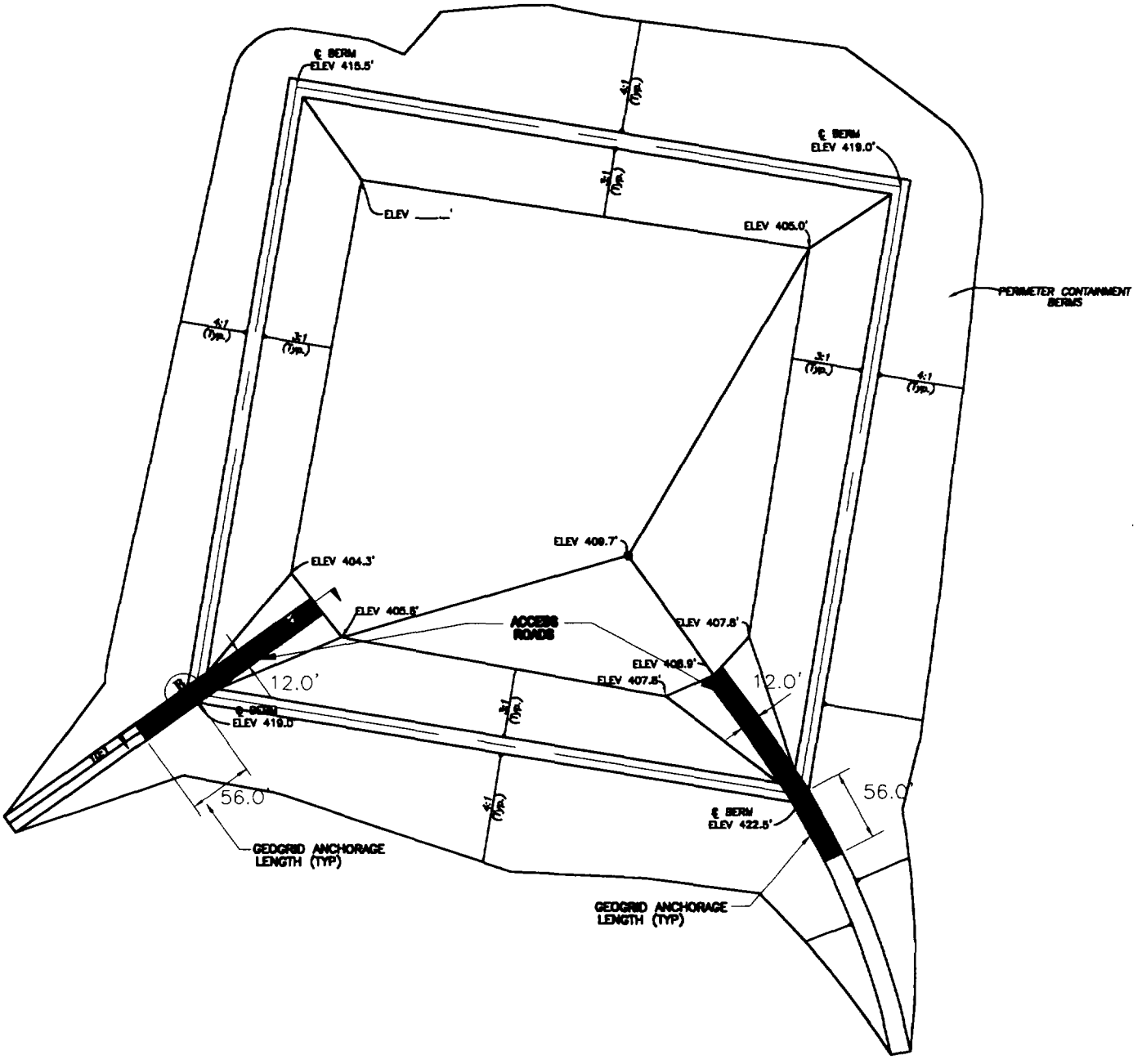
NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC. SAUGET AREA 1 CAHOKIA, ILLINOIS	URS Greiner Woodward Clyde 7650 WEST COURTNEY CAMPBELL CSWY. TAMPA, FLORIDA 33607-1462 TEL: 813.286.1711 FAX: 813.287.8591			LEACHATE COLLECTION LAYER OUTLET PIPE SECTION	PROJECT NUMBER C10000405L00
	SCALE NTS	DRAWN BY: CRH	DATE: 10/23/00		FIGURE NUMBER 4-8
		CHECKED BY:	DATE:		
	LINER DETAILS_MOD1.dwg - Layout Fig4-8				

ATTACHMENT 16

PLAN OF GEOGRID DEPLOYMENT



NOT FOR CONSTRUCTION

PREPARED FOR: SOLUTIA INC.	Drawn: R. HAYDEN	PROJECT NAME	FIGURE
URSGWC JOB NUMBER: C100004051.00	Design: M. BRUNGARD	SOLUTIA INC. SAUGET AREA 1	4-9
URS Greiner Woodward Clyde A Division of URS Corporation 7650 W. Courtney Campbell Causeway Tampa, Florida 33607-1462 Tel: 813.286.1711 Fax: 813.287.8591	Checked: G. WANTLAND	DRAWING TITLE ACCESS ROAD PLAN	
	Date: OCT. 30, 2000		

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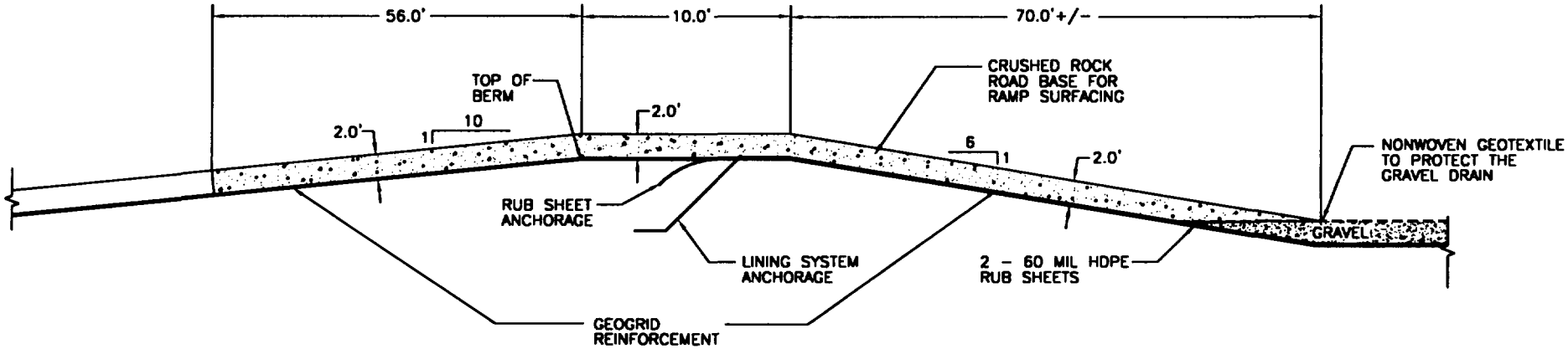


B ACCESS ROAD SECTION DETAIL

NTS

NOT FOR CONSTRUCTION

LAYER THICKNESSES SHOWN ARE COMPACTED THICKNESS

SOUTIA INC. SAUGET AREA 1 CAHOKIA, ILLINOIS	**URS Greiner Woodward Clyde** 7650 WEST COURTNEY CAMPBELL CSWY. TAMPA, FLORIDA 33607-1462 TEL: 813.286.1711 FAX: 813.287.8591		ACCESS ROAD DETAIL	PROJECT NUMBER C10000405.00
	SCALE NTS	DRAWN BY: CRH CHECKED BY:	DATE: 10/23/00 DATE:	FIGURE NUMBER 4-10
	LINER DETAILS_MOD1.dwg - Layout Fig4-10			

ATTACHMENT 17

REVISED SPECIFICATION 02244

SECTION 02244

GEOMEMBRANE

PART 1 GENERAL

1.1 SECTION INCLUDES

A. The Contractor shall furnish all material, labor and equipment for the installation of the geomembrane as specified herein and as shown on the Drawings, and shall install the geomembrane and other geosynthetic components of the cover system in close coordination with the Construction Manager.

1.2 REFERENCES

A.	ASTM D638 -	Test Method for Tensile Properties of Plastics.
B.	ASTM D792 -	Test Method for Specific Gravity (Relative Density) and Density of Plastics by Displacement.
C.	ASTM D1004 -	Test Method for Initial Tear Resistance of Plastic Film and Sheeting.
D.	ASTM D1204 -	Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature.
E.	ASTM D1238, Condition E -	Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.
F.	ASTM D1505 -	Test Method for Density of Plastics by the Density - Gradient Technique.
G.	ASTM D1603 -	Test Method for Carbon Black in Olefin Plastics.
H.	ASTM D1693 -	Test Method for Environmental Stress-Cracking of Ethylene Plastics.
I.	ASTM D4339 -	Terminology for Geosynthetics.
J.	ASTM D4437 -	Standard Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes.
K.	ASTM D4833 -	Test Method for Index Puncture Resistance of

		Geotextiles, Geomembranes and Related Products.
L.	ASTM D4885 -	Test Method for Determining Performance Strength of Geomembranes by Wide Strip Tensile Method
M.	ASTM D5199 -	Test Method for Measuring Thickness of Plastics.
N.	GRI GM6 -	Standard Practice for Pressurized Air Channel Test for Dual Seamed Geomembranes.

1.3 DEFINITIONS

A. Batch: A quantity of resin, usually the capacity of one railcar, used in the fabrication of High Density Polyethylene (HDPE) geomembrane rolls. The finished rolls are identified by a roll number corresponding to the resin batch used.

B. Bridging: Condition existing when the geomembrane is not in contact with the underlying material.

C. Contractor: The party responsible for manufacturing, shipping, field handling, transporting, storing, deploying, seaming, temporary restraining (against wind), and installing the geomembrane. This responsibility includes the work performed by the Manufacturer and the Installer.

D. Manufacturer: The party responsible for production of any of the various geosynthetic components.

E. Installer: The part responsible for installation of the geosynthetics.

F. Extrudate: HDPE material produced in the form of a rod used by the Contractor to extrusion weld panels of geomembrane together.

G. Geomembrane: Very-low permeability synthetic flexible membrane liner (FML) barrier used to minimize fluid migration.

H. Geomembrane Subsurface: Material surface upon which geomembrane will be placed.

I. Quality Assurance Laboratory (Third Party Laboratory): Party, independent from the Owner, Manufacturer, and Contractor, responsible for conducting laboratory tests on samples of geomembrane obtained at the site.

J. Panel: The unit area of geomembrane, a roll or a portion of a roll, that will be seamed in the field.

K. Panel Layout Drawings: Drawings submitted by the Contractor indicating panel numbers, field seams, and details.

L. Subgrade: Soil material directly below the geomembrane.

1.4 TESTING

A. Contractor shall retain the services of an independent testing laboratory. At a minimum, Contractor shall be responsible for providing the following quality control information:

1. Compliance testing for installed geosynthetics.

2. Quality control testing during construction.

B. The Contractor shall inspect and ensure all work is in conformance with these Specifications.

C. Contractor shall inform the Construction Manager prior to conducting all quality control testing to allow oversight.

D. Contractor shall submit all quality control data (both pre-construction and construction) with a cover letter signed and sealed by a Illinois registered professional engineer indicating the requirements of the Specifications were achieved and the data is representative of the material tested.

