CITY WATER, LIGHT AND POWER
CITY OF SPRINGFIELD, ILLINOIS

MISTY BUSCHER, MAYOR
DOUG BROWN, CHIEF UTILITY ENGINEER

VIA E-MAIL: dierich.andrea@epa.gov

September 23, 2025

Andrea Dierich
EPA Project Officer
US EPA, Region 5
77 W Jackson Blvd
Chicago, IL 60604

RE: CCR Surface Impoundments
Revised Closure and Post-Closure Plans

Dear Ms. Dierich:

Provided herein are the revised Closure and Post-Closure Plans for the CCR Surface Impoundments. CWLP agreed to revise the 2016 Closure and Post-Closure Plans in accordance with paragraph 275 and Attachment 3 of the Consent Agreement and Final Order (CAFO) effective January 14, 2025.

Should you have any questions or require additional information, please contact me at 217-757-8610 ext. 1110.

Sincerely,

PJ Becker
Environmental Health and Safety Manager

Certification of City Water, Light and Power

City of Springfield, Office of Public Utilities, d/b/a City Water, Light and Power provides the following certification as required by paragraph 300 of the Consent Agreement and Final Order effective January 14, 2025.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I have no personal knowledge that the information submitted is other than true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Signature: 
Name: PJ Becker
Title: Environmental Health and Safety Manager
Date: 9/23/2025

Dallman and Lakeside Ash Ponds

Closure Plan

City Water, Light and Power
Springfield, Sangamon County, Illinois

September 23, 2025

Table of Contents

1. Responses to Attachment 3 Items 1

1.1 Closure Plan 1
1.1.1 A narrative describing how the unit will be closed and covered (40 CFR §257.102(b) and (d)). 1
1.1.2 Lake Springfield, Lakeside Ash Pond, and Clarification Pond affect groundwater after closure. 1
1.1.3 Detailed information included in all construction drawings. 1
1.1.4 A liquid migration assessment (horizontal and vertical) after final cover installation. 1
1.1.5 A design sufficient to withstand a 1,000-year flood event. 1
1.1.6 A discussion of the permeability of the final cover system. 2
1.1.7 A demonstration that there will not be sloughing or movement of the final cover system. 2
1.1.8 A closure schedule that describes the sequential steps that will be taken to close the unit. 2
1.1.9 A description of all methods for removing free liquids. 2
1.1.10 A description of how the wastes and materials remaining in the units will be stabilized. 2
1.1.11 Supporting calculations and information that the final cover system will be designed and constructed consistent with recognized and generally accepted good engineering practices. For example, the plan should include, when appropriate: 2
1.1.11.1 Supporting calculations and information that the final cover system will be designed and constructed consistent with recognized and generally accepted good engineering practices. 2
1.1.11.2 Geotechnical information demonstrating that the final cover system will not reduce slope stability. 2
1.1.11.3 Information regarding the potential settlement of CCR. 2
1.1.11.4 Drawings and cross sections showing the vertical and horizontal extent of CCR. 2
1.1.11.5 Drawings and cross sections showing the extent of the protective soil layer necessary to support vegetation. 2
1.1.11.6 Calculations demonstrating that the geocomposite drainage layer can effectively transmit liquid off the geomembrane. 3
1.1.11.7 Calculations demonstrating that the perimeter drainage ditches can provide adequate capacity. 3
1.1.11.8 Calculations supporting the size of any culverts used to support drainage 3
1.1.11.9 Provide for a Construction Quality Assurance Plan. 3
1.1.11.9.a Trial seams tested for peel strength and shear strength via ASTM D 6392. 3
1.1.11.9.b Non-destructive field seam continuity testing via ASTM D 5641 or ASTM D 5820. 3
1.1.11.9.c An organized, grid-based visual survey for geomembrane penetrations. 3
1.1.11.9.d Manufacturer requirements as needed to meet the manufacturer's warranty. 3
1.1.11.9.e A log to document where each test occurred. 3

2. Introduction 4

2.1 Regulatory Requirements 4

3. Site Background 4

3.1 Lakeside Ash Pond 4
3.2 Dallman Ash Pond 4
3.3 Clarification Pond 6

4. Closure of the CWLP Surface Impoundments 6

4.1 Introduction 6
4.2 Lakeside Ash Pond Closure 6
4.3 Dallman Ash Pond Closure 10
4.3.1 Alternative Final Cover System 10
4.3.2 Closure Process 11
4.3.3 Post-Closure Groundwater 13

5. Construction Quality Assurance Plan 14

5.1 Introduction 14
5.2 Responsibility and Authority of Project Personnel 14
5.2.1 Owner 16
5.2.2 Design Engineer 16
5.2.3 CQA Personnel 16
5.2.3.1 Key Personnel (Owner's Representative) 16
5.2.3.2 Document Control 18
5.2.4 Testing and Monitoring Firms 18
5.2.4.1 Soil/Concrete Testing (Lab and Field) 18
5.2.4.2 Surveyor 18
5.2.4.3 Geosynthetics Monitor and Geosynthetics Testing Laboratory 19
5.2.5 Contractors, Suppliers and Installers 19
5.3 Project Meetings 19
5.3.1 Preconstruction Meetings 19
5.3.2 Progress Meetings 20
5.3.3 Problem or Work Deficiency Meetings 20
5.4 In-Progress Acceptance of Work 21
5.4.1 Introduction 21
5.4.2 Elements of Work Requiring Prior Acceptance 21
5.5 Sampling and Testing Requirements 21
5.5.1 Introduction 21
5.5.2 Soils 22
5.5.2.1 Foundations and Berms 22
5.5.3 Geosynthetics 23
5.5.3.1 Geomembrane 23
5.5.3.1.a Prequalification Testing 23
5.5.3.1.b Installer Certification of Placement Surface 23
5.5.3.1.c Placement Testing for Seam Overlap 23
5.5.3.1.d Placement Non-Destructive Testing 23
5.5.3.1.e Pre-Placement Destructive Testing 25
5.5.3.1.f Grid-Based Visual Inspection 27
5.5.3.2 Geotextile 27
5.5.3.2.a Prequalification Testing 27
5.5.3.2.b Installer Certification of Placement Surface 27
5.5.3.2.c Deployment 28
5.5.3.3 Synthetic Turf 28
5.5.3.3.a Prequalification Testing 28
5.5.3.3.b Installer Certification of Placement Surface 29
5.5.3.3.c Deployment 29

5.5.4 Drainage Media 29
5.5.4.1 Coarse Aggregate 29
5.5.4.1.a Prequalification Testing 29
5.5.4.1.b Material Placement 29
5.5.4.1.c Certification of Work 30
5.5.4.2 Specified Aggregate Infill 30
5.5.4.2.a Prequalification Testing 30
5.5.4.2.b Material Placement 30
5.5.4.2.c Certification of Work 30
5.5.5 Other Material Placement Testing 30
5.5.5.1 Placement Testing of Dewatering System Piping System 30
5.5.5.2 Placement Testing of Surface Water Management System 31
5.5.5.3 Placement Testing of Concrete 31
5.6 Corrective Measures 31
5.7 Documentation Of Sampling, Inspections and Testing 31
5.7.1 Daily Summary Reports 31
5.7.2 Daily Inspection Reports 31
5.7.3 Photographs 32
5.8 Acceptance Report 32
5.9 Construction Management Activities 32
5.9.1 Requests for Information (RFIs) 32
5.9.2 Review of Contractor Submittals 32
5.9.3 Field Change Order Process 33
5.10 Document Control and Project Records 33
5.10.1 CQA Plan 33
5.10.2 Project Records 34

6. References 36

Appendices

Appendix A ClosureTurf® Documentation
Appendix B Final Cover HELP Model Results
Appendix B.1 40 CFR 257.102(d) Final Cover HELP Model Results
Appendix B.2 ClosureTurf® Final Cover HELP Model Results
Appendix C CQA Plan Table C.1
Appendix D 1,000-year Storm Drainage Calculations
Appendix E Settlement and Slope Stability Calculations
Appendix F Closure Plan Drawings and Sections

Figures and Tables

Figures

Figure 1. Site Location Map 5
Figure 2. Closure Schedule for Lakeside and Dallman Ash Ponds 7
Figure 3. Dallman Dewatering Well Location Map 12
Figure 4. Project Organization Chart 15
Figure 5. Control of CQA Documents and Samples 35

Tables

Table 1. Physical Properties of LAP CCR 6
Table 2. Physical Properties of DAP CCR 11
Table 3. Lower Cohesive Unit Permeability Results 13
Table 4. Installer Certifications for Acceptance of Work 21
Table 5. Geomembrane Destructive Seam Tests and Frequency 26

Copyright © 2025 by Hanson Professional Services Inc. All rights reserved. This document is intended solely for the individual or the entity to which it is addressed. The information contained in this document shall not be duplicated, stored electronically, or distributed, in whole or in part, by anyone other than the recipient without the express written permission of Hanson Professional Services Inc., 1525 S. Sixth St., Springfield, IL 62703, (217) 788-2450, www.hanson-inc.com. Unauthorized reproduction or transmission of any part of this document is a violation of federal law. Any concepts, designs and project approaches contained herein are considered proprietary. Any use of these concepts and approaches by others is considered a violation of copyright law.

1. Responses to Attachment 3 Items

1.1 Closure Plan

1.1.1 A narrative describing how the unit will be closed and covered (40 CFR §257.102(b) and (d)).

See Section 4. Closure of the CWLP Surface Impoundments.

1.1.2 Lake Springfield, Lakeside Ash Pond, and Clarification Pond affect groundwater after closure.

See Section 4.3.3 Post-Closure Groundwater.

1.1.3 Detailed information included in all construction drawings.

See Appendix F Closure Plan Drawings and Sections.

1.1.4 A liquid migration assessment (horizontal and vertical) after final cover installation.

Using Darcy's Law (Q=kiA, where Q is the water volume per unit time, k is hydraulic conductivity, i is the gradient, and A is the area) an estimate of the seepage volume can be determined. Using the hydraulic conductivity values from the lower cohesive unit and berm testing (see Section 4.3.3 and Table 3) the following table shows the calculations:

Horizontal				***Vertical***			***Units***
k =	6.90E-07			3.42E-07			cm/sec
t =	35	Clarification	DAP	17.40	Basal Sand	DAP	
h =	-23.4757	546.5	523	7.57	530	523	
i =	-0.67073			0.519561			—
A =	100			100			sq ft
A =	92903			92903			sq cm
Q =	-4.30E-02			1.65E-02			cu cm/sec

For the horizontal scenario, k is the geometric mean of the Shelby tube tests, t is the horizontal thickness of the Clarification Pond/DAP berm, h is the difference in head between the Clarification Pond and DAP, i is the gradient (dh/dt), and A is assumed to be 100 sq. ft. For the vertical scenario, k is the Shelby tube sample values, t is the geometric mean thickness of the lower confining unit beneath DAP, h is the difference in head between the floor of DAP and the basal sand unit plus the geometric mean thickness of the lower confining unit beneath DAP, and A is assumed to be 100 sq. ft.

The horizontal Darcy's calculation shows that the seepage volume is 4.30×10^{-2} cu. cm/sec into DAP and the vertical seepage volume is 1.65×10^{-2} cu. cm/sec into DAP. The dewatering wells are intended to remain in place and working to keep seepage water from coming in contact with CCR.

1.1.5 A design sufficient to withstand a 1,000-year flood event.

A discussion of the storm water ditch design, letdown structure, and sizing calculations for a 1,000-year storm event may be found in Appendix D 1,000-year Storm Drainage Calculations.

1.1.6 A discussion of the permeability of the final cover system.

See Section 4.3.1 Alternative Final Cover System

1.1.7 A demonstration that there will not be sloughing or movement of the final cover system.

Discussions regarding sloughing or movement of the final cover system are in Appendix E Settlement and Slope Stability Calculations.

1.1.8 A closure schedule that describes the sequential steps that will be taken to close the unit.

See Figure 2. Closure Schedule for Lakeside and D.

1.1.9 A description of all methods for removing free liquids.

See Section 4.3.2 Closure Process

1.1.10 A description of how the wastes and materials remaining in the units will be stabilized.

See Section 4.3.2 Closure Process and Appendix E Settlement and Slope Stability Calculations.

1.1.11 Supporting calculations and information that the final cover system will be designed and constructed consistent with recognized and generally accepted good engineering practices. For example, the plan should include, when appropriate:

1.1.11.1 Supporting calculations and information that the final cover system will be designed and constructed consistent with recognized and generally accepted good engineering practices.

Discussions regarding the final cover system are in Appendix E Settlement and Slope Stability Calculations.

1.1.11.2 Geotechnical information demonstrating that the final cover system will not reduce slope stability.

Discussions regarding slope stability of the final cover system are in Appendix E Settlement and Slope Stability Calculations.

1.1.11.3 Information regarding the potential settlement of CCR.

Discussions regarding settlement are in Appendix E Settlement and Slope Stability Calculations.

1.1.11.4 Drawings and cross sections showing the vertical and horizontal extent of CCR.

A plan view and supporting cross sections are on Drawings C104 and C203.

1.1.11.5 Drawings and cross sections showing the extent of the protective soil layer necessary to support vegetation.

The ClosureTurf® system does not use vegetation or a protective soil cover layer.

1.1.11.6 Calculations demonstrating that the geocomposite drainage layer can effectively transmit liquid off the geomembrane.

See the ClosureTurf® documentation in Appendix A ClosureTurf® Documentation and the ClosureTurf® HELP model output in Appendix B.2 ClosureTurf® Final Cover HELP Model Results.

1.1.11.7 Calculations demonstrating that the perimeter drainage ditches can provide adequate capacity.

A discussion of the storm water ditch design, letdown structure, and sizing calculations for a 1,000-year storm event may be found in Appendix D 1,000-year Storm Drainage Calculations.

1.1.11.8 Calculations supporting the size of any culverts used to support drainage.

A discussion of the storm water ditch design, letdown structure, and sizing calculations for a 1,000-year storm event may be found in Appendix D 1,000-year Storm Drainage Calculations.

1.1.11.9 Provide for a Construction Quality Assurance Plan.

See Section 5. Construction Quality Assurance Plan.

1.1.11.9.a Trial seams tested for peel strength and shear strength via ASTM D 6392.

The relevant ASTM standard is listed for the relevant test in Section 5.5.3.1.

1.1.11.9.b Non-destructive field seam continuity testing via ASTM D 5641 or ASTM D 5820.

The relevant ASTM standard is listed for the relevant test in Section 5.5.3.1.

1.1.11.9.c An organized, grid-based visual survey for geomembrane penetrations.

See Section 5.5.3.1.f for a discussion of the grid-based inspections.

1.1.11.9.d Manufacturer requirements as needed to meet the manufacturer's warranty.

Manufacturer's requirements are outlined in Specification 01 73 19 Installation of ClosureTurf v 21061.pdf located in Appendix A ClosureTurf® Documentation.

1.1.11.9.e A log to document where each test occurred.

All testing shall be documented on the Daily Inspection Reports (Form CQAP-8.2).

2. Introduction

2.1 Regulatory Requirements

This document amends the CWLP 2016 Closure Plan (AEI, 2016a) to meet the requirements of 40 CFR 257.102 and the January 2025 Consent Agreement and Final Order.

§ 257.102

- This regulation sets forth the criteria and requirements for the closure or retrofitting of CCR units. These include a written closure plan that includes how the unit will be closed, the type of closure (clean close or close-in-place), an estimate of maximum inventory, an estimate of the largest area for final cover, and a closure completion schedule.

Consent Agreement and Final Order Count 8

- Clarification of identified deficiencies in the original Closure Plan (AEI, 2016) to 40 CFR 257.102 requirements.

Consent Agreement and Final Order Attachment 3

- Additional requirements to be considered in the Closure Plan.

3. Site Background

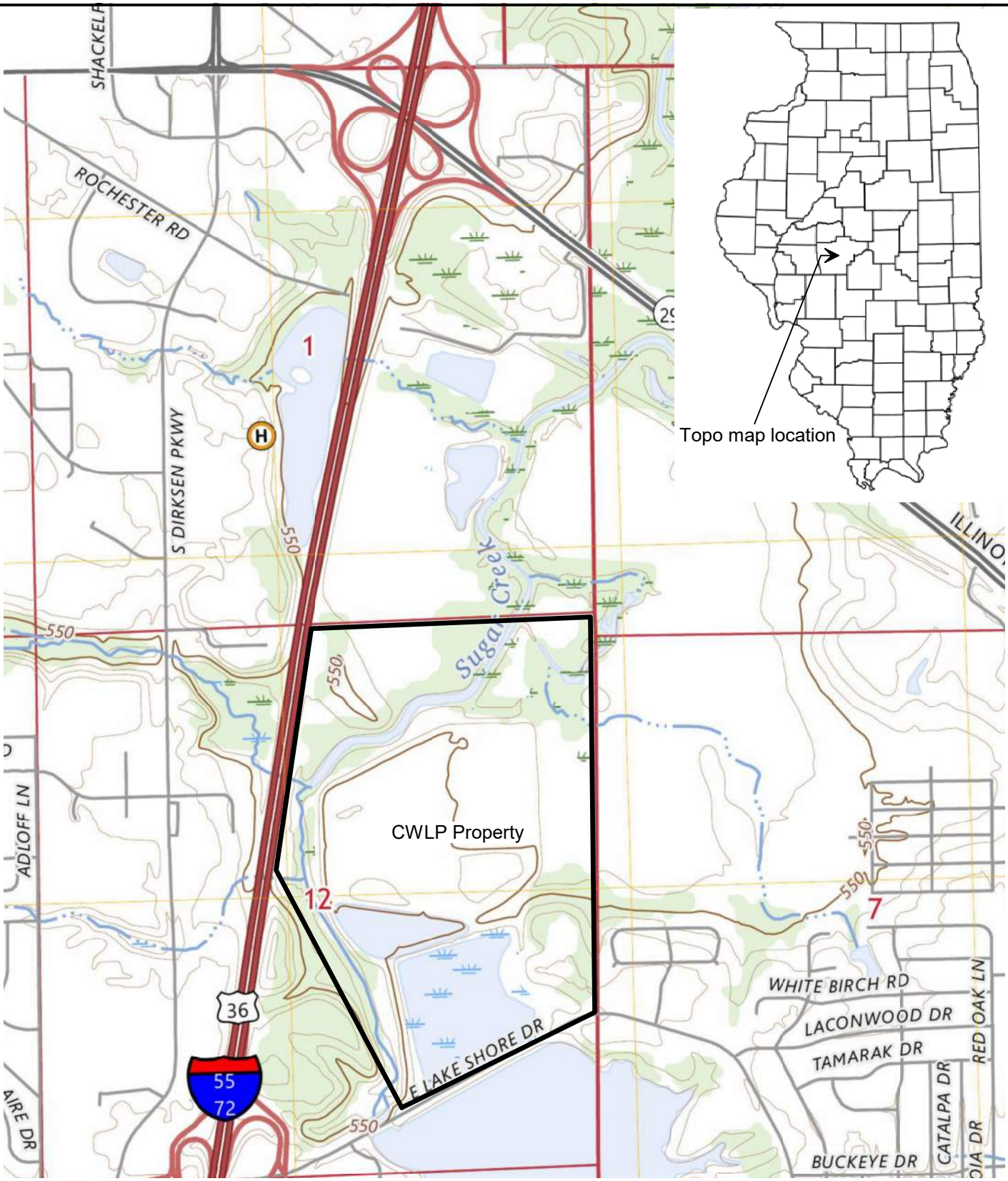
The CWLP ash ponds are in Section 12 R.5W, T.15N of the Third Principal Meridian in Springfield, Sangamon County, Illinois. The Site is in the Springfield Plain of the Central Lowland Province Physiographic Division of Illinois (Leighton et al., 1948).

3.1 Lakeside Ash Pond

The older of the two (2) impoundments is Lakeside Ash Pond (LAP). LAP has a footprint of approximately 36 acres and contains approximately 1,565,000 cubic yards (cu. yd.) of CCR along with water treatment plant sludge. The current footprint is the maximum area that would require final cover if LAP was closed-in-place. The floor of LAP is approximately elevation 530 ft. and slopes upward in the southeast corner following the natural topography.

3.2 Dallman Ash Pond

Dallman Ash Pond (DAP) has a footprint of approximately 36 acres and currently contains approximately 1,217,000 cu. yd. of CCR. In the past, there were two (2) Illinois Department of Transportation (IDOT) construction projects that used approximately 875,000 cu. yd. of DAP CCR for a maximum volume of CCR of almost 2,100,000 cu. yd. The current footprint is the maximum area that would require final cover if DAP was closed-in-place. The floor of DAP slopes from the south to the northeast corner (from elevation 525 ft. to about 523 ft. Note that the bottom of DAP at boring D4 is over elevation 530 ft. (see Figure 3).



SCALE: 1 inch equals 400 feet

0 400 800 1200

CONTOUR INTERVAL = 10 feet

© Copyright Hanson Professional Services Inc. 2025

HANSON

Site Location Map

Dallman and Lakeside Ash Ponds
City Water, Light and Power
Springfield, Sangamon Co., Illinois

HANSON NO. 25E0006.00 FIGURE 1

3.3 Clarification Pond

The Clarification Pond footprint is approximately 7.8 acres and is a non-CCR unit. The Clarification Pond collects storm water runoff from DAP and LAP for treatment and discharge at National Pollutant Discharge Elimination System (NPDES) Outfall 004. Unit 2 Landfill leachate and process water from the Lime Lagoons is also discharged to the Clarification Pond for treatment and discharge at Outfall 004. A modification of the CWLP NPDES permit is currently pending at Illinois Environmental Protection Agency (IEPA) Bureau of Water to allow treatment and discharge of pore water in contact with CCR (dewatering fluids).

4. Closure of the CWLP Surface Impoundments

4.1 Introduction

CWLP intends to consolidate LAP into DAP. The Clarification Pond will remain in place to handle the existing process water discharges that are discharged through Outfall 004. A summary of closure steps and associated timeline are in Figure 2.

4.2 Lakeside Ash Pond Closure

It is CWLP's intention to close LAP by consolidating its CCR into DAP. The removal of CCR will be done in a two-step process. First, much of the unsaturated CCR will be excavated and placed into DAP, and second, the saturated CCR will be sluiced to DAP and placed into geotextile bags to assist with consolidation and dewatering of the LAP CCR. Table 1 lists some of the physical properties of the LAP CCR.

Table 1. Physical Properties of LAP CCR

Sample Boring/Depth	Bulk Density (gm/cc)	Bulk Density (lb/cu ft)	Particle Density (gm/cc)	Porosity (%)	Field Capacity (%)	Wilting Point (%)
LB01 24.5-26.0	0.72	44.94	2.46	70.6	60.0	19.9
LB02 12.0-13.5	1.35	84.27	2.54	46.8	11.1	4.2
LB03 19.5-21.0	0.79	49.31	2.16	63.2	53.0	9.9
LB04 12.0-13.5	0.84	52.43	2.25	62.8	49.9	9.0
LB05 19.5-21.0	0.73	45.57	2.24	67.5	60.6	11.0

Source: Agvice Laboratories, Northwood, ND

The important properties listed in Table 1 are porosity and field capacity. Porosity identifies how much water the CCR can hold (as a percentage). Field capacity is defined as "the amount of water held in soil after the gravitational water has drained away." (Foth & Turk, 1972).

Hanson suspects that the difference in properties from LB02 and the rest of the samples is the percentage of bottom ash. Note in Table 2 that the DB04 sample has similar property differences, and the location of this sample is associated with bottom ash discharges from Dallman Unit 31 and Unit 32.

Figure 2.
Closure Schedule for LAP and DAP

Tasks	Time (in weeks)																																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
1. Preliminary grading, including storm water ditches																																										
2. Install toe drain on west and north sides of Dallman																																										
3. Install dewatering wells																																										
4. Dewater & Consolidate Dallman																																										
5. Move unsaturated Lakeside CCR to Dallman and grade																																										
6. Move saturate Lakeside CCR to geotextile bags at Dallman																																										
7. Place soil/berm material over geotextile bags and install drainage structures																																										
8. Install geomembrane																																										
9. Install engineered turf and granular infill																																										
10. Construction quality assurance																																										
11. Plat of survey																																										
12. Documentation of closure activities																																										

I:\25jobs\25E0006_00\Admin\14-Reports\CPPCP\ClosureTimeline_20250923.xlsx

Figure 2.
Closure Schedule for LAP and DAP

| Tasks | Time (in weeks) | | |

Figure 2.
Closure Schedule for LAP and DAP

Tasks	Time (in weeks)																																					
	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
1. Preliminary grading, including storm water ditches																																				
2. Install toe drain on west and north sides of Dallman																																				
3. Install dewatering wells																																				
4. Dewater & Consolidate Dallman																																				
5. Move unsaturated Lakeside CCR to Dallman and grade																																				
6. Move saturate Lakeside CCR to geotextile bags at Dallman																																				
7. Place soil/berm material over geotextile bags and install drainage structures																																				
8. Install geomembrane																																				
9. Install engineered turf and granular infill																																				
10. Construction quality assurance																																				
11. Plat of survey																																				
12. Documentation of closure activities																																				

I:\25jobs\25E0006_00\Admin\14-Reports\CPPCP\ClosureTimeline_20250923.xlsx

Excluding data from LB02, LAP samples show porosity (n) values in the low-60% to 70% range, and field capacities that range from around 50% to over 60%. The field capacity percentages are an indication of the volume of water that is retained within the CCR after it has been drained. Therefore, the volume of water removed is only the portion of the total water within the CCR that can be removed by gravity drainage. It is this water-holding capacity of the LAP CCR that will allow the sluicing of the material for consolidation into DAP.

During the closure process, the unsaturated CCR will need to be trucked from LAP to DAP. Once placed into DAP, the CCR will be graded to allow the placement of the saturated CCR into the geotextile bags that will allow containment, dewatering, and consolidation of the sluiced LAP CCR.

Once the majority of CCR has been consolidated into DAP, decontamination of the base of LAP will begin. The base of the LAP will be visually inspected for CCR, and this material will be removed and consolidated at DAP. Any riprap, stone, or other remaining materials that show visual influence of CCR will also be removed and consolidated into DAP. Removal of any soil on the surface of Spalding Dam and excavation of in situ soil at the toe of Spalding Dam will be prohibited due to the potential of creating dam instability. Upon completion of CCR removal, any previous erosion control structures for Spalding Dam will be replaced. The area formerly occupied by LAP will become a storage area for excess water released from Lake Springfield.

4.3 Dallman Ash Pond Closure

4.3.1 Alternative Final Cover System

CWLP intends to use WatershedGeo's ClosureTurf® system for the final cover. ClosureTurf® is a patented, three component system comprised of a structured geomembrane, an engineered turf, and a specified aggregate infill. ClosureTurf® meets the requirements of 40 CFR 257.102(d)(3)(ii):

1) The permeability of the ClosureTurf® is less than the geometric mean permeability of Shelby tube samples collected from the in-situ soils immediately beneath the CCR at the bottom of DAP. That geometric mean permeability is 4.53×10^{-7} cm/sec.
2) The studded surface of the structured geomembrane liner (AGRU MicroDrain®) behaves similarly to a biplanar geocomposite drainage net. This rapidly removes precipitation (or other fluids) and prevents ponding and reduces infiltration.
3) HELP model results show that the ClosureTurf® performs better than the final cover system described in 40 CFR 257.102(d)(3)(i). HELP model v4.0 results are in Appendix A. The ClosureTurf® equivalent hydraulic conductivity from the HELP model was 1.46×10^{-11} cm/sec versus an equivalent hydraulic conductivity of 1.22×10^{-8} cm/sec for the 40 CFR 257.102(d)(3)(i) final cover.
4) The engineered turf cover has been tested for wind uplift resistance, shear strength, puncture resistance, and UV longevity. It is also erosion resistant. ClosureTurf® supporting documentation is in Appendix B.

The HELP Model version 4.0 (USEPA, 2020) was used for the performance assessment of the regulatory final cover and the ClosureTurf® final cover. The General Information, Weather data (precipitation, temperature, solar radiation, wind/humidity, and other parameters), and Runoff Curve Number were the same in both

scenarios, which was specific to either the model latitude/longitude or Springfield Capital Airport. Also the same in both scenarios were the geomembrane defects (5 pinholes per acre and 1 installation defect per acre). The Soil & Design layers were either taken from the 40 CFR 257.102(d)(3)(i) description or from the ClosureTurf® Design Guidance Manual Table 8-1 (in Appendix B). A custom layer was setup for the CCR using the Table 2 (for the physical properties of the DAP CCR) data and silty clay loam was used to represent the Lower Cohesive Unit in both scenarios. Model scenario outputs are in Appendix A.

4.3.2 Closure Process

DAP will be closed in place along with the consolidated contents of LAP. This will increase the CCR volume in DAP to 2,782,000 cu. yd. when closed and covered The first step for DAP closure will be some limited grading and ditching to allow precipitation to be better directed to the Clarification Pond for discharge, followed by the installation of dewatering wells to aid in removal of the pore water in the CCR held above field capacity (see Table 2). The dewatering well locations are identified on Figure 3. This figure shows the ten (10) dewatering well locations, anticipated radius of influence, and the floor topography. Hanson anticipates that the sidewalls will gravity drain to the floor, and any drainable pore water will either be removed by the dewatering wells or will flow downslope to the northeast corner of DAP for removal. These dewatering wells will remain in place during and after construction to ensure that the CCR remains at or below field capacity. Dewatering well details are located on Sheet C501 of the plan set found in Appendix F.

Table 2. Physical Properties of DAP CCR

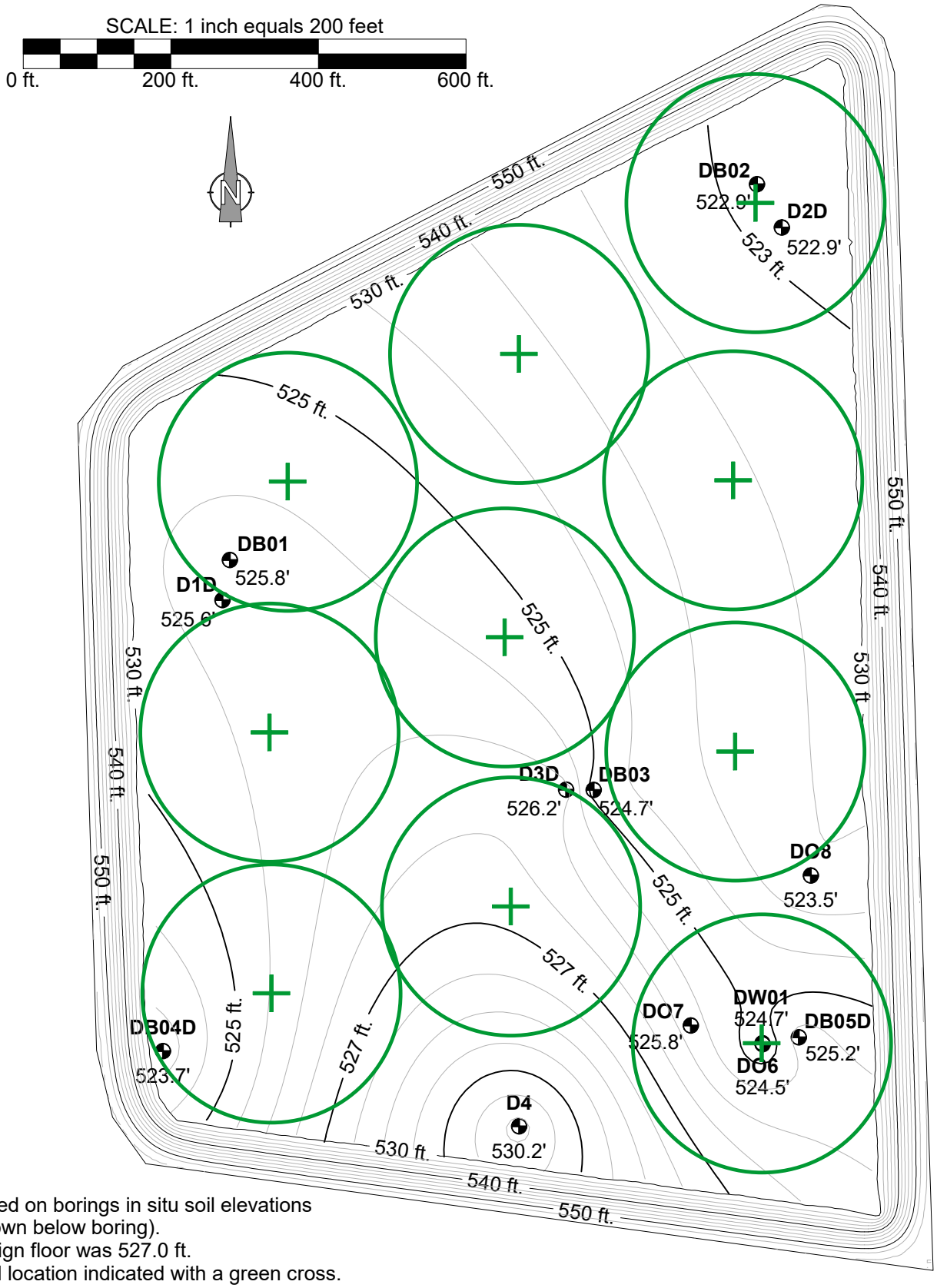
Sample Boring/Depth	Bulk Density (gm/cc)	Bulk Density (lb/cu ft)	Particle Density (gm/cc)	Porosity (%)	Field Capacity (%)	Wilting Point (%)
DB01 9.5-11.0	1.04	64.92	2.20	52.6	37.3	6.5
DB02 17.0-18.5	0.93	58.05	2.11	55.9	41.9	6.9
DB03 22.0-23.5	0.97	60.55	2.21	55.9	39.1	6.0
DB04 2.0- 3.5	1.40	87.39	2.50	44.0	18.2	3.9
DB05 14.5-16.0	1.02	63.67	2.15	52.7	40.0	6.9

Source: Agvice Laboratories, Northwood, ND

Once dewatered and settlement of CCR has begun, the surface of DAP will be graded to support runoff to the perimeter drainage ditches. Consolidation of the dry CCR from LAP will continue following this grading process.

Once the saturated LAP CCR has been exposed, sluicing of the CCR to geotextile bags (typically 6-8 ft. tall, 45 ft. wide, and 90 ft. long) will begin. These geotextile bags will provide both structural support for the CCR and aid in dewatering and settlement of the CCR. Geotextile bags will be stacked to provide a 4:1 side slope and a 3% cap. The "steps" in the stacked geotextile bag structure will be filled in with random soil to provide a stable and flat surface to apply the geomembrane portion of the final cover system.

The ClosureTurf® geomembrane panels will be placed from the top of DAP downslope to the perimeter drainage ditches, through the drainage ditches, and into an anchor trench located at the inboard edge of the perimeter berms. Geomembrane panels will be overlap welded and tested in accordance with the procedures described in the CQA Plan (Section 5.5.3.1.c). ClosureTurf® documentation is in Appendix A. Once the geomembrane panels are sealed and tested the CCR in DAP will effectively be isolated from any precipitation infiltration back into the CCR.



Based on borings in situ soil elevations
(shown below boring).
Design floor was 527.0 ft.
Well location indicated with a green cross.
Green circles are the well radius of influence.

Copyright Hanson Professional Services Inc. 2025

Contour Interval
Floor = 0.5 ft.
Sidewall = 2 ft.

HANSON

Dallman Dewatering Well Location Map

Dallman and Lakeside Ash Ponds
City Water, Light and Power
Springfield, Sangamon Co., Illinois

HANSON NO. 25E0006.00 FIGURE 3

I:\25jobs\25E0006_00Admin\14-Reports\CPPCP/DallmanDWellMap_20250711.srf

Pursuant to 40 CFR 257.102(d), closure in place of DAP will:

1) Control, minimize, or eliminate post-closure infiltration of liquids into the CCR and prevent releases of CCR, leachate, or contaminated runoff using the ClosureTurf® final cover system.
2) The final cover system slopes will preclude the probability of impounding water, sediment, or slurry.
3) Slope stability calculations indicate that movement of the final cover system or its foundation is unlikely (see Appendix E).
4) The ClosureTurf® final cover system is designed to be maintenance-free.
5) And is designed to be completed in as short a time as practical, consistent with good engineering practices.

4.3.3 Post-Closure Groundwater

Groundwater in the upper-most aquifer, after consolidation of LAP and final cover installation at DAP, should not be affected. The two water bodies up-gradient of DAP are Lake Springfield and the Clarification Pond. Neither should affect groundwater elevations, and the Clarification Pond should not have any interaction with DAP. Some factors that preclude surface water/groundwater interaction include:

1) Spalding Dam is constructed with a concrete cutoff wall that is keyed into bedrock (on the west side of the dam) or has a steel sheet pile wall located underneath (on the eastern side of the dam) to prevent seepage beneath the dam.
2) The Clarification Pond is constructed on the lower confining unit and permeability tests collected from the floors of the ash ponds have a geometric mean hydraulic conductivity of 3.42×10^{-7} cm/sec (see Table 3).

Table 3. Lower Cohesive Unit Permeability Results

Boring ID (depth in ft)	**Permeability** (cm/sec)
D1 (38.5'-40.5')	5.1×10^{-8}
D2 (35.5'-37.5')	2.8×10^{-7}
D3 (29.5'-31.5')	2.1×10^{-6}
D4 (34.5'-36.5')	1.4×10^{-6}
L1 (36'-38')	4.5×10^{-7}
L3 (34.5'-36.5')	8.5×10^{-8}
L4 (17'-19')	1.7×10^{-8}
L5 (37.5'-39.5')	6.8×10^{-6}
Average	1.40×10^{-6}
Geometric Mean	3.42×10^{-7}
Median	3.65×10^{-7}

NOTE: Test ran according to ASTM D-5084.

3) The berm between the Clarification Pond and DAP also had permeability tests performed. Both samples had hydraulic conductivity results of 6.9 x 10^{-7} cm/sec (BH01 at 7-9 ft. and BH02 at 16.5-18.5).

4) DAP will be dewatered prior to construction of the final cover system. This coupled with the low hydraulic conductivity results from the permeability tests should prevent influence on the upper-most aquifer.

5. Construction Quality Assurance Plan

5.1 Introduction

This Plan describes the Construction Quality Assurance (CQA or Plan) program for the Dallman Ash Pond at CWLP's facility in Springfield, Sangamon County, Illinois. The Plan has been developed based on the requirements of 35 Illinois Administative Code (IAC) Part 811, Subpart E entitled *Construction Quality Assurance Programs*.

The Plan requires a scheduled program of CQA monitoring, inspection, sampling and testing to verify compliance with project plans and specifications.

Appendix C lists the testing methods, acceptance requirements, and testing frequencies that shall guide the implementation of this Plan. Also listed is the party responsible for conducting the testing for each of the constucted components of the required under this Plan. This Plan requires oversight by a CQA Officer for all testing carried out by the geosynthetic installers.

The CQA Plan also requires preparation by the CQA Officer of an acceptance report at the end of construction that provides all inspection and testing documentation and certifies that the facility has been constructed in accordance with the engineering design.

This Plan is intended to supplement the project plans and specifications. Where a conflict exists, the CQA Plan will govern.

5.2 Responsibility and Authority of Project Personnel

The project participants involved in the construction and quality assurance oversight of the construction are shown in Figure 4. *Project Organization Chart*. The Owner is the City of Springfield Illinois (City or CWLP) who will retain a General Contractor to construct the facility and a CQA Officer to provide the quality assurance oversight services. The following lists the responsibilities and authority of each of the participants shown in Figure 4.

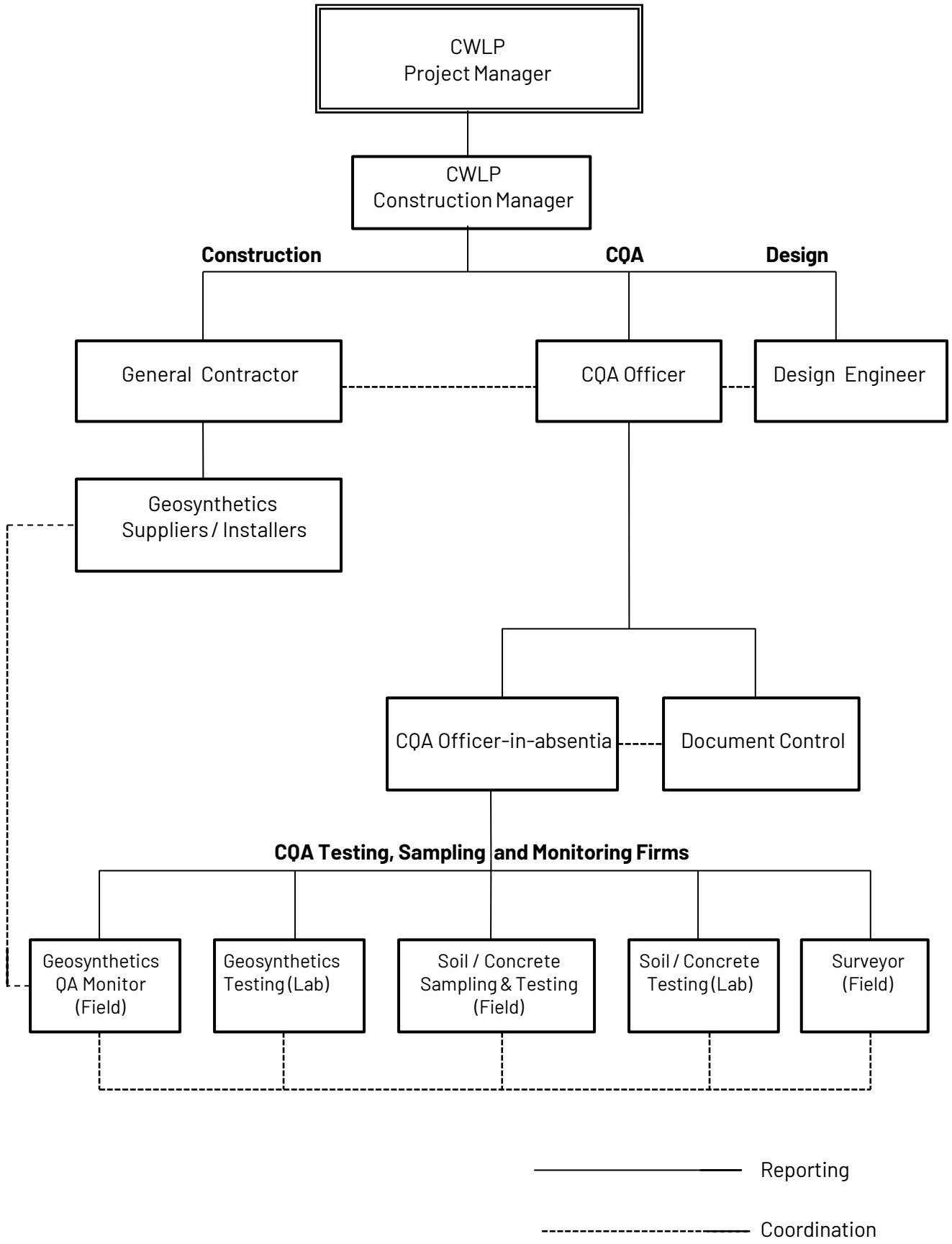


Figure 4 Project Organization Chart

5.2.1 Owner

CWLP is responsible for obtaining all necessary permits for construction and operation of the facility. CWLP retains under contract all parties for the construction including the General Contractor, the Design Engineer, the CQA Officer, and any CQA testing and monitoring firms.

The CWLP Construction Manager will oversee coordinating overall construction activities and will act as CWLP's primary interface with the General Contractor. The Construction Manager coordinates all matters involving contract issues with the CWLP Project Manager including approving field changes to the project plans and specifications.

5.2.2 Design Engineer

The Design Engineer is responsible for development of plans and specifications that fulfill the needs of the Owner and meet the requirements of the regulatory agencies. The Design Engineer is also responsible for responding to contractor requests for information (RFIs) during the construction process as may be required to clarify the plans and specifications or to address identified conflicts in the documents. The Design Engineer is further responsible for developing any modifications to the plans and specifications as may be required to address changed field conditions, field cost savings, design improvements, or other necessary or desired modifications as approved by the Owner.

5.2.3 CQA Personnel

5.2.3.1 Key Personnel (Owner's Representative)

CWLP will retain a CQA Officer for the project who will report directly to CWLP's Construction Manager (see Figure 4). The CQA Officer shall be a Professional Engineer registered in the State of Illinois, who is a person other than the Owner or an employee of the Owner, and who will supervise and be responsible for all inspection, testing, and other activities required to be implemented as part of the CQA program. The CQA Officer will also be responsible for, and will provide direct supervision to, any testing and monitoring firms shown in Figure 4 who will perform the monitoring, testing, sampling, and inspections required by the CQA program as described more specifically in Section 5.5. The CQA Officer will be present at the outset of major undertakings and at critical times during the construction. The time that the CQA Officer must be at the project site will be dependent upon the type of construction being conducted. The CQA Officer will exercise his/her own professional judgment to be present at the project site as required to assume full responsibility for the inspection and testing performed by those persons under his/her direct supervision. The CQA Officer shall have sufficient on-site staff to adequately carry out the quality assurance activities specified herein.

If the CQA Officer is unable to be present to perform duties as outlined, then the CQA Officer will provide, in writing, reasons for his/her absence including designation of the person who will exercise professional judgment in carrying out the duties of a CQA Officer as the designated CQA Officer-in-absentia. A signed statement shall be provided and recorded that the CQA Officer assumes full responsibility for all inspections performed and reports prepared by the designated CQA Officer-in-absentia during any absence of the CQA Officer.

It is required that the CQA Officer (or their designated representative), with on-site support personnel as required, provide oversight of the monitoring, inspection, testing, and/or sampling of the following construction activities for the facility:

- Test liners,
- Excavation, grading, and preparation of the subgrade and foundation,
- Placement of the compacted soil liner,
- Placement of geosynthetic components,
- Installation of the leachate drainage and collection systems,
- Construction of surface water ditches, channels, berms, and drainage structures, and
- Placement of concrete structures.

The CQA Officer (or their designated representative) must certify that the sampling, inspection and test results for the major elements of the construction are in compliance with established design requirements before subsequent sequential items of the construction can be initiated. The major elements of work requiring compliance certification include:

- Subgrade prior to placement of soil test liners,
- Soil test liner prior to placement of the compacted clay liner,
- Subgrade prior to placement of the compacted clay liner,
- Compacted clay liner prior to placement of the geomembrane,
- Geomembrane prior to placement of the geotextile cushion,
- Geotextile cushion prior to placement of the drainage layer,
- Piping installation prior to completed placement of the drainage layer,
- Drainage layer prior to placement of geotextile separation fabric,
- Cushion dirt prior to placement of the upper geomembrane (gypsum stack only),
- Upper geomembrane prior to installation of the ring drains (gypsum stack only), and
- Geosynthetic installations in anchor trenches prior to backfilling.

Certification will require a review of all inspection, sampling, and testing completed for the work item to ensure that all design requirements have been met, a visual inspection of the work item, and the completion and signing of form CQAP-2.1 *CQA Certification* by the CQA Officer (or their designated representative). The contractor or installer for the immediately following item of work shall not be allowed to initiate work until completion of the signed form by the CQA Officer (or their designated representative).

The completed and signed forms CQAP-2.1 shall be filed as project records in accordance with the provisions of Section 5.10.

5.2.3.2 Document Control

The staff of the CQA Officer shall include a Document Control person who will be responsible for: (1) control of the CQA Plan to ensure that only current documents are being employed by the CQA staff and (2) filing of all CQA records related to the monitoring, sampling, inspecting and testing specified in the CQA Plan.

Requirements for control of the CQA Plan and for filing of project records are presented in Section 5.10.

5.2.4 Testing and Monitoring Firms

The testing and monitoring firms, under the direction of the CQA Officer (see Figure 4), shall be responsible for conducting the quality assurance sampling (where appropriate), inspection, and testing required by Section 5.5 of the CQA Plan except that only monitoring and limited (independent) sampling and testing shall be required for the geosynthetics (i.e., geomembranes and geotextiles). The suppliers and installers shall be responsible for all the sampling and testing required by Section 5.5 for the geosynthetics (see Section 5.5.3).

Testing and monitoring firms may be one or several, as long as each firm (or firms) is qualified in accordance with Section 5.5.3.

5.2.4.1 Soil/Concrete Testing (Lab and Field)

One or more soil/concrete testing firms that has been qualified by the Illinois Department of Transporation (IDOT) will be retained to perform the laboratory testing required by the CQA Plan. Materials will be sampled by the testing firm or by persons designated by the CQA Officer. Materials sampled and tested will include fine-grained soils, coarse-grained soils, aggregates, rip rap, and concrete.

Each firm shall be required to provide "certificates of calibration" (or other proof of calibration) to the CQA Officer for each of the measuring and/or test equipment used in the laboratory or field; except that such certificates are not required for commercial grade equipment such as rulers, tape measures, or other devices that provide adequate accuracy for their intended purpose.

All field and laboratory forms proposed for collection of data shall be subject to review by CWLP prior to use. Forms deemed to be incomplete or otherwise unacceptable shall be modified to meet the intent of the CQA Plan.

5.2.4.2 Surveyor

One or more surveyors will be retained to verify attainment of specified elevations, slopes, and grades within the tolerances required by the CQA Plan. The firm(s) selected shall have the capacity to complete all work by or under the supervision of an Illinois Professional Land Surveyor.

Each surveyor will be required to provide "certificates of calibration" (or other proof of calibration) to the CQA Officer for each surveying device used; except that such certificates are not required for commercial grade equipment such as rulers, tape measures, or other devices that provide adequate accuracy for their intended purpose.

All field forms proposed for collection of data shall be subject to review by CWLP prior to use. Forms deemed to be incomplete or otherwise unacceptable shall be modified to meet the intent of the CQA Plan.

5.2.4.3 Geosynthetics Monitor and Geosynthetics Testing Laboratory

A geosynthentics monitoring firm may be retained to conduct oversight of the quality assurance inspections, testing, and sampling carried out in the field by the suppliers and installers of the geosynthetics (see Section 5.2.5) to ensure that the requirements of the CQA Plan are met including directing additional inspection, sampling, and testing as may be deemed necessary by the monitoring firm and/or the CQA Officer. The monitoring firm may also collect representative samples of the geosynthetics for independent testing by a geosynthetics testing laboratory as directed by the CQA Officer.

The geosynthetics testing laboratory will be independent of both the manufacturer and the installer of the geosynthetics and will be required to have its own quality assurance (QA) plan for the project work. The QA Plan shall be subject to review by CWLP prior to start of services.

All field and laboratory forms proposed for collection of data shall be subject to review by CWLP prior to use. Forms deemed to be incomplete or otherwise unacceptable shall be modified to meet the intent of the CQA Plan.

5.2.5 Contractors, Suppliers and Installers

The contractor, subcontractors, suppliers, and installers are responsible for completing their portions of the work within specified schedules and in accordance with the requirements of the plans and specifications. They additionally shall accommodate the monitoring, sampling, inspections, and testing that are the responsibility of the CQA Officer under the CQA Plan.

The geosynthetic suppliers and installers shall provide the quality assurance inspection, sampling, and testing as required by Section 5.5.3 of the CQA Plan. Additionally, the geosynthetic suppliers shall be required to submit "certificates of acceptance" for certain items of work that precede their construction activities. The "certificates of acceptance" are more specifically discussed in Section 5.4.

5.3 Project Meetings

Periodic meetings will be held during the life of the project to enhance coordination among the various parties involved. Meetings will include preconstruction meetings, routine progress meetings, and as needed, problem or work deficiency meetings.

5.3.1 Preconstruction Meetings

Preconstruction meetings shall be held at the site for the major earthwork items and geosynthetic installations. At a minimum, the CWLP Construction Manager, the CQA Officer, representatives of the testing firms, and the earthwork contractor or geosynthetic installer should attend. In addition to the topics for discussion as listed in the project specifications, the following CQA items will be covered:

- Discuss the established protocol for inspections, tests, and sampling including use of form CQAP-8.2 *Daily Inspection Report* (see Section 5.7.2),

- Discuss items of work requiring CQA Officer certification or installer acceptance before subsequent work items can be initiated (see Section 5.4), and
- Discuss the established protocol for handling construction deficiencies, corrective measures, and retesting (see Section 5.6).

The meeting shall be conducted by the CWLP Construction Manager or the CQA Officer and will be documented by CQA personnel with distribution to all attendees. Meeting minutes will be filed as project records in accordance with Section 5.10.

5.3.2 Progress Meetings

At the discretion of the CWLP Construction Manager or the CQA Officer, progress meetings will be scheduled to discuss on-going and up-coming construction activities. The meetings will be attended by the CWLP Construction Manager, the CQA Officer, and the appropriate site foreman (i.e. when earthwork is being performed, the earthwork foreman will be present; when geosynthetics are being installed, the installer foreman will be present, etc.). In addition to the topics of discussion regarding progress, the following CQA items should be reviewed:

- Discuss the established protocol for inspections, tests, and sampling including use of form CQAP-8.2 *Daily Inspection Report* (see Section 5.7.2),
- Discuss items of work requiring CQA Officer certification or installer acceptance before new work items can be initiated (see Section 5.4), and
- Discuss the established protocol for handling construction deficiencies, corrective measures, and retesting (see Section 5.6).

These meetings will be documented by the CQA Officer with distribution to all attendees including the CWLP Project Manager. Meeting minutes will be filed as project records in accordance with Section 5.10.

5.3.3 Problem or Work Deficiency Meetings

Special meetings will be convened by the CQA Officer when a problem or work deficiency is present (or anticipated) that is (or could be) of a serious nature. At a minimum, the meetings should be attended by the CWLP Construction Manager, earthwork or installer foremen as appropriate, and the CQA Officer. The CWLP Project Manager should attend those meetings that include discussions of severe and/or recurring problems or deficiencies. The purpose of these meetings is to define and resolve the problem or work deficiency in the following manner:

- Define the problem or deficiency and its probable causes,
- Discuss alternative actions to address the problem or deficiency,
- Implement the selected action to resolve the problem or deficiency, and
- Verify that the implemented action has been effective.

The meeting will be documented by the CQA Officer with distribution to all attendees including the CWLP Project Manager. Meeting minutes will be filed as project records in accordance with Section 5.10.

5.4 In-Progress Acceptance of Work

5.4.1 Introduction

It is very important during placement of the geosynthetics not to entrap fugitive clay, stones, sand, etc. that could damage the geosynthetic, cause clogging of drains or filters, or hamper seaming of the geosynthetic. The geosynthetic installers shall accept responsibility for inspecting the substrate (daily) to ensure such entrapments are not present within the substrate area to be covered each day. When found acceptable, the installer shall complete and sign form CQAP-4.1 *Installer Certificate of Acceptance* that documents (on a daily basis) acceptance of the substrate for geosynthetic placement. The installer shall provide the original signed document to the CQA Officer (or their designated representative) for their signature of receipt.

Completed and signed forms CQAP-4.1 shall be filed as project records in accordance with the provisions of Section 5.10.

5.4.2 Elements of Work Requiring Prior Acceptance

The following table cites the elements of work that shall require daily "certificates of acceptance" for the substrate including the installer responsible for providing the certification. Any other areas of geosynthetic installation not included in the table shall still be subject to the requirements of this section.

Table 4. Installer Certifications for Acceptance of Work

Substrate to Be Accepted by Installer	Installer
1. Surface of Geotextile Bag Infill Soils	Geomembrane Installer
2. Surface of Geomembrane	Geotextile Cushion Installer
3. Surface of Drainage Layer	Geotextile Filter Installer
4. Surface of Cushion Dirt	Geomembrane Installer

5.5 Sampling and Testing Requirements

5.5.1 Introduction

Prequalification and placement sampling/testing requirements for the various materials and construction activities are summarized in Table C.1 in Appendix C. Frequencies for material placement testing listed in Table C.1 in Appendix C are based on the volume of material used in construction and are to be considered minimums. The CQA Officer shall select the specific locations for testing on a random basis exercising professional judgment to ensure that testing and sampling fairly represent the construction.

The testing firms under the direction of the CQA Officer shall be responsible for the sampling (as applicable) and testing listed in Appendix C Table C.1 in Appendix C for: (1) the Soils Prequalification and Placement Testing, (2) the Drainage Media Prequalification and Placement Testing, and (3) the Other Material Placement Testing. The geosynthetic installers shall be responsible for the sampling listed in Table C.1 in Appendix C for the Geosynthetics Prequalification and Placement Testing. Independent laboratory testing will be coordinated through the geosynthetic monitoring firm and/or the CQA Officer.

Custody of samples and transfer from the sampling location to the test facility shall be established and documented through the use of form CQAP-6.1 *Chain of Custody Record*. The sampling party shall enter sample descriptions (including proposed use), sampling dates and times, and types/quantities of samples on the form, including methods or types of testing to be carried out, and relinquish custody of the samples to the testing firm by signing and dating the form at the bottom. The samples shall be shipped or delivered to the testing firm with the white and yellow carbon copies of form CQAP-6.1. The sampling party shall retain the pink copy for its records.

The testing firm shall document receipt of the samples by signing and dating the form at the bottom and retaining the yellow copy for its records. The testing firm shall return the white copy of form CQAP-6.1 to the Document Controller with the submittal of test results. The return of any samples by the testing firm shall be documented by signing and dating relinquishment at the bottom of the form and identifying the returned samples in the "Remarks or Observations" column. The Document Controller shall document receipt of any returned samples by signing and dating the white copy at the bottom of the form. The Document Controller shall retain the white copy of the form as a project record in accordance with Section 5.10.

The results of the sampling and testing shall be documented on a daily basis by each testing firm or installer providing the quality assurance activities, and the originals of the sampling and testing results shall be provided to the CQA Officer. The CQA Officer shall complete form CQAP-8.2 *Daily Inspection Report* (see Section 5.7.2) for each of the testing firms or installer approving results and attach the results to the form. The completed form CQAP-8.2 and attached results shall be incorporated into the form CQAP-8.1 *Daily Summary Report* (see Section 5.7.1).

5.5.2 Soils

5.5.2.1 Foundations and Berms

The CQA Officer shall direct verification of excavated foundation (subgrade) depths and grades as specified in Section 5.5.2.1 except that the foundation grid shall be as directed by the CQA Officer. Foundation fills shall be as specified in Section 5.5.2.1.

Prequalification testing for material sources shall meet the requirements in Table C.1 in Appendix C.

The CQA Officer shall direct appropriate personnel to conduct the following inspection activities during berm construction:

- Observation of fill material characteristics,
- Observation of loose lift thickness,
- Observation of clod size reduction and material homogenization, and
- Placement testing as specified in Table C.1 in Appendix C.

Construction shall be documented on "as-built" plans.

The CQA Officer shall review the sampling and test results for the landfill containment berms and if found in agreement with the prequalification and placement requirements, provide certification for the work using form CQAP-2.1.

5.5.3 Geosynthetics

5.5.3.1 Geomembrane

5.5.3.1.a Prequalification Testing

The contractor shall direct the geomembrane manufacturer to supply an inventory list of rolls to the Owner's geosynthetics QA monitor firm and/or the CQA Officer, who will select rolls to be prequalified for the type and frequency of prequalification testing listed in Table C.1 in Appendix C.

The geomembrane manufacturer shall procure and submit samples from the designated prequalification rolls to the independent geosynthetics laboratory (see Section 5.2.4) for verification of selected manufacturer's guaranteed properties. Such samples shall be 3 ft long by the entire width of the roll.

In addition, the manufacturer shall submit documentation that the materials supplied have been tested for the parameters listed in the manufacturer's list of guaranteed properties at the frequency stated in the list of guaranteed properties. The results of such testing, including identification of all individual rolls tested, shall be submitted to the CQA Officer for review. The manufacturer shall certify that all rolls meet the manufacturer's guaranteed properties, in accordance with the specified testing frequency rate.

Geomembrane prequalification testing shall be completed prior to delivery.

5.5.3.1.b Installer Certification of Placement Surface

Prior to daily geomembrane placement, the installer shall provide to the CQA Officer daily "certificates of acceptance" (form CQAP-4.1) which document the installer's inspection and acceptance of the underlying surface as being suitable for the geomembrane installation (see Section 5.4).

All daily "certificates of acceptance" (form CQAP-4.1) shall be filed as project records in accordance with Section 5.10.

5.5.3.1.c Placement Testing for Seam Overlap

The contractor and installer shall arrange geomembrane sections such that the use of field seams is minimized and that horizontal seams are not used on side slopes. Seam overlaps shall be field measured by the installer to verify the requirement in Table C.1 in Appendix C is met for all seams within the geomembrane footprint. Seam overlaps shall be "shingled" in the downslope direction. The CQA Officer shall direct appropriate personnel to make independent measurements of a representative number of seam overlaps for additional verification of the requirement in Table C.1. in Appendix C

At completion of geomembrane placement, the installer shall provide the CQA Officer with "as-built" drawings of the geomembrane installation showing all seam locations and seam measurement locations.

5.5.3.1.d Placement Non-Destructive Testing

The installer shall conduct non-destructive testing of seams at the frequency specified in Table C.1 in Appendix C. All seams shall be nondestructively tested over their full-length using a vacuum test unit, air pressure test, or other method approved by the CQA Officer. Continuity testing will be completed as the seaming progresses.

All boots on pipes or other equipment penetrating the liner shall be tested using vacuum box, "spark" tests, or other means as approved by the CQA Officer.

The CQA Officer shall direct appropriate personnel to monitor all non-destructive testing carried out by the installer.

The installer shall submit all non-destructive field-testing results to the CQA Officer for filing as project records in accordance with Section 5.10.

Vacuum testing and air pressure testing procedures shall be as given in the following sections.

Vacuum Testing (Extruded Welds)
The following procedures are applicable to those processes which produce an extruded weld (per ASTM D5641).

Equipment
The following equipment shall be used when conducting vacuum tests:

- A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, a port hole or valve assembly, and a vacuum gauge,
- A steel vacuum tank and pump assembly equipped with a pressure controller and pipe connections,
- A rubber pressure/vacuum hose with fittings and connections,
- A bucket, and
- A soapy solution.

Procedures
The following procedures will be followed:

1) Energize the vacuum pump and reduce the tank pressure to approximately 10 in. of Hg gauge.
2) Wet a strip of geomembrane approximately 12 in. wide by 48 in. long (an area larger than the coverage size of the vacuum box) with the soapy solution.
3) Place the box over the wetted area.
4) Close the bleed valve and open the vacuum valve.
5) Verify that a leak tight seal is created.
6) For a period of not less than 10 seconds, examine the geomembrane through the viewing window for the presence of soap bubbles.
7) If no bubble appears after 10 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area, repeat the process.
8) All areas where soap bubbles appear will be marked and repaired and then retested until passing test results are obtained.

Air Pressure Testing (For Double Fusion Seam Only)
The following procedures are applicable to those processes which produce a double seam with an enclosed space (after ASTM D5820).

Equipment
The equipment will be comprised of the following:

- An air pump (manual or motor driven) equipped with pressure gauge capable of generating and sustaining a pressure between 25 psi to 30 psi and mounted on a cushion to protect the geomembrane,
- A rubber hose with fittings and connections, and
- A sharp hollow needle, or other approved pressure feed device.

Procedures
The following procedures will be observed:

1) Both ends of the seam to be tested will be sealed.
2) A needle or other approved pressure feed device will be inserted into the tunnel created by the fusion weld.
3) A protective cushion will be inserted between the air pump and the geomembrane.
4) The air pump will be energized to a pressure between 25 psi and 30 psi. The valve will be closed, and the pressure will be sustained for approximately 5 minutes.
5) If loss of pressure exceeds 3 psi or does not stabilize, the faulty area will be located, then repaired and retested until passing test results are obtained.
6) At the conclusion of a passing air pressure test, the opposite end of the seam will be slit and subsequent drop in pressure will be monitored. This will ensure that the entire seam was completely tested.
7) Remove needle or other approved pressure feed device and seal.

5.5.3.1.e Pre-Placement Destructive Testing

General
Destructive seam tests shall be performed daily on samples that were used to check the weld quality of each welder used for seaming. The purpose of these tests is to evaluate seam strength. Seam strength testing must be completed before each welder can be used on the placed geomembrane. Testing will follow the requirements of ASTM D6392.

The CQA Officer shall direct appropriate personnel to monitor all destructive testing carried out by the installer.

The installer shall submit the results of all destructive testing to the CQA Officer for filing as project records in accordance with Section 5.10.

Field Testing

The installer shall test in the field, by tensiometer, ten, 1-inch-wide sample strips from the samples identified for destructive testing; five for peel and five for shear. The requirements and frequency for field testing shall be as provided in the table at the end of this section.

The installer shall conduct all field tests and mark all samples and portions with their number. The installer shall also log the date, time, ambient temperature, seaming unit ID number, name of seamer, welding apparatus temperatures and pressures, and pass or fail description, and attach a copy to each sample portion.

Geosynthetic Quality Assurance Laboratory Testing

Successful prequalifying field tests shall identify samples for laboratory testing. The installer's quality assurance laboratory shall be as selected by the installer with concurrence of the CQA Officer.

Testing shall include shear strength and peel adhesion. At least five specimens from each sample shall be tested by the installer's laboratory for each method. Specimens shall be selected alternately by test from the samples (i.e., peel, shear). All laboratory testing shall be accordance with ASTM D 4437.

The CQA Officer shall direct appropriate personnel to have additional samples tested for peel and shear strength by the independent geosynthetics laboratory as deemed necessary.

Procedures for Destructive Test Failure

Whenever a sample fails a destructive test, whether the test was conducted in the laboratory or by field tensiometer, the installer must remove the welding unit from service and determine the cause of the failed test.

Once the welding unit issues have been corrected, the Installer must show that the welding unit produced two (2) passing destructive tests (two sets of 5 peel and 5 shear tests).

The installer will document all actions taken in conjunction with destructive test failures.

Table 5. Geomembrane Destructive Seam Tests and Frequency

Property	Test Method	60-mil HDPE	40-mil HDPE	40-mil LLDPE	Frequency
Seam Shear Strength	ASTM D 4437	120 ppi	80 ppi	44 ppi	See Note 1
Seam Peel Strength (hot wedge fusion)	ASTM D 4437	78 ppi	52 ppi	40 ppi	See Note 1
Seam Peel Strength (fillet extrusion)	ASTM D 4437	72 ppi	45 ppi	40 ppi	See Note 1

Notes:

1) Destructive testing of seams shall occur at the beginning of each day for each welding unit to be used that day.
2) Values apply for both smooth and textured geomembranes.

5.5.3.1.f Grid-Based Visual Inspection

A grid-based visual inspection will be performed on the geomembrane to identify any penetrations or defects. The CQA Officer or their designee will use the geomembrane panels as the basis for the grid. The inspector will follow 2 to 3 panels behind the installation crew so that the entire geomembrane can be inspected while the Installer is still on site.

Any identified defects will be marked with spray paint and its GPS coordinates logged. These coordinates will be given to the Installer so that they can repair the identified problem(s). Key aspects of this inspection include:

1) Physical damage – look for tears, punctures, or rips, especially around seams, edges, and areas exposed to potential damage.
2) Seams and Joints - These areas are prone to failure, so pay close attention to their condition.
3) Wrinkles and Stress Concentrations – Minimize these during installation to prevent future problems.
4) Changes in Flexibility or Texture – Unusual rigidity or softness can be a sign of damage.

5.5.3.2 Geotextile

5.5.3.2.a Prequalification Testing

The contractor shall direct the geotextile manufacturer to supply an inventory list of rolls to the Owner's geosynthetics QA monitor firm and/or the CQA Officer, who will select rolls to be prequalified for the type and frequency of prequalification testing listed in Table C.1 in Appendix C.

The geotextile manufacturer shall procure and submit samples from the designated prequalification rolls to the independent geosynthetics laboratory (see Section 5.2.4.3) for verification of selected manufacturer's guaranteed properties. Such samples shall be 3 ft long by the entire width of the roll.

In addition, the manufacturer shall submit documentation that the materials supplied have been tested for the parameters listed in the manufacturer's list of guaranteed properties at the frequency stated in the list of guaranteed properties. The results of such testing, including identification of all individual rolls tested, shall be submitted to the CQA Officer for review. The manufacturer shall certify that all rolls meet the manufacturer's guaranteed properties, in accordance with the specified testing frequency rate.

Geotextile prequalification testing shall be completed prior to delivery.

5.5.3.2.b Installer Certification of Placement Surface

Prior to daily geotextile placement, the installer shall provide to the CQA Officer daily "certificates of acceptance" (form CQAP-4.1) which document the installer's inspection and acceptance of the underlying surface as being suitable for the geotextile installation (see Section 5.4).

All daily "certificates of acceptance" (form CQAP-4.1) shall be filed as project records in accordance with Section 5.10.

5.5.3.2.c Deployment

Incoming rolls of geotextile shall be inventoried and inspected by the installer. Manufacturer's certifications will be inspected for conformance with the requirements of this plan. Holes, tears, or other visible defects will be recorded in the CQA Officer's daily report and clearly marked on the synthetic for identification of necessary repairs.

The installer shall check that the geosynthetic installation conforms to the construction requirements and manufacturer's recommendations. The CQA Officer shall direct appropriate personnel to oversee the inspections by the installer.

On slopes steeper than 10H:1V, all geotextiles shall be continuously sewn. Geotextiles shall be overlapped a minimum of 3 in. prior to seaming. This requirement does not apply to the leachate system filter fabric. All sewing shall be done using thread with physical, chemical, and ultraviolet high resistance properties equal to or exceeding those of the geotextile. The CQA Officer shall direct appropriate personnel to make independent measurements of a representative number of seam overlaps for additional verification of the requirement in Table C.1 in Appendix C.

The 10-oz. cushion geotextile (immediately above the geomembrane liner and beneath the drainage layer) shall be placed with vertical seams running up the slopes and into the anchor trench. Horizontal seams (perpendicular to the slope) shall be allowed on side slopes for the 4-oz. filter geotextile overlaying the drainage layer to facilitate staged construction of the drainage layer going up the slope. All overlaps shall be "shingled" so that water or other material cannot run down the slope between the geotextile seams.

5.5.3.3 Synthetic Turf

5.5.3.3.a Prequalification Testing

The contractor shall direct the synthetic turf manufacturer to supply an inventory list of rolls to the Owner's geosynthetics QA monitor firm and/or the CQA Officer, who will select rolls to be prequalified for the type and frequency of prequalification testing listed in Table C.1 in Appendix C.

The synthetic turf manufacturer shall procure and submit samples from the designated prequalification rolls to the independent geosynthetics laboratory (see Section 5.2.4.3) for verification of selected manufacturer's guaranteed properties. Such samples shall be 3 ft long by the entire width of the roll.

In addition, the manufacturer shall submit documentation that the materials supplied have been tested for the parameters listed in the manufacturer's list of guaranteed properties at the frequency stated in the list of guaranteed properties. The results of such testing, including identification of all individual rolls tested, shall be submitted to the CQA Officer for review. The manufacturer shall certify that all rolls meet the manufacturer's guaranteed properties, in accordance with the specified testing frequency rate.

Synthetic turf prequalification testing shall be completed prior to delivery.

5.5.3.3.b Installer Certification of Placement Surface

Prior to daily synthetic turf placement, the installer shall provide to the CQA Officer daily "certificates of acceptance" (form CQAP-4.1) which document the installer's inspection and acceptance of the underlying surface as being suitable for the geotextile installation (see Section 5.4).

All daily "certificates of acceptance" (form CQAP-4.1) shall be filed as project records in accordance with Section 5.10.

5.5.3.3.c Deployment

Incoming rolls of synthetic turf shall be inventoried and inspected by the installer. Manufacturer's certifications will be inspected for conformance with the requirements of this plan. Holes, tears, or other visible defects will be recorded in the CQA Officer's daily report and clearly marked on the synthetic for identification of necessary repairs.

The installer shall check that the geosynthetic installation conforms to the construction requirements and manufacturer's recommendations. The CQA Officer shall direct appropriate personnel to oversee the inspections by the installer.

On slopes steeper than 10H:1V, all synthetic turf shall be continuously sewn or fusion seamed. Synthetic turf shall be overlapped a minimum of 5 in. prior to seaming. All sewing shall be done using thread with physical, chemical, and ultraviolet high resistance properties equal to or exceeding those of the geotextile (207 Polyester or equivalent). The CQA Officer shall direct appropriate personnel to make independent measurements of a representative number of seam overlaps for additional verification of the requirement in Table C.1 in Appendix C.

5.5.4 Drainage Media

5.5.4.1 Coarse Aggregate

5.5.4.1.a Prequalification Testing

Each source of material for the coarse aggregate shall be tested for hydraulic conductivity and grain size in accordance with Table C.1 in Appendix C to determine suitability of the source.

5.5.4.1.b Material Placement

The CQA Officer shall direct that inspection of piping as provided in Section 5.5.5.2 be completed prior to placement of coarse aggregate around the piping. Compaction of the coarse aggregate shall not be allowed during placement to avoid breakdown of materials.

The CQA Officer shall direct appropriate personnel to take an initial sample of the coarse aggregate within the first 100 cu. yds. of material placement and test for hydraulic conductivity and grain size to confirm suitability of the source. Continuing sampling and testing shall be completed at the frequencies specified in Table C.1 in Appendix C.

Gradation tests may be considered passing provided the hydraulic conductivity requirements are met, and the specified percentage of fines is not exceeded.

5.5.4.1.c Certification of Work

The CQA Officer shall review the sampling and test results for the coarse aggregate and, if found in agreement with the prequalification and placement requirements, provide certification for the work using form CQAP-2.1.

5.5.4.2 Specified Aggregate Infill

5.5.4.2.a Prequalification Testing

Each source of material for the Specified Aggregate Infill shall be tested for grain size, specific gravity, and fine aggregate angularity in accordance with Table C.1 in Appendix C to determine suitability of the source.

5.5.4.2.b Material Placement

The CQA Officer shall direct appropriate personnel to install the aggregate infill using either a conveyor system or express blowers operated by Manufacturers Representatives approved installers. CQA Personnel shall confirm final thickness of the aggregate infill is at least ½-inch by no greater than ¾-inch thickness at a rate of 20 locations per acre.

The CQA Officer shall direct appropriate personnel to take an initial sample of the aggregate infill and test for grain size. Continuing sampling and testing shall be completed at the frequencies specified in Table C.1 in Appendix C.

Gradation tests may be considered passing provided they fall within the range specified in Table 1 of Section 31 05 16.

5.5.4.2.c Certification of Work

The CQA Officer shall review the sampling and test results for the aggregate infill and, if found in agreement with the prequalification and placement requirements, provide certification for the work using form CQAP-2.1.

5.5.5 Other Material Placement Testing

5.5.5.1 Placement Testing of Dewatering System Piping System

The CQA Officer shall direct the surveyor firm to check the invert elevations and plan coordinates for the constructed piping system at the locations and frequencies specified in Table C.1 in Appendix C.

The CQA Officer or other CQA staff shall inspect pipe size, materials, and connections including all components of the dewatering systems to verify compliance with plan and specification requirements.

The measured grades and coordinates shall be documented on “as-built” drawings furnished to the CQA Officer by the surveyor.

The CQA Officer shall review the survey results for the dewatering system and, if found in agreement with the placement requirements, provide certification for the work using form CQAP-2.1.

5.5.5.2 Placement Testing of Surface Water Management System

The CQA Officer shall direct the survey firm to determine the elevations and grades of the constructed berms and channels in accordance with the requirements and frequency specified in Table C.1 in Appendix C.

The measured elevations and grades shall be documented on "as-built" drawings furnished to the CQA Officer by the surveyor.

5.5.5.3 Placement Testing of Concrete

The CQA Officer shall direct the soil test firm to carry out placement testing for concrete in accordance with the requirements and frequency specified in Table C.1 in Appendix C.

The contractor shall submit proposed concrete mix designs to the CQA Officer for review prior to ordering of concrete.

The CQA Officer shall review the concrete testing results and, if found in agreement with the placement requirements, provide certification for the work using form CQAP-2.1.

5.6 Corrective Measures

The CQA Officer shall reject and require replacement of all materials for which sampling, testing, or inspection results show that prequalification requirements are not met. The CQA Officer shall also reject workmanship (and require corrective rework) for which sampling, testing, or inspection results show that material placement requirements are not met. The lateral and/or vertical extent of corrective measures for rework shall be based on the frequency of testing and judgment of the CQA Officer.