1.5 SUBMITTALS

A. General

1. Contractor shall submit qualification information on the Manufacturer, Installer and Geosynthetic Testing Laboratory.

2. Contractor shall submit prequalification data on each geosynthetic material to the Construction Manager for approval prior to procurement transport, stockpiling or use.

3. Contractor shall submit results of all quality control data and information to the Construction Manager within 1 work day of receipt.

4. Contractor shall submit all observations and documentation generated by its quality control personnel daily for the current day's activities.

5. Contractor shall submit results of all field surveys and documentation within 1 day of generation including copies of data, field books and notes. Copies of survey information signed and sealed by a Illinois licensed surveyor shall be submitted written 1 day of receipt.

B. Manufacturer

The Manufacturer shall submit the following prior to installing geosynthetics:

1. A list of material properties including certified test results attached to samples of the proposed geosynthetic material.

2. The origin and identification of the resin used to manufacture the products.

3. Submit all quality control documentation required by these Specifications prior to installation.

C. Installer

The Installer shall submit the following prior to installation:

1. Resume of Superintendent to be assigned to the project including dates/duration of employment.

2. Resume of Master Seamer including dates/duration of employment.

3. A list of personnel to be performing field seaming operations with pertinent experience information.

4. All geosynthetic quality control certificates .

5. Certification that the extrudate is comprised of the same resin as the geomembrane to be used.

6. Description of seaming techniques and apparatus to be used.

7. Properties of extrudate to be used.

D. Raw Materials

1. Copy of quality control certificates issued by resin suppliers.

2. Production date(s) of resin.

3. Reports on tests conducted to confirm quality of resin used to manufacture geomembrane rolls assigned to considered facility. Report shall indicate compliance with requirements in Part 2 – Products of this Specification.

4. Statement that no reclaimed polymer is added to resin during manufacture of actual geomembrane to be used in this project.

E. Geomembrane Roll Production: Copy of quality control certificates indicating compliance with requirements of Part 2 of this Specification.

F. Installation Panel Layout Drawing identifying placement patterns and seams, both fabricated (if applicable) and field seams, as well as any variance or additional details which deviate from the Drawings. Layout shall be drawn to scale and shall be adequate for use as the construction plan, and shall include information such as dimensions, panel numbering, and installation details. The Engineer shall review all Panel Layout Drawings prior to installation. Panel Layout Drawings, as prepared by the Contractor and reviewed by the Engineer, shall be submitted to USEPA 30 days prior to liner installation.

G. Installation Schedule.

H. During installation the Contractor shall submit:

1. Quality control documentation recorded during installation.

3. Daily subgrade acceptance for each area to be covered signed by the Installer.

I. Warranties:

1. Submit a material warranty signed by the geomembrane manufacturer. The material warranty shall be against manufacturing defects and workmanship, and against deterioration due to ozone, ultraviolet, and other exposure to the elements, for a period of one year from final acceptance. The material warranty shall be limited to replacement of material, and shall not cover installation of replacement geomembrane.

2. Submit workmanship warranty signed by the geomembrane installer. The installer shall warrant the geomembrane system to be installed to be free of defects in workmanship for a period of 2 years following the date of final acceptance of the work under this Contract. The workmanship warranty shall cover installation of replacement geomembrane.

J. Submittals Required for Project Closeout

1. Record Drawing: Submit reproducible drawings of record showing changes from the approved installation drawings. The record drawings shall include the identification and location of each repair, cap strip, penetration, boot, and sample taken from the installed geomembrane.

2. Quality Control Record: Submit copies of all material and seam test results. Each test shall be identified by date of sample, date of test, sample location, name of individual who performed the test, and standard test method used.

3. Weld Test Summary Report: Submit copies of report showing normal distribution of all test results, and individual test results identifying the high, low, and average of the five coupon samples in each test.

1.6 QUALIFICATIONS

A. Manufacturer

1. Manufacturer shall have at least 5 years continuous experience in the manufacturing of HDPE geomembrane rolls and experience totaling 2 million sq ft of manufactured HDPE for at least 10 completed facilities.

2. The Manufacturer shall have an internal quality control program that meets standard industry requirements.

B. Installer

1. The Installer shall have at least 5 years continuous experience in the installation of HDPE geomembrane and experience totaling 2 million sq ft of installed HDPE geomembrane for at least 10 completed facilities.

2. The Installer's Superintendent shall have previously managed at least two installation projects which entail at least 100,000 ft^2 of HDPE geomembrane.

3. Personnel performing seaming operations shall be qualified by experience or by successfully passing seaming tests. At least one "Master Seamer" shall have experience seaming a minimum of 1 million sq. ft. of HDPE geomembrane using same type of seaming apparatus in use on-site. The "Master Seamer" shall have experience seaming textured and non-textured material and shall provide direct supervision, as required, over less experienced seamers.

C. Quality Assurance Program

Manufacturer/Contractor shall agree to participate in and conform with all items and requirements of these Specifications and the Construction Quality Assurance Manual for the Installation of Geosynthetic Components.

1.7 DELIVERY, STORAGE AND HANDLING

A. Deliver and store geomembrane in strict accordance with the manufacturer's recommendations.

B. Geomembrane delivered to the site shall be inspected for damage, unloaded, and stored with a minimum of handling. The storage area shall be such that materials are protected from mud, soil, dirt, and debris. Geomembrane may be stored directly on prepared level surface, but no more than three rolls in height.

C. The Contractor shall be responsible for coordination and payment of shipping, unloading, storing, handling and installing geomembrane.

D. Use appropriate handling equipment to load, move or deploy geomembrane rolls. Appropriate handling equipment includes slings, spreader bars or an equipment bucket which has been properly protected.

E. Damaged or unacceptable materials shall be replaced at no additional cost to the Owner.

PART 2 PRODUCTS

2.1 MANUFACTURERS

A. GSE Lining Technology, Inc. (Gundle/SLT), Houston, Texas.

B. Approved Equal

2.2 GEOMEMBRANE

A. The geomembrane shall consist of new, first-quality products designed and manufactured specifically for the purpose of this work, as satisfactorily demonstrated by prior use.

B. The geomembrane shall be high-density polyethylene (HDPE) with a UV-stabilized surface and contain no plasticizers, fillers, chemical additives, reclaimed polymers, or extenders.

C. Approximately 2 percent carbon black shall be added to the resin for ultraviolet resistance.

D. The only other compound elements shall be anti-oxidants and heat stabilizers, of which up to 1.5 percent total, as required for manufacturing, may be added.

E. The geomembrane shall be supplied as a single-ply continuous sheet with no factory seams. Rolls shall have a minimum width of 22 feet.

F. The roll length shall be maximized to provide the largest manageable sheet for the fewest field seams.

G. All rolls shall be identified with a unique roll number printed on a label affixed to the inside and outside of the roll.

H. Each roll shall have a continuous identification printed on the membrane showing manufacturer, thickness, material, and date of manufacture.

I. HDPE geomembrane shall meet the following requirements:

HDPE REQUIREMENTS

Properties	Test Method	Requirements	Testing Frequency (minimum)
Liner Thickness, mils (nominal)	ASTM D5199	60	Per Roll
Density (g/cc)	ASTM D1505-A	0.94	200,00 lb
Melt Flow Index (g/10 min)	ASTM D1238-E	1.0 (max)	Per Batch
Tensile Properties (min. ave.) 1. Tensile Strength @ Break (ppi) 2. Elongation @ Break (%)	ASTM D638 Type IV Dumb-bell @ 2 ipm (2.0" Gauge Length) (NSF 54, Mod.)	 228 700	20,000 lb
Tear Resistance (min. ave.)	ASTM D1004 Die C	42 lb	45,000 lb
Low Temperature Brittleness °F	ASTM D746-B	-107 (max)	
Dimensional Stability % Change Each direction	ASTM D1204 212 °F 1 hr	± 2	
Stress Crack Resistance (hrs)	ASTM D5397	200	Per Batch
Puncture Resistance (min. ave.)	ASTM 4833	180 lb	45,000 lb
Carbon Black Content (%) Carbon Black Dispersion	ASTM D1603 ASTM D5596	2 A1, A2 and B1	20,000 lb 45,000 lb
Oxidative Induction Time (OIT) (a) Standard OIT (min. ave.) -or- (b) High Pressure OIT (min. ave.)	 ASTM D3895 ASTM D5885	 100 minutes 400 minutes	200,000 lb
Oven Aging at 85° (a) Standard OIT (min. ave.) - % retained after 90 days -or-	ASTM D5721 ASTM D3895 ASTM D5885	 55% 80%	Per Batch

Properties ...	Test Method	Requirements	Testing Frequency (minimum)
(b) High Pressure OIT (min. ave.) - % retained after 90 days			
UV Resistance (a) Standard OIT (min. ave.) -or- (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs	GM 11 ASTM D3895 ASTM D5885	 Not Recommend 50%	Per Batch

J. Geomembrane shall not have striations, roughness, pinholes or bubbles on the surface

2.3 EXTRUDATE

A. Extrudate shall be made from the same resin as the geomembrane.

B. Additives shall be thoroughly dispersed in the extrudate.

C. Additives shall be free of contamination by moisture or foreign matter.

2.4 FIELD SEAMS

A. Approved processes for seaming are extrusion welding and fusion double seam welding. Fusion double seam welding will be the primary method for joining long, straight seams. Extrusion welding will be the primary seaming method in areas such as corners, sumps, pipe penetrations, tear repairs and cap strips where fusion double seam welding is not feasible.

B. Only apparatus which has been specifically approved by make and model shall be used.

C. Proposed alternate processes shall be documented and submitted by the Contractor for approval by the Construction Manager.

D. Resin used for extrusion welding shall be produced from same resin type as geomembrane.

E. Physical properties of the welding resin shall be the same as those of the resin used in the geomembrane.

F. Geomembrane seams shall meet following requirements:

HDPE GEOMEMBRANE
SEAM PROPERTIES

Property	Qualifier	Unit	Specified Value	Test Method
Shear Strength (at yield point)	minimum	lb/in width	220 and FTB[1]	ASTM D4437
Peel Adhesion Fusion	minimum	lb/in width	150 and FTB[1]	ASTM D4437
Peel Adhesion Extrusion	minimum	lb/in width	130 and FTB[1]	ASTM D4437

Note:

[1] = Film Tear Bond (FTB) is defined as failure of one of the sheets by tearing, instead of separating from the other sheet at the weld interface area (i.e., sheet fails before the weld fails).

2.5 EQUIPMENT

A. Welding Equipment:

1. The Contractor shall provide welding equipment equipped with gauges showing temperatures at the nozzle (extrusion welder) or at the wedge (wedge welder), or have the equipment capable of measuring the temperature of the nozzle (hot air).

2. Equipment shall be maintained in adequate number to avoid delaying work, and shall be supplied by a power source capable of providing constant voltage under a combined-line load.

3. Electric generator shall not be placed on the membrane, unless otherwise approved by the Construction Manager.

B. Field Tensiometer:

1. The Contractor shall provide a tensiometer for onsite shear and peel testing of geomembrane seams.

2. The tensiometer shall be motor driven and have jaws capable of traveling at a measured rate of two (2) inches per minute.