5.7 Documentation Of Sampling, Inspections and Testing

5.7.1 Daily Summary Reports

A daily summary report shall be prepared by the CQA Officer or their designated representative (i.e. CQA Officer-in-absentia), or under the direct supervision of the CQA Officer or designated representative, during each day of activity. Form CQAP-8.1 *Daily Summary Report* shall serve as the base document to which the daily inspection reports (see Section 5.7.2) are to be attached.

Each report shall be signed by the CQA Officer or their designated representative (i.e., CQA Officer-in-absentia). The original report (and attachments) shall be submitted to the Document Controller and filed as a project record in accordance with Section 5.10.

5.7.2 Daily Inspection Reports

A daily inspection report shall be prepared by the CQA Officer or their designated representative (i.e., CQA Officer-in-absentia), or under the direct supervision of the CQA Officer or designated representative, for each day that materials, or placement of materials, are being inspected, sampled, or tested. Form CQAP-8.2 *Daily Inspection Report* shall serve as the base document to which the test data, photographic records, test results, etc. are to be attached. Such attachments shall provide the signature of the responsible inspector.

Each report shall be signed by the CQA Officer or their designated representative (i.e., CQA Officer-in-absentia. The original report (and attachments) shall be incorporated into the daily summary report.

5.7.3 Photographs

Photographs may be incorporated into the daily inspection report or daily summary report to provide a visual record of work progress, inspection/testing activity, construction work, or other items considered important to the report. The photographs, at a minimum, shall be furnished with the following information:

- The location, date and time of the photograph,
- A description of the item photographed including direction of view (N, S, E or W),
- Personnel, testing agencies, installers or contractors present, and
- Name and signature of photographer.

5.8 Acceptance Report

Upon completion of the construction contract, the CQA Officer shall submit an acceptance report to the relevant regulatory agency. The acceptance report shall contain the following:

- A certification by the CQA Officer that the construction has been prepared and constructed in accordance with the engineering design,
- "As-built" drawings as specified herein, and
- All daily summary reports.

5.9 Construction Management Activities

5.9.1 Requests for Information (RFIs)

The General Contractor or installer may, after exercising due diligence to locate required information, request from the CQA Officer clarification or interpretation of the contract documents. The General Contractor or installer shall make specific reference to the contract drawing(s) or specification(s) in question and include estimates of any cost or schedule impacts that could possibly be associated with the requested clarification or interpretation.

The General Contractor or installer shall initiate the RFI in a timely manner using form CQAP-10.1 *Request for Information*. The CQA Officer shall, with reasonable promptness, respond to the RFI on the same form CQAP-10.1 and return a copy of the completed form to the party making the request as final disposition of the matter.

Additional copies of the completed form shall be distributed as directed by the CQA Officer. All RFIs shall be filed as project records in accordance with Section 5.10.

5.9.2 Review of Contractor Submittals

The contractor shall submit shop drawings, product data, and samples to the CQA Officer in accordance with the requirements of the project specifications and with such promptness as to cause no delay of the work. The contractor shall not authorize purchase, fabrication, erection, processing, or shipping of any

items associated with the submittal until review of the shop drawings, product data, or samples has been completed by the CQA Officer and no resubmittals are required by the CQA Officer.

All submittals from subcontractors shall be reviewed first by the contractor to satisfy the contractor's responsibilities for lengths, dimensions, quantities, means and methods, and other such items.

The CQA Officer and/or Design Engineer shall review the submittals for conformance with design concepts and conformance with the information shown in the contract documents. Upon completion of review, the CQA Officer shall return the submittal to the contractor with one of the following notations for each item in the submittal:

- No exceptions taken,
- Furnish as corrected,
- Revise and resubmit,
- Submit specified item, or
- Rejected.

The contractor shall resubmit corrected shop drawings, product data, or samples for those items noted as requiring revision or submission or noted as rejected.

The CQA Officer shall maintain copies of all submittals and a log documenting submittal descriptions, dates of receipt, dates of return, review personnel, and actions taken on the submittals. Copies of submittals and the log shall be filed as project records in accordance with Section 5.10.

5.9.3 Field Change Order Process

The contractor shall be responsible for preparing requests for Field Change Order (FCO) in accordance with CWLP procedures and submitting the FCO requests on the appropriate CWLP FCO form to the CQA Officer.

The CQA Officer shall be responsible for reviewing the FCO with the Design Engineer, determining agreement or non-agreement with the requested change, and submitting the documented decision to the contractor on the appropriate CWLP FCO form with copies to the CWLP Project Manager. Agreement to the FCO shall require signature approval of the CWLP Project Manager.

The CQA Officer shall maintain an on-going log of authorized FCOs and running balance of project costs. Copies of the FCOs and log of authorized FCOs shall be retained as project records in accordance with Section 5.10.

5.10 Document Control and Project Records

5.10.1 CQA Plan

The CQA Officer shall control the preparation, issue, and revisions of the CQA Plan so that correct documents are being employed by the project participants. The CQA Plan, including all changes thereto, shall be reviewed for adequacy and approved for release by the project management personnel for the firm retained by CWLP to provide the CQA Officer and support staff.

The Document Control person shall issue controlled copies of the CQA Plan and maintain all records associated with its preparation, issue and revisions.

5.10.2 Project Records

The maintenance of project records during construction of the landfill shall be the responsibility of the Document Controller and shall be protected against damage, deterioration, and loss. Records shall be maintained in a manner as to be readily identifiable and retrievable.

Control of CQA documents and samples during the construction process shall be as shown in Figure 5. All original CQA documents from both the field and laboratories shall be ultimately furnished to the Document Controller for filing and maintenance.

Project records shall be made available to the CWLP Project Manager as requested during construction and, when requested, shall be turned over to CWLP at completion of the construction contract.

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

- CQA Plan (all revision levels),
- CQA Plan documentation (reviews, issuance, and revisions),
- Meeting minutes,
- Daily summary reports (form CQAP-8.1),
- Daily inspection reports (form CQAP-8.2),
- Manufacturer's QA results/certifications,
- Certificates of acceptance by geosynthetic installers,
- CQA certifications (form CQAP-2.1),
- Certificates of calibration for inspection, measuring and test equipment,
- "As-built" drawings,
- Laboratory test results for soils, drainage media, and concrete,
- Laboratory test results for geosynthetics,
- Laboratory certifications of manufacturer's guaranteed properties for geosynthetics,
- Contractor Requests for Field Change Order (CWLP FCO form),
- Log of Authorized Field Change Orders,
- Shop drawing submittals,
- Log of shop drawing submittals,
- Requests for information from contractor/installers,
- Responses to requests for information, and
- Acceptance report.

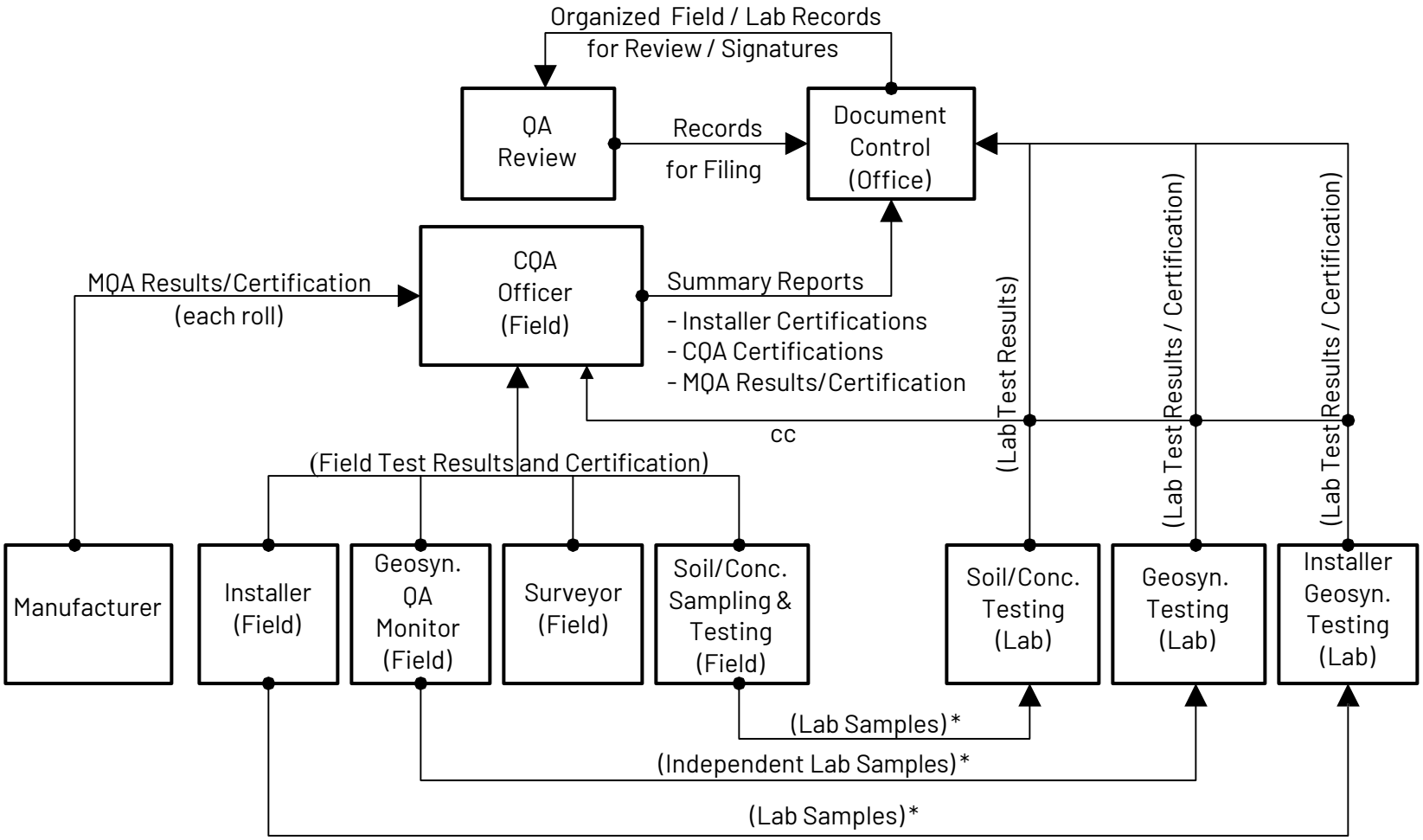


Figure 5. Control of CQA Documents and Samples

*Transmittal letters shall direct the original lab test results/certifications to be sent to Document Control with copies to the CQA Officer. All samples subject to chain-of-custody requirements.

6. References

AEI, 2016a. "Closure Plan for Coal Combustion Residuals Surface Impoundments", October 2016, Andrews Engineering, Inc., Springfield, IL. 10 pp.

Foth, H. D. and Turk, L. M., 1772. Fundamentals of Soil Science, Fifth Edition, John Wiley and Sons, Inc., New York, NY. 454 pp.

Leighton, M.M., G.E. Ekblaw, and L. Horberg, 1948. "Physiographic Divisions of Illinois, Report of Investigations No. 129," Illinois State Geological Survey, Urbana, IL. 33 pp.

415 Illinois Compiled Statutes 5/3/135 (2023) "Illinois Environmental Protection Act", https://www.ilga.gov/legislation/ilcs/ilcs3.asp?ActID=1585&ChapterID=36

USEPA, 2020. "Hydrologic Evaluation of Landfill Performance HELP 4.0 User Manual", EPA/600/B-20/219, Center for Environmental Solutions and Emergency Management, U.S. Environmental Protection Agency, Cincinnati, OH, 27 pp. + 7 app.

USGS, 1965. *Springfield East, Ill, USGS 7½-minute Series*, United States Geological Survey, US Department of Interior, Reston, VA, 1965.

Appendix A

ClosureTurf® Documentation

DESIGN GUIDANCE MANUAL

ClosureTurf® Final Cover System

June 3rd, 2024

Copyright 2024, Watershed Geosynthetics LLC.

ClosureTurf® and PowerCap™ are US registered trademarks which designate products from Watershed Geosynthetics LLC and/or its affiliated companies (collectively, "WG") that are the subject of issued and/or pending US and foreign patents and patent applications. All information provided herein by WG concerning these products are based upon data derived from independent third-party testing. This information, however, should not be used or relied upon for any specific use without first consulting with an independent professional engineer licensed in the geographic area in which a project is located. Since the actual site conditions, and the installation and use of these products are beyond our control and are likely different from our test conditions, no guaranty or warranty of any kind, expressed or implied, is made by WG with respect to these products.

Version History

Version Number	Date	Description of Major Changes
v.23041	10 February 2023	Issued for Publication
v.24155	03 June 2024	• Added CT HF (high-friction engineered turf) • Changed the term "Sand Infill" to "Aggregate Infill" • Updated Sections 1.2, 2.4, 4.1, 5.2, 6.2, 10.2, and Appendices A, B and F

TABLE OF CONTENTS

1. Introduction 1
   - 1.1. Purpose and Scope of Design Guidance Manual 1
   - 1.2. Components of ClosureTurf 2
   - 1.3. Benefits of ClosureTurf 4
   - 1.4. ClosureTurf Applications 5

2. Final Cover Slope Stability 7
   - 2.1. Potential Failure Modes 7
   - 2.2. Veneer Stability Analysis Method 7
   - 2.3. ClosureTurf Interface Shear Strength 8
   - 2.4. General Guidance on Maximum Slope 9
   - 2.5. Example Calculation 10

3. Wind Uplift Resistance 11
   - 3.1. Analysis Method 11
   - 3.2. Wind Tunnel Test Results 12
   - 3.3. Wind Uplift Analysis Procedure 14
   - 3.4. Example Calculations 14

4. Puncture and Tearing Loads and Resistance 15
   - 4.1. Design Considerations 15
   - 4.2. Puncture Resistance Test Summary 16

5. Surface Water Management 17
   - 5.1. Hydrology, Channel Sizing, and Channel Infill Selection 17
   - 5.2. General Design Considerations 18
     - 5.2.1. Hydrology 18
     - 5.2.2. Typical ClosureTurf Stormwater Management Features 18
     - 5.2.3. Channel Infill Selection for ClosureTurf Stormwater Management Features 19
     - 5.2.4. Energy Dissipation 19
     - 5.2.5. Stormwater Pond Design 20

v.24155

6. Hydraulic Stability of Aggregate Infill 21
6.1. Hydraulic Testing and Performance Specifications 21
6.2. Suggested Method for Calculating Hydraulic Shear Stress 22

7. Landfill Gas Management 23
7.1. ClosureTurf Gas Management 23
7.2. Integration with Gas Management System 24
7.3. Surficial Gas Collection System 25

8. ClosureTurf Performance Equivalency 27
8.1. Regulatory Requirements 27
8.2. Infiltration Reduction Equivalency 28
8.3. Erosion Resistance Equivalency 29

9. ClosureTurf Design Life 30
9.1. Longevity of System Components 30
9.2. Service Life Projection of Turf Fibers 30
9.3. Summary 32

10. Other Considerations 33
10.1. Settlement 33
10.2. Thermal Effects 34
10.3. Impact of Animals 35
10.4. Resistance to Fires 36
10.5. Resistance to Lightning 37
10.6. Measures to Prevent Vandalism 37
10.7. Post-Closure Care 37
10.8. Beneficial Use for Solar Development 37

11. References 39

LIST OF APPENDICES

Appendix A	ClosureTurf Interface Shear Strength Test Results
Appendix B	Example Calculation for ClosureTurf Veneer Slope Stability
Appendix C	Example Calculation for Wind Uplift of ClosureTurf
Appendix D	ClosureTurf Hydrostatic Puncture Test Report
Appendix E	Parametric Study Results for Pond Design
Appendix F	Evaluation of Aggregate Infill Criteria for ClosureTurf
Appendix G	Example Aggregate Infill Hydraulic Shear Calculations
Appendix H	ClosureTurf UV Longevity Evaluation Reports
Appendix I	Example Calculation for Pull-Out Resistance of ClosureTurf for Thermal Effects
Appendix J	ClosureTurf Deep Freeze Test Results
Appendix K	ClosureTurf Fire Resistance Test Report

v.24155

1. Introduction

ClosureTurf®, illustrated below in Figure 1-1, is a three-component system patented by Watershed Geosynthetics, LLC (Watershed Geo®) that consists of, from bottom to top, a structured geomembrane, an engineered turf, and a specified infill. ClosureTurf is primarily used as a final cover system at landfills and other waste containment facilities undergoing closure. As described herein, ClosureTurf offers a variety of benefits over traditional soil cover systems.

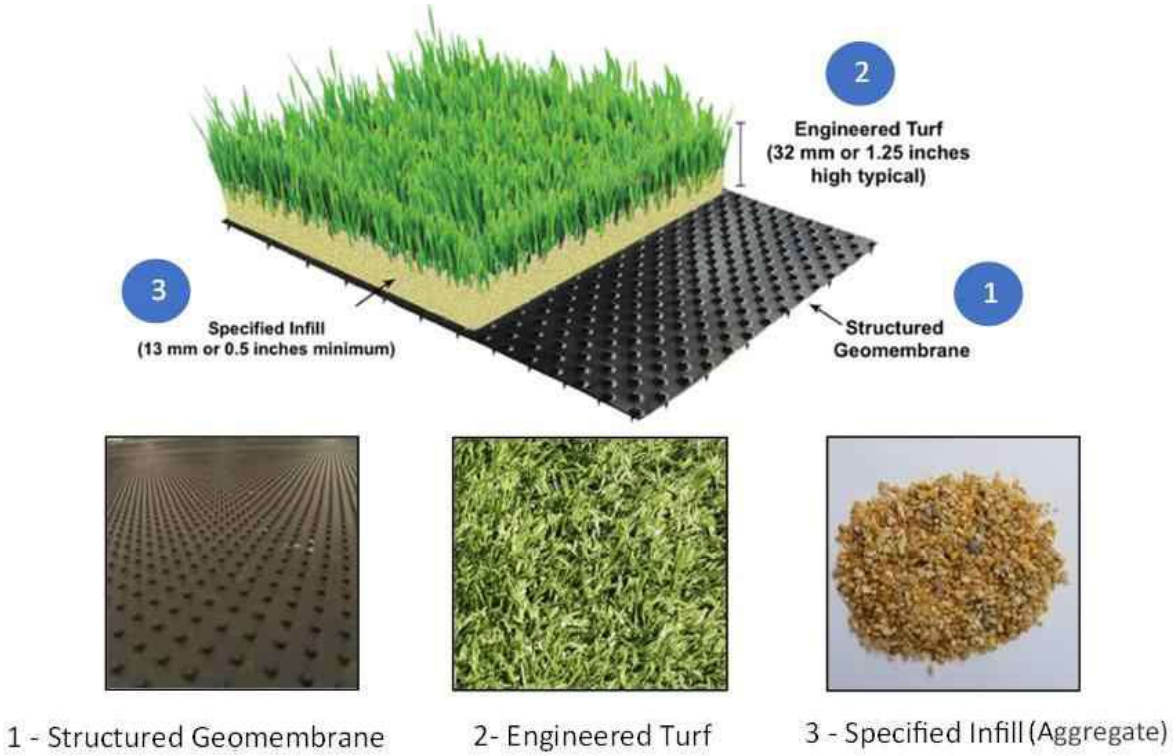


Figure 1-1. ClosureTurf Components

1.1. Purpose and Scope of Design Guidance Manual

This design guidance manual, referred to as the Design Guidance, was developed to guide the engineering design of landfill and waste containment facility closures using ClosureTurf. The Design Guidance is an update to the ClosureTurf Design Guidance Manual dated February 2023.

The Design Guidance describes technical factors relevant to ClosureTurf that are frequently considered during landfill closure design and provides guidance on how to address these factors.

Each project will require the design engineer to tailor the ClosureTurf system design to project requirements as well as the site and facility conditions. Furthermore, it may be necessary to adjust the design to address field conditions encountered during installation. Watershed Geo cannot anticipate all the possible ways that this product may be designed; therefore, this Design Guidance should be considered as guidance only.

Watershed Geo maintains an online technical library to provide the latest product information and technical documents for ClosureTurf, including the product data sheets, design guidance manual, installation guidance, technical specifications, construction details, etc. Instructions on how to access the technical library can be found on Watershed Geo's website through this link: https://watershedgeo.com/downloads/ct-technical/. The design engineer is encouraged to contact Watershed Geo if additional information or assistance on ClosureTurf design is needed. Contact information can be found at: https://watershedgeo.com/contact/.

1.2. Components of ClosureTurf

As illustrated in Figure 1-1, the bottom component of ClosureTurf is a structured geomembrane that serves as the hydraulic barrier to minimize rainfall infiltration. The structured geomembrane is made with either a high-density polyethylene (HDPE) or linear low-density polyethylene (LLDPE) formulation. The engineered turf overlying the structured geomembrane is made of HDPE synthetic grass blades tufted into a double-layer polypropylene (PP) woven geotextile backing. The engineered turf provides the appearance and texture of natural grass for the cover system, while also protecting the geomembrane from weathering. The infill component is usually a specified aggregate material placed between the blades of the engineered turf. It provides additional protection of ClosureTurf from wind uplift and weathering, while improving trafficability of the cover system by people, vehicles, and equipment. In areas with concentrated flows (e.g., drainage swales and perimeter channels), the cementitious HydroBinder® infill is recommended instead of the specified aggregate infill (further discussed in Section 5).

The components of ClosureTurf can be selected from available product options to address specific site conditions. Three types of structured geomembranes are currently available for use in ClosureTurf: MicroSpike®, MicroDrain®, and Super GripNet® manufactured by Agru America. All three types are available in HDPE and LLDPE formulations. The structured geomembrane should be selected based on factors including slope angle, interface shear strength, drainage of stormwater, and construction costs. The three types of structured geomembranes shown on Figure 1-2 are described below:

- MicroSpike consists of both top and bottom surfaces having consistent texturing patterns.
- MicroDrain has studs on its top face to create a transmissive drainage layer, thereby eliminating the need for a separate geonet or geocomposite drainage layer. The bottom face of the geomembrane uses the same texturing pattern as MicroSpike.
- Super GripNet also has studs on the top face to create a transmissive drainage layer. The bottom of Super GripNet has a spiked surface to increase the interface shear strength between ClosureTurf and subgrade for cover stability on steep slopes.

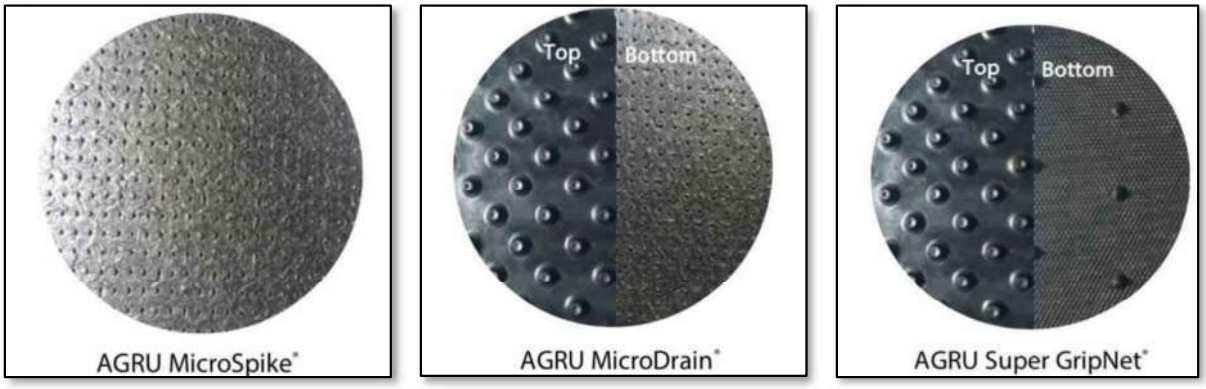


Figure 1-2. Structured Geomembranes Available for ClosureTurf

Four types of engineered turf are available for the ClosureTurf system: CT, CT X, CT HD, and CT HF. The types differ by the tufting gauge (i.e., turf fiber density), tufting pattern, and color. CT is the standard turf commonly used for closure applications. It is generally available in two colors: olive green and tan. CT X is the blended turf that contains a mixture of both olive green and tan turf fibers. It has a similar turf fiber density to CT. It can be customized for aesthetic purposes to better blend with surrounding landscapes. CT HD is the high-density turf that has a higher turf fiber density approximately twice of CT. CT HD provides higher seam strength, wind uplift resistance, and hydraulic shear resistance against potential aggregate infill movement, which results in less post-closure maintenance. CT HD is also generally available in olive green and tan colors. CT HF is the high-friction turf with an offset tufting pattern. It has a similar turf fiber density to CT. Because of the alternating turf stitch pattern, CT HF provides a higher interface friction against the geomembrane than the other types of engineered turf. CT HF is available in olive green and tan colors, too.

The specified aggregate infill is typically a coarse, angular sand. Watershed Geo recommends that the aggregate infill should meet Watershed Geo's technical specification to achieve adequate

hydraulic shear resistance and minimize potential movement in the field. Hydraulic stability of the aggregate infill is discussed in detail in Chapter 6. Watershed Geo evaluates potential sources of locally available aggregate infill and maintains a database of appropriate sources to assist customers and installers in identifying a material source. Contact Watershed Geo for potential aggregate infill sources near a project location, as needed.

1.3. Benefits of ClosureTurf

ClosureTurf has been developed to address long-standing challenges with traditional soil cover systems, including the following:

- Sites where suitable soil materials are unavailable or where it is expensive to import from an off-site source;
- Performance issues stemming from erosion of the soil cover and/or difficulty in sustaining healthy vegetation;
- Problems with slope instability caused by cracking and veneer-type sliding that adversely affect the integrity of the traditional soil cover system; and
- Need for frequent and sometimes extensive post-closure maintenance.

With the engineered turf and a specified aggregate infill layer, ClosureTurf overcomes the above challenges and provides the following advantages and benefits:

- ClosureTurf requires minimal soil (i.e., only the thin layer of aggregate infill). Sites with limited available soil can avoid purchasing and importing large quantities of soil required for a traditional soil cover system.
- For sites that would otherwise require large quantities of soil to be imported, the elimination of these materials benefits neighbors and local communities by reducing nuisance caused by truck traffic, dust, mud tracked onto public roads, chances of vehicle accidents, and noise during construction.
- At landfills, depending on permits, it is possible that the elimination of the soil layers in a traditional soil cover system can provide additional capacity (airspace) for waste disposal, which represents an opportunity to increase site life as well as landfill revenue.
- In general, ClosureTurf can be constructed faster than traditional soil cover systems.

- Upon completion of installation, ClosureTurf is fully functional and able to perform as designed. Traditional soil cover systems take one or more growing seasons to establish vegetation. The soil cover is particularly vulnerable to erosion problems during this interim period.
- As a manufactured product in accordance with stringent industrial standards and procedures, ClosureTurf properties are consistent and verifiable. This results in a reliable finished product that performs more predictably and consistently than traditional soil cover systems.
- Because the specified aggregate infill layer used in ClosureTurf is thin, the probability of a veneer-type soil cover failure above the geomembrane is negligible. With relatively high interface shear strength, the ClosureTurf system is inherently more stable than traditional soil covers from a geotechnical engineering perspective.
- Compared with traditional soil cover systems, ClosureTurf is more tolerant of differential settlement because of the flexible geosynthetic components.
- Stormwater runoff quality is significantly improved at sites using ClosureTurf compared to sites with traditional soil cover systems.
- Significantly lower post-closure maintenance costs are expected for ClosureTurf than for a traditional soil cover system because no mowing, fertilization, or revegetation is required.
- Site maintenance and system repairs are easier with ClosureTurf compared to traditional soil cover systems, as no soil excavation is required for ClosureTurf.
- Installation of ClosureTurf conserves water and natural soil and requires fewer truck trips and less heavy equipment; therefore, the environmental impact is much smaller. A study has shown that approximately 65% to 75% reduction in carbon emissions can be achieved when using ClosureTurf instead of a traditional soil cover system (Joshi 2023).
- ClosureTurf provides an improved base for solar arrays at closed landfills than traditional soil cover systems due to elimination of soil erosion and reduction in post-closure maintenance.

1.4. ClosureTurf Applications

Engineered specifically for waste containment facilities, ClosureTurf has been used at sites ranging from local municipalities to large industrial, utility, and United States Environmental

Protection Agency (USEPA) Superfund sites. The waste types in those facilities include municipal solid waste (MSW), construction and demolition debris, industrial sludge and byproducts, coal combustion residuals (CCR), hazardous waste, and contaminated materials. ClosureTurf has been installed successfully in differing climatic regions that experience heavy rainfall, hurricane-force winds, and extreme temperatures, as well as areas with seismic activity. A map of ClosureTurf project sites can be found at: https://watershedgeo.com/.

2. Final Cover Slope Stability

This chapter addresses slope stability considerations associated with the use of ClosureTurf for final closure of landfills and other waste containment facilities.

2.1. Potential Failure Modes

Veneer-type slope instability is the propensity of the cover layer (or veneer) of a final cover system to slide. Veneer-type sliding failures have occurred with soil-geosynthetic cover systems placed over steep slopes of landfills, especially after major storm events (Koerner and Soong 1998), resulting in rupture, tearing, or cracking of the cover system components. In such cases, sliding of the cover system occurred along the weakest interface between the cover system components (e.g., soil-geosynthetic or geosynthetic-geosynthetic interface).

The stability of ClosureTurf on side slopes should be evaluated by calculating the factor of safety (FS) against veneer slope instability. The critical slip surface for ClosureTurf is along either the interface between the engineered turf and geomembrane or the interface between the geomembrane and subgrade (i.e., foundation layer of the cover system). Hence, this chapter focuses on the method for evaluating the veneer stability of these interfaces.

In addition to veneer stability, the design engineer should evaluate other potential modes of slope instability (e.g., global waste slope stability) that do not necessarily pertain to ClosureTurf. Those potential modes are beyond the scope of this Design Guidance.

2.2. Veneer Stability Analysis Method

The static and pseudo-static (i.e., seismic) veneer stability of ClosureTurf on a slope can be evaluated using methods based on limit equilibrium, such as closed-form equations developed for both finite and infinite slope configurations. In practice, closed-form equations are widely used because they are simple, practical, technically-sound, and can be easily coded in a spreadsheet. Examples of these equations include Giroud et al. (1995a) and Matasovic (1991). The design engineer is responsible for selecting an appropriate method for analyzing the stability of a particular slope or set of slopes.

Inputs to a veneer slope stability analysis include, but are not limited to, the unit weight of ClosureTurf, interface shear strength between the engineered turf and geomembrane, interface shear strength between the geomembrane and subgrade material, and the hydraulic head acting

on the geomembrane component of ClosureTurf. The hydraulic head on the geomembrane can be estimated using equations presented in the literature (e.g., Thiel and Stewart 1993) or using the Hydrologic Evaluation of Landfill Performance (HELP) software developed by the USEPA (Schroeder et al. 1994a and 1994b; Tolaymat and Krause 2020). Inputs for the hydraulic head calculation include weather data and characteristics of the ClosureTurf (i.e., transmissivity, slope, and length of the drainage layer). Additionally, external loading (e.g., vehicular loading) may need to be included in a veneer stability analysis, if applicable.

The design engineer should review technical guidance and state and federal solid waste regulations to understand if there are any specific methods or target FSs required by the regulations for the veneer slope stability of a landfill final cover system.

2.3. ClosureTurf Interface Shear Strength

As stated above, inputs to a ClosureTurf veneer stability analysis require information on shear strengths along two interfaces (i.e., between the engineered turf and geomembrane and between the geomembrane and subgrade material). Watershed Geo conducted interface shear testing in accordance with ASTM D5321 to evaluate the interface shear strength of the engineered turf layer against the underlying geomembrane. Appendix A provides the results of interface shear strength tests between the different types of engineered turf and structured geomembrane used in ClosureTurf. Test results indicate peak interface friction angles are 34 degrees for the CT HD turf, 36 degrees for the CT turf, and greater than 45 degrees for the CT HF turf, when using the Super GripNet geomembrane (or the MicroDrain geomembrane that has the same studded top surface); and 19 degrees for the CT HD turf, 23 degrees for the CT turf, and 40 degrees for the CT HF turf, when using the MicroSpike geomembrane. Measured large displacement shear strengths were lower than the peak interface strengths reported above (i.e., strain-softening).

The interface shear strength between the geomembrane and the subgrade material depends on the subgrade material at the site. Therefore, when selecting the appropriate interface friction angle for the veneer stability analysis, it is recommended that project-specific interface shear testing be conducted using samples of subgrade material collected from the site.

The design engineer should use the selected interface shear strength parameters to perform a veneer stability analysis of ClosureTurf to evaluate whether the calculated FS meets or exceeds the target FS. Alternatively, the design engineer may back-calculate the minimum required interface shear strength parameters to achieve the target FS. These values can then be

incorporated into the technical specifications as minimum required parameters; and the project specifications would require the contractor to perform interface shear testing to verify that the construction materials supplied to the project have adequate interface shear strengths to meet the target FS.

2.4. General Guidance on Maximum Slope

Table 2-1 provides the design engineer with general guidance on the maximum allowable slope at which each ClosureTurf system can be constructed. This table was developed by Watershed Geo based on results of interface shear testing conducted between the engineered turf and geomembrane and assumed typical values of interface shear strength between the geomembrane and subgrade material. Therefore, it is important to note that this table should be used for preliminary design purposes only. The design engineer should conduct project-specific interface shear testing to evaluate the critical interface (i.e., the interface with the lowest interface shear strength) and perform detailed slope stability analyses for the site-specific design.

Table 2-1. Maximum Allowable Slope for Preliminary Design of ClosureTurf [(1) (2) (3) (4) (5) (6)]

Geomembrane	Engineered Turf		
	CT HD (High-Density Turf)	**CT (Standard Turf)**	**CT HF (High-Friction Turf)**
MicroSpike	5H:1V	4H:1V	3H:1V
MicroDrain	3H:1V	3H:1V	2.5H:1V
Super GripNet	3H:1V	2.5H:1V	2H:1V[(2)]

Notes:

1. The table above is used for preliminary design purposes only. Site-specific slope stability analysis should be performed for the final design with an adequate safety factor by the project design engineer.
2. For slopes steeper than 2H:1V, additional measures (e.g., additional anchor trench or ballast) may be required to improve veneer stability, as determined by the design engineer to account for site-specific conditions. Contact Watershed Geo for more guidance, if needed.
3. The interface shear strength between the engineered turf and geomembrane has been tested by SGI Testing Services, LLC and the test results are provided in Appendix A.
4. The interface shear strength between the geomembrane and subgrade is dependent on the site subgrade materials. For the purpose of developing Table 2-1, the peak interface friction angle

between the geomembrane and subgrade was assumed to be 31 degrees for MicroSpike and MicroDrain and 37 degrees for Super GripNet. Site-specific interface shear testing should be conducted to obtain the interface friction angle for the detailed slope stability analyses.

5. Table 2-1 does not account for seismic conditions. If the site is in a seismic impact zone, additional slope stability analyses should be performed to evaluate the slope stability under the design earthquake event.
6. If PowerCap™, Watershed Geo's patented solar energy generation system, is considered for future beneficial site use, MicroSpike is recommended for use only on the landfill top deck with a slope equal to or less than 10 percent (%) when CT and CT HD are used; and on a maximum slope of 3H:1V when CT HF is used. Otherwise, Super GripNet or MicroDrain should be considered. Contact Watershed Geo for more guidance on maximum allowable slopes associated with PowerCap installation.

2.5. Example Calculation

Appendix B provides an example calculation for final cover veneer slope stability of ClosureTurf.

3. Wind Uplift Resistance

Exposed geomembranes can be lifted by wind, causing the geomembrane to be torn or pulled from the anchor trench. ClosureTurf is not an exposed geomembrane system. Unlike an exposed geomembrane system, the engineered turf and aggregate infill above the structured geomembrane provide resistance against wind uplift.

This chapter presents a wind uplift calculation method for ClosureTurf. The pressure necessary to cause an exposed geomembrane to lift is typically calculated based on the negative pressure relative to atmospheric pressure (suction) induced by wind and the resulting strain on the geomembrane. The calculation method for exposed geomembranes developed by Giroud et al. (1995b) and Giroud and Zornberg (1997) is used in this Design Guidance. Because ClosureTurf is not an exposed geomembrane, additional steps are needed to analyze the system's resistance to wind uplift that involve the engineered turf and aggregate infill.

3.1. Analysis Method

When wind flows over obstacles, local air pressure increases or decreases depending on the geometry of the obstacles that the flow encounters. If the air pressure becomes negative (relative to atmospheric pressure), suction (or uplift pressure) occurs. If the suction is strong enough, geomembrane cover systems can be lifted by wind. For ClosureTurf, the weight of the geomembrane, engineered turf, and aggregate infill is intended to counteract this wind uplift pressure.

Wind uplift pressure acting on ClosureTurf can be calculated using Equation 3-1 (Dedrick 1973; Wayne and Koerner 1988; Giroud et al. 1995b):

$$P = \frac{1}{2} C_p \rho U(H)^2 \cdot K_d \cdot K_e \quad (3\text{-}1)$$

In this equation, P is the wind-generated uplift pressure normal to the surface in pounds per square foot, C_p is a wind pressure coefficient, ρ is the air density (= 0.0024 slug per cubic foot at 59 degrees Fahrenheit [°F] and sea level), $U(H)$ is the mean upstream wind speed in feet per second at the height of the slope, K_d is the wind directionality factor (= 1.10), and K_e is the ground elevation factor.

The ground elevation factor can be calculated using Equation 3-2 (ASCE 2022):

$$K_e = e^{-0.000362 \cdot Z_e} \quad (3\text{-}2)$$

In the above equation, Z_e is the ground elevation above sea level in feet.

3.2. Wind Tunnel Test Results

Watershed Geo has conducted extensive wind tunnel testing of ClosureTurf at the Iowa State University Aerodynamic and Atmospheric Boundary Layer Wind and Gust Tunnel. The key observations made during the wind tunnel testing are as follows:

- The wind-induced uplift pressures varied along the side slopes and top deck. Uplift pressures were observed approximately from the middle of windward (i.e., slopes facing the wind) slope extending along the top deck to the leeward side slopes.
- The maximum uplift pressure occurred near the crest of the windward slope.
- Windward slopes experienced higher wind uplift pressures than leeward slopes.
- The measured maximum wind uplift pressures were larger for a 3H:1V slope than those for a 4H:1V slope.
- For the given test conditions, the wind uplift pressure experienced by ClosureTurf is about 70% lower than the wind uplift pressure experienced by an exposed smooth geomembrane cover. This lower uplift pressure appears to be associated with turbulence created by the engineered turf.
- For the given test conditions, the maximum uplift pressure experienced by a high-density turf (CT HD) is lower than that experienced by a standard density turf (CT). On a 4H:1V slope, the maximum wind uplift pressure of CT HD is 17% lower than that of CT; and on a 3H:1V slope, the maximum wind uplift pressure of CT HD is 24% lower than that of CT.

The wind tunnel test results are presented in the form of wind pressure coefficients, C_p. Figures 3-1 and 3-2 show the wind pressure coefficient distributions for 3H:1V and 4H:1V slopes, respectively, with two types of engineered turfs, CT and CT HD. No wind tunnel tests have been conducted for the blended turf CT X or high-friction turf CT HF. Since CT X and CT HF have similar turf density to CT, the wind pressure coefficients of CT can be applied to CT X and CT HF.

It is noted that positive wind pressure coefficients correspond to downward pressure (or compression) and negative wind pressure coefficients correspond to upward pressure (or uplift). The horizontal locations of the measurement points, *x*, are normalized by the length of the model, *L*, in Figures 3-1 and 3-2.

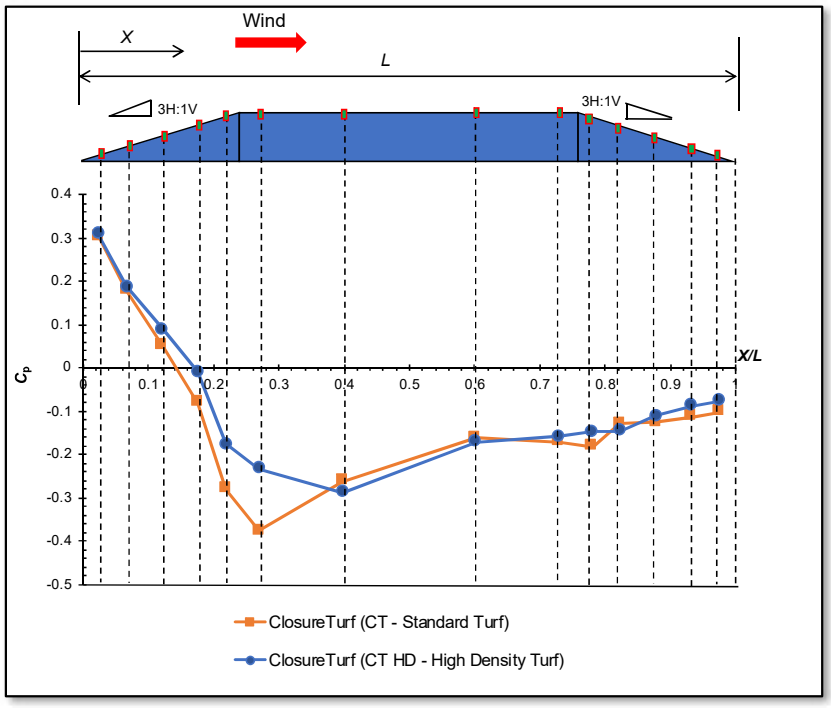


Figure 3-1. Wind Pressure Coefficients for ClosureTurf on a 3H:1V Slope

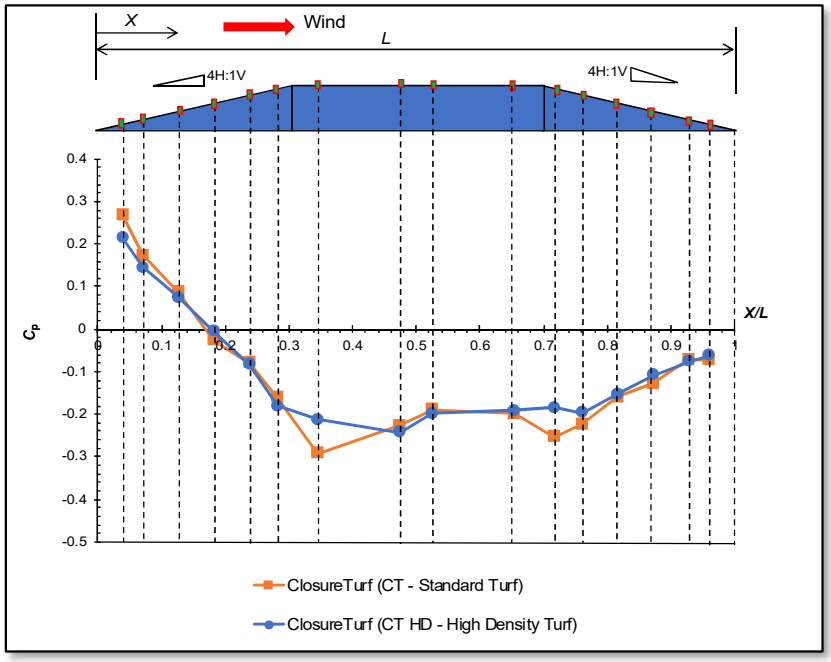


Figure 3-2. Wind Pressure Coefficients for ClosureTurf on a 4H:1V Slope

v.24155

3.3. Wind Uplift Analysis Procedure

The procedure for wind uplift analysis of ClosureTurf consists of the following steps (see Appendix C for more details):

1. Select the maximum absolute value of the negative wind pressure coefficient, C_p, based on the results of wind tunnel testing and the landfill slope configuration.
2. Select the appropriate design wind speed for the location of the project. The basic wind speed, corresponding to a 3-second gust at 32.8 feet above ground, at locations in the United States can be obtained from an online database (https://asce7hazardtool.online/) based on recommendations in ASCE 7-22 (ASCE 2022).
3. Calculate the mean hourly design wind speed at the top of the landfill from the basic wind speed.
4. Calculate the maximum wind uplift pressure using Equation 3-1. The critical location is usually at or near the windward crest.
5. Calculate the weight of ClosureTurf on a per square foot basis.
6. Calculate an FS against the maximum wind uplift pressure by dividing the weight of ClosureTurf by the wind uplift pressure. A minimum FS in the range of 1.1 to 1.2 is considered adequate for purposes of design against the maximum wind uplift pressure. The basis for these minimum FS values is given in Appendix C to this Design Guidance.
7. If the target FS is not met, a tension strain analysis is performed to evaluate whether the wind-induced tension in the ClosureTurf system is acceptable, as discussed in Appendix C.

3.4. Example Calculations

Appendix C presents example wind uplift calculations for ClosureTurf using the procedures presented above.

4. Puncture and Tearing Loads and Resistance

This chapter presents a summary of design considerations regarding the puncture and tearing loads induced on ClosureTurf and the resistance of the system to these loads.

4.1. Design Considerations

Potential sources for puncture and tearing stresses applied to ClosureTurf are similar to sources considered for traditional cover systems with geomembranes. The geomembrane component of ClosureTurf can potentially be punctured by large or sharp objects in the subgrade. Puncture can be induced by equipment loads on top of ClosureTurf. In addition, equipment traveling on slopes induce static and dynamic loads (e.g., equipment weight, acceleration, and braking), which may cause the cover system to slide or components of the system to tear.

To avoid puncturing the ClosureTurf geomembrane, the following should be taken into consideration:

- The subgrade should be prepared such that it:
    - has relatively uniform and smooth surface; and
    - is free of sharp objects, oversized particles, and other deleterious materials that could damage the geomembrane.
- Subgrade soil should conform to the requirements of the project technical specifications.
- Anchor trenches should be free of sharp objects and other deleterious materials.
- Construction stakes and hubs in the subgrade should be removed and resulting holes backfilled.
- Any potentially damaging particles, including stones, construction debris, and soil clods that accumulate on the exposed geomembrane during ClosureTurf installation should be removed before placing the engineered turf on the geomembrane.

The maximum particle size of the subgrade material should be determined by the design engineer based on the anticipated equipment loading and puncture resistance properties of the geomembrane.

With the subgrade meeting the requirements described above, the following should be taken into consideration regarding equipment loads to prevent ClosureTurf from tearing:

- Do not allow equipment with ground contact pressures exceeding 5 pounds per square inch (psi) on the partially constructed system until aggregate infill has been installed.
- Do not allow equipment with ground contact pressure greater than 35 psi on slopes steeper than 15% or ground contact pressure greater than 85 psi on slopes less than 15%, after ClosureTurf installation is complete.

It should be noted that the above-mentioned limits on equipment loading are for the general guidance purposes only and based on assumptions that: (1) the subgrade is firm and unyielding and able to support the equipment without creating rutting or bearing capacity issues; and (2) the subgrade is free of sharp rock fragments or stones, large stones and other deleterious matter such as tree roots, construction debris and metallic objects that could cause damage to ClosureTurf, as previously discussed. The design or construction quality assurance (CQA) engineer should specify the maximum allowed equipment loading limits based on site-specific conditions.

The contractor should use rubber-tired or -tracked equipment and limit the speed of equipment traveling on ClosureTurf. The equipment is not allowed to make sharp turns, sudden acceleration/deceleration, or repetitive passes on ClosureTurf. The design engineer should evaluate the maximum allowable equipment speed on ClosureTurf. Appendix B presents an example ClosureTurf veneer slope stability analysis considering equipment loading.

A puncture resistance analysis of the geomembrane can be performed by the engineer, as needed, using commonly accepted approaches (e.g., Wilson-Fahmy et al. 1997, Narejo et al. 1997, and Koerner et al. 1997).

4.2. Puncture Resistance Test Summary

To examine puncture resistance, Watershed Geo had SGI Testing Services conduct tests on samples of the engineered turf and structured geomembrane. The specific geomembrane used in the testing was 40-mil HDPE MicroSpike. Testing was conducted in accordance with the *Standard Test Method for Large-Scale Hydrostatic Puncture Testing of Geosynthetics* (ASTM D5514) using Virginia Department of Transportation #57 aggregate. For a maximum loading of 85 psi, the geomembrane component was deformed but not punctured. Because no punctures were observed in the geomembrane component for the loading of 85 psi, the ultimate static puncture strength of the system is expected to be greater than 85 psi. Additional details on the hydrostatic puncture testing are provided in Appendix D.

5. Surface Water Management

This chapter provides guidance on the design of open channels with ClosureTurf to manage surface water. The chapter addresses landfill hydrology, final cover conveyance channels, infill materials, and downstream considerations related to energy dissipation systems and sediment storage volumes in ponds.

5.1. Hydrology, Channel Sizing, and Channel Infill Selection

Table 5-1 presents parameters for defining site hydrology when applying the Rational Method or the Soil Conservation Service Unit Hydrograph Method to evaluate hydrologic performance of ClosureTurf. These parameters are used for sizing conveyance channels using Manning's Equation and selecting infill materials as a function of permissible and computed flow velocities.

Table 5-1. Hydrology and Hydraulics Parameter Recommendations for ClosureTurf-lined Areas

Runoff Process	Parameter	Value
Rainfall to Runoff	Curve Number	92 - 95, or as selected by the design engineer
	Rational "C"	0.74 - 0.78, or as selected by the design engineer
Sheet Flow	Manning's Roughness	0.22 (when slope $\leq$ 10%) 0.12 (when slope > 10%)
	Maximum Flow Length	Selected such that flow depth is $\leq$ 0.1 foot, or as required
Shallow Concentrated Flow	Average Velocity [(1)] (feet/second)	TR-55 unpaved condition (calculated as 16.135 x $(S)^{0.5}$, where S is the surface slope in feet/foot), or as selected by the design engineer
Concentrated Flow [(2)]	Manning's Roughness	0.02 (when using HydroBinder)

Notes:

1. The suggested value is based on Part 630 Hydrology, National Engineering Handbook (NRCS 2010) for shallow concentrated flow over an unpaved surface or grassed waterway of a given slope. Check local requirements for suitability.
2. Hydraulically stable stone (gravel/riprap) or HydroBinder other than the aggregate infill should be used in concentrated flow locations.

The terminology in Table 5-1 is based on Hydraulic Engineering Circular Number 22 (HEC-22), *Urban Drainage Design Manual* (FHWA 2009). Only the parameters that are influenced by the selection of ClosureTurf over traditional cover systems are discussed herein. For example, many state or local agencies require that a design storm event be selected from Atlas 14 Point Precipitation Frequency Estimates published by the National Oceanic and Atmospheric Administration (NOAA 2022). However, because this design requirement is applicable for all cover systems, it is not addressed in this Design Guidance. It is also recommended that the design engineer consider applicable federal (e.g., *Urban Drainage Design Manual*, FHWA 2009) and state (e.g., *Georgia Stormwater Management Manual*, ARC 2016) design guidelines, as appropriate for the site location and standards of practice, during the design process.

5.2. General Design Considerations

5.2.1. Hydrology

Because longer drainage lengths are typically possible with ClosureTurf compared to traditional soil cover systems, the need for drainage benches to intercept and manage runoff may be eliminated or the spacing of benches, if still needed, can be increased. The ability to maintain sheet flow for extended distances is a significant advantage to ClosureTurf.

Due to the relative impermeability of the underlying geomembrane and small thickness of the aggregate infill layer, curve numbers for ClosureTurf tend to be higher than those of traditional soil cover systems. This may affect the runoff volumes and rates to be managed by stormwater ponds and other downstream features, which are discussed in Section 5.2.5.

5.2.2. Typical ClosureTurf Stormwater Management Features

Regulatory requirements generally specify that a network of final cover channels be designed to route runoff generated within a final cover area so that this runoff does not increase peak discharge rates and total runoff volumes associated with any predevelopment outfalls of a site. Typical landfill or other site development regulations for channel sizing will also require conveyance of specific design storms, such as the 25-year/24-hour storm event, or the 100-year/24-hour storm event with some degree of freeboard, or both. Note that, for reasons to be described in Chapter 6, storm events selected to size drainage benches and channels may differ from those selected for evaluating hydraulic stability of the ClosureTurf aggregate infill.

Typical final cover drainage features include benches, berms, swales, downchutes, perimeter channels, etc. Relevant standard details are provided in Watershed Geo's online technical library.

5.2.3. Channel Infill Selection for ClosureTurf Stormwater Management Features

Stone (gravel or riprap) or HydroBinder is recommended as a ClosureTurf infill option within channels rather than aggregate infill. The relative costs and advantages of HydroBinder versus stone depend on site-specific conditions.

When stone is used, the design engineer should assess whether a nonwoven geotextile cushion should be placed between the stone and ClosureTurf to reduce the potential for damage to the ClosureTurf system including puncture of the ClosureTurf geomembrane component.

When HydroBinder or other low permeability binder infill is used, water relief vents (e.g., a slit cut into the HydroBinder layer with an insert to maintain water flow, i.e., a piece of geocomposite, geonet, studded geomembrane such as Agru's MicroDrain®, etc.) should be considered to relieve hydraulic pressure within the ClosureTurf drainage layer at locations where the internal drainage capacity is decreased or restricted (e.g., upstream of riprap check dams, sharp decreases in slope, grade breaks at downchutes, terminations/connections to concrete structures, such as headwalls and drop inlets, etc.)

The spacing of water relief vents is site-specific, depending on multiple variables (e.g., channel slope, drainage area to the channel, location of structures, etc.). A spacing of approximately 200 ft can be used as a general guidance for a HydroBinder-lined drainage swale or channel and should be adjusted by the design engineer based on site-specific conditions. It is also suggested that vents be installed immediately upstream of any location in the drainage swale or channel that restricts flow within the internal drainage layer (e.g., concrete headwalls, drop inlets, or cross stream check dams). For a HydroBinder-lined downchute, water relief vents are suggested at locations immediately above the benches, if any, and toe of the slope. The width of the vent is suggested to be approximately 1/3 of the channel or downchute bottom width.

Also, as is standard practice for the design of any channel lining system, the calculated flow velocity for the selected design storm should be compared to the permissible flow velocity of the ClosureTurf with the HydroBinder infill within channels, which is considered to be 29 ft/s, if a FS of 2.0 is desired.

5.2.4. Energy Dissipation

Similar to any surface water conveyance terminating and transitioning flow direction at the toe of a slope, proper energy dissipation is necessary at the base of downslope channels using ClosureTurf and around any relatively sharp changes in flow direction. Proper energy dissipation

techniques can be found in HEC 14, *Hydraulic Design of Energy Dissipators for Culverts and Channels* (FHWA 2006).

Where concrete energy dissipators are required, polyethylene (PE) embedment strips can be cured into the concrete dissipators and later welded to the geomembrane component of ClosureTurf to maintain a continuous closure system. Alternatively, batten strips with concrete anchors may be used. Where stone energy dissipators are used, placement of HydroBinder around the footprint of stone is suggested to minimize loss of aggregate infill placed in the vicinity of the energy dissipators.

5.2.5. Stormwater Pond Design

Because runoff from ClosureTurf may generate greater peak discharge rates and volumes compared to those from traditional soil cover systems, projects using stormwater ponds to attenuate flows prior to discharge may need an increased stormwater pond size. However, this potential increase to pond size can be at least partially offset by a reduction or elimination of the required sediment storage volume that must be managed (i.e., the volume of ClosureTurf aggregate infill transported by runoff will typically be small and often negligible relative to the volume of sediment transported by runoff from a traditional soil cover system). As a reference, Appendix E presents a parametric study comparing pond design for traditional soil cover versus the ClosureTurf final cover system.

6. Hydraulic Stability of Aggregate Infill

The specified aggregate infill is one of the three components of ClosureTurf. The infill serves as a protective layer for the turf and geomembrane components. While the turf and geomembrane components are not directly sensitive to hydraulic forces, washout of the aggregate infill layer can increase exposure of the turf and geomembrane to puncture stresses, ultraviolet (UV) degradation, and wind uplift.

Washout of the aggregate infill can occur when raindrops dislodge individual aggregate particles (i.e., splash erosion), when planar flow concentrations during a storm impose hydraulic shear stresses high enough to mobilize the infill (i.e., sheet erosion), or when a combination of the two mechanisms occurs.

This chapter presents evaluation methods and performance requirements for the aggregate infill based on an extensive testing program to establish allowable shear stresses, material specification requirements, recommended design methods to compare calculated shear stresses with allowable ones, and the selection of an alternative infill in case calculated shear stresses exceed allowable ones.

This chapter is limited in scope to areas of a ClosureTurf installation that receive sheet flow or shallow concentrated flow. It is considered best practice to use supplemental/alternative infill materials in ClosureTurf concentrated flow channels, as discussed in Section 5.2.3.

6.1. Hydraulic Testing and Performance Specifications

Hydraulic stability of aggregate infill has been independently tested by TRI Environmental (TRI) and the Civil Infrastructure Testing and Evaluation Lab (CITEL), two third-party laboratories, in general accordance with ASTM D 6460, *Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion*, and ASTM D 6459, *Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hillslopes from Rainfall-Induced Erosion.* A summary of the aggregate infill testing program and results and the development of the aggregate infill specification based on the test results is provided as Appendix F.

The ClosureTurf Aggregate Infill Specification is available at Watershed Geo's online technical library. The aggregate infill must meet criteria for fine aggregate angularity, specific gravity, and particle size distribution. When the aggregate infill meets material specifications, the permissible

hydraulic shear stress of the aggregate infill is suggested to be 0.8 psf for standard density turf (i.e. CT, CT X and CT HF) or 1.5 psf for high density turf (CT HD).

6.2. Suggested Method for Calculating Hydraulic Shear Stress

For design, the calculated hydraulic shear stresses for a ClosureTurf installation should be less than the suggested permissible hydraulic stresses for the aggregate infill, as indicated above. The example calculations included as Appendix G provide a suggested method to estimate the hydraulic shear stress on ClosureTurf using widely accepted engineering methods such as those presented in HEC 22, Urban Drainage Design Manual (FHWA 2009). Two different hydraulic shear stress calculations are presented in the appendix, differentiated by location and the choice of geomembrane used in ClosureTurf. Typically, multiple drainage paths are evaluated to establish a maximum anticipated hydraulic shear stress for design. If the calculated maximum hydraulic shear stress exceeds the permissible value, mitigation options include flattening the slope, shortening drainage lengths (e.g., addition of a drainage bench), and using infill with a higher permissible shear stress (e.g., HydroBinder, as discussed in Chapter 5).

Based on Watershed Geo's experience, it is suggested that the maximum drainage length on a typical landfill slope (e.g., 3H:1V or 4H:1V) be limited to the drainage length calculated using the permissible aggregate infill hydraulic shear stress of 0.8 psf for CT, CT X and CT HF (1.5 psf for CT HD) or 350 ft, whichever is smaller, or an alternative length as determined appropriate by the design engineer. Depending on the size of drainage area of the landfill top deck, a stormwater diversion berm is also suggested to separate top deck runoff and the runoff from the side slope. The diversion berm is intended to reduce the amount of runoff on the side slope, as well as mitigate potential localized aggregate infill movement resulting from geometry change and surface irregularities due to imperfections during construction and differential landfill settlement along the crest line.

7. Landfill Gas Management

For waste containment facilities that contain organic waste materials and generate gas (e.g., MSW landfills), a landfill gas management system should be considered to control gas emissions from these facilities in accordance with regulatory requirements on landfill closure and gas emissions. This chapter provides general design considerations of the landfill gas management system associated with ClosureTurf.

7.1. ClosureTurf Gas Management

Due to the light weight of ClosureTurf compared to a soil cover, ClosureTurf is susceptible to uplift caused by landfill gas pressure buildup underneath the cover system. The design of a gas-generating landfill closed with ClosureTurf should include a landfill gas management plan to prevent gas uplift of ClosureTurf. The design engineer should evaluate the site conditions and regulatory requirements to determine whether a passive landfill gas venting system or an active landfill gas collection and control system (GCCS) is required. For landfills that allow free venting of gas, passive gas vents (PGVs) should be considered to relieve gas pressure under ClosureTurf. For landfills where an active gas collection system is required, pressure relief valves (PRVs) should be considered in combination with the active gas collection system to provide gas pressure relief in case of system malfunction, such as a flare shutdown. Details of the PGV and PRV developed by Watershed Geo for use with ClosureTurf can be found at Watershed Geo's online technical library. Figure 7-1 is a photo of a ClosureTurf PRV installed in the field.



Figure 7-1. ClosureTurf Pressure Relief Valve (PRV) Installed in Field

The ClosureTurf PRV is designed with an internal one-way check valve that closes under the vacuum applied to the GCCS and opens under positive gas pressure accumulated beneath the geomembrane of ClosureTurf. Based on laboratory flow test results, the suggested design maximum gas flow rate for each PRV is 50 standard cubic feet per minute (scfm) under a pressure differential equal to one inch of water column.

PRVs are typically installed at a minimum density of one per acre of installed ClosureTurf. However, the design engineer should evaluate whether additional PRVs are necessary based on a site-specific landfill gas generation rate analysis, for example, using the Landfill Gas Emissions Model (LandGEM) developed by USEPA (USEPA 2005) and taking into account the field measurements of landfill gas flow rates, if available.

7.2. Integration with Gas Management System

A conventional active landfill GCCS consists of vertical gas extraction wells, gas collection wellheads, lateral and header gas collection pipes, condensate sumps, gas blowers, and flare stations. ClosureTurf has been installed at landfills with the conventional active GCCS, as shown in Figure 7-2.



Figure 7-2. ClosureTurf Integrated with Landfill Gas Collection System

Geomembrane boots are used to seal penetrations around gas collection wellheads and pipes. An example pipe penetration detail is available at Watershed Geo's online technical library. Gas collection pipes can be installed either above or below the ClosureTurf cover system. Table 7-1 summarizes the advantages and disadvantages of these two installation options for the design engineer to consider.

Table 7-1. Advantages and Disadvantages of GCCS Pipe Installation Options

Above ClosureTurf System		Below ClosureTurf System	
Advantages	Disadvantages	Advantages	Disadvantages
No or fewer pipe penetrations	Pipes exposed to weather, including freeze-thaw and thermal expansion/ contraction	Pipes protected from weather by the ClosureTurf system	Possible leak points created by pipe penetrations
Increased ability to inspect, repair, or upgrade piping	More visible; aesthetics may be a consideration	Pipes concealed beneath the ClosureTurf system	More difficult to inspect, repair, or upgrade pipes
Less expensive to install	Potential damage due to external loads (e.g., traffic)	Less susceptible to damage due to external loads (e.g., traffic)	More expensive to install

7.3. Surficial Gas Collection System

Watershed Geo has developed a surficial gas collection system to use with ClosureTurf installations (Figure 7-3). This system consists of surficial gas collection wellheads, gas collection strips, and PRVs. The collection strips may consist of Super GripNet, single-sided geocomposite, or other materials that facilitate the lateral flow of gas. The system allows a vacuum to be applied to the wellhead to extract the gas from the surface below the geomembrane of ClosureTurf.

The locations of the surficial gas collection strips and wellheads should be established by the design engineer in the landfill gas management plan. If the surficial gas collection system is connected to a conventional GCCS with vertical gas extraction wells, it is recommended that automatic isolation of the surficial gas collection system be incorporated in the design to prevent potential backflow of landfill gas during a flare shutdown event.

Details of the surficial gas collection system, including the surficial gas collection wellhead detail not shown on Figure 7-3, are available at Watershed Geo's online technical library.

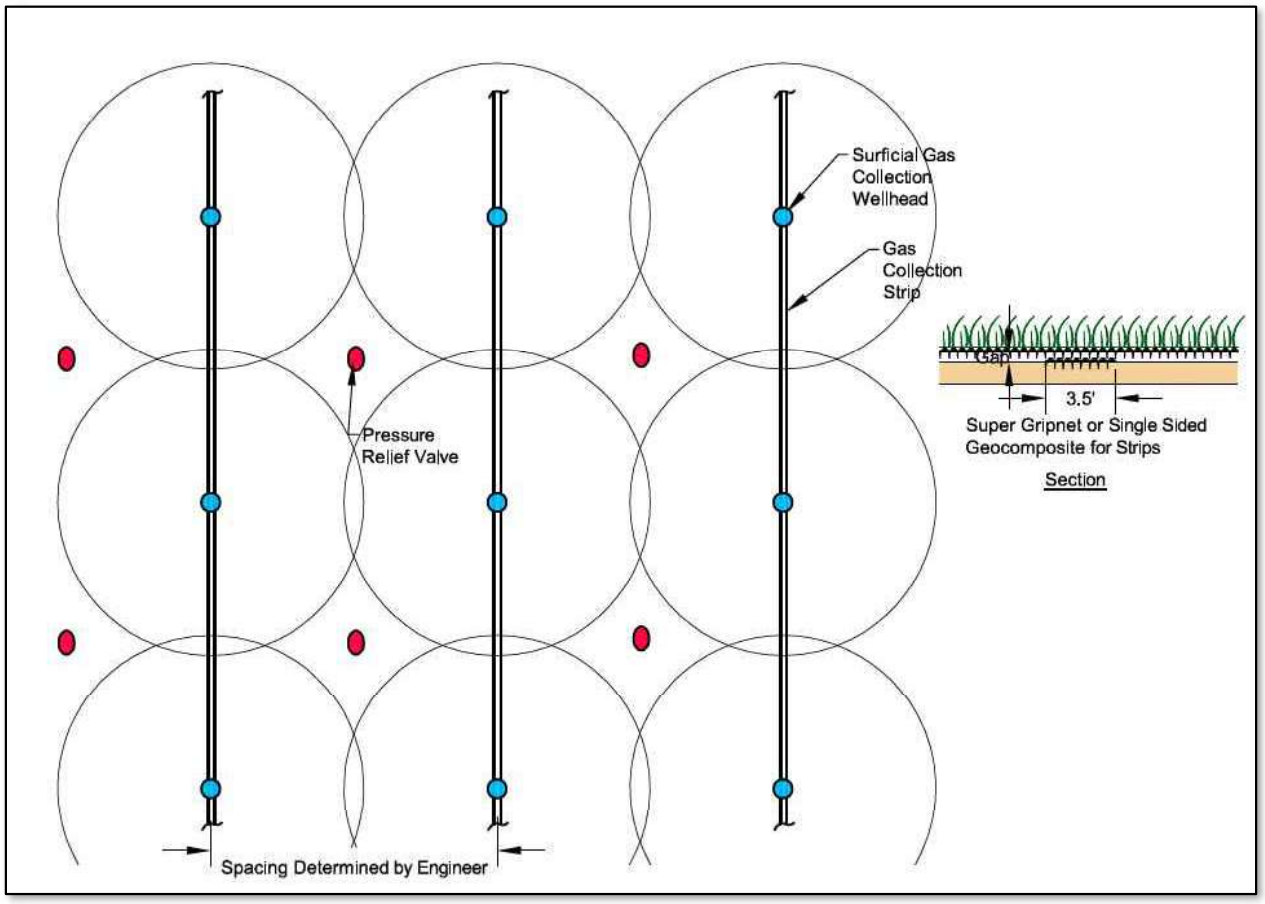


Figure 7-3. Illustration of ClosureTurf Surficial Gas Collection System

8. ClosureTurf Performance Equivalency

This chapter compares the performance of ClosureTurf with USEPA-prescribed minimum design requirements for final cover systems at MSW landfills and coal combustion residuals (CCR) units. This comparison is presented in terms of reduction in infiltration through the cover system and erosion resistance.

8.1. Regulatory Requirements

USEPA has established minimum requirements for the management of MSW landfills through Title 40 Code of Federal Regulations (CFR) Part 258, commonly referred to as Resource Conservation and Recovery Act (RCRA) Subtitle D requirements. 40 CFR §258.60(a) requires that the final cover system be designed and constructed to meet the following criteria:

(1) Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1×10^{-5} centimeters per second (cm/sec), whichever is less, and

(2) Minimize infiltration through the closed MSW landfill unit by the use of an infiltration layer that contains a minimum of 18 inches of earthen material, and

(3) Minimize erosion of the final cover by the use of an erosion layer that contains a minimum of 6 inches of earthen material that is capable of sustaining native plant growth.

For closure of coal combustion residuals (CCR) units (e.g., CCR landfills and surface impoundments), the USEPA prescribes minimum final cover system requirements under 40 CFR §257.102(d)(3)(i), which are similar to those for MSW landfills.

Many state regulations adopt the federal requirements for final cover systems. Furthermore, the Federal and state regulations allow for the use of alternative final cover systems, provided it can be demonstrated that the performance of the alternative system is equivalent to or better than the prescriptive final cover system, for example, as stated under 40 CFR §258.60(b) and 40 CFR §257.102(d)(3)(ii). The following sections present methods to demonstrate that ClosureTurf is equivalent to the final cover systems prescribed by the regulations, both in terms of reduction of infiltration through the cover system and erosion resistance.

8.2. Infiltration Reduction Equivalency

The hydrologic performance of ClosureTurf has been evaluated using the HELP model to demonstrate its equivalency to the prescribed minimum design requirements in federal regulations and similar state regulations. Table 8-1 provides typical parameters for modeling the components of ClosureTurf in the HELP model.

Table 8-1. Typical Material Properties for ClosureTurf Used in HELP Model

Component	Thickness	HELP Material Texture # (1)	Hydraulic Conductivity	HELP Layer Type
Engineered Turf (2)	0.5 in (2)	2	2.5×10^{-2} cm/sec (3)	Vertical Percolation Layer
Studded Drainage Layer for Geomembrane	130 mil (0.13 in)	20	Varies (4,5)	Lateral Drainage Layer
Geomembrane	40 to 50 mil (0.04 to 0.05 in)	35	2.0×10^{-13} cm/sec (6)	Flexible Membrane Liner

Notes:

1. The HELP material texture numbers are typically used in the HELP model for the default values of total porosity, field capacity, and wilting point.
2. The engineered turf component and thickness represent the combination of the synthetic turf and aggregate infill. A larger thickness of 0.6 in may also be used to consider the approximate thickness of the geotextile backing.
3. The hydraulic conductivity is based on a typical value for sand.
4. The hydraulic conductivity of the drainage layer is calculated using the transmissivity of the studded geomembrane divided by its thickness. Based on the laboratory test results included in Appendix G, the transmissivity of the studded geomembrane (MicroDrain or Super Gripnet) is a function of hydraulic gradient: $\theta = 2.542 \times 10^{-3}/i^{0.376}$, m^2/sec, where i is the hydraulic gradient, for example, for a 3H:1V slope, i ≈ 33% or 0.33. To calculate the hydraulic conductivity of the drainage layer in the unit of cm/sec, the calculated transmissivity needs to be converted to cm^2/sec and the thickness of the studs needs to be converted to cm (i.e., from 0.13 in to 0.33 cm).
5. The hydraulic conductivity of the drainage layer may be reduced to account for creep, intrusion, and/or clogging expected under long-term conditions.
6. The hydraulic conductivity of the geomembrane represents a typical value from manufacturers.

A commonly used approach to demonstrate a reduction in infiltration rates is to evaluate the ratio of the calculated annual infiltration rate through ClosureTurf to the rate through the prescriptive final cover system. Multiple case studies examined by Carlson et al. (2019) have demonstrated the infiltration rate through ClosureTurf is much less than or equivalent to the calculated infiltration rates through final cover systems meeting the prescriptive minimum design requirements. A similar infiltration equivalency demonstration for ClosureTurf can be performed for a landfill site based on the site-specific conditions and the prescriptive soil cover requirements by the state where the landfill is located, as a part of the permit application package.

8.3. Erosion Resistance Equivalency

The prescribed final cover systems rely on establishing and maintaining vegetative cover to provide erosion resistance. When adequate vegetation is not established, either during the period soon after closure completion or on a seasonal/long-term basis (e.g., droughts, etc.), maintenance is necessary to repair and reseed the eroded area; and this could result in poor runoff water quality and dusty conditions until proper vegetation is established.

ClosureTurf is different from vegetated soil covers because its manufactured/specified properties have been developed to be inherently erosion-resistant, and the system is effective upon completion of installation, without a lengthy period to establish vegetation. The synthetic engineered turf and aggregate infill have been shown through laboratory testing (and verified by field performance) to provide excellent resistance to wind and water erosion. When ClosureTurf is designed in accordance with the recommendations provided in this Design Guidance (e.g., related to hydraulic and wind uplift considerations) and installed properly, it is expected to provide equivalent or superior water and wind erosion resistance to vegetated final cover systems, thus reducing the need for post-closure maintenance and repairs.

As another indicator of superior erosional performance in terms of runoff quality, the lack of fine-grained soil materials in the ClosureTurf infill makes the system less susceptible to erosion-induced suspension of solids and related migration of sediment particles. For example, a case study from De Abreu and Franklin (2014) measured a turbidity of 11 nephelometric turbidity units (NTU) for the runoff from ClosureTurf, whereas runoff generated from a clayey cover soil at the same site produced a turbidity of 371 NTU.

9. ClosureTurf Design Life

This chapter discusses the UV longevity and the projected design life of ClosureTurf.

9.1. Longevity of System Components

Longevity of ClosureTurf depends on the longevity of individual components (i.e., structured geomembrane, engineered turf, and specified aggregate infill). Because the geomembrane is covered by the engineered turf and specified infill, the unexposed geomembrane has an anticipated service life of at least 200 years under most climate conditions (Koerner et al. 2011; Scholl et al. 2023). The engineered turf geotextile backing has an expected service life greater than 100 years, provided it remains covered with the specified infill (Gobla 2014; Scholl et al. 2023). The specified infill will not degrade appreciably from weathering for centuries. The most critical ClosureTurf component with respect to longevity is the exposed engineered turf fibers forming the "grass" matrix that hold the specified infill in place.

9.2. Service Life Projection of Turf Fibers

A multi-year testing program was instituted to evaluate the service life of the engineered turf fibers. Outdoor weathering testing was initially conducted on samples of turf fibers placed at the test field of Atlas Material Testing Solutions located in New River, Arizona. Samples of the weathered turf fibers after approximately 1, 5, 7 and 10 years of exposure were sent to a geosynthetics laboratory and tested for remaining tensile strength. The results were independently reviewed by a third-party consulting firm (Geosyntec 2015) and the evaluation report is provided in Appendix H. Based on the evaluation results, the half-life of the turf fibers was projected based on semi-log linear extrapolation to be more than 100 years (Figure 9-1). As noted in the report, the service life of the turf fibers was expected to be much longer than the projected half-life.

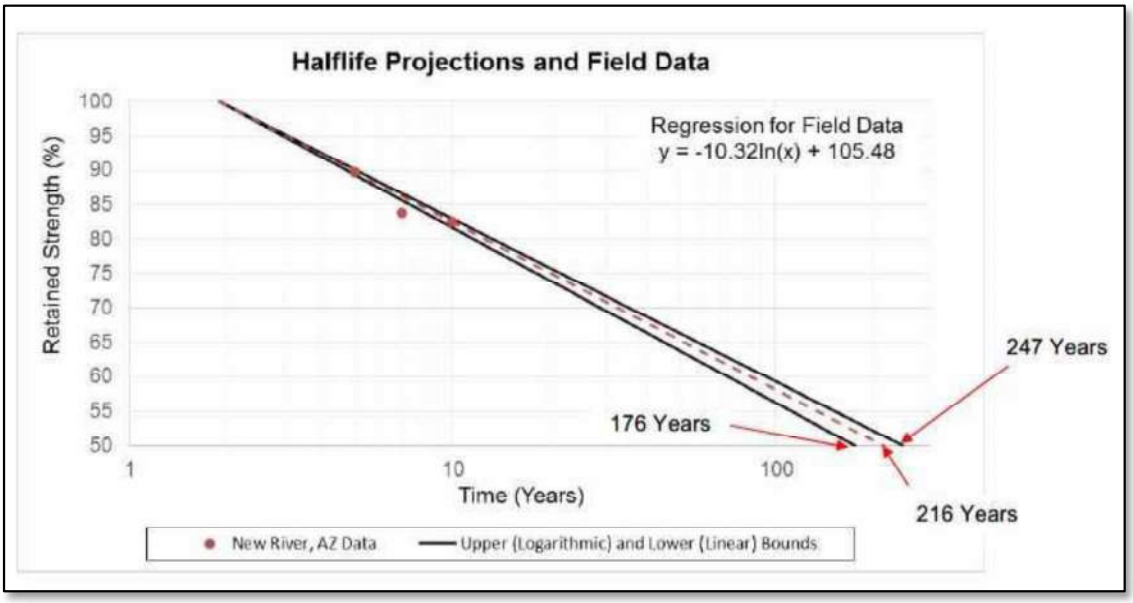


Figure 9-1. Half-Life Projection of Turf Fibers of ClosureTurf (Geosyntec 2015)

Subsequently, field samples of the turf fibers were collected from multiple sites to evaluate the real-world performance. In addition, an accelerated natural weathering program has been undertaken on samples of the turf fibers at the same Atlas facility in Arizona using Fresnel Solar Collectors. The accelerated results equivalent up to 21 years of UV exposure have been obtained to date. The 2015 UV longevity evaluation report has been updated to incorporate the new test results (Geosyntec 2022). The updated evaluation report is provided in Appendix H.

The new data from the real-world field and accelerated weathering test results are plotted in Figure 9-2, along with the data points from the initial 10-year weathering test and projected trend lines. The new data points clearly support the projected half-life of more than 100 years for the turf fibers, as most of them are above the projected trend lines.

The accelerated weathering testing is still ongoing. The projection plot will be updated once additional data points beyond the equivalent 21-year become available.

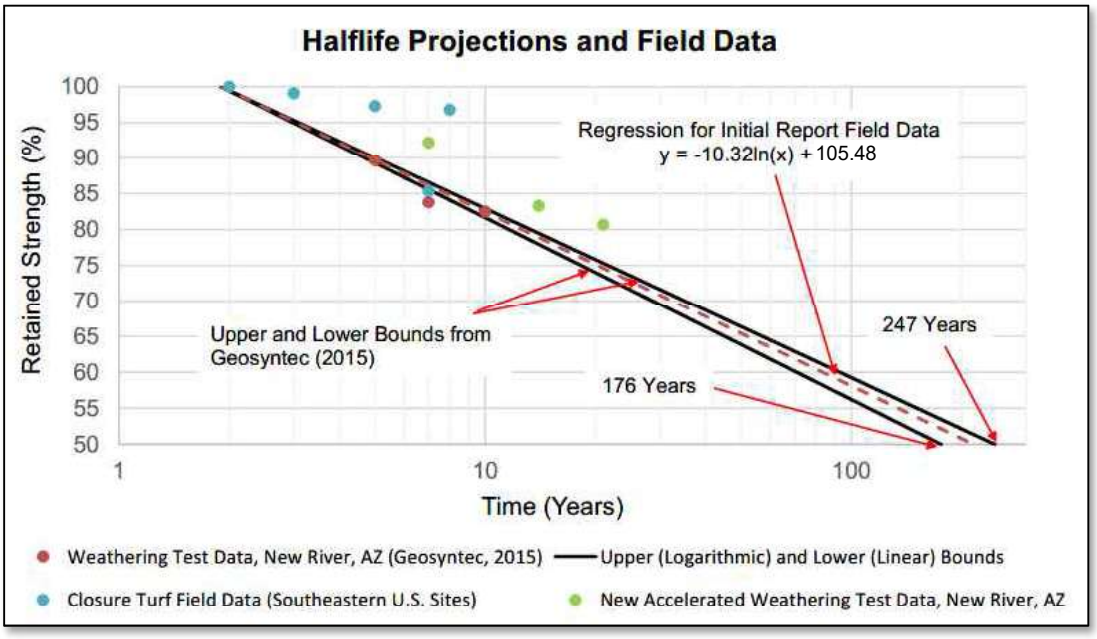


Figure 9-2. Half-Life Projection of Turf Fibers of ClosureTurf with Additional Field and Accelerated Weathering Data (Geosyntec 2022)

9.3. Summary

Based on the results of field samples and weathering test results, ClosureTurf is projected to have a design life, represented by the service life, of 100 years or longer, provided it is installed and maintained appropriately in accordance with engineering design drawings, technical specifications, and post-closure care procedures.

10. Other Considerations

This chapter addresses several considerations for design of ClosureTurf cover systems not discussed in previous chapters. These other considerations are:

- Settlement
- Thermal effects
- Impact of animals
- Resistance to fire and lightning
- Measures to prevent vandalism
- Post-closure care
- Beneficial use for solar development

10.1. Settlement

ClosureTurf is a light-weight cover system with an average weight on a unit area of approximately 5 psf, compared to approximately 240 psf or more for a typical soil cover system. As a result, installation of ClosureTurf induces significantly less additional settlement of the underlying waste mass than installation of the traditional soil cover system. Since the waste is usually inhomogeneous, differential settlement may occur over time after the landfill is closed. The differential settlement may result in tension in the final cover system, causing a soil cover to crack. Unlike the soil cover, ClosureTurf is made of flexible geosynthetic materials, which can tolerate relatively large differential settlements. The settlement can be estimated during the design using one-dimensional consolidation equations coded in a calculation spreadsheet or commercially available computer software.

The differential settlement may cause grade reversal and hence, localized ponding of rainwater, which needs to be repaired as part of post-closure maintenance. Repair of depressions is straightforward for ClosureTurf because there is no excavation of thick soil layers. One repair approach with ClosureTurf is to cut one or more holes at the location of the depression. Flowable backfill (usually a mix of fly ash, cement, and water) is then pumped into the depressed area to raise “subgrade” for the ClosureTurf to its original grade. After mitigating settlements, the holes in the geomembrane are patched and seamed with new pieces of geomembrane; the engineered

turf is repaired using a heat-bonded seam; and aggregate infill is replaced to cover the repaired area.

10.2. Thermal Effects

Stress cracks of geomembrane can result from relatively large temperature changes over a brief duration and from other causes. Stress cracking of the structured geomembrane component of ClosureTurf was evaluated using the *Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test* (ASTM D5397). For example, the product specification sheets for 50-mil HDPE Super GripNet and MicroDrain report stress crack resistance at more than 500 hours based on testing in accordance with ASTM D5397, which meets the minimum acceptable resistance for geomembranes per GRI-GM13 (GSI 2016).

Results of freeze-thaw tests ranging from -20 to +30 degrees Celsius (°C) (Comer et al. 1996) indicated "neither geomembrane sheets nor their associated seams were adversely affected." The performance of the geomembrane component of ClosureTurf with respect to freeze-thaw cycling is expected to be similar to the performance of geomembranes in the Comer et al. (1996) study.

Similar to other HDPE and LLDPE geomembranes, ClosureTurf should typically not be installed at ambient temperatures below 35°F or above 104°F. If ClosureTurf is planned for installation outside the above-mentioned temperature range, it should be demonstrated before installation that the integrity of the geomembrane is not affected by the weather conditions (USBR 2014).

Wrinkles could form during installation of ClosureTurf due to thermal expansion. HDPE geomembranes typically have a higher coefficient of thermal expansion than LLDPE geomembranes (Scheirs 2009). Best wrinkle management practices, including but not limited to acclimation of geomembrane to ambient temperatures and "snapping" of geomembrane to reduce excess slack, should be implemented during installation to minimize wrinkles.

Wrinkling is a dynamic process and may continue due to temperature fluctuations after installation of ClosureTurf. Small wrinkles may migrate downslope due to gravity and thermal cycling over time, forming larger wrinkles in or near drainage swales on side slopes, if any, and perimeter channels at the toe of side slopes. Wrinkles may affect the aesthetics of ClosureTurf; however, wrinkles themselves generally do not have adverse impacts on the overall performance of ClosureTurf in terms of infiltration reduction, erosion resistance, and final cover structural

integrity. Therefore, wrinkles of ClosureTurf observed after closure usually do not require repairs, unless desired by the site owner for aesthetic reasons. If the aggregate infill is displaced from the top of a wrinkle, resulting in exposed geotextile backing, new aggregate infill should be placed to cover the exposed geotextile backing. A binding agent, such as the cementitious HydroBinder® or the polyurethane-based DuraGuard™ can be used to keep the aggregate infill in place on top of a wrinkle.

After installation, temperature changes may cause the ClosureTurf system to contract and develop tensile stresses. Calculations of factors of safety against pull-out can be performed, as determined by the design engineer, to evaluate whether these tensile stresses may cause the cover system to pull out of perimeter anchor trenches. Appendix I provides an example calculation for pull-out resistance for one potential design scenario.

In cold climate regions, freezing temperatures may cause ClosureTurf to bridge over the concave-shaped bottom of stormwater drainage swales and channels due to thermal contraction. Adding dead weight, such as crushed stone (e.g., gravel or riprap), on ClosureTurf can mitigate the bridging (also known as trampolining) effect. The drainage stone should be sized by the design engineer such that it will not be displaced by the hydraulic shear force from the concentrated flow. The properly sized and hydraulically stable drainage stone can then be used in lieu of the HydroBinder infill in the design. Best management practices, including ballasting with sandbags, should be used to help temporarily control potential bridging or trampolining during ClosureTurf installation in cold climate regions.

Watershed Geo worked with GSI to test the integrity of ClosureTurf under deep freeze conditions. No tears or punctures were observed in the structured geomembrane or engineered turf component of ClosureTurf during the deep freeze test. Appendix J presents the details of the deep freeze test. Additionally, there have been no reported observations of damage to installed ClosureTurf as a result of freezing temperatures in field conditions.

10.3. Impact of Animals

Traditional vegetated soil cover systems can provide suitable habitats for burrowing animals and birds. Burrowing animals can pose problems to the integrity and performance of traditional cover systems (Lutton et al. 1979). ClosureTurf does not include soil layers that can provide a suitable habitat for burrowing animals. Watershed Geo has not observed evidence of burrowing animal activities to date. Nonetheless, should evidence of burrowing ever be discovered, the disturbed area of ClosureTurf can be easily repaired. ClosureTurf has little attraction for birds because it

does not provide a suitable habitat. However, bird damages to ClosureTurf have been observed at landfill sites where there is a working phase with food sources. The damages often occurred in localized areas around landfill gas wellheads and drainage berms, where the bird could perch. Birds appear to target the black geotextile backing of the engineered turf, not the geomembrane. For sites with a bird nuisance, the damaged turf can be repaired and infilled with HydroBinder for additional protection. Bird droppings may cause some grasses or weeds to grow on ClosureTurf in limited areas, usually in drainage swales and perimeter channels where ponded water is present due to subgrade depression. Observed grass or weeds growing at the ClosureTurf site can be readily addressed as part of site maintenance.

Hoofed animals (e.g., deer or elk) have been observed at ClosureTurf sites, but they do not inhabit these areas because no food source is present. Furthermore, there have been no reports of damage to ClosureTurf trampled by animal hoofs at these sites. The aggregate infill and engineered turf prevent direct contact of the hoofs with the underlying geomembrane and dissipate contact pressures. Estimates of maximum ground contact pressure for a typical adult hoofed animals are less than the allowable loading limits of ClosureTurf suggested by Watershed Geo. Should the geomembrane be damaged from hoofed animals, it can be repaired by replacing the geomembrane in patches and seaming.

10.4. Resistance to Fires

Grasses used on traditional cover systems are composed of organic matter that is combustible under certain climatic and seasonal conditions. Fires on vegetated covers can be ignited by natural or human-induced causes, and once started, can rapidly spread. Unlike natural grass, ClosureTurf is a synthetic product that is unlikely to propagate fires under field conditions.

To further evaluate the fire resistance of ClosureTurf, Watershed Geo conducted tests using the *Standard Test Methods for Fire Tests of Roof Coverings* (ASTM E108). When exposed to flame as prescribed by the test conditions, some damage to ClosureTurf was observed in the form of melting of the engineered turf. The underside of the Super GripNet also displayed some effects from the fire. Despite the observed damages, the geomembrane component of the cover system was not breached by fire. Furthermore, the damaged area observed during the fire resistance test was confined and the fire didn't spread. Additional details on the setup and results of the fire resistance tests are provided in Appendix K.

10.5. Resistance to Lightning

ClosureTurf is not a conductor of electricity and therefore, is unlikely to be hit by lightning strikes. However, if lightning does strike the system and causes a fire, the damage is expected to be localized based on the observations during the fire resistance tests. Damage from lightning strikes can be repaired by patching the damaged geomembrane and engineered turf and replacing the aggregate infill.

10.6. Measures to Prevent Vandalism

Geosynthetic materials are susceptible to damage from vandalism. Although vandalism has not been observed at any ClosureTurf installation, it could potentially be vandalized, thereby affecting the performance of the system during the post-closure care period. Measures should be taken to prevent or discourage vandalism during the post-closure care period, which may include the following, as necessary:

- Use of a chain-link fence or other suitable fence along the property boundary;
- Posting of appropriate signs (e.g., no trespassing) on the fence at the entrance and within the property boundary; and/or
- Use of cameras, video surveillance, and/or motion sensors at key locations at the facility.

10.7. Post-Closure Care

Landfill post-closure care (e.g., final cover system maintenance) is required by the federal and state regulations for a minimum period of 30 years. ClosureTurf does not require significant maintenance activities in comparison to traditional soil cover systems, i.e., no mowing, fertilizing, revegetation, etc. However, regular inspection of ClosureTurf is still required to identify any damages or aggregate infill movement, followed by repairs, as necessary. The ClosureTurf Post-Closure Care Manual is available at Watershed Geo's online technical library.

10.8. Beneficial Use for Solar Development

Several landfills closed with ClosureTurf have been beneficially reused to develop solar fields for electricity generation. Compared with a traditional landfill soil cover system, the ClosureTurf system provides a stable foundation for a solar field for the following reasons:

- Less maintenance is required with ClosureTurf, which lowers the risk of damage to the solar panels from personnel and equipment.
- No vegetation overgrowth is present that may block sunlight and negatively impact power generation efficiency of the solar panels.
- Dust, which can lower the efficiency of a solar array, is less likely to be generated.
- Rainwater from the drip edge of solar panels is less likely to erode the cover system.

Watershed Geo has developed a patented solar power generation system, PowerCap™, specifically for installation on ClosureTurf. No penetrations through or mechanical connections to the ClosureTurf final cover system are required for this system. The system can be installed on landfill side slopes and top deck, maximizing power generation at the site.

More information on solar development can be found at Watershed Geo's website: https://watershedgeo.com/products/powercap/.

It should be noted that if future solar development is planned during the landfill closure, potential impact of the solar arrays on the final cover system (e.g., access roads, stormwater management, slope stability, final cover settlement, etc.) should be evaluated and incorporated into the landfill closure design.

11. References

ARC 2016. “2016 Edition of the Georgia Stormwater Management Manual.” Volume 2. Atlanta Regional Commission. February.

ASCE 2022. “Minimum Design Loads and Associated Criteria for Buildings and Other Structures.” (ASCE/SEI 7-22). American Society of Civil Engineers. Reston, Virginia.

Carlson, C.P., Zhu, M., and Ebrahimi, A. 2019. “Hydrologic Performance of Synthetic Turf Cover Systems and Their Equivalency to Prescriptive Cover Systems.” 2019 Geosynthetics Conference Proceedings, Houston, Texas, pp. 843–850.

Comer, A.I., Sculli, M.L., and Hsuan, Y.G. 1996. “Freeze-Thaw Cycling and Cold Temperature Effects on Geomembrane Sheets and Seams.” United States Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, Ohio. EPA/600/S-96/004

De Abreu, R.C. and Franklin, J. 2014. “Design and Installation of a Geosynthetic Final Cover Utilizing Artificial Turf in Louisiana.” *7th International Congress on Environmental Geotechnics 2014*. Melbourne, Australia, 10–14 November. pp. 1397–1404.

Dedrick, A.R. 1973. “Air Pressures Over Reservoir, Canal, and Water Catchment Surfaces Exposed to Wind.” Ph.D. diss., Utah State University.

FHWA 2006. “Hydraulic Design of Energy Dissipators for Culvers and Channels.” Circular Number 14 (HEC-14), Department of Transportation, Third Edition. July. Revised October 2021.

FHWA 2009. “Urban Drainage Design Manual.” Circular Number 22 (HEC-22), Department of Transportation, Third Edition. September. Revised August 2013.

Geosyntec Consultants 2015. “Literature Review and Assessment of ClosureTurf UV Longevity.” Letter Report Prepared by Geosyntec Consultants for Watershed Geo, 15 May 2015.

Geosyntec Consultants 2022. “Assessment of ClosureTurf UV Longevity.” Letter Report Prepared by Geosyntec Consultants for Watershed Geo, 22 November 2022.

Geosynthetics Research Institute (GRI) 2019. “Exposed Lifetime Prediction of Geosynthetics Using Laboratory Weathering Devices.” Folsom, Pennsylvania. August 19.

Giroud, J.P., Bachus, R.C., and Bonaparte R. 1995a. “Influence of Water Flow on the Stability of Geosynthetic-Soil Layered Systems on Slopes.” *Geosynthetics International* 2:6, pp. 1149–1180.

Giroud, J.P., Pelte, T., and Bathurst, R.J. 1995b. “Uplift of Geomembranes by Wind.” *Geosynthetics International* 2:6, pp. 897–952.

Giroud, J.P. and Zornberg, J.G. 1997. “Uplift of Geomembranes by Wind – Extension of Equations.” *Geosynthetics International* 4:2, pp. 187–207.

Gobla, M.J. 2014. “Design Standards No. 13 – Embankment Dams, Chapter 19: Geotextiles.” United States Department of Interior, Bureau of Reclamation, Washington D.C., USA.

GSI 2016. “Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes.” Rev. 14. Geosynthetic Institute, Folsom, Pennsylvania.

Joshi, R. 2023. “Environmental, Social, and Governance (ESG) Offerings of an Engineered Turf Final Cover System.” *In Proceedings of Geosynthetics 2023*, pp. 539 – 548.

Koerner, R.M., Husan, G.Y., and Koerner, G.R. 2011. “Geomembrane Lifetime Prediction: Unexposed and Exposed Conditions.” *GRI White Paper No. 6*, Geosynthetic Institute, Folsom, Pennsylvania.

Koerner, R.M. and Soong, T.Y. 1998. “Analysis and Design of Veneer Cover Soils.” *Sixth International Conference on Geosynthetics Conference Proceedings* 1:1–23.

Koerner, R.M., Wilson-Fahmy, R.R., and Narejo, D. 1997. “Puncture Protection of Geomembranes; Part III Examples,” *Geosynthetics International* 3:5, pp. 655-675.

Lutton, R.J., Regan, G.L., and Jones, L.W. 1979. *Design and Construction of Covers for Solid Waste Landfills.* United States Environmental Protection Agency, Office of Research and Development, Municipal Environmental Research Laboratory.

Matasovic, N. 1991. “Selection of Method for Seismic Slope Stability Analysis.” *Proceedings: Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics.* St. Louis, Missouri, March 11–15. Paper 7.20, pp. 1057–1062.

Narejo, D., Koerner, R.M., and Wilson-Fahmy, R.R. 1997. "Puncture Protection of Geomembranes; Part II Experimental," *Geosynthetics International* 3:5, pp. 629-653.

NOAA. 2022. Atlas 14 Point Precipitation Frequency Estimates. United States Department of Commerce, National Oceanic and Atmospheric Administration. https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html. Accessed in November 2022.

NRCS. 2010. "National Engineering Handbook." Part 630 Hydrology, United States Department of Agriculture, Natural Resources Conservation Division.

Scheirs, J. 2009. "Key Performance Properties of Geomembranes." In *A Guide to Polymetric Geomembranes: A Practical Approach.* Hoboken: Wiley

Scholl, B., Zhu, M., and Yuan, Z. 2023. "Engineered Turf Landfill Closure: How Long Will It Last?" In Proceedings of the Geosynthetics Conference 2023, pp. 143 – 151.

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

Schroeder, P.R., Dozier, T.S., Zappi, P.A., McEnroe, B.M., Sjostrom, J.W., and Peyton, R.L. 1994b. "The Hydrologic Evaluation of Landfill Performance (HELP) Model Engineering Documentation for Version 3." United States Environmental Protection Agency, Office of Research and Development, Washington, D.C. EPA/600/R-94/168b

Thiel, R.S. and Stewart, M.G. 1993. "Geosynthetic Landfill Cover Design Methodology and Construction Experience in the Pacific Northwest." *Geosynthetics 93 Conference Proceedings.* International Fabrics Association International. St. Paul, Minnesota, pp. 1131–1144.

Tolaymat, T. and Krause, M. 2020. "Hydrologic Evaluation of Landfill Performance (HELP) 4.0 User Manual." United States Environmental Protection Agency Office of Research and Development, Washington, D.C. EPA/600/B-20/2019

USBR 2014. "Design Standard No. 13 Embankment Dams, Chapter 20: Geomembranes." Phase 4 (Final). United States Bureau of Reclamation, Washington, D.C.

USEPA. 2005. “Landfill Gas Emissions Model (LandGEM).” United States Environmental Protection Agency, Washington, D.C. EPA/600/R-05/047

Watershed Geo. 2014. “Technical Submittal for ClosureTurf — Alternative Final Cover, Closure of Municipal Solid Waste Landfill Units.” December 2.

Wayne, M.H. and Koerner, R.M. 1988. “Effect of Wind Uplift on Liner Systems.” *Geotechnical Fabrics Report*, July/August.

Wilson-Fahmy, R.F., Narejo, D., and Koerner, R.M. 1997. “Puncture Protection of Geomembranes; Part I Theory,” *Geosynthetics International* 3:5, pp. 605-628.

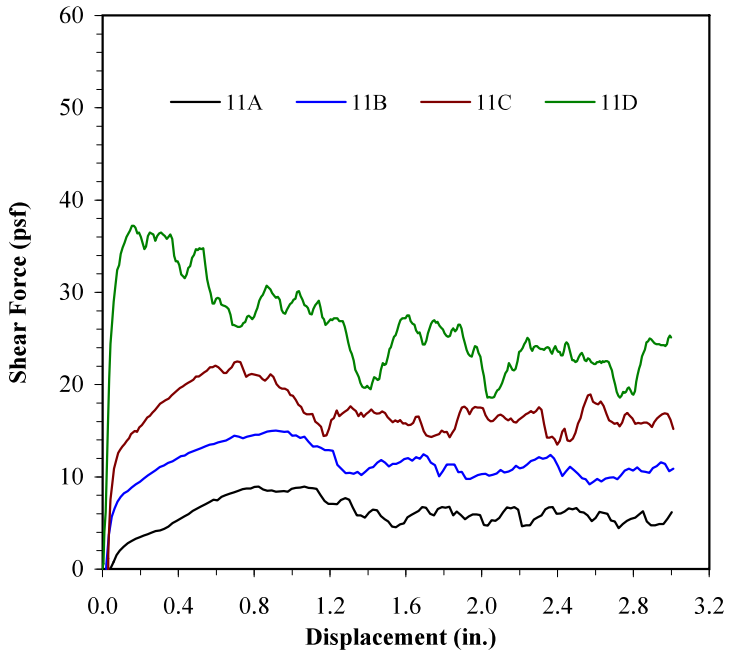
Appendix A
ClosureTurf Interface Shear Strength Test Results

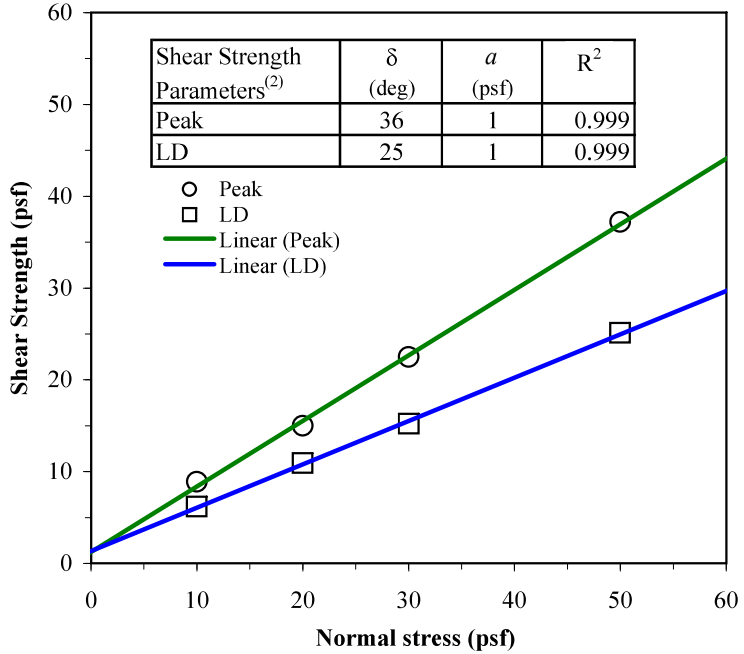
WATERSHED GEOSYNTHETICS LLC

INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
CT32 Synthetic Turf with base geotextile side down against
Agru 50-mil Super Gripnet LLDPE geomembrane with stud side up
Lower Shear Box: Concrete sand

Note: The CT turf is denoted as the "CT32 Synthetic Turf" in this test report.





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation		Lower Soil			Upper Soil			Soil Shear Strength		Shear Strengths		Failure Mode
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	γ_d (pcf)	ω_i (%)	ω_f (%)	ϕ (deg)	c (psf)	τ_P (psf)	τ_{LD} (psf)	
11A	12 x 12	10	0.04	10	24	-	-	-	-	-	-	-	-	-	-	8.9	6.2	(1)
11B	12 x 12	20	0.04	20	24	-	-	-	-	-	-	-	-	-	-	15.0	10.9	(1)
11C	12 x 12	30	0.04	30	24	-	-	-	-	-	-	-	-	-	-	22.5	15.2	(1)
11D	12 x 12	50	0.04	50	24	-	-	-	-	-	-	-	-	-	-	37.2	25.1	(1)

NOTES:
(1) Sliding (i.e., shear failure) occurred at the interface between the geotextile side of the turf and the stud side of Agru 50-mil Super Gripnet.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

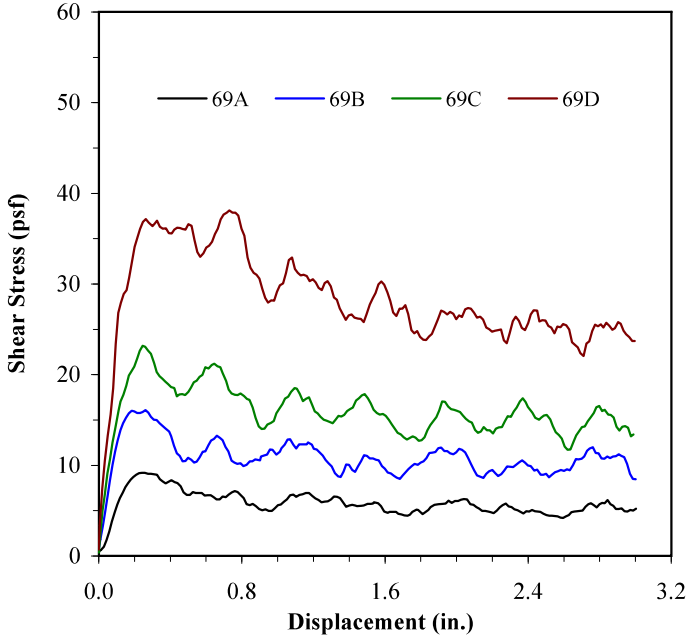
DATE OF TEST:	5/28/2019
FIGURE NO.	1
PROJECT NO.	SGI19014
DOCUMENT NO.	
FILE NO.	

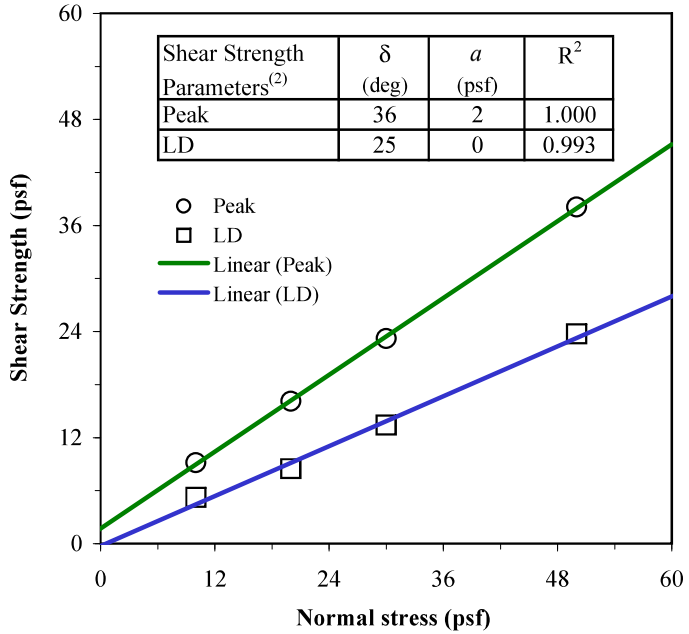
SGI TESTING SERVICES, LLC

WATERSHED GEOSYNTHETICS LLC
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
Synthetic turf CT-32 with base geotextile side down against
Agru 50-mil MicroDrain LLDPE geomembrane #GTA0127680003 with stud side up
Lower Shear Box: Concrete sand

Note: The CT turf is denoted as the "CT32 Synthetic Turf" in this test report.





Test No.	Shear Box Size (in x in)	Normal Stress (psf)	Shear Rate (in/min)	Soaking		Consolidation		Upper Soil			Lower Soil			GCL		Shear Strength		Secant Angle		Failure Mode
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	γ_d (pcf)	ω_i (%)	ω_f (%)	ω_i (%)	ω_f (%)	τ_P (psf)	τ_{LD} (psf)	δ_P (deg)	δ_{LD} (deg)	
69A	12 x 12	10	0.04	-	-	-	-	-	-	-	-	-	-	-	-	9.2	5.2	43	28	(1)
69B	12 x 12	20	0.04	-	-	-	-	-	-	-	-	-	-	-	-	16.1	8.5	39	23	(1)
69C	12 x 12	30	0.04	-	-	-	-	-	-	-	-	-	-	-	-	23.2	13.4	38	24	(1)
69D	12 x 12	50	0.04	-	-	-	-	-	-	-	-	-	-	-	-	38.1	23.7	37	25	(1)

NOTES:
(1) Sliding (i.e., shear failure) forced to occurr at the interface between the bsae geotextile side of synthetic turf and the stud side of geomembrane.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test .

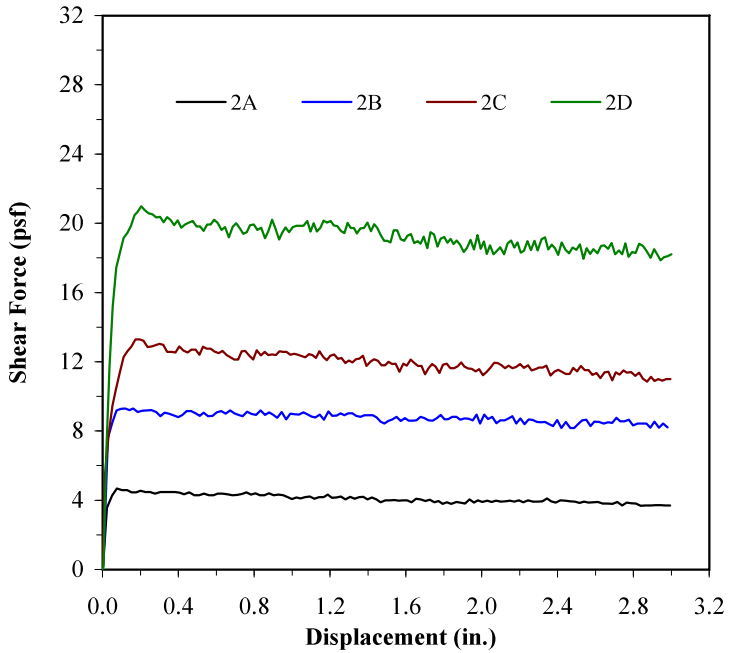
SGI TESTING SERVICES, LLC

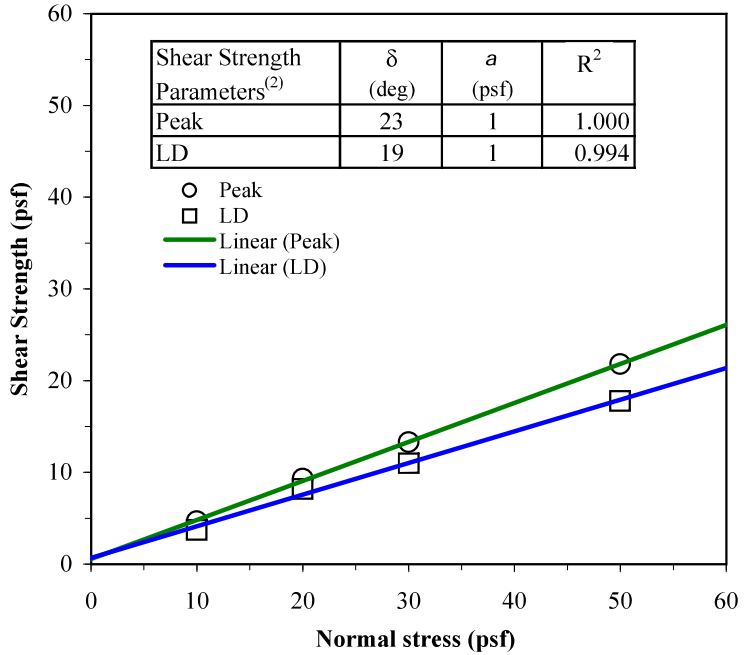
DATE OF REPORT:	12/27/2023
FIGURE NO.	1
PROJECT NO.	SGI23014
DOCUMENT NO.	
FILE NO.	

WATERSHED GEOSYNTHETICS LLC
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
CT32 Synthetic Turf with base geotextile side down against
Agru 40-mil Microspike LLDPE geomembrane with dull side up
Lower Shear Box: Concrete sand

Note: The CT turf is denoted as the "CT32 Synthetic Turf" in this test report.





Shear Strength Parameters[2]	δ (deg)	a (psf)	R^2
Peak	23	1	1.000
LD	19	1	0.994

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation		Lower Soil			Upper Soil			Soil Shear Strength		Shear Strengths		Failure Mode
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	γ_d (pcf)	ω_i (%)	ω_f (%)	ϕ (deg)	c (psf)	τ_P (psf)	τ_{LD} (psf)	
2A	12 x 12	10	0.04	10	24	-	-	-	-	-	-	-	-	-	-	4.7	3.7	(1)
2B	12 x 12	20	0.04	20	24	-	-	-	-	-	-	-	-	-	-	9.3	8.2	(1)
2C	12 x 12	30	0.04	30	24	-	-	-	-	-	-	-	-	-	-	13.3	11.0	(1)
2D	12 x 12	50	0.04	50	24	-	-	-	-	-	-	-	-	-	-	21.8	17.8	(1)

NOTES:
(1) Sliding (i.e., shear failure) occurred at the interface between the geotextile side of heavy closure turf and the dull side of agru 40-mil microspike LLDPE geomembrane.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

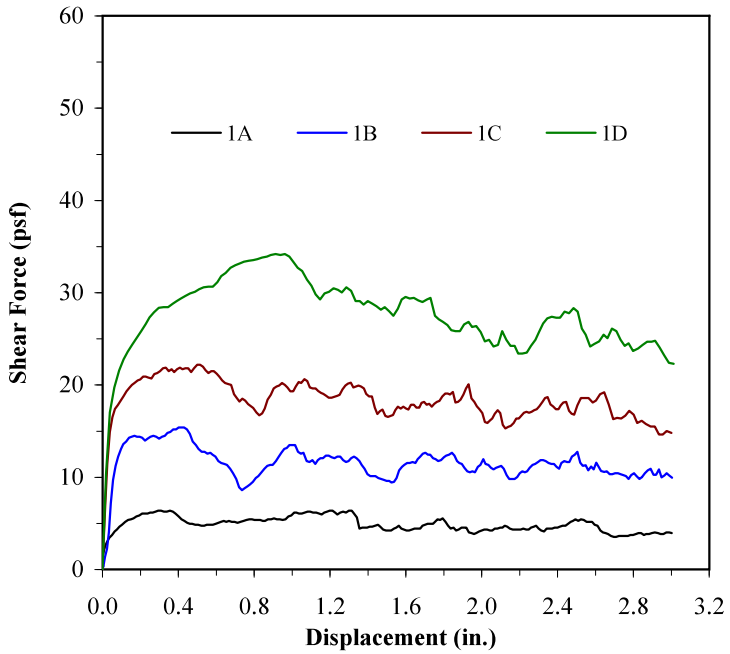
DATE OF TEST:	5/6/2019
FIGURE NO.	1
PROJECT NO.	SGI19014
DOCUMENT NO.	
FILE NO.	

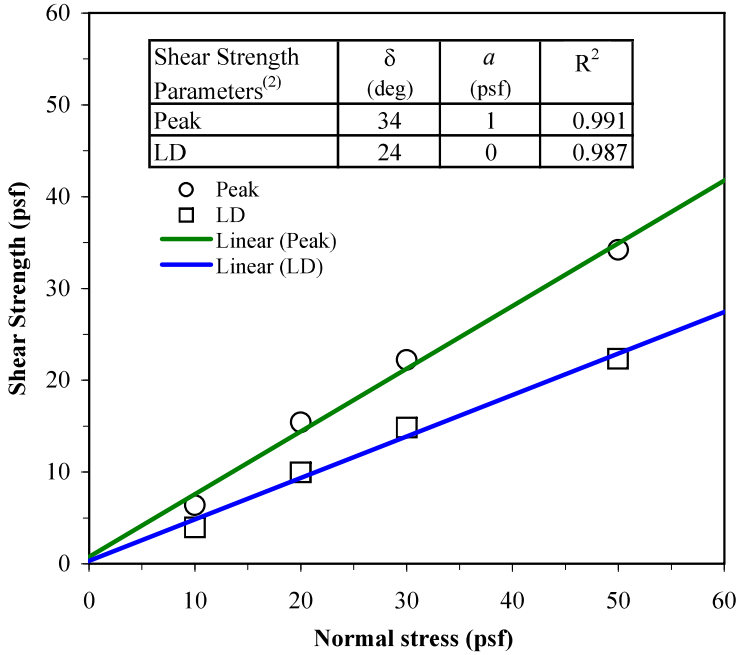
SGI TESTING SERVICES, LLC

WATERSHED GEOSYNTHETICS LLC
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand /
New ClosureTurf with geotextile side down /
Agru 50-mil SuperGripnet with studs side up /
Lower Shear Box: Concrete sand

Note: The CT HD turf is denoted as the "New ClosureTurf" in this test report.





Shear Strength Parameters[2]	δ (deg)	*a* (psf)	R^2
Peak	34	1	0.991
LD	24	0	0.987

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Lower Soil γ_d (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	Upper Soil γ_d (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	Soil Shear Strength ϕ (deg)	Soil Shear Strength c (psf)	Shear Strengths τ_P (psf)	Shear Strengths τ_{LD} (psf)	Failure Mode
1A	12 x 12	10	0.04					-	-	-						6.4	3.9	(1)
1B	12 x 12	20	0.04					-	-	-						15.4	9.9	(1)
1C	12 x 12	30	0.04					-	-	-						22.2	14.8	(1)
1D	12 x 12	50	0.04					-	-	-						34.2	22.3	(1)

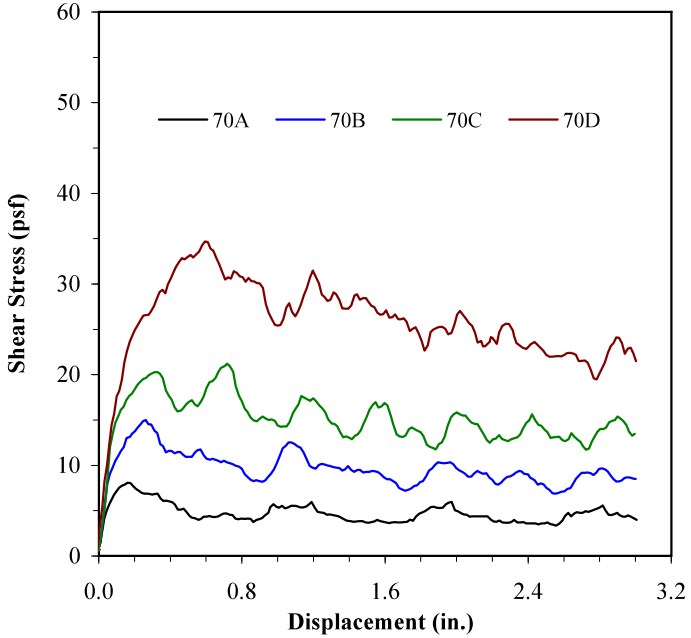
NOTES:
(1) Sliding (i.e., shear failure) occurred at the interface between the base geotextile of ClosureTurf and studs side of Agru SuperGripnet geomembrane.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

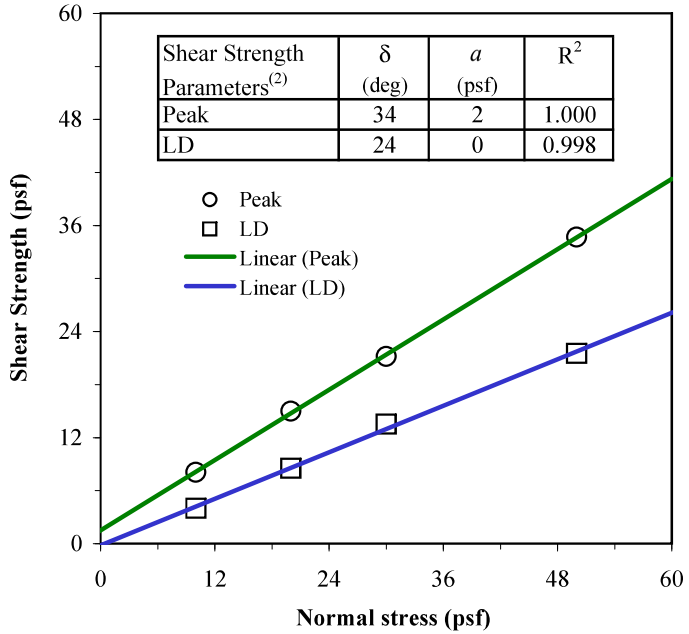
SGI TESTING SERVICES, LLC

DATE OF TEST:	6/7/2018
FIGURE NO.	1
PROJECT NO.	SGI18014
DOCUMENT NO.	
FILE NO.	

WATERSHED GEOSYNTHETICS LLC
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
Synthetic turf CT-HD (CT43) with base geotextile side down against
Agru 50-mil MicroDrain LLDPE geomembrane #GTA0127680003 with stud side up
Lower Shear Box: Concrete sand





Test No.	Shear Box Size (in x in)	Normal Stress (psf)	Shear Rate (in/min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Upper Soil γ_d (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	Lower Soil γ_d (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Strength τ_P (psf)	Shear Strength τ_{LD} (psf)	Secant Angle δ_P (deg)	Secant Angle δ_{LD} (deg)	Failure Mode
70A	12 x 12	10	0.04	-	-	-	-	-	-	-	-	-	-	-	-	8.1	4.0	39	22	(1)
70B	12 x 12	20	0.04	-	-	-	-	-	-	-	-	-	-	-	-	15.0	8.5	37	23	(1)
70C	12 x 12	30	0.04	-	-	-	-	-	-	-	-	-	-	-	-	21.2	13.5	35	24	(1)
70D	12 x 12	50	0.04	-	-	-	-	-	-	-	-	-	-	-	-	34.7	21.5	35	23	(1)

NOTES:
(1) Sliding (i.e., shear failure) forced to occurr at the interface between the bsae geotextile side of Synthetic turf and the stud side of geomembrane.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test .

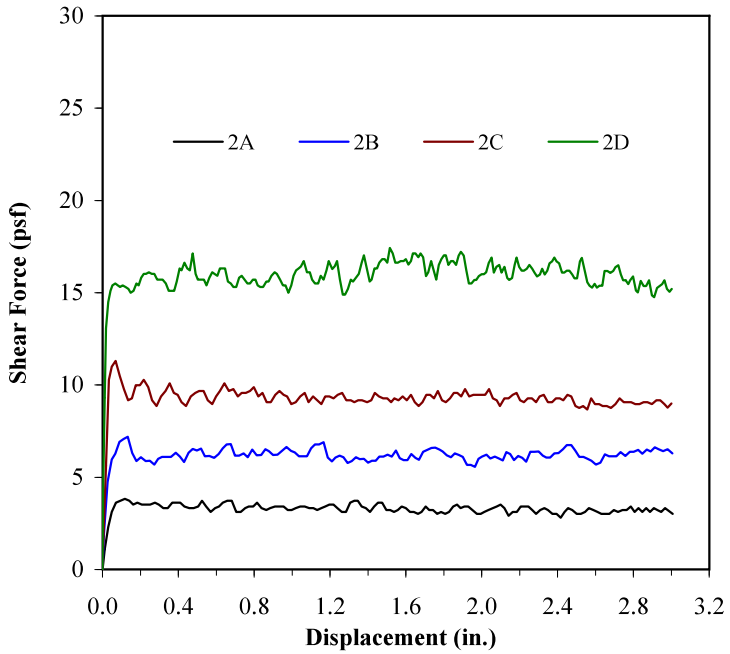
SGI TESTING SERVICES, LLC

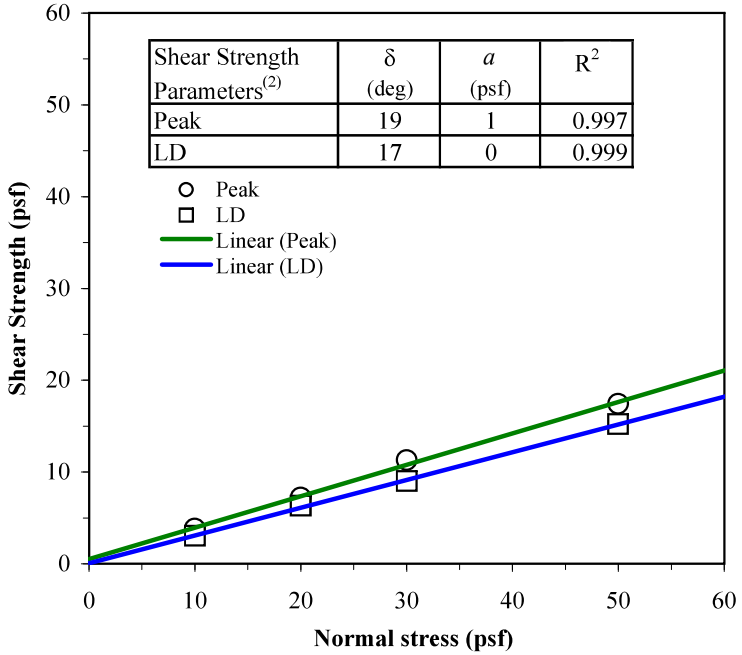
DATE OF REPORT:	12/27/2023
FIGURE NO.	2
PROJECT NO.	SGI23014
DOCUMENT NO.	
FILE NO.	

WATERSHED GEOSYNTHETICS LLC
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand/
New ClosureTurf with geotextile side down /
Agru 40-mil Microspike HDPE geomembrane with dull side up and shiny side down/
Lower Shear Box: Concrete sand

Note: The CT HD turf is denoted as the "New ClosureTurf" in this test report.





Shear Strength Parameters[2]	δ (deg)	*a* (psf)	R^2
Peak	19	1	0.997
LD	17	0	0.999

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Lower Soil γ_d (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	Upper Soil γ_d (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	Soil Shear Strength ϕ (deg)	Soil Shear Strength c (psf)	Shear Strengths τ_P (psf)	Shear Strengths τ_{LD} (psf)	Failure Mode
2A	12 x 12	10	0.04					-	-	-						3.8	3.0	(1)
2B	12 x 12	20	0.04					-	-	-						7.2	6.3	(1)
2C	12 x 12	30	0.04					-	-	-						11.3	9.0	(1)
2D	12 x 12	50	0.04					-	-	-						17.4	15.2	(1)

NOTES:
(1) Sliding (i.e., shear failure) occurred at the interface between the base geotextile of ClosureTurf and dull side of Agru Microspike HDPE geomembrane.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

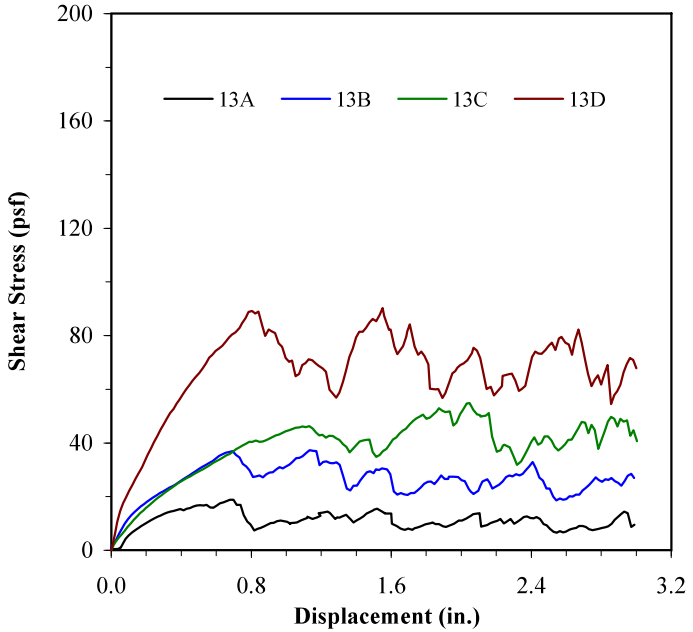
SGI TESTING SERVICES, LLC

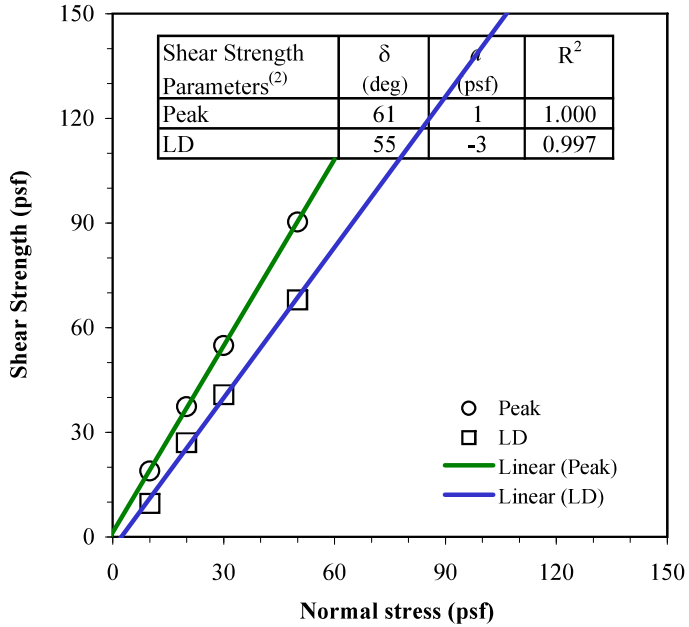
DATE OF TEST:	6/28/2018
FIGURE NO.	2
PROJECT NO.	SGI18014
DOCUMENT NO.	
FILE NO.	

WATERSHED GEOSYNTHETICS LLC
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
100% Vv stitch turf with approximately a 0.5" thick sand layer on top and base geotextile side down against Agru 50-mil Super Gripnet LLDPE geomembrane with stud side up
Lower Shear Box: Concrete sand

Note: The CT HF turf is denoted as the "Vv stitch turf" in this test report.





Test No.	Shear Box Size (in x in)	Normal Stress (psf)	Shear Rate (in/min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Upper Soil γ_d (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	Target Soil Compaction γ_d (pcf)	Target Soil Compaction ω_i (%)	Target Soil Compaction ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Strength τ_P (psf)	Shear Strength τ_{LD} (psf)	Secant Angle δ_P (deg)	Secant Angle δ_{LD} (deg)	Failure Mode
13A	12 x 12	10	0.04	-	-	-	-	-	-	-	-	-	-	-	-	18.9	9.5	62	44	(1)
13B	12 x 12	20	0.04	-	-	-	-	-	-	-	-	-	-	-	-	37.3	27.0	62	53	(1)
13C	12 x 12	30	0.04	-	-	-	-	-	-	-	-	-	-	-	-	54.9	40.7	61	54	(1)
13D	12 x 12	50	0.04	-	-	-	-	-	-	-	-	-	-	-	-	90.3	67.9	61	54	(1)

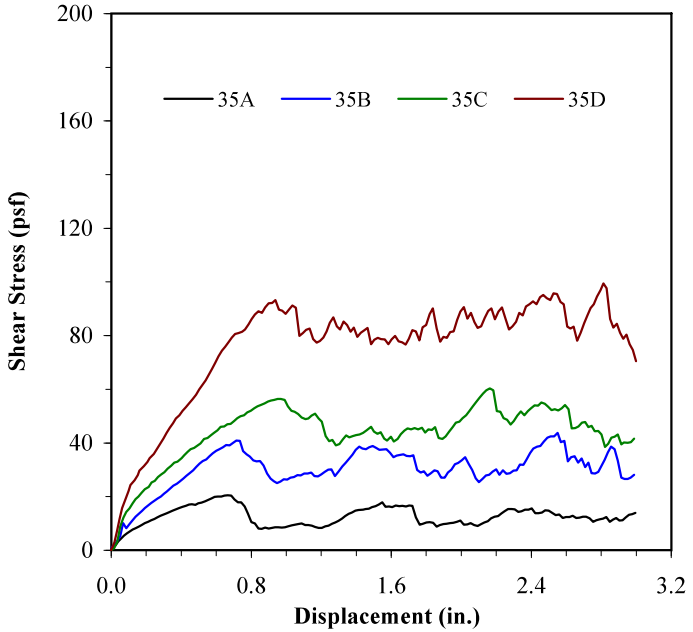
NOTES:
(1) Sliding (i.e., shear failure) forced to occurr at the interface between the base geotextile side of Synthetic turf and the stud side of Super Gripnet geomembrane.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test .

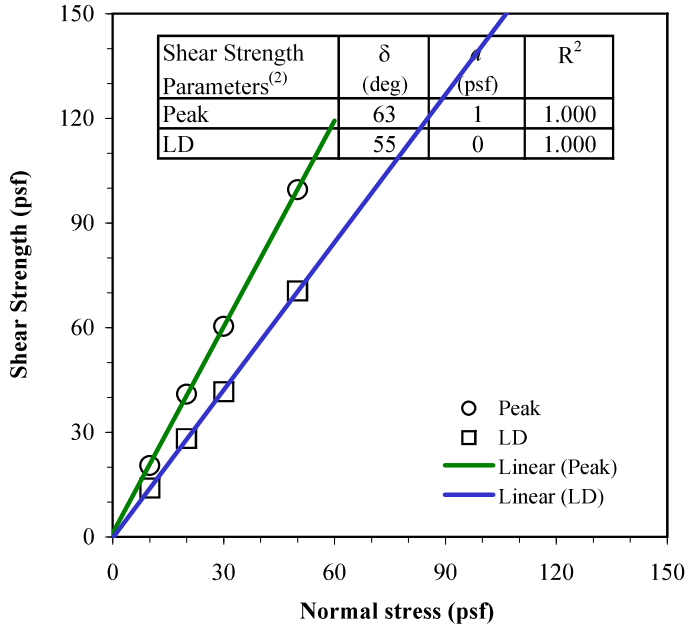
SGI TESTING SERVICES, LLC

DATE OF REPORT:	3/20/2024
FIGURE NO.	3
PROJECT NO.	SGI24014
DOCUMENT NO.	
FILE NO.	

WATERSHED GEOSYNTHETICS LLC
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
CT-HF turf with approximately a 0.5" thick sand layer on top and base geotextile side down against
Agru 50-mil MicroDrain LLDPE geomembrane #GTA0127680003 with stud side up
Lower Shear Box: Concrete sand





Test No.	Shear Box Size (in x in)	Normal Stress (psf)	Shear Rate (in/min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Upper Soil γ_d (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	Target Soil Compaction γ_d (pcf)	Target Soil Compaction ω_i (%)	Target Soil Compaction ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Strength τ_P (psf)	Shear Strength τ_{LD} (psf)	Secant Angle δ_P (deg)	Secant Angle δ_{LD} (deg)	Failure Mode
35A	12 x 12	10	0.04	-	-	-	-	-	-	-	-	-	-	-	-	20.5	13.9	64	54	(1)
35B	12 x 12	20	0.04	-	-	-	-	-	-	-	-	-	-	-	-	40.9	28.2	64	55	(1)
35C	12 x 12	30	0.04	-	-	-	-	-	-	-	-	-	-	-	-	60.4	41.6	64	54	(1)
35D	12 x 12	50	0.04	-	-	-	-	-	-	-	-	-	-	-	-	99.5	70.5	63	55	(1)

NOTES:
(1) Sliding (i.e., shear failure) forced to occurr at the interface between the base geotextile side of Synthetic turf and the stud side of MicroDrain geomembrane.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test .

SGI TESTING SERVICES, LLC

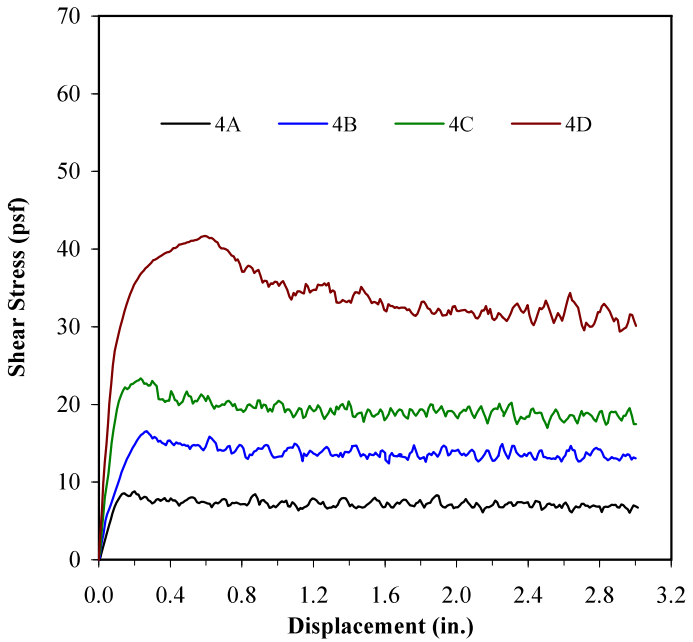
DATE OF REPORT:	3/28/2024
FIGURE NO.	1
PROJECT NO.	SGI24014
DOCUMENT NO.	
FILE NO.	

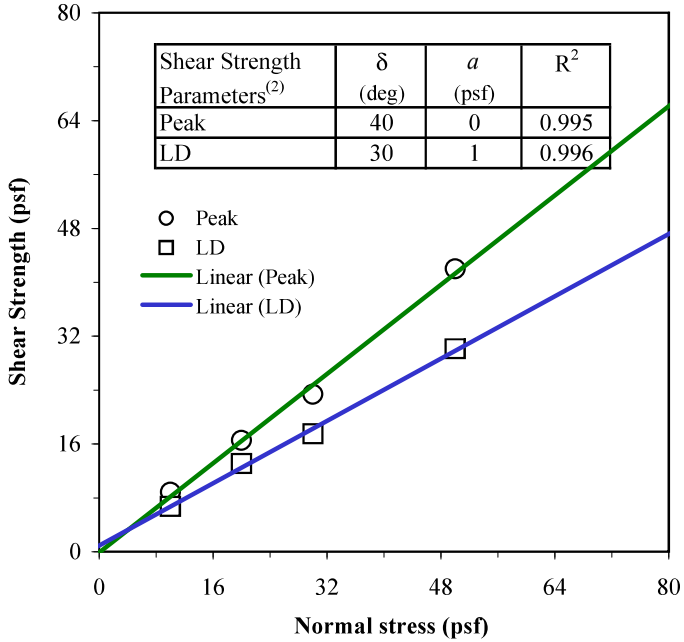
WATERSHED GEOSYNTHETICS LLC

INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
Synthetic turf (VV Stitch) with base GT side down against
Agru 40-mil Microspike LLDPE GM with dull side up (shear in the weak direction)
Lower Shear Box: Concrete sand

Note: The CT HF turf is denoted as the "Synthetic Turf (VV Stitch)" in this test report.





Shear Strength Parameters[2]	δ (deg)	*a* (psf)	R^2
Peak	40	0	0.995
LD	30	1	0.996

Test No.	Shear Box Size (in x in)	Normal Stress (psf)	Shear Rate (in/min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Upper Soil γ_d (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	Lower Soil γ_d (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Strength[2] τ_P (psf)	Shear Strength[2] τ_{LD} (psf)	Secant Angle δ_P (deg)	Secant Angle δ_{LD} (deg)	Failure Mode
4A	12 x 12	10	0.04	-	-	-	-	-	-	-	-	-	-	-	-	8.8	6.7	41.4	33.8	(1)
4B	12 x 12	20	0.04	-	-	-	-	-	-	-	-	-	-	-	-	16.6	13.1	39.6	33.2	(1)
4C	12 x 12	30	0.04	-	-	-	-	-	-	-	-	-	-	-	-	23.4	17.5	37.9	30.2	(1)
4D	12 x 12	50	0.04	-	-	-	-	-	-	-	-	-	-	-	-	42.0	30.1	40.0	31.0	(1)

NOTES:
(1) Sliding (i.e., shear failure) occurred at the interface between the base geotextile of synthetic turf and the dull side of microspike geomembrane.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test .

DATE OF REPORT: 3/30/2021

SGI TESTING SERVICES, LLC

FIGURE NO.	2
PROJECT NO.	SGI21014
DOCUMENT NO.	
FILE NO.	

Appendix B
Example Calculation for ClosureTurf Veneer Slope Stability

EXAMPLE CALCULATION FOR CLOSURETURF VENEER SLOPE STABILITY

PURPOSE

This example calculation evaluates the veneer stability of a ClosureTurf installed as a final cover system for a hypothetical landfill. The analysis presented herein is based on the procedure presented in Chapter 9 of the document titled "*Geotechnical and Stability Analyses for Ohio Waste Containment Facilities"* published by the State of Ohio Environmental Protection Agency (OEPA 2004).

It is noted that the approaches presented in this appendix are for reference purposes. The design engineer may choose other commonly accepted approaches to evaluate the veneer slope stability of ClosureTurf.

METHODOLOGY

Static and Seismic Veneer Slope Stability

Slope stability of a final cover system can be evaluated based on infinite slope or finite slope methods. The infinite slope method considers an infinite slope length whereby driving and resisting forces occur only parallel to an interface (i.e., slip plane). The finite slope method considers a slope of finite length and additionally accounts for the toe-buttressing effect. For this example calculation, static and seismic slope stability analyses of the ClosureTurf system is performed using an infinite slope method developed by Matasovic (1991). This method was selected because of the simplicity of its equation.

$$FS = \frac{\dfrac{a}{\gamma_c\, z_c\, cos^2\beta} + \tan\delta\,\left(1 - \dfrac{\gamma_w\,(z_c - d_w)}{\gamma_c\, z_c}\right) - k_s \tan\beta \tan\delta}{k_s + \tan\beta}$$

where:

FS	=	factor of safety;
β	=	slope inclination angle;
δ	=	friction angle along the critical slip surface;
a	=	adhesion intercept along the critical slip surface;
z_c	=	depth of the critical slip surface measured from the top of final cover (i.e., thickness of aggregate infill);
γ_c	=	unit weight of aggregate infill;
γ_w	=	unit weight of water = 62.4 pcf;
d_w	=	depth to water surface measured from the top of final cover (i.e., $z_c - h_{avg}$); and
k_s	=	seismic coefficient.

Target Factors of Safety

Target factors of safety of 1.5, 1.3, and 1.0 for long-term static, temporary static, and seismic conditions, respectively, are typically considered for veneer stability of a landfill final cover system. However, the design engineer should select the appropriate target factors of safety in accordance with project requirements, standard engineering practices, and/or regulatory requirements, as applicable.

Hydraulic Head on Geomembrane

The average hydraulic head acting on the geomembrane is computed using equations presented in OEPA (2004). These equations are:

$$h_{avg} = \frac{P\,(1 - RC)L\,(\cos\beta)}{k_d\,(sin\,\beta)}$$

or if $P\,(1 - RC) > k_c$, use:

$$h_{avg} = \frac{k_c\,L\,(\cos\beta)}{k_d\,(sin\,\beta)}$$

or if h_{avg} from the above calculation is greater than T_d then use: $h_{avg} = T_d + T_c$

Where:

h_{avg}	=	average hydraulic head;
P	=	precipitation;
β	=	slope inclination angle;
L	=	slope length;
T_c	=	thickness of cover soil (i.e., aggregate infill);
RC	=	runoff coefficient (SCS Runoff Curve Number/100);
k_d	=	hydraulic conductivity of drainage layer;
T_d	=	thickness of drainage layer; and
k_c	=	hydraulic conductivity of cover soil (i.e., aggregate infill).

Selection of Seismic Coefficient

The seismic coefficient (k_s) represents the seismic loading as a static horizontal destabilizing force within the pseudo-static framework. It should correspond to a design seismic hazard level satisfying regulatory seismic requirements and/or project design criteria (e.g., two percent probability of exceedance in 50 years for a landfill design). An appropriate seismic coefficient can be selected by following either a commonly accepted simplified procedure (e.g., Chapter 4 of Richardson et al. [1995] or Bray et al. [1998]) or a more technically robust procedure (e.g., using site-specific ground response analyses), as determined by the project design engineer. Note that for

veneer stability of a landfill final cover, the seismic coefficient should be estimated at the final cover, which accounts for local site effects and wave propagation through waste.

Veneer Slope Stability with Equipment Load

Slope stability of the ClosureTurf system with equipment load can be evaluated using a similar approach (i.e., infinite slope method) as presented above. The weights of the ClosureTurf system and equipment as well as a dynamic load from equipment acceleration or deceleration act as driving forces, while the adhesive and frictional interface shear strengths of the ClosureTurf system provide resisting forces. The factor of safety is calculated as the ratio of the resisting forces to the driving forces:

$$FS_{equip} = \frac{F_a + F_r}{(W_s + W_v) \cdot \sin(\beta) + F_d}$$

where:

F_a = adhesive resistance along the critical slip surface;
F_r = frictional resistance along the critical slip surface;
F_d = dynamic equipment force along the slope surface;
W_s = weight of ClosureTurf;
W_v = weight of equipment; and
β = slope inclination angle.

The adhesive and frictional resistances of the ClosureTurf system interfaces are calculated using the following equations, respectively.

$$F_a = b \cdot l \cdot a$$

$$F_r = (W_s + W_v) \cdot \cos(\beta) \cdot \tan(\delta)$$

where:

b = equipment contact width;
l = equipment contact length;
a = interface adhesion intercept along the critical slip surface;
β = slope inclination angle; and
δ = interface friction angle along the critical slip surface.

The dynamic equipment force (F_d) can be calculated using the following equation:

$$F_d = m \cdot \frac{v}{t}$$

where:

m = equipment mass;
v = equipment velocity; and
t = duration of acceleration/deceleration.

INPUT PARAMETERS AND ANALYSIS ASSUMPTIONS

Veneer stability analyses are performed for a slope that is considered the longest and steepest of the design grades of the landfill final cover system. For the purpose of this example, the following input parameters were assumed:

Slope Geometry [1]

Slope inclination angle, β = 18.43° (i.e., 3 horizontal to 1 vertical)

Slope maximum height, H = 63 ft

Slope Length, L = 63/sin 18.43° ≅ 200 ft = 6,096 cm

ClosureTurf

Aggregate infill thickness, z_c = 0.5 in

Total unit weight of aggregate infill, γ_c = 115 pcf

Critical interface friction angle, δ = 36° (see Attachment B-1)[2]

Critical interface adhesion intercept, a = 0 psf

Runoff curve number (CN): varies from 91 to 96 - a value of 95 was selected (Attachment B-2)

Drainage stud height, T_d = 3.3 mm (see Attachment B-3)

Transmissivity, θ = 3.86 x 10^{-3} m^2/sec (see Attachment B-4)

Precipitation Data [3]

Precipitation, P = 4.34 in/hour (or 11.02 cm/3600 sec = 3.06 x 10^{-3} cm/sec)

Seismic Parameters

Estimated maximum acceleration at the base of landfill = 0.10g

Equipment Parameters

Equipment weight = 8,000 lb

Equipment mass = 8,000 lb/32.2 ft/sec^2 = 248 lb/ft/sec^2

Equipment velocity = 10 miles per hour = 14.7 ft/sec

Deceleration time = 2 sec

---

[1] Slope geometry is typically obtained from the final cover system grading plan.

[2] For this example, it is assumed that the critical interface is between the CT turf and Super GripNet geomembrane. Interface shear test should be performed between the geomembrane and site-specific subgrade soils to assess the critical interface.

[3] In the Ohio EPA Procedure, the 100-yr, 1-hr storm was used to calculate the head on the interface for final slopes under the saturated static conditions.

CALCULATIONS AND RESULTS

Calculate the hydraulic head on the geomembrane

Step 1 - Calculate the Long-term Transmissivity of the ClosureTurf® Drainage Layer

$$\theta_L = \frac{\theta}{FS_I \text{ x } FS_{Cr} \text{ x } FS_{CC} \text{x } FS_B \text{ x } FS_S}$$

θ_L = long-term transmissivity;
θ = tested transmissivity;
FS_I = reduction factor to account for intrusion;
FS_{Cr} = reduction factor to account for creep;
FS_{CC} = reduction factor to account for chemical clogging;
FS_B = reduction factor to account for biological clogging; and
FS_S = reduction factor to account for clogging due to infiltration of fines.

A reduction factor FS_s of 4.0 was considered to account for potential clogging due to infiltration of fines[4]. The other reduction factors are not considered to be applicable to ClosureTurf and therefore, were assumed to be 1.0.

$$\theta_L = \frac{3.86 \text{ x } 10^{-3}}{1.0 \text{ x } 1.0 \text{ x } 1.0 \text{ x } 1.0 \text{ x } 4.0} = 9.65 \text{ x } 10^{-4} \ m^2/\text{sec} = 9.65 \ cm^2/\text{sec}$$

Step 2 - Convert the Transmissivity to Hydraulic Conductivity

$$k_d = \frac{\theta_L}{T_d} = \frac{9.65}{0.33} = 29.24 \ cm/sec$$

Step 3 – Calculate the Average Hydraulic Head

Check if $P(1\text{-}RC) > k_c$

$$P(1\text{-}RC) = 3.06 \text{ x } 10^{-3} \text{ x } (1 - 95/100) = 1.53 \text{ x } 10^{-4} \text{ cm/sec}$$

This value is less than the permeability of the aggregate infill, which has a typical permeability in the order of 10^{-2} cm/sec. Therefore, the following equation is used to calculate the hydraulic head:

[4] The reduction factor of 4.0 is considered for typical soil-geosynthetic cover and is conservative for ClosureTurf as there is no soil layer on top that could clog the internal drainage layer.

$$h_{avg} = \frac{P\,(1 - RC)\ \times\ L\,(\cos\beta)}{k_d(\sin\beta)} = \frac{1.53\ \times\ 10^{-4}\ \times\ 6{,}096\ \times\ (\cos 18.43^o)}{29.24\ \times\ (\sin 18.43^o)} = 0.096\ cm = 0.038\ in$$

The calculated hydraulic head is less than the thickness of the internal drainage layer (T_d), which is 0.33 cm.

Step 2 – Calculate the static and seismic FS

Depth to water surface, $d_w = z_c - h_{avg} = 0.5 - 0.038 = 0.462$ *inch*

Static Veneer Slope Stability

$$FS_{Static} = \frac{0 + \tan 36^o\ \left(1 - \frac{62.4\ (0.5 - 0.462)}{115\ \times\ 0.5}\right) - 0}{0 + \tan 18.43^o} = 2.1$$

Seismic Veneer Slope Stability

The seismic coefficient at the final cover should be used for the veneer stability analysis of ClosureTurf. In this example, the seismic coefficient is estimated using Figure B.1 (Attachment B-5) for simplicity. Using the estimated maximum acceleration at the base of landfill (the input parameter in this example) and assuming that the seismic behavior of this example landfill is similar to that with 100 ft of waste shown in Figure B.1, the seismic coefficient at the final cover surface is estimated to be 0.14g. The factor of safety of the veneer stability of ClosureTurf under seismic loading is calculated as:

$$FS_{Seismic} = \frac{0 + \tan 36^o\ \left(1 - \frac{62.4\ (0.5 - 0.462)}{115\ \times 0.5}\right) - 0.14\ \times \tan 18.43^o \times \tan 36^o}{0.14 + \tan 18.43^o} = 1.4$$

Veneer Slope Stability for ClosureTurf with Equipment Load

The following was assumed in the evaluation of slope stability for ClosureTurf with equipment load:

- No hydraulic head (i.e., equipment operation during dry weather)
- No seismic load.

The frictional resistance (F_r) and dynamic equipment load (F_d) are calculated as follows.

$$F_r \approx 8{,}000\ \times \cos 18.43^o\ \times \tan 36^o\ = 5{,}514\ \text{lb}$$

$$F_d = m \cdot \frac{v}{t} = 248 \times \frac{14.7}{2} = 1{,}823\ \text{lb}$$

Note that the weight of ClosureTurf (less than one percent of the equipment load) was ignored for simplicity. Then the factor of safety is calculated as:

$$FS_{equip} = \frac{F_a + F_r}{(W_s + W_v) \cdot \sin(\beta) + F_d} = \frac{0 + 5{,}514}{(8{,}000) \times \sin 18.43^o + 1{,}823} = 1.3$$

Note that the above calculation is to evaluate the effect of a dynamic equipment force on the veneer slope stability of the ClosureTurf final cover. The effect of equipment load on bearing capacity and settlement of the final cover subgrade should be evaluated separately by the project design engineer, as necessary.

SUMMARY AND CONCLUSIONS

The factor of safety for veneer stability was calculated for a landfill with a 3 horizontal to 1 vertical (3H:1V) slope, a typical slope for a municipal solid waste landfill. The computed factors of safety are equal to or greater than the target factors of safety of 1.5, 1.3, and 1.0 for long-term static, temporary static, and seismic conditions, respectively.

REFERENCES

Bray, J.D., Rathje, E.M., Augello, A.J., and Merry S.M. (1998), "Simplified Seismic Design Procedure for Geosynthetic-Lined, Solid-Waste Landfills."

Matasovic, N. (1991). "Selection of Method for Seismic Slope Stability Analysis," Proc. of the 2nd International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics (2), St. Louis, MO, pp. 1057-1062.

Ohio Environmental Protection Agency (OEPA) (2004), "Geotechnical and Stability Analyses for Ohio Waste Containment Facilities", Geotechnical Resource Group, September 14, 2004.

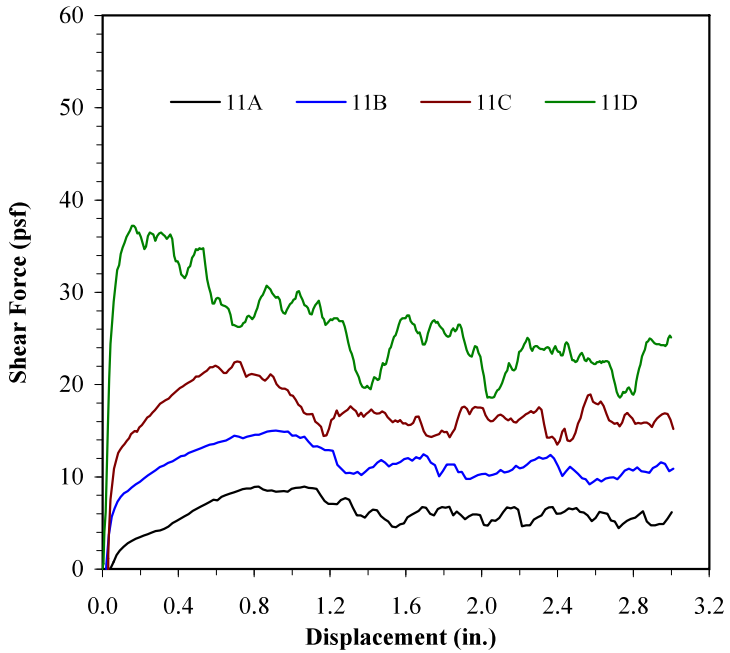
Richardson, G., Kavazanjian, E., and Matasovic, N. (1995). "RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities," US EPA Contract No. 68-C3-0315.