3. The tensiometer shall be in good working order, built to ASTM specifications, and accompanied by evidence of recent calibration.

4. It shall be equipped with a gauge that measures the force in unit pounds exerted between the jaws and have a digital readout.

C. Punch Press:

1. The Contractor shall provide a punch press for the onsite preparation of specimens for testing.

2. The press shall be capable of cutting specimens in accordance with ASTM D4437.

D. Vacuum Box:

1. The Contractor shall provide a vacuum box for onsite testing of geomembrane seams.

2. The vacuum box shall have a transparent viewing window on top and a soft, closed-cell neoprene gasket attached to the bottom.

3. The housing shall be rigid and equipped with a bleed valve and vacuum gauge.

4. A separate vacuum source shall be connected to the vacuum box.

5. The equipment shall be capable of inducing and holding a vacuum of 5 psi.

E. Air Pressure Testing (for double seam with an enclosed space):

1. The equipment shall consist of a manual or motor driven air pump equipped with a pressure gauge.

2. The equipped shall be capable of generating and sustaining pressure over 25 psi.

3. Equipment shall be mounted on a cushion to protect the geomembrane.

4. It shall be equipped with a rubber hose with fittings and connections along with a sharp hollow needle.

5. Other pressure feed devices with a gauge and an accuracy of one (1) psi may be used, as approved by the Construction Manager.

PART 3 EXECUTION

3.1 SURFACE CONDITIONS

A. Contractor shall remove all gravel and other protrusions from geomembrane subgrade. Grade stakes or hubs shall also be removed from subgrade prior to geomembrane placement.

B. Special care must be taken to maintain prepared soil surface. Soil surface shall be observed daily to evaluate desiccation cracking. Damage to subgrade shall be repaired to the satisfaction of the Construction Manager.

C. Do not place geomembrane in area which has become softened by precipitation.

D. Contractor shall certify to the Construction Manager in writing daily that the surface on which the geomembrane will be placed is acceptable.

3.2 PREPARATIONS

A. Damage to geomembrane subsurface during geomembrane deployment or other activities shall be repaired prior to installation.

B. Subgrade shall be smooth and consist of clean fine graded material free of rocks, protrusions, sharp objects and deleterious material of any kind.

C. Edges of excavations and grade changes should be rounded to a minimum six (6) inch radius.

D. Geomembrane material may be placed when air temperature is greater than 35°F, and increasing or less than 100°F, unless other limits are approved, in writing, by the Construction Manager.

E. Do not place during precipitation in presence of excessive moisture (e.g., fog, dew), in area of ponded water, or during excessive winds.

3.3 ANCHOR TRENCH

A. The anchor trench shall be excavated by the Contractor to the lines and grades shown on the Plans prior to geomembrane deployment.

B. Contractor shall remove all loose soil from the anchor trench prior to geomembrane deployment No loose soil shall be allowed to underlie the geomembrane.

C. Excavated surface of the anchor trench shall be protected by the Contractor from desiccation or excessive moisture.

D. Contractor shall not damage geomembrane during backfill placement in anchor trench.

3.4 DEPLOYMENT

A. Each panel deployed shall be assigned a simple and logical identifying code consistent with the submitted panel layout drawings.

B. No more panels shall be deployed in one day that can be welded during that same day.

C. Tack welding may be acceptable as a temporary measure; however, tack welded panels shall not be left overnight.

D. Panels shall be shingled on all slopes such that the upper panel of a cross-seam is overlapped above the lower panel.

E. Panels shall be oriented perpendicular to the line of the slope crest (i.e., down and not across slope) anchored securely and deployed down the slope in a controlled manner. Panels shall not be pulled up the slope.

F. Ballast, that will not damage the geomembrane, shall be used to prevent uplift due to wind. Methods used shall minimize wrinkles.

G. Contractor shall securely anchor the geomembrane on a daily basis to prevent "pull-out" from the anchor trench with materials and methods approved by the Construction Manager. Special attention should be given to geomembrane shrinkage overnight.

H. Folds shall be immediately removed on all installations.

I. Personnel walking on the geomembrane shall not engage in activities or wear types of shoes, that could damage the geomembrane.

J. Smoking shall not be permitted while working on the geomembrane.

K. Vehicular traffic directly on the geomembrane shall not be permitted.

L. Equipment shall not damage the geomembrane by handling, trafficking, leakage of hydrocarbons, or any other means.

M. The geomembrane surface shall not be used as a work area, for preparing patches, storing tools and supplies, or other uses. If needed, a protective cover may be spread out as a work surface.

N. Material shall be placed in a manner to allow for geomembrane shrinkage, contraction and to avoid bridging.

3.5 SEAMING

A. Seam Layout

1. In general, orient end seams (traverse) parallel to line of maximum slope, i.e., oriented along, not across, slope. In corners and odd-shaped geometric locations, minimize numbers of field seams.

2. Seam coding system shall be compatible with panel coding system.

3. During welding operations, at least one Master Seamer shall be present and shall provide supervision over other welders.

4. The surface of the geomembrane shall be clean of grease, moisture, dust, dirt, debris, or other foreign material.

5. Solvents or adhesives shall not be used unless the product is approved in writing by the Construction Manager.

6. Panels shall overlap by a minimum of four (4) inches for all welds.

7. Seams shall be welded to the outside edge of panels placed under anchor berms or in anchor trenches.

8. Fishmouths or wrinkles at seam overlaps shall be cut to achieve a flat overlap.

9. The cut fishmouths or wrinkles shall be extrusion welded or patched where the overlap is more than three (3) inches.

10. When there is less than three (3) inches overlap, an oval or round patch extending a minimum of six (6) inches beyond the cut in each direction shall be used.

11. Seams shall be welded only when ambient temperature is between 35°F and 100°F as measured 6 inches above the geomembrane surface unless other limits are approved in writing by the Engineer.

B. Extrusion Seaming

1. Adjacent panels shall be tack bonded together using procedures that do not damage the geomembrane, allow required tests to be performed, and are not detrimental to final seaming.

2. Welding apparatus shall be free of heat-degraded extrudate before welding.

3. The geomembrane surface shall be abraded a maximum of 1/4 inch beyond the weld bead area, using a disc grinder, or equivalent, not more than one hour before extruding seam.

4. The ends of all seams, which are more than five (5) minutes old, shall be ground when restarting the weld.

5. Grinding depth shall not exceed ten (10) percent of the liner thickness.

6. Use apparatus equipped with gauges giving temperature in apparatus and at nozzle.

7. Provide documentation of extrudate to the Construction Manager and certify that extrudate is compatible with specifications and is comprised of same resins as geomembrane.

8. Maintain one spare operable seaming apparatus on-site. Equipment used for seaming shall not damage geomembrane. Protect geomembrane from damage in heavily trafficked areas.

9. Purge extruder prior to beginning seam until all heat-degraded extrudate has been removed from barrel.

10. Place electric generator on smooth base. Place smooth insulating plate or fabric beneath hot welding apparatus after use.

C. Fusion Seaming

1. Welding apparatus shall be automated, vehicular-mounted, and equipped with gauges indicating applicable temperatures and pressures.

2. Edges of cross seams shall be ground smooth including top and bottom prior to welding.

3. Maintain one spare operable seaming apparatus on-site. Equipment used for seaming shall not damage geomembrane. Protect geomembrane from damage in heavily trafficked areas.

D. Trial Welds

1. Trial welds shall be performed on geomembrane samples to verify welding equipment operations and performance of seaming methods and conditions.

2. Minimum of two (2) trial welds per day or shift per welding apparatus shall be made, one made prior to the start of work and one completed at mid shift.

3. Welds shall be made under the same surface and environmental conditions as the production welds (i.e., in contact with geomembrane subsurface and similar ambient temperature).

E. Trial Weld Testing

1. Sample shall be at least three (3) feet long and two (2) feet wide with the seam centered lengthwise.

2. Three (3), 1-inch wide test strips shall be cut from the trial weld.

3. Each of the specimens shall be tested in the field by the Contractor for peel and shear using a digital tensiometer.

4. Remaining sample shall be retained for future testing.

5. A trial weld specimen shall pass when the results are achieved for both peel and shear tests as shown herein. For double-wedge welding, both welds shall be individually tested and both shall be required to pass in peel.

6. Seaming apparatus or seamer shall not be accepted and shall not be used for seaming until deficiencies are corrected and two consecutive successful full trial seams are achieved

3.6 MATERIAL QUALTY EVALUATION

A. Contractor shall submit an affidavit and/or quality control certificate signed by the geomembrane manufacturer certifying that the geomembrane blankets and/or rolls meet or exceed specified requirements to the Construction Manager for approval prior to geomembrane deployment.

B. Preinstallation material quality evaluation testing shall be performed as follows:

1. Raw material for geomembrane and extrudate rod or bead:

• ASTM D792	1 per batch
• ASTM D1238, Condition E	1 per batch
• ASTM D746	1 per batch

2. Geomembrane Roll:

• ASTM D5199	Continuous or 25 per sheet
• ASTM D638	1 per 50,000 ft^2
• ASTM D1505-A	1 per 50,000 ft^2
• ASTM D1004, Die C	1 per 50,000 ft^2
• ASTM D4833	1 per 50,000 ft^2
• ASTM D1603	1 per 100,000 ft^2

C. Conformance Testing

1. Samples shall be obtained at a frequency of one sample per 50,000 square feet.

2. The Contractor shall obtain samples and forward them to a laboratory designated by the Construction Manager.

3. Tests shall be performed to determine geomembrane Density (ASTM D1505), Thickness (ASTM D5199) and Tensile Strength (ASTM D 638).

4. The sample shall be across the entire width of the roll excluding the first three (3) feet, and shall be cut three (3) feet long by width of roll.

3.7 CONSTRUCTION QUALTY EVALUATION

A. Contractor shall non-destructively test all field seams over their full length using a vacuum test unit, air pressure (for double fusion seams only), or other approved methods. Non-destructive testing shall be carried out daily as the seaming progresses and not at completion of all seaming or at the completion of the day.

B. Vacuum testing shall conform to the following requirements:

1. The equipment shall consist of 2 vacuum box assemblies consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, a port hole or valve assembly, a vacuum gauge, a vacuum pump assembly equipped with a pressure control, a rubber pressure/vacuum hose with fittings and connections, a soapy solution and an applicator.

2. Testing shall conform to the following procedure: Brush soapy solution on geomembrane (approximately 12" x 36"). Place vacuum box over the wetted seam area. Close bleed valve and open vacuum valve, and ensure that a leak-tight seal is created. Apply a vacuum of approximately five (5) psi. Examine the geomembrane through the viewing window for the presence of soap bubbles for not less than fifteen (15) seconds. All areas where soap bubbles appear shall be marked and repaired as described in this Section. If no bubble(s) appear after 15 seconds, close vacuum valve and open bleed valve, move box over next adjoining area with minimum three (3) inches overlap, and repeat process.

C. Air Pressure Testing (for double seam with an enclosed space):

1. The equipment shall consist of an air pump (manual or motor driven) equipped with a pressure gauge capable of generating and sustaining pressure over twenty-five (25) psi and mounted on a cushion to protect the geomembrane, a rubber hose with fittings and connections, a sharp hollow needle, or other approved pressure feed device, and a gauge with an accuracy of one (1) psi.