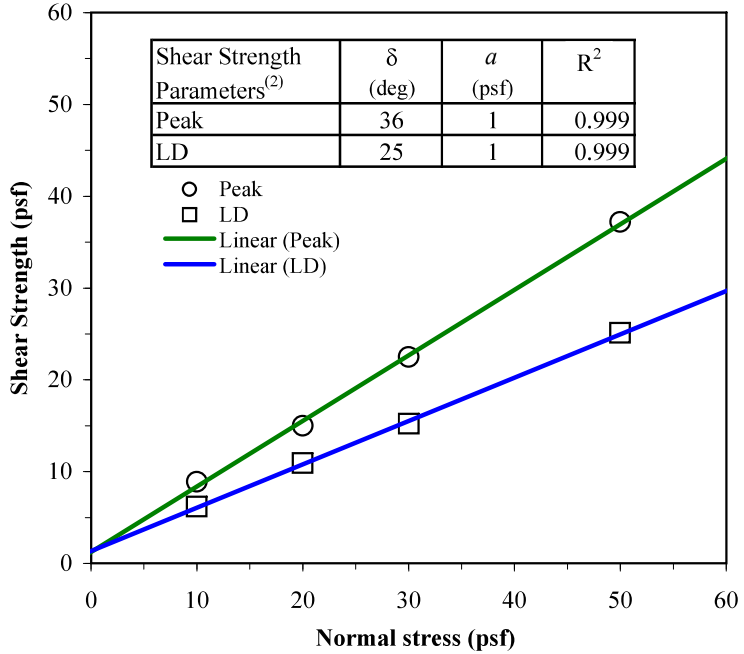
Attachment B-1
ClosureTurf Interface Shear Strength Test Report

WATERSHED GEOSYNTHETICS LLC
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
CT32 Synthetic Turf with base geotextile side down against
Agru 50-mil Super Gripnet LLDPE geomembrane with stud side up
Lower Shear Box: Concrete sand

Note: The CT turf is denoted as the "CT32 Synthetic Turf" in this test report.





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation		Lower Soil			Upper Soil			Soil Shear Strength		Shear Strengths		Failure Mode
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	γ_d (pcf)	ω_i (%)	ω_f (%)	ϕ (deg)	c (psf)	τ_P (psf)	τ_{LD} (psf)	
11A	12 x 12	10	0.04	10	24	-	-	-	-	-	-	-	-	-	-	8.9	6.2	(1)
11B	12 x 12	20	0.04	20	24	-	-	-	-	-	-	-	-	-	-	15.0	10.9	(1)
11C	12 x 12	30	0.04	30	24	-	-	-	-	-	-	-	-	-	-	22.5	15.2	(1)
11D	12 x 12	50	0.04	50	24	-	-	-	-	-	-	-	-	-	-	37.2	25.1	(1)

NOTES:
(1) Sliding (i.e., shear failure) occurred at the interface between the geotextile side of the turf and the stud side of Agru 50-mil Super Gripnet.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

DATE OF TEST:	5/28/2019
FIGURE NO.	1
PROJECT NO.	SGI19014
DOCUMENT NO.	
FILE NO.	

SGI TESTING SERVICES, LLC

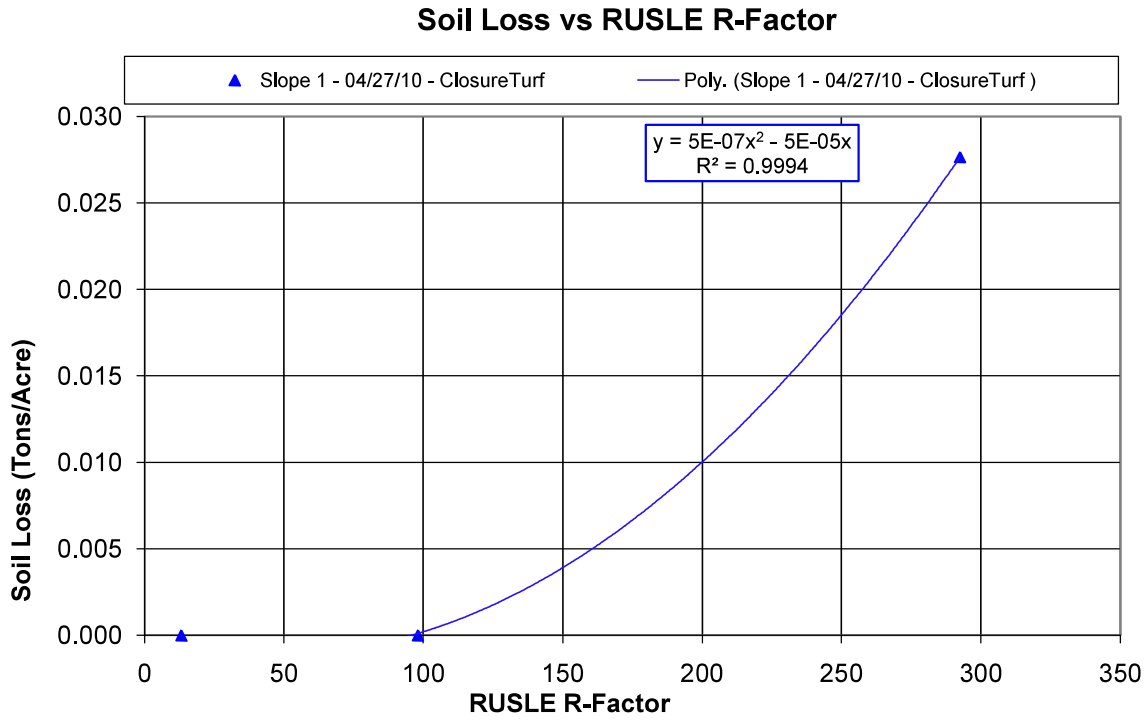
Attachment B-2

ClosureTurf Rainfall Test Report

Project: ASTM D 6459
Client: RPH
Test Date: 4/26/2010
Rainfall Rates: 2,4,6 in/hr (target); 20 minutes at each intensity (60 min. total)
Bed Size & Slope: 8-ft wide x 40-ft long; 3H:1V
Sand Ballast Layer, lbs: 1130 (approximately 1/2-inch thick, hand spread)

Plot	Intensity (in/hr)	Runoff (gallons)	Cumm. R-Factor	Soil Loss (lbs/slope)	Sediment Yield (tons/acre)	% of Ballast in Runoff/Seepage
ClosureTurf	2.36	93	13.13	0.00	0.00	0.04%
	4.65	258	97.99	0.00	0.00	
	6.57	360	292.43	0.41	0.03	

Time (min)	Cumm. Rainfall (in)	Cumm. Runoff (in)	Peak Runoff (cfs)	CN[1]	Rational "C"[2]
20	0.79	0.46	0.013	96.2	0.74
40	2.34	1.76	0.026	94.5	0.76
60	4.53	3.56	0.038	91.3	0.78



1. The effective runoff curve number was determined by solving for S in the equation Q = [(P-0.2S)2/(P+0.8S)] where Q is the depth of runoff (in) and P is the rainfall depth (in). Then, CN = 1000/(S+10).

2. The rational "C" coefficient was determined by solving for C in Q = C I A where Q is the peak discharge rate (cfs), I is the peak rainfall intensity (in/hr) and A is the drainage area (acre).

Note: The testing is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose

CJS 5/5/10
Quality Review / Date

Attachment B-3

ClosureTurf Product Datasheet

ClosureTurf® w 50 mil Super Gripnet® Liner

Product Data	Test Method	LLDPE Values	HDPE Values
Thickness (nominal), mil (mm)	ASTM D5994	50 (1.25)	50 (1.25)
Thickness (min. avg.), mil (mm)	ASTM D5994	47.5 (1.19)	47.5 (1.19)
Thickness (lowest indiv.), mil (mm)	ASTM D5994	42.5 (1.06)	42.5 (1.06)
Drainage Stud Height (min. avg.), mil (mm)	ASTM D7466	130 (3.3)	130 (3.3)
Friction Spike Height (min. avg.), mil (mm)	ASTM D7466	175 (4.45)	175 (4.45)
Density, g/cc	ASTM D792, Method B	0.939 (max.)	0.94 (min.)
Tensile Properties (avg. both directions)	ASTM D6693, Type IV		
Strength @Yield (min. avg.), lb/in. width (N/mm)		N/A	110 (19.3)
Elongation @ Yield (min. avg.), % (GL=1.3 in.)		N/A	12
Strength@Break (min. avg.), lb./in. width (N/mm)		105 (18.4)	110 (19.3)
Elongation@Break (min. avg.), %(GL=2.0 in.)		300	200
Tear Resistance (min. avg.), lbs. (N)	ASTM D1004	30 (133)	38 (169)
Puncture Resistance (min. avg.) lbs. (N)	ASTM D4833	55 (245)	80 (356)
Carbon Black Content (range %)	ASTM D4218	2-3	2-3
Carbon Black Dispersion (Category)	ASTM D5596	Only near spherical agglomerates for 10 views in Cat. 1 or 2	
Stress Crack Resistance (Single Point NCTL), hours	ASTM D5397, Appendix	N/A	500
Oxidative Induction Time, minutes	ASTM D3895, 200°C, 1 atm O_2	≥140	≥140

Agru America's geomembranes are certified to pass Low Temp. Brittleness via. ASTM D746 (-80°C), and Dimensional Stability via. ASTM D1204 (± 2% @ 100°C)

ENGINEERED TURF COMPONENT (CT)

Product Data	Test Method	Values
Yarn Type	N/A	Polyethylene, Fibrillated
Yarn Color	N/A	Olive Green, Play Green, Tan
Yarn Weight (Total Product Weight)	ASTM D5261 (sample size, 1 yd^2)	≥20 oz. / sq. yd. (≥ 32 oz. / sq. yd.)
Tensile Strength of Yarn	ASTM D2256	15 lbs. min.
CBR Puncture	ASTM D6241	1,500 lb. (MARV)
Tensile Product (MD/XD)	ASTM D4595	2,100 MD / 1,600 XD lb/ft (MARV)
Interface Friction between ClosureTurf CT and Super Gripnet®	ASTM D5321	35°, min. Peak*
Engineered Turf Fiber UV Stability	ASTM G147	>60% retained tensile strength at 100 yrs. (projected)
Backing System UV Stability (Exposed)	ASTM G154 Modified Cycle 1., UVA340	110 lbs./ft. retained tensile strength at 6,500 hrs (projected)
Aerodynamic Evaluation	GTRI Wind Tunnel	120 mph with max. uplift of 0.12 lb/sf
Rainfall Induced Erosion	ASTM D6459	Infill Loss 0.1% at 6 in./hr. Rainfall
Steady State Hydraulic Overtopping (ClosureTurf® w/ HydroBinder®)	ASTM D7277/D7276	5 ft. overtopping resulting in 29 ft/s velocity and 8.8 psf shear stress for Manning's *n* value of 0.02
Full Scale Wave Overtopping Test Cumulative Volume (ClosureTurf® with HydroBinder®)	Colorado State University Wave Simulator	165,000 ft^3/ft
Full Scale Wave Overtopping Test Discharge (ClosureTurf® with HydroBinder®)	Colorado State University Wave Simulator	4.0 $ft^3/s/ft$
HydroBinder® Infill Mix	ASTM C387 / ASTM C109	3/4 in. infill 5,000 psi (min. at 28 days)

*Engineered turf/geomembrane interface. Geomembrane/subgrade interface is site specific and should be evaluated per Engineer of Record's requirements.

SUPPLY INFORMATION (Standard Roll Dimensions)

	Thickness		Width		Length		Area (approx.)		Weight (avg.)	
	mil	mm	ft.	m	ft.	m	ft^2	m^2	lbs	kg
Super Gripnet®	50	1.25	23	7	575	175	13,225	1,225	~5,000	~2,268
Turf Component	N/A	N/A	15	4.6	300	91.44	4,500	418	~1,000	~454

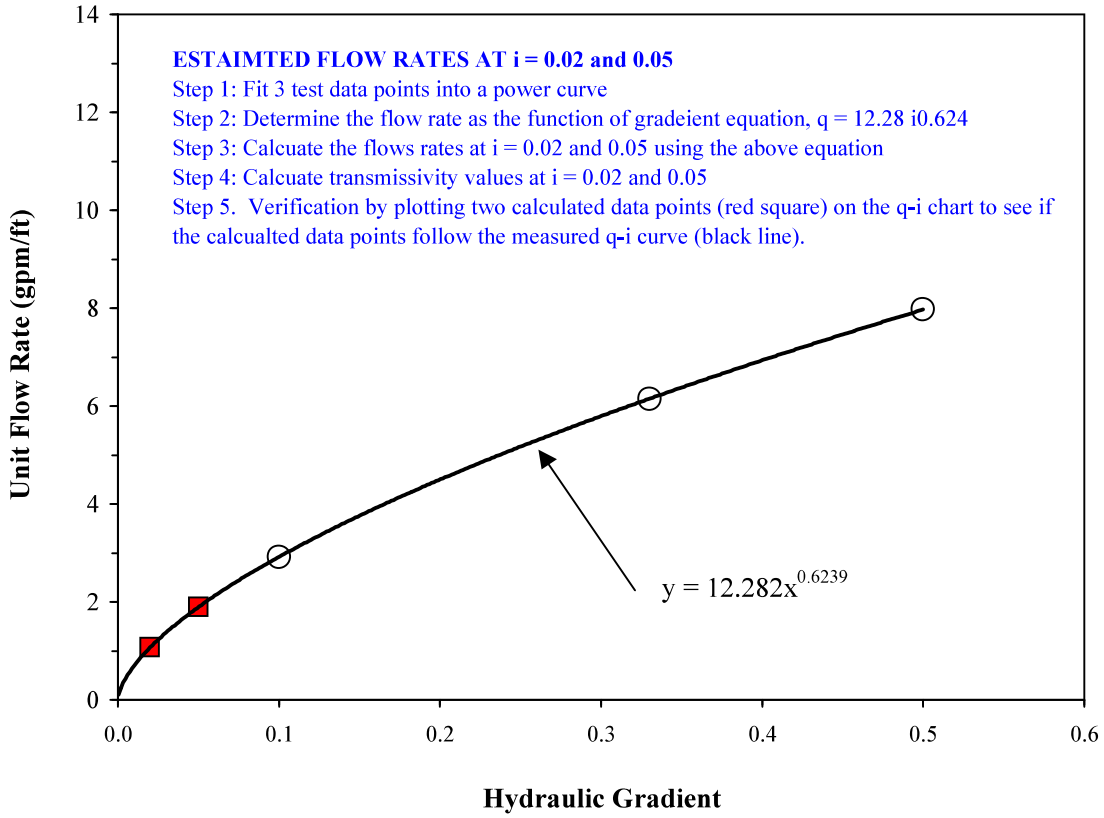
ClosureTurf®, HydroTurf®, VersaCap®, TerraArmor® and PowerCap™ are U.S. registered trademarks which designate products from Watershed Geosynthetics LLC and/or its affiliated companies (collectively, "WG") that are the subject of issued and/or pending U.S. and foreign patents and patent applications. All information provided herein by WG concerning these products are based upon data derived from independent third-party testing. This information, however, should not be used or relied upon for any specific use without first consulting with an independent professional licensed in the geographic area in which a project is located. Since the actual site conditions, and the installation and use of these products are beyond our control, no guaranty or warranty of any kind, expressed or implied, is made by WG with respect to these products.

Attachment B-4

ClosureTurf Transmissivity Test Report

CLOSURETURF LLC -LANDFILL COVER SYSTEM
HYDRAULIC TRANSMISSIVITY TESTING (ASTM D 4716)

Test Configuration (from Top to Bottom): Sand Layer/Polytex Artificial Grass with Geotextile Side Down/ Agru 50-mil Super Gripnet LLDPE Geomembrane with Studs Side Up



Test No.	Flow Direction	Specimen Size Width x Length (in. x in.)	Total Normal Stress[(1)] σ_n (psf)	Seating Time t (hour)	Hydraulic Gradient i (-)	Transmissivity $\theta = 0.00020697\left(\frac{q}{i}\right)$ (m^2/sec)	Flow Rate $q = 12.28i^{0.624}$ (gpm/ft)	Flow Rate q' (l/min/m)
					0.02	1.11E-02	1.07	
					0.05	7.84E-03	1.89	
1	MD	12 x12	47	0.25	0.10	6.04E-03	2.92	36.3
2	MD	12 x12	47	0.25	0.33	3.86E-03	6.15	76.4
3	MD	12 x12	47	0.25	0.50	3.30E-03	7.97	99.0

NOTE:
Total normal stress = total weight (sand + steel plate + surcharge) divided by the plan area of test specimen (1 square ft). A normal stress of 47 psf is approximately the minimum total stress required to keep the specimen from uplifting.

DATE TESTED:	1/11/2013
FIGURE NO.	A-1
PROJECT NO.	SGI10007
DOCUMENT NO.	
FILE NO.	

SGI TESTING SERVICES, LLC

Attachment B-5

Seismic Hazard Data

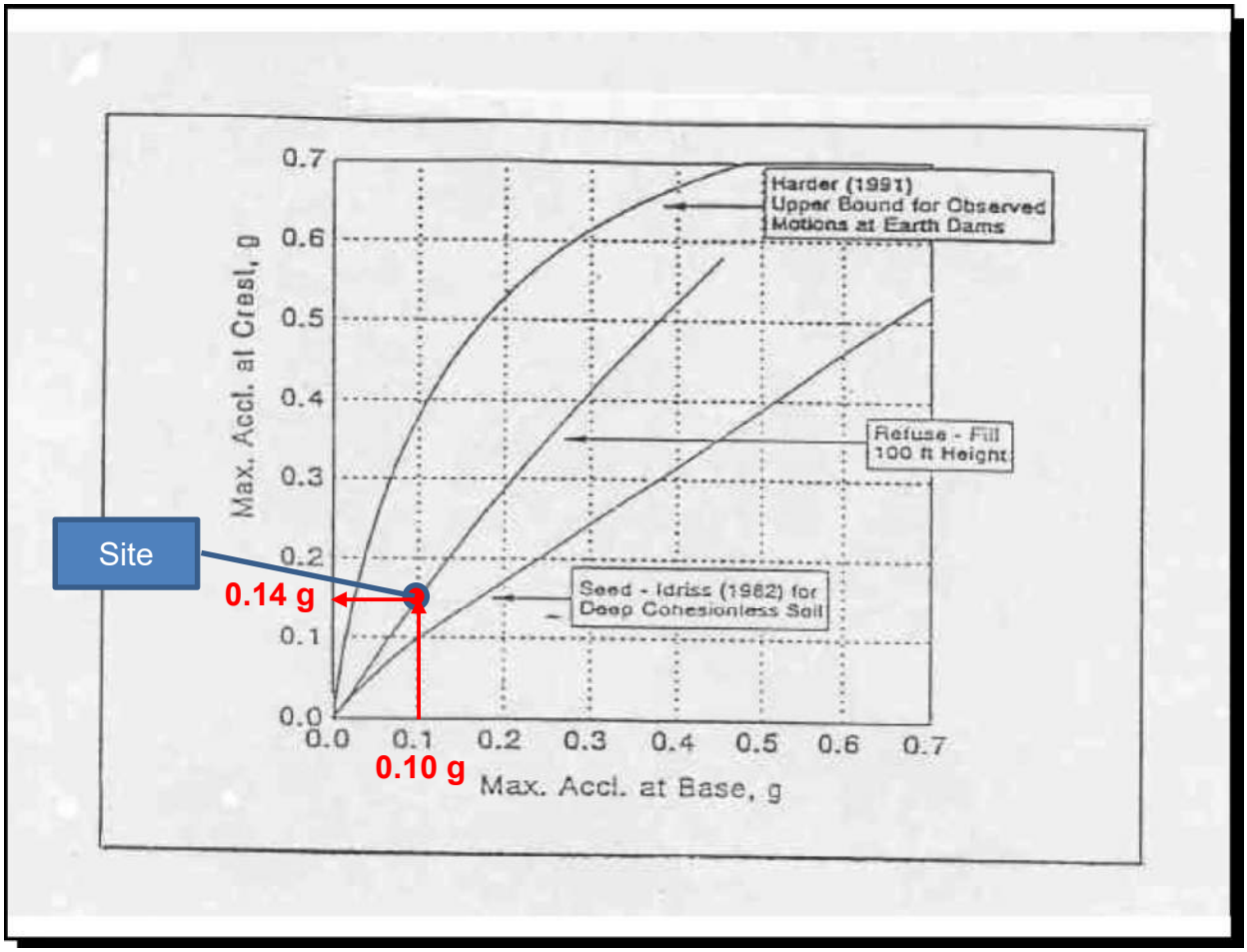


Figure B.1. The relationship between maximum horizontal seismic acceleration at the base and crest of 100 feet of refuse, on top of deep cohesionless soils, and on top of earth dams. (Singh and Sun, 1995)

Appendix C
Example Calculation for Wind Uplift of ClosureTurf

WG WatershedGeo® Unearthing Solutions

Technical Note

WIND UPLIFT ANALYSIS OF CLOSURETURF®

1. Introduction

This technical note presents design methodologies and example calculations for evaluating wind loads on ClosureTurf® final cover system (ClosureTurf). ClosureTurf consists of a structured geomembrane, an engineered turf, and a specified infill (Figure 1).

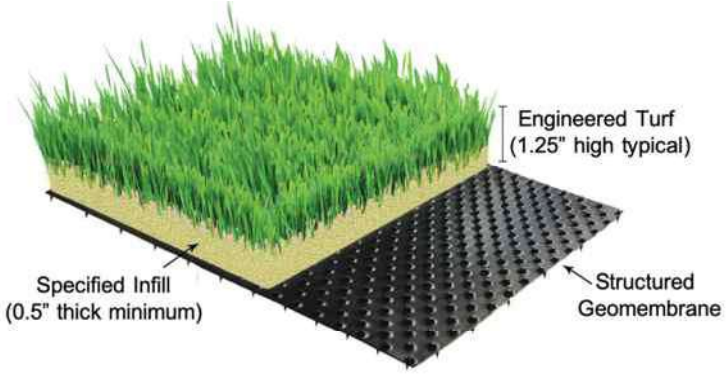


Figure 1. ClosureTurf® Final Cover System

2. Design Methodology

2.1 Wind Pressure Equation

Wind pressure acting on the ClosureTurf surface can be calculated using the following equation (e.g., Dedrick, 1973; Giroud et al., 1995; Wayne and Koerner, 1988; Zheng, et al., 2020; Zhu, et al. 2022):

$$P = \frac{1}{2} \cdot C_p \cdot \rho \cdot U(H)^2 \cdot K_e \cdot K_d$$

where,

P = wind-generated pressure normal to the ClosureTurf surface (pounds per square foot [psf]);
C_p = wind pressure coefficient (dimensionless);
ρ = air density (ρ = 0.0024 slug/cubic foot [ft^3] at 59ºF and sea level);
$U(H)$ = upstream mean wind speed (feet/second [ft/s]) at the height of slope H (feet [ft]);
K_d = wind directionality factor (K_d = 1.1); and
K_e, = ground elevation factor (ASCE, 2022), $K_e = e^{-0.0000362 \cdot Z_e}$, where Z_e is the ground elevation above sea level (ft).

2.2 Design Wind Speed

The design wind speed $U(H)$ at a height of slope H can be estimated from the basic wind speed following the recommendations in ASCE 7-22 (ASCE, 2022). The basic wind speed at locations in the U.S. can be obtained from the online database provided by the ASCE (https://asce7hazardtool.online/). The database can be used to search for wind speed based on location and Mean Recurrence Interval (MRI) or Risk Category. The basic wind speed corresponds to the 3-second gust speed at 32.8 ft (or 10 m) above ground in open terrain, and it is denoted as $U_3(32.8\ ft)$. An example of basic wind speeds for structures located in Atlanta, GA is shown in Figure 2. Basic wind speeds increase as the MRI increases from 10 years (i.e., MRI 10-Year) to approximately 3,000 years for Risk Category IV.

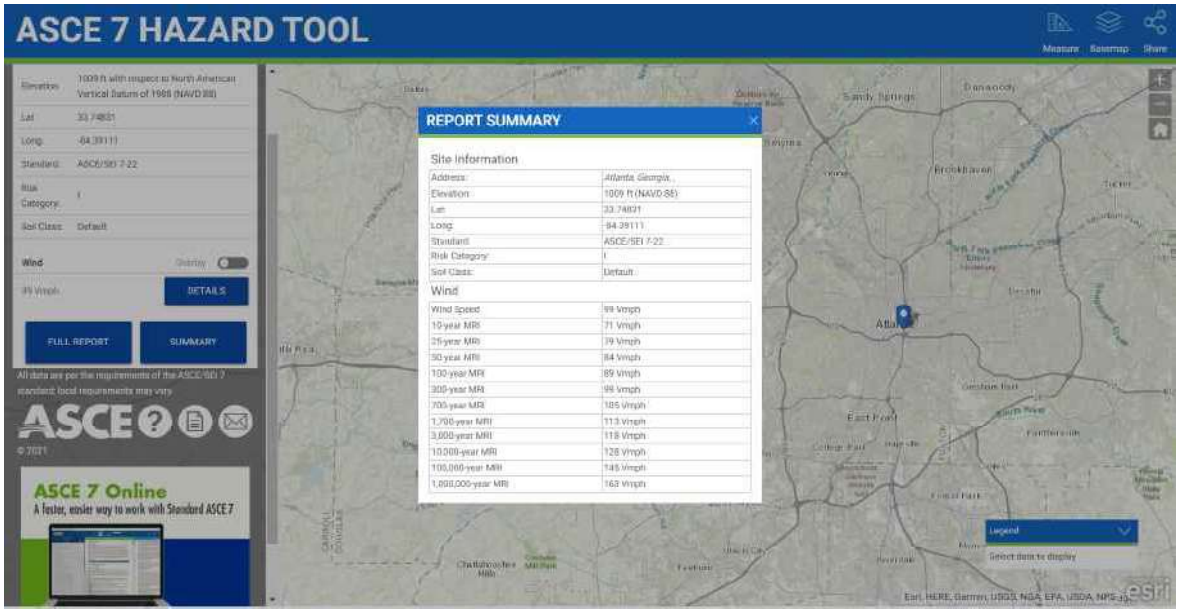


Figure 2. Basic Wind Speeds for Structures Located in Atlanta, GA based on ASCE Database

The professional engineer designing the ClosureTurf should consult with the site owner/operator to select a basic wind speed for design that corresponds to an appropriate MRI, based on any applicable federal, state, or local regulations, industry standards, historical wind records, and the owner/operator's long-term maintenance strategy for the site.

Basic wind speed, which, as previously noted, corresponds to a 3-second gust, can be converted to mean hourly wind speed at 32.8 ft above ground, $U(32.8\ ft)$, using a factor of approximately 1.5 for open terrain (Vickery and Skerlj, 2005):

$$U(32.8\ ft) = U_3(32.8\ ft)\ /\ 1.5$$

Using $U(32.8\ ft)$ as the reference wind speed, the mean hourly wind speed at the top of a landfill, $U(H)$, with H being the height of landfill slope, is calculated using the Power-Law equation for atmospheric boundary layers (Peterson and Hennessey, 1978):

$$\frac{U(H)}{U(32.8\,ft)} = \left(\frac{H}{32.8}\right)^{\alpha}$$

where, α is the Power-Law exponent. A value of 0.14 is used herein based on the wind tunnel test results of ClosureTurf. This exponent corresponds to an open terrain boundary condition. Therefore, the equation above can be re-arranged as follows:

$$U(H) = U(32.8\,ft) \cdot \left(\frac{H}{32.8}\right)^{0.14}$$

2.3 Wind-Pressure Coefficient

Profiles of the wind-pressure coefficient, C_p, developed based on the wind tunnel test results of ClosureTurf are presented in Figures 3 and 4 for landfills with 4H:1V and 3H:1V slopes, respectively. The corresponding C_p values are listed in Tables 1 and 2. Two types of engineered turf were tested, specifically, CT with standard density turf and CT HD with higher density turf.

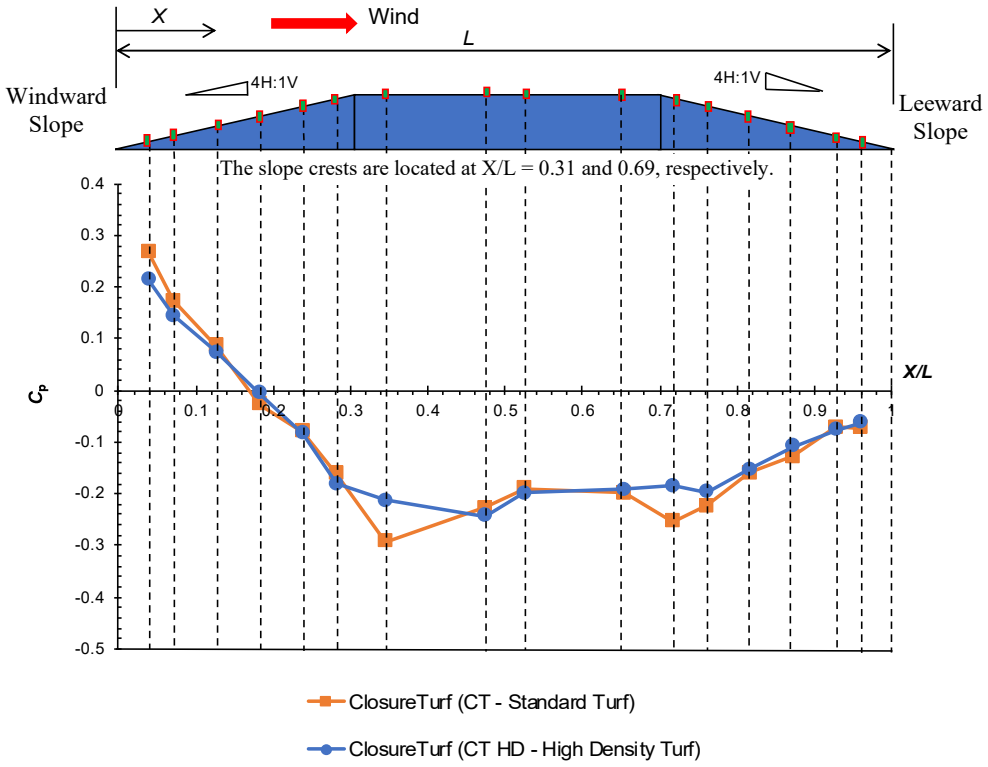


Figure 3. Average Wind-Pressure Coefficient Profiles for ClosureTurf (4H:1V Slopes)

Note: Positive values correspond to wind load acting toward the surface (i.e., downward pressure or compression). Negative values correspond to wind load acting away from the surface (i.e., uplift pressure or suction). This note applies to the other figures and tables of C_p in this Technical Note.

WG
24137

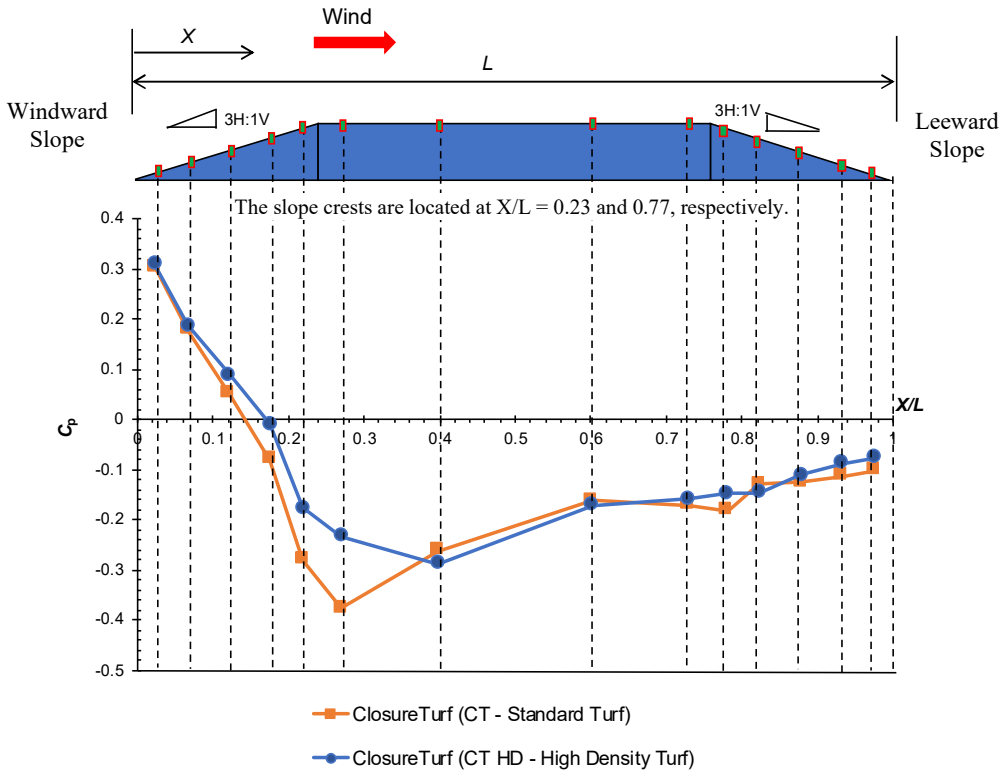


Figure 4. Average Wind-Pressure Coefficient Profiles for ClosureTurf (3H:1V Slopes)

Table 1. Average Wind-Pressure Coefficients for ClosureTurf (4H:1V Slopes)

X/L	Wind Pressure Coefficient, *Cp* (4H:1V Slope)	
	CT (Standard Turf)	CT HD (High Density Turf)
0.04	0.27	0.22
0.07	0.17	0.15
0.13	0.09	0.08
0.18	-0.03	-0.01
0.24	-0.08	-0.08
0.28	-0.16	-0.18
0.35	-0.29	-0.21
0.47	-0.23	-0.24
0.53	-0.19	-0.20
0.65	-0.20	-0.19
0.72	-0.25	-0.18
0.76	-0.22	-0.20
0.82	-0.16	-0.15
0.87	-0.13	-0.11
0.93	-0.07	-0.08
0.96	-0.07	-0.06

Note: The slope crests are located at X/L = 0.31 and 0.69, respectively.

WG
24137

Table 2. Average Wind-Pressure Coefficients for ClosureTurf (3H:1V Slopes)

X/L	Wind Pressure Coefficient, C_p (3H:1V Slope)	
	CT (Standard Turf)	CT HD (High Density Turf)
0.02	0.30	0.31
0.07	0.18	0.19
0.12	0.05	0.09
0.18	-0.08	-0.01
0.22	-0.28	-0.18
0.27	-0.38	-0.23
0.40	-0.26	-0.29
0.60	-0.16	-0.17
0.73	-0.17	-0.16
0.78	-0.18	-0.15
0.82	-0.13	-0.15
0.88	-0.12	-0.11
0.93	-0.11	-0.09
0.98	-0.10	-0.08

Note: The slope crests are located at X/L = 0.23 and 0.77, respectively.

3. ClosureTurf Wind Uplift Analysis Example

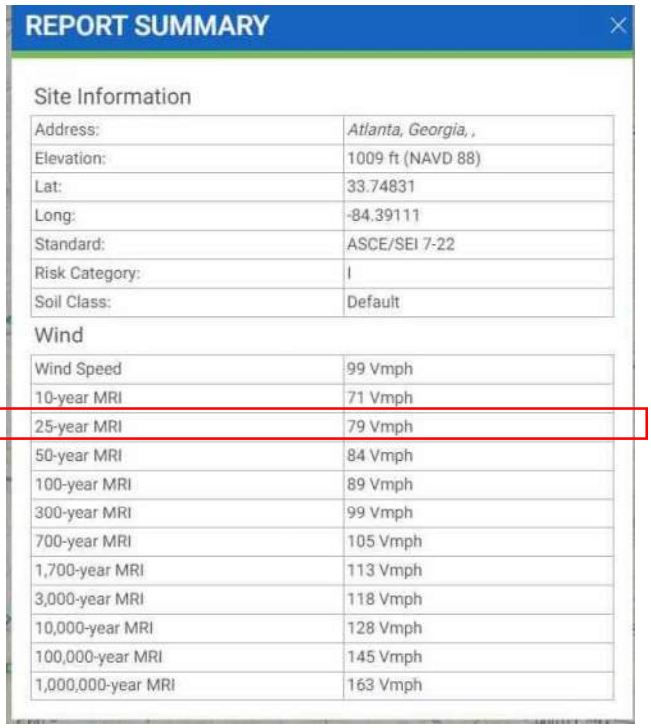
This section provides a wind uplift analysis example of ClosureTurf. For convenience, the C_p values are reported in the example as absolute values and the context of the value (i.e., uplift or compression) in each case is made clear.

Example 1: A hypothetical landfill site is located in Atlanta, GA. It has a slope of 3H:1V with a maximum height of 100 ft. The top deck of the landfill is at El. 1,150 ft above mean sea level. The maximum length of top deck is 200 ft with a maximum slope of 5%. ClosureTurf is selected to close the site with the standard-density engineered turf CT and 50-mil Super Gripnet geomembrane. The specified thickness of aggregate infill is 0.5 in. minimum, not to exceed 0.75 in. Perform a wind uplift analysis for the proposed ClosureTurf final cover system.

Solution:

Step 1: Select $U_3(32.8\ ft)$ according to ASCE 7-22

Go to https://asce7hazardtool.online/ and search for Atlanta, GA. The results are:



REPORT SUMMARY

Site Information

Address:	*Atlanta, Georgia, ,*
Elevation:	1009 ft (NAVD 88)
Lat:	33.74831
Long:	-84.39111
Standard:	ASCE/SEI 7-22
Risk Category:	I
Soil Class:	Default

Wind

Wind Speed	99 Vmph
10-year MRI	71 Vmph
25-year MRI	79 Vmph
50-year MRI	84 Vmph
100-year MRI	89 Vmph
300-year MRI	99 Vmph
700-year MRI	105 Vmph
1,700-year MRI	113 Vmph
3,000-year MRI	118 Vmph
10,000-year MRI	128 Vmph
100,000-year MRI	145 Vmph
1,000,000-year MRI	163 Vmph

For the purpose of illustrating the wind uplift design methodology, MRI 25-Year (i.e., a 25-year recurrence interval) is used in the example. The basic wind speed for MRI 25-Year is 79 mph (equal to 115.9 ft/s), which corresponds to the 3-second gust speed at 32.8 ft above ground. Therefore, $U_3(32.8\ ft)$ = 79 mph = 115.9 ft/s.

Step 2: Calculate $U(H)$ with H = 100 ft

The mean hourly wind speed for open terrain is:

$$U(32.8\ ft) = \frac{U_3(32.8\ ft)}{1.5} = \frac{115.9}{1.5} = 77.3\ ft/s$$

The mean hourly wind speed at the top of the landfill is:

$$U(H) = U(32.8\ ft) \cdot \left(\frac{H}{32.8\ ft}\right)^{0.14} = 77.3 \times \left(\frac{100}{32.8}\right)^{0.14} = 90.4\ ft/s$$

Therefore, at the height of H = 100 ft, the mean hourly wind speed $U(H)$ = 90.4 ft/s.

Step 3: Select Wind-Pressure Coefficient (C_p) Values

Because the landfill slope is 3H:1V and the engineering turf is the standard turf CT, the C_p profile in Figure 4 (and Table 2) for CT is used for calculation of wind uplift pressure. According to Table 2, the maximum C_p value, $C_{p,max}$, is 0.38 (uplift).

Step 4: Calculate Ground Elevation Factor

$$K_e = e^{-0.0000362 \cdot Z_e} = e^{-0.0000362 \times 1150} = 0.959$$

Step 5: Calculate Maximum Wind Uplift Pressure

$$P_{max} = \frac{1}{2} \cdot C_{p,max} \cdot \rho \cdot U(H)^2 \cdot K_e \cdot K_d$$
$$= 0.5 \times 0.38 \times 0.0024 \times 90.4^2 \times 0.959 \times 1.1 = 3.93\ psf$$

The maximum wind uplift is expected to occur on the top deck near the crest of slope.

Step 6: Estimate Self-Weight of ClosureTurf

Using the minimum aggregate thickness of 0.5 in. and a unit weight of aggregate of 115 pcf, the calculated self-weight of the aggregate infill layer is: (0.5/12) x 115 = 4.79 psf. (Note: It has been observed that contractors typically provide more than the minimum amount of aggregate infill to assure the minimum 0.5 in. aggregate thickness specification is met. Based on experience, typical final infill thicknesses have been in the range of 0.50 to 0.75 in. Overfill is not considered in the wind load calculation, which provides a degree of conservatism to the analysis.)

According to the ClosureTurf datasheet (see excerpt below), CT turf weighs about 1,000 pounds (lbs) over 4,500 ft^2 and the 50-mil Super Gripnet weighs about 5,000 lbs over 11,500 ft^2. Therefore, the self-weights per unit area of these two materials are, respectively, 1000 lbs/4,500 ft^2 = 0.22 psf (for CT turf) and 5,000 lbs/11,500 ft^2 = 0.43 psf (for 50-mil Super Gripnet).

	Thickness		Width		Length		Area (approx.)		Weight (avg.)	
	mil	mm	ft.	m	ft.	m	ft²	m²	lbs	kg
Super Gripnet®	50	1.25	23	7	500	152	11,500	1,068	~5,000	~2,268
Turf Component	N/A	N/A	15	4.6	300	91.44	4,500	418	~1,000	~454

The total self-weight of the ClosureTurf is therefore: 4.79 + 0.22 + 0.43 = 5.44 psf > 3.93 psf.

Step 7: Calculate Factor of Safety against Wind Uplift

The factor of safety (FS) against the initiation of uplift, FS (uplift) is calculated to be 1.38 (i.e., 5.44 psf/3.93 psf).

Due to the combination of small uncertainty in the design parameters, limited consequences of failure, and conservatism in the analysis, a minimum FS in the range of 1.1 to 1.2 is considered adequate for purposes of design. Therefore, the ClosureTurf cover is anticipated to have sufficient resistance against potential initiation of wind uplift for the considered conditions.

4. Remarks

It is suggested that if the design engineer wishes to increase the level of conservatism, it can be achieved by selecting a larger FS or starting the analysis using a more conservative basic wind speed. The final decision on selecting these parameters is the responsibility of the design engineer.

If the calculated maximum wind uplift pressure becomes greater than the self-weight of ClosureTurf, the following design measures can be considered:

1. Tension-strain analysis – A tension-strain analysis can be performed to evaluate whether the wind-induced tension in the ClosureTurf is acceptable. The methodology presented in the technical paper by Giroud et al. (1995) for evaluation of tension and strain in exposed geomembranes due to wind uplift can be used to evaluate ClosureTurf. The design methodology and an analysis example are presented in Attachment C-1 of this Technical Note.
2. Thicker aggregate infill – The C_p profiles in Figure 3 or Figure 4, depending on the slope, can be used to identify any area (which is likely to be limited to the vicinity of the slope crest) where thicker aggregate infill is required to provide the necessary ballast. It is suggested, however, that the maximum aggregate thickness not exceed 1.0 in., since turf fiber height is about 1.25 in. and aggregate infill close to or above the turf surface is subject to movement by wind.
3. Rock ballast – In some cases a stormwater diversion berm or conveyance ditch on the landfill top deck may be considered for the effect that it has on ballasting the ClosureTurf. The ballasting effect of rock- or gravel-lined swales near the slope crest can also be accounted for in the wind load calculation.
4. Anchor trench – An anchor trench may be considered on the top deck near the slope crest to provide additional resistance to wind load, if necessary. In some cases, the anchor trench may be required for other reasons, for example, phased construction of the final cover system.
5. A combination of the above-mentioned design measures can be considered.

Attachment C-1
ClosureTurf Wind-Induced Tension-Strain Analysis

A.1. Design Methodology

A published and widely accepted methodology from the technical literature for evaluating wind uplift of exposed geomembranes is adopted herein to evaluate the wind-induced tension of ClosureTurf when uplifted, with modifications made to include the engineered turf component.

The wind-induced "uplift tension-strain relationship" of a geomembrane has been developed by Giroud et al. (1995), which is expressed as:

$$\varepsilon_w = \frac{2T_w}{S_e L} sin^{-1}\left[\frac{S_e L}{2T_w}\right] - 1 \quad \ldots\ldots (1)$$

Where, ε_w is the strain in the geomembrane induced by wind uplift; T_w, lb/ft, is the tension in the geomembrane induced by wind uplift; L, ft, is the length of geomembrane exposed to wind between two anchors (measured along the slope); and S_e is the effective suction, lb/ft^2.

A schematic representation of an uplifted geomembrane used by Giroud et al. (1995) to develop the above governing equation is shown in Figure A-1. Note that the notation T in the figure is changed to T_w in Eq. (1) to indicate the tension induced by wind uplift. The wind-induced uplift is assumed to be 2-dimensional (i.e., plane strain conditions) in order to develop the equation.

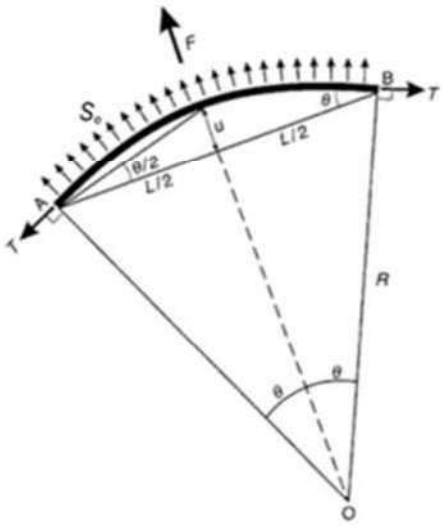


Figure A-1. Schematic Representation of Uplifted Geomembrane (after Giroud et al., 1995)

The effective suction, S_e, is the difference between the wind uplift pressure P, lb/ft^2, and the normal component of the unit weight of geomembrane per unit area W, lb/ft^2 (see Figure A-2):

$$S_e = P - W cos\beta \quad \ldots\ldots (2)$$

where β is the slope angle.

WG
24137

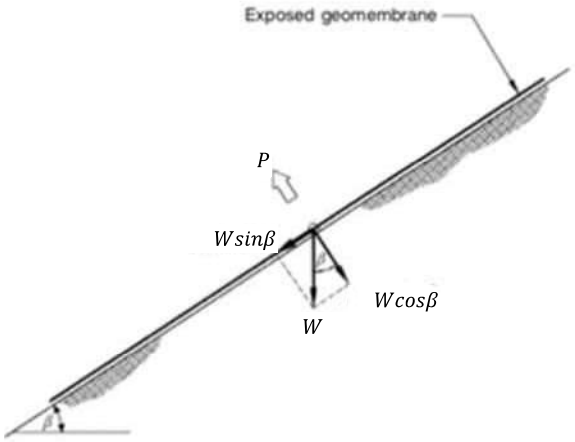


Figure A-2. Geomembrane on a Slope and Subject to Wind-Induced Uplift
(after Zornberg and Giroud, 1997)

Assuming the geomembrane has a linear elastic tension-strain relationship (i.e., the strain is within the range of elastic deformations):

$$T_w = J\varepsilon_w \quad \ldots\ldots (3)$$

where *J*, lb/ft, is the tensile stiffness of geomembrane (i.e., the product of the tensile modulus and thickness).

The "uplift tension-strain relationship" expressed in Eq. (1) can be re-written as:

$$\frac{S_e L}{2J\varepsilon_w} = sin\left[\frac{S_e L}{2J}(1+\frac{1}{\varepsilon_w})\right] \quad \ldots\ldots (4)$$

This equation has no explicit solution and therefore, the calculated wind-induced tensile strain must be determined by iteration. However, Giroud (2009) provided a quasi-exact, explicit solution to the above equation to facilitate calculations:

$$\varepsilon_w = \frac{0.3467\left(\frac{S_e L}{J}\right)^{2/3}}{1-0.3103\left(\frac{S_e L}{J}\right)^{2/3}} \quad \ldots\ldots (5)$$

The difference between the value of strain obtained from the quasi-exact solution and the exact solution is less than 0.01% for strains between 0 and 20% and less than 0.2% for a strain of 40% (Giroud, 2009). Note that the maximum allowable tensile strain for design is in the range of 5 to 15% depending on the type of geomembrane being considered (Peggs, et al., 2005). Typical design tensile strains will be less than these maximum allowable values. Hence the range of tensile strains considered herein is within the range of high accuracy for the quasi-exact solution.

WG
24137

After the tensile strain is obtained using Eq. (5), the tension in the uplifted geomembrane can be calculated using Eq. (3). The factor of safety (FS) against yield of the geomembrane, FS_y, is calculated using the tension at yield divided by the tension in the uplifted geomembrane:

$$FS_y = \frac{T_y}{T_w} \ldots\ldots (6)$$

where T_y, lb/ft, is the tension at yield, which can be found in the geomembrane product data sheet provided by the manufacturer. Note that the tension at yield approximately defines the limit of elastic behavior of the geomembrane.

During wind tunnel testing conducted on ClosureTurf, it was observed that the engineered turf and underlying geomembrane were lifted together due to wind loads (in other words, they did not separate). For purposes of the tension analysis, it is assumed that the engineered turf has the same elongation and hence, the same tensile strain as the geomembrane. Tension in the engineered turf can be calculated using Eq. (3) with the tensile stiffness for the engineered turf. Similar to the geomembrane, the FS against yield of the engineered turf can be calculated using Eq. (6) with the tension at yield for the engineered turf.

An example calculation is presented in the section below to illustrate the analysis procedure and use of the above equations.

A.2. Wind Uplift and Tension-Strain Analysis Example:

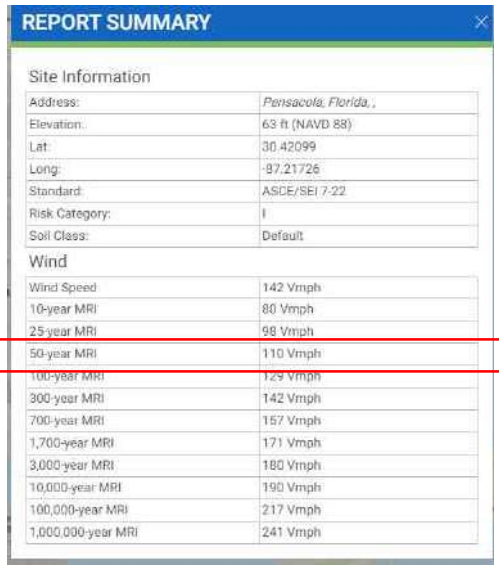
Problem: A hypothetical landfill site is located in Pensacola, FL. It has a side slope of 3H:1V with a maximum vertical height of 100 ft. The top deck of the landfill is at El. 200 ft above mean sea level. The maximum length of top deck is 200 ft with a maximum slope of 5%. ClosureTurf is selected as the final cover to close the site that consists of the standard-density engineered turf CT and 50-mil LLDPE Super Gripnet geomembrane. The specified thickness of aggregate infill is 0.5 in. minimum, not to exceed 0.75 in. Perform a wind uplift analysis for the proposed ClosureTurf final cover system.

Solution:

Part 1 – Calculate Maximum Wind Uplift Pressure

Step 1: Select basic wind speed according to ASCE 7-22

The basic wind speed, $U_3(32.8\,ft)$, corresponds to the 3-second gust speed at 32.8 ft above ground. It can be obtained from the online database: https://asce7hazardtool.online/. Using this database and searching for Pensacola, FL, the results are shown in the figure below. For the purposes of illustrating the tension-strain analysis presented in the second part of the example, the basic wind speed for Mean Return Interval (MRI) 50-Year is selected, which is 110 mph. Therefore, $U_3(32.8\,ft)$ = 110 mph = 161.3 ft/s.



REPORT SUMMARY

Site Information

Address:	*Pensacola, Florida, ,*
Elevation:	63 ft (NAVD 88)
Lat:	30.42099
Long:	-87.21726
Standard:	ASCE/SEI 7-22
Risk Category:	I
Soil Class:	Default

Wind

Wind Speed	142 Vmph
10-year MRI	80 Vmph
25-year MRI	98 Vmph
50-year MRI	110 Vmph
100-year MRI	129 Vmph
300-year MRI	142 Vmph
700-year MRI	157 Vmph
1,700-year MRI	171 Vmph
3,000-year MRI	180 Vmph
10,000-year MRI	190 Vmph
100,000-year MRI	217 Vmph
1,000,000-year MRI	241 Vmph

Figure A-3. Selection of Basic Wind Speed According to ASCE 7-22

Step 2: Calculate mean hourly wind speed at top of landfill

The mean hourly wind speed that corresponds to the selected basic wind speed is:

$$U(32.8\,ft) = \frac{U_3(32.8\,ft)}{1.5} = \frac{161.3}{1.5} = 107.5\,ft/s$$

The mean hourly wind speed at the top of the landfill (i.e., H = 100 ft) is:

$$U(H) = U(32.8\,ft) \cdot \left(\frac{H}{32.8\,ft}\right)^{0.14} = 107.5 \times \left(\frac{100}{32.8}\right)^{0.14} = 125.7\,ft/s$$

Therefore, at a height of H = 100 ft, the mean hourly wind speed $U(H)$ = 125.7 ft/s.

Step 3: Select maximum wind pressure coefficient value

Because the landfill slope is 3H:1V and the engineering turf is the standard turf CT, the C_p profile in Figure 4 (and Table 2) for CT, as presented in Section 2.3 of this Technical Note, is used for calculation of wind uplift pressure. According to Table 2, the maximum C_p value, $C_{p,max}$, is 0.38 (uplift). Note that for convenience, the C_p value is reported as an absolute value and the context of the value (i.e., uplift) is made clear.

Step 4: Calculate maximum wind uplift pressure

The maximum wind uplift is expected to occur on the top deck near the crest of slope.

$$P_{max} = \frac{1}{2} \cdot C_{p,max} \cdot \rho \cdot U(H)^2 \cdot K_e \cdot K_d$$

The ground elevation factor corresponding to El. 200 ft is calculated as:

$$K_e = e^{-0.0000362 \cdot Z_e} = e^{-0.0000362 \times 200} = 0.993$$

The wind directionality factor, K_d, is selected as 1.1.

The maximum wind uplift pressure is calculated as:

$$P_{max} = 0.5 \times 0.38 \times 0.0024 \times 125.7^2 \times 0.993 \times 1.1 = 7.87\ psf$$

Step 5: Estimate self-weight of ClosureTurf

Using the minimum aggregate thickness of 0.5 in. and a unit weight of aggregate of 115 pcf, the calculated self-weight of the aggregate infill layer is: (0.5/12) x 115 = 4.79 psf. (Note: It has been observed that contractors typically provide more than the minimum amount of aggregate infill to assure the minimum 0.5 in. aggregate thickness specification is met. Based on experience, typical final infill thicknesses have been in the range of 0.50 to 0.75 in. Overfill is not considered in the wind load calculation, which provides a degree of conservatism to the analysis.)

According to the ClosureTurf datasheet (see Table A-1), CT turf weighs about 1,000 lbs over 4,500 ft^2 and the 50-mil Super Gripnet weighs about 5,000 lbs over 11,500 ft^2. Therefore, the selfweights per unit area of these two materials are, respectively, 1000 lbs/4,500 ft^2 = 0.22 psf (for CT turf) and 5,000 lbs/11,500 ft^2 = 0.43 psf (for 50mil Super Gripnet).

Table A-1. Dimensions and Weights of ClosureTurf Components

	Thickness		Width		Length		Area (approx.)		Weight (avg.)	
	mil	mm	ft.	m	ft.	m	ft^2	m^2	lbs	kg
Super Gripnet®	50	1.25	23	7	500	152	11,500	1,068	~5,000	~2,268
Turf Component	N/A	N/A	15	4.6	300	91.44	4,500	418	~1,000	~454

The total self-weight of the ClosureTurf is therefore: W = 4.79 + 0.22 + 0.43 = 5.44 psf .

Step 6: Calculate factor of safety against wind uplift

The factor of safety (FS) against the initiation of uplift, *FS (uplift)* is calculated to be:

$$FS\ (uplift) = W/P_{max} = 5.44/7.87 = 0.69$$

The calculated FS is less than 1.0; therefore, the ClosureTurf cover is anticipated to experience wind uplift under the selected basic wind speed. A tension-strain analysis is performed next.

Part 2 – Tension-Strain Analysis

Step 7: Back-calculate critical wind pressure coefficient

The critical wind pressure coefficient (i.e., the wind pressure coefficient required to just initiate uplift at the design wind speed), C_p', is back-calculated for the condition where the maximum wind uplift pressure, P'_{max}, equals the self-weight of ClosureTurf:

$$W = P'_{max} = \frac{1}{2} \cdot C_p' \cdot \rho \cdot U(H)^2 \cdot K_d \cdot K_e$$

$$C_p' = \frac{2W}{\rho \cdot U(H)^2 \cdot K_d \cdot K_e} = \frac{2 \times 5.44}{0.0024 \times 125.7^2 \times 0.993 \times 1.1} = 0.26 \text{ (uplift)}$$

Step 8: Identify area subject to wind uplift (i.e., "uplifted zone")

The line representing the critical wind pressure coefficient intercepts the wind pressure coefficient profile for the standard-density turf at X/L of approximately 0.21 and 0.42, respectively, as shown in the figure below.

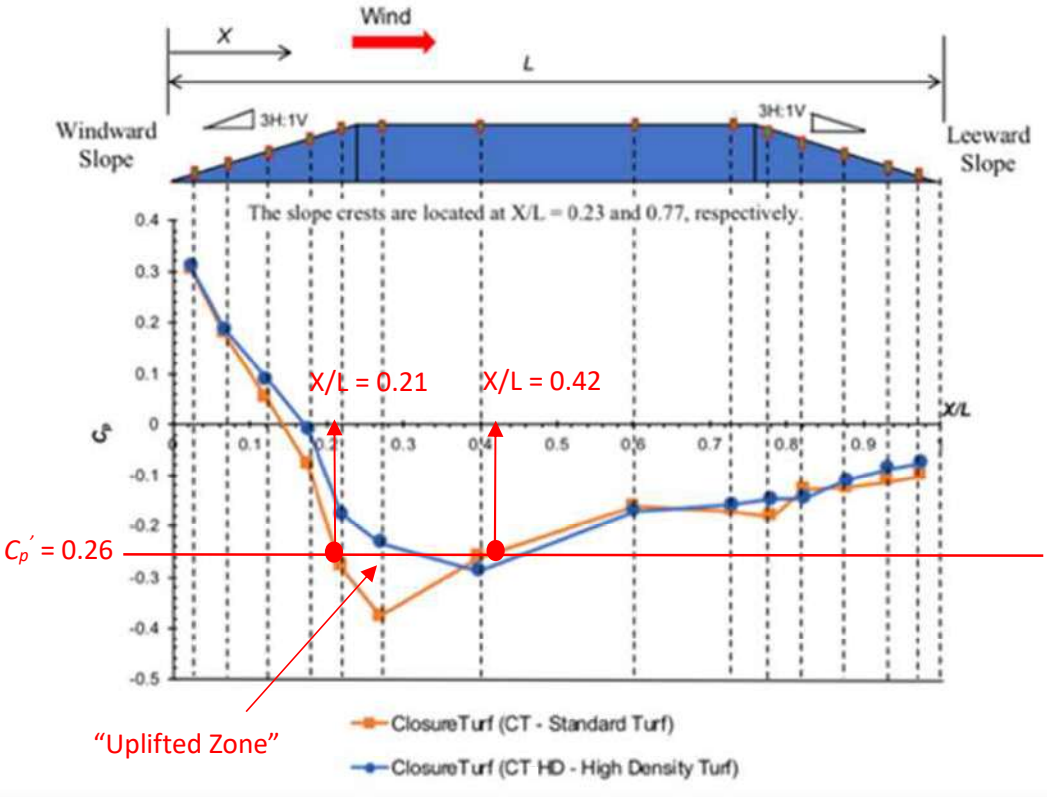


Figure A-4. Wind Pressure Coefficient Profile for 3H:1V Slopes

The area below the critical coefficient line (i.e., X/L between 0.21 and 0.42) is considered to be

WG
24137

the “uplifted zone”, where the wind-induced uplift pressure exceeds the selfweight of ClosureTurf and therefore, ClosureTurf is expected to be lifted. The remaining area is not expected to experience uplift because the uplift pressure induced by wind is less than the selfweight of ClosureTurf.

Step 9: Calculate average wind pressure coefficient in the “uplifted zone”

By simplifying the wind pressure profile of the “uplifted zone” as a triangle, the average wind coefficient in this zone can be estimated as:

$$\overline{C_p} = C_p' + \frac{1}{2}\left(C_{p,max} - C_p'\right) = 0.26 + \frac{1}{2}(0.38 - 0.26) = 0.32 \text{ (uplift)}$$

Step 10: Calculate average wind uplift pressure in “uplifted zone”

It is noted that the maximum C_p is used in Step 4 to evaluate the initiation of wind uplift. In contrast, the average C_p is used in this step to estimate the average wind uplift pressure in the “uplifted zone” and the average tensile strains in ClosureTurf in the subsequent steps.

The average wind uplift pressure in the “uplifted zone” is calculated as:

$$\overline{P} = \frac{1}{2} \cdot \overline{C_p} \cdot \rho \cdot U(H)^2 \cdot K_e \cdot K_d = 0.5 \times 0.32 \times 0.0024 \times 125.7^2 \times 0.993 \times 1.10 = 6.63\ psf$$

Step 11: Calculate normal component of average wind uplift pressure in “uplifted zone”

A majority of the “uplifted zone” is located on the top deck (i.e., X/L between 0.42 and 0.23 [crest]) and a small portion is located on the windward slope (i.e., X/L between 0.21 and 0.23[crest]). The slope of top deck is 5% (or β_{top} = 2.9 degrees) and the slope of the sideslope is 3H:1V (or β_{side} = 18.4 degrees). The weighted average of the normal component of the unit weight of ClosureTurf (see Figure A-2) in the “uplifted zone” is calculated as:

$$\overline{W cos\beta} = \frac{W cos 2.9^{\circ} \times (0.42 - 0.23) + W cos 18.4^{\circ} \times (0.23 - 0.21)}{0.42 - 0.21} = 0.994W$$

Because a majority of the “uplifted zone” is on the top deck, the normal component of the unit weight of ClosureTurf is very close to the total unit weight.

Step 12: Calculate effective suction

To account for a target wind resistance FS of 1.1, as discussed at the end of Section 3 of this Technical Note, the reduced unit weight of ClosureTurf (i.e., W/1.1) is used to calculate the effective suction, S_e, in the “uplifted zone”:

$$S_e = \bar{P} - \frac{\overline{W cos\beta}}{1.1} = \bar{P} - \frac{0.994W}{1.1} = 6.63 - \frac{0.994 \times 5.44}{1.1} = 1.71\ psf$$

Step 13: Calculate slope distance of "uplifted zone"

Based on the site geometry, the total horizontal distance at the base of the landfill is:

$$L_{landfill} = 2 \times (3 \times 100) + 200 = 800\ ft$$

The horizontal distance of the "uplifted zone" on the windward slope is: (0.23 – 0.21) x 800 ft = 16 ft. The horizontal distance of the "uplifted zone" on the top deck is: (0.42 – 0.23) x 800 ft = 152 ft.

The slope distance on the windward slope is: 16/cos18.4° = 16.9 ft. The slope distance on the top deck is: 152/cos2.9° = 152.2 ft.

The total slope distance of the "uplifted zone", *L*, is: 16.9 + 152.2 = 169.1 ft.

Step 14: Calculate ClosureTurf tensile stiffness

Assuming linear elastic deformation, the tension-strain relationship is expressed as:

$$T_w = J\varepsilon_w$$

ClosureTurf consists of the geomembrane and engineered turf components. The wind-induced tension in the ClosureTurf system is the sum of the tension in these two components:

$$T_w = T_{w,GM} + T_{w,ET} = J_{GM}\varepsilon_{w,GM} + J_{ET}\varepsilon_{w,ET}$$

where, GM denotes the geomembrane component and ET denotes the engineered turf component. Based on observations during wind tunnel testing showing that the engineered turf and underlying geomembrane were lifted together, it is assumed that the engineered turf and geomembrane have the same elongation and hence, the same tensile strain:

$$\varepsilon_{w,GM} = \varepsilon_{w,ET} = \varepsilon_w$$

Hence,

$$T_w = J_{GM}\varepsilon_{w,GM} + J_{ET}\varepsilon_{w,ET} = (J_{GM} + J_{ET})\varepsilon_w$$

Therefore, the total stiffness of ClosureTurf is:

$$J = J_{GM} + J_{ET}$$

Given that only 2-dimensional wind uplift is considered herein and the wind-uplift loading is short term, wide width tensile test results are considered appropriate for wind-uplift design. The wide width tensile testing according to ASTM D4885 was conducted on samples of the structured geomembranes of ClosureTurf (i.e., MicroSpike®, MicroDrain®, and Super Gripnet®). The results of this test program are summarized in Table A-2. Examples of the test results are included in Attachment C-2.

Table A-2. Wide Width Tensile Properties of Structured Geomembranes of ClosureTurf

Structured Geomembrane			Stiffness (lb/in)	Yield Strength (lb/in)	Yield Strain (%)	Maximum Strength (lb/in)	Elongation at Break (%)
HDPE	40-mil MicroSpike®	MD	2,681	100.8	15.9	105.7	485.9
		XD	3,059	108.6	10.6	108.6	413.1
	50-mil MicroDrain®	MD	2,739	124.3	29.8	147.4	393.6
		XD	4,053	146.3	10.9	146.3	458.2
	50-mil Super Gripnet®	MD	3,189	152.6	41.4	191.1	414.8
		XD	4,002	161.9	10.3	161.9	404.5
LLDPE	40-mil MicroSpike®	MD	1,193	69.7	22.5	80.2	476.9
		XD	1,391	69.9	17.8	74.2	487.6
	50-mil MicroDrain®	MD	1,972	106.4	24.8	130.2	466.4
		XD	2,192	110.1	14.3	119.2	483.2
	50-mil Super Gripnet®	MD	1,576	89.3	36.5	119.6	446.7
		XD	2,096	98.1	15.2	113.4	487.4

Notes: (1) MD = Machine Direction; XD = Cross-Machine Direction; (2) The stiffness values are the mean values of "Initial Tangent Modulus (lbs/in)" in the test reports.

Based on the wide width tensile test results, the stiffness values for the 50-mil HDPE and LLDPE Super Gripnet geomembranes are:

- For 50-mil HDPE Super Gripnet:
  - Machine Direction: $J_{GM,\ 50\text{-}mil\ HDPE\ SG,\ MD}$ = 3198 lb/in = 3.8×10^4 lb/ft
  - Cross-Machine Direction: $J_{GM,\ 50\text{-}mil\ HDPE\ SG,\ XD}$ = 4002 lb/in = 4.8×10^4 lb/ft

- For 50-mil LLDPE Super Gripnet:
  - Machine Direction: $J_{GM,\ 50\text{-}mil\ LLDPE\ SG,\ MD}$ = 1576 lb/in = 1.9×10^4 lb/ft
  - Cross-Machine Direction: $J_{GM,\ 50\text{-}mil\ LLDPE\ SG,\ XD}$ = 2096 lb/in = 2.5×10^4 lb/ft

The wide width tensile testing was also conducted on the standard-density engineered turf (see Attachment C-3). The average peak tensile strength was reported as 3,633 lb/ft at 28.2% strain on MD and 2,300 lb/ft at 9.8% strain on XD. The tension-strain curve before the peak is approximately linear. Therefore, the stiffness of the standard engineered turf is calculated as:

$$J_{ET,\ MD} = 3633 \text{ lb/ft} / 0.282 = 1.3 \times 10^4 \text{ lb/ft}$$

$J_{ET,\,XD}$ = 2300 lb/ft / 0.098 = 2.3x10^4 lb/ft

For the hypothetical project in this example, the 50-mil LLDPE geomembrane and standarddensity engineered turf are considered. Since during panel layout the machine direction of the engineered turf usually aligns with the machine direction of the engineered turf, the total stiffness of ClosureTurf is calculated as follows:

- $J = J_{GM,50-mil\ LLDPE\ SG,MD} + J_{ET,MD} = 1.9 \times 10^4 + 1.3 \times 10^4 = 3.2 \times 10^4$, along MD of engineered turf and structured geomembrane
- $J = J_{GM,50-mil\ LLDPE\ SG,XD} + J_{ET,XD} = 2.5 \times 10^4 + 2.3 \times 10^4 = 4.8 \times 10^4$, along XD of engineered turf and structured geomembrane

Step 15: Calculate tensile strain in ClosureTurf

The tensile strain in ClosureTurf is calculated along both the MD and XD of the engineered turf and structured geomembrane, as tension may be induced in either direction depending on the panel layout and wind direction.

The strain in ClosureTurf along the MD of the engineered turf and structured geomembrane is calculated as:

$$\varepsilon_{w,MD} = \frac{0.3467\left(\frac{S_e L}{J}\right)^{2/3}}{1 - 0.3103\left(\frac{S_e L}{J}\right)^{2/3}} = \frac{0.3467\left(\frac{1.71 \times 169.1}{3.2 \times 10^4}\right)^{2/3}}{1 - 0.3103\left(\frac{1.71 \times 169.1}{3.2 \times 10^4}\right)^{2/3}} = 0.015 = 1.5\%$$

The strain in ClosureTurf along the XD of the engineered turf and structured geomembrane is calculated as:

$$\varepsilon_{w,XD} = \frac{0.3467\left(\frac{S_e L}{J}\right)^{2/3}}{1 - 0.3103\left(\frac{S_e L}{J}\right)^{2/3}} = \frac{0.3467\left(\frac{1.71 \times 169.1}{4.8 \times 10^4}\right)^{2/3}}{1 - 0.3103\left(\frac{1.71 \times 169.1}{4.8 \times 10^4}\right)^{2/3}} = 0.012 = 1.2\%$$

The calculated tensile strain values are significantly less than the tensile strain at yield of the 50mil LLDPE Super Gripnet in either MD (i.e., 36.5%) or XD (i.e., 15.2%) (see Table A-2). These values are also significantly less than the tensile strain at yield in either MD (i.e., 28.2%) or XD (i.e., 9.8%) of the engineered turf. The calculated tensile strain values indicate that both the geomembrane and engineered turf are within the range of elastic deformations.

Step 16: Calculate tension in ClosureTurf

The tension in ClosureTurf along the MD of the engineered turf and structured geomembrane is calculated as:

$$T_{w,GM,MD} = 1.9 \times 10^4 \times 0.015 = 285\ lb/ft \text{ (Geomembrane)}$$

$$T_{w,ET,MD} = 1.3 \times 10^4 \times 0.015 = 195\ lb/ft \text{ (Engineered Turf)}$$

The total tension along MD is: $T_{w,MD} = 285 + 195 = 480\ lb/ft$

The tension in ClosureTurf along the XD of the engineered turf is calculated as:

$$T_{w,GM,XD} = 2.5 \times 10^4 \times 0.012 = 300\ lb/ft \text{ (Geomembrane)}$$

$$T_{w,ET,XD} = 2.3 \times 10^4 \times 0.012 = 276\ lb/ft \text{ (Engineered Turf)}$$

The total tension along XD is: $T_{w,XD} = 300 + 276 = 576\ lb/ft$

Step 17: Calculate factor of safety (FS) against yield

For the 50-mil LLDPE Super Gripnet geomembrane, the wide width tensile strength at yield is 89.3 lb/in (or 1,072 lb/ft) in the MD and 98.1 lb/in (or 1,177 lb/ft) in the XD, as presented in Table A-2. The FS against yield is calculated as:

$$FS_{y,GM} = \frac{T_y}{T_w} = \frac{1072}{285} = 3.8 \text{ (MD)}$$

$$FS_{y,GM} = \frac{T_y}{T_w} = \frac{1177}{300} = 3.9 \text{ (XD)}$$

For the standard-density engineered turf, the wide width tensile strength at yield is 3,633 lb/ft (MD) and 2,300 lb/ft (XD). The FS against yield is calculated as:

$$FS_{y,ET} = \frac{T_y}{T_w} = \frac{3633}{195} = 18.6\ (MD)$$

$$FS_{y,ET} = \frac{T_y}{T_w} = \frac{2300}{276} = 8.3\ (XD)$$

A minimum acceptable FS of 2.0 is selected in this example to incorporate both a global FS of 1.5 and possible minor reductions in ClosureTurf stiffness due to construction-related and long-term exposure-related effects. The above calculated FSs against yield of the geomembrane and engineered turf are greater than the minimum acceptable FS. Therefore, tensile yield of the geomembrane and engineered turf components of ClosureTurf in the "uplifted zone" due to

wind-induced loads should not occur. The ClosureTurf located outside the "uplifted zone" is not expected to experience uplift based on the analysis results. In addition, the ClosureTurf final cover system is required to be terminated in an anchor trench along the perimeter of the landfill, providing additional wind uplift resistance in areas proximal to the anchor trench.

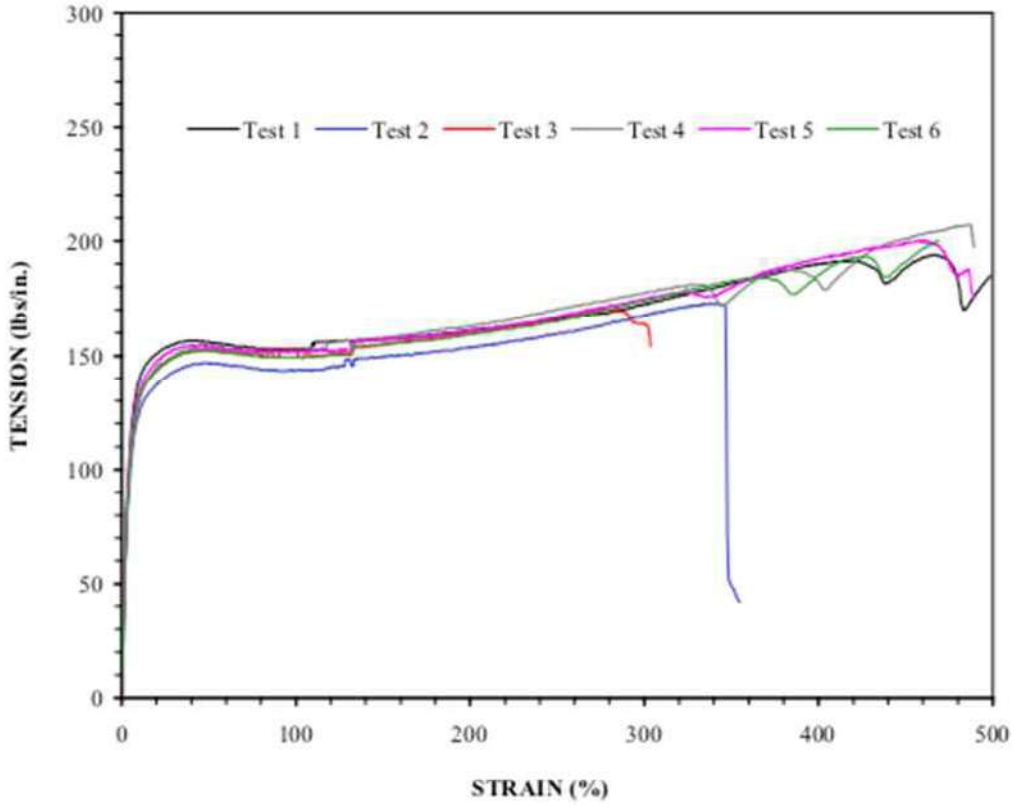
Based on the analysis results for the hypothetical example landfill, wind uplift in a local area near the landfill slope crest is expected under the selected design wind speed; however, no damage to the engineered turf or underlying structured geomembrane is anticipated due to the wind-induced loads. The ClosureTurf final cover system at this hypothetical landfill site is judged to have an adequate FS against tensile yield due to wind uplift.