2. Testing shall conform to the following procedure: Seal both ends of the seam to be tested. Insert needle or other approved pressure-feed device into the channel created by the double-wedge weld. Energize the air pump to a minimum pressure of twenty-five (25) psi, close the valve, and sustain the pressure for at least five (5) minutes. If pressure loss exceeds two (2) psi or does not stabilize, locate faulty area and repair as described in this Section. Puncture opposite end of the seam to release air. If blockage is present, locate and test seam on both sides of blockage. Remove needle or other approved pressure-feed device and seal penetration holes by extrusion welding.

D. Spark Testing: For those extrusion welded seams which are unable to be tested by a vacuum box, the spark test method shall be used with a 24-gauge copper wire placed 1/8" under the top sheet overlap and a Holiday detector operating at 20,000 volts.

E. Field seam locations that cannot be non-destructively tested by the Contractor as determined by the Construction Manager shall be cap-stripped using the same materials as the underlying geomembrane.

3.8 DESTRUCTIVE TESTING

A. Sample Location

1. Collect destructive test samples at a minimum frequency of one test per 500 feet of seam length. Test locations shall be determined during seaming. Locations may be prompted by appearance of excess heating, contamination, offset welds, or suspected defect. The Construction Manager shall be responsible for choosing the locations. The Construction Manager shall not notify the Contractor in advance of selecting locations where seam samples will be taken.

2. The Contractor shall cut samples at locations designated by the Construction Manager as the seaming progresses to obtain-laboratory test results before the geomembrane is covered. The Construction Manager shall number each sample and mark the sample number and location on the panel layout drawing.

3. The Contractor shall immediately repair all holes in the geomembrane resulting from destructive sampling. The continuity of the repair shall be vacuum tested in accordance with this Section.

4. The destructive sample shall be eighteen (18) inches wide by forty-two (42) inches long with the seam centered lengthwise. The sample shall be cut into three (3) equal parts for distribution to the Contractor, the Laboratory and the Owner for archiving.

B. Laboratory Testing

1. Samples shall be tested in peel and shear (ASTM D4437).

2. All tests shall exhibit a Film Tearing Bond type of separation in which the geomembrane material tears before the weld.

3. At least five (5) coupons shall be tested by each test method.

4. Four (4) of the five (5) coupons shall meet the minimum requirements stated herein.

5. Test results shall be provided verbally within 24 hours after receiving samples, and within three (3) days in written form.

C. Destructive Test Failure

1. One of two options shall be followed:

a. Option 1: Reconstruct the seam between any two (2) passed test locations.

b. Option 2: Trace the weld to an intermediate location at least ten (10) feet minimum or to where the seam ends, in both directions from the location of the failed test to collect a destructive test sample at both locations. Check the next seam welded using the same welding device if required to obtain an additional sample (i.e., if one side of the seam is less than ten (10) feet long). Bounding laboratory samples shall be taken, and destructive testing shall be performed per this Section. If the bounding samples pass, then the seam shall be reconstructed between the test sample locations. If any additional samples fail, then the process shall be repeated to establish the zone in which the seam shall be reconstructed.

2. Reconstruction methods shall include extrusion welding of previously wedge welded seams, cap stripping of seam, or replacing seam with a new one (1) foot wide panel and welding in place.

D. Acceptable seams shall be bounded by two locations from which samples have passed destructive tests. For reconstructed seams exceeding fifty (50) feet, a sample taken from within the reconstructed seam shall also pass destructive testing. Whenever a sample fails, additional testing may be required for seams that were welded by the same welder and welding apparatus or were welded during the same shift.

3.9 DEFECTS AND REPAIRS

A. The geomembrane shall be examined for defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter.

B. The geomembrane surface shall be clean at the time of the examination.

C. Each suspect location shall be repaired and non-destructively tested.

D. Geomembrane shall not be covered at locations which have been repaired until test results with passing values are available.

E. Damaged geomembrane shall be removed and replaced with acceptable geomembrane if damage cannot be satisfactorily repaired.

F. Any portion of the geomembrane exhibiting a flaw, or failing a destructive or non-destructive test shall be repaired.

G. The Contractor shall be responsible for repair of damaged or defective areas. One of the procedures listed below shall be recommended by the Contractor and approved by the Engineer:

1. Patching: Used to repair large and small holes, tears, undispersed raw materials, and contamination by foreign matter.

2. Abrading and Re-welding: Used to repair small seam sections (less than twelve (12) inches long).

3. Spot Welding: Spot welding is not allowed.

4. Capping: Used to repair large lengths of failed seams.

5. Removing unsatisfactory material and replacing with new material.

H. Geomembrane surfaces to be repaired shall be abraded (extrusion welds only) no more than 1/2 hour prior to the repair.

1. Patches or caps shall extend at least six (6) inches beyond the edge of the defect, and all corners of material to be patched and the patches shall be rounded to a radius of at least four (4) inches.

2. The geomembrane below large caps shall be cut to avoid water or gas collection between the two sheets.

I. Repairs shall be verified using the following procedure:

1. Each patch repair shall be non-destructively tested using methods specified in this Section.

2. Destructive testing may be required at the discretion of the Construction Manager.

3.10 GEOMEMBRANE ACCEPTANCE

A. Contractor shall retain all ownership and responsibility for the geomembrane until final acceptance by the Construction Manager.

B. Construction Manager will accept the geomembrane installation when the installation is finished and all required documentation from the Contractor has been received and approved, and verification of the adequacy of all field seams and repairs, including associated testing, is complete.

3.11 MATERIALS IN CONTACT WITH GEOMEMBRANE

A. General

1. Carefully install materials in contact with geomembrane surfaces to minimize damage potential.

2. Clamps, clips, bolts, nuts, or other fasteners used to secure geomembrane to each appurtenance shall have lifespan equal to or exceeding geomembrane's.

B. Pipes and Other Appurtenances

1. Install geomembrane around appurtenances, such as pipes, protruding through geomembrane as shown in Plans. Unless otherwise specified, initially install geomembrane sleeve or apron around each appurtenance prior to geomembrane installation.

2. After material is placed and seamed, complete final field seam connection between appurtenance sleeve or apron and geomembrane. Maintain sufficient initial overlap of appurtenance sleeve so shifts in location of geomembrane can be accommodated.

3. Extreme care shall be taken while seaming around appurtenances because both nondestructive and destructive seam testing might not be feasible. Do not damage geomembrane while making connections to appurtenances.

END OF SECTION 02244

ATTACHMENT 18

REVISED SPECIFICATION 02245

SECTION 02245

GEOSYNTHETIC CLAY LINER (GCL)

PART 1 GENERAL

1.1 SECTION INCLUDES

A. This section includes the requirements for procurement, transportation, storage, handling, installation, and protection of geosynthetic clay liner (GCL).

1.2 REFERENCES

A. American Society for Testing Materials (ASTM)

1. ASTM E496 - Test Method for Plate Water Absorption of Cohesive Soils.

2. ASTM D4643 - Test Method for Determination of Water Content of Soil (modified)

3. ASTM D5084 - Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter (modified).

4. ASTM D5321 - Test Method for Determining the Coefficient of Soil an Geosynthetic or Geosynthetic Friction by the Direct Shear Method.

5. ASTM D3776 - Test Method for Mass Per Unit Area of Textiles.

6. ASTM D4632 - Test Method for Grab Breaking Load and Elongation of Geotextiles.

7. ASTM D3786 - Test Method for the Mullen Burst Strength of Textiles.

B. U.S. Pharmacopoeia - National Formulary XVII, page 1210

1. USP-NF-XVII - Test Method for the Free Swell of Bentonite Clay.

C. Geosynthetics Research Institute, Drexel University

1. GRI-GCL-1 - Test Method for the Confined Swell of Geosynthetic Clay Liners.

1.3 SUBMITTALS

A. Pre-installation: Submit the following to the Engineer for approval prior to GCL deployment.

1. Manufacturer's specification for GCL which includes properties contained in Tables 1 and 2.

2. Written certification that the GCL meets the properties listed in Tables 1 and 2.

3. Written certification that GCL manufacturer has continuously inspected GCL for the presence of needles and found GCL to be needle-free.

4. Written certification from the GCL manufacturer that the bentonite will not shift during transportation or installation thereby causing thin spots in the body of the GCL.

5. Quality control certificates signed by a responsible entity of the GCL manufacturer. Each quality control certificate shall include roll identification numbers, and results of quality control tests. At a minimum, results shall be given for tests and corresponding methods specified in Tables 1 and 2.

6. Written certification that sealing material is made of same natural sodium bentonite as the GCL.

B. Installation: Submit the following as installation proceeds: Subgrade surface acceptance, signed by the Contractor for each area that will be covered directly by GCL.

1.4 DELIVERY, STORAGE AND HANDLING

A. Packing and Shipping

1. GCL shall be supplied in rolls wrapped individually in relatively impermeable and opaque protective covers.

2. GCL rolls shall be marked or tagged with the following information:

a. Manufacturer's name

b. Product identification

c. Roll number

d. Roll dimensions

e. Roll weight

B. Storage and Protection:

1. The Contractor shall provide on-site storage area for GCL rolls from time of delivery until installation. The GCL rolls must be stored off the ground until they are installed.

2. After Contractor mobilization, store and protect GCL from dirt, water, ultraviolet light exposure, and other sources of damage.

3. Preserve integrity and readability of GCL roll labels.

PART 2 PRODUCTS

2.1 MATERIALS

A. The active ingredient of the GCL shall be natural sodium bentonite. The bentonite shall be encapsulated between two polypropylene textiles.

B. For side slopes steeper than 7H:1V the GCL shall be needle punched with high strength polypropylene thread to provide internal shear strength reinforcing. The internal shear reinforcing mechanism shall resist failure due to thread pull-out over long-term creep situations.

C. The textiles shall be sufficiently porous to allow bentonite flow-through such that the permeability of the overlap seams is equal to or less than the permeability of the body of the GCL sheet without the addition of granular or paste bentonite.

D. The bentonite and textiles used to manufacture the GCL shall have the following minimum properties:

TABLE 1

Test Designation	Test Method	Frequency of Testing	Report Value
Clay[1]			[5]
Free swell	D 5890	One per truck or railcar but min., every 50 tonnes	Minimum average
Fluid loss	D 5891	One per truck or railcar but min., every 50 tonnes	Minimum average
Geosynthetic Materials			[5]
Geotextiles			
Mass per unit area	D 5261	20,000 m^2 (200,000 ft^2)	Typical and MARV

Test Designation	Test Method	Frequency of Testing	Report Value
Grab tensile strength (MD and CD)	D 4632	20,000 m^2 (200,000 ft^2)	MARV
Finished GCL[2]			
Clay mass per unit area (dried)[3]	D 5993	4,000 m^2 (40,000 ft^2)	MARV
Clay moisture content	D 4643	4,000 m^2 (40,000 ft^2)	Average value[6]
Grab tensile strength (MD and CD)[4]	D 4632	20,000 m^2 (200,000 ft^2)	MARV
Index flux[5]	D 5887	Once weekly with the last 20 values reported[7]	Maximum value

E. The final GCL product shall have the following minimum properties:

TABLE 2

Property	Test Method	Value	Units	Min. Test Freq.
Bentonite Content @ 20% Moisture Content	Weigh 12" x Roll Width	1.0	lbs./sq. ft.	1/20,000 sf
Confined Swell	GRI-GCL-1	150	%	1/300,000 sf
Permeability under 5 psi effective confining pressure	ASTM D5084	5×10^{-9}	cm/sec	1/1,000,000 sf
Overlap Seam Permeability under psi effective confining pressure	ASTM D5084	5×10^{-9}	cm/sec	1/1,000,000 sf
Hydrated Internal Residual Shear Resistance*	ASTM D5321	10	degrees	Periodic
Hydrated Internal Residual Shear Resistance**	ASTM D532	700 6	psf cohesion degrees friction angle	Periodic

* For side slopes less than or equal to 7H:1V.

** For side slopes steeper than 7H:1V. Residual shear strength measured at 3" of displacement.

F. The bentonite shall be continuously adhered to both geotextiles to ensure that the bentonite will not be displaced during handling, transportation, storage and installation, including cutting, patching and fitting around penetrations.

G. The bentonite sealing compound or bentonite granules used to seal penetrations and make repairs shall be made of the same natural sodium bentonite as the GCL and shall be as recommended by the GCL manufacturer.

PART 3 EXECUTION

3.1 SUBGRADE PREPARATION

A. The Construction Manager shall obtain certification from the Installer that the surface on which the GCL will be placed is acceptable. The Certificate of Acceptance shall be provided prior to GCL installation.

B. After the surface has been accepted by the Installer, it is the Installer's responsibility to indicate to the Construction Manager any change in surface condition that may require repair. If the Construction Manager concurs with the Installer, then the Earthwork Subcontractor shall be notified and the Construction Manager shall confirm that the surface is repaired.

C. The subgrade shall be maintained at the specified moisture content until covered by the GCL. Upon placement of panel(s), the Installer is responsible for maintaining/repairing the surface covered by the GCL unless otherwise agreed.

3.2 EXAMINATION

A. The Engineer will collect samples of GCL to be installed for conformance testing.

3.3 INSTALLATION

A. GCL Deployment: Handle GCL in a manner to ensure it is not damaged. At a minimum, comply with the following:

1. On slopes, anchor the GCL securely and deploy it down the slope in a controlled manner.

2. Weight the GCL with sandbags or equivalent in the presence of wind.

3. Cut GCL with a geotextile cutter (hook blade), scissors, or other approved device. Protect adjacent materials from potential damage due to cutting of GCL.

4. Prevent damage to underlying layers during placement of GCL.

5. During GCL deployment, do not entrap in or beneath GCL, stones, trash, or moisture that could damage GCL.

6. Visually examine entire GCL surface. Ensure no potentially harmful foreign objects such as needles are present.

7. Do not place GCL in the rain or at time of impending rain.

8. Do not place GCL in areas of ponded water.

9. Replace GCL that is hydrated before placement of overlying geomembrane.

10. In general, only deploy GCL that can be covered during that day by geomembrane or a minimum of twelve (12) inches of approved cover soil.

11. Orient the preferred GCL surface in relation to prepared soil or other geosynthetics as directed by the Representative.

12. On side slopes, run GCL to the bottom of the slope as indicated.

13. Seam areas or runs shall also be flat and clear of any large rocks, debris or ruts.

14. Contacting surfaces shall be clean and clear of dirt or native soil with all edges pulled tight to maximize contact and to smooth out any wrinkles or creases.

15. Overlaps shall be a minimum of six (6) inches.

16. A proper seam shall cover the six (6) inch lap line and leave the nine (9) inch match line exposed.

17. The Contractor shall only work on an area that can be completed in one working day.

18. Completion shall be defined as the full installation and anchoring of the liner and placement of the overlying specified geomembrane liner.

B. Overlaps:

1. On slopes, overlap GCL to the manufacturer's match line

2. In general, no horizontal seams are allowed on side slopes. Any horizontal seams on side slopes will be overlapped so that liquid will run from the top of the higher panel to the top of the lower panel. GCL shall not be placed so that liquid from a higher panel can run underneath a lower panel.

3. Apply granular bentonite to overlapped area at a rate of 1/4 pound per linear foot.

4. At sumps, overlap GCLs at least one (1) foot.

5. At bottom of collection sumps, unroll an extra layer of GCL on top of previously installed GCL. Avoid placing seams on top of underlying seams.

6. Seams shall be augmented with granular bentonite to ensure seam integrity.

7. Granular bentonite shall be dispersed evenly from the panel edge to the lap line at a minimum rate of ¼ pound per linear foot continuously along all seams or overlap areas.

8. Accessory bentonite shall be of the same type as the material within the composite liner itself. Adhesives may be used on seams to keep panels in contact during backfill operations, if necessary.

C. Defects and Repairs:

1. Repair all flawed or damaged areas by placing a patch of the same material extending at least one (1) foot beyond the flaw or damaged area.

2. Treat seams of repaired areas as per stated in Overlaps above.
3. The edges of the patch shall be fastened to the repaired liner with construction adhesive, in addition to the bentonite-enhanced seam.

D. Interface with Other Products: Ensure the following when deploying overlying material.

1. GCL and underlying materials are not damaged.

2. Minimal slippage of GCL on underlying layers occurs.

3. No excess tensile stresses occur in GCL.

3.4 ANCHOR TRENCH SYSTEMS

A. Anchor trenches shall be excavated to the lines and grades shown on the Drawings prior to placement of the GCL.

B. To minimize desiccation of the clay, no more than the amount of trench required for the GCL to be anchored in one day shall be excavated.

C. The corners of the anchor trench where the GCL enters the trench shall be rounded to a smooth radius prior to the installation of the GCL.

D. No loose soil shall be allowed to underlie the GCL in the anchor trench.

E. The GCL shall be temporarily anchored with sand bags or other approved means until the overlying geosynthetics are placed and secured.

3.5 EQUIPMENT

A. Storage

1. Wooden pallets for above ground storage of GCL.

2. Heavy, waterproof tarpaulin for protecting unused GCL.

B. Installation

1. Equipment used for GCL deployment shall utilize a spreader bar to prevent slings from damaging edges.

2. Steel pipe shall be inserted into roll core for lifting.

3. Sand bags for securing tarpaulin.

4. 3-inch wide grips for moving GCL panels into place for each installation technician.

5. Bentonite Sealing Compound and/or Granular Bentonite for securing around penetrations and structures.

6. Equipment used for the placement of all liners above the GCL shall not exceed a ground pressure of four (4) psi.

END OF SECTION 02245

ATTACHMENT 19

REVISED SPECIFICATION 02246

SECTION 02246

GEONET

PART 1 GENERAL

1.1 SECTION INCLUDES

A. This section includes the requirements for geonet procurement, transportation, storage, handling and installation.

1.2 REFERENCES

A. ASTM D413 - Standard Test Methods for Rubber Property – Adhesion to Flexible Substrate.

B. ASTM D792 - Test Method for Specific Gravity (Relative Density) and Density of Plastics by Displacement.

C. ASTM D1238 - Condition E Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.

D. ASTM D1505 - Test Method for Density of Plastics by the Density – Gradient Technique.

E. ASTM D1603 - Test Method for Carbon Black in Olefin Plastics.

F. ASTM D4439 - Terminology for Geosynthetics.

G. ASTM D4716 - Standard Test Method for Constant Head Hydraulic Transmissivity (In-plane Flow) of Geotextiles and Geotextile Related Products.

1.3 SUBMITTALS

A. General

1. Contractor shall submit qualification information on the Manufacturer, Installer and Geosynthetic Testing Laboratory.

2. Contractor shall submit prequalification data on each geosynthetic material to the Construction Manager for approval prior to procurement, transport, stockpiling or use.

3. Contractor shall submit results of all quality control data and information to the Construction Manager within 1 work day of receipt.

4. Contractor shall submit all observations and documentation generated by its quality control personnel daily for the current day's activities.

5. Contractor shall submit results of all field surveys and documentation within 1 day of generation including copies of data, field books and notes. Copies of survey information signed and sealed by a Illinois licensed surveyor shall be submitted within 1 day of receipt.

6. Contractor shall submit signed documentation that the geonet was installed in accordance with the Plans and Specifications.

B. Manufacturer

The Manufacturer shall submit the following prior to installing geosynthetics:

1. A list of material properties including certified test results attached to samples of the proposed geosynthetic material.

2. The origin and identification of the resin used to manufacture the product.

3. Submit all quality control documentation required by these Specifications prior to installation.

C. Installer

The Installer shall submit the following prior to installation:

1. Resume of superintendent to be assigned to the project including dates/duration of employment. The superintendent shall have demonstrated experience of two similar projects.

2. A list of personnel to be performing field seaming operations with pertinent experience information.

3. All geosynthetic quality control certificates.

1.4 TESTING

A. Contractor shall retain the services of an independent testing laboratory. At a minimum, Contractor shall be responsible for providing the following quality control information:

1. Compliance testing for installed geosynthetics.

2. Quality control testing during construction.

B. The Contractor shall inspect and ensure all work is in conformance with these Specifications.

C. Contractor shall inform the Construction Manager prior to conducting all quality control testing to allow oversight.

D. Contractor shall submit all quality control data (both pre-construction and construction) with a cover letter signed and sealed by a Illinois registered professional engineer indicating the requirements of the Specifications were achieved and the data is representative of the material tested.

1.5 QUALITY ASSURANCE

A. Geonet shall be free of defects, rips, holes, or flaws.

B. It shall be manufactured in widths and lengths that will permit installation of geonet with as few laps as possible.

C. Geonet shall be marked with the Manufacturer's name, product identification, lot number, roll number, and roll dimensions.

D. Contractor shall provide a storage area such that geonet is protected from mud, dirt, dust, debris, and exposure to ultraviolet (UV) light and heat.

E. Contractor shall submit all material and workmanship warranties for the geonet installation.

1.6 GEONET TRANSPORTATION, HANDLING, AND STORAGE

A. Transportation of geonet is responsibility of Contractor, who shall be liable for all damages to geonet prior to and during transportation to Site.

B. Handling, storage, and care of geonet on-site is responsibility of Contractor prior to, during and after geonet installation.

C. Contractor shall retain ownership of geonet until installation is accepted by the Construction Manager. Contractor shall be liable for all damages to geonet incurred prior to final acceptance of installation by Construction Manager.

PART 2 PRODUCTS

2.1 GEONET

A. Provide products for the geonet comprised of high-density polyethylene (HDPE). The geonet shall be manufactured by extruding two sets of strands to form a three

dimensional structure to provide plane flow and shall meet the following minimum average roll values except as noted.

GEONET PROPERTIES			
Property	**Test**	**Value**	**Units**
Density	ASTM D792 or D1505	0.90 min.	g/cu cm
Thickness	ASTM D5199	200 min.	mils
Melt Flow Index	ASTM D1238	1.0 max.	g/10 min.
Carbon Black Content	ASTM D1603	2-3 range	%
Tensile Strength at Break:			
• Machine Direction	ASTM D751	25 min.	PPI
• Cross Direction	ASTM D751	15 min.	PPI
Transmissivity	ASTM D4716	1.0	cm/sec

PART 3 EXECUTION

3.1 GEONET PLACEMENT AND HANDLING

A. Handle all geonet in such a manner as to ensure it is not damaged in any way.

B. Geonet shall be anchored and installed by rolling it down the slope so as to continually keep the material in tension.