Attachment C-2

Examples of Wide Width Tensile Test Results
of Structured Geomembranes of ClosureTurf

24137

WATERSHED GEOSYNTHETICS LLC
WIDE-WIDTH TENSILE TESTING OF GEOMEMBRANE (ASTM D 4885)
Agru 50-mil HDPE Super Gripnet Geomembarne # GTA 0068830036 in MD
SGI Lab Sample ID: S23273



Test No.	Initial Tangent Modulus (lbs/in)	Tension at 5% (lbs/in)	Tension at 10% (lbs/in)	Yield Strength (lbs/in)	Yield Strain (%)	Max Strength (lbs/in)	Elongation at Breaking (%)
1	3004	112.1	139.1	156.7	37.2	194.1	464.2
2	3125	100.2	124.7	146.9	46.4	173.0	334.4
3	3251	106.0	130.7	151.8	43.0	170.0	271.3
4	3045	103.8	129.7	153.2	39.5	206.9	483.0
5	3501	109.5	134.2	154.7	38.8	200.0	456.1
6	3207	106.2	131.2	152.3	43.5	202.6	479.9
Mean	3189	106.3	131.6	152.6	41.4	191.1	414.8
STD	179	4.2	4.8	3.3	3.5	15.8	89.5

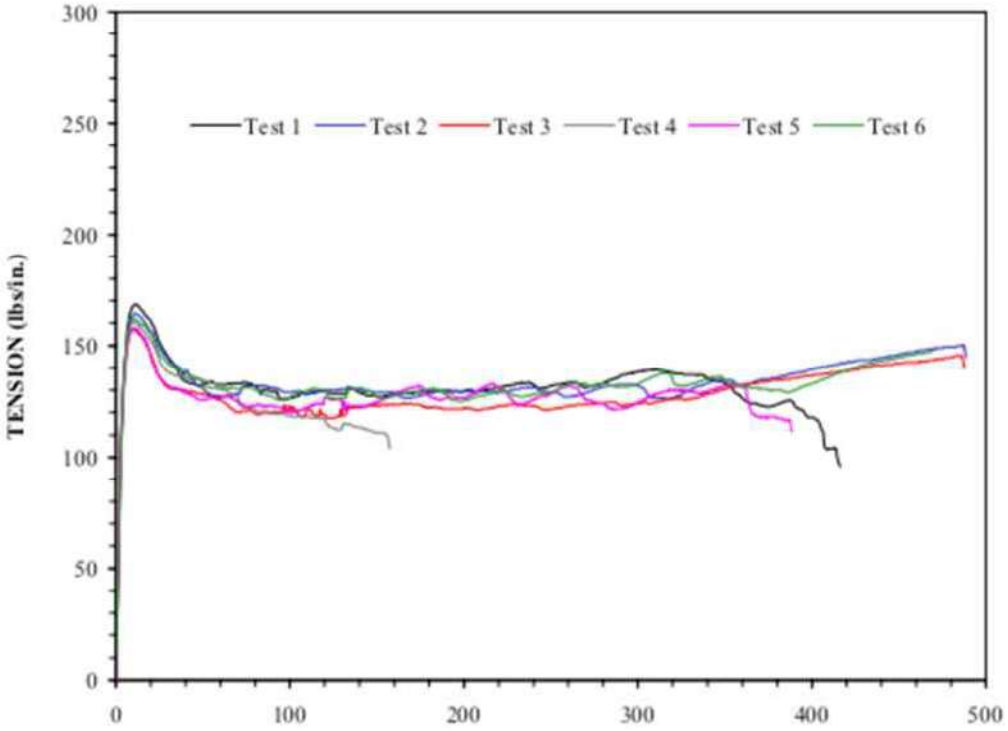
NOTES:

Clamp:	Curtis Sure Grip with cushion
Specimen Width (in.):	8.0
Specimen Length (in.):	8.0
Gage Length (in.)	4.0
Strain Rate (% per minute):	10

SGI TESTING SERVICES, LLC

DATE OF REPORT:	11/3/2021
FIGURE NO.	9
PROJECT NO.	SGI21014
DOCUMENT NO.	
FILE NO.	

WATERSHED GEOSYNTHETICS LLC
WIDE-WIDTH TENSILE TESTING OF GEOMEMBRANE (ASTM D 4885)
Agru 50-mil HDPE Super Gripnet Geomembarne # GTA 0068830036 in XD
SGI Lab Sample ID: S23273



Test No.	Initial Tangent Modulus (lbs/in)	Tension at 5% (lbs/in)	Tension at 10% (lbs/in)	Yield Strength (lbs/in)	Yield Strain (%)	Max Strength (lbs/in)	Elongation at Breaking (%)
1	3855	140.5	167.8	168.6	11.3	168.6	416.2
2	3779	139.3	163.8	164.6	10.9	164.6	488.5
3	4218	138.6	157.2	157.2	9.4	157.2	487.7
4	4195	140.6	160.6	160.6	9.7	160.6	157.3
5	3981	135.7	157.7	158.2	10.4	158.2	388.5
6	3983	138.5	161.9	162.1	10.2	162.1	489.0
Mean	4002	138.9	161.5	161.9	10.3	161.9	404.5
STD	177	1.8	4.0	4.2	0.7	4.2	128.5

NOTES:

Clamp:	Curtis Sure Grip with cushion
Specimen Width (in.):	8.0
Specimen Length (in.):	8.0
Gage Length (in.)	4.0
Strain Rate (% per minute):	10

SGI TESTING SERVICES, LLC

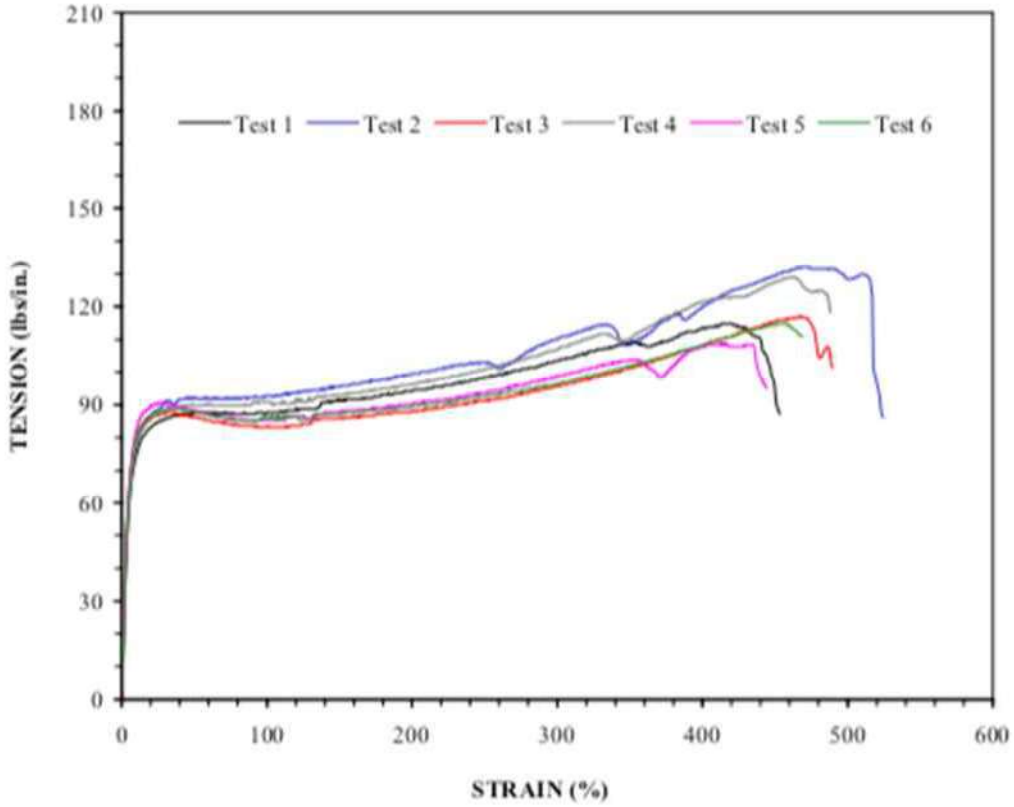
DATE OF REPORT:	11/4/2021
FIGURE NO.	10
PROJECT NO.	SGI21014
DOCUMENT NO.	
FILE NO.	

WATERSHED GEOSYNTHETICS LLC

WIDE-WIDTH TENSILE TESTING OF GEOMEMBRANE (ASTM D 4885)

Agru 50-mil LLDPE Super Gripnet Geomembarne #FNA0039890078 in MD

SGI Lab Sample ID: S23269



Test No.	Initial Tangent Modulus (lbs/in)	Tension at 5% (lbs/in)	Tension at 10% (lbs/in)	Yield Strength (lbs/in)	Yield Strain (%)	Max Strength (lbs/in)	Elongation at Breaking (%)
1	1593	57.9	74.8	87.2	41.3	115.3	417.7
2	1815	62.8	78.6	91.8	39.0	132.5	470.0
3	1694	63.7	80.0	87.6	33.5	117.3	467.4
4	1514	60.6	77.1	89.8	40.8	129.1	460.4
5	1383	64.2	82.5	90.7	27.8	108.9	412.7
6	1460	60.9	79.4	88.6	36.8	114.8	451.7
Mean	1576	61.7	78.7	89.3	36.5	119.6	446.7
STD	159	2.3	2.6	1.8	5.1	9.1	25.3

NOTES:

Clamp:	Curtis Sure Grip with cushion
Specimen Width (in.):	8.0
Specimen Length (in.):	8.0
Gage Length (in.)	4.0
Strain Rate (% per minute):	10

SGI TESTING SERVICES, LLC

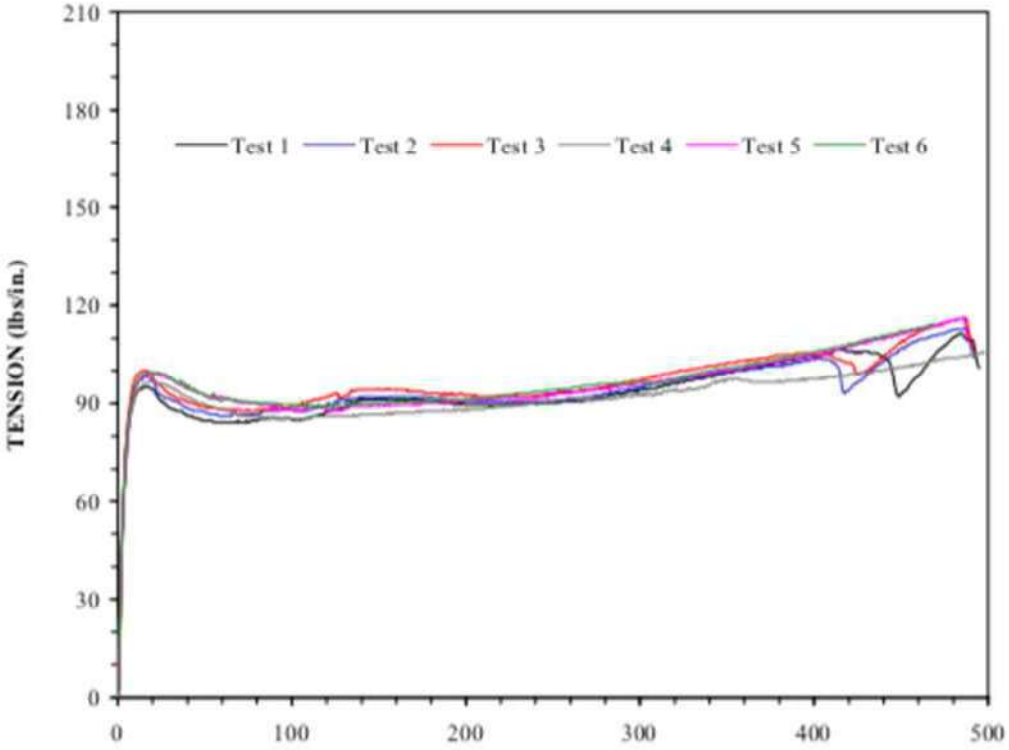
DATE OF REPORT:	10/24/2021
FIGURE NO.	1
PROJECT NO.	SGI21014
DOCUMENT NO.	
FILE NO.	

WATERSHED GEOSYNTHETICS LLC

WIDE-WIDTH TENSILE TESTING OF GEOMEMBRANE (ASTM D 4885)

Agru 50-mil LLDPE Super Gripnet Geomembame #FNA0039890078 in XD

SGI Lab Sample ID: S23269



Test No.	Initial Tangent Modulus (lbs/in)	Tension at 5% (lbs/in)	Tension at 10% (lbs/in)	Yield Strength (lbs/in)	Yield Strain (%)	Max Strength (lbs/in)	Elongation at Breaking (%)
1	2034	75.3	92.6	95.1	14.4	111.3	482.8
2	2180	79.3	95.2	98.5	15.9	113.3	486.7
3	2064	80.5	97.7	100.0	13.5	116.8	487.4
4	2149	74.5	92.2	96.6	16.0	105.9	497.1
5	2048	75.4	94.0	99.0	17.0	116.3	485.4
6	2102	77.3	95.2	99.5	14.3	116.8	485.0
Mean	2096	77.1	94.5	98.1	15.2	113.4	487.4
STD	58	2.4	2.0	1.9	1.3	4.3	5.0

NOTES:

Clamp:	Curtis Sure Grip with cushion
Specimen Width (in.):	8.0
Specimen Length (in.):	8.0
Gage Length (in.)	4.0
Strain Rate (% per minute):	10

DATE OF REPORT:	11/3/2021
FIGURE NO.	2
PROJECT NO.	SGI21014
DOCUMENT NO.	
FILE NO.	

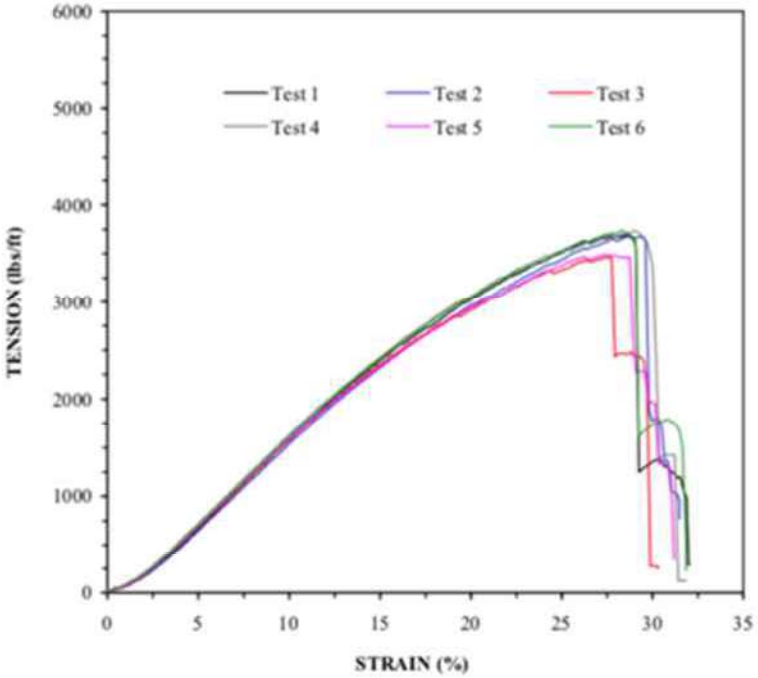
SGI TESTING SERVICES, LLC

Attachment C-3

Wide Width Tensile Test Results of Standard-Density Engineered Turf

WG
24137

WATERSHED GEOSYNTHETICS LLC
WIDE-WIDTH TENSILE TESTING (ASTM D 4595)
CT32 Synthetic Turf Sample in MD
SGI Sample ID No. S22008



Test No.	Tension at 2% (lb/ft)	Tension at 5% (lb/ft)	Tension at 10% (lb/ft)	Ultimate Strength (lb/ft)	Strain at Ultimate (%)
1	177	670	1580	3689	28.4
2	166	650	1541	3675	28.6
3	185	683	1571	3464	27.4
4	205	725	1636	3734	29.0
5	191	701	1583	3494	27.3
6	193	699	1605	3741	28.3
Mean	186	688	1586	3633	28.2
STD	13	26	32	122	0.7

NOTES:

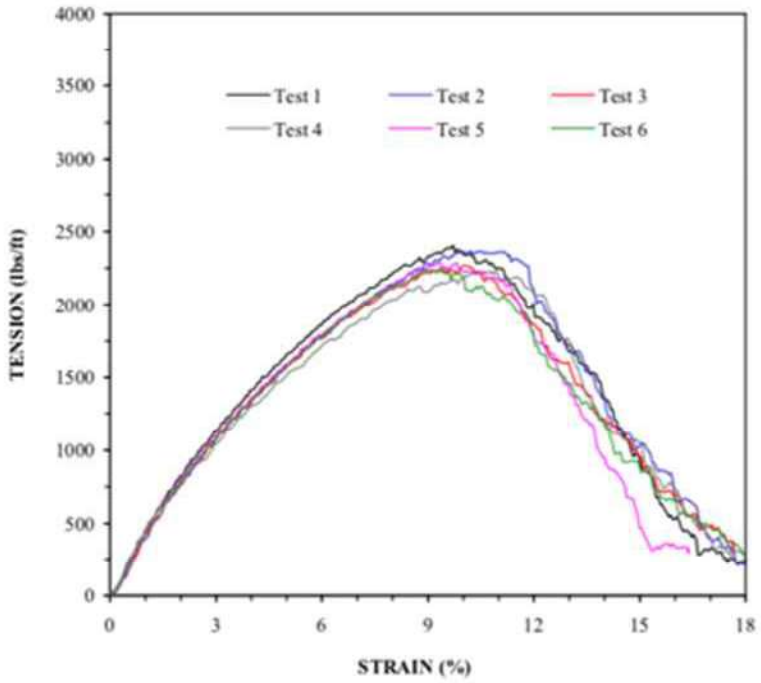
Clamp:	Curtis
Specimen Width (in.):	8.0
Yarn Count (yarns/in.):	Not Measured
Specimen Length (in.):	8
Preload (lbs):	1% of breaking load
Strain Rate (% per minute):	10

SGI TESTING SERVICES, LLC

DATE TESTED:	4/10/2019
FIGURE NO.	2
PROJECT NO.	SGI19014
DOCUMENT NO.	
FILE NO.	

Note: “CT32 Synthetic Turf” denoted in the test report is the standard-density engineered turf, CT.

WATERSHED GEOSYNTHETICS LLC
WIDE-WIDTH TENSILE TESTING (ASTM D 4595)
CT32 Synthetic Turf Sample in XD
SGI Sample ID No. S22008



Test No.	Tension at 2% (lb/ft)	Tension at 5% (lb/ft)	Tension at 10% (lb/ft)	Ultimate Strength (lb/ft)	Strain at Ultimate (%)
1	825	1662	NA	2405	9.7
2	772	1584	2359	2368	10.2
3	769	1577	NA	2265	10.0
4	786	1514	2182	2228	10.6
5	809	1582	NA	2284	9.3
6	792	1570	NA	2247	9.3
Mean	792	1582	NC	2300	9.8
STD	22	47	NC	71	0.5

NOTES:

Clamp:	Curtis
Specimen Width (in.):	8.0
Yarn Count (yarns/in.):	Not Measured
Specimen Length (in.):	8
Preload (lbs):	1% of breaking load
Strain Rate (% per minute):	10

SGI TESTING SERVICES, LLC

DATE TESTED:	4/10/2019
FIGURE NO.	3
PROJECT NO.	SGI19014
DOCUMENT NO.	
FILE NO.	

Note: “CT32 Synthetic Turf” denoted in the test report is the standard-density engineered turf, CT.

References

American Society of Civil Engineers (ASCE) (2022). "Minimum Design Loads and Associated Criteria for Buildings and Other Structures," ASCE standard, ASCE/ SEI 7-22.

Dedrick, A.R. (1973). "Air Pressures Over Reservoir, Canal, and Water Catchment Surfaces Exposed to Wind," Ph.D. Dissertation, Utah State University, Logan, Utah.

Giroud, J.P. (2009). "An Explicit expression for strain in geomembrane uplifted by wind." *Geosynthetics International*, Vol. 16, No. 6, 500-502.

Giroud, J.P., Pelte, T. and Bathurst, R.J. (1995). "Uplift of Geomembranes by Wind," Geosynthetics International, Vol. 2, No. 6, pp. 897-952.

Peggs, I.D., Schmucker, B., and Carey, P. (2005). "Assessment of maximum allowable strains in polyethylene and polypropylene geomembranes." *Geo-Frontiers Congress 2005*, January 24-26, 2005, Austin, Texas.

Peterson, E.W. and Hennessey, Jr., J.P. (1978). "On the Use of Power Laws for Estimates of Wind Power Potential," J. Appl. Meteorology, Vol. 17, pp. 390-394.

Vickery, P.J., and Skerlj, P.F. (2005). "Hurricane Gust Factors Revisited," J. Struct. Eng., 131(5), 825–832.

Wayne, M.H. and Koerner, R.M. (1988). "Effect of Wind Uplift on Liner Systems," Geotechnical Fabrics Report, July/August.

Zheng, J., Sarkar, P., Jafari, M., Hou, F., Li, Z., Sun, Q., and Zhu, M. (2020). "Wind Tunnel Study of ClosureTurf Landfill Final Cover System," Geo-Congress 2020, ASCE GSP 316, pp. 650-658.

Zornberg, J. and Giroud, J.P. (1997). "Uplift of geomembranes by wind – extension of equations." *Geosynthetics International*, Vol. 4, No. 2: 187-207.

Zhu, M., Sarkar, P., Hou, F., and Zheng, J. (2022). "Wind Tunnel Study and Uplift Analysis of Geosynthetic Covers.", Geo-Congress 2022, GSP 331: 543-553.

LIMITATIONS

ClosureTurf®, HydroTurf®, VersaCap®, TerraArmor® and PowerCap™ are U.S. registered trademarks which designate products from Watershed Geosynthetics LLC and/or its affiliated companies (collectively, "WG") that are the subject of issued and/or pending U.S. and foreign patents and patent applications. All information provided herein by WG concerning these products are based upon data derived from independent third-party testing. This information, however, should not be used or relied upon for any specific use without first consulting with an independent professional engineer licensed in the geographic area in which a project is located. Since the actual site conditions, and the installation and use of these products are beyond our control, no guaranty or warranty of any kind, expressed or implied, is made by WG with respect to these products.

Appendix D
ClosureTurf Hydrostatic Puncture Test Report

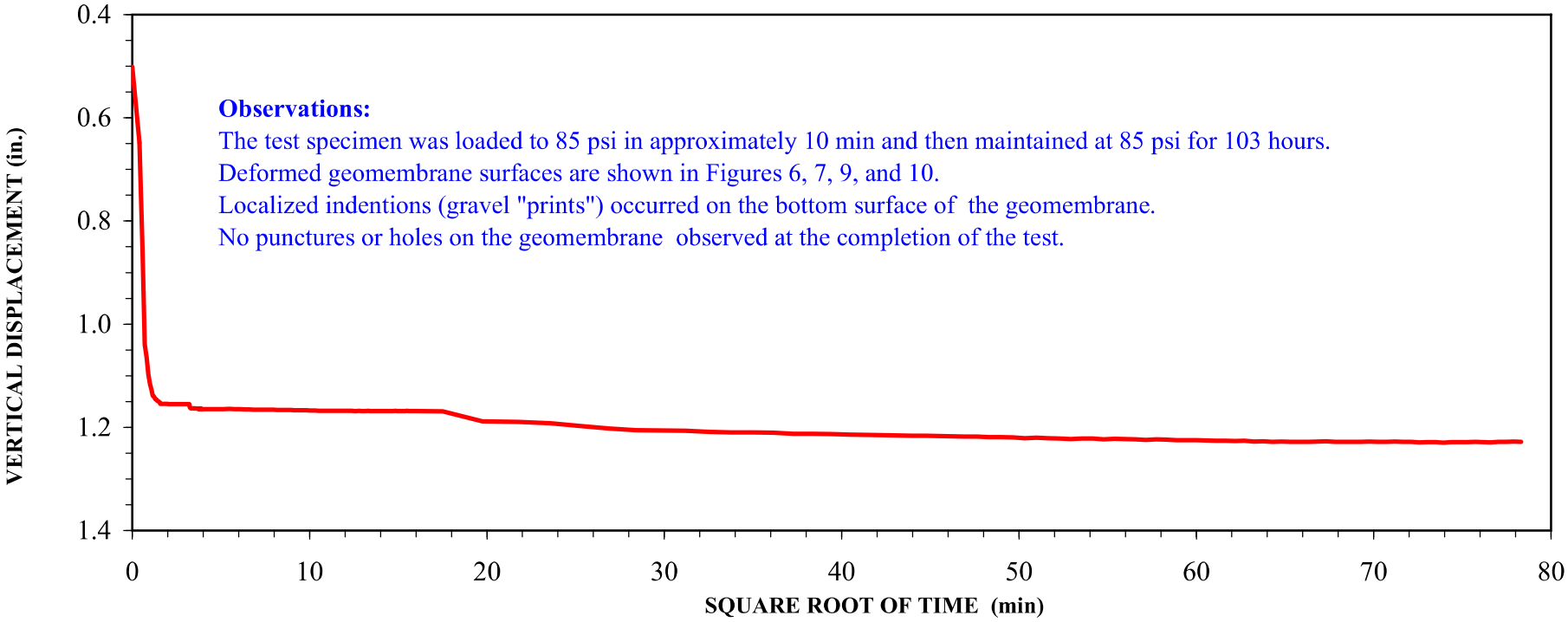
Hydrostatic Puncture Test Report

Notes:

1. The testing was performed on the HydroTurf sample; however, the test results are applicable to ClosureTurf because they both consist of structured geomembrane and engineered turf.
2. The testing was performed on a 40-mil MicroSpike geomembrane. If a thicker (i.e., 50-mil) MicroDrain or Super Gripnet geomembrane is used in ClosureTurf, th epuncture performance is expected to be improved.
3. The testing was performed at a maximum loading of 85 psi. Since no punctures or holes were observed, the ultimate static puncture strength of the system was not reached and therefore, should be greater than 85 psi.

WATERSHED GEOSYNTHETICS LLC- VIRGINIA PROJECT
HYDROSTATIC PUNCTURE TESTING (ASTM D 5514[(1)])

Concrete sand
HydroeTurf (2.25" long monofilament) #ZH37391 with geotextile (straight stitching pattern) down
Agru 40-mil Microspike HDPE geomembrane #G18C000439 with dull side up and shiny side down
VDOT #57 stone nominally compacted



Test	Test Specimen Size				Normal	Total	Concrete sand			#57 Stone		
	Length	Width	Upper Soil Thickness	Lower Soil Thickness	Stress	Duration	γ_d	ω_i	ω_f	γ_d	ω_i	ω_f
No.	(in.)	(in.)	(in.)	(in.)	(psi)	(hours)	(pcf)	(%)	(%)	(pcf)	(%)	(%)
1	12.0	12.0	3.0	6.0	85	102						

NOTE: (1) *Localized strains of the deformed geomembrane not calculated.*

SGI TESTING SERVICES, LLC

DATE OF REPORT:	3/2/2018
FIGURE NO.	A-2
PROJECT NO.	SGI18014
DOCUMENT NO.	
FILE NO.	

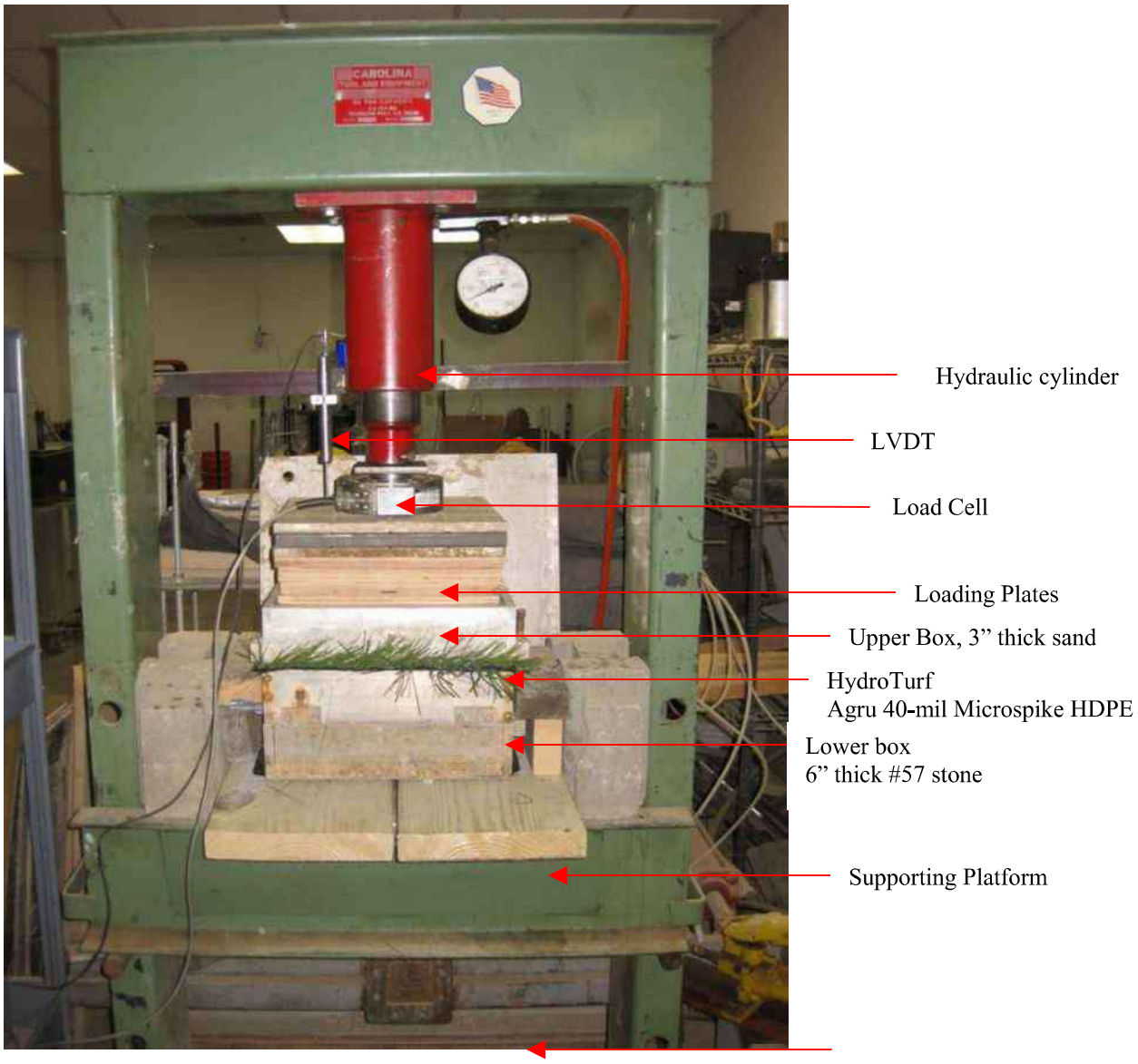


Figure 1. View of hydrostatic puncture test setup.



Figure 2. Compacted VDOT #57 stone in the lower box.



Figure 3. HydroTurf and geomembrane placed on top of compacted #57 stone.



Figure 4. Concrete sand placed in the upper box on top of HydroTurf.



Figure 5. Bottom surface of HydroTurf after the completion of test.



Figure 6. Deformed top surface of the geomembrane after the completion of test. No punctures or holes observed.



Figure 7. Deformed bottom surface of the geomembrane in contact with #57 stone after the completion of test. No punctures or holes observed.

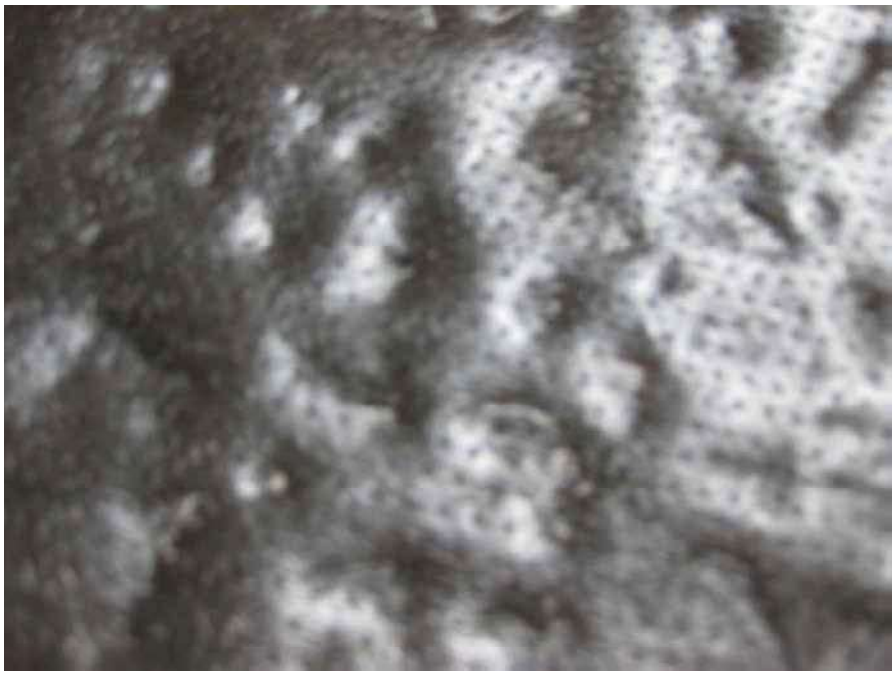


Figure 8. Deformed bottom surface of the geomembrane in contact with #57 stone after the completion of test. No punctures or holes observed.



Figure 9. Deformed top surface of the geomembrane after the completion of test. No punctures or holes observed.

Appendix E
Parametric Study Results for Pond Design

Comparing Stormwater Pond Design for Traditional Soil Cover versus Engineered Synthetic Turf Cover

Antonio Sanchez[1] and Ming Zhu[2]

[1]Geosyntec Consultants, 1255 Roberts Blvd. NW, Suite 200, Kennesaw, GA 30144
[2]Watershed Geosynthetics, 11400 Atlantis Place, Suite 200, Alpharetta, GA 30022

CONFERENCE: 2019 World of Coal Ash – (www.worldofcoalash.org)

KEYWORDS: Landfill Final Cover, Stormwater Pond Design, Engineered Synthetic Turf Cover

ABSTRACT: A parametric study is performed to compare the stormwater pond design of a conceptual waste disposal site with two final cover systems: a traditional soil cover system and an engineered synthetic turf cover system, ClosureTurf®. The geometry of the conceptual site and the design storm events are varied in the study. Two representative runoff curve numbers (CN) are considered for the traditional soil cover system. The stormwater pond is designed with the capacity to attenuate the stormwater runoff flows, as well as to promote water quality treatment through settling of suspended solids. Because the runoff from the ClosureTurf cover system carries little to no solids, the analysis is also performed without the requirement of sediment storage volume for ClosureTurf.

The stormwater analysis results of the traditional soil cover system and the ClosureTurf cover system are compared, including the time of concentration, the perimeter channel peak flow depth, and the stormwater pond peak depth, peak discharge, and peak storage. The analysis results of the conceptual site indicate that the ClosureTurf cover system generates higher peak runoff flow rates than the traditional soil cover system. Under the 25-year (yr), 24-hour (hr) design storm event, the calculated peak storage of the stormwater pond for the ClosureTurf cover system increases by approximately 5% and 10%, respectively, compared to the traditional soil cover system with a CN of 84 and 74; while under the 100-yr, 24-hr design storm event, it increases by approximately 10% and 20%, respectively.

INTRODUCTION

The final cover system is critical to environmental closures of waste disposal facilities, e.g., landfills and coal combustion residual (CCR) impoundments. A traditional soil cover system is typically comprised of (from top to bottom): (i) a topsoil layer; (ii) a vegetative soil layer; (iii) a geocomposite drainage layer; and (iv) a geomembrane barrier layer. The traditional soil cover system design necessitates a construction process with a steady supply of final cover soils. Furthermore, on-going maintenance of the traditional soil cover system is required to establish vegetative cover, which often

includes repairing erosion and addressing sedimentation issues during construction and operation of the final cover system.

ClosureTurf is a relatively new alternative to traditional soil cover systems that has been used in the past 10 years. It is comprised of (from bottom to top): (i) a structured geomembrane, (ii) an engineered turf, and (iii) a specialized sand infill (bonded or unbonded). This system replaces the topsoil and vegetative soil layers thereby mitigating the need for a supply of final cover soils. It has also demonstrated other benefits, including faster construction speed, improved runoff quality, reduced post-closure maintenance cost, and less environmental and community impact (e.g., no land disturbance for borrow soils and less truck trips through neighboring communities).

This study presents a comparative analysis of the stormwater pond design between the traditional soil cover system and the ClosureTurf cover system. The sections below discuss the design criteria, design methodology, input parameters, and analysis results.

DESIGN CRITERIA

The following criteria are used in designing the stormwater pond.

Peak Flow Management

A fundamental aspect of landfill engineering is the design of stormwater pond to satisfy local and state regulatory requirements for pre-development versus post-development hydrology. The stormwater pond is designed such that the pre-development peak discharge flow rate is less than the post-development for the 2-, 5-, 10-, 25-, and 100-yr, 24-hr storm events.

Wet Detention Pond

The stormwater pond is designed as a wet detention pond to achieve water quality and quantity performance. A wet detention pond is an impounded area with the capacity to attenuate the stormwater runoff flows and promote water quality treatment through settling of suspended solids. The wet detention pond for the traditional soil cover system is required to include the sediment storage volume within the permanent pool volume. For ClosureTurf, the sediment storage volume is not needed because the runoff carries little to no solids.

The wet detention pond is designed with a primary spillway to manage flows up to the 25-yr, 24-hr storm event and an emergency spillway to support managing flows up to the 100-yr, 24-hr storm event without overtopping. Under the 25-yr, 24-hr storm event, the pond is designed without overtopping into the emergency spillway. Under the 100-yr, 24-hr storm event, the pond is designed to have at least 1.0 feet (ft) (0.3 meters, m) of freeboard. A pre-treatment forebay is not considered in the study.

Water Quality Volume (WQV)

WQV is the storage needed to capture and treat the runoff from 90% of the average annual rainfall. For the purposes of this study, the WQV for the site is assumed to be runoff for the 1.0-inch (2.5 centimeters, or cm) rainfall event and the design treatment is the release of the WQV over 24 to 72 hr after the storm event.

Sediment Storage Volume

For a traditional soil cover system, the permanent pool within the stormwater pond is typically required to include the sediment storage volume for erosion and sedimentation management. The sediment storage volume used in this study is equivalent to 67 cubic yards per acre of drainage area (or 127 cubic meters per hectare). As discussed previously, this volume is not needed for ClosureTurf. For the purposes of this study, ClosureTurf is analyzed with and without the sediment storage volume to evaluate its effect on the overall stormwater pond design.

Channel Geometry

Stormwater runoff and concentrated discharges from the final cover are conveyed to the wet detention pond via perimeter channels. In this study, the perimeter channels are designed to convey the flow for the 25-yr, 24-hr storm event with at least 0.5 ft (0.15 m) of freeboard.

DESIGN METHODOLOGY

Modeling Software

The design calculations for the drainage areas, channels, and ponds are performed using the hydrology and hydraulic procedures in the Soil Conservation Service (SCS) Technical Release (TR-55) [SCS, 1986] and other recognized engineering procedures and equations, such as the Manning's kinematic equation, that are encoded in the HydroCAD™ software [HydroCAD, 2018].

Runoff Curve Number

SCS TR-55 includes the Runoff Curve Number Method for estimating runoff flow depth.

$$Q = \frac{(P-0.2S)^2}{P+0.8S} \quad (1)$$

$$S = \frac{1000}{CN} - 10 \quad (2)$$

Where, Q = runoff (inches, in.); P = rainfall (in.); S = potential maximum retention after runoff begins (in.); and CN = curve number. S expresses the soil and cover conditions of the drainage area through the variable CN, which has a range of 0 to 100.

Travel Time

SCS TR-55 includes the travel time methods for sheet flow, shallow concentrated flow, and open channel flow. For the purposes of this study, it is assumed that sheet flow and shallow concentrated flow characterize the stormwater runoff over the cover systems. Travel time for sheet flow is calculated as follows [SCS, 1986]:

$$T_S = \frac{0.007\ (nL)^{0.8}}{(P_2{}^{0.5})s^{0.4}} \quad (3)$$

Where, T_s = sheet flow travel time (hr); n = Manning's roughness coefficient; L = sheet flow length (ft); P_2 = 2-yr, 24-hr rainfall (in.); and s = slope of hydraulic grade line (land slope, ft/ft).

After a maximum of 100 ft, sheet flow is assumed to become shallow concentrated flow. Travel time for shallow concentrated flow is calculated [SCS, 1986] as follows:

$$T_{sc} = \frac{L}{3600V} \quad (4)$$

$$V = Ks^{0.5} \quad (5)$$

Where, T_{sc} = shallow concentrated flow travel time (hr); L = shallow concentrated flow length (ft); V = unpaved surface flow velocity (ft per second, or fps); K is the velocity factor (fps); and s = slope of hydraulic grade line (land slope, ft/ft).

Time of Concentration

The sum of T_s and T_{sc} for a drainage area is the time of concentration, which is the total duration time for runoff to travel from the hydraulically most distant point in the drainage to a point of interest, such as an outfall or confluence.

INPUT PARAMETERS

ClosureTurf exhibits a reduced potential for evapotranspiration and stormwater infiltration due to absence of soil layers in the final cover system. Therefore, it is important to summarize the difference in input parameters used for the traditional soil cover system and ClosureTurf cover system to calculate the stormwater runoff.

Rainfall

For the purposes of the study, Effingham, South Carolina is selected as the site location. The vicinity of the site is classified as either a Type II or III rainfall distribution [SCS, 1986]. Table 1 [NOAA, 2019] lists the rainfall depths associated with the 24-hr design storm events.

Table 1. Rainfall Depths for 24-hr Storm Events

24-hr Storm Event	Rainfall Depth (in.; cm in parentheses)
2-yr	3.54 (9.0)
5-yr	4.52 (11.5)
10-yr	5.38 (13.7)
25-yr	6.71 (17.0)
100-yr	9.20 (23.4)

Existing Conditions and Site Design

The site is assumed to be a 40-acre (16-hectare) area with a combined woods and grass land cover under the existing conditions. The site soils are assumed to be of the hydrologic soil group (HSG) 'B' classification, which is designated for moderately deep and well-draining soils with fine to course texture. The drainage within the site is characterized by a 1% land slope from the headwaters of the site down to the outfall.

The conceptual site design for both the final cover systems is assumed to be a simple landfill design comprised of a singular peak elevation with a shallow top deck that drains onto steeper side slopes. The side slopes do not include benches because their length is less than 100 ft (30.5 m), which is the maximum sheet flow length. The stormwater runoff from the side slopes is collected and conveyed by channels that discharge into the stormwater pond. For the purposes of this study, the top deck slopes and side slopes vary to assess the effect on the stormwater pond design. Table 2 lists the top deck and side slope variations for each scenario. A schematic of the site stormwater management system is presented in Figure 1.

Table 2. Site Geometry Scenarios

Scenario	Side Slopes	Top Deck Slopes
1	5H:1V	1%
2	5H:1V	2%
3	5H:1V	5%
4	5H:1V	8%
5	3H:1V	1%
6	3H:1V	2%
7	3H:1V	5%
8	3H:1V	8%

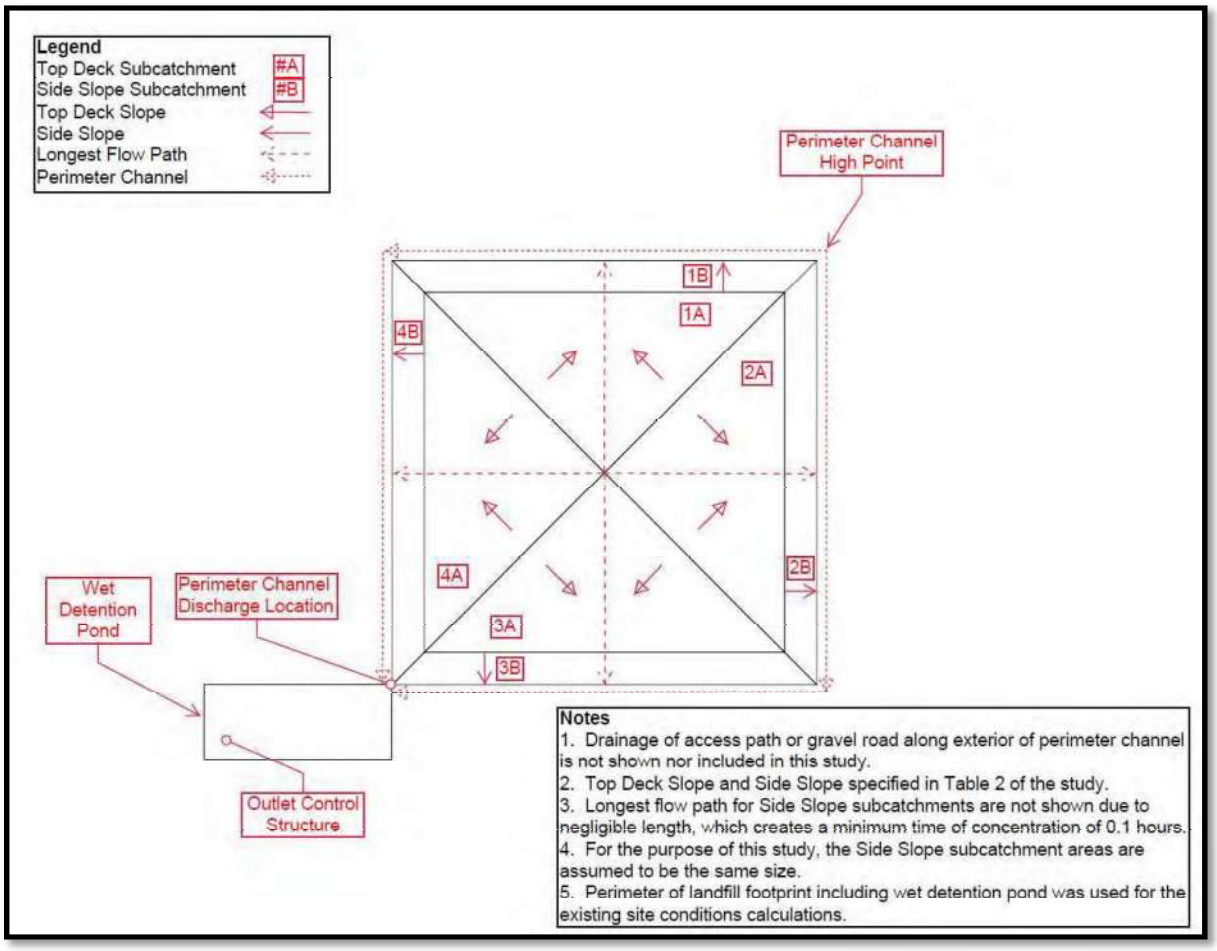


Figure 1. Final Cover Stormwater Management System Schematic

Runoff Curve Number

The CN is determined by the hydrologic soil group (HSG), cover type, treatment, and hydrologic condition, and antecedent runoff condition (ARC). For the existing site conditions, a CN value of 58 corresponds to a "woods and grass in good conditions" land use for HSG B. For the traditional soil cover, two CN values are considered in the study to represent a typical range used in the landfill design: (1) A CN value of 74 corresponds to "open space in good condition" land use for HSG C. HSG C is comprised of moderately fine to fine texture soils with low infiltration rates and they consist chiefly of soils with a layer that mitigate infiltration; and (2) A CN value of 84 corresponds to "open space in fair condition" land use for HSG D, which have clay soils and lower infiltration rates. For ClosureTurf, a CN value ranges from 92 to 95 for high intensity and normal intensity rainfall events [Watershed Geosynthetics, 2018]. A CN value of 95 is a conservative assumption for runoff calculations and thus considered in the study.

The CN values for the drainage areas under each site condition are summarized in Table 3 [Watershed Geosynthetics, 2018; HydroCAD™, 2018].

Table 3. Curve Numbers Used in Analyses

Condition	Curve Number (CN)
Existing Conditions	58
Traditional Soil Cover System (HSG C, good condition)	74
Traditional Soil Cover System (HSG D, fair condition)	84
ClosureTurf Cover System	95
Stormwater Pond	98

Manning's Roughness Coefficient for Sheet Flow

The Manning's roughness coefficients are selected for the existing conditions, the traditional soil cover system, and ClosureTurf cover system, as presented in Table 4. The existing conditions are characterized as woods with light underbrush. The traditional soil cover system is characterized as dense grass. The ClosureTurf cover system parameters are selected from the ClosureTurf Design Manual [Watershed Geosynthetics, 2018].

Table 4. Manning's Roughness Coefficient for Sheet Flow

Condition	Manning's Roughness Coefficient, n
Existing Conditions	0.40
Traditional Soil Cover System	0.15
ClosureTurf Cover System	0.12 (for slopes > 10%) 0.22 (for slopes < 10%)

Velocity Factors for Shallow Concentrated Flow

The conditions associated with selecting the velocity factors for the existing conditions, traditional soil cover, and ClosureTurf are characterized as woodland, short grass pasture, and unpaved [Watershed Geosynthetics, 2018], respectively. The selected velocity factors are summarized in Table 5.

Table 5. Velocity Factors for Shallow Concentrated Flow

Shallow Concentrated Flow Land Use	Velocity Factor, K, (fps; mps in parentheses)
Existing Conditions	5 (1.5)
Traditional Soil Cover System	7 (2.1)
ClosureTurf Cover System	16.1 (4.9)

The relationship between the shallow concentrated flow velocity, the velocity factor, and slope is shown in Equation (5) in the previous section.

Wet Detention Pond

In this study, the wet detention pond is designed as a rectangular prismatoid with a length to width ratio (at bottom) of 3 to 1 to avoid short circuiting of inflows that can reduce the potential for settling of suspended solids. The side slopes of bottom dimensions are fixed at 175-ft (53.3 m) wide and 525-ft (160 m) long, and the side slopes are fixed at 3 Horizontal to 1 Vertical (3H:1V).

Outlet Control Structures

The outlet control structure is selected to be a perforated vertical riser structure with circular vertical orifice perforations and a singular horizontal orifice. In addition, an emergency spillway is included to manage the high intensity storm (i.e., the 100-yr, 24-hr storm event).

Channel Geometry and Lining

Typical landfill design includes perimeter channels that capture runoff or concentrated discharges from the final cover system. These flows are then conveyed to the stormwater pond. The perimeter channels were designed using a cross-sectional geometry with a 4-ft (1.2-m) bottom width, a 4-ft (1.2-m) depth, 3H:1V side slopes, and a 0.5% longitudinal slope. The perimeter channel design includes the selection of a channel lining design of either vegetation or riprap lining, which depends on the degree of erosional forces within the channels. Riprap channel lining is selected for both the traditional soil cover and ClosureTurf. A 15-in. thick channel lining comprised of a 6-in. (15.2-cm) d_{50} riprap is considered for both design scenarios, which corresponds to a Manning's roughness coefficient of 0.069 [HydroCAD^{TM}, 2018].

ANALYSIS RESULTS

The following results are presented for a 10-ft (3-m) deep wet detention pond design that includes a primary spillway comprised of a 4-in. (10.2-cm) diameter vertical low-flow orifice and a 36-in. (91-cm) diameter horizontal orifice as well as a 20-ft (16-m) wide weir as an emergency spillway. The 4-in. (10.2-cm) diameter vertical low-flow orifice satisfies the 24- to 72-hr drawdown requirement. They are located at depths of 0.8 ft (0.2 m), 5.5 ft (1.7 m), and 7.5 ft (2.3 m), respectively, from the bottom of the pond to satisfy the design criteria for the wet detention ponds that include a sediment storage volume. When the sediment storage volume is not included, the low-flow orifice depth is lowered to the bottom of the pond at 0.0 ft.

Time of Concentration

Table 6 presents the calculated times of concentration of the top deck subcatchments by varying the slope from 1% to 8%.

Table 6. Time of Concentration for Varying Top Deck Subcatchments

Top Deck Slope	Time of Concentration (minutes)	
	Traditional Soil Cover System	ClosureTurf Cover System
1%	26.1	20.7
2%	17.6	14.1
5%	11.4	9.2
8%	9.2	7.5

The side slope subcatchments have a travel time set as the minimum value of 0.1 hr (or 6 minutes) given the short flow lengths. The differences in calculated travel times of the side slope subcatchments are negligible (i.e., less than 0.1 minutes) by varying the slope from 5H:1V to 3H:1V. Furthermore, the analysis results indicate that, generally, the variations in the top deck slopes and side slopes have a negligible impact on the design of the wet detention pond. These results are expected given that the side slope lengths are short and steep for the assumed conceptual site. Although the calculated total time of concentration of flow from the top deck and side slopes varies, the discharges are concentrated into the large and long perimeter channels that provide additional flow rate attenuation prior to discharging to the wet detention pond.

The site geometry with the 8% top deck and 3H:1V side slopes is used to evaluate the stormwater pond design presented in the sections below.

Peak Flow Depth in Perimeter Channels

The calculated peak flow depth within the perimeter channels are presented in Table 7.

Table 7. Perimeter Channel Peak Flow Depth

24-hr Storm Event	Peak Flow Depth (ft; m in parentheses)		
	Traditional Soil Cover System		ClosureTurf Cover System
	CN = 74	CN = 84	
2-yr	1.3 (0.4)	2.0 (0.6)	2.2 (0.7)
5-yr	1.7 (0.5)	2.3 (0.7)	2.5 (0.8)
10-yr	2.0 (0.6)	2.6 (0.8)	2.7 (0.8)
25-yr	2.4 (0.7)	2.9 (0.9)	3.1 (0.9)
100-yr	3.1 (0.9)	3.4 (1.0)	3.6 (1.1)

The results indicate that ClosureTurf cover system requires slightly deeper perimeter channels than the traditional soil cover system.

Peak Discharge (Pre- versus Post-Development)

Table 8 presents the calculated peak discharge flow rates from the site under the pre-development condition (i.e., the existing conditions) and the post-development condition (i.e., after the site is closed with either the traditional soil cover or ClosureTurf).

Table 8. Comparison of Peak Discharge

24-hr Storm Event	Peak Discharge (cfs; cms in parentheses)				
	Existing Conditions	Traditional Soil Cover System		ClosureTurf Cover System	
		CN = 74	CN = 84	With Sediment Storage[1]	No Sediment Storage
2-yr	5 (0.14)	1 (0.03)	1 (0.03)	1 (0.03)	1 (0.03)
5-yr	13 (0.4)	1 (0.03)	1 (0.03)	3 (0.09)	1 (0.03)
10-yr	22 (0.6)	1 (0.03)	3 (0.09)	10 (0.28)	6 (0.17)
25-yr	37 (1.0)	4 (0.11)	11 (0.3)	31 (0.88)	20 (0.6)
100-yr	70 (2.0)	26 (0.7)	43 (1.2)	65 (1.8)	50 (1.4)

Note: [1]. The case with sediment storage is analyzed to show its effect on the stormwater pond design of the ClosureTurf cover system. Sediment storage volume is not needed for the ClosureTurf cover system because the runoff carries little to no suspended solids.

The results indicate that the ClosureTurf cover system generally generates more peak discharges than the traditional soil cover system. However, both final cover systems generate lower peak discharges than the existing conditions and thus satisfy the pre- and post-development design criteria.

Peak Flow Depth in Pond

Table 9 presents the calculated peak depth within the wet detention pond.

Table 9. Wet Detention Pond Peak Depth

24-hr Storm Event	Peak Depth (ft; m in parentheses)			
	Traditional Soil Cover System		ClosureTurf Cover System	
	CN = 74	CN = 84	With Sediment Storage[1]	No Sediment Storage
2-yr	2.8 (0.9)	3.7 (1.1)	4.9 (1.5)	4.2 (1.3)
5-yr	3.8 (1.2)	4.8 (1.5)	5.7 (1.7)	5.5 (1.7)
10-yr	4.7 (1.4)	5.6 (1.7)	5.9 (1.8)	5.8 (1.8)
25-yr	5.7 (1.7)	6.0 (1.8)	6.5 (2.0)	6.2 (1.9)
100-yr	6.4 (2.0)	7.0 (2.1)	7.9 (2.4)	7.5 (2.3)

See Note 1 under Table 8.

Peak Storage in Pond

The peak storage in the wet detention pond is calculated based on the peak flow depth presented in Table 9 using the stage-storage relationship of the wet detention pond and the results are presented in Table 10.

Table 10. Wet Detention Pond Peak Storage

24-hr Storm Event	Peak Storage, (acre-ft; 1,000 cubic meters in parentheses)			
	Traditional Soil Cover System		ClosureTurf Cover System	
	CN = 74	CN = 84	With Sediment Storage[1]	No Sediment Storage
2-yr	6.3 (7.8)	8.4 (10.4)	11.5 (14.2)	9.8 (12.1)
5-yr	8.7 (10.7)	11.4 (14.1)	13.6 (16.8)	13.1 (16.2)
10-yr	11.0 (13.6)	13.5 (16.7)	14.2 (17.5)	13.9 (17.1)
25-yr	13.6 (16.8)	14.3 (17.6)	15.8 (19.5)	15.1 (18.6)
100-yr	15.5 (19.1)	17.2 (21.2)	19.8 (24.4)	18.8 (23.2)

See Note 1 under Table 8.

The calculated peak storage volumes for the ClosureTurf cover system are greater than those for the traditional soil cover system. With no sediment storage volume required for the ClosureTurf cover system, the calculated peak storage of the pond increases by approximately 5% and 10%, respectively, compared to the traditional soil cover system with a CN of 84 and 74 under the 25-yr, 24-hr design storm event; while under the 100-yr, 24-hr design storm event, it increases by approximately 10% and 20%, respectively.

SUMMARY

This paper presents a parametric study to compare the stormwater pond design of a conceptual waste disposal site with two final cover systems: the traditional soil cover system and the ClosureTurf cover system. As expected, the study indicates that the stormwater pond design is largely affected by the selected runoff curve number (CN) for the final cover system. The ClosureTurf cover system, which usually has a higher CN than the traditional soil cover system, generates higher peak runoff rates and volumes, which results in the need for a slightly deeper perimeter drainage channel and a moderately larger stormwater pond. Because the ClosureTurf cover system has no soil layers and the runoff carries little to no suspended solids, the sediment storage volume is not needed, which offsets a portion of the increase in the stormwater pond size due to the higher CN of ClosureTurf.

The analysis results presented in this paper indicate that, under the assumed 25- or 100-yr, 24-hr design storm event, the stormwater pond size for the ClosureTurf cover

system may increase by approximately 5% to 20% depending on the selected CN for the traditional soil cover system, which is assumed to vary from 74 to 84 in the analyses. When a higher CN is used in the stormwater pond design for the traditional soil cover system, the increase in the pond size is smaller when the ClosureTurf cover system is considered.

It should be noted that the study presented in the paper is based on the assumed conceptual site plan and hydrologic and hydraulic conditions. A site-specific analysis should be performed to evaluate difference in the stormwater pond design for these two final cover systems, especially for a site where the stormwater pond has already been constructed according to the original closure design of the traditional soil cover system. Furthermore, when selecting the final cover system for waste disposal facilities, other factors should be evaluated too, including regulatory requirements, technical performance, construction and post-closure maintenance costs, environmental and community impact, etc., to achieve safe, economical, and sustainable closures.

REFERENCES

HydroCAD™ Software Solutions, LLC (2018), *HydroCAD™ Stormwater Modeling System Version 10*. Chocorua, New Hampshire.

National Oceanic and Atmospheric Administration (NOAA) (2019), *Precipitation Frequency Data Server (PFDS).* NOAA, Hydrologic Design Studies Center. Washington, D.C.

Soil Conservation Service (SCS) (1986), *Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55), 2nd Edition.* United States Department of Agriculture, SCS. Washington, D.C.

Watershed Geosynthetics (2018), *ClosureTurf® Design Guidelines Manual.* Alpharetta, Georgia.

Appendix F
Evaluation of Aggregate Infill Criteria for ClosureTurf

Technical Note

EVALUATION OF AGGREGATE INFILL CRITERIA FOR CLOSURETURF®

Aggregate infill is one component of the ClosureTurf® three-component system. An extensive testing program was implemented to evaluate the criteria and performance properties for the aggregate infill in the ClosureTurf system. The program included large scale hydraulic performance testing by independent third-party laboratories including TRI Environmental (TRI) at the Denver Downs Research facility in Greeneville, South Carolina and the Civil Infrastructure Testing and Evaluation Lab (CITEL) at Pennsylvania State University in University Park, Pennsylvania. A description of the hydraulic testing procedures and results are provided in this document.

AGGREGATE INFILL FUNCTION

The aggregate infill component of ClosureTurf is utilized as a protective layer for the geotextile backing of the engineered turf component. The polypropylene geotextile backing material contains ultraviolet (UV) radiation degradation inhibitors protecting it against UV damage. Aggregate infill functions as an additional protective layer against UV degradation of the geotextile backing. Optimal aggregate infill performance occurs with minimal aggregate movement.

Laboratories tested aggregate infill mobilization in ClosureTurf in general accordance with ASTM D 6460, *Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion* and ASTM D 6459 *Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hillslopes from Rainfall-Induced Erosion*. The results of the testing were also analyzed in accordance with each Standard to quantify infill mobilization during tested conditions. Photographs of tested aggregate samples are provided as Attachment A.

AGGREGATE INFILL LARGE SCALE HYDRAULIC TESTING

The TRI large-scale hydraulic testing (ASTM D 6460) was conducted in a rectangular flume having a 0.10 ft/ft slope. CITEL testing was conducted in a variable slope flume with slope settings of 0.10, 0.20 and 0.30 ft/ft. Installed subgrade was a loamy soil over which ClosureTurf with a ½-inch aggregate infill was installed following installation guidelines. Water is supplied to the

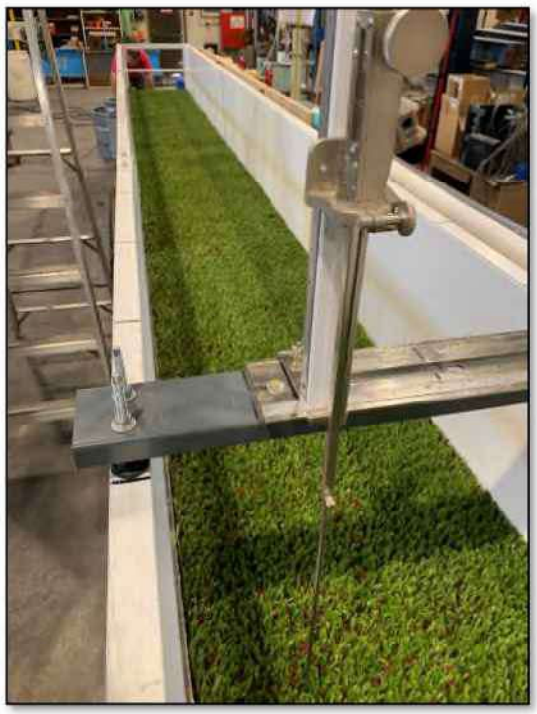
24135

facility by gravity flow or pumps and controlled and measured through upstream sluice gates or magnetic flow meters as presented in Figure 1.

A test consists of measuring infill thickness, initiating overtopping flow on the ClosureTurf® for a period of 30 minutes, discontinuing overtopping flow and measuring infill depth to evaluate aggregate loss. The test procedure is repeated a minimum of four times with increasing overtopping flow amounts or until enough aggregate infill has been removed to expose the majority of the geotextile backing.



TRI Facility



CITEL Facility

Figure 1. ClosureTurf® Flume Installation

Reported test results include aggregate infill loss during each 30-minute overtopping period and the corresponding hydraulic shear stress during the 30-minute test period. The testing was conducted on six different aggregate infills having a range of grain size distributions, fine aggregate angularities and specific gravities. Aggregate infill angularity and specific gravity are presented in Table 1. Tested aggregate infill grain size distributions are presented in Figure 2. Hydraulic shear stress results are presented in Figure 3. Testing also included three engineered turf profiles: ClosureTurf (CT), high friction ClosureTurf (CT HF) and high density ClosureTurf (CT HD). CT is the standard engineered turf. CT HF has similar turf blade count to ClosureTurf with an alternating turf stitch orientation. CT HD has a higher turf blade count density with approximately double the turf blade count of CT. Figure 4 presents aggregate mobilization results based on turf density.

Table 1. Tested Aggregate Infill Angularity and Specific Gravity

Test Aggregate No.	Fine Aggregate Angularity (FAA) (%) (ASTM C 1252 / AASHTO T 304) (Method A)	Bulk Specific Gravity, Dry (SG) (ASTM C 128 / AASHTO T 84)
1	47.2	2.64
2	40.5	2.60
3	43.1	2.59
4	45.7	2.64
5	47.1	2.85
6	43.7	1.96

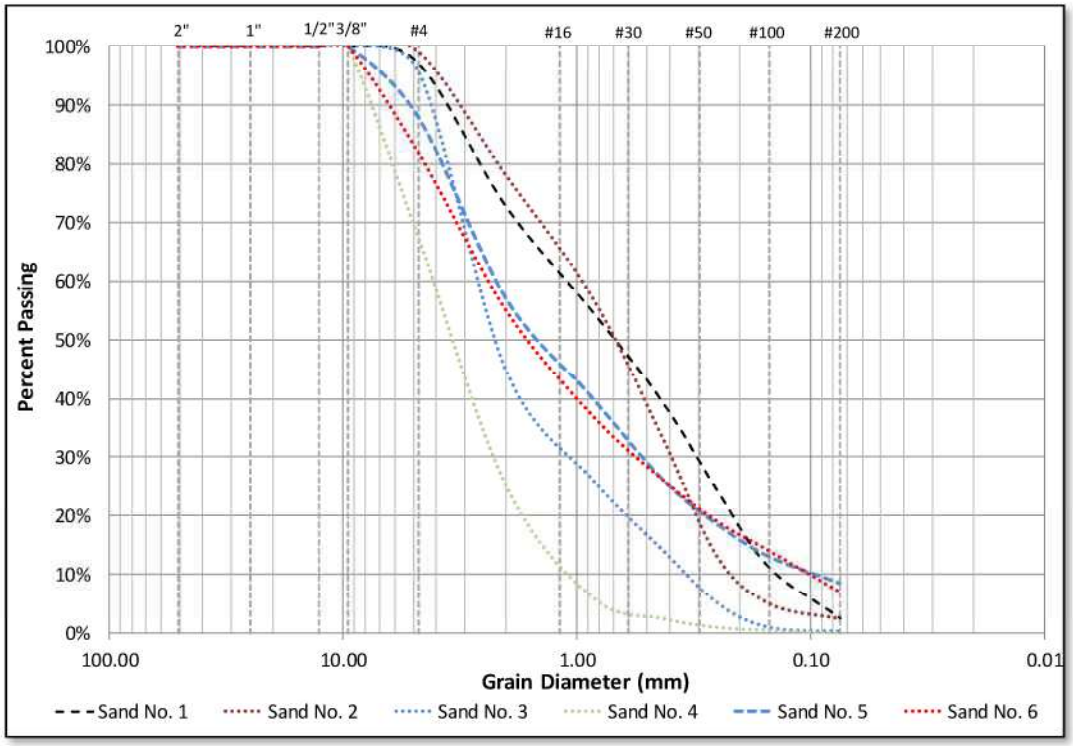


Figure 2. Tested Aggregate Infill Grain Size Distributions (ASTM C 136 / AASHTO T 27)

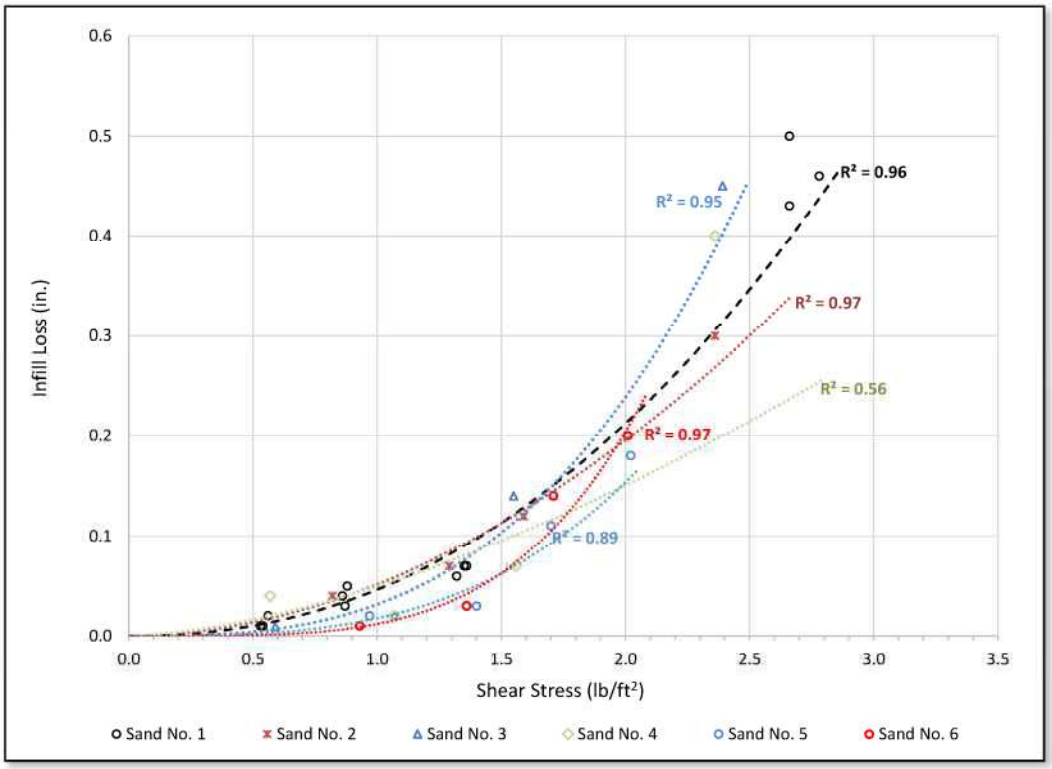


Figure 3. Measured Infill Loss as a Function of Hydraulic Shear Stress

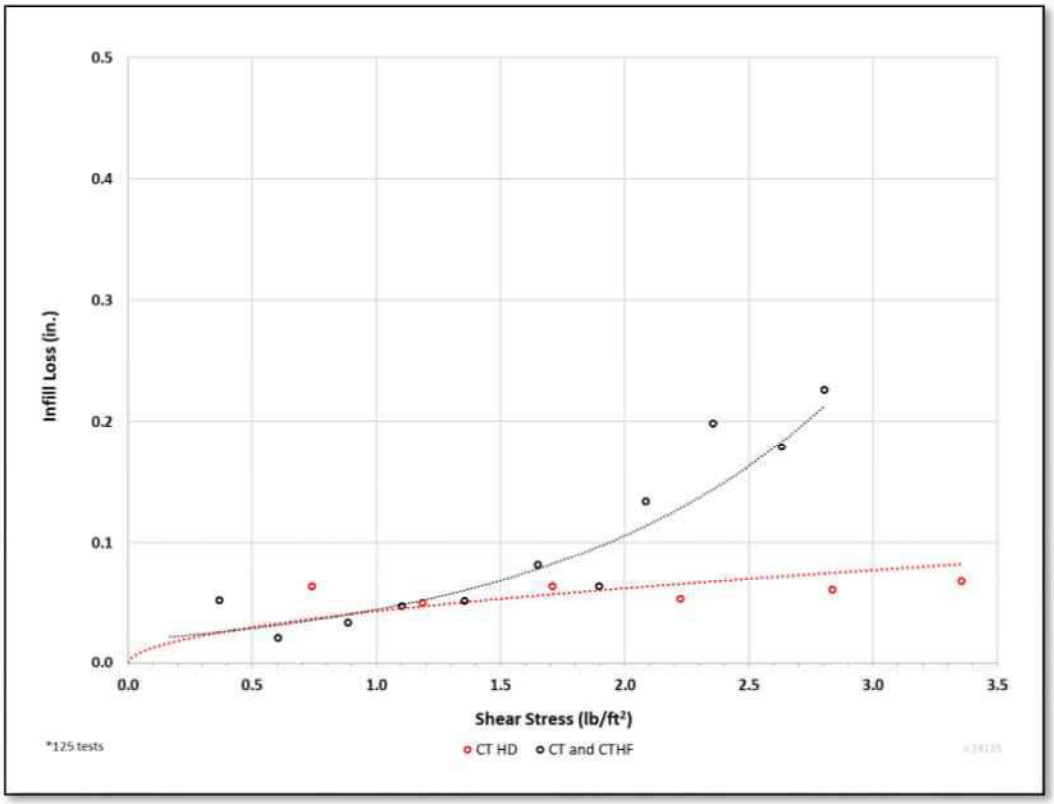


Figure 4. Aggregate Mobilization Comparison by Turf Density

WG
24135

AGGREGATE INFILL LARGE SCALE RAINFALL EROSION TESTING

The TRI large-scale rainfall erosion testing (ASTM D 6459) was conducted on a rectangular plot measuring 40 feet by 8 feet (length x width) and having a 0.33 ft/ft slope. The subgrade was a loamy soil over which ClosureTurf with a ½-inch aggregate infill was installed following installation guidelines as presented in Figure 5a. Artificial rainfall is produced by ten "rain trees" arranged around the perimeter of the test slope. Each rain tree has four sprinkler heads atop a 15 ft. riser pipe. The rainfall system produces target rainfall intensities of 2, 4 and 6 inches per hour at pre-calibrated rain drop size distributions for a period of 20 minutes per intensity resulting in a one-hour test. Incremental infill losses are presented in Table 2. All runoff was collected during testing to quantify sediment mobilization. Testing in progress is presented in Figure 5b.

Table 2. Aggregate Infill Rainfall Erosion Results

Test Aggregate No.	Nominal Rainfall Intensity (in./hr.)	Incremental Infill Loss (%)	
		Standard Density Turf	High Density Turf
1	2.0	0.01	0.01
1	4.0	0.03	0.01
1	6.0	0.04	0.05
3	2.0	0.00	-
3	4.0	0.00	-
3	6.0	0.00	-
4	2.0	0.00	-
4	4.0	0.00	-
4	6.0	0.00	-



(a) Infill Installation **(b) Testing in Progress**

Figure 5. ClosureTurf® TRI Rainfall Erosion Testing

Based on the large scale rainfall erosion and hydraulic shear test results and aggregate infill material properties, an aggregate infill specification was developed as summarized in Figure 6 and as appears in the Watershed Geo® CSI specification, SECTION 31 05 16, *ClosureTurf® AGGREGATE INFILL COMPONENT*.

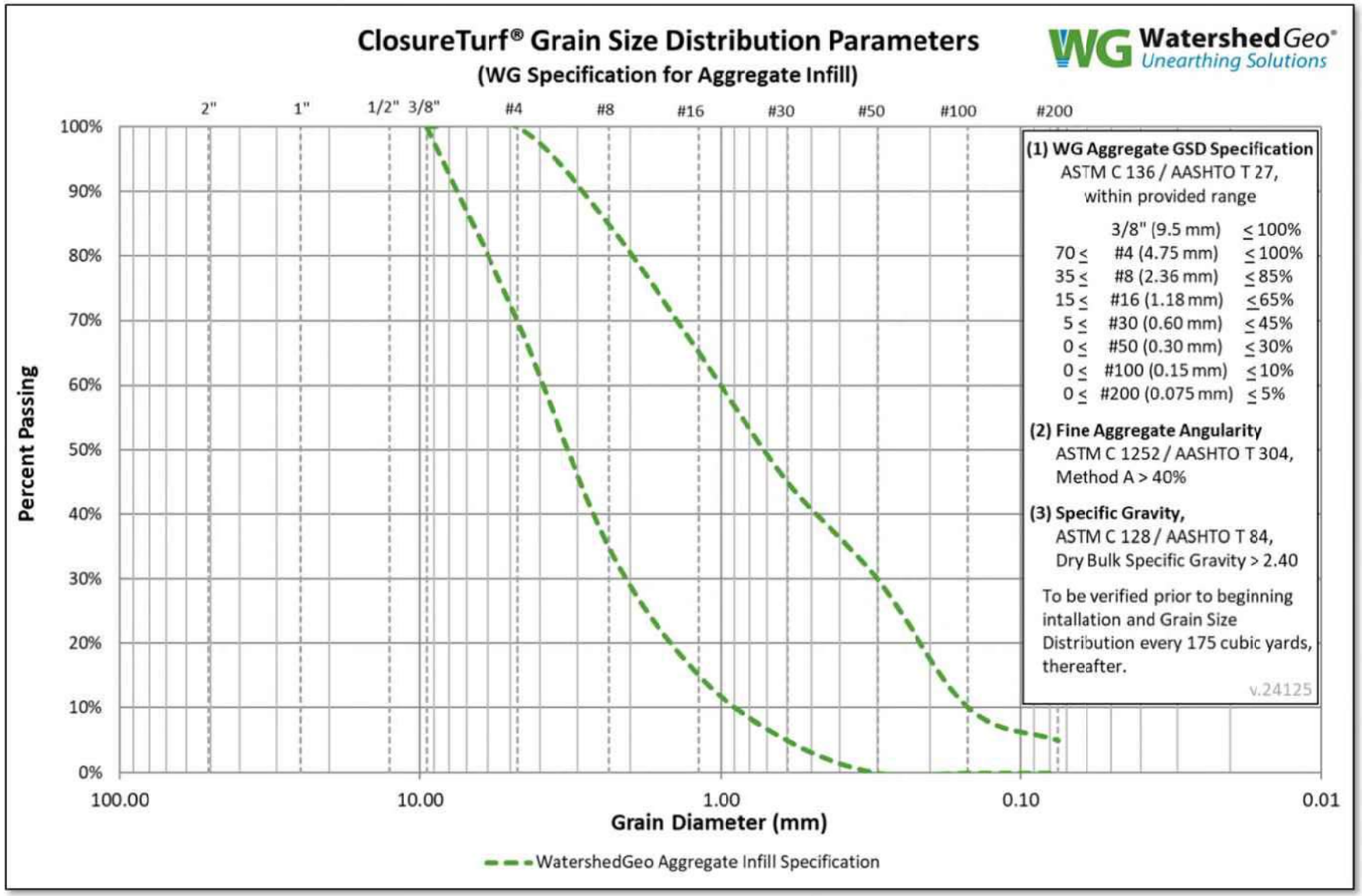


Figure 6. ClosureTurf® Aggregate Infill Specification

Attachment A



Figure A1. Tested Aggregate No. 1



Figure A2. Tested Aggregate No. 2



Figure A3. Tested Aggregate No. 3



Figure A4. Tested Aggregate No. 4

WG
24135



Figure A5. Tested Aggregate No. 5



Figure A6. Tested Aggregate No. 6

LIMITATIONS

ClosureTurf® is a U.S. registered trademark which designates a product from Watershed Geosynthetics LLC. This product is the subject of issued U.S. and foreign patents and/or pending U.S. and foreign patent applications. All information, recommendations and suggestions appearing in this literature concerning the use of our products are based upon tests and data believed to be reliable; however, this information should not be used or relied upon for any specific application without independent professional examination and verification of its accuracy, suitability and applicability. Since the actual use by others is beyond our control, no guarantee or warranty of any kind, expressed or implied, is made by Watershed Geosynthetics LLC as to the effects of such use or the results to be obtained, nor does Watershed Geosynthetics LLC assume any liability in connection herewith. Any statement made herein may not be absolutely complete since additional information may be necessary or desirable when particular or exceptional conditions or circumstances exist or because of applicable laws or government regulations. Nothing herein is to be construed as permission or as a recommendation to infringe any patent.