C. In the presence of wind, geonets shall be weighted with sandbags or equivalent. Such sandbags shall be installed during placement and shall remain until replaced with earthen cover material.

D. Geonets shall be cut using an approved cutter only. If in place, special care must be taken to protect geomembrane from damage which could be caused by cutting of geonets.

E. During placement, care shall be taken not to entrap in geonet stones, excessive dust, or moisture that could hamper subsequent seaming. If geonet is not free of debris and soil prior to installation, Contractor shall clean geonet prior to installation.

F. The Contractor shall examine the geonet over the entire surface, after installation, to ensure that no potentially harmful foreign objects are present. Any foreign objects so encountered shall be removed by Contractor, or geonet shall be replaced.

G. Geonet shall not be welded or tack welded to the underlying geomembrane.

3.2 QUALITY CONTROL

A. Visual inspections of shipment and storage activities shall be made by the Construction Manager to assure that the geonet has been protected from ultraviolet light exposure, precipitation or other inundation, and dirt, dust, puncture, cutting or any other damaging or deleterious conditions.

B. Contractor shall designate each roll with a roll number (identification code) which is consistent with the layout plan. The rolls shall be positioned on the site as shown on the approved layout drawings. Instructions on boxes or wrapping containing the geotextile materials shall be followed to assure that rolls are unrolled in the proper direction.

3.3 MATERIAL QUALITY EVALUATION

A. Contractor shall submit an affidavit and/or quality control certificate signed by the manufacturer certifying that the geosynthetic rolls meet or exceed specified requirements to the Construction Manager for approval prior to deployment.

B. Preinstallation material quality evaluation testing shall be performed as follows:

• ASTM D5199	4 per roll
• ASTM D792	1 per 50,000 ft^2
• ASTM D751	1 per 50,000 ft^2
• ASTM D1238	1 per 100,000 ft^2
• ASTM D1603	1 per 100,000 ft^2

C. Conformance Testing

1. Samples shall be obtained at a frequency of one sample per 50,000 square feet.

2. The Contractor shall obtain samples and forward them to a laboratory designated by the Construction Manager.

3. Tests shall be performed to determine Density (ASTM D792), Thickness (ASTM D5199), and Tensile Strength (ASTM D751).

4. The sample shall be across the entire width of the roll excluding the first three (3) feet, and shall be cut three (3) feet long by width roll.

5. Samples shall be 3 feet long by roll width. Machine direction shall be marked on sample with an arrow.

3.4 GEONET SEAMS AND OVERLAPS

A. The geonet shall be overlapped at least 4 inches on downslope seams and joined by colored plastic ties every 5 feet.

B. On transverse (horizontal) seams the geonet shall be overlapped 12 inches and joined by colored plastic ties every 12 inches. No horizontal seams will be allowed on slopes greater than 6:1.

C. Metallic devices are not allowed.

D. Seams shall be tied continuously through the anchor trenches and toe drains every 12 inches.

E. Unless prior approval is obtained, no horizontal seams shall be allowed on side slopes.

F. In the event horizontal seams on side slopes can not be avoided, adjacent rolls shall be tied every 6 inches.

3.5 GEONET REPAIR

A. Any holes or tears in geonet shall be repaired as follows: A patch made from same geonet material shall overlap the undamaged geonet a minimum of 12 inches on all sides and tied every 6 inches.

END OF SECTION 02246

ATTACHMENT 20

REVISED SPECIFICATION 02932

SECTION 02932

SEEDING

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Provide all labor, material, equipment and incidentals required to seed, fertilize, mulch and maintain the vegetated cover.

1.2 REFERENCES

A. FS 0-F-241 - Fertilizers, Mixed Commercial

1.3 DEFINITIONS

A. Weeds: Includes Dandelion, Jimsonweek, Quackgrass, Horsetail, Morning Glory, Rush Grass, Mustard, Lambsquarter, Chickweek, Cress, Crabgrass, Canadian Thistle, Nutgrass, Poison Oak, Blackberry, Tansy Ragwort, Johnson Grass, Poison Ivy, Nut Sedge, Nimble Will, Bindweed, Bent Grass, Wild Garlic, Perennial Sorrel, And Brome Grass.

1.4 REGULATORY REQUIREMENTS

A. Contractor shall comply with regulatory agency requirements for fertilizer and herbicide composition.

B. Contractor shall provide seed mixture in containers showing percentage of seed mix, year of production, net weight, date of packaging, and location of packaging.

C. Contractors shall submit maintenance requirements for continuing maintenance of established vegetated cover.

D. Contractor shall include maintenance instructions, cutting method and maximum grass height; types application frequency, and recommended coverage of fertilizer, and watering schedule to be performed by Solutia.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Products shall be delivered to site to support progress of work.

B. Products shall be stored and protected from deleterious conditions.

C. Grass seed mixture shall be delivered in sealed containers. Seed in damaged packaging is not acceptable.

D. Fertilizer shall be delivered in waterproof bags showing weight, chemical analysis, and name of manufacturer.

1.6 MAINTENANCE PERIOD

A. Notwithstanding the Contractor's warranty, the Owner will pay the Contractor a lump sum price to maintain the Work in its accepted condition for one (1) year. The Maintenance Period shall start from the date of the Construction Manager's Final Acceptance. The Contractor's Maintenance Period Work shall include:

1. Supply and placement of fill materials to re-establish final grades and the landfill cover thickness in accordance with the design drawings and specifications.

2. Supply and install E&S controls to minimize erosion of the landfill cover.

3. Establish and maintain successful revegetation of the cover in accordance with this specification.

4. Contractor is responsible for repairing any settlement areas that occur in the 12-month maintenance period.

B. The Contractor's Manager will inspect the grass growth at the end of the Maintenance Period. During the Maintenance Period, the Contractor shall sample the topsoil to develop fertilizer requirement, apply fertilizer, kill grubs and weeds, reseed, and cut the grass.

1.7 SUBMITTALS

A. Contractor shall submit certification that seed mixture conforms to this section and the requirements of the State of Illinois.

B. Contractor shall submit all material and workmanship warranties related to seeding.

PART 2 PRODUCTS

2.1 SEED MIXTURE

A. Seed mixture shall conform to Class Type I of the Illinois DOT Specifications Section 250 Seeding:

1. Kentucky Bluegrass: 50 lbs/acre
2. Perennial Ryegrass: 35 lbs/acre
3. Creeping Red Fescue 25 lbs/acre

2.2 ACCESSORIES

A. Mulching material shall be dry mulch consisting of straw or hay of one or more of the following types: oat, rye and wheat straw. Only undeteriorated mulch can be readily cut into the soil and shall be used.

B. Fertilizer: Ratio of nitrogen to phosphorous to potassium - 1:1:1.

PART 3 EXECUTION

3.1 INSPECTION

A. Contractor shall verify that prepared soil base is ready to receive the work of this section.

B. Contractor shall certify in writing that the condition of the soil base is ready to receive seeding. Beginning of installation means acceptance of existing site conditions.

3.2 FERTILIZING

A. Contractor shall apply fertilizer at a rate of 270 lbs/acre for combined nutrients.

B. Contractor shall apply fertilizer after smooth raking of topsoil.

C. Contractor shall apply fertilizer at the same time or with same machine as will be used to apply seed.

D. Fertilizer shall be mixed thoroughly into upper 2 inches of topsoil.

E. Contractor shall lightly water fertilized areas to aid the dissipation of fertilizer.

3.3 SEEDING

A. Contractor shall apply seed with a machine that places the seed in direct contact with the soil, packs and covers the seed in one continuous operation. Contractor shall not seed any areas in excess of that which can be mulched on the same day.

B. Contractor shall not sow immediately following rain, when ground is too dry, or during windy periods. Seed operation shall stop when wind speeds exceed 15 mph.

C. Contractor shall select an appropriate roller to facilitate grass growth.

D. Seeding machinery can be mounted on rubber tires or tracks but must maintain a ground pressure not exceeding 8 lbs/sq in.

E. Immediately following seeding and compacting, mulch shall be applied to a thickness of 1/8 inches.

F. Water shall be applied to irrigate the newly seeded ground cover for period of 60 days. The irrigation procedures shall be designed such as the topsoil will be saturated to a depth of at least 4 inches when the system is in use.

3.4 WARRANTY PERIOD

A. The warranty period shall extend for a period of 1 year after acceptance of conditions by the Construction Manager.

B. Contractor shall immediately reseed areas which show bare spots at no additional cost to the Construction Manager.

3.5 SCHEDULE

A. Seeding and fertilizers shall be applied to all areas disturbed during construction.

3.6 SUCCESSFUL REVEGETATION

A. Contractor shall reestablish a diversified, self-sustaining stand of grass that is adapted to the region. The Construction Manager will determine acceptability of the grass growth in accordance with the following:

1. Landfill shall have at least 85% groundcover of permanent grass species.

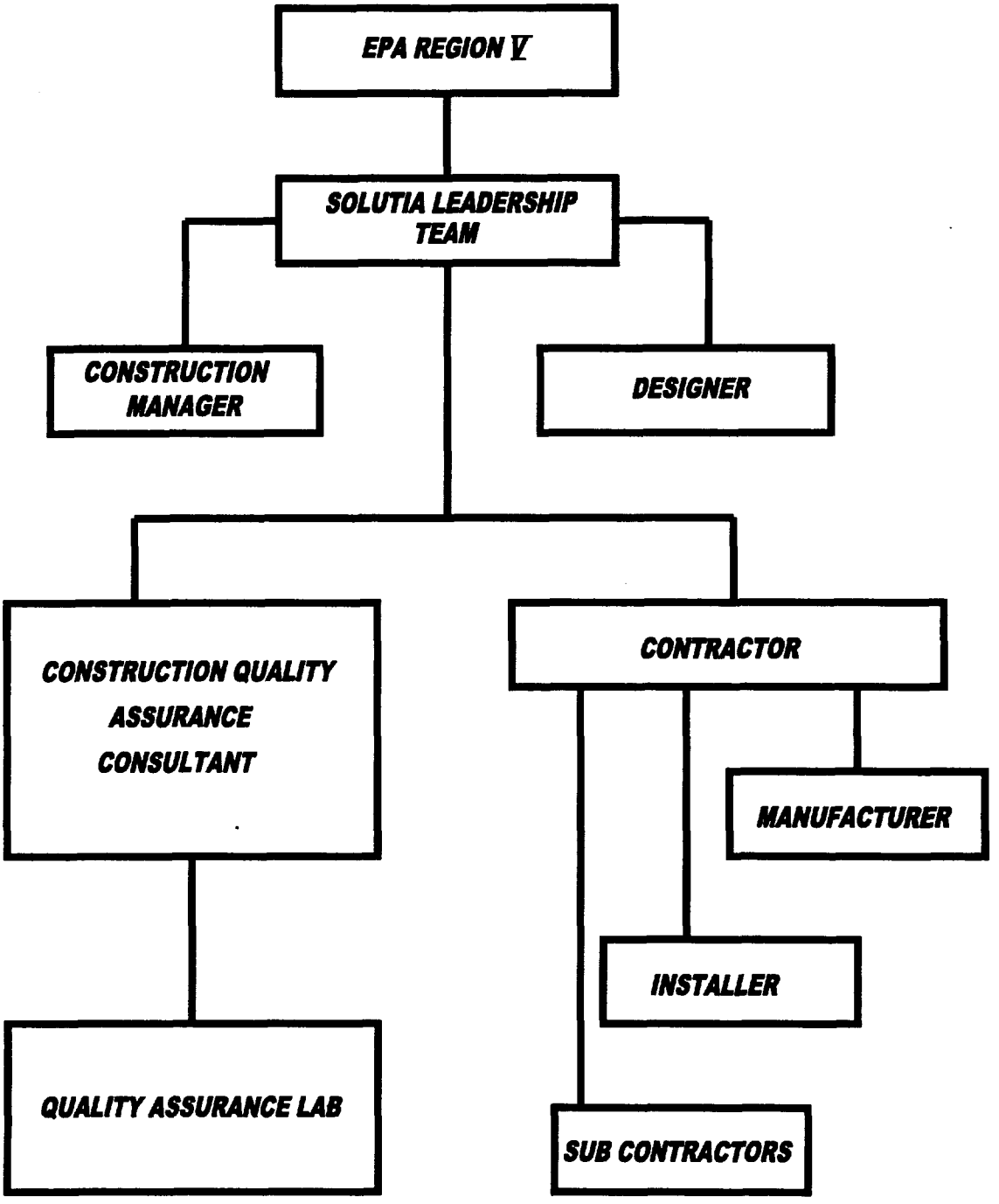
2. No area or patch greater than 36-inch x 36-inch shall be barren.