Appendix G
Example Aggregate Infill Hydraulic Shear Calculations

Technical Note

EXAMPLE AGGREGATE INFILL HYDRAULIC SHEAR CALCULATIONS

INTRODUCTION

Aggregate infill hydraulic stability in ClosureTurf® has been independently tested by the third-party laboratories, TRI Environmental and the Civil Infrastructure Testing and Evaluation Lab (CITEL). Test results demonstrate minimal aggregate infill mobilization at hydraulic shear values exceeding 1.5 lb/ft^2. The suggested design value for evaluating the potential for infill mobilization is 0.8 lb/ft^2 for standard density turf (i.e., CT, CT X and CT HF) or 1.5 lb/ft^2 for high density turf (CT HD).

An example set of calculations utilizing site specific parameters to estimate hydraulic shear from rainfall runoff are provided. The purpose of the calculations is to evaluate whether the calculated maximum hydraulic shear stress in the aggregate infill of ClosureTurf exceeds the suggested critical hydraulic shear stress. The calculations that follow are meant to serve as a suggested method to estimate the maximum hydraulic shear stress possible at potential ClosureTurf installations.

Two different hydraulic shear calculations are evaluated, differentiated by location and the choice of geomembrane liner used in the ClosureTurf system. The drainage length details are as follows, and the calculation results are summarized in Table 1.

1. Top deck with CT and MicroSpike® + side slope with CT and Super Gripnet® or MicroDrain®.
2. Side slope with CT and Super Gripnet® or MicroDrain®.

Table 1. Summary of Hydraulic Shear Calculation Results

Drainage Path No.	Segment No.	Slope (%)	Length (ft)	Geomembrane Liner	Calculated Maximum Hydraulic Shear Stress (psf)	Suggested Critical Hydraulic Shear Stress (psf)	Hydraulic Shear Stress (Meets or Does Not Meet)
1	1	3	208	MicroSpike	0.15	0.8	meets suggested criteria
	2	32	111	Super Gripnet/ MicroDrain	0.48	0.8	meets suggested criteria
2	1	27	383	Super Gripnet	0.53	0.8	meets suggested criteria

Drainage Path 1 – MicroSpike® on Top Deck & Super Gripnet®/MicroDrain® on the Side Slope – 100-year, 60-minute Design Storm

Drainage Path 1 consists of a top deck with a 3.0% slope and a drainage length of approximately 208 ft which drains to a side slope with a drainage length of approximately 111 ft at a 32% slope (3.1H:1V). The calculation assumes CT and MicroSpike geomembrane for the top deck and CT and Super Gripnet or MicroDrain geomembrane for the side slope.

Design Parameters:

Top Deck:

- Drainage length: L_1 = 208 ft (See Figure 1)
- Slope: S_1 = 3%
- Slope angle: $\alpha_1 = \tan^{-1}(3/100) = 1.72°$
- Hydraulic gradient: i_1 = 3.0% or 0.03
- Manning's roughness coefficient: n_1 = 0.22 (for slope ≤ 10%; See Watershed Geo ClosureTurf Design Guidance Manual)
- Geomembrane type: MicroSpike (without internal drainage layer)

Side Slope:

- Drainage length: L_2 = 111 ft (see Figure 1)
- Slope: S_2 = 3.1H:1V (32.3%)
- Slope angle: $\alpha_2 = \tan^{-1}(1/3.1) = 17.9°$
- Hydraulic gradient: i_2 = 32.3% or 0.323
- Manning's roughness coefficient: n_2 = 0.12 (for slope > 10%; See Watershed Geo ClosureTurf Design Guidance Manual)
- Geomembrane type: Super Gripnet or MicroDrain (with internal drainage layer)
- Transmissivity of ClosureTurf with Super Gripnet or MicroDrain (use the data in Figure 4, the ClosureTurf transmissivity test report by SGI to calculate the transmissivity at the slope of 32.3% or i = 0.323):
    - Flow Rate: $q = 12.28 \times i^{0.624} = 12.28 \times 0.323^{0.624} = 6.07\ gpm/ft$
    - Transmissivity: $\theta_{i=0.323} = 0.00020697 \times \frac{q}{i} = 0.00020697 \times \frac{6.07}{0.323} = 3.89 \times 10^{-3}\ m^2/sec$

Other Design Parameters:

- Design rainfall intensity (see Figures 2 and 3, the 100-yr, 1-hr rainfall intensity map):

$$R = 3.78\frac{in}{hr} = 0.315\frac{ft}{hr}$$

- Critical hydraulic shear stress of ClosureTurf with aggregate infill:

$$\tau_C = 0.8\ psf$$

v.24137

Step 1: Calculate the maximum hydraulic shear stress of flow on the top deck:

Flow rate on the top deck under the design rainfall intensity (assuming unit width of 1 ft of final cover):

$$q_1 = L_1 \cdot R \cdot \cos\alpha_1 = 208\ ft \times 0.315\frac{ft}{hr} \times \cos 1.72° = 65.49\frac{ft^2}{hr} = 0.0182\frac{ft^2}{s}$$

The flow rate:

$$q_1 = v_1 \cdot A_1 = v_1 \cdot (H_1 \times 1\ ft) = v_1 \cdot H_1$$

Where, H_1 is flow depth on the top deck (ft). Using the Manning's Equation and assuming the hydraulic radius equals to the flow depth (in ft):

$$v_1 = \frac{1.49}{n_1} H_1^{\frac{2}{3}} \sqrt{S_1}$$

Therefore,

$$q_1 = v_1 \cdot H_1 = \frac{1.49}{n_1} H_1^{\frac{2}{3}} \sqrt{S_1} \cdot H_1 = \frac{1.49}{n_1} H_1^{\frac{5}{3}} \sqrt{S_1}$$

Solve the above equation for H_1,

$$H_1 = \left(\frac{q_1 \cdot n_1}{1.49 \cdot \sqrt{S_1}}\right)^{\frac{3}{5}} = \left(\frac{0.0182 \times 0.22}{1.49 \cdot \sqrt{0.03}}\right)^{\frac{3}{5}} = 0.0821ft$$

The maximum hydraulic shear stress by the water flow on slope:

$$\tau_1 = \gamma_w \cdot H_1 \cdot S_1 = 62.4\frac{lb}{ft^3} \times 0.0821ft \times 0.03 = 0.15\ psf < \tau_c (= 0.8\ psf) \quad \checkmark$$

The calculated maximum hydraulic shear stress on the aggregate infill is less than the suggested critical hydraulic shear stress, indicating minimal aggregate infill mobilization is expected to occur.

WG v.24137

Step 2: Calculate the maximum hydraulic shear stress of flow on the side slope

Water from the top deck will flow onto the side slope. The total flow at the end of the side slope is:

$$q_{total} = q_1 + q_2 = q_1 + L_2 \cdot R \cdot \cos\alpha_2 = 65.49\frac{ft^2}{hr} + \left(111ft \times 0.315\frac{ft}{hr} \times \cos 17.9°\right)$$
$$= 98.76\frac{ft^2}{hr} = 0.0274\frac{ft^2}{s}$$

Part of the flow is expected to be through the internal drainage channel of the Super Gripnet or MicroDrain (i.e., the space within the drainage studs of Super Gripnet or MicroDrain). The internal flow capacity of ClosureTurf with Super Gripnet or MicroDrain is:

$$q_{int} = \theta_{i=0.323} \cdot i_2 = 3.89 \times 10^{-3}\frac{m^2}{sec} \times 0.323$$
$$= 3.89 \times 10^{-3} \times \frac{(3.28ft)^2}{\left(\frac{1}{3600}\right)hr} \times 0.323 = 48.66\frac{ft^2}{hr}$$

The remaining flow will be through the turf and aggregate infill:

$$q'_{total} = q_{total} - q_{int} = 98.76\frac{ft^2}{hr} - 48.66\frac{ft^2}{hr} = 50.10\frac{ft^2}{hr} = 0.0139\frac{ft^2}{s}$$

The flow rate:

$$q'_{total} = v_2 \cdot A_2 = v_2 \cdot (H_2 \times 1\,ft) = v_2 \cdot H_2$$

Where, H_2 is flow depth on the slope (ft). Using the Manning's Equation and assuming the hydraulic radius equals to the flow depth (in ft):

$$v_2 = \frac{1.49}{n_2} H_2^{\frac{2}{3}}\sqrt{S_2}$$

Therefore,

$$q'_{total} = v_2 \cdot H_2 = \frac{1.49}{n_2} H_2^{\frac{2}{3}}\sqrt{S_2} \cdot H_2 = \frac{1.49}{n_2} H_2^{\frac{5}{3}}\sqrt{S_2}$$

Solve the above equation for H_2,

$$H_2 = \left(\frac{q'_{total} \cdot n_2}{1.49 \cdot \sqrt{S_2}}\right)^{\frac{3}{5}} = \left(\frac{0.0139 \times 0.12}{1.49 \cdot \sqrt{0.323}}\right)^{\frac{3}{5}} = 0.0238ft$$

The maximum hydraulic shear stress by the water flow on the slope:

$$\tau_2 = \gamma_w \cdot H_2 \cdot S_2 = 62.4\frac{lb}{ft^3} \times 0.0238ft \times 0.323 = 0.48\,psf < \tau_c(= 0.8\,psf) \quad ✓$$

The calculated maximum hydraulic shear stress on the aggregate infill is less than the suggested critical hydraulic shear stress, indicating minimal aggregate infill mobilization is expected to occur.

WG v.24137

Drainage Path 2 – Side Slope with Super Gripnet® – 100-year, 60-minute Design Storm

Drainage Path 2 consists of a side slope with a drainage length of approximately 383 ft at a 3.7H:1V slope. This calculation assumes CT and Super Gripnet geomembrane for the side slope.

Design Parameters:

Side Slope:

- Drainage length: L_1 = 383 ft (See Figure 1)
- Slope: S_1 = 3.7H:1V (27.0%)
- Slope angle: $\alpha_1 = \tan^{-1}(1/3.7) = 15.12°$
- Hydraulic gradient: i_1 = 27.0% or 0.270
- Manning's roughness coefficient: n_2 = 0.12 (for slope > 10%; See Watershed Geo ClosureTurf Design Guidance Manual)
- Geomembrane type: Super Gripnet (with internal drainage layer)
- Transmissivity of ClosureTurf with Super Gripnet or MicroDrain (use the data in Figure 4, the ClosureTurf transmissivity test report by SGI to calculate the transmissivity at the slope of 27.0% or i = 0.270):
  - Flow Rate: $q = 12.28 \times i^{0.624} = 12.28 \times 0.270^{0.624} = 5.42\ gpm/ft$
  - Transmissivity: $\theta_{i=0.270} = 0.00020697 \times \frac{q}{i} = 0.00020697 \times \frac{5.42}{0.270} = 4.15 \times 10^{-3}\ m^2/sec$

Other Design Parameters:

- Design rainfall intensity (see Figures 2 and 3, the 100-yr, 1-hr rainfall intensity map):

$$R = 3.78\frac{in}{hr} = 0.315\frac{ft}{hr}$$

- Critical hydraulic shear stress of ClosureTurf with aggregate infill:

$$\tau_C = 0.8\ psf$$

Step 1: Calculate the maximum hydraulic shear stress of flow on the side slope:

Flow rate on the side slope under the design rainfall intensity (assuming unit width of 1 ft of final cover):

$$q_1 = L_1 \cdot R \cdot \cos\alpha_1 = 383\ ft \times 0.315\frac{ft}{hr} \times \cos 15.12° = 116.5\frac{ft^2}{hr} = 0.0324\frac{ft^2}{s}$$

Part of the flow is expected to be through the internal drainage channel of the Super Gripnet (i.e., the space within the drainage studs of Super Gripnet). The internal flow capacity of ClosureTurf with Super Gripnet is:

$$q_{int} = \theta_{i=0.270} \cdot i_1 = 4.15 \times 10^{-3}\frac{m^2}{sec} \times 0.270$$
$$= 4.15 \times 10^{-3} \times \frac{(3.28ft)^2}{\left(\frac{1}{3600}\right)hr} \times 0.270 = 43.40\frac{ft^2}{hr}$$

v.24137

The remaining flow will be through the turf and aggregate infill:

$$q'_{total} = q_{total} - q_{int} = 116.5\frac{ft^2}{hr} - 43.40\frac{ft^2}{hr} = 73.10\frac{ft^2}{hr} = 0.0203\frac{ft^2}{s}$$

The flow rate:

$$q'_{total} = v_1 \cdot A_1 = v_1 \cdot (H_1 \times 1\ ft) = v_1 \cdot H_1$$

Where, H_1 is flow depth on the slope (ft). Using the Manning's Equation and assuming the hydraulic radius equals to the flow depth (in ft):

$$v_1 = \frac{1.49}{n_1} H_1^{\frac{2}{3}} \sqrt{S_1}$$

Therefore,

$$q'_{total} = v_1 \cdot H_1 = \frac{1.49}{n_1} H_2^{\frac{2}{3}} \sqrt{S_1} \cdot H_1 = \frac{1.49}{n_1} H_1^{\frac{5}{3}} \sqrt{S_1}$$

Solve the above equation for H_1,

$$H_1 = \left(\frac{q'_{total} \cdot n_1}{1.49 \cdot \sqrt{S_1}}\right)^{\frac{3}{5}} = \left(\frac{0.0203 \times 0.12}{1.49 \cdot \sqrt{0.270}}\right)^{\frac{3}{5}} = 0.0315\ ft$$

The maximum hydraulic shear stress by the water flow on the slope:

$$\tau_1 = \gamma_w \cdot H_1 \cdot S_1 = 62.4\frac{lb}{ft^3} \times 0.0315 ft \times 0.270 = 0.53\ psf < \tau_c (= 0.8\ psf) \quad \checkmark$$

The calculated maximum hydraulic shear stress on the aggregate infill is less than the suggested critical hydraulic shear stress, indicating minimal aggregate infill mobilization is expected to occur.

WG v.24137

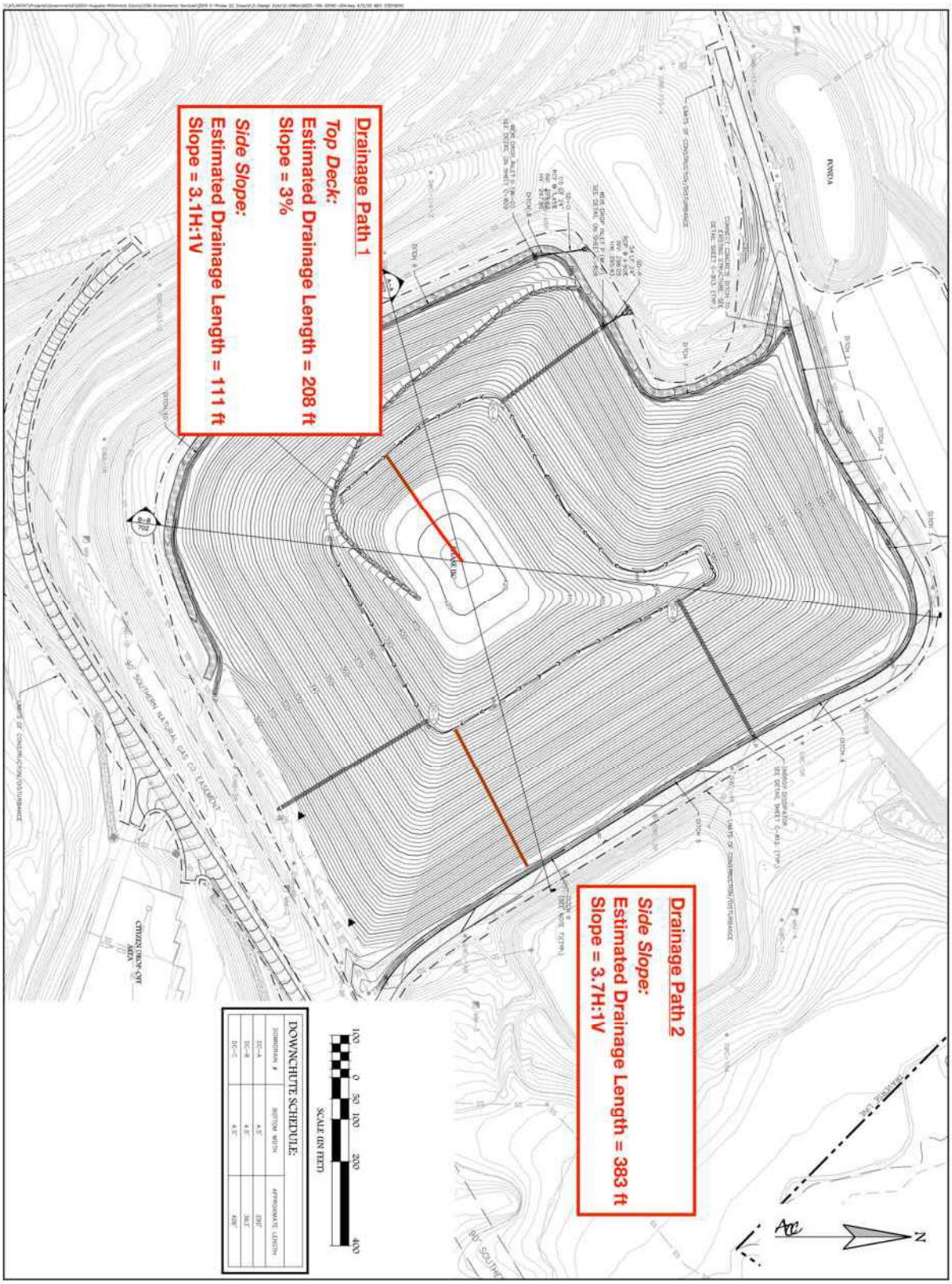


Figure 1. Grading plan with drainage path identified

v.24137

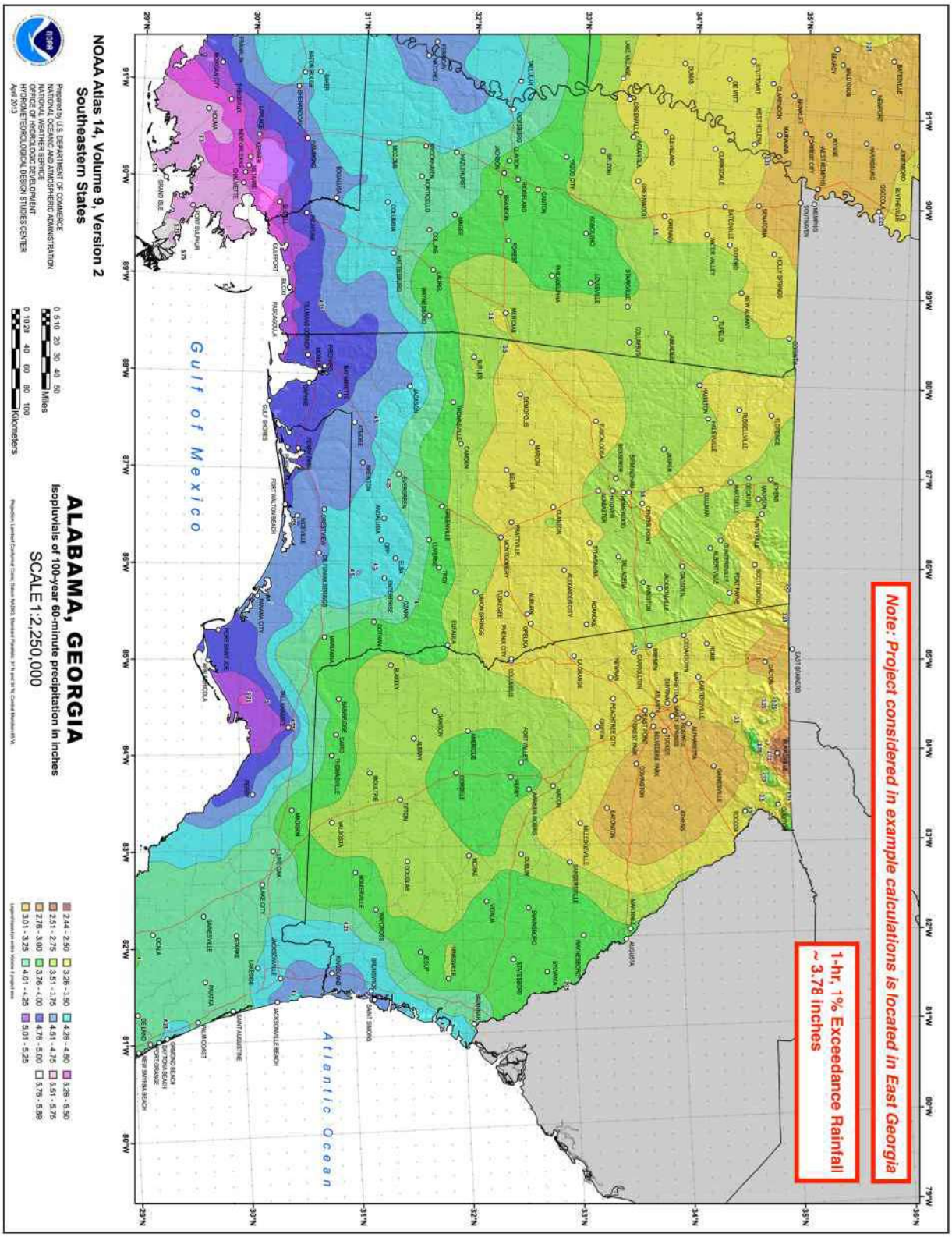


Figure 2. Alabama & Georgia Isopluvials (NOAA Atlas 14)

v.24137

NOAA Atlas 14, Volume 9, Version 2

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.414 (0.346-0.502)	0.485 (0.405-0.589)	0.604 (0.502-0.736)	0.705 (0.582-0.863)	0.849 (0.674-1.07)	0.963 (0.743-1.23)	1.08 (0.800-1.42)	1.20 (0.846-1.62)	1.36 (0.920-1.89)	1.49 (0.975-2.09)
10-min	0.606 (0.506-0.736)	0.710 (0.593-0.863)	0.885 (0.735-1.08)	1.03 (0.852-1.26)	1.24 (0.987-1.57)	1.41 (1.09-1.81)	1.58 (1.17-2.07)	1.76 (1.24-2.37)	2.00 (1.35-2.76)	2.18 (1.43-3.06)
15-min	0.739 (0.618-0.897)	0.866 (0.723-1.05)	1.08 (0.896-1.31)	1.26 (1.04-1.54)	1.52 (1.20-1.92)	1.72 (1.33-2.20)	1.93 (1.43-2.53)	2.14 (1.51-2.89)	2.44 (1.64-3.37)	2.66 (1.74-3.73)
30-min	1.09 (0.908-1.32)	1.27 (1.06-1.55)	1.58 (1.32-1.93)	1.85 (1.53-2.26)	2.23 (1.77-2.82)	2.53 (1.95-3.24)	2.83 (2.10-3.72)	3.15 (2.22-4.25)	3.59 (2.42-4.96)	3.93 (2.57-5.50)
60-min	1.41 (1.18-1.71)	1.64 (1.37-1.99)	2.03 (1.69-2.47)	2.38 (1.96-2.91)	2.90 (2.31-3.69)	3.32 (2.57-4.28)	3.78 (2.81-4.98)	4.26 (3.01-5.76)	4.93 (3.34-6.85)	5.48 (3.58-7.68)
2-hr	1.74 (1.46-2.09)	2.00 (1.68-2.41)	2.48 (2.08-2.99)	2.91 (2.42-3.52)	3.57 (2.88-4.52)	4.12 (3.23-5.28)	4.72 (3.55-6.18)	5.36 (3.84-7.21)	6.28 (4.29-8.66)	7.03 (4.64-9.77)
3-hr	1.92 (1.63-2.29)	2.19 (1.86-2.62)	2.70 (2.28-3.24)	3.19 (2.67-3.83)	3.94 (3.21-4.99)	4.58 (3.62-5.86)	5.29 (4.00-6.92)	6.07 (4.37-8.14)	7.19 (4.95-9.89)	8.11 (5.39-11.2)
6-hr	2.28 (1.95-2.69)	2.57 (2.19-3.05)	3.14 (2.67-3.73)	3.70 (3.12-4.41)	4.59 (3.78-5.78)	5.37 (4.28-6.82)	6.24 (4.77-8.11)	7.20 (5.25-9.60)	8.62 (6.00-11.8)	9.79 (6.56-13.4)
12-hr	2.71 (2.33-3.17)	3.04 (2.62-3.56)	3.68 (3.16-4.33)	4.30 (3.67-5.08)	5.30 (4.41-6.60)	6.17 (4.97-7.75)	7.13 (5.51-9.18)	8.21 (6.04-10.8)	9.78 (6.87-13.2)	11.1 (7.50-15.0)
24-hr	3.17 (2.76-3.67)	3.56 (3.09-4.13)	4.30 (3.72-5.00)	5.00 (4.30-5.84)	6.09 (5.10-7.48)	7.03 (5.71-8.73)	8.06 (6.28-10.2)	9.20 (6.83-12.0)	10.8 (7.69-14.5)	12.2 (8.35-16.4)
2-day	3.65 (3.20-4.19)	4.11 (3.61-4.72)	4.96 (4.33-5.71)	5.74 (4.98-6.64)	6.95 (5.86-8.42)	7.97 (6.52-9.77)	9.08 (7.13-11.4)	10.3 (7.70-13.3)	12.0 (8.61-15.9)	13.4 (9.29-17.9)
3-day	3.99 (3.52-4.55)	4.48 (3.95-5.12)	5.37 (4.72-6.15)	6.20 (5.41-7.13)	7.46 (6.33-8.99)	8.53 (7.02-10.4)	9.69 (7.66-12.1)	11.0 (8.25-14.0)	12.8 (9.19-16.8)	14.2 (9.91-18.9)
4-day	4.29 (3.80-4.87)	4.80 (4.25-5.45)	5.72 (5.05-6.53)	6.58 (5.77-7.54)	7.90 (6.72-9.47)	9.01 (7.45-10.9)	10.2 (8.11-12.7)	11.5 (8.72-14.7)	13.4 (9.71-17.6)	15.0 (10.4-19.7)
7-day	5.03 (4.50-5.67)	5.61 (5.00-6.33)	6.65 (5.91-7.52)	7.61 (6.72-8.64)	9.06 (7.77-10.8)	10.3 (8.57-12.4)	11.6 (9.29-14.3)	13.1 (9.95-16.5)	15.1 (11.0-19.6)	16.8 (11.8-22.0)
10-day	5.70 (5.12-6.39)	6.33 (5.67-7.10)	7.45 (6.65-8.38)	8.47 (7.51-9.57)	10.0 (8.62-11.8)	11.3 (9.45-13.5)	12.7 (10.2-15.5)	14.2 (10.9-17.8)	16.3 (12.0-21.1)	18.1 (12.8-23.5)
20-day	7.65 (6.94-8.49)	8.39 (7.59-9.31)	9.66 (8.71-10.8)	10.8 (9.66-12.1)	12.4 (10.8-14.4)	13.8 (11.6-16.2)	15.2 (12.3-18.3)	16.7 (12.9-20.7)	18.8 (13.9-24.0)	20.5 (14.7-26.5)
30-day	9.36 (8.53-10.3)	10.2 (9.29-11.3)	11.6 (10.6-12.9)	12.9 (11.6-14.3)	14.6 (12.7-16.7)	16.0 (13.5-18.6)	17.4 (14.1-20.7)	18.8 (14.6-23.1)	20.8 (15.5-26.3)	22.4 (16.1-28.7)
45-day	11.6 (10.6-12.7)	12.6 (11.6-13.9)	14.3 (13.1-15.8)	15.7 (14.3-17.4)	17.6 (15.3-20.0)	19.0 (16.2-21.9)	20.4 (16.7-24.1)	21.8 (17.0-26.5)	23.6 (17.6-29.6)	25.0 (18.1-31.9)
60-day	13.6 (12.5-14.8)	14.8 (13.6-16.2)	16.8 (15.4-18.4)	18.4 (16.7-20.2)	20.4 (17.8-22.9)	21.9 (18.7-25.0)	23.3 (19.1-27.3)	24.6 (19.3-29.7)	26.3 (19.7-32.7)	27.5 (20.0-34.9)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

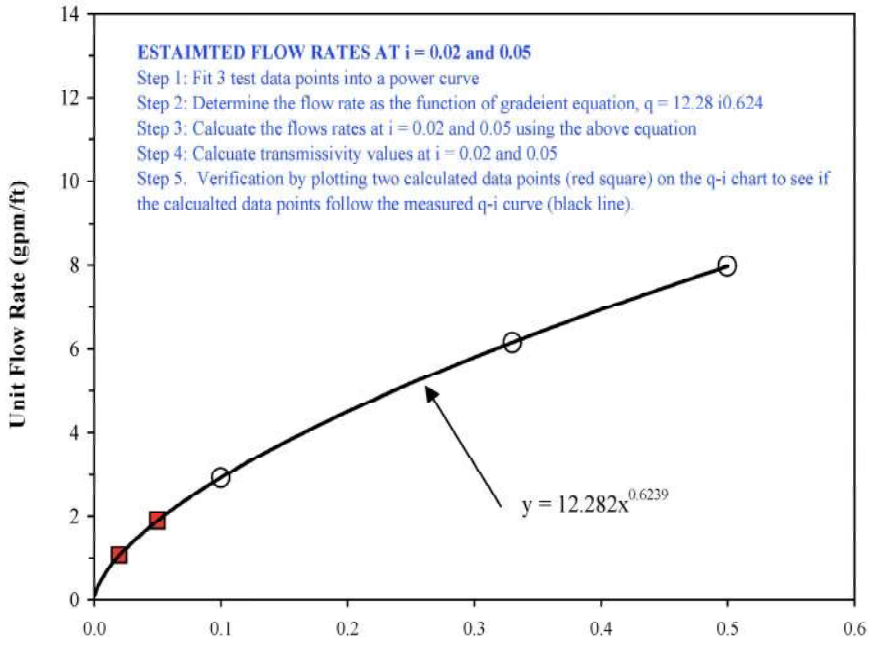
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Figure 3. NOAA Precipitation Data

v.24137

CLOSURETURF LLC -LANDFILL COVER SYSTEM
HYDRAULIC TRANSMISSIVITY TESTING (ASTM D 4716)
Test Configuration (from Top to Bottom): Sand Layer/Polytex Artificial Grass with Geotextile Side Down/ Agru 50-mil Super Gripnet LLDPE Geomembrane with Studs Side Up



Test No.	Flow Direction	Specimen Size Width x Length (in. x in.)	Total Normal Stress[1] σ_n (psf)	Seating Time t (hour)	Hydraulic Gradient i (-)	Transmissivity $\theta = 0.00020697\left(\frac{q}{i}\right)$ (m^2/sec)	Flow Rate $q = 12.28i^{0.624}$ (gpm/ft)	Flow Rate q' (l/min/m)
					0.02	1.11E-02	1.07	
					0.05	7.84E-03	1.89	
1	MD	12 x12	47	0.25	0.10	6.04E-03	2.92	36.3
2	MD	12 x12	47	0.25	0.33	3.86E-03	6.15	76.4
3	MD	12 x12	47	0.25	0.50	3.30E-03	7.97	99.0

NOTE:
Total normal stress = total weight (sand + steel plate + surcharge) divided by the plan area of test specimen (1 square ft). A normal stress of 47 psf is approximately the minimum total stress required to keep the specimen from uplifting.

SGI TESTING SERVICES, LLC

DATE TESTED:	1/11/2013
FIGURE NO.	A-1
PROJECT NO.	SGI10007
DOCUMENT NO.	
FILE NO.	

Figure 4. Transmissivity test report of ClosureTurf with internal drainage layer

v.24137

Appendix H
ClosureTurf UV Longevity Evaluation Reports

2022 Evaluation Report

Geosyntec consultants

1255 Roberts Boulevard, Suite 200
Kennesaw, Georgia 30144
PH 678.202.9500
FAX 678.202.9501
www.geosyntec.com

22 November 2022

José Urrutia, P.E.
Vice President of Engineering
Watershed Geosynthetics
11400 Atlantis Place, Suite 200
Alpharetta, GA 30022

Subject: Assessment of ClosureTurf® UV Longevity

Dear Mr. Urrutia:

Watershed Geosynthetics, Inc. (Watershed) has patented an alternative landfill closure system termed ClosureTurf®. ClosureTurf® consists of high-density polyethylene (HDPE) grass blades tufted through a double-layer polypropylene (PP) geotextile backing which overlies an HDPE or linear low-density polyethylene (LLDPE) structured geomembrane (i.e., Super Gripnet®, MicroDrain®, or MicroSpike®) manufactured by AGRU America Inc. The addition of a layer of sand ballast during installation completes the system. The sand ballast provides cover for the lower portion of the HDPE grass blades, the PP geotextile backing, and the structured geomembrane (Figure 1).

A report titled "Literature Review and Assessment of ClosureTurf® UV Longevity" was prepared by Geosyntec Consultants, Inc. (Geosyntec) and dated 15 May 2015 (Geosyntec, 2015). Watershed has requested that Geosyntec provide an updated assessment of the longevity of the ClosureTurf® system with regard to ultraviolet (UV) exposure and degradation. This report (Report) supersedes the Geosyntec (2015) report. Since ClosureTurf® has elements (i.e., the HDPE grass blades) that are permanently exposed to UV radiation, this Report will be focused on the exposed portion of the system.

Geosyntec's approach to this Report incorporates updated laboratory and field data from samples at multiple sites throughout the Southeastern United States (U.S.) and Arizona into the assessment of HDPE grass blade longevity. This Report concludes with a summary of the analysis along with brief discussion for recommendations.

EXECUTIVE SUMMARY

This Report incorporates updated laboratory and field data regarding the retained tensile strength of HDPE geomembrane and synthetic grass blade materials as a function of exposure to ultraviolet (UV) radiation to estimate the longevity of the exposed grass blades of the ClosureTurf® product.

The laboratory update includes a release of additional data from a Geosynthetics Research Institute (GRI) testing program measuring the effects of UV radiation on HDPE geomembrane strips. The test program incubates HDPE geomembrane strip samples under a UV lamp at elevated temperatures (60°C, 70°C, and 80°C) to accelerate the degradation. The tensile strength and elongation of each strip are then measured after a given period of exposure. Data from this test program for HDPE geomembrane can be converted to field exposure for a given site following the method presented in Richgels (2016). Such a conversion was performed for this Report for five sites, where field test data for the ClosureTurf® HDPE grass blades were also obtained. The five sites are: (i) Atlas Testing Facility, New River, Arizona; (ii) Saufley Field Landfill, Pensacola, Florida; (iii) LaSalle-Grant Landfill in Jena, Louisiana; (iv) Baldwin County Landfill, Georgia; and (v) Berkely County Landfill, South Carolina.

Once the conversion from the GRI laboratory UV exposure to the field UV exposure at each site was completed, extrapolations of retained tensile strength of HDPE geomembrane as a function of UV exposure were made to obtain estimates of half-life (i.e., 50% retained tensile strength) and 12.5% retained tensile strength. The 12.5% value was selected to illustrate extended longevity when performance requirements support the selection of service-life tensile strength values lower than the half-life tensile strength values. The extrapolations included an upper bound (Arrhenius) and a lower bound (linear) of retained tensile strength as a function of UV exposure. Based on the GRI laboratory data for HDPE geomembrane, the resulting upper bound estimate of the half-life of an HDPE grass blade is 93 years in New River, Arizona with a lower bound estimate of 75 years, assuming that the laboratory results of HDPE geomembrane are applicable to HDPE grass blades. For the sites in the Southeastern U.S., the upper bound half-life estimate is 157 years, while the lower bound estimate is 83 years. If the 12.5% retained strength is considered for the HDPE grass blades, rather than the half-life, the upper and lower bound estimates for the New River, Arizona site are 216 years and 181 years, respectively. For the Southeastern U.S., if the 12.5% retained strength is considered, the upper bound and lower bound estimates are 376 and 204 years, respectively.

The field test data from the five sites consisted of measurements of the tensile strength of the ClosureTurf® HDPE grass blades at given durations of field exposure. The New River, Arizona site is a field weathering testing facility where samples of ClosureTurf® HDPE grass blades were exposed to sunlight concentrated by an array of mirrors to accelerate the degradation process by a factor of seven. The remaining four sites in the Southeastern U.S. are waste facilities where ClosureTurf® was installed. The field test data of ClosureTurf® HDPE grass blades from the New River, Arizona site (i.e., the accelerated weathering testing site) as well as the four Southeastern U.S. sites (i.e., the real-world weathering sites) consistently plotted above the upper bound curve developed from the GRI laboratory data for HDPE geomembrane. This suggests that the length of time required to reach half-life (or any

other value of the percent retained tensile strength) of the HDPE grass blades in the field is longer than indicated by the estimates from the conversion of GRI laboratory data. The disparity is likely due to ignoring the antioxidant depletion phase in the laboratory data as well as site environmental factors (e.g., moisture, shading, slopes, etc.) that are not included in the method of conversion from laboratory exposure to field exposure.

Given these factors and results it is reasonable to expect that the half-life of the HDPE grass blades of the ClosureTurf® product is on the order of 100 years under the New River, Arizona climatic conditions. Since the New River, Arizona site has the highest levels of UV irradiance and temperature in the United States, sites located elsewhere will have greater half-life estimates in general proportion to the ratio of UV irradiance. Furthermore, performance requirements of the ClosureTurf® HDPE grass blades may permit evaluation of longevity beyond the half-life, thereby extending the expected duration of field performance.

DATA SUMMARY

Data sets currently available when this Report is prepared represent an expansion over what was available during the Geosyntec (2015) study. The current data includes measurements of tensile strength of HDPE grass blades after UV exposure from multiple sites where ClosureTurf® has been installed and tensile strength of HDPE geomembrane and grass blades from additional accelerated weathering tests. The data sets of direct measurement of tensile strength as a function of UV exposure utilized in this Report include:

1. Geosynthetics Research Institute (GRI) laboratory data release on the effects of accelerated weathering of HDPE geomembrane strips presented by Dr. Robert Koerner at GeoAmericas (2016). The effects are measured in terms of changes to tensile strength as a function of UV exposure under a fluorescent lamp at various temperatures. The data contains updates from GRI in addition to what was included in the Geosyntec (2015) Report.

2. Data from the New River, Arizona field testing facility. The data includes measurements of retained tensile strength of HDPE grass blades exposed to full spectrum radiation using sunlight concentrated by mirrors to accelerate the weathering process. The testing setup accelerates the effects of exposure duration by a factor of seven.

3. Tensile strength test results of HDPE grass blade samples retrieved from the following ClosureTurf® sites: (i) Saufley Field Landfill, Pensacola, Florida; (ii) LaSalle-Grant Landfill, Jena, Louisiana; (iii) Baldwin County Landfill, Georgia; and (iv) Berkely County Landfill,

South Carolina. The data include measurements of retained tensile strength as a function of real-world sunlight exposure in years.

DATA DISCUSSION

The GRI data set involves controlled exposure of geosynthetic samples to temperature and UV radiation simulating solar maximum exposure with a UV source at three constant temperatures (60°C, 70°C, and 80°C). The testing program is performed in accordance with ASTM D7238 procedures for *Standard Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus.* Charts were produced with this updated data in Richgels (2016), which presents the retained tensile strength of the HDPE geomembrane test samples incubated at each temperature set as a function of the cumulative UV exposure (Figure 2). Stages A to B (antioxidant depletion and transition periods) and Stage C (polymer oxidation) are distinguished in the charts, and the Stage C data points were selected for the regression.

The application of the GRI laboratory data to individual field sites requires conversion of the exposure conditions of the laboratory to local site conditions. While site specific exposure information for the Atlas Testing Facility in New River, Arizona was included in Richgels (2015a, 2015b), exposure conversion to other sites had to be developed. Richgels (2016) performed such a conversion from the GRI laboratory data to several sites in Florida using solar radiation and temperature data from the National Renewable Energy Laboratory (NREL). The temperature and radiation data for each site is expressed by NREL in a Total Meteorological Year (TMY3), a multiyear dataset from which 12 months are chosen that best represent the median conditions. Geosyntec adopted this same procedure for the sites included in this Report.

The Geosyntec (2015) report presented tensile property testing of the field samples of the HDPE grass blades exposed to the New River, Arizona environment at the Atlas Testing Facility for approximate exposure periods of 1, 5, 7, and 10 years. The average values for tensile strength retained at each corresponding period was determined to be 97.2%, 89.7%, 83.8%, and 82.5%, respectively. Watershed is conducting additional accelerated weathering testing at the same facility using the Equatorial Mount with Mirrors for Acceleration (EMMA) solar concentration device, which provides approximately seven years of UV radiation exposure in one calendar year. Additional tensile property testing was performed on samples of the HDPE grass blades collected from the accelerated weathering testing. The approximate exposure periods for these samples were one, two, and three calendar years, which correspond to accelerated exposure periods of approximately 7, 14, and 21 years, respectively. The average values for tensile strength retained for these exposure periods are 92.2%, 83.3%, and 80.7%, respectively (Figure 3).

Similar data was collected for field samples of the HDPE grass blades weathered under climatic conditions at the landfills in Berkley County, South Carolina, Baldwin County, Georgia, Pensacola, Florida, and Jena, Louisiana. The exposure periods of the samples for these sites were:

- Berkley County, 2 years
- Baldwin County, 3 years
- Pensacola, Florida, 5 years
- Jean, Louisiana, 7 and 8 years

The average values for tensile strength retained for these exposure periods were 100%, 99.1%, 97.3%, 85.4%, and 96.8%, respectively (Figure 4). Because the yearly irradiation is fairly uniform in the Southeastern region of the U.S. (Figure 5), the field data obtained from sites in this region were grouped together on a single plot, as shown in Figure 4. The new EMMA and field test data were added onto the figure of half-life projections presented in the Geosyntec (2015) Report, as shown in Figure 6. The new data, which are plotted at or above the trend lines, support the longevity of ClosureTurf projected in the Geosyntec (2015) Report.

PERFORMANCE REQUIREMENTS

The acceptable level of degradation for a given property of polyolefins due to exposure to UV radiation should be based on the performance requirements of that particular aspect of the product. In the case of HDPE grass blades of the ClosureTurf® system, performance requirements for tensile strength may be as low as 2.5 to 3.5 pounds (lbs.) based on the applied loads of pullout forces from equipment operation and water runoff (Diguilo, 2013). Since the original manufactured strength of an HDPE grass blade is a minimum of approximately 20 lbs., the performance requirement is approximately 12.5%, if no factor of safety is included. Both the original manufactured strength of the product and the performance requirement should be evaluated for each individual application. However, for the purposes of this Report, Geosyntec utilized 12.5% of original strength as the performance requirement to illustrate the difference in duration with the half-life criterion.

HDPE GRASS BLADE LONGEVITY EVALUATION

In order to develop a prediction for the longevity of the HDPE grass blades with respect to UV degradation for each of the sites from which field data was collected, Geosyntec implemented the method found in Richgels (2016) for two levels of retained tensile strength (i.e., 50% and 12.5% of the

original property value). The method uses the same calculation procedure used in Richgels (2015a and 2015b) but incorporates the updated data from GRI and UV irradiance and temperature data collected from NREL for each site. In the Geosyntec (2015) Report, Geosyntec performed the calculations in accordance with the Richgels (2015a and 2015b) procedure for Arizona climatic conditions and compared the results with the results presented therein, which were generally in agreement. Once the half-life estimates were calculated, Geosyntec repeated the calculations for 12.5% of retained strength. The same two levels of retained tensile strength (i.e., 50% and 12.5%) were utilized in this Report.

Half-Life Estimation (50% of Retained Strength)

The assessment of half-life is based on the updated data from GRI using retained tensile strength of HDPE geomembrane samples incubated under a UV lamp at elevated temperatures. The elevated temperatures accelerate the UV weathering process in accordance with ASTM D7238.

The GRI data includes samples tested at three elevated temperatures: (i) 80 degrees Celsius (°C); (ii) 70°C; and (iii) 60°C. The 80°C data set reached 50% retained strength, the 70°C data set reached approximately 60% retained strength, and the 60°C data set reached approximately 80% retained strength. Logarithmic extrapolations to 50% retained strength were performed for each temperature data set. The amount of exposure time (on a log scale) corresponding to the 50% retained strength plotted vs. the inverse of the corresponding temperature (80°C, 70°C and 60°C) is shown in Figure 7. Figure 7 allows for extrapolation to find the laboratory exposure time required to achieve 50% retained strength at temperatures lower than the test temperatures (i.e., actual field temperatures).

Once the relationship between temperature and laboratory exposure is defined, a relationship between laboratory exposure and field exposure for a particular site can be constructed. Sites included in this Report are: (i) Atlas Testing Facility, New River, Arizona; (ii) Saufley Field Landfill, Pensacola, Florida; (iii) Lasalle-Grant Landfill, Jena, Louisiana; (iv) Berkley County Landfill, South Carolina; and (v) Baldwin County Landfill, Georgia. These locations correspond to the sites where Watershed has obtained tensile strength measurements on HDPE grass blade samples.

Richgels (2015a and 2015b) presents monthly averages at the Arizona site for: (i) peak turf temperature; and (ii) irradiance as a fraction of the laboratory lamp irradiance. The monthly averages of these parameters for the sites outside of Arizona were obtained from NREL, and the irradiance as a fraction of the laboratory lamp irradiance was determined for each site. The average turf temperature was conservatively estimated by increasing the measured ambient temperature by a factor of two (Richgels, 2016). Using these two parameters for a given month combined with the Arrhenius function, an estimate of half-life loss per month is obtained. Summation of the half-life lost per month over a year yields the annual half-life loss. The inverse of the annual half-life loss is the predicted half-life in years. Using this method to estimate the

half-life for the Pensacola region, Richgels obtained a half-life of approximately 200 years, while Geosyntec obtained a half-life of 132 years (Table 1). The difference is attributable to rounding errors in the logarithmic projections and updates to the solar radiation and temperature information used in NREL datasets. The half-life estimates for the sites in New River, Arizona, Jena, Louisiana, Berkley County, South Carolina, and Baldwin County, Georgia were calculated by Geosyntec as 93, 151, 157, and 157 years, respectively.

Following the suggestion of Koerner et al. (2015), Richgels (2016) treated the results of the half-life mentioned above as an upper bound estimate. For the lower bound estimate, Koerner et al. (2015) suggested performing a linear extrapolation of the laboratory data to lower field temperatures, rather than using the Arrhenius function. With the linear extrapolation, the ratio of monthly irradiance to laboratory lamp irradiance is scaled linearly to calculate the number of months required to reach half-life at 80ºC, 70ºC and 60ºC. Linear extrapolations per month are made from the elevated lab temperatures to the corresponding average turf temperature in that month (Table 2 and Figures 8 through 12). The resulting half-life loss per month is summed to obtain half-life loss per year. The inverse of that result is the half-life in years. For the Pensacola region, Richgels (2016) calculates a half-life of 118 years using this linear model. Geosyntec's calculation resulted in a half-life of 83 years. The half-life estimates for the sites located in New River, Arizona, Jena, Louisiana, Berkley County, South Carolina, and Baldwin County, Georgia were calculated as 75, 91, 90, and 90 years, respectively.

Figure 13 shows the upper (Arrhenius - logarithmic) and lower (linear) bound curves calculated by Geosyntec along with the field data on the HDPE grass blades provided by Watershed (2014 and 2022) for the New River, AZ site. Because of the uniformity of the annual irradiance among the southeastern sites (Figure 5), little variation was observed in the calculated upper and lower bound curves for these sites. Therefore, Figure 14 shows the limits of the calculated upper and lower bound curves for the southeastern sites along with the field data from these sites. As shown in these figures, the field data falls above the upper and lower bound curves. Note that the first point from the field data collected from the Atlas Testing Facility in Arizona at approximately 1 year is omitted from the trend line (Figure 13). This is because the first data point is assumed to be within the antioxidant phase of degradation rather than the polymer oxidation stage as suggested by Rowe et al. (2010). Additional discussion regarding the stages of degradation for polyolefin materials can be found in CUR 243 (2012).

Service Life Estimation Based on Performance Requirements (12.5% of Retained Strength)

Geosyntec repeated the calculations discussed above but extrapolated the GSI laboratory data down to 12.5% retained strength rather than 50% at 80ºC, 70ºC and 60ºC for the sites located in New River, Arizona, Pensacola, Florida, Jena, Louisiana, Berkley County, South Carolina, and Baldwin County, Georgia. The upper bound (Arrhenius - logarithmic) estimates were 216, 314, 359, 376, and 376 years, respectively. The lower bound (linear) estimates were 181, 204, 223, 236, and 221 years, respectively.

The estimates of service life at 12.5% retained strength provided in the Geosyntec (2015) Report were too large to be reasonable. A likely explanation is that the samples tested at 80ºC, 70ºC and 60ºC had not degraded enough to produce accurate predictions at 12.5% retained strength. Given that the updated data from GRI included additional exposure at each of the three test temperatures, a better estimate for time of exposure to reach 12.5% strength was obtained for this Report. However, if the retained strength for laboratory samples approaches 12.5% retained strength in future data releases, the estimates for the corresponding time of exposure may be further refined.

SUMMARY AND CONCLUSIONS

Watershed has provided Geosyntec with supplemental ClosureTurf® accelerated weathering test data from the Atlas Testing Facility, New River, AZ and new field test data from four ClosureTurf® sites located in the Southeastern U.S. Following the laboratory to field conversion method presented in Richgels (2016), Geosyntec calculated the expected exposure duration at the 50% and 12.5% retained tensile strengths of HDPE grass blades under the exposure conditions at the five locations, based on the GRI laboratory UV test results for HDPE geomembrane and then compared them with the test results of field samples of HDPE grass blades.

The method included upper bound and lower bound calculations for each site. The results of the upper bound calculations using the GRI laboratory data yielded exposure durations for 50% retained tensile strength of: (i) 132 years for Saufley Field Landfill in Pensacola, Florida; (ii) 151 years for LaSalle-Grant Landfill in Jena, Louisiana; (iii) 157 years for the Berkely County Landfill; (iv) 157 years for the Baldwin County Landfill; and (v) 93 years for the Atlas Testing Facility in New River, Arizona.

The results of the lower bound calculations using the GRI laboratory data yielded exposure durations for 50% retained tensile strength of: (i) 83 years for Saufley Field Landfill in Pensacola, Florida; (ii) 91 years for LaSalle-Grant Landfill in Jena, Louisiana; (iii) 90 years for the Berkely County Landfill; (iv) 90 years for the Baldwin County Landfill; and (v) 75 years for the Atlas Testing Facility in New River, Arizona.

These calculations were repeated using 12.5% retained tensile strength to illustrate the difference in exposure duration if a performance-based criteria is used rather than half-life. The results of the upper bound calculations yielded exposure durations of: (i) 314 years for Saufley Field Landfill in Pensacola, Florida; (ii) 359 years for LaSalle-Grant Landfill in Jena, Louisiana; (iii) 376 years for the Berkely County Landfill; (iv) 376 years for the Baldwin County Landfill; and (v) 216 years for the Atlas Testing Facility in New River, Arizona.

The lower bound calculations yielded exposure durations for 12.5% retained tensile strength of: (i) 204, years for Saufley Field Landfill in Pensacola, Florida; (ii) 223 years for LaSalle-Grant Landfill in Jena,

Louisiana; (iii) 236 years for the Berkely County Landfill; (iv) 221 years for the Baldwin County Landfill; and (v) 181 years for the Atlas Testing Facility in New River, Arizona.

The results above for the Saufley Field Landfill site in Pensacola, Florida were compared with the results given in Richgels (2016) where a similar conversion was performed. Richgels (2016) obtained an upper bound duration for 50% retained strength of 200 years and a lower bound result of 118 years, compared with Geosyntec's results of 132 years and 83 years, respectively. The differences between Geosyntec and Richgels calculations were attributed to rounding and updates to solar radiation and temperature information used in NREL datasets. However, the comparison generally demonstrates agreement between Geosyntec and Richgels (2016).

Plots of the field data and the upper and lower bound half-life estimates based on the GRI data for the New River, AZ site and the sites in the Southeastern U.S. are shown in Figures 13 and 14, respectively. As displayed in the figures, the field data consistently plots above the upper bound estimates. This difference may be attributable to environmental factors not accounted for in the laboratory or laboratory to field conversion method. These environmental factors may include orientation of the samples in the field, shading from slopes or adjacent grass blades, moisture conditions, etc. (GRI, 2019). Furthermore, as demonstrated in GRI (2019), it is seen that the laboratory lifetimes are somewhat lower than the field lifetimes, indicating that the laboratory incubation devices are more severe in their exposure and radiation when compared to field conditions. Additionally, field samples in the early stages of weathering may be within the antioxidant phase of degradation rather than the polymer oxidation stage as suggested by Rowe *et. al.* (2010). As indicated in Koerner (2011), the duration of the antioxidant depletion phase is dependent upon the type and amount of the various antioxidants present in the formulation. Furthermore, the physical loss of antioxidants involves the distribution of antioxidants in the material and their volatility and extractability to the site-specific environment (Koerner, 2011). Therefore, variations between the field data and the half-life estimates using the GRI laboratory data may be attributable to differences in the rate at which the proprietary antioxidant formulation present in the HDPE grass blades degrades due to site-specific environmental conditions. Finally, because the extrapolation performed to estimate laboratory exposure time required to reach 50% degradation was based upon the regression of the polymer oxidation data points (Stage C) from the GRI data, the half-life projections herein represent a conservative estimate which do not account for the antioxidant depletion phase.

Therefore, a 100-year half-life estimate for the HDPE grass blades of ClosureTurf® is supported for sites in the Southeastern U.S., given that the upper and lower bound estimates bracket a 100-year half-life and the field data regressions plot above the upper bound (Figure 14). While the estimated upper-bound half-life for New River, AZ falls slightly below 100 years due to the higher solar irradiance, the trends observed in the field data also support a half-life estimate that is also on the order of 100 years (Figure 13). The slight disparity between the upper bound estimate and field data is consistent with the discussion provided above. Furthermore, performance requirements of the ClosureTurf® HDPE grass blades may permit

evaluation of longevity beyond the half-life, thereby extending the expected duration of field performance with a longer service life.

CLOSING

Geosyntec appreciates the opportunity to assist Watershed in the development of its ClosureTurf® products. Questions and comments may be directed to either of the undersigned at 678-202-9500.

Sincerely,

Will Tanner, P.E.
Principal Engineer (GA, NC, SC, AL, FL)

Chris Abdeen, E.I.T.
Senior Staff Engineer

Attachments: References
Tables
Figures

Copies to: Bryan Scholl (Watershed)
Mike Ayers (Watershed)

REFERENCES

CUR 243 (2012) "Durability of Geosynthetics". Stichting CURNET, Gouda, The Netherlands.

Diguilo, D. (2013) "ClosureTurf™ – The Next Generation Closure System". Northern New England SWANA Conference, Lebanon, New Hampshire, September 25, 2013.

Geosyntec Consultants (2015) "Literature Review and Assessment of ClosureTurf® UV Longevity". Kennesaw, Georgia, May 15, 2015.

Geosynthetics Research Institute (2019) "Exposed Lifetime Prediction of Geosynthetics Using Laboratory Weathering Devices". Folsom, Pennsylvania, August 19, 2019.

Koerner, R., Hsuan, Y., Koerner, G. (2011) "GSI White Paper 6 - Geomembrane Lifetime Prediction: Unexposed and Exposed Conditions". Geosynthetics Institute, Folsom, Pennsylvania, February 8, 2011.

Koerner, R., Koerner, G., and Hsuan, Y. (2015) "Lifetime Predictions of Covered and Exposed Geomembranes". Webinar GSI-W14, January 14, 2015.

Koerner, R. (2016) "Lifetime Predictions of Covered and Exposed Geomembranes". Keynote Lecture GeoAmericas 2016, Dr. Robert Koerner, Geosynthetics Research Institute. April 2016.

National Renewable Energy Laboratory (2022). NSRDB Data Viewer (nrel.gov). June 2022.

Richgels, C., Ayers, M., and Urrutia, J. (2015a) "Estimation of Geographic Ultraviolet Radiation Levels and Impact on Geosynthetic Cover Systems". Proceedings of Geosynthetics 2015, Portland, Oregon, February 15-18, 2015.

Richgels, C. (2015b) "Estimation of Geographic Ultraviolet Radiation Levels and Impact on Geosynthetic Cover Systems". Geosynthetics 2015, Portland, Oregon, February 15-18, 2015.

Richgels, C. (2016) "ClosureTurf Longevity – State of Florida". October 21, 2016.

Rowe, K., Islam, M., Hsuan, Y. (2010) "Effects of Thickness of the Aging of HDPE Geomembranes". Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 136(2), p.299-309.

Watershed Geosynthetics (2014) "Technical Submittal for ClosureTurf™ – Alternative Final Cover, Closure of Municipal Soild Waste Landfill Units", December 2, 2014.

TABLES

Table 1. HDPE Grass Blade Upper Bound Half-Life Calculations- Saufley Landfill, Pensacola, FL

Month	UV Lamp On[1] (hrs/day)	Average Peak Turf Temp [2] (C)	Average Peak Turf Temp (K)	Average Peak Turf Temp (1/K)	Reaction Rate[3]	Lab Half-Life[4] (lamp hrs)	Field Equivalent[5] (days)	Field Equivalent[6] (months)	Half Life Loss per Month[7]
January	5.19	24.99	298.14	0.0034	-13.72	909876	175241	5653	0.000176899
February	5.42	25.13	298.28	0.0034	-13.71	902464	166396	5943	0.000168273
March	6.80	29.60	302.75	0.0033	-13.45	692347	101754	3282	0.000304656
April	7.09	38.19	311.34	0.0032	-12.96	425411	60016	2001	0.000499866
May	8.83	46.69	319.84	0.0031	-12.50	269585	30519	984	0.001015757
June	7.43	51.58	324.73	0.0031	-12.25	209627	28210	940	0.001063454
July	6.41	54.56	327.71	0.0031	-12.10	180417	28147	908	0.001101362
August	6.15	53.40	326.55	0.0031	-12.16	191246	31118	1037	0.000964064
September	7.15	52.63	325.78	0.0031	-12.20	198737	27785	896	0.001115708
October	7.14	42.52	315.67	0.0032	-12.73	336152	47112	1520	0.000658012
November	6.75	31.70	304.85	0.0033	-13.33	613209	90913	3030	0.000329987
December	5.06	26.43	299.58	0.0033	-13.63	834692	164850	5318	0.000188049
Lab	20							**Yearly Half-life Loss[8]**	0.007586087
								Half-life[9] (years)	131.82

Notes:

(1) UV lamp on (hours per day) is determined as the ratio of UV irradiance determined in accordance with Richgels (2016) to the lamp irradiance used in the laboratory study conducted by GRI (3.05 MJ/m^2/day).

(2) Monthly average ambient temps for Pensacola, FL from NREL database multiplied by a factor of 2 to estimate monthly average peak turf temp (Richgels, 2016).

(3) Reaction rate is calculated from the regression curve shown in Figure 7 for the upper bound (logarithmic) case.

(4) Lab half-life in hours is equal to 1/e^(Reaction Rate).

(5) Field equivalent (days) is calculated by dividing the lab half-life in hours by the UV lamp on hours per day.

(6) Field equivalent in days is converted to months using the given days in that particular month.

(7) Half-life loss per month is the inverse of the corresponding field equivalent in months.

(8) The yearly half-life loss is the sum of each individual months half-life loss.

(9) The half-life in years is the inverse of the yearly half-life loss.

Table 2. HDPE Grass Blade Lower Bound Half-Life Calculations- Saufley Landfill, Pensacola, FL

Month	UV Lamp On[(1)] (hours/day)	Months @ 80 C[(2)]	Months @ 70 C[(2)]	Months @ 60 C[(2)]	Average Peak Turf Temp[(3)] (C.)	Half-life Months (from Regression)	Half-life Loss per month
January	5.19	316	644	787	24.99	1700	0.000588355
February	5.42	334	682	834	25.13	1794	0.000557343
March	6.80	241	491	601	29.60	1208	0.000828074
April	7.09	239	487	596	38.19	1037	0.000963898
May	8.83	185	378	463	46.69	682	0.001465817
June	7.43	228	465	568	51.58	750	0.001333715
July	6.41	256	521	638	54.56	782	0.001279345
August	6.15	267	544	665	53.40	839	0.001192233
September	7.15	237	483	590	52.63	759	0.001316773
October	7.14	230	468	573	42.52	920	0.001086971
November	6.75	251	512	626	31.70	1219	0.000820551
December	5.06	324	660	807	26.43	1706	0.000586084
Lab	20					**Yearly Half-life Loss**	0.01106492
						Half-life (years)	83.20

Notes:

(1) UV lamp on (hours per day) is determined as the ratio of UV irradiance determined in accordance with Richgels (2016) to the lamp irradiance used in the laboratory study conducted by GRI (3.05 MJ/m^2/day).

(2) The months required at each temperature is calculated using the regressions from Figure 8 for each temperature, projected down to half-life, then dividing the lamp-hours at half-life by the UV lamp on hours per day for a given month. Once this calculation is done for 80, 70 and 60 C, a linear regression (as shown in Figure 8) is used to obtain the half-life months at the corresponding average peak turf temp.

(3) Monthly average ambient temps for Pensacola, FL from NREL database multiplied by a factor of 2 to estimate monthly average peak turf temp (Richgels, 2016).

FIGURES





Note: The sand ballast infill is not shown in the sample photo on the left, but is shown in a field application photo on the right.

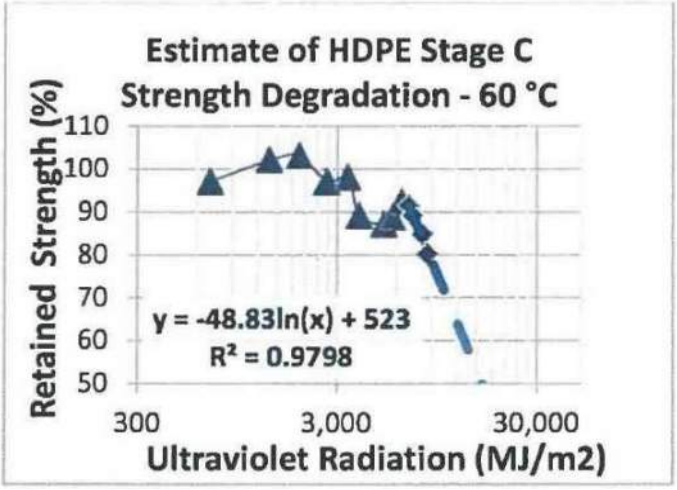
ClosureTurf®Components

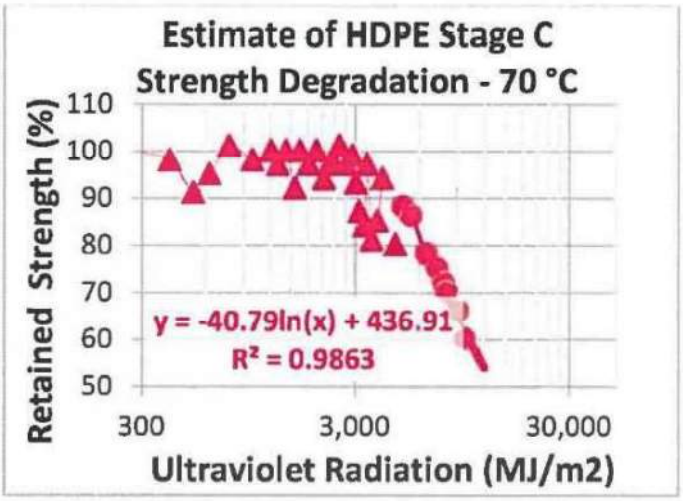
Watershed Geosynthetics – ClosureTurf® UV Assessment

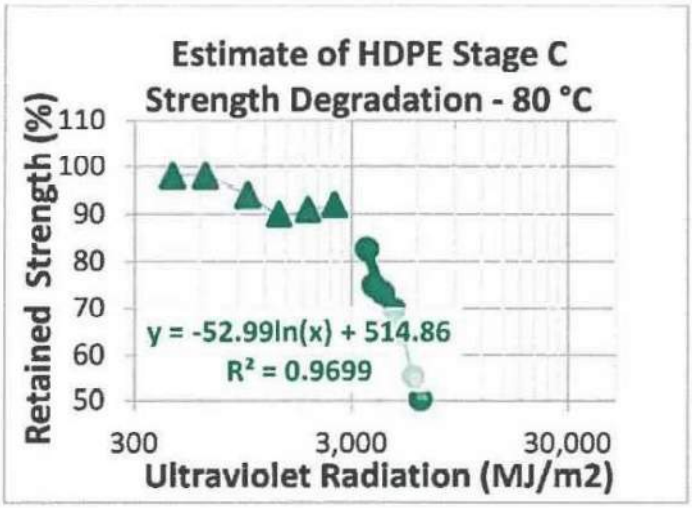
Geosyntec consultants

Figure 1

Kennesaw, GA | August 2022







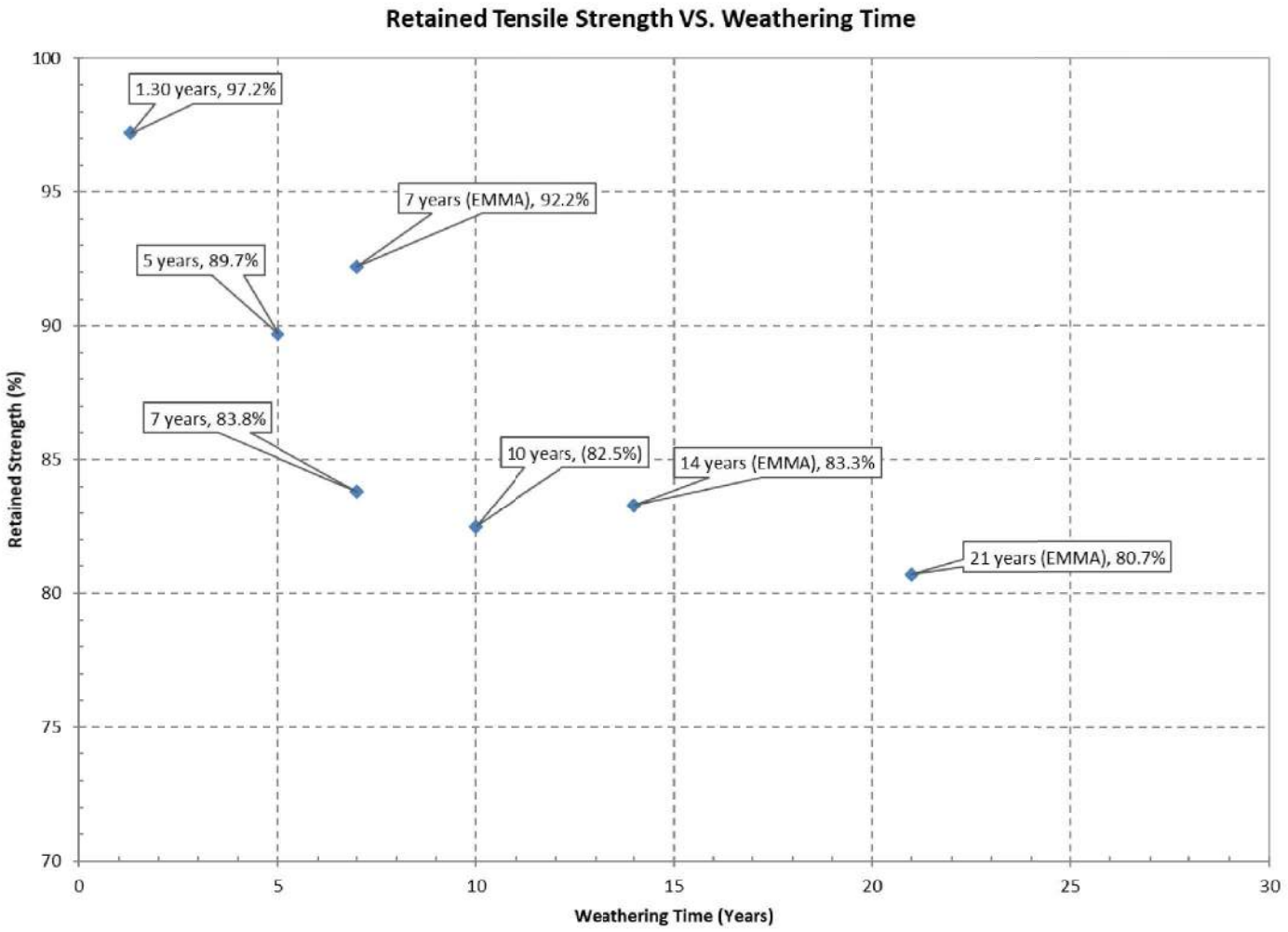
GRI Data Release - Three Stage Oxidation of HDPE for Different Temperatures

Watershed Geosynthetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure 2

Kennesaw, GA | August 2022



Notes:

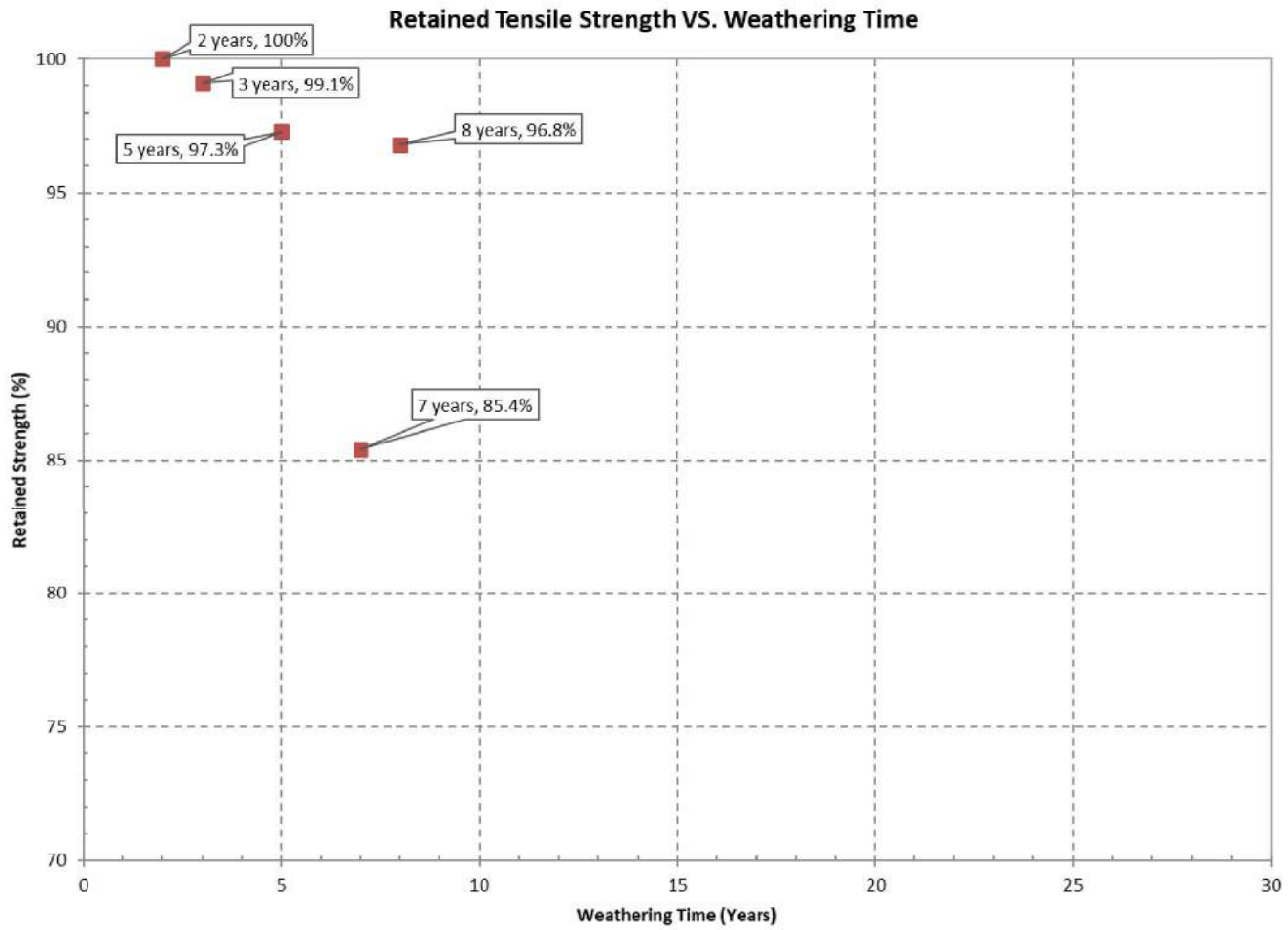
1. The first data point at Weathering Time of 1.3 years is considered to be within the initial stage of UV degradation (i.e., anti-oxidant depletion), rather than polymer oxidation which is represented by the final six data points.
2. Each data point represents the average result of 10 tensile strength tests.
3. The accelerated weathering testing is conducted using the Equatorial Mount with Mirrors for Acceleration (EMMA) solar concentration device, which provides approximately seven years of UV radiation exposure in one calendar year.

Field Test Data (Watershed 2014, 2022)
New River, AZ Atlas Testing Facility
Watershed Geosynthetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure **3**

Kennesaw, GA | November 2022



Notes:

1. Each data point represents the average result of 10 tensile strength tests.

Field Test Data (Watershed, 2022)
Southeastern United States Locations
Watershed Geosynthetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure **4**

Kennesaw, GA | November 2022

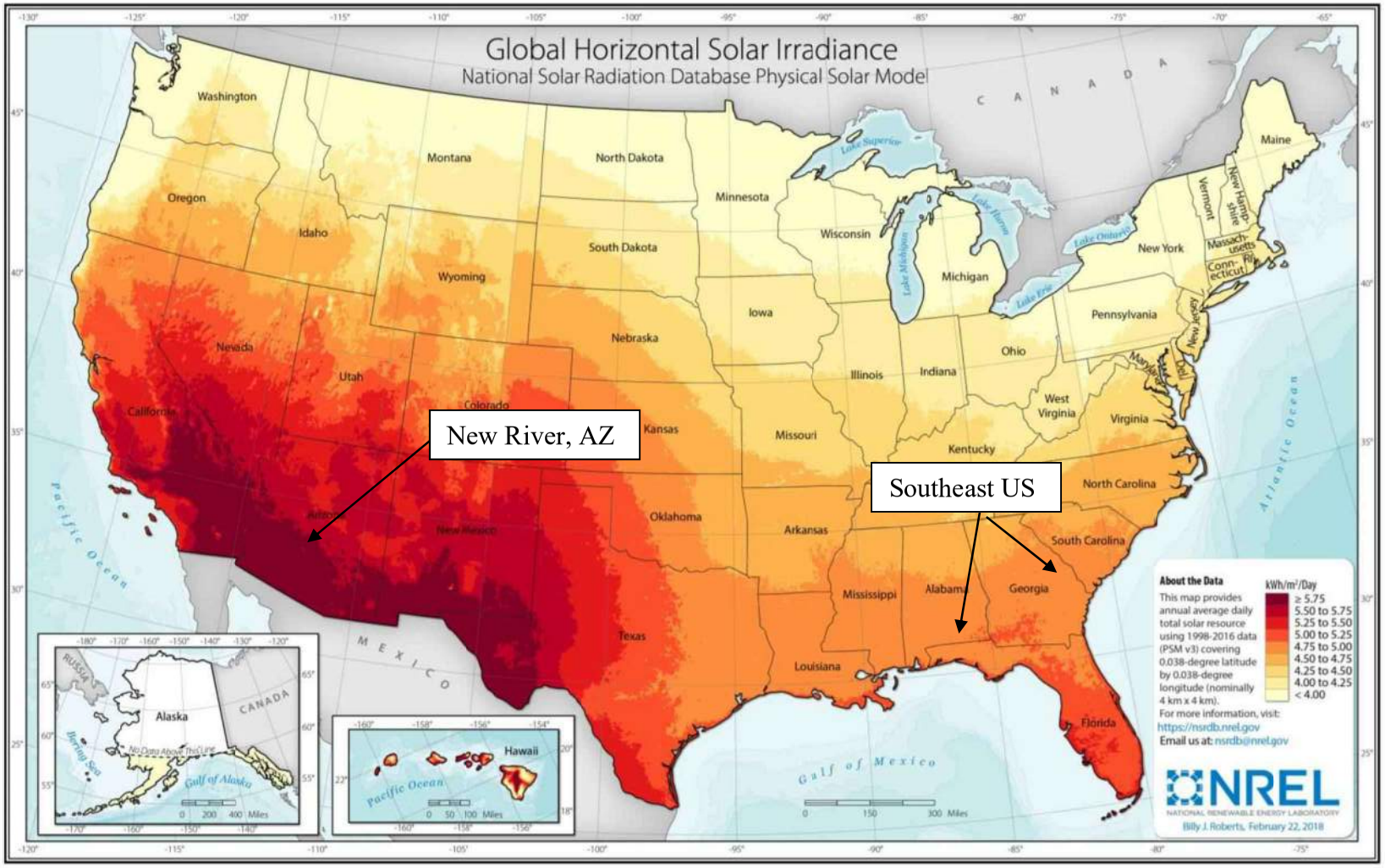


Image available at: https://www.nrel.gov/gis/solar-resource-maps.html

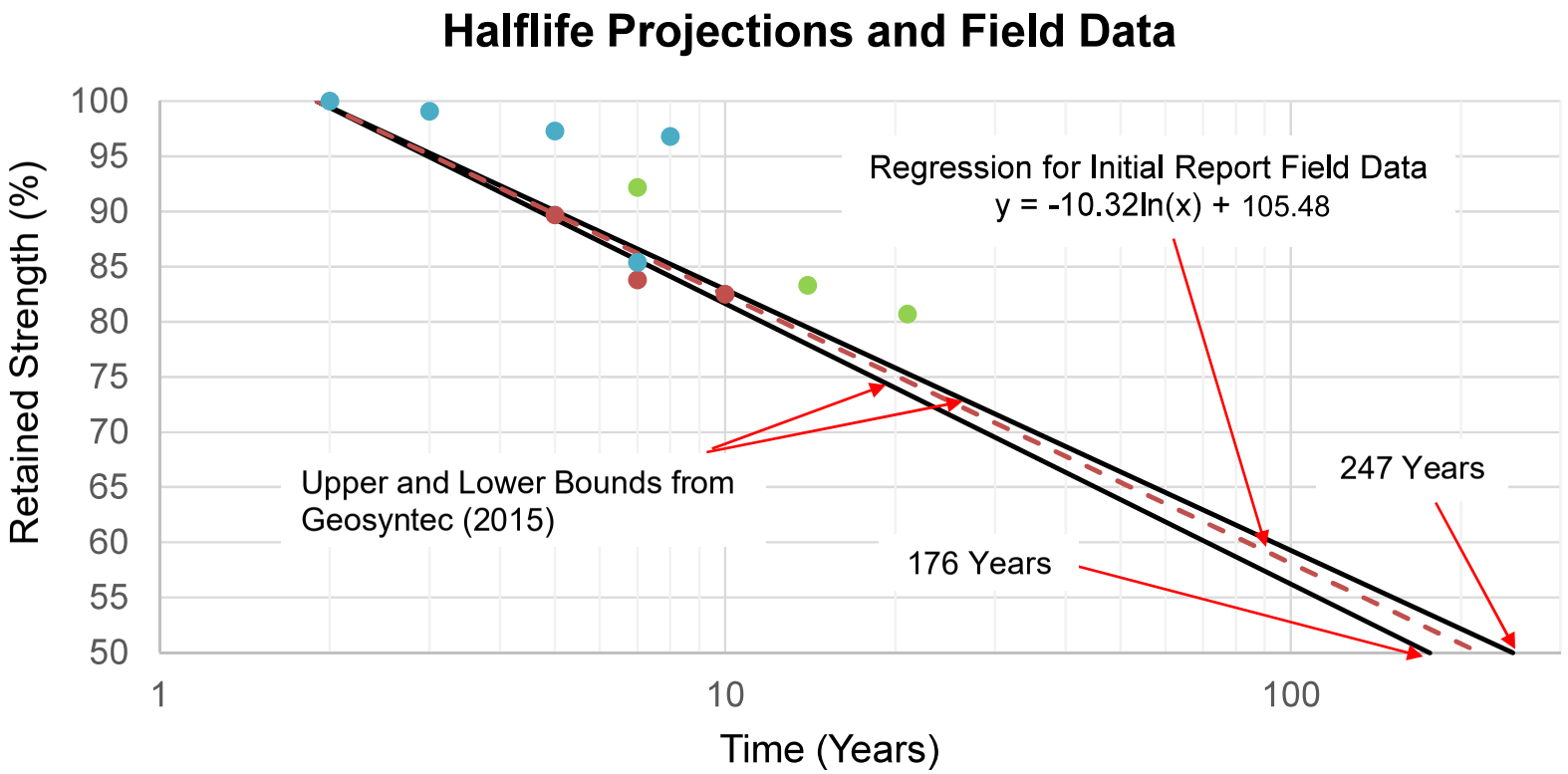
Horizontal Solar Irradiance

Watershed Geosynthetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure 5

Kennesaw, GA | November 2022



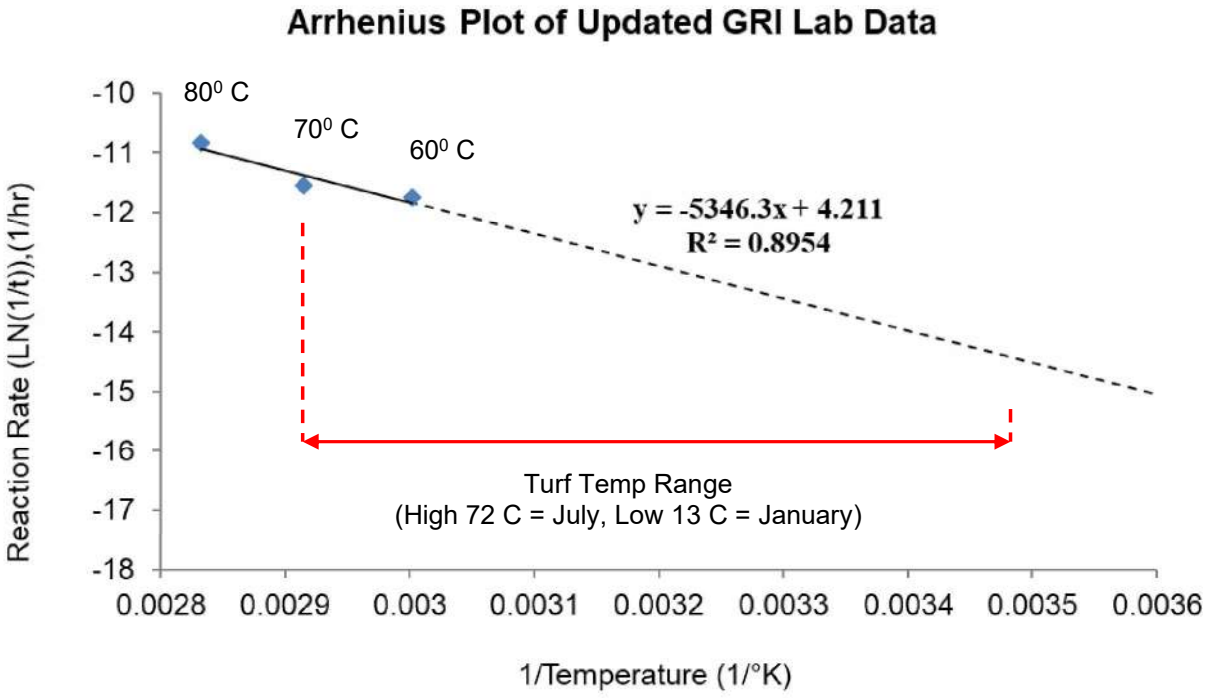
Geosyntec (2015) Halflife Projections
Vs. New Field and Accelerated Weathering Data

Watershed Geosythetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure **6**

Kennesaw, GA | November 2022



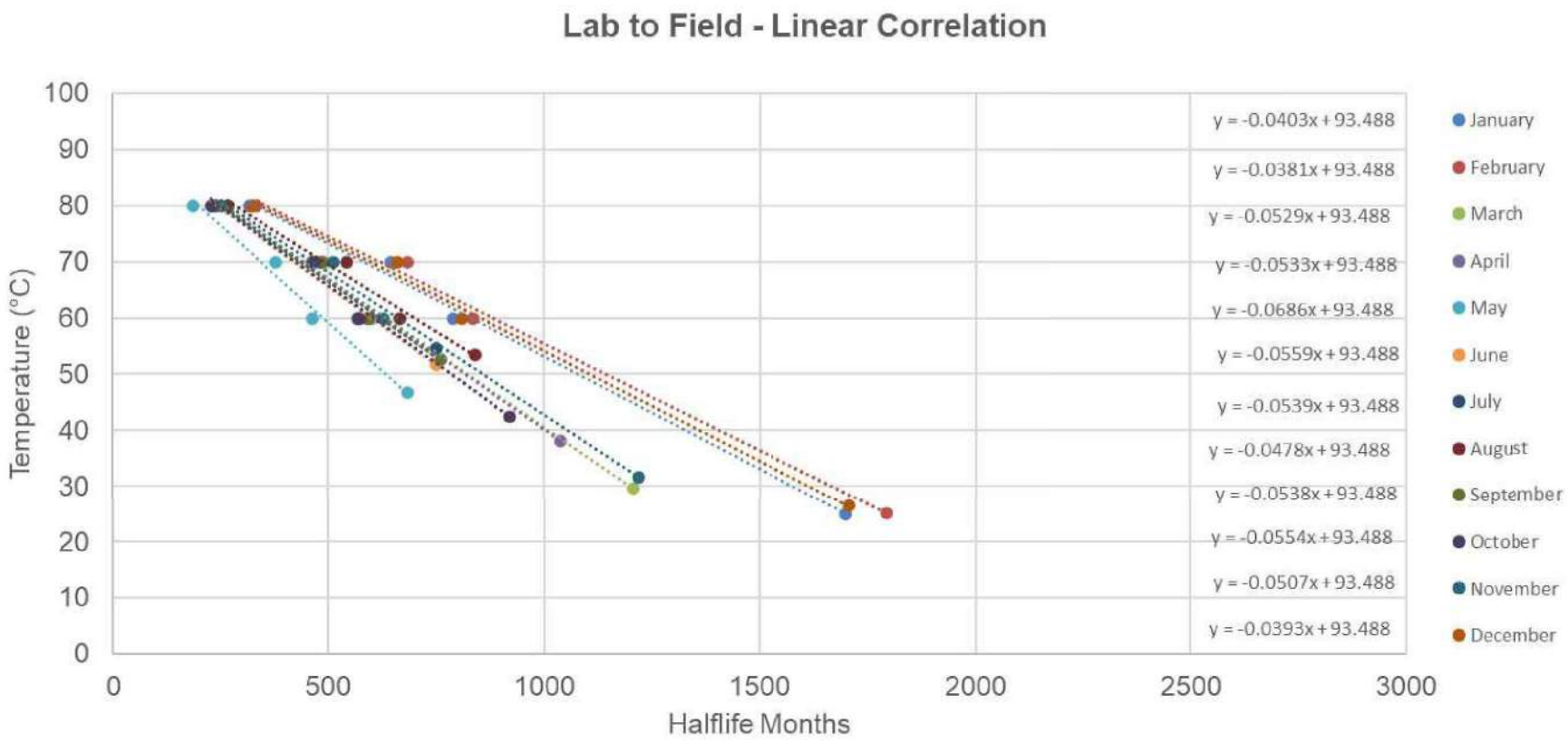
Arrhenius Plot of Lab Data

Watershed Geosynthetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure 7

Kennesaw, GA | November 2022



Notes:

1. Each month was projected down to the turf temperature to get the half-life months. The inverse of half-life months is half-life loss per month. The sum of all the half-life losses for each month in a year is the yearly half-life loss, the inverse of which is the half-life. An example calculation for the Saufley Landfill site is provided in Table 2.
2. Trendline equations are listed in order chronologically from January to December.

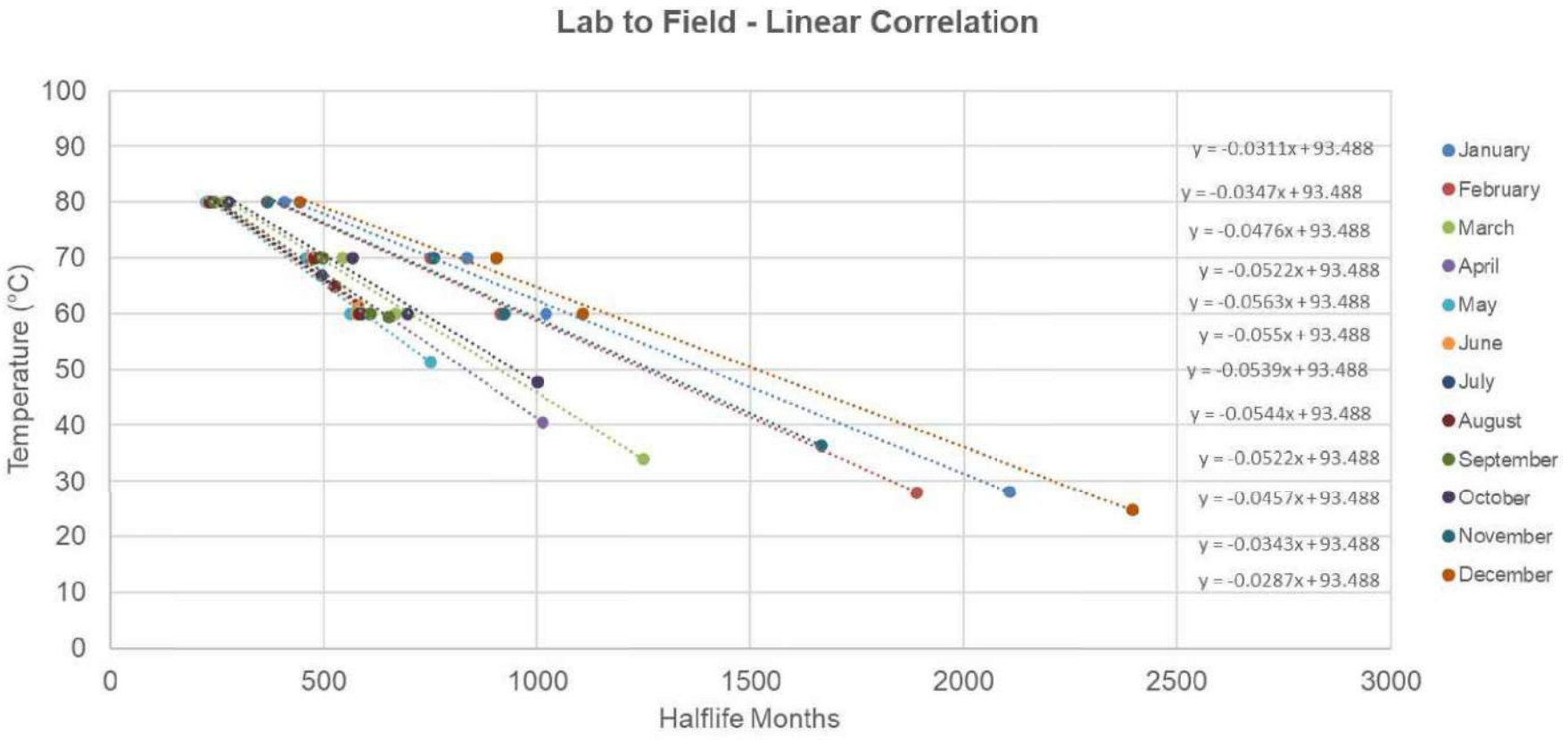
Linear Extrapolations for Half-life Months – Saufley Field Landfill, Pensacola, FL

Watershed Geosythetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure **8**

Kennesaw, GA | November 2022



Notes:

1. Each month was projected down to the turf temperature to get the half-life months. The inverse of half-life months is half-life loss per month. The sum of all the half-life losses for each month in a year is the yearly half-life loss, the inverse of which is the half-life. An example calculation for the Saufley Landfill site is provided in Table 2.
2. Trendline equations are listed in order chronologically from January to December.

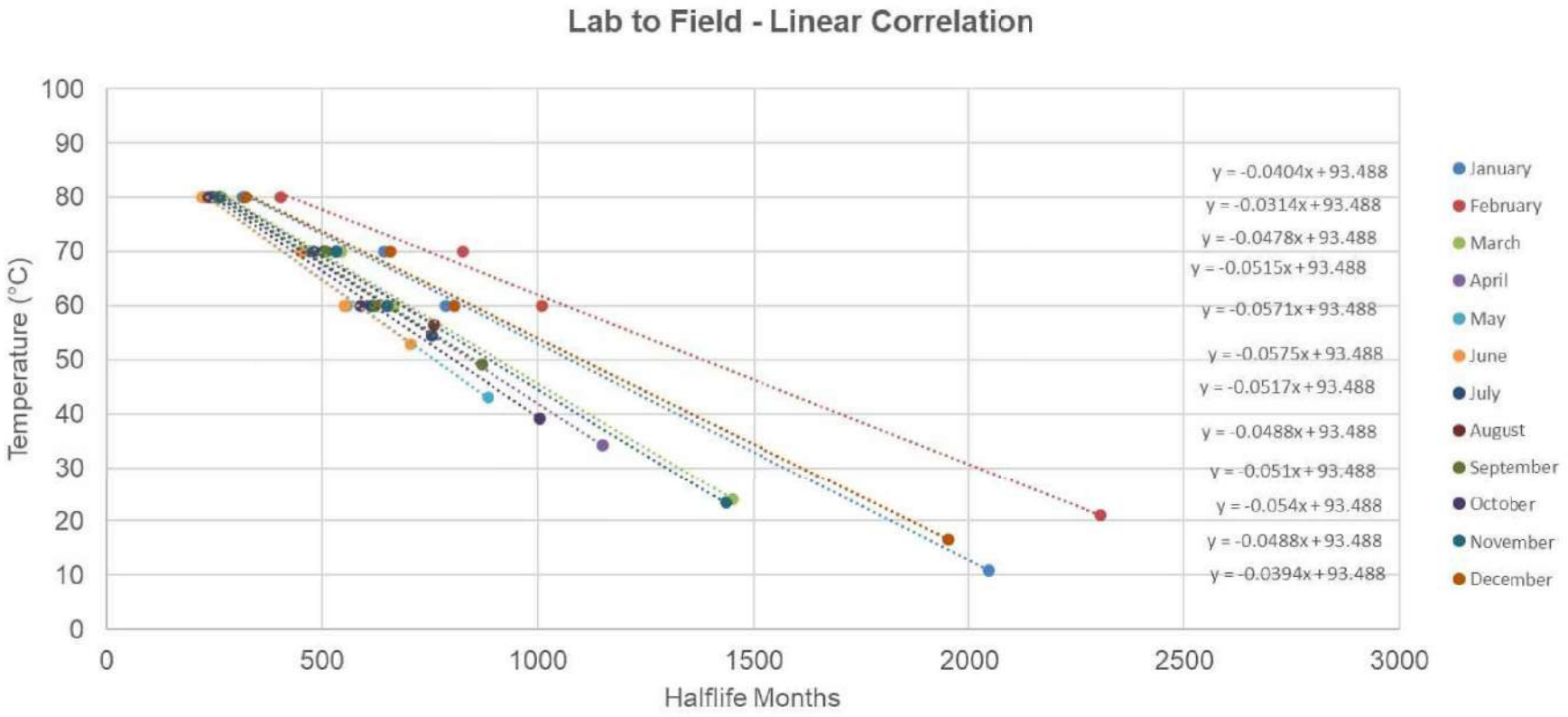
Linear Extrapolations for Half-life Months – New River, Arizona

Watershed Geosythetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure 9

Kennesaw, GA | November 2022



Notes:

1. Each month was projected down to the turf temperature to get the half-life months. The inverse of half-life months is half-life loss per month. The sum of all the half-life losses for each month in a year is the yearly half-life loss, the inverse of which is the half-life. An example calculation for the Saufley Landfill site is provided in Table 2.
2. Trendline equations are listed in order chronologically from January to December.

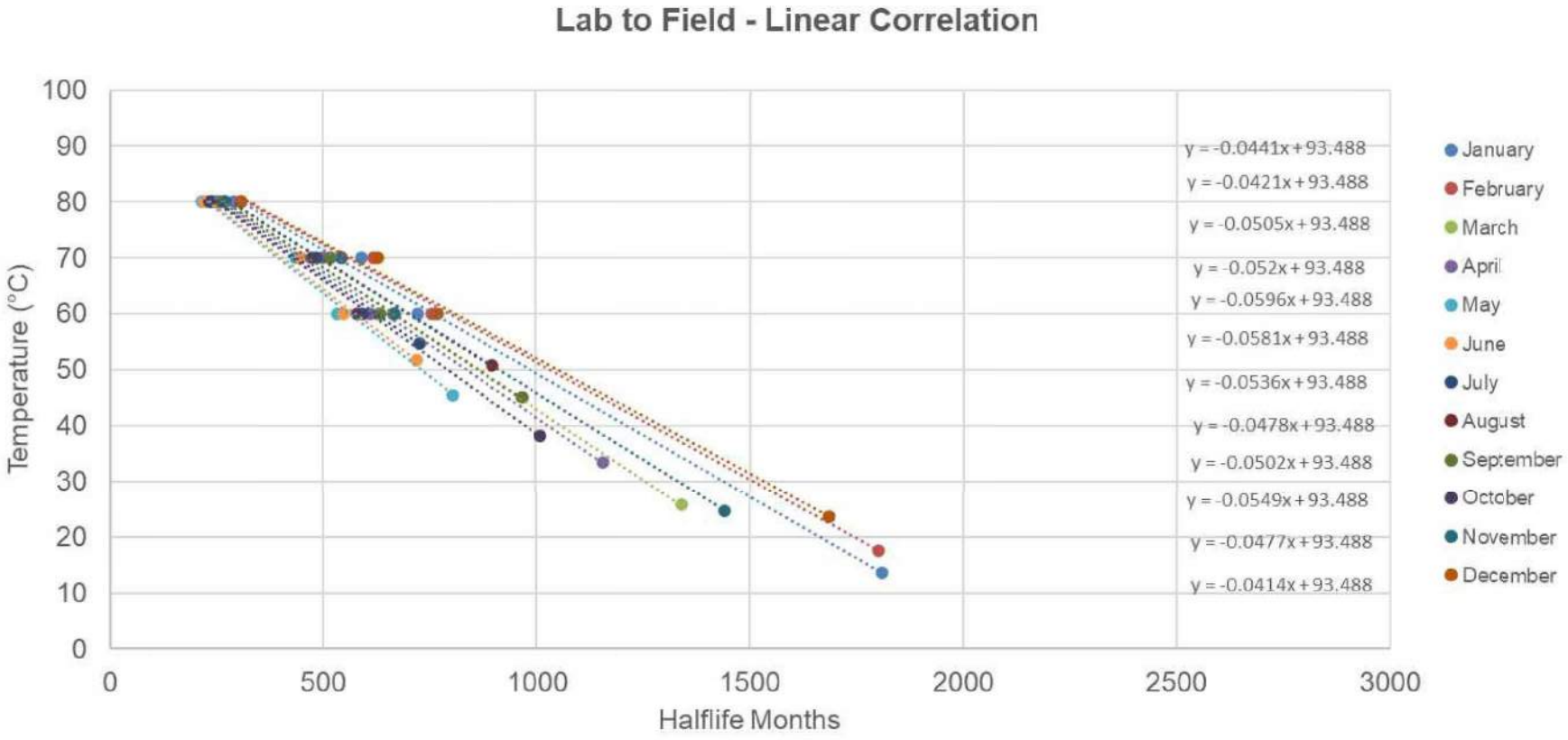
Linear Extrapolations for Half-life Months – Lasalle-Grant Landfill, Jena, LA

Watershed Geosythetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure **10**

Kennesaw, GA | November 2022



Notes:

1. Each month was projected down to the turf temperature to get the half-life months. The inverse of half-life months is half-life loss per month. The sum of all the half-life losses for each month in a year is the yearly half-life loss, the inverse of which is the half-life. An example calculation for the Saufley Landfill site is provided in Table 2.
2. Trendline equations are listed in order chronologically from January to December.

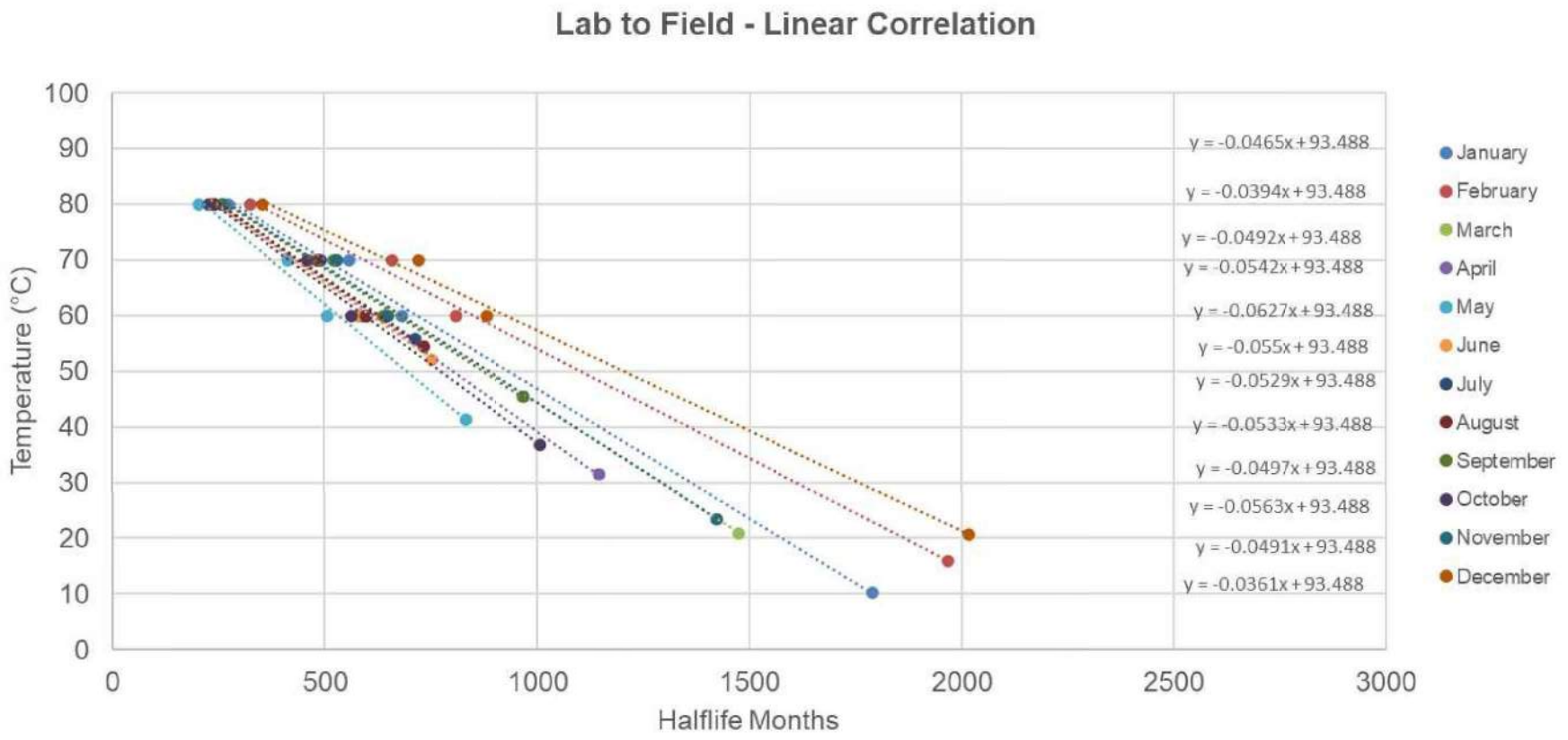
Linear Extrapolations for Half-life Months – Berkley Co., SC

Watershed Geosythetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure **11**

Kennesaw, GA | November 2022



Notes:

1. Each month was projected down to the turf temperature to get the half-life months. The inverse of half-life months is half-life loss per month. The sum of all the half-life losses for each month in a year is the yearly half-life loss, the inverse of which is the half-life. An example calculation for the Saufley Landfill site is provided in Table 2.
2. Trendline equations are listed in order chronologically from January to December.

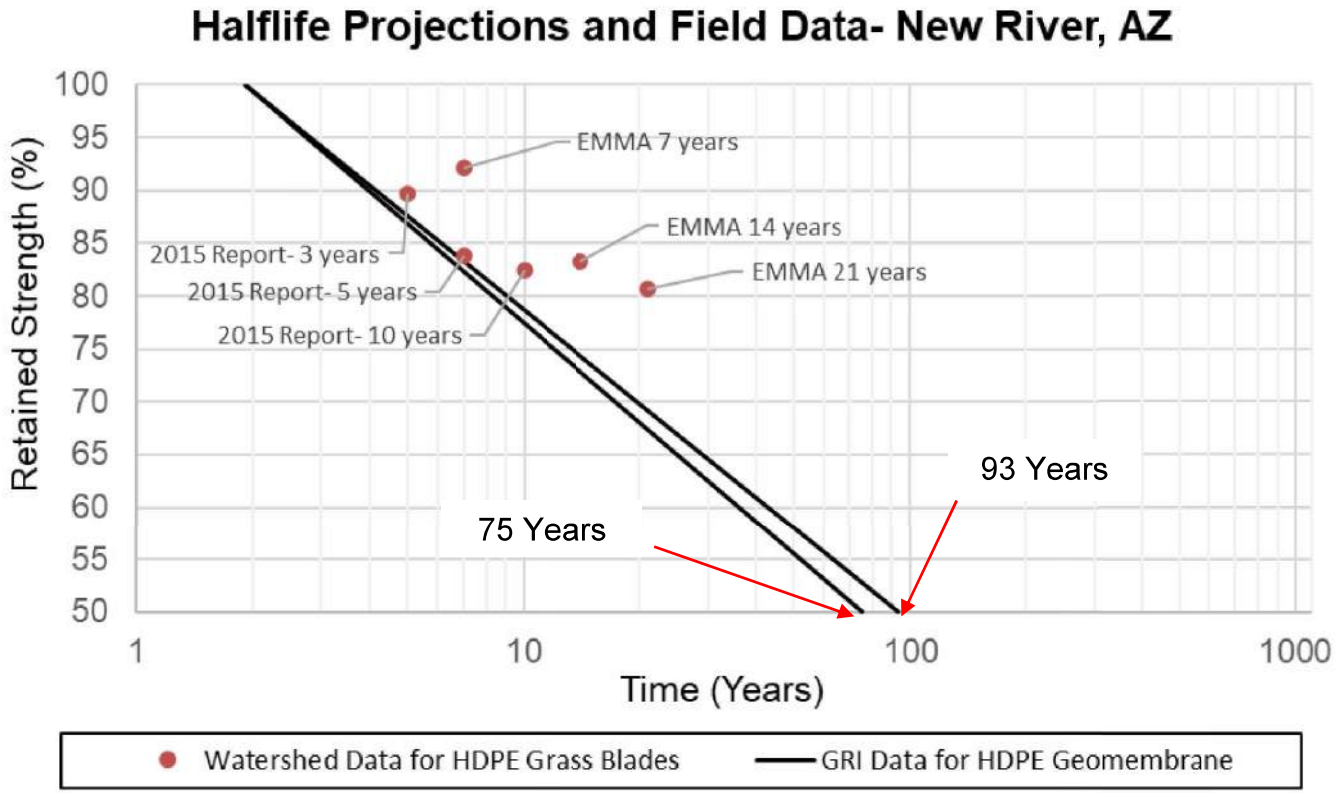
Linear Extrapolations for Half-life Months – Baldwin Co., GA

Watershed Geosythetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure **12**

Kennesaw, GA | November 2022

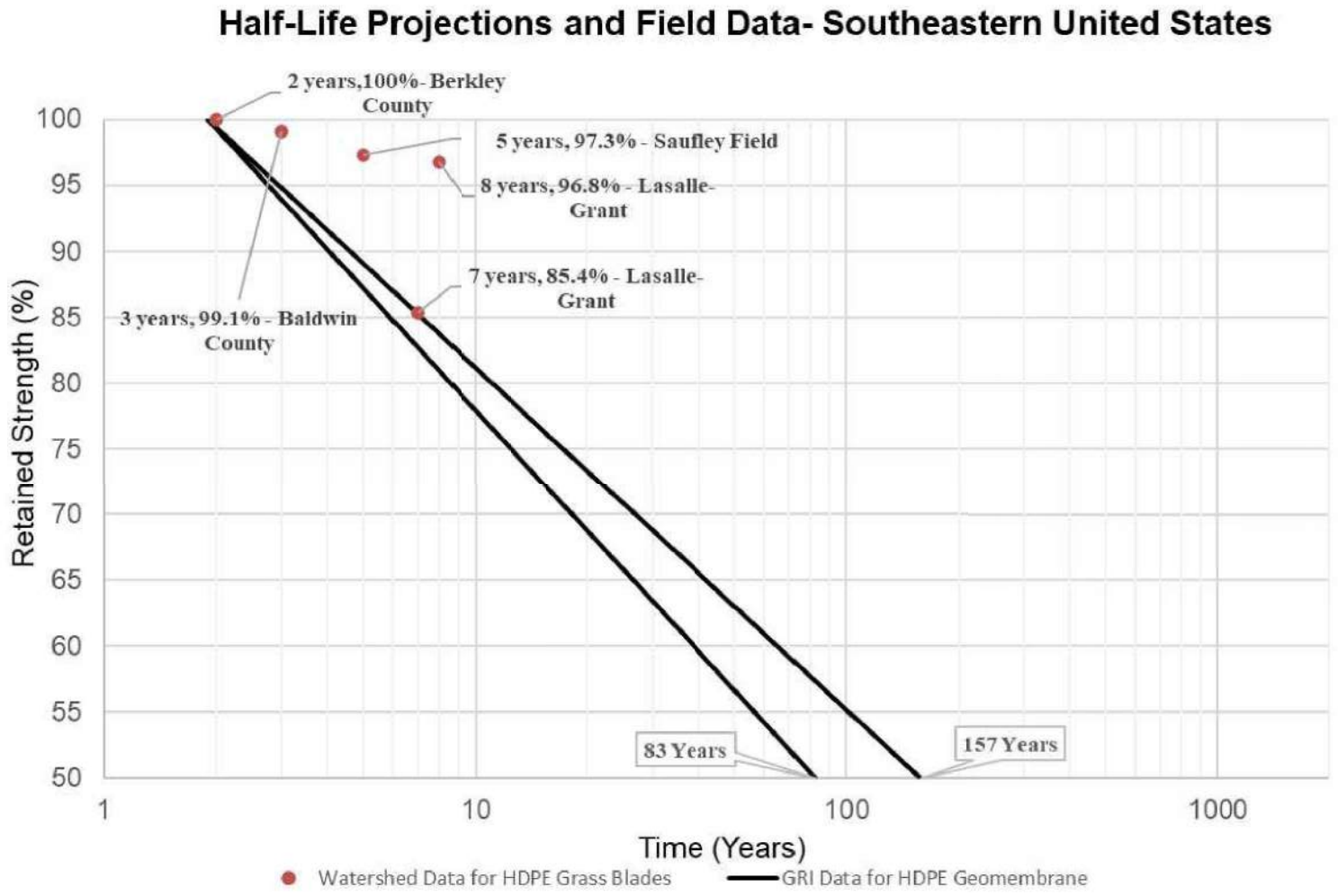


Halflife Projections
Upper and Lower Bound Estimates- New River, AZ
Watershed Geosythetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure **13**

Kennesaw, GA | November 2022



Note: The upper and lower bound half-life estimates represent the limits of the estimates for the sites in the Southeastern United States.

Halflife Projections
Upper and Lower Bound Estimates- SE United States
Watershed Geosythetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure **14**

Kennesaw, GA | November 2022

2015 Evaluation Report

Geosyntec consultants

1255 Roberts Boulevard, Suite 200
Kennesaw, Georgia 30144
PH 678.202.9500
FAX 678.202.9501
www.geosyntec.com

15 May 2015

José Urrutia, P.E.
Vice President of Engineering
Watershed Geosynthetics
11400 Atlantis Place, Suite 200
Alpharetta, GA 30022

Subject: Literature Review and Assessment of ClosureTurf® UV Longevity

Dear Mr. Urrutia:

Watershed Geosynthetics, Inc. (Watershed) has patented an alternative landfill closure system termed, ClosureTurf®. ClosureTurf® consists of high-density polyethylene (HDPE) grass blades tufted through a polypropylene (PP) geotextile backing which overlies Super Gripnet®, an HDPE or linear low-density polyethylene (LLDPE) geomembrane manufactured by AGRU America Inc. The addition of a layer of sand ballast during installation completes the system. The sand ballast provides cover for the lower portion of the HDPE grass blades, the PP geotextile backing, and the Super Gripnet® (Figure 1). The ClosureTurf® system, therefore, is a "hybrid" closure system in the sense that it is neither a traditional soil cover or an exposed geomembrane. ClosureTurf® has been used to close a number of landfills throughout the United States. A select list of sites where it has been used is shown in Table 1. Applications extend to other facilities as well, such as capping of coal ash ponds.

Watershed has requested that Geosyntec Consultants, Inc. (Geosyntec) provide an assessment of the longevity of the ClosureTurf® system with regard to UV degradation. Since ClosureTurf® has elements (i.e., the HDPE grass blades) that are permanently exposed to UV radiation, this assessment will be particularly focused on the exposed portion of the system. However, the UV longevity of the PP geotextile backing and HDPE geomembrane will also be addressed by reference.

Geosyntec's approach to this assessment has been to conduct a literature review of pertinent documents available (journal papers, white papers, presentations, etc.), distill the results of the review, and perform limited analysis. This report concludes with a summary of the review and analysis along with brief discussion for recommendations.

EXECUTIVE SUMMARY

The UV longevity assessment of the ClosureTurf® system (Figure 1) began with a literature review. In general, relatively little published information was discovered regarding exposed HDPE grass blade degradation. The information that is available consists of retained tensile strength test results of HDPE grass blades after exposure (1, 5, 7 and 10 years) at a field test facility in New River, Arizona (Watershed, 2014). Extrapolation of this data by Watershed (2014) resulted in a prediction of 65% retained tensile strength after 100 years of service. In addition, Richgels *et al* (2015) published half-life (i.e., 50% retained tensile strength) predictions of exposed HDPE grass blades using a laboratory data release from the Geosynthetics Institute (GSI) on HDPE geomembrane strips exposed to UV lamp irradiation. Richgels *et al* (2015) obtains an upper bound and lower bound half-life predictions of 247 years and 176 years, respectively. Extrapolation of the field data from New River, Arizona yielded a half-life of 216 years.

Geosyntec checked the calculations shown in Richgels *et al* (2015) and obtained 277 years and 214 years for the upper and lower bound estimates of HDPE grass blade half-life. Differences in the results between Geosyntec and Richgels *et al* (2015) are attributed to rounding. Geosyntec attempted to repeat these calculations for actual performance requirements (i.e., 12.5% of original tensile strength) of the HDPE grass blades rather than a randomly assigned half-life, however the predictions resulted in service lives that were too lengthy to be reasonable. The most likely explanation is that the laboratory data has not degraded enough to allow for service life predictions using 12.5% retained tensile strength. Future data releases from GSI will aid in providing more accurate predictions below the half-life.

Based on Richgels *et al* (2015) predictions, as well as the prediction given in Watershed (2014) it appears that the half-life of the HDPE grass blades exposed to Arizona-like conditions is on the order of 100 years. These results are promising; however additional field test data is needed to improve the half-life predictions, particularly since half-life predictions for exposed HDPE geomembrane are also approximately 100 years (Koerner *et al*, 2015). Understanding the differences in weathering between HDPE grass blades in a synthetic turf and an HDPE geomembrane will provide additional insight into the similar half-life predictions of the two geosynthetics. Finally, the service life of the HDPE grass blades in the ClosureTurf® system should ideally be based on its performance requirements rather than a half-life which will result in a longer service life prediction.

In addition to the HDPE grass blades, there are two unexposed elements of the ClosureTurf® system: (i) the PP geotextile backing for turf component; and (ii) the Super Gripnet® which consist of a HDPE geomembrane (see Figure 1).

Watershed has incorporated UV degradation inhibitors into the PP geotextile backing which, according to Watershed has lead to an improvement in UV resistance by a factor of 14 over the original prediction of 65% retained tensile strength after 100 years (Watershed, 2014). Koerner (2011) has estimated that covered HDPE geomembrane will have a half-life of 446 years at 20 degrees Celsius and 265 years at 25 degrees Celsius.

Therefore, the most critical component of the ClosureTurf® appears to be the exposed HDPE grass blades when it comes to UV degradation. However, degradation of the HDPE grass blades to unserviceable levels can be remediated by replacement of the turf component of the ClosureTurf® system.

BACKGROUND AND LITERATURE REVIEW SUMMARY

In total, Geosyntec has reviewed approximately 40 technical documents to date. The database is a combination of documents provided to Geosyntec by Watershed as well as documents collected by Geosyntec. A complete reference list of the documents in the database can be made available upon request.

In general, relatively little information was found on the topic of exposed HDPE grass blades with respect to degradation due to UV radiation. The documents that were obtained and reviewed are listed below.

1. Field test data provided by Watershed from the New River, Arizona testing facility on the HDPE grass blades (Watershed, 2014).

2. Testing results (Atlas-MTS) discussing the UV longevity of polyethylene and polypropylene grass used for outdoor European athletic facilities.

3. Technical paper by Richgels, *et al.* (2015a) published in the conference proceedings for Geosynthetics 2015 in Portland, Oregon.

4. Presentation by Richgels., C. at the Geosynthetics Conference for 2015 in Portland, Oregon (Richgels, 2015b).

5. Presentation by Diguilio, D. at the Northern New England SWANA Conference on 25 September 2013 (Diguilio, 2013).

The following documents on the topic of HDPE Geomembrane degradation due to UV exposure were reviewed and found to contain useful information regarding this assessment.

1. Geosynthetic Research Institute (GRI) White Paper #6 (Koerner *et al.*, 2011). This white paper contained degradation data (% retained strength and elongation) on laboratory aged samples of 1.5 mm HDPE geomembrane. Aging was completed using a UV Fluorescent device per ASTM D7238 at 70 degrees Celsius (^{o}C).

2. Geosynthetic Institute (GSI) webinar presentation by Koerner *et al.*, (2015). This presentation contained a slide that compared predicted (laboratory vs. field) half-life of geomembranes of various resins, including HDPE, as well as a suggestion for estimating lower bound half-life.

3. Journal paper authored by Rowe *et al.* (2010) published in the Journal of Geotechnical and Geoenvironmental Engineering.

DISCUSSION OF DOCUMENTS AND DATA

The data from the New River, AZ testing facility on the artificial grass component of ClosureTurf® (Watershed, 2014) appears to be the only data set of its kind in our compiled database. The data consists of tensile property testing from field samples exposed to the Arizona environment at approximate exposure periods of 1, 5, 7 and 10 years. At each of the four exposure periods, 20 samples were tested for a total of 80 tests. The average values for tensile strength retained at each corresponding time period is 97%, 90%, 84% and 83%, respectively (Figure 2).

One additional data point was found in the Atlas-MTS document. That data point indicated that approximately 90% of tensile strength of polyethylene grass would be available after 20 years of field exposure assuming average European climatic conditions (temperature, irradiance, etc.). However, the average European irradiance is approximately one-half to one-third that of Arizona (Figure 3) notwithstanding temperature effects. Therefore, the Atlas-MTS data point will be consistent with the data from the New River, AZ facility in the 7 to 10 year time frame once adjusted for the relative levels of exposure and temperature between Europe and Arizona. As such, this data point will not extend the exposure duration covered by the New River, AZ data.

The paper and corresponding presentation by Richgels (2015a, 2015b) utilized the laboratory data released from the GSI on UV degradation of HDPE samples to make upper and lower bound estimates of the field half-life of the HDPE grass blades. The upper bound method utilizes Arrhenius

modeling of lab data to project exposure times at half-life to site temperatures combined with ratios of UV irradiance between the laboratory lamp and monthly average irradiance at New River, AZ to develop half-life loss per month. A similar procedure using a linear extrapolation (rather than Arrhenius) was demonstrated for a lower bound estimate. The Watershed (2014) field data set was plotted in between the upper and lower bound estimates. This method is further discussed in the section below titled, "HDPE Grass Blade Service Life Calculations".

Koerner *et al.* (2011) discusses the UV longevity of both exposed and unexposed geomembranes made from various resins, including HDPE based on GSI's laboratory testing program. This document is particularly useful in regard to the ClosureTurf® elements that are considered non-exposed (i.e., the PP geotextile backing for the turf component and the underlying HDPE geomembrane).

The presentation by Koerner *et al.* (2015) includes estimates of half-life of exposed HDPE geomembranes as well as a recommendation for linear data extrapolation as a lower bound limit that was implemented by Richgels (2015b).

PERFORMANCE REQUIREMENTS

The definition of service life of an HDPE (or other resin) geosynthetic (grass blades and geotextiles/geomembranes) typically invokes the half-life criteria. However, the half-life criteria is arbitrary and while useful as a general indicator for comparison it does not directly relate to any aspect of field performance for ClosureTurf® or any other geosynthetic. Therefore it is more appropriate to define the service life in terms of field requirements placed on the material.

HDPE Grass Blades

For the case of the HDPE grass blades on the ClosureTurf® system, tensile strength requirements fall in the range of 2.5 to 3.5 lbs, based on applied loads of pullout forces from equipment operation and water runoff forces (Diguilo, 2013). The ClosureTurf® HDPE grass blades are manufactured with 20 lbs. of tensile strength immediately following the process (Diguilo, 2013). Therefore, without considering a factor of safety, the required tensile strength of the HDPE grass blade is equal to approximately 12.5% to 17.5% of original strength capacity.

PP Geotextile Backing and HDPE Geomembrane

Performance requirements for the PP geotextile backing and HDPE geomembrane depend on more site-specific parameters (e.g., steepness of slopes, seismicity, etc.) than the HDPE grass blades. Therefore until a parametric study is completed which will define the performance requirements over a range of expected conditions, the half-life will have to be used as a benchmark for degradation of the PP geotextile and HDPE geomembrane.

HDPE GRASS BLADE SERVICE LIFE CALCULATIONS

In order to develop a prediction for the longevity of the HDPE grass blades with respect to UV degradation, Geosyntec implemented the method found in Richgels (2015a, 2015b) for two levels of retained tensile strength. The first level is the 50% of tensile strength, or half-life, criterion that is commonly used as a benchmark for geosynthetic service life. Geosyntec performed this calculation to compare our results with the results presented by Richgels (2015a, 2015b). Once the half-life estimates were calculated, Geosyntec attempted to repeat the calculations using a retained tensile strength of 12.5% of an HPDE grass blade.

Half-Life Estimation (50% of Retained Strength)

The assessment utilized by Richgels (2015a, 2015b) begins with a laboratory data release from GSI (Figure 4). The data includes retained tensile strength of HDPE samples that have been incubated under a UV lamp at elevated temperatures, which accelerates the UV weathering process in accordance with ASTM D7238.

As mentioned, the GSI data includes samples tested at three elevated temperatures: (i) 80 degrees Celsius (^{o}C); (ii) 70^{o}C; and (iii) 60^{o}C. The testing program appears to have originally included only the 70^{o}C data, with the 80 ^{o}C and 60^{o}C testing added at a later date (therefore, weathering is not as advanced). The 70^{o}C data set has reached approximately 66%, while the 80^{o}C and 60^{o}C data sets have reached approximately 78% and 86%, respectively. Nonetheless, logarithmic extrapolations to 50% retained strength were performed for each data set. The amount of exposure time (on a log scale) corresponding to the 50% retained strength plotted vs. the inverse of the corresponding temperature (80^{o}C, 70^{o}C and 60^{o}C) is shown in Figure 5. Figure 5 allows for extrapolation to find the laboratory exposure time required to achieve 50% retained strength at temperatures lower than the test temperatures (i.e., actual field temperatures).

Once the curve is defined relating any temperature to a level of laboratory lamp exposure, the remaining task is to develop a relationship between laboratory exposure and field exposure for a

particular site. In this case, the testing site in New River, AZ where Watershed has performed tests on HDPE grass blades, was selected.

Richgels (2015a, 2015b) presents monthly averages at the site for: (i) peak turf temperature; and (ii) irradiance as a fraction of the laboratory lamp irradiance. Using these two values for a given month combined with the Arrhenius model, an estimate of half-life loss per month is obtained. Summation of the half-life lost per month over a year yields the annual half-life loss. The inverse of the annual half-life loss is the predicted half-life in years. Using this method, Richgels obtains a half-life of approximately 247 years, while Geosyntec obtained a half-life of 277 years using the same data (Table 2). The difference is attributable to rounding errors in the logarithmic projections.

Following the suggestion of Koerner *et al.* (2015), Richgels (2015b) treated the results of the half-life mentioned above as an upper bound estimate. For the lower bound estimate, Koerner *et al.* (2015) suggests performing a linear extrapolation of the laboratory data to lower field temperatures, rather than using the Arrhenius model.

With the linear extrapolation, the ratio of monthly irradiance to laboratory lamp irradiance is scaled linearly to calculate the number of months required to reach half-life at 80C, 70C and 60C. Linear extrapolations per month are made from the elevated temperatures to the corresponding peak turf temperature in that month. The resulting half-life loss per month is summed to obtained half-life loss per year. The inverse of that result is the half-life in years. Richgels (2015b) calculates a half-life of 176 years using this linear model. Geosyntec's calculation using the same data resulted in a half-life of 214 years (Table 3 and Figure 6). The difference in the calculations is approximately the same as with the calculation using the Arrhenius (logarithmic) model.

Figure 7 shows the calculated upper (Arrhenius - logarithmic) and lower (linear) bound curves calculated by Richgels (2015b) along with the field data on the HDPE grass blades provided by Watershed (2014). As shown in Figure 7, the trend line fit to the field data falls in between the upper and lower bound curves produced by Richgels (2015b). Note that the first point from the field data at approximately 1 year is omitted from the trend line. This is because the first data point is assumed to be within the anti-oxidant phase of degradation rather than the polymer oxidation stage as suggested by Rowe *et al.* (2010). Additional discussion regarding the stages of degradation for polyolefin materials can be found in CUR 243 (2012).

Service Life Estimation Based on Performance Requirements (12.5% of Retained Strength)

Geosyntec repeated the calculations discussed above for the estimation of half-life, but extrapolated the GSI laboratory data down to 12.5% rather than 50% at 80C, 70C and 60C. Upper bound

(Arrhenius – logarithmic) and lower bound (linear) estimates were 2,500 years and 2,043 years, respectively.

These estimates of service life are simply too large to be reasonable. A likely explanation is that the samples tested at 80C, 70C and 60C have not degraded enough to produce accurate predictions at 12.5% retained strength. As previously mentioned, the data for 80C has reached 78% retained strength; the data for 70C has reached 66% retained strength; and the data for 60C has reached 86% retained strength. Therefore, the extrapolation for each of these data sets to 50% retained strength will be much more accurate than extrapolations to 12.5%. In addition, small uncertainties in log-based extrapolations will greatly influence results.

For these reasons, it is not practical or useful at this time to quantitatively assess service life in terms of actual performance requirements when those requirements are substantially below the half-life. There is some value, however in a qualitative use of performance requirements in comparisons with half-life estimates (i.e., to establish the factor of safety remaining at 50% degradation).

SUMMARY AND CONCLUSIONS

Geosyntec's literature review of approximately 40 documents yielded few sources of UV degradation data for exposed HDPE grass blades. Relevant data that was found included the field test data from the New River, AZ testing facility provided by Watershed (2014) and one data point from Atlas-MTS. The Atlas-MTS data point indicated that HDPE grass blades in average European climatic conditions would retain approximately 90% of its original strength after 20 years of field exposure. Taking into account the differences in temperature and UV irradiance between New River, AZ and European averages, the data point is consistent with the New River, AZ test data in the 7 to 10 year range.

Following the method presented in Richgels (2015a, 2015b) for HDPE grass blades, Geosyntec calculated an upper bound half-life of 277 years compared with Richgels 247 years using the Arrhenius (semi-log) extrapolations to site temperatures and ratio of laboratory lamp to field irradiance. Geosyntec calculated a lower bound half-life based on linear temperature extrapolations, as suggested by Koerner *et al.* (2015), of 214 years compared with 176 years obtained by Richgels (2015b). The differences between Geosyntec and Richgels calculations were attributed to rounding. As shown in Figure 7, the field data from New River, AZ suggests a half-life of 216 years when considering only the last three data points (i.e., polymer oxidation stage).

Another prediction of HDPE grass blade degradation is included in Watershed (2014) using the same (New River, AZ) field data. That prediction of retained tensile strength at 100 years of service life is 65%.

Therefore, it appears that the half-life of the HDPE grass blades will be on the order of 100 years based on the existing field data set and extrapolation methods found in the literature and presented herein. The results are promising; however additional field test data is needed to improve the half-life prediction, particularly since the half-life predictions for exposed HDPE geomembranes are also approximately 100 years (Koerner, 2015). Half-life predictions presented herein will also need to be revisited when additional labratory data is released from the GSI testing program.

Geosyntec attempted to calculate the service life of the HDPE grass blades using 12.5% of retained strength, rather than an arbitrarily assigned half-life. However, the calculation resulted in unreasonably long service life. This result is likely due to uncertainties in extrapolating the laboratory data released from GSI down to the 12.5% retained strength level. The data release has degraded to 78%, 66% and 86% for the 80 ^{o}C, 70 ^{o}C, and 60 ^{o}C test temperatures. Therefore, extrapolations to 50% may be warranted while extrapolations to 12.5% may not be until additional lab data is available. That being said, it should be recognized that half-life, or 50% of retained strength, has a factor of safety of 2.8 to 4.0 when considering the tensile capacity performance requirements of HDPE grass blades.

With regard to the unexposed elements of the ClosureTurf® system, Watershed (2014) indicates that the retained tensile strength of the PP geotextile backing prior to the addition of UV inhibitors is 65% after 100 years. This estimate is based on exhumed samples of the geotextile from the LaSalle-Grant Landfill in Louisiana. According to Watershed (2014), the addition of proprietary UV inhibitors to the PP geotextile backing has led to an improvement in UV resistance by a factor of 14. The final geosynthetic in the ClosureTurf® system is the covered HDPE geomembrane. Koerner (2011) estimates that the half-life of a covered HDPE geomembrane is 446 years at 20C, and 265 years at 25C. Furthermore, the degradation of the unexposed elements of the ClosureTurf® system invoke the half-life criteria. As discussed with regard the exposed HPDE grass blades, actual performance requirements should ideally be used to determine system longevity. However, the existing testing programs need to be allowed to degrade further before projections to lower values are made.

It is worth reiterating that applications of ClosureTurf® in areas of the United States where the UV irradiance and the temperatures are lower will result in longer half-life predictions than discussed above. In some cases (e.g., the Northeastern States), the differences will likely be quite large when compared with Arizona.

Finally, once UV degradation of the most susceptible component of ClosureTurf® (i.e., the exposed HDPE grass blades) does result in a tensile break, replacement of the HDPE grass and PP geotextile backing can be performed.

CLOSING

Geosyntec appreciates the opportunity to assist Watershed in the development of its ClosureTurf® products. Questions and comments may be directed to either of the undersigned at 678-202-9500.

Sincerely,

Will Tanner, P.E.
Project Engineer

Ming Zhu, Ph.D., P.E.
Senior Engineer

Attachments: References
Tables
Figures

Copies to: Bill Gaffigan (Geosyntec)
Mike Ayers (Watershed)

REFERENCES

Atlas Materials Testing Solutions, (Atlas-MTS). "Artificial Grass Yarns – Improving Sports Performance".

CUR 243, (2012) "Durability of Geosynthetics". Stichting CURNET, Gouda, The Netherlands.

Diguilo, D. (2013), "ClosureTurf™ – The Next Generation Closure System". Northern New England SWANA Conference, Lebanon, New Hampshire, September 25, 2013.

Koerner, R., Hsuan, Y., Koerner, G., (2011) "GSI White Paper 6 - Geomembrane Lifetime Prediction: Unexposed and Exposed Conditions". Geosynthetics Institute, Folsom, Pa., February 8, 2011.

Koerner, R., Koerner, G., and Hsuan, Y. (2015) "Lifetime Predictions of Covered and Exposed Geomembranes". Webinar GSI-W14, January 14, 2015.

Richgels, C., Ayers, M., and Urrutia, J., (2015a) "Estimation of Geographic Ultraviolet Radiation Levels and Impact on Geosynthetic Cover Systems". Proceedings of Geosynthetics 2015, Portland Oregon, February 15-18, 2015.

Richgels, C. (2015b) "Estimation of Geographic Ultraviolet Radiation Levels and Impact on Geosynthetic Cover Systems". Geosynthetics 2015, Portland, Oregon, February 15-18, 2015.

Rowe, K., Islam, M., Hsuan, Y., (2010) "Effects of Thickness of the Aging of HDPE Geomembranes". Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 136(2), p.299-309.

Watershed Geosynthetics, (2014) "Technical Submittal for ClosureTurf™ – Alternative Final Cover, Closure of Municipal Soild Waste Landfill Units", December 2, 2014.

TABLES

Table 1. Selected Sites where ClosureTurf® has been Installed.

Select ClosureTurf® Installations				
Installation	**Type**	**Acres**	**State**	**Year**
Progressive - Weatherford	Public – MSW	8.5	Texas	2010
Progressive - Timberland	Public - MSW	4	Louisiana	2011
Crazy Horse (Salinas SWA – Monterey)	City – MSW	65	California	2012
Saufley Landfill (Escambia)	Public – C&D	22.5	Florida	2012
Georgia Pacific	Independent	70	Georgia	2013
Berkeley County Landfill	City - MSW	12	South Carolina	2013
Lanchester Landfill (Chester)	City - MSW	7	Pennsylvania	2013
Tangipahoa Parish	City – MSW	22	Louisiana	2013
Sandtown – (Berkeley County)	City – MSW	4	Delaware	2013
Si-County Landfill	EPA – Region 6	5	Texas	2014
Holcim Cement Landfill (Kiln Dust)	Independent	46	New York	2015

Table 2. HDPE Grass Blade Upper Bound Half-Life Calculations (Geosyntec)

Month	UV Lamp On[1] (hrs/day)	Peak Turf Temp[2] (C)	Peak Turf Temp (K)	Peak Turf Temp (1/K)	Reaction Rate[3]	Lab Half-Life[4] (lamp hrs)	Field Equivalent[5] (days)	Field Equivalent[6] (months)	Half Life Loss per Month[7]
January	4.00	27.99	301.14	0.0033	-15.67	6385286	1596322	51494	1.94196E-05
February	4.94	27.96	301.11	0.0033	-15.67	6401982	1296604	46307	2.15949E-05
March	6.13	33.94	307.09	0.0033	-15.11	3632197	593012	19129	5.22755E-05
April	6.94	40.58	313.73	0.0032	-14.50	1983742	285945	9531	0.000104915
May	7.25	51.21	324.36	0.0031	-13.58	792646	109330	3527	0.000283544
June	7.31	61.52	334.67	0.0030	-12.75	344593	47124	1571	0.00063662
July	6.94	66.82	339.97	0.0029	-12.34	228887	32993	1064	0.000939599
August	7.00	64.80	337.95	0.0030	-12.50	267230	38176	1273	0.000785841
September	6.94	59.43	332.58	0.0030	-12.91	406208	58553	1889	0.000529439
October	5.88	47.74	320.89	0.0031	-13.88	1062504	180852	5834	0.000171411
November	4.56	36.38	309.53	0.0032	-14.88	2899472	635501	21183	4.72069E-05
December	3.69	24.68	297.83	0.0034	-15.99	8826208	2393548	77211	1.29515E-05
Lab	20							**Yearly Half-life Loss[8]**	0.003604818
								Half-life[9] (years)	277.41

Notes:

(1) UV Lamp On (hours per day) is given in Richgels (2015a, 2015b).
(2) Peak Turf Temps for New River, AZ given in Richgels (2015a, 2015b).
(3) Reaction Rate is calculated from the regression curve shown in Figure 4 for the upper bound (logarithmic) case.
(4) Lab half-life in hours is equal to 1/e^(Reaction Rate).
(5) Field equivalent (days) is calculated by dividing the lab half-life in hours by the UV lamp on hours per day.
(6) Field equivalent in days is converted to months using the given days in that particular month.
(7) Half-life loss per month is the inverse of the corresponding field equivalent in months.
(8) The yearly half-life loss is the sum of each individual months half-life loss.
(9) The half-life in years is the inverse of the yearly half-life loss.

Table 3. HDPE Grass Blade Lower Bound Half-Life Calculations (Geosyntec)

Month	UV Lamp On[(1)] (hours/day)	Months @ 80 C[(2)]	Months @ 70 C[(2)]	Months @ 60 C[(2)]	Peak Turf Temp[(3)] (C.)	Half-life Months (from Regression)	Half-life Loss per month
January	4.00	692	1507	3078	27.99	6948	0.000143933
February	4.94	620	1352	2761	27.96	6256	0.000159849
March	6.13	452	984	2010	33.94	4059	0.00024637
April	6.94	412	898	1834	40.58	3213	0.000311281
May	7.25	382	832	1698	51.21	2248	0.000444747
June	7.31	391	852	1740	61.52	1580	0.000633027
July	6.94	399	869	1775	66.82	1237	0.00080834
August	7.00	395	861	1759	64.80	1371	0.000729293
September	6.94	412	898	1834	59.43	1826	0.000547629
October	5.88	471	1026	2095	47.74	3070	0.000325779
November	4.56	627	1365	2788	36.38	5321	0.000187929
December	3.69	750	1635	3339	24.68	7945	0.000125871
Lab	20					**Yearly Half-life Loss**	0.00466405
						Half-life (years)	214.41

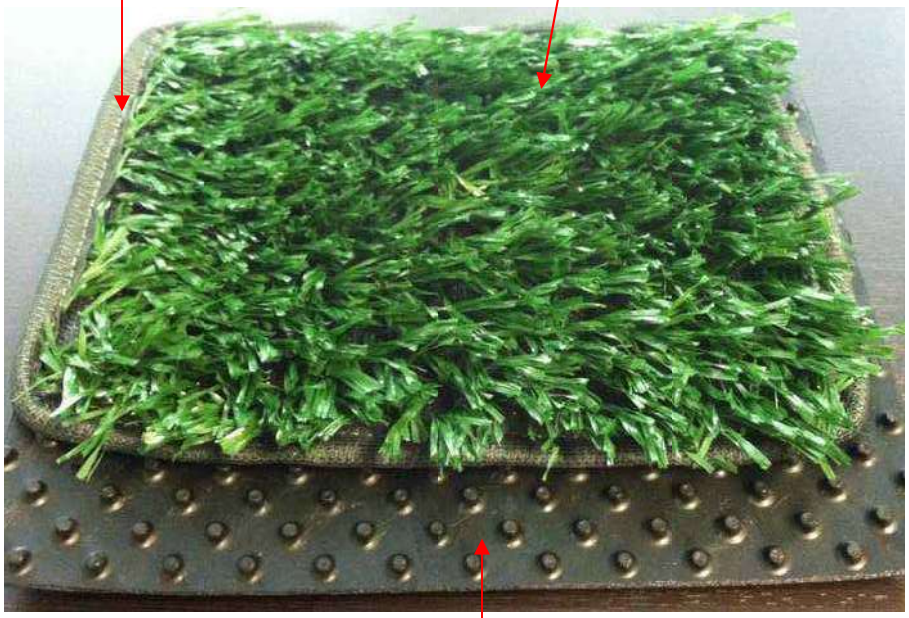
Notes:

(1) UV Lamp On (hours per day) is given in Richgels (2015a, 2015b).

(2) The months required at each temperature is calculated using the regressions from Figure 4 for each temperature, projected down to half-life, then dividing the lamp-hours at half-life by the UV lamp on hours per day for a given month. Once this calculation is done for 80, 70 and 60 C, a linear regression (as shown in Figure 5) is used to obtain the half-life months at the corresponding peak turf temp.

(3) Peak turf temperatures given in Richgels (2015a, 2015b).

FIGURES





Note: The sand ballast infill is not shown in the sample photo on the left, but is shown in a field application photo on the right.

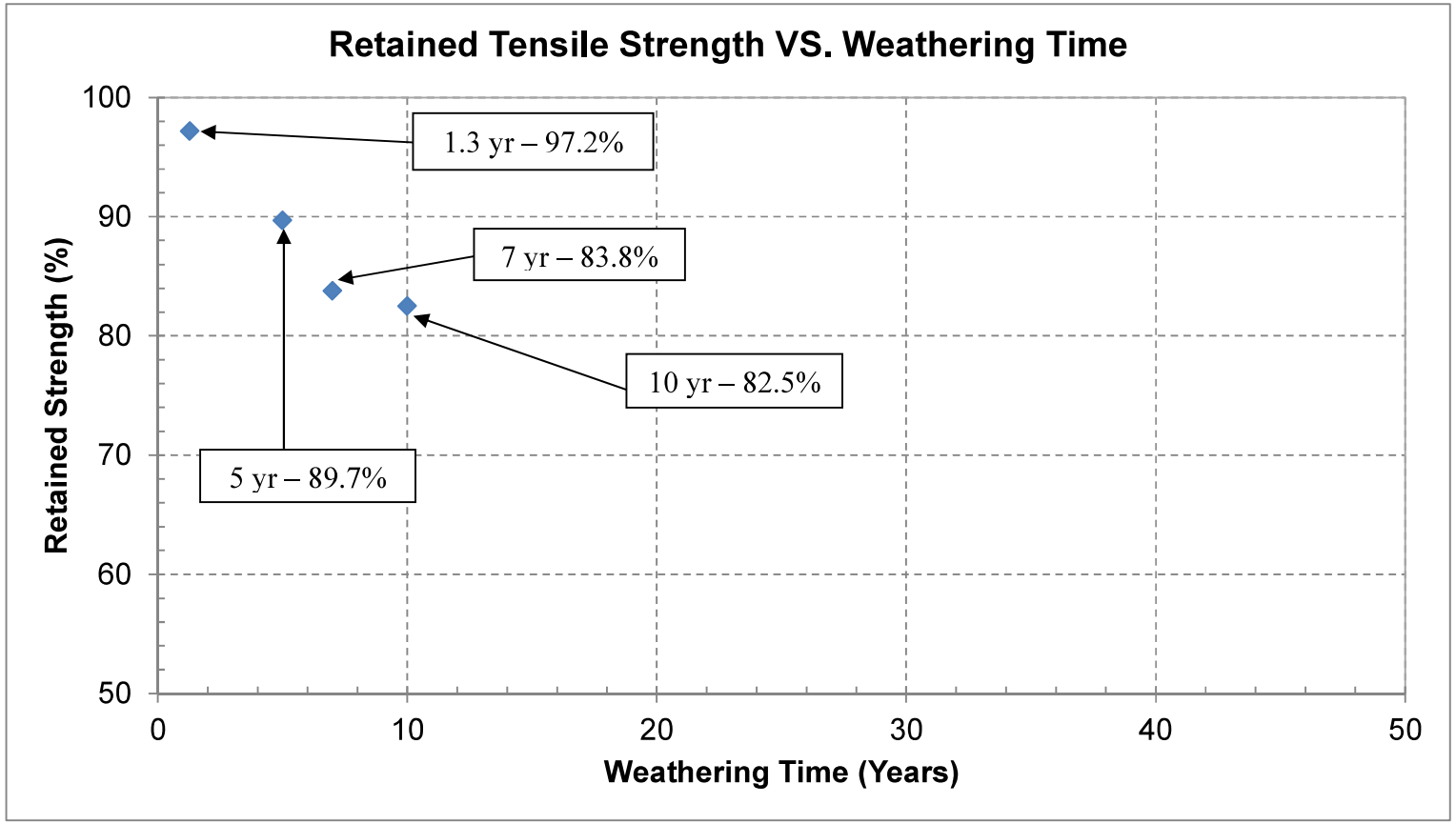
ClosureTurf®Components

Watershed Geosynthetics – ClosureTurf® UV Assessment

Geosyntec consultants

Kennesaw, GA | 23-April-2015

Figure **1**



Notes:

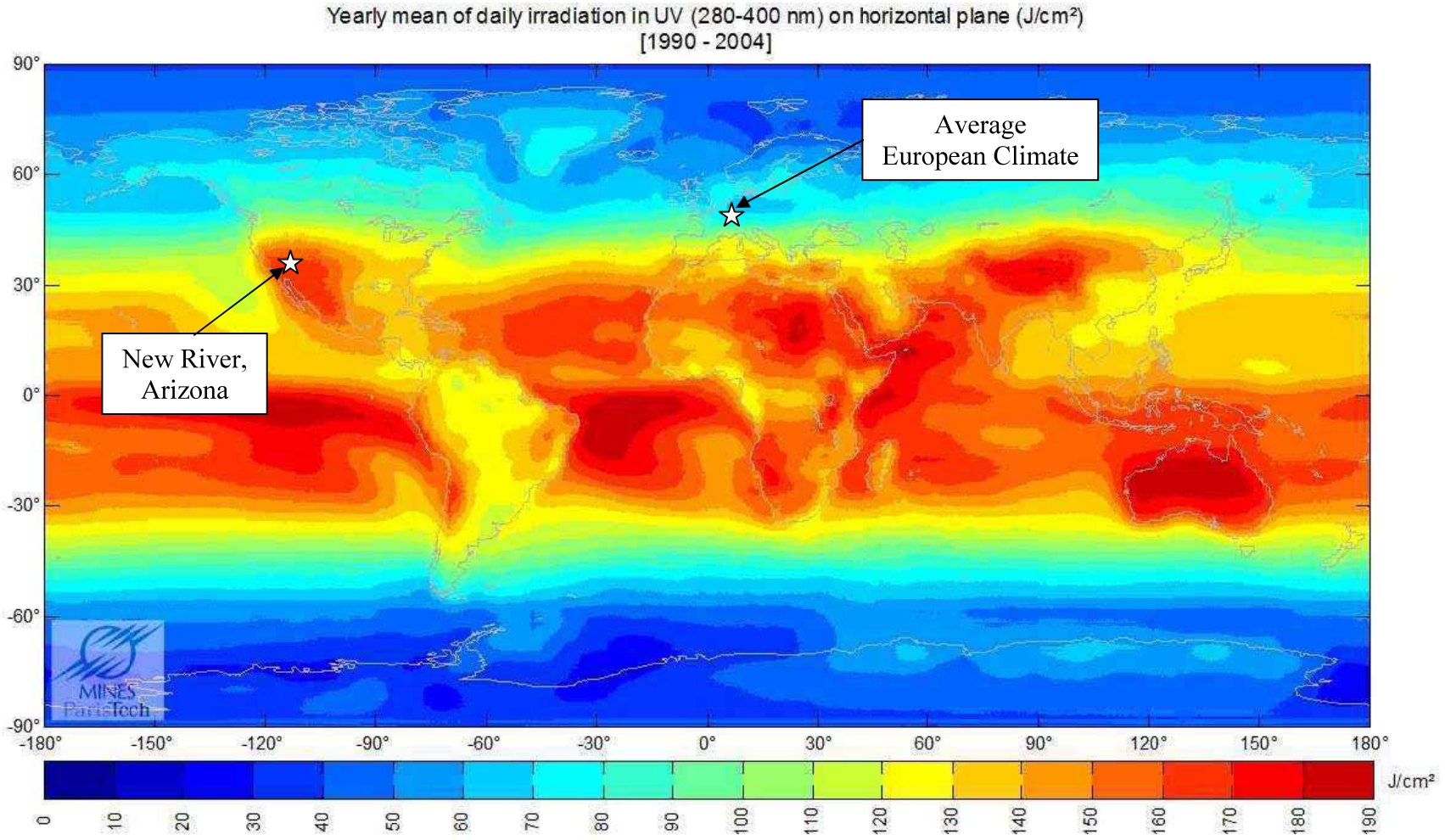
1. The first data point at Weathering Time of 1.3 years is considered to be within the initial stage of UV degradation (i.e., anti-oxidant depletion), rather than polymer oxidation which is represented by the final three data points.
2. Each data point represents the average result of 20 tensile break tests.

Field Test Data (Watershed, 2014)
New River, AZ Atlas Testing Facility
Watershed Geosynthetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure **2**

Kennesaw, GA | 25-April-2015



1 J/cm^2 = 4.755 ft-lbs/in^2

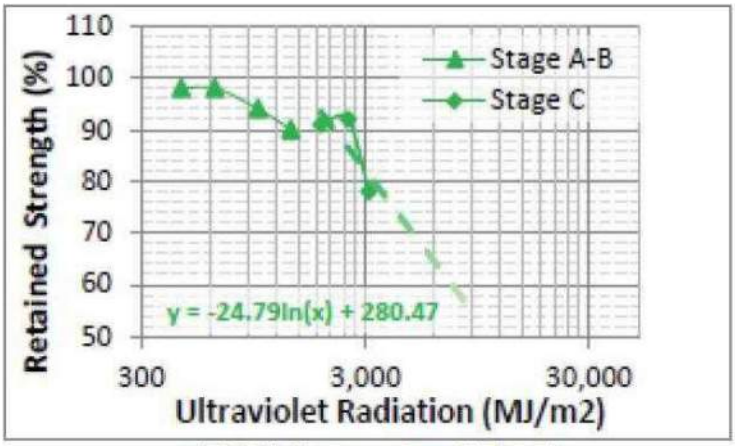
Yearly Irradiation in the Ultraviolet Range

Watershed Geosynthetics – ClosureTurf® UV Assessment

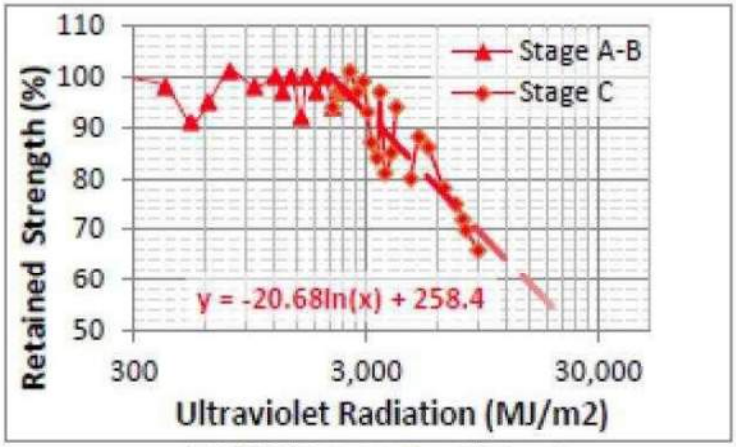
Geosyntec consultants

Figure 3

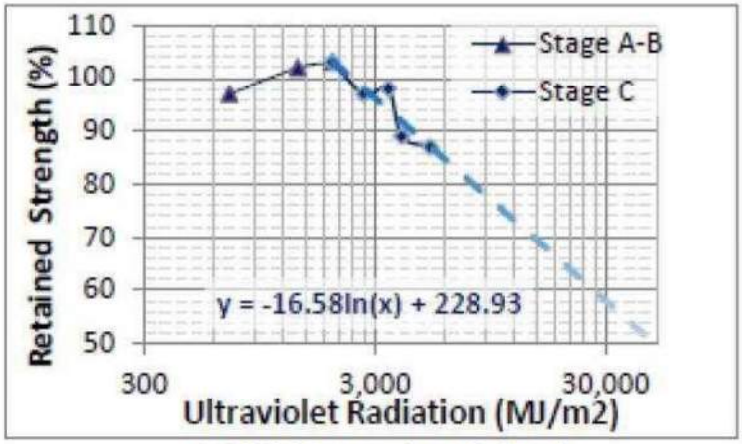
Kennesaw, GA | 23-April-2015



a) 80°C Temperature Dataset



b) 70°C Temperature Dataset



c) 60°C Temperature Dataset

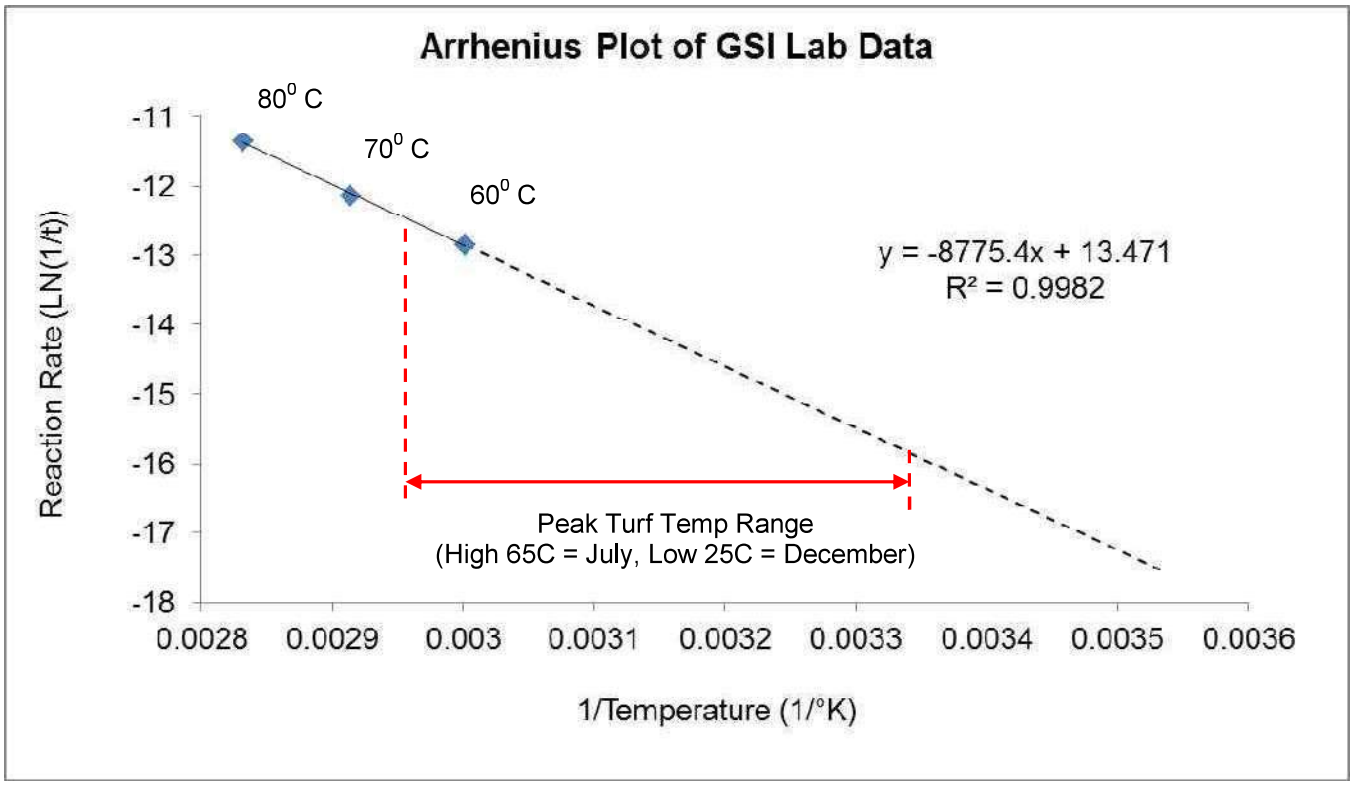
GSI Data Release - Three Stage Oxidation of HDPE for Different Temperatures

Watershed Geosynthetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure 4

Kennesaw, GA | 23-April-2015



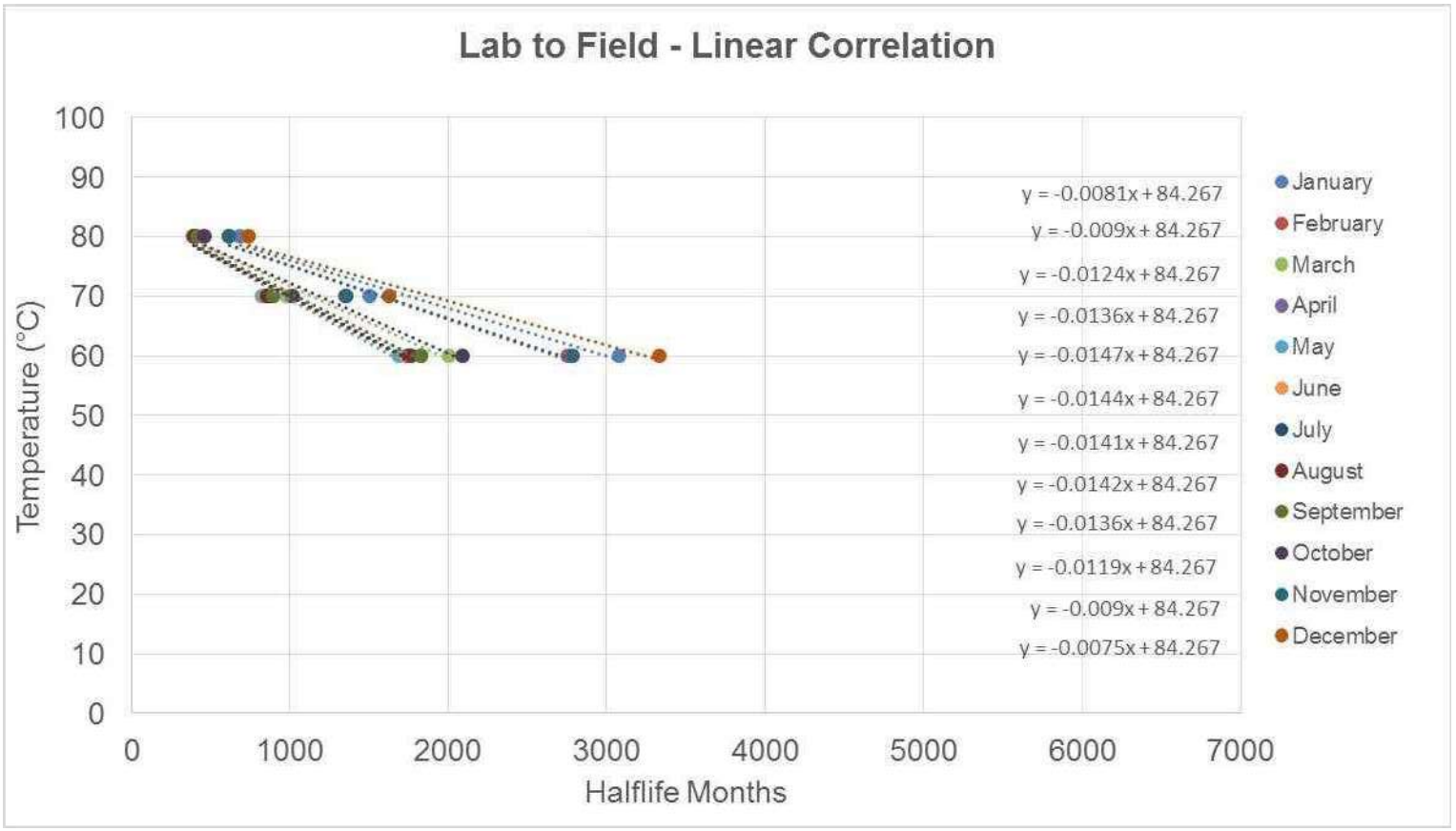
Note: Richgels (2015b) mentions that the use of peak turf temperature is conservative since it only occurs for approximately one hour per day.

Arrhenius Plot of Lab Data
Watershed Geosynthetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure 5

Kennesaw, GA | 23-April-2015



Note: Each month was projected down to the peak turf temperature given in Table 3 to get the half-life months. The inverse of half-life months is half-life loss per month. The sum of all the half-life losses for each month in a year is the yearly half-life loss, the inverse of which is the half-life.

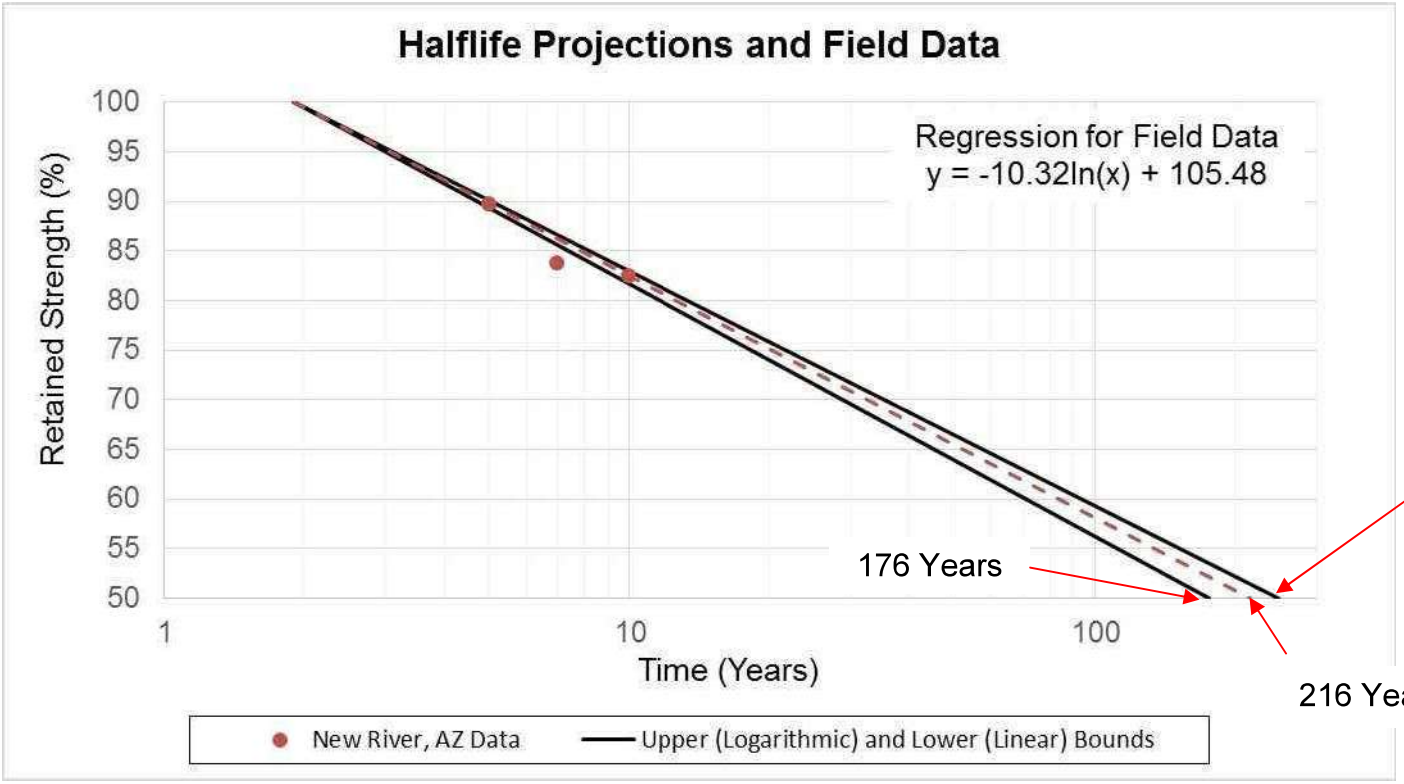
Linear Extrapolations for Half-life Months

Watershed Geosythetics – ClosureTurf® UV Assessment

Geosyntec consultants

Kennesaw, GA | 23-April-2015

Figure 6



Note: Geosyntec calculated an upper bound half-life of 277 years and a lower bound half-life of 214 years using the same data and method. Difference between Geosyntec and Richgels calculations are attributed to rounding.

Halflife Projections (Richgels, 2015a, 2015b)
Upper and Lower Bound Estimates
Watershed Geosythetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure **7**

Kennesaw, GA | 23-March-2015

Appendix I
Example Calculation for Pull-Out Resistance of ClosureTurf for Thermal Effects

EXAMPLE CALCULATION FOR PULL-OUT RESISTANCE OF CLOSURETURF FOR THERMAL EFFECTS

PURPOSE

The pull-out resistance of a ClosureTurf termination along a 3H:1V sideslope is evaluated for a 3-foot deep and 2-foot wide anchor trench. The factor of safety against pull-out is estimated by calculating the tensile force induced by thermal contraction of the geomembrane component of ClosureTurf (i.e., 50-mil Super GripNet or MicroDrain) and the resisting forces along the proposed anchor trench.

METHOD

The factor of safety against pull-out of the ClosureTurf geomembrane component of the anchor trench was evaluated based on a force equilibrium analysis as the ratio of the sum of the resisting forces, $F_{resisting}$, to the sum of the driving forces, $F_{driving}$, as follows:

$$FS_{pull\ out} = \frac{\sum F_{resisting}}{\sum F_{driving}} \quad (1)$$

Driving Forces

The driving force consists of the tensile force caused by thermal contraction of the geomembrane component after installation, calculated as follows:

$$T_t = J * \alpha * \Delta T \quad (2)$$

where:

T_t = tensile force due to thermal contraction of geomembrane component [pounds per foot (lb/ft)];

J = elastic modulus of HDPE geomembrane component (lb/ft);

α = coefficient of thermal expansion for HDPE geomembrane component [inverse degrees Fahrenheit (1/°F)]; and

ΔT = temperature change of geomembrane component after installation (°F).

The elastic modulus (J) for the geomembrane component (i.e., Super GripNet or MicroDrain) is not provided in the manufacturer product data sheets; therefore, the elastic modulus was estimated from the tensile yield strength (σ_y) and corresponding yield strain (ε) reported in the product data sheets as follows:

$$J = \frac{\sigma_y}{\varepsilon} \quad (3)$$

where:

J = elastic modulus of geomembrane component (lb/ft);

σ_y = tensile strength at yield for 50-mil HDPE Super GripNet and MicroDrain (i.e., 110 lb/in. = 1,320 lb/ft); and

ε = tensile strain at yield for 50-mil HDPE Super GripNet and MicroDrain (i.e., 13%).

The elastic modulus for the geomembrane component was calculated to be approximately 10,000 lb/ft using Equation 3.

The coefficient of thermal expansion (α) for the geomembrane component was estimated as 6.7×10^{-5} / °F based on typical values for HDPE geomembranes. Tensile force due to thermal contraction of the geomembrane component (T_t) was calculated for a temperature change (ΔT) conservatively selected as 100°F. The tensile force calculation is presented below.

Resisting Forces

For the ClosureTurf termination, the analysis of resisting forces was performed based on a frictionless pulley system (Qian et al. 2002), which allows the geomembrane component to be considered as a continuous member along its entire length. The resisting forces against pull-out were calculated as the frictional forces between both sides of ClosureTurf and the adjacent materials along the anchor trench, as shown in Figure I-1.

The frictional forces that act along flat planes of ClosureTurf were calculated as the product of the normal force acting on the plane and the tangent of the interface friction angle between the ClosureTurf component and the adjacent material. For forces F_1 and F_2, the normal force was taken as the weight of the overlying soil. For forces F_3 and F_4, the normal force was estimated as the at-rest lateral earth pressure at mid-depth within the anchor trench.

The frictional forces F_1 through F_4 were calculated according to Equations 4 through 7, respectively, below and act in the direction shown in Figure I-1.

$$F_1 = \gamma_{at} * d_{at} * w_{at} * \tan(\delta_U) \quad (4)$$

$$F_2 = \gamma_{at} * d_{at} * w_{at} * \tan(\delta_L) \quad (5)$$

$$F_3 = 0.5 * \gamma_{at} * {d_{at}}^2 * K_0 * \tan(\delta_U) \quad (6)$$

$$F_4 = 0.5 * \gamma_{at} * {d_{at}}^2 * K_0 * \tan(\delta_L) \quad (7)$$

where:

γ_{at} = unit weight of anchor trench backfill material [pounds per cubic foot (pcf)];

d_{at} = depth of anchor trench [feet (ft)];

w_{at} = width of anchor trench (ft);

δ_U = interface friction angle between turf and overlying anchor trench backfill material (degrees);

δ_L = interface friction angle between geomembrane component and underlying material (degrees);

K_0 = coefficient of at-rest earth pressure [i.e., 1-sin(ϕ)]; and

ϕ = friction angle of anchor trench backfill material (degrees).

The interface friction angle between the geomembrane component and the underlying material (δ_L) was taken as the internal friction angle of ClosureTurf provided in the manufacturer product data sheets (i.e., 35 degrees). The interface friction angle between the turf and the overlying backfill material (δ_U) is expected to be lower than δ_L, because the grass blades provide a lower frictional resistance on the upper side of ClosureTurf. For this calculation, δ_U was estimated as two thirds of δ_L (i.e., 23.3 degrees).

CALCULATIONS

The tensile force due to thermal contraction of the geomembrane component was calculated using Equation 2:

$$T_t = 10{,}000 \times 6.7\text{x}10^{-5} \times 100 = 67 \text{ lb/ft} \quad (2)$$

The resisting frictional forces acting along the anchor trench were calculated using Equations 4 through 7 for a 3-ft deep and 2-ft wide anchor trench (i.e., d_{at} = 3 ft, w_{at} = 2 ft), as shown below. Typical values of unit weight of backfill (γ_{at}) of 125 pcf and friction angle of 32 degrees were used for this calculation.

$$K_0 = 1 - \sin(\phi) = 0.47$$

$$F_1 = 125 \times 3 \times 2 \times \tan(23.3) = 323 \text{ lb/ft} \quad (4)$$

$$F_2 = 125 \times 3 \times 2 \times \tan(35) = 525 \text{ lb/ft} \quad (5)$$

$$F_3 = 0.5 \times 125 \times (3)^2 \times 0.47 \times \tan(23.3) = 114 \text{ lb/ft} \quad (6)$$

$$F_4 = 0.5 \times 125 \times (3)^2 \times 0.47 \times \tan(35) = 185 \text{ lb/ft} \quad (7)$$

The sum of resisting forces acting along the anchor trench was calculated, as follows:

$$\sum F_{resisting} = 323 + 525 + 114 + 185 = 1147 \text{ lb/ft}$$

The sum of resisting forces was compared to the tensile yield strength of the geomembrane component:

$$1147 < 1320 \quad \text{O.K.}$$

The factor of safety against pull-out was calculated using Equation 1, as follows:

$$FS_{pull\ out} = \frac{1147}{67} = 17.1 \tag{1}$$

SUMMARY AND CONCLUSIONS

The factor of safety against pull-out of a ClosureTurf termination was calculated for a 3-ft deep and 2-ft wide anchor trench. The factor of safety against pull-out is calculated as 17.1, and therefore, the ClosureTurf termination is not expected to pull out of the anchor trench due to forces induced by thermal contraction.

REFERENCES

Qian, X., R.M. Koerner, and D.H. Gray. 2002. *Geotechnical Aspects of Landfill Design and Construction*. Prentice-Hall Inc.

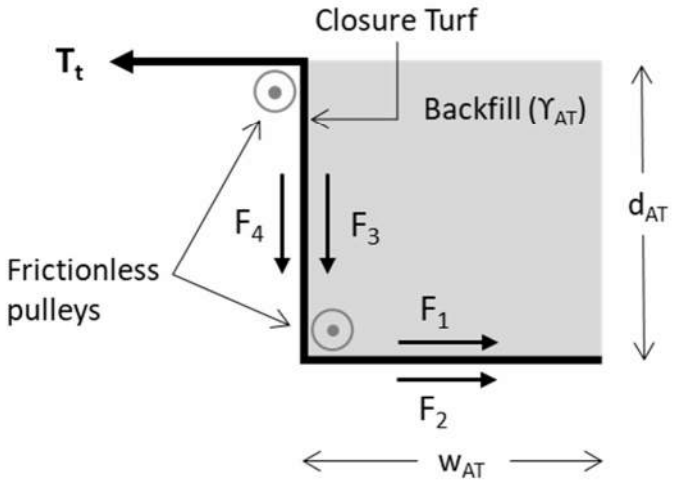


Figure I-1. ClosureTurf Termination within Anchor Trench

Appendix J
ClosureTurf Deep Freeze Test Results

Can you drive on WatershedGeo's ClosureTurf when it is frozen?

George R. Koerner Ph.D., P.E. & CQA
Geosynthetic Institute (GSI) 475 Kedron Ave. Folsom, PA 19033 U.S.A.

Date: September 25, 2018

Introduction

Any engineered barrier should be challenged as to its performance when placed in extreme climates. It is for this reason that we were asked to investigate the performance of WatershedGeo's ClosureTurf when exposed and stressed under extremely cold conditions. This material has been placed in a location where emergency vehicles will need to traffic the material in the depth of winter. Several owners are asking, "will this material hold up under traffic, in such conditions?" This concern is applicable to many locations in the continental United States and has greater significance in Canada and Alaska.

The effects of driving on WatershedGeo's ClosureTurf when it was frozen was studied at the Geosynthetic Institute (GSI) in September of 2018. Samples in the form of 300 mm (12 in.) by 300 mm (12 in.) squares were exposed repeatedly to temperature cycles between -60°C to +20°C. After five thermal cycles, the specimens experienced vehicle traffic and then were observed for damage in the cold condition. After visual inspection, the samples were tested for tensile properties and compared to baseline results. Please note that this mechanical testing was conducted at standard laboratory temperature after the materials reached temperature equilibrium.

It should be clearly stated that this is not a freeze-thaw study. That issue has been investigated by several researchers which include, but are not limited to, the U.S. Bureau of Reclamation, EPA, Comer et. al. (1996) Hsuan et. al. (1994), LaFleur, et. al., (1984) and Rollin et. al., (1984). All these studies show that the geomembrane component of the closure system and their seams performed extremely well even after hundreds of freeze-thaw cycles. The work by Zimmie and LaPlante (1990) shows that compacted clay liners (CCL) do not fair well when exposed to the same extreme conditions.

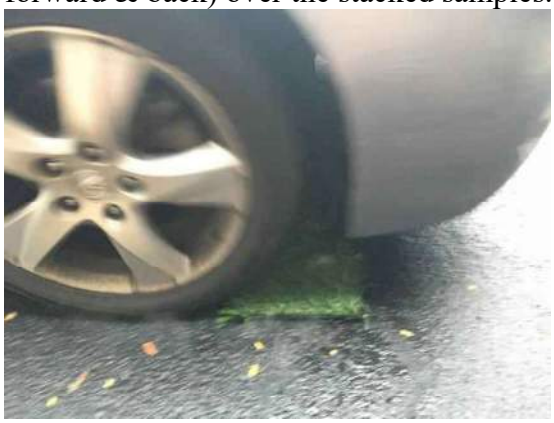
Summary of Procedure

1. A sandwich of turf and geomembrane coupons are exposed to five (5) repetitive cycles of freezing via immersion in a dry ice bath at (-60 Degree Celsius) and then thawing at room temperature. Each exposure lasts for one-hour of freezing followed by an hour of thawing. The process is shown in the figures below.





2. After the fifth quench, the samples were trafficked by a 1 ton, 26 psi tire pressure, 8" wide wheel rubber tire vehicle. The vehicle made two passes as shown in the figures below (i.e., forward & back) over the stacked samples.



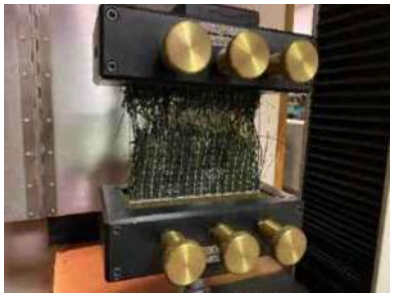

3. After the exposure described above, the samples were observed for damage. As can be seen in the figures below, neither the turf nor the geomembrane was damaged. The only observed difference between the before and after specimens was that the spikes on the underside of the geomembrane were bent over from trafficking.





4. The expose and unexposed samples were also tested for retained tensile properties. As can be seen in the figures below the turf was tested via ASTM D4595 "Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method" and the geomembrane specimens were tested via ASTM D4885 " Standard Test Method for Determining Performance Strength of Geomembranes by the Wide Strip Tensile Method."





Three specimens from the centrally located areas of the exposed and unexposed turf and geomembrane coupons were used to determine the tensile properties and calculate the average value for comparison purposes. Pictures of the turf tested before and after failure are shown above. Photographs of the geomembrane testing during different stages of elongation are shown below.







Results

Average exposed coupon results were compared to the unexposed results. As can be seen in the tabular results below, there were no statistical differences between the before and after exposure wide width tensile test results for either the turf or the geomembrane. This holds true for the strength and elongation characteristics of both materials.

Turf Before Exposure

Spec. Number	Break Load (lbs)	Break Strength (ppi)	Break deflection (in)	Break Elongation (%)
1-MD	2025	**253**	1.14	**29**
2-MD	2311	**289**	1.23	**31**
3-MD	2193	**274**	1.19	**30**
Ave.		**272**		**30**
Std.		18.0		1
Cv		6.6		4

Turf After Exposure

Spec. Number	Break Load (lbs)	Break Strength (ppi)	Break deflection (in)	Break Elongation (%)
1-MD	2112	**264**	1.25	**31**
2-MD	2240	**280**	1.29	**32**
3-MD	2138	**267**	1.16	**29**
Ave.		**270**		**31**
Std.		8.5		2
Cv		3.1		5

Geomembrane before exposure

Spec. Number	Yield Load (lbs)	Yield Strength (ppi)	Yield deflection (in)	Yield Elongation (%)	Break Load (lbs)	Break Strength (ppi)	Break deflection (in)	Break Elongation (%)
1-MD	887	**111**	0.26	**7**	1255	**157**	28.1	**703**
2-MD	894	**112**	0.28	**7**	1311	**164**	29.9	**748**
3-MD	899	**112**	0.3	**8**	1274	**159**	29	**725**
Ave.		**112**		**7**		**160**		**725**
Std.		0.8		1		3.6		23
Cv		0.7		7		2.2		3

Geomembrane after exposure

Spec. Number	Yield Load (lbs)	Yield Strength (ppi)	Yield deflection (in)	Yield Elongation (%)	Break Load (lbs)	Break Strength (ppi)	Break deflection (in)	Break Elongation (%)
1-MD	879	**110**	0.32	**8**	1341	**168**	30.2	**755**
2-MD	901	**113**	0.31	**8**	1229	**154**	29.5	**738**
3-MD	882	**110**	0.34	**9**	1315	**164**	30	**750**
Ave.		**111**		**8**		**162**		**748**
Std.		1.5		0		7.3		9
Cv		1.3		5		4.5		1

Conclusions

Like all performance simulation testing, this humble experiment is not completely representative of the entire field conditions. This procedure is only intended to induce property changes associated with the end use conditions due to extreme cold and vehicular traffic. It is not a survivability nor a long-term durability study. It also does not proport to model field conditions such as differential settlement or the case of yielding subgrade under closure systems when trafficked. In addition, note that rather small unrestrained pieces of the materials were exposed to

traffic on rigid asphaltic pavement. The evaluation is limited; however, it is still considered relevant based on the actual conditions tested.

With all the above written, we again ask the question; “Can you drive on WatershedGeo’s ClosureTurf when it is frozen?” We believe the answer is **yes**, cautiously in a pinch with light ground pressure, rubber-tired equipment.

References

Comer, A. I. and Hsuan, Y. G. (1996), “Freeze-Thaw Cycling and Cold Temperature Effects on Geomembrane Sheets and Seams,” U. S. Bureau of Reclamation Report R-96-03, March, 136 pgs.

Comer, A. I., Sculli, M. L. and Hsuan, Y. G. (1995), “Effects of Freeze-Thaw Cycling on Geomembrane Sheets and Their Seams,” Proc. of Geosynthetics ’95, Nashville, TN, pp. 853-866.

EPA (1991) "Technical Guidance Document: "Inspection Techniques for the Fabrication of Geomembrane Field Seams," EPA/530/SW-91/051, May 1991.

Hsuan, Y. G., Sculli, M. L. and Koerner R. M. “EFFECTS OF FREEZE/TUA W CYCLING ON GEOMEMBRANES AND THEIR SEAMS; PART I- STRENGTH TESTS AT +20°C´Proceeding GRI-7 Conference of Geosynthetic Liner Systems at GSI, IFAI, St. Paul, MN 1994, pp. 202-217.

LaFleur, J., Akber, S.Z., Hammamju, Y., and Marcotte, M., (1985) "Tensile Strength of Bonded Geotextile-Geomembrane and Composites," Second Canadian Symposium on Geotextiles and Geomembranes, Canadian Geotechnical Soc., Edmonton, Alberta, Canada, pp. 219-224.

Rollin, A. L., Lafleur, J., Marcotte, M., Dascal, O. and Akber, Z. (1984), “Selection Criteria for the Use of Geomembranes in Dams and Dykes in Northern Climate,” Proc. of the Intl. Conf. on Geomembranes, Denver, CO, pp. 493-499.

Zimmie, T.F., and La Plante, C. (1990)"The Effects of Freeze-thaw Cycles on the Permeability of a Fine-Grained Soil," Proc., 22nd Mid-Atlantic Ind. Waste Conf., Drexel Univ., Philadelphia.

Appendix K
ClosureTurf Fire Resistance Test Report

RICHGELS ENVIRONMENTAL SERVICES

June 15, 2020

Jose Urrutia
Vice President of Engineering
Watershed Geosynthetics.
11400 Atlantis Place
Suite 200
Alpharetta, GA 30022

RE: CLOSURETURF FIRE TEST CT AND CT-HD

Dear Jose:

Richgels Environmental Services (RES) had initially investigated the fire resistance of ClosureTurf CT in June 2015. RES' concern at the time was the State of California had declared wildfire as a "reasonable foreseeable" risk for solid waste landfill surfaces after wildfire events at landfills resulting in destruction of landfill gas collection systems and other supporting infrastructure. The most recent occurrence at Butte County's Neal Road Landfill in 2018 during the Camp Fire (destroyed the town of Paradise, CA). The American Society for Testing and Materials (ASTM) test Method E108 *Standard Test Methods for Fire Tests of Roof Coverings* is designed to test asphalt composite roofs for fire resistance. Section 10 of this test method is similar to field conditions such as large brush or trees adjacent to landfill surfaces from which burning embers could fall thus igniting grasses on the landfill surface.

Thus, this method was chosen to assess fire resistance of both the CT and CT-HD versions of ClosureTurf (data sheets attached). This investigation performed the Burning Brand Test (Section 10 of ASTM E108**)** conducted with 3 different brand sizes, Class A, B and C. The Class A brand is 12 inches square in length, width and nominally 3 inches in depth. The Class B brand is 6 inches square and nominally 3 inches in depth. The Class C brand is a 2-inch cube. The CT test was performed in California in June 2015. After development of the denser CT-HD version, its fire test was conducted in August 2018 under my supervision at Watershed Geo's Research and Development Laboratory in Louisiana.

Test Preparation

Brands for both the Class A and Class B tests were constructed using nominal 1x1 (¾ " x ¾" finished) pine stock and fastened together with 3d finishing nails. Strips were spaced ¼" apart using a ¼" template to provide consistent strip spacing. The Class A brand was built with 36 each 12" long strips. Class B brand was built with 18 each 6" long strips. The Class C brand was made with a 1-1/2" long piece of 2x2 pine stock with perpendicular saw kerfs on opposite sides per ASTM E108 specifications. The completed brands were oven cured overnight. ASTM E108 specifications recommend curing the brands in an oven for 24 hours at an oven temperature between 105°F and 120°F. Home ovens only go as low as 150°F, so the brands were just cured overnight (Figure 1). All brands were judged as nearly "bone dry," which was confirmed by their ignitability (below).

The test site subgrade was stripped of vegetation and bladed smooth with a straight shovel before placing 50-mil, LLDPE Super Gripnet geomembrane samples. ClosureTurf test pads were prepared using dimensions specified in ASTM E108 – 4'-4" by 3'-4." All test pads received 60 pounds of commercially available sand that met ASTM C33 specifications (Figure 2). Sand was poured evenly over the pads and raked in place per recommended construction practice. This is an equivalent application of 4.2 psf, less than the ClosureTurf manufacturer's recommended sand ballast application (5 psf).

Assuming a sand unit weight of 120 pcf,, sand applied at a rate of 5 psf would spread to approximately 0.5 inches deep. An application rate of 4.2 psf would be 0.42 inches. The thickness difference of 0.08 inches would expose that much more of HDPE grass tufting hence is considered conservative for the purposes of this examination.

Figure 1



Figure 2



Test Execution

The Class A brand was ignited over charcoal and propane outdoor grills for the CT and CT-HD tests respectively. Each large face was exposed to the ignition source for 30 seconds. Each side face was exposed for 45 seconds each. The final exposure of the brand faces per ASTM E108 procedures were not done as the brands were fully aflame and the pine stock was beginning to be consumed. The total ignition time was four minutes.

After the prescribed ignition time, the fully aflame brands were placed on the turf samples (Figure 3). Turf blades melted to the top of the sand ballast in proximity of the burning brand, yet the turf did not ignite nor self-propagate flame away from the brand in either test. A slight wind developed during testing fanning flames to one side.

Figure 3



ClosureTurf CT



ClosureTurf CT-HD

The Class B brands were also ignited over outdoor grills as described above for the Class A brands. Each face was placed on the grill for 30 seconds. Each side face was exposed for 30 seconds each. As with the Class A brands, the Class B brands were fully aflame after the last side face was placed against the grills. Total ignition time was 3 minutes.

The Class C brands were ignited over the grills as described above. Four of the brand faces were placed on the grills for 30 seconds for a total of 2 minutes ignition time.

The Class A brand finished burning with open flame approximately 30 minutes after placement. No fire propagation away from brand in the CT nor CT-HD tests occurred. The same was true for the Class B and C brand tests.

Post Test Inspections

The Class A and B brands were nearly entirely consumed. (Figure 4) Only a few pieces of brand were left after fire test completion. Grass tufts in both the CT and CT-HD samples were melted up to 6 inches away from the Brand A (Figure 5) edge in the melt zone. Ballast sand was discolored under the brand within burn zone.

The Class B brands were also nearly entirely consumed. Only a few pieces of brand were left after fire test completion. Grass tufts were melted up to 4 inches away from the brand edge as shown in Figure 6. Sand discolored under brand but retained natural color within melt zone.

The melt zone around the Class C brand was up to 4 inches in the longest dimension (Figure 7).

Figure 4



Brand A Closure CT



Brand A ClosureTurf CT-HD

Figure 5



Figure 6



Brand B ClosureTurf CT



Brand B ClosureTurf CT-HD

Figure 7



Brand C ClosureTurf CT Brand C ClosureTurf CT-HD

Upon peeling back the turf component of the tested samples, it was found the turf had melted on to the SGN and was essentially consumed by the fire within the burn zone of all the Class A and B tests. The SGN drainage studs were intact up to the boundary of the brand and melted down to the geomembrane sheet within the burn zone. The woven geotextile beyond the burn zone – or under the melt zone - was undamaged as shown in Figure 8.

Figure 8



The entire system was pulled back to observe if the fire had burned through the SGN for both tested samples.

The underside of the SGN displayed observable effects from the fire but was not broached. The SGN burn zone boundary for results typical to all Class A and Class B tests is shown in Figure 9. Some of the soil and organic debris beneath the burn zone was dry and adhering to the SGN. Spikes beneath the burn zone were gone, while spikes in areas immediately neighboring the burn zone were intact.

The Class A brand burn zone damage to the SGN was essentially the dimensions of the brand – 12" x 12".

Figure 9



Figure 10



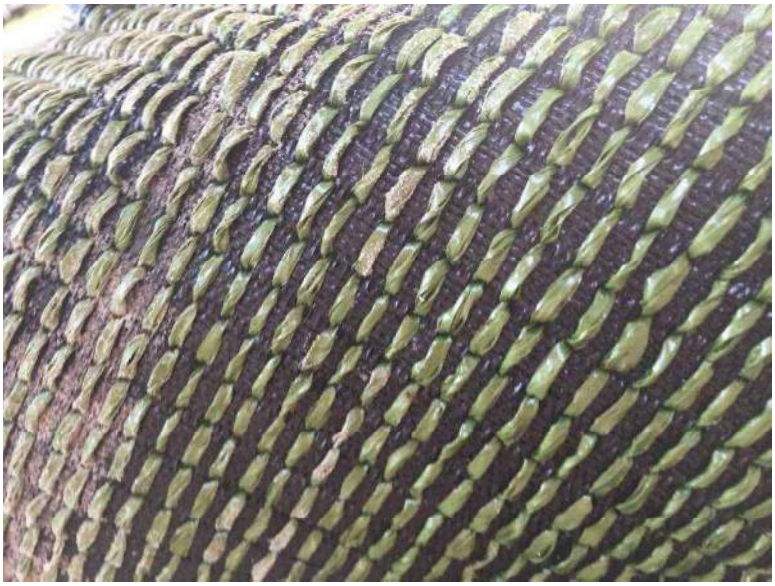
Sand discoloration beneath the burn zone was also observed in the Class B brand test. The underside of the SGN displayed observable melting from the fire but was not broached (Figure 10). Again dry soil and organic debris was found adhering to the SGN underside.

The Class B brand melt zone was slightly larger than the dimensions on the brand – 7-1/2" 7-1/2" for the CT test. For both the Class A and B tests, studs in the immediate vicinity of the burn zone were completely intact. Studs with the burn zone were flattened.

Class C brands were stuck to the underlying grass tufts after the fire had gone out. The CT test brand was not fully consumed by the fire. Note sand discoloration under the brand and minor melting of nearby grass tufts in Figure 7.

For both tests, Class C brands displayed no melting effect on the woven geotextile component in the turf (Figure 11) There were no observable impacts to the SGN either.

Figure 11



Conclusions

1. ClosureTurf exposure to fire is contained to the vicinity of the fire source. It does not spread.
2. None of the ASTM burning brand tests burned through the SGN component of ClosureTurf. This is important when considering active gas control maybe near site perimeter where burning embers may fall.

These results are relevant to concerns in California with respect to wildfire. Wildfire danger is a regulated consideration for closed landfills with surface infrastructure such as landfill gas (LFG) collection wells and piping. California considers wildfire a reasonably foreseeable event for which site owners must provide corrective action cost estimates. Vegetated surfaces provide fuel for fire propagation to other combustible structures such as LFG collection systems. This corrective action requirement could be coming to other states. Use of ClosureTurf as a final cover system should reduce these concerns and related financial burdens for corrective action financial liabilities.

If you have any questions, please call or email the undersigned.

Very Truly Yours

Chris Richgels, PE

Richgels Environmental Service



Appendix B

Final Cover HELP Model Results

Appendix B.1

40 CFR 257.102(d) Final Cover HELP Model Results

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE HELP MODEL
VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: CWLP Dallman Ash Pond (Std. Co… **Simulated On:** 7/15/2025 15:31

Layer 1

Type 1 - Vertical Percolation Layer (Cover Soil) SiCL - Silty Clay Loam (Moderate)
Material Texture Number 26

Thickness	=	6	inches
Porosity	=	0.445	vol/vol
Field Capacity	=	0.393	vol/vol
Wilting Point	=	0.277	vol/vol
Initial Soil Water Content	=	0.4327	vol/vol
Effective Sat. Hyd. Conductivity	=	1.90E-06	cm/sec

Layer 2

Type 1 - Vertical Percolation Layer SiCL - Silty Clay Loam
Material Texture Number 12

Thickness	=	18	inches
Porosity	=	0.471	vol/vol
Field Capacity	=	0.342	vol/vol
Wilting Point	=	0.21	vol/vol
Initial Soil Water Content	=	0.471	vol/vol
Effective Sat. Hyd. Conductivity	=	4.20E-05	cm/sec

Layer 3

Type 4 - Flexible Membrane Liner LDPE Membrane
Material Texture Number 36

Thickness	=	0.04	inches
Effective Sat. Hyd. Conductivity	=	4.00E-13	cm/sec
FML Pinhole Density	=	5	Holes/Acre
FML Installation Defects	=	1	Holes/Acre
FML Placement Quality	=	3	Good

Layer 4

Type 1 - Vertical Percolation Layer

Coal Combustion Residuals Material Texture Number 45

Thickness	=	360	inches
Porosity	=	0.52	vol/vol
Field Capacity	=	0.39	vol/vol
Wilting Point	=	0.065	vol/vol
Initial Soil Water Content	=	0.39	vol/vol
Effective Sat. Hyd. Conductivity	=	7.00E-04	cm/sec

Layer 5

Type 3 - Barrier Soil Liner SiCL - Silty Clay Loam Material Texture Number 12

Thickness	=	36	inches
Porosity	=	0.471	vol/vol
Field Capacity	=	0.342	vol/vol
Wilting Point	=	0.21	vol/vol
Initial Soil Water Content	=	0.471	vol/vol
Effective Sat. Hyd. Conductivity	=	4.20E-05	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	90.1	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	6	inches
Initial Water in Evaporative Zone	=	2.596	inches
Upper Limit of Evaporative Storage	=	2.67	inches
Lower Limit of Evaporative Storage	=	1.662	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	168.43	inches
Total Initial Water	=	168.43	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	39.77 Degrees
Maximum Leaf Area Index	=	3.3
Start of Growing Season (Julian Date)	=	103 days
End of Growing Season (Julian Date)	=	286 days
Average Wind Speed	=	10 mph
Average 1st Quarter Relative Humidity	=	72 %
Average 2nd Quarter Relative Humidity	=	66 %
Average 3rd Quarter Relative Humidity	=	73 %
Average 4th Quarter Relative Humidity	=	65 %

Note: Evapotranspiration data was obtained for Springfield, Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.336523	2.34694	3.65042	3.899823	4.906736	4.019345
3.485628	3.062774	3.110144	3.335429	4.510665	3.737905

Note: Precipitation was simulated based on HELP V4 weather simulation for: Lat/Long: 39.77/-89.6

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
39.2	43.3	50.1	60.5	70.3	81
84.3	82.1	74.2	61.7	54	43

Note: Temperature was simulated based on HELP V4 weather simulation for: Lat/Long: 39.77/-89.6
Solar radiation was simulated based on HELP V4 weather simulation for: Lat/Long: 39.77/-89.6

Annual Totals for Year 1			
	inches	cubic feet	percent
Precipitation	51.42	186,651.9	100.00
Runoff	16.495	59,877.0	32.08
Evapotranspiration	32.692	118,671.1	63.58
Percolation/Leakage through Layer 3	2.232295	8,103.2	4.34
Average Head on Top of Layer 3	19.3840	---	---
Percolation/Leakage through Layer 5	2.232295	8,103.2	4.34
Average Head on Top of Layer 5	0.0059	---	---
Change in Water Storage	0.0002	0.5900	0.00
Soil Water at Start of Year	174.5858	633,746.6	339.53
Soil Water at End of Year	174.5860	633,747.2	339.53
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 2			
	inches	cubic feet	percent
Precipitation	45.78	166,165.5	100.00
Runoff	17.028	61,810.1	37.20
Evapotranspiration	26.647	96,729.0	58.21
Percolation/Leakage through Layer 3	2.204513	8,002.4	4.82
Average Head on Top of Layer 3	18.9276	---	---
Percolation/Leakage through Layer 5	2.204513	8,002.4	4.82
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	-0.1036	-376.0	-0.23
Soil Water at Start of Year	174.5860	633,747.2	381.40
Soil Water at End of Year	174.4724	633,334.8	381.15
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0100	36.4	0.02
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 3			
	inches	cubic feet	percent
Precipitation	50.58	183,615.9	100.00
Runoff	18.410	66,826.6	36.39
Evapotranspiration	30.754	111,636.4	60.80
Percolation/Leakage through Layer 3	2.190373	7,951.1	4.33
Average Head on Top of Layer 3	18.6977	---	---
Percolation/Leakage through Layer 5	2.190373	7,951.1	4.33
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	-0.7708	-2,798.2	-1.52
Soil Water at Start of Year	174.4724	633,334.8	344.92
Soil Water at End of Year	173.7116	630,573.0	343.42
Snow Water at Start of Year	0.0100	36.4	0.02
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 4			
	inches	cubic feet	percent
Precipitation	34.72	126,016.0	100.00
Runoff	6.273	22,771.1	18.07
Evapotranspiration	25.969	94,268.0	74.81
Percolation/Leakage through Layer 3	2.154070	7,819.3	6.20
Average Head on Top of Layer 3	18.0073	---	---
Percolation/Leakage through Layer 5	2.154070	7,819.3	6.20
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	0.3189	1,157.5	0.92
Soil Water at Start of Year	173.7116	630,573.0	500.39
Soil Water at End of Year	174.0305	631,730.6	501.31
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 5			
	inches	cubic feet	percent
Precipitation	52.20	189,495.8	100.00
Runoff	18.367	66,671.4	35.18
Evapotranspiration	31.386	113,931.4	60.12
Percolation/Leakage through Layer 3	2.187428	7,940.4	4.19
Average Head on Top of Layer 3	18.6504	---	---
Percolation/Leakage through Layer 5	2.187428	7,940.4	4.19
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	0.2624	952.6	0.50
Soil Water at Start of Year	174.0305	631,730.6	333.37
Soil Water at End of Year	174.2929	632,683.2	333.88
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 6			
	inches	cubic feet	percent
Precipitation	44.51	161,585.5	100.00
Runoff	13.423	48,726.1	30.16
Evapotranspiration	28.848	104,718.5	64.81
Percolation/Leakage through Layer 3	2.184002	7,927.9	4.91
Average Head on Top of Layer 3	18.5925	---	---
Percolation/Leakage through Layer 5	2.184002	7,927.9	4.91
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	0.0587	213.0	0.13
Soil Water at Start of Year	174.2929	632,683.2	391.55
Soil Water at End of Year	174.3516	632,896.2	391.68
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 7			
	inches	cubic feet	percent
Precipitation	33.25	120,687.9	100.00
Runoff	6.746	24,489.2	20.29
Evapotranspiration	23.240	84,360.8	69.90
Percolation/Leakage through Layer 3	2.121933	7,702.6	6.38
Average Head on Top of Layer 3	17.5768	---	---
Percolation/Leakage through Layer 5	2.121933	7,702.6	6.38
Average Head on Top of Layer 5	0.0056	---	---
Change in Water Storage	1.1392	4,135.2	3.43
Soil Water at Start of Year	174.3516	632,896.2	524.41
Soil Water at End of Year	174.5506	633,618.8	525.01
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.9401	3,412.6	2.83
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 8			
	inches	cubic feet	percent
Precipitation	42.21	153,222.7	100.00
Runoff	14.704	53,375.2	34.84
Evapotranspiration	27.124	98,458.5	64.26
Percolation/Leakage through Layer 3	2.156280	7,827.3	5.11
Average Head on Top of Layer 3	18.0434	---	---
Percolation/Leakage through Layer 5	2.156280	7,827.3	5.11
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	-1.7736	-6,438.3	-4.20
Soil Water at Start of Year	174.5506	633,618.8	413.53
Soil Water at End of Year	173.7171	630,593.1	411.55
Snow Water at Start of Year	0.9401	3,412.6	2.23
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 9			
	inches	cubic feet	percent
Precipitation	38.49	139,731.6	100.00
Runoff	8.567	31,098.5	22.26
Evapotranspiration	27.245	98,900.0	70.78
Percolation/Leakage through Layer 3	2.166488	7,864.4	5.63
Average Head on Top of Layer 3	18.3038	---	---
Percolation/Leakage through Layer 5	2.166488	7,864.4	5.63
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	0.5148	1,868.9	1.34
Soil Water at Start of Year	173.7171	630,593.1	451.29
Soil Water at End of Year	174.2319	632,461.9	452.63
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 10			
	inches	cubic feet	percent
Precipitation	37.06	134,541.3	100.00
Runoff	9.337	33,895.1	25.19
Evapotranspiration	25.137	91,248.8	67.82
Percolation/Leakage through Layer 3	2.182252	7,921.6	5.89
Average Head on Top of Layer 3	18.5622	---	---
Percolation/Leakage through Layer 5	2.182252	7,921.6	5.89
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	0.4066	1,475.8	1.10
Soil Water at Start of Year	174.2319	632,461.9	470.09
Soil Water at End of Year	174.5263	633,530.3	470.88
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.1122	407.5	0.30
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 11			
	inches	cubic feet	percent
Precipitation	46.90	170,246.5	100.00
Runoff	16.529	59,998.7	35.24
Evapotranspiration	28.149	102,179.6	60.02
Percolation/Leakage through Layer 3	2.201307	7,990.7	4.69
Average Head on Top of Layer 3	18.8765	---	---
Percolation/Leakage through Layer 5	2.201307	7,990.7	4.69
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	0.0213	77.5	0.05
Soil Water at Start of Year	174.5263	633,530.3	372.13
Soil Water at End of Year	174.6598	634,015.2	372.41
Snow Water at Start of Year	0.1122	407.5	0.24
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 12			
	inches	cubic feet	percent
Precipitation	43.97	159,605.3	100.00
Runoff	14.809	53,755.0	33.68
Evapotranspiration	27.397	99,451.4	62.31
Percolation/Leakage through Layer 3	2.138767	7,763.7	4.86
Average Head on Top of Layer 3	17.7539	---	---
Percolation/Leakage through Layer 5	2.138767	7,763.7	4.86
Average Head on Top of Layer 5	0.0056	---	---
Change in Water Storage	-0.3760	-1,364.8	-0.86
Soil Water at Start of Year	174.6598	634,015.2	397.24
Soil Water at End of Year	174.2838	632,650.4	396.38
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 13			
	inches	cubic feet	percent
Precipitation	50.32	182,656.5	100.00
Runoff	17.459	63,375.9	34.70
Evapotranspiration	30.550	110,895.7	60.71
Percolation/Leakage through Layer 3	2.183856	7,927.4	4.34
Average Head on Top of Layer 3	18.5886	---	---
Percolation/Leakage through Layer 5	2.183856	7,927.4	4.34
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	0.1260	457.5	0.25
Soil Water at Start of Year	174.2838	632,650.4	346.36
Soil Water at End of Year	174.4099	633,107.8	346.61
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 14			
	inches	cubic feet	percent
Precipitation	32.31	117,286.9	100.00
Runoff	2.372	8,609.5	7.34
Evapotranspiration	27.760	100,767.6	85.92
Percolation/Leakage through Layer 3	2.112321	7,667.7	6.54
Average Head on Top of Layer 3	17.4166	---	---
Percolation/Leakage through Layer 5	2.112321	7,667.7	6.54
Average Head on Top of Layer 5	0.0056	---	---
Change in Water Storage	0.0667	242.1	0.21
Soil Water at Start of Year	174.4099	633,107.8	539.79
Soil Water at End of Year	174.4766	633,349.9	540.00
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 15			
	inches	cubic feet	percent
Precipitation	35.13	127,507.3	100.00
Runoff	8.717	31,641.2	24.82
Evapotranspiration	24.329	88,313.4	69.26
Percolation/Leakage through Layer 3	2.152287	7,812.8	6.13
Average Head on Top of Layer 3	18.0742	---	---
Percolation/Leakage through Layer 5	2.152287	7,812.8	6.13
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	-0.0717	-260.2	-0.20
Soil Water at Start of Year	174.4766	633,349.9	496.72
Soil Water at End of Year	174.4049	633,089.7	496.51
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 16			
	inches	cubic feet	percent
Precipitation	46.97	170,507.5	100.00
Runoff	14.946	54,253.1	31.82
Evapotranspiration	29.892	108,506.8	63.64
Percolation/Leakage through Layer 3	2.145861	7,789.5	4.57
Average Head on Top of Layer 3	17.8693	---	---
Percolation/Leakage through Layer 5	2.145861	7,789.5	4.57
Average Head on Top of Layer 5	0.0056	---	---
Change in Water Storage	-0.0115	-41.9	-0.02
Soil Water at Start of Year	174.4049	633,089.7	371.30
Soil Water at End of Year	174.3934	633,047.9	371.27
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 17			
	inches	cubic feet	percent
Precipitation	52.69	191,267.7	100.00
Runoff	13.271	48,174.9	25.19
Evapotranspiration	35.438	128,638.4	67.26
Percolation/Leakage through Layer 3	2.205654	8,006.5	4.19
Average Head on Top of Layer 3	18.9467	---	---
Percolation/Leakage through Layer 5	2.205654	8,006.5	4.19
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	1.7763	6,447.9	3.37
Soil Water at Start of Year	174.3934	633,047.9	330.97
Soil Water at End of Year	174.2911	632,676.8	330.78
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	1.8785	6,818.9	3.57
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 18			
	inches	cubic feet	percent
Precipitation	43.84	159,156.7	100.00
Runoff	14.160	51,400.7	32.30
Evapotranspiration	29.372	106,619.9	66.99
Percolation/Leakage through Layer 3	2.206518	8,009.7	5.03
Average Head on Top of Layer 3	18.9625	---	---
Percolation/Leakage through Layer 5	2.206518	8,009.7	5.03
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	-1.8935	-6,873.6	-4.32
Soil Water at Start of Year	174.2911	632,676.8	397.52
Soil Water at End of Year	174.2761	632,622.2	397.48
Snow Water at Start of Year	1.8785	6,818.9	4.28
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 19			
	inches	cubic feet	percent
Precipitation	38.79	140,797.2	100.00
Runoff	9.082	32,969.3	23.42
Evapotranspiration	27.258	98,946.9	70.28
Percolation/Leakage through Layer 3	2.181688	7,919.5	5.62
Average Head on Top of Layer 3	18.5495	---	---
Percolation/Leakage through Layer 5	2.181688	7,919.5	5.62
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	0.2649	961.5	0.68
Soil Water at Start of Year	174.2761	632,622.2	449.31
Soil Water at End of Year	174.5410	633,583.7	450.00
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 20			
	inches	cubic feet	percent
Precipitation	36.71	133,246.2	100.00
Runoff	9.654	35,044.5	26.30
Evapotranspiration	25.383	92,140.0	69.15
Percolation/Leakage through Layer 3	2.181155	7,917.6	5.94
Average Head on Top of Layer 3	18.4487	---	---
Percolation/Leakage through Layer 5	2.181155	7,917.6	5.94
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	-0.5113	-1,855.9	-1.39
Soil Water at Start of Year	174.5410	633,583.7	475.50
Soil Water at End of Year	174.0297	631,727.7	474.11
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 21			
	inches	cubic feet	percent
Precipitation	44.49	161,487.2	100.00
Runoff	15.804	57,368.9	35.53
Evapotranspiration	25.545	92,726.6	57.42
Percolation/Leakage through Layer 3	2.198367	7,980.1	4.94
Average Head on Top of Layer 3	18.8288	---	---
Percolation/Leakage through Layer 5	2.198367	7,980.1	4.94
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	0.9398	3,411.6	2.11
Soil Water at Start of Year	174.0297	631,727.7	391.19
Soil Water at End of Year	174.4060	633,093.7	392.04
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.5635	2,045.6	1.27
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 22			
	inches	cubic feet	percent
Precipitation	45.43	164,920.9	100.00
Runoff	9.900	35,937.0	21.79
Evapotranspiration	33.040	119,935.2	72.72
Percolation/Leakage through Layer 3	2.188568	7,944.5	4.82
Average Head on Top of Layer 3	18.6675	---	---
Percolation/Leakage through Layer 5	2.188568	7,944.5	4.82
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	0.3042	1,104.3	0.67
Soil Water at Start of Year	174.4060	633,093.7	383.88
Soil Water at End of Year	174.6598	634,015.2	384.44
Snow Water at Start of Year	0.5635	2,045.6	1.24
Snow Water at End of Year	0.6139	2,228.4	1.35
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 23			
	inches	cubic feet	percent
Precipitation	43.25	157,010.6	100.00
Runoff	14.335	52,036.0	33.14
Evapotranspiration	27.138	98,511.3	62.74
Percolation/Leakage through Layer 3	2.186201	7,935.9	5.05
Average Head on Top of Layer 3	18.6277	---	---
Percolation/Leakage through Layer 5	2.186201	7,935.9	5.05
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	-0.4057	-1,472.6	-0.94
Soil Water at Start of Year	174.6598	634,015.2	403.80
Soil Water at End of Year	173.8485	631,070.1	401.93
Snow Water at Start of Year	0.6139	2,228.4	1.42
Snow Water at End of Year	1.0195	3,700.9	2.36
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 24			
	inches	cubic feet	percent
Precipitation	35.29	128,113.1	100.00
Runoff	9.292	33,730.3	26.33
Evapotranspiration	24.593	89,273.5	69.68
Percolation/Leakage through Layer 3	2.127789	7,723.9	6.03
Average Head on Top of Layer 3	17.5740	---	---
Percolation/Leakage through Layer 5	2.127789	7,723.9	6.03
Average Head on Top of Layer 5	0.0056	---	---
Change in Water Storage	-0.7203	-2,614.5	-2.04
Soil Water at Start of Year	173.8485	631,070.1	492.59
Soil Water at End of Year	174.1478	632,156.4	493.44
Snow Water at Start of Year	1.0195	3,700.9	2.89
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 25			
	inches	cubic feet	percent
Precipitation	49.03	177,975.2	100.00
Runoff	17.276	62,713.6	35.24
Evapotranspiration	29.076	105,545.7	59.30
Percolation/Leakage through Layer 3	2.224994	8,076.7	4.54
Average Head on Top of Layer 3	19.2618	---	---
Percolation/Leakage through Layer 5	2.224994	8,076.7	4.54
Average Head on Top of Layer 5	0.0059	---	---
Change in Water Storage	0.4516	1,639.2	0.92
Soil Water at Start of Year	174.1478	632,156.4	355.19
Soil Water at End of Year	174.5994	633,795.7	356.11
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 26			
	inches	cubic feet	percent
Precipitation	38.33	139,125.2	100.00
Runoff	8.089	29,364.4	21.11
Evapotranspiration	28.109	102,034.9	73.34
Percolation/Leakage through Layer 3	2.177795	7,905.4	5.68
Average Head on Top of Layer 3	18.4924	---	---
Percolation/Leakage through Layer 5	2.177795	7,905.4	5.68
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	-0.0494	-179.5	-0.13
Soil Water at Start of Year	174.5994	633,795.7	455.56
Soil Water at End of Year	174.5499	633,616.2	455.43
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 27			
	inches	cubic feet	percent
Precipitation	33.69	122,301.7	100.00
Runoff	6.252	22,694.2	18.56
Evapotranspiration	25.174	91,383.4	74.72
Percolation/Leakage through Layer 3	2.108476	7,653.8	6.26
Average Head on Top of Layer 3	17.3510	---	---
Percolation/Leakage through Layer 5	2.108476	7,653.8	6.26
Average Head on Top of Layer 5	0.0056	---	---
Change in Water Storage	0.1571	570.3	0.47
Soil Water at Start of Year	174.5499	633,616.2	518.08
Soil Water at End of Year	174.6113	633,838.9	518.26
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0957	347.6	0.28
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 28			
	inches	cubic feet	percent
Precipitation	51.63	187,402.1	100.00
Runoff	16.841	61,131.9	32.62
Evapotranspiration	32.722	118,780.2	63.38
Percolation/Leakage through Layer 3	2.229422	8,092.8	4.32
Average Head on Top of Layer 3	19.2364	---	---
Percolation/Leakage through Layer 5	2.229422	8,092.8	4.32
Average Head on Top of Layer 5	0.0059	---	---
Change in Water Storage	-0.1661	-602.8	-0.32
Soil Water at Start of Year	174.6113	633,838.9	338.22
Soil Water at End of Year	174.5410	633,583.7	338.09
Snow Water at Start of Year	0.0957	347.6	0.19
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 29			
	inches	cubic feet	percent
Precipitation	45.56	165,377.9	100.00
Runoff	13.130	47,663.3	28.82
Evapotranspiration	30.548	110,889.3	67.05
Percolation/Leakage through Layer 3	2.207865	8,014.6	4.85
Average Head on Top of Layer 3	18.9845	---	---
Percolation/Leakage through Layer 5	2.207865	8,014.6	4.85
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	-0.3276	-1,189.3	-0.72
Soil Water at Start of Year	174.5410	633,583.7	383.11
Soil Water at End of Year	174.2133	632,394.4	382.39
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 30			
	inches	cubic feet	percent
Precipitation	44.94	163,118.7	100.00
Runoff	13.464	48,873.6	29.96
Evapotranspiration	29.565	107,321.7	65.79
Percolation/Leakage through Layer 3	2.187101	7,939.2	4.87
Average Head on Top of Layer 3	18.6424	---	---
Percolation/Leakage through Layer 5	2.187101	7,939.2	4.87
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	-0.2798	-1,015.7	-0.62
Soil Water at Start of Year	174.2133	632,394.4	387.69
Soil Water at End of Year	173.9335	631,378.8	387.07
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 31			
	inches	cubic feet	percent
Precipitation	34.31	124,551.9	100.00
Runoff	7.803	28,323.9	22.74
Evapotranspiration	23.713	86,077.7	69.11
Percolation/Leakage through Layer 3	2.141050	7,772.0	6.24
Average Head on Top of Layer 3	17.8899	---	---
Percolation/Leakage through Layer 5	2.141050	7,772.0	6.24
Average Head on Top of Layer 5	0.0056	---	---
Change in Water Storage	0.6552	2,378.3	1.91
Soil Water at Start of Year	173.9335	631,378.8	506.92
Soil Water at End of Year	174.5887	633,757.1	508.83
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 32			
	inches	cubic feet	percent
Precipitation	48.06	174,469.3	100.00
Runoff	16.643	60,415.3	34.63
Evapotranspiration	28.864	104,775.0	60.05
Percolation/Leakage through Layer 3	2.220578	8,060.7	4.62
Average Head on Top of Layer 3	19.0932	---	---
Percolation/Leakage through Layer 5	2.220578	8,060.7	4.62
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	0.3356	1,218.2	0.70
Soil Water at Start of Year	174.5887	633,757.1	363.25
Soil Water at End of Year	174.5723	633,697.3	363.21
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.3521	1,278.0	0.73
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 33			
	inches	cubic feet	percent
Precipitation	41.70	151,354.2	100.00
Runoff	13.172	47,815.0	31.59
Evapotranspiration	26.631	96,669.4	63.87
Percolation/Leakage through Layer 3	2.163855	7,854.8	5.19
Average Head on Top of Layer 3	18.2598	---	---
Percolation/Leakage through Layer 5	2.163855	7,854.8	5.19
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	-0.2714	-985.1	-0.65
Soil Water at Start of Year	174.5723	633,697.3	418.69
Soil Water at End of Year	174.6530	633,990.2	418.88
Snow Water at Start of Year	0.3521	1,278.0	0.84
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 34			
	inches	cubic feet	percent
Precipitation	37.40	135,757.9	100.00
Runoff	8.939	32,447.5	23.90
Evapotranspiration	26.477	96,110.6	70.80
Percolation/Leakage through Layer 3	2.082443	7,559.3	5.57
Average Head on Top of Layer 3	16.9200	---	---
Percolation/Leakage through Layer 5	2.082443	7,559.3	5.57
Average Head on Top of Layer 5	0.0055	---	---
Change in Water Storage	-0.0990	-359.5	-0.26
Soil Water at Start of Year	174.6530	633,990.2	467.00
Soil Water at End of Year	174.5539	633,630.7	466.74
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 35			
	inches	cubic feet	percent
Precipitation	40.58	147,295.2	100.00
Runoff	11.551	41,930.3	28.47
Evapotranspiration	27.050	98,189.9	66.66
Percolation/Leakage through Layer 3	2.204890	8,003.8	5.43
Average Head on Top of Layer 3	18.9335	---	---
Percolation/Leakage through Layer 5	2.204890	8,003.8	5.43
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	-0.2283	-828.8	-0.56
Soil Water at Start of Year	174.5539	633,630.7	430.18
Soil Water at End of Year	174.3256	632,801.9	429.61
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 36			
	inches	cubic feet	percent
Precipitation	35.09	127,386.5	100.00
Runoff	9.301	33,763.2	26.50
Evapotranspiration	23.955	86,955.4	68.26
Percolation/Leakage through Layer 3	2.126895	7,720.6	6.06
Average Head on Top of Layer 3	17.5520	---	---
Percolation/Leakage through Layer 5	2.126895	7,720.6	6.06
Average Head on Top of Layer 5	0.0056	---	---
Change in Water Storage	-0.2900	-1,052.8	-0.83
Soil Water at Start of Year	174.3256	632,801.9	496.76
Soil Water at End of Year	174.0356	631,749.1	495.93
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 37			
	inches	cubic feet	percent
Precipitation	33.08	120,090.1	100.00
Runoff	6.919	25,114.3	20.91
Evapotranspiration	23.428	85,045.3	70.82
Percolation/Leakage through Layer 3	2.106150	7,645.3	6.37
Average Head on Top of Layer 3	17.3183	---	---
Percolation/Leakage through Layer 5	2.106150	7,645.3	6.37
Average Head on Top of Layer 5	0.0055	---	---
Change in Water Storage	0.6295	2,285.1	1.90
Soil Water at Start of Year	174.0356	631,749.1	526.06
Soil Water at End of Year	174.0587	631,833.2	526.13
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.6063	2,201.0	1.83
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 38			
	inches	cubic feet	percent
Precipitation	39.77	144,368.2	100.00
Runoff	9.015	32,722.6	22.67
Evapotranspiration	28.676	104,092.8	72.10
Percolation/Leakage through Layer 3	2.185969	7,935.1	5.50
Average Head on Top of Layer 3	18.6247	---	---
Percolation/Leakage through Layer 5	2.185969	7,935.1	5.50
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	-0.1053	-382.3	-0.26
Soil Water at Start of Year	174.0587	631,833.2	437.65
Soil Water at End of Year	174.5597	633,651.9	438.91
Snow Water at Start of Year	0.6063	2,201.0	1.52
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 39			
	inches	cubic feet	percent
Precipitation	47.81	173,553.6	100.00
Runoff	16.717	60,680.9	34.96
Evapotranspiration	29.198	105,989.1	61.07
Percolation/Leakage through Layer 3	2.162376	7,849.4	4.52
Average Head on Top of Layer 3	18.2347	---	---
Percolation/Leakage through Layer 5	2.162376	7,849.4	4.52
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	-0.2661	-965.8	-0.56
Soil Water at Start of Year	174.5597	633,651.9	365.10
Soil Water at End of Year	174.2937	632,686.1	364.55
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 40			
	inches	cubic feet	percent
Precipitation	43.52	157,986.7	100.00
Runoff	14.973	54,350.2	34.40
Evapotranspiration	25.751	93,477.0	59.17
Percolation/Leakage through Layer 3	2.198772	7,981.5	5.05
Average Head on Top of Layer 3	18.7336	---	---
Percolation/Leakage through Layer 5	2.198772	7,981.5	5.05
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	0.6000	2,177.9	1.38
Soil Water at Start of Year	174.2937	632,686.1	400.47
Soil Water at End of Year	174.3697	632,962.1	400.64
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.5239	1,901.8	1.20
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 41			
	inches	cubic feet	percent
Precipitation	36.01	130,711.6	100.00
Runoff	10.974	39,835.0	30.48
Evapotranspiration	24.009	87,151.8	66.67
Percolation/Leakage through Layer 3	2.155836	7,825.7	5.99
Average Head on Top of Layer 3	18.1310	---	---
Percolation/Leakage through Layer 5	2.155836	7,825.7	5.99
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	-1.1297	-4,100.9	-3.14
Soil Water at Start of Year	174.3697	632,962.1	484.24
Soil Water at End of Year	173.7639	630,763.1	482.56
Snow Water at Start of Year	0.5239	1,901.8	1.45
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 42			
	inches	cubic feet	percent
Precipitation	42.90	155,735.9	100.00
Runoff	10.613	38,523.4	24.74
Evapotranspiration	29.111	105,674.5	67.85
Percolation/Leakage through Layer 3	2.203268	7,997.9	5.14
Average Head on Top of Layer 3	18.9077	---	---
Percolation/Leakage through Layer 5	2.203268	7,997.9	5.14
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	0.9752	3,540.1	2.27
Soil Water at Start of Year	173.7639	630,763.1	405.02
Soil Water at End of Year	174.5872	633,751.5	406.94
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.1520	551.7	0.35
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 43			
	inches	cubic feet	percent
Precipitation	41.90	152,095.6	100.00
Runoff	10.715	38,894.9	25.57
Evapotranspiration	29.146	105,799.2	69.56
Percolation/Leakage through Layer 3	2.126865	7,720.5	5.08
Average Head on Top of Layer 3	17.6525	---	---
Percolation/Leakage through Layer 5	2.126865	7,720.5	5.08
Average Head on Top of Layer 5	0.0056	---	---
Change in Water Storage	-0.0879	-319.1	-0.21
Soil Water at Start of Year	174.5872	633,751.5	416.68
Soil Water at End of Year	174.6513	633,984.1	416.83
Snow Water at Start of Year	0.1520	551.7	0.36
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 44			
	inches	cubic feet	percent
Precipitation	54.28	197,049.3	100.00
Runoff	19.599	71,145.8	36.11
Evapotranspiration	32.458	117,823.8	59.79
Percolation/Leakage through Layer 3	2.245969	8,152.9	4.14
Average Head on Top of Layer 3	19.5056	---	---
Percolation/Leakage through Layer 5	2.245969	8,152.9	4.14
Average Head on Top of Layer 5	0.0059	---	---
Change in Water Storage	-0.0201	-73.1	-0.04
Soil Water at Start of Year	174.6513	633,984.1	321.74
Soil Water at End of Year	174.6311	633,911.0	321.70
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 45			
	inches	cubic feet	percent
Precipitation	44.24	160,601.5	100.00
Runoff	16.982	61,644.0	38.38
Evapotranspiration	25.396	92,187.0	57.40
Percolation/Leakage through Layer 3	2.147057	7,793.8	4.85
Average Head on Top of Layer 3	17.9837	---	---
Percolation/Leakage through Layer 5	2.147057	7,793.8	4.85
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	-0.2819	-1,023.4	-0.64
Soil Water at Start of Year	174.6311	633,911.0	394.71
Soil Water at End of Year	174.3492	632,887.7	394.07
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 46			
	inches	cubic feet	percent
Precipitation	41.66	151,210.6	100.00
Runoff	10.542	38,267.4	25.31
Evapotranspiration	28.661	104,040.9	68.81
Percolation/Leakage through Layer 3	2.175800	7,898.2	5.22
Average Head on Top of Layer 3	18.4577	---	---
Percolation/Leakage through Layer 5	2.175800	7,898.2	5.22
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	0.2766	1,004.1	0.66
Soil Water at Start of Year	174.3492	632,887.7	418.55
Soil Water at End of Year	173.8305	631,004.7	417.30
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.7953	2,887.1	1.91
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 47			
	inches	cubic feet	percent
Precipitation	40.01	145,247.7	100.00
Runoff	11.751	42,655.0	29.37
Evapotranspiration	26.239	95,246.3	65.58
Percolation/Leakage through Layer 3	2.154818	7,822.0	5.39
Average Head on Top of Layer 3	18.1123	---	---
Percolation/Leakage through Layer 5	2.154818	7,822.0	5.39
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	-0.1310	-475.6	-0.33
Soil Water at Start of Year	173.8305	631,004.7	434.43
Soil Water at End of Year	174.4948	633,416.2	436.09
Snow Water at Start of Year	0.7953	2,887.1	1.99
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 48			
	inches	cubic feet	percent
Precipitation	37.82	137,281.1	100.00
Runoff	11.326	41,112.4	29.95
Evapotranspiration	23.452	85,130.1	62.01
Percolation/Leakage through Layer 3	2.176197	7,899.6	5.75
Average Head on Top of Layer 3	18.3646	---	---
Percolation/Leakage through Layer 5	2.176197	7,899.6	5.75
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	0.8648	3,139.1	2.29
Soil Water at Start of Year	174.4948	633,416.2	461.40
Soil Water at End of Year	174.6598	634,015.2	461.84
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.6997	2,540.0	1.85
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 49			
	inches	cubic feet	percent
Precipitation	44.19	160,407.9	100.00
Runoff	15.892	57,686.7	35.96
Evapotranspiration	26.778	97,202.7	60.60
Percolation/Leakage through Layer 3	2.194456	7,965.9	4.97
Average Head on Top of Layer 3	18.7635	---	---
Percolation/Leakage through Layer 5	2.194456	7,965.9	4.97
Average Head on Top of Layer 5	0.0058	---	---
Change in Water Storage	-0.6742	-2,447.3	-1.53
Soil Water at Start of Year	174.6598	634,015.2	395.25
Soil Water at End of Year	174.2671	632,589.6	394.36
Snow Water at Start of Year	0.6997	2,540.0	1.58
Snow Water at End of Year	0.4183	1,518.4	0.95
Annual Water Budget Balance	0.0000	0.0000	0.00

Annual Totals for Year 50			
	inches	cubic feet	percent
Precipitation	46.29	168,044.1	100.00
Runoff	13.814	50,145.2	29.84
Evapotranspiration	30.336	110,120.2	65.53
Percolation/Leakage through Layer 3	2.168453	7,871.5	4.68
Average Head on Top of Layer 3	18.3406	---	---
Percolation/Leakage through Layer 5	2.168453	7,871.5	4.68
Average Head on Top of Layer 5	0.0057	---	---
Change in Water Storage	-0.0256	-92.8	-0.06
Soil Water at Start of Year	174.2671	632,589.6	376.44
Soil Water at End of Year	174.6598	634,015.2	377.29
Snow Water at Start of Year	0.4183	1,518.4	0.90
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	0.0000	0.0000	0.00

Average Annual Totals Summary

Title: CWLP Dallman Ash Pond (Std. Cover)
Simulated on: 7/15/2025 15:31

	Average Annual Totals for Years 1 - 50*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	42.40	[5.89]	153,920.5	100.00
Runoff	12.439	[3.946]	45,155.0	29.34
Evapotranspiration	27.788	[2.84]	100,870.9	65.53
Subprofile1				
Percolation/leakage through Layer 3	2.173346	[0.03576]	7,889.2	5.13
Average Head on Top of Layer 3	18.3935	[0.5867]	---	---
Subprofile2				
Percolation/leakage through Layer 5	2.173346	[0.03576]	7,889.2	5.13
Average Head on Top of Layer 5	0.0057	[0.0001]	---	---
Water storage				
Change in water storage	0.0015	[0.6422]	5.3730	0.00

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: CWLP Dallman Ash Pond (Std. Cover)
Simulated on: 7/15/2025 15:31

	Peak Values for Years 1 - 50*		
	(inches)		(cubic feet)
Precipitation	4.06		14,750.3
Runoff	3.635		13,194.5
Subprofile1			
Percolation/leakage through Layer 3	0.006895		25.0
Average head on Layer 3	23.9998		
Subprofile2			
Percolation/leakage through Layer 5	0.006895		25.0
Average head on Layer 5	0.0066		
Other Parameters			
Snow water	4.2388		15,386.8
Maximum vegetation soil water	0.4450	(vol/vol)	
Minimum vegetation soil water	0.2770	(vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: CWLP Dallman Ash Pond (Std. Cover)
Simulated on: 87/15/2025 15:31
Simulation period: 50 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	2.6700	0.4450
2	8.4779	0.4710
3	0.0000	0.0000
4	140.4000	0.3900
5	16.9560	0.4710
Snow