3. No trees, wood shrubs or deep-rooted plants shall be allowed to grow on the revegetated areas.

END OF SECTION 02932

ATTACHMENT 21

CONSTRUCTION QUALITY ASSURANCE PROJECT ORGANIZATION CHART



PREPARED FOR: SOLUTIA	Drawn:	PROJECT NAME SOLUTIA INC. SAUGET AREA 1	FIGURE 4-1
URSGWC JOB NUMBER: C100003899.00	Design:		
URS Greiner Woodward Clyde A Division of URS Corporation 7650 W. Courtney Campbell Causeway Tampa, Florida 33607-1462 Tel: 813.286.1711 Fax: 813.287.8591	Checked: G. WANTLAND	DRAWING TITLE CONSTRUCTION QUALITY ASSURANCE PROTECT ORGANIZATION CHART	
	Date: OCT. 30, 2000		

ATTACHMENT 22

GEOSYNTHETIC CQA REVISIONS

6.1 QUALITY CONTROL DOCUMENTATION

Prior to the installation of any geosynthetic clay liner (GCL), the Manufacturer or Installer shall provide the Construction Manager with the following information:

1. The origin (supplier's name and production plant), identification (brand name and number), and production date.
2. Copies of the quality control certificates issued by the supplier.
3. Reports on tests conducted by the Manufacturer to verify that the quality used to manufacture the GCL meets the Specifications.
4. Reports on quality control tests conducted by the Manufacturer to verify that the GCL manufactured for the project meets the project specifications.
5. A specification for the GCL which includes all properties contained in the Specifications measured using the appropriate test methods.
6. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.
7. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificates shall include roll identification numbers, sampling procedures and results of quality control tests. At a minimum, results shall be given for:

    a. Swell Index
    b. Mass per unit area
    c. Thickness
    d. Grab Tensile Strength
    e. Permeability

    Quality control tests shall be performed in accordance with the frequency and test methods identified in the Specifications.

The Manufacturer shall identify all rolls of GCLs with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
4. Roll dimensions

The Geosynthetic CQA Consultant shall review these documents and shall report any discrepancies with the above requirements to the Construction Manager. The Geosynthetic CQA Consultant shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.
4. Roll packages are appropriately labeled.
5. Certified minimum properties meet the Specifications.

6.2 CONFORMANCE TESTING

Upon delivery of the rolls of GCL, the Geosynthetic CQA Consultant shall ensure that conformance test samples are obtained for the GCL. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance to the Specifications.

At a minimum, the following tests shall be performed:

1. Swell Index
2. Mass per unit area
3. Thickness
4. Permeability

These conformance tests shall be performed in accordance with the test methods specified in the Solutia specifications. Other conformance tests required by the project specifications shall be performed.

6.2.1 Sampling Procedures

The rolls to be sampled shall be selected by the Geosynthetic CQA Consultant. Samples shall be taken across the entire width of the roll and shall not include the first 3 ft (1 m). Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic CQA Consultant shall mark the machine direction on the samples with an arrow.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the Geosynthetic CQA Consultant based on a review of all roll information including quality control documentation and manufacturing records.

6.2.2 Test Results

All conformance test results shall be reviewed and by the Geosynthetic CQA Consultant prior to the deployment of the GCL. The Geosynthetic CQA Consultant shall examine all results from

laboratory conformance testing and shall report any nonconformance to the Construction Manager. The Geosynthetic CQA Consultant shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications. Based upon the recommendations of the Geosynthetic CQA Consultant the Construction Manger will accept or reject the GCL.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different Solutia approved Geosynthetic QALs at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Construction Manager.

If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out of specification and rejected. Alternatively, at the option of the Construction Manager, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

6.3 GCL DEPLOYMENT

The Geosynthetic CQA Consultant shall examine rolls upon delivery and any deviation from the above requirements shall be reported to the Construction Manager.

The Installer shall handle all GCL in such a manner as to ensure that it is not damaged in any way, and the following shall be complied with:

1. On slopes, the GCL shall be secured and rolled down the slope in such a manner as to continually keep the GCL sheet in tension. If necessary, the GCL shall be positioned by hand after being unrolled to minimize wrinkles.
2. In the presence of wind, all GCL shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.
3. Unless otherwise specified, GCL shall not be welded to geomembrane.

4. GCL shall only be cut using scissors or other cutting tools approved by the Construction Manager that will not damage the underlying geosynthetics. Care shall be taken not to leave tools in the GCL.
5. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the GCL.
6. During placement of GCL, care shall be taken not to entrap dirt or excessive dust that could cause clogging of the drainage system, and/or stones that could damage the adjacent geomembrane. In this regard, care shall be taken with the handling of sandbags, to prevent rupture or damage of the sandbag.

The Geosynthetic CQA Consultant shall note any noncompliance and report it to the Construction Manager.

6.4 SEAMS AND OVERLAPS

Adjacent GCL shall be joined according to construction drawings and specifications. At a minimum, the following requirements shall be met:

1. Adjacent rolls shall be overlapped by at least 4 inches (100 mm).
2. In general, no horizontal seams shall be allowed on side slopes.
3. In the corners of the side slopes of rectangular landfills, where overlaps between perpendicular GCL strips are required, an extra layer of GCL shall be unrolled along the slope, on top of the previously installed GCL, from top to bottom of the slope.
4. When more than one layer of GCL is installed, joints shall be staggered.

The Geosynthetic CQA Consultant shall note any noncompliance and report it to the Construction Manager.

6.5 DEFECTS AND REPAIRS

Any holes or tears in the GCL shall be repaired by placing a patch extending 1 ft (0.3 m) beyond the edges of the hole or tear. If the hole or tear width across the roll is more than 50% of the width of the roll, the damaged area shall be repaired as follows:

1. On the base of the landfill, the damaged area shall be cut out and the two portions of the GCL shall be joined as indicated in the Specifications.
2. On sideslopes, the damaged GCL shall be removed and replaced.

The Geosynthetic CQA Consultant shall observe any repair and report any noncompliance with the above requirements in writing to the Construction Manager.

ATTACHMENT 23

GEOSYNTHETIC PROPERTY TABLE

GEOSYNTHETIC MATERIAL PROPERTIES
SAUGET AREA 1 TSCA LANDFILL

Material Type	Property	Test Method	Requirements		Frequency
			Value	Units	
HDPE Geomembrane					
	Liner Thickness, mils (nominal)	ASTM D5199	60		Per Roll
	Density (g/cc)	ASTM D1505-A	0.94		200,00 lb
	Melt Flow Index (g/10 min)	ASTM D1238-E	1.0 (max)		Per Batch
	Tensile Properties (min. ave.)	ASTM D638 Type IV Dumb-bell @ 2 ipm (2.0" Gauge Length) (NSF 54, Mod.)			20,000 lb
	1. Tensile Strength @ Break (ppi)		228		
	2. Elongation @ Break (%)		700		
	Tear Resistance (min. ave.)	ASTM D1004 Die C	42 lb		45,000 lb
	Low Temperature Brittleness °F	ASTM D746-B	-107 (max)		
	Dimensional Stability % Change Each Direction	ASTM D1204 212 °F 1 hr	± 2		
	Stress Crack Resistance (hrs)	ASTM D5397	200		Per Batch
	Puncture Resistance (min. ave.)	ASTM 4833	180 lb		45,000 lb
	Carbon Black Content (%)	ASTM D1603	2		20,000 lb
	Carbon Black Dispersion	ASTM D5596	A1, A2 and B1		45,000 lb
	Oxidative Induction Time (OIT)				200,000 lb
	(a) Standard OIT (min. ave.) -or-	ASTM D3895	100 minutes		
	(b) High Pressure OIT (min. ave.)	ASTM D5885	400 minutes		

Material Type	Property	Test Method	Requirements		Frequency
			Value	Units	
	UV Resistance	GM 11			Per Batch
	(a) Standard OIT (min. ave.)	ASTM D3895	Not Recommend	N/A	
	-or-				
	(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs	ASTM D5885	50%	N/A	
Geotextile					Per Batch
	Mass per Area	ASTM D 5261	16	oz/yd^2	
	Grab Strength	ASTM D 4632	380	lbs	
	Elongation	ASTM D 4632	60	%	
	AOS	ASTM D 4751	100	U.S. Sieve	
	Permittivity	ASTM D 4491	0.7	sec^{-1}	
	Trapezoidal Tear Strength	ASTM D 4533	145	lbs	
	Burst Strength	ASTM D 3786	750	psi	
	Puncture Strength	ASTM D 4833	240	lbs	
Geonet					Per Batch
	Density	ASTM D792 or D1505	0.90 min.	g/cu cm	
	Thickness	ASTM D5199	200 min.	mils	
	Melt Flow Index	ASTM D1238	1.0 max.	g/10 min.	
	Carbon Black Content	ASTM D1603	2-3 range	%	
	Tensile Strength at Break:				
	• Machine Direction	ASTM D751	25 min.	PPI	
	• Cross Direction	ASTM D751	15 min.	PPI	
	Transmissivity	ASTM D4716	1.0	cm/sec	

Material Type	Property	Test Method	Requirements		Frequency
			Value	Units	
Geosynthetic Clay Liner					
	Bentonite Content @ 20% Moisture Content	Weigh 12" x Roll Width	1.0	lbs/sq ft	1/20,000 sf
	Confined Swell	GRI-GCL-1	150	%	1/300,000 sf
	Permeability under 5 psi effective confining pressure	ASTM D5084	5×10^{-9}	cm/sec	1/1,000,000 sf
	Overlap Seam Permeability under psi effective confining pressure	ASTM D5084	5×10^{-9}	cm/sec	1/1,000,000 sf
	Hydrated Internal Residual Shear Resistance	ASTM D5321	10	degrees	Periodic
	Hydrated Internal Residual Shear Resistance	ASTM D532	16	degrees	Periodic

ATTACHMENT 24

SOIL MATERIAL PROPETY TABLE

TABLE 1A

PRE-CONSTRUCTION TESTING FREQUENCY FOR MATERIALS EVALUATION OF SOIL COMPONENTS OF LINING AND FINAL COVER SYSTEMS

SAUGET AREA 1 TSCA LANDFILL
SOLUTIA INC.
CAHOKIA, ILLINOIS

Test Type and ASTM Description	Compacted Fill (cu.yd)	Tracked-in Place Fill (cu.yd)	Drainage Material Sand (cu.yd)	Drainage Material Gravel (cu.yd)	Protective Soil (cu.yd)	Vegetative Cover (cu.yd)
Moisture Content (D2216)	1 per source	1 per source	1 per source	1 per source	1 per source	1 per source
Atterberg Limits (D4318)	1 per source	1 per source	----------	----------	1 per source	1 per source
Particle Size (Clays – D1140) (Sands, Gravel – D422)	1 per source	1 per source	1 per source	1 per source	1 per source	1 per source
Moisture Density (D698)	1 per source	1 per source	----------	----------	1 per source	1 per source
Permeability (Clays – D5084) (Sands, Gravel – D2434)	1 per source	1 per source	1 per source	1 per source	1 per source	1 per source

TABLE 1B

CONSTRUCTION TESTING FREQUENCY FOR MATERIALS EVALUATION OF SOIL COMPONENTS OF LINING AND FINAL COVER SYSTEMS

SAUGET AREA 1 TSCA LANDFILL
SOLUTIA INC.
CAHOKIA, ILLINOIS

Test Type and ASTM Description	Compacted Fill (cu yd)	Tranked-in Place Fill (cu yd)	Drainage Material Sand (cu yd)	Drainage Material Gravel (cu yd)	Protective Fill (cu yd)	Vegetative Cover (cu yd)
Moisture Content (D2216)	1 per 20,000	1 per 10,000	1 per 10,000	1 per 10,000	1 per 50,000	1 per 20,000
Atterberg Limits (D4318)	1 per 20,000	1 per 10,000	----------	----------	----------	1 per 10,000
Particle Size (Clays – D1140) (Sands, Gravel – D422)	1 per 20,000	1 per 10,000	1 per 10,000	1 per 10,000	1 per 50,000	1 per 10,000
Moisture Density (D698)	1 per 20,000	1 per 20,000	----------	----------	1 per 50,000	1 per 20,000
Permeability (Clays - D5084) (Sands, Gravel - D2434)	1 per 50,000	1 per 20,000	1 per 10,000	1 per 10,000	----------	1 per 20,000

TABLE 1C

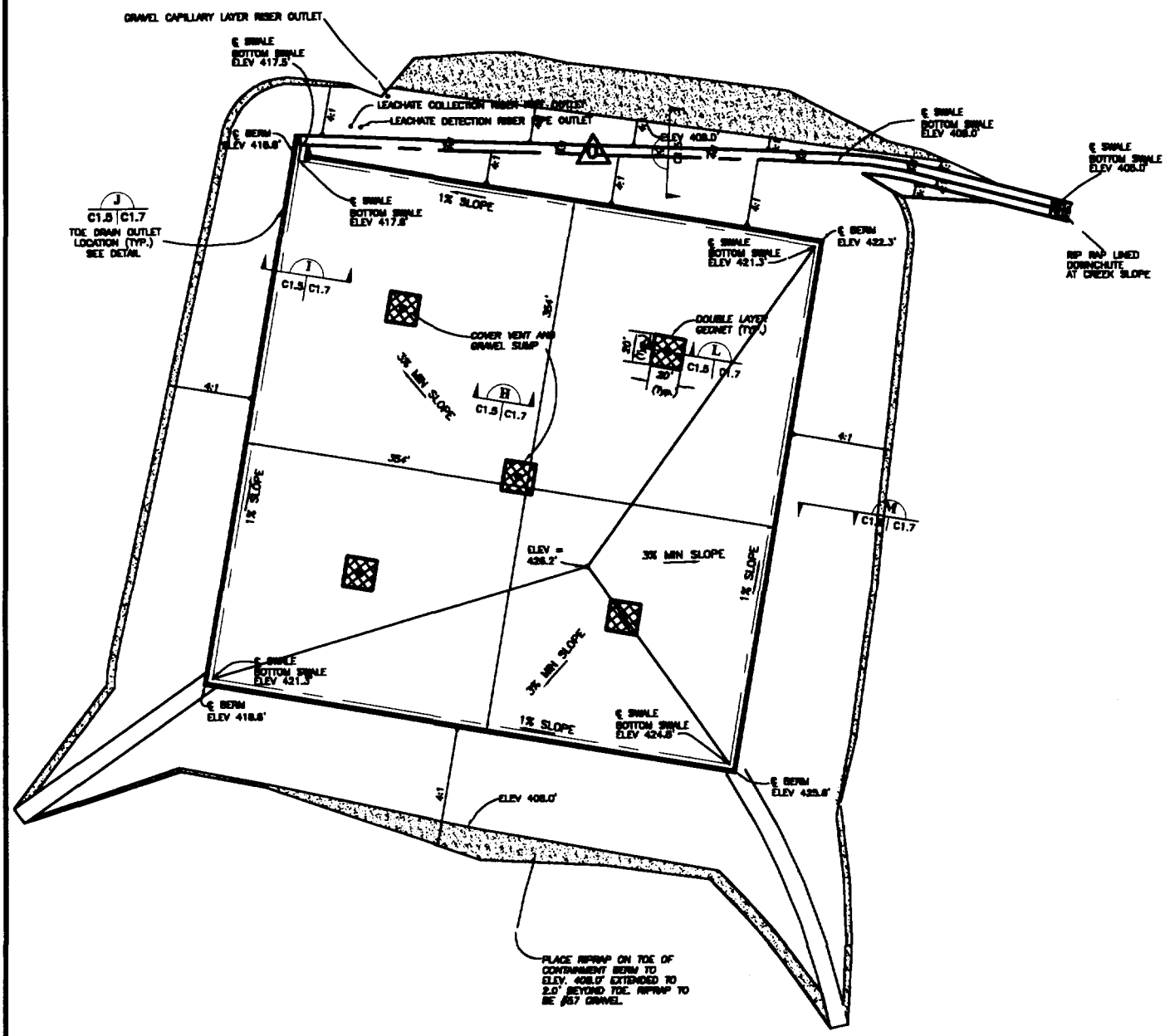
TESTING FREQUENCY FOR CONSTRUCTION QUALITY EVALUATION OF SOIL COMPONENTS OF LINING AND FINAL COVER SYSTEMS

SAUGET AREA 1 TSCA LANDFILL
SOLUTIA INC.
CAHOKIA, ILLINOIS

Test Type and ASTM Description	Compacted Fill	Tracked-in Place Fill	Drainage Material Sand	Drainage Material Gravel	Protective Fill	Vegetative Cover
Field Placed Moisture and Density (D2922/D3017)	1 per 2,000 yd^3	1 per 15,000 ft^2 or 6 per lift (minimum)	----------	----------	----------	1 per 2,000 yd^3
Field Placed Density/Moisture Verification (D2937)	1 per 15,000 yd^3	1 per 2,000 yd^3 or 1 per lift (minimum)	----------	----------	----------	----------
Layer Bonding	----------	1 per layer	----------	----------	----------	----------
Survey of As Built Configuration	• Base of fill • Completed section • As directed	All appurtenant components 50 feet center to center or minimum 6 points per grade at least the following locations: • Base of excavation • Top of first clay lift for each layer • Top of all collection systems • Base and top of all sumps and drains • As directed by the owner or his representative				
Inplace Permeability	----------	----------	----------	----------	----------	----------

ATTACHMENT 25

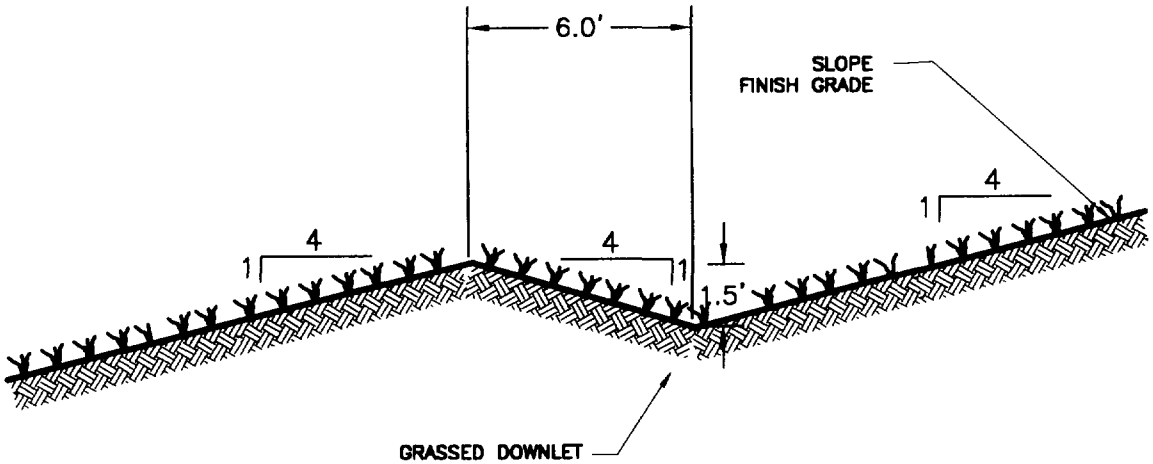
REVISED COVER SYSTEM FIGURES



NOT FOR CONSTRUCTION

PREPARED FOR: SOLUTIA INC.	Drawn: R. HAYDEN	PROJECT NAME SOLUTIA INC. SAUGET AREA 1	FIGURE 5-1
URSGWC JOB NUMBER: C100004051.00	Design: M. BRUNGARD		
URS Greiner Woodward Clyde A Division of URS Corporation 7650 W. Courtney Campbell Causeway Tampa, Florida 33607-1462 Tel: 813.286.1711 Fax: 813.287.8591	Checked: G. WANTLAND	DRAWING TITLE COVER SYSTEM PLAN	
	Date: OCT. 30, 2000		

S:\C10000\4000\4051.00\EPA COMMENT RESPONSE\REVISED FIGURES\C1.5_COVSYSPL_REV1.DWG 11/01/00 10:47



K DOWNCHUTE SECTION
C1.5 C1.7 N.T.S.

NOT FOR CONSTRUCTION

SOUTIA INC. SAUGET AREA 1 CAHOKIA, ILLINOIS	URS Greiner Woodward Clyde 7650 WEST COURTNEY CAMPBELL CSWY. TAMPA, FLORIDA 33607-1462 TEL: 813.286.1711 FAX: 813.287.8591		LEACHATE COLLECTION LAYER OUTLET PIPE SECTION	PROJECT NUMBER C10000406L00
	SCALE NTS	DRAWN BY: CRH CHECKED BY:	DATE: 10/23/00 DATE:	FIGURE NUMBER 5-6
	Downchute Section.dwg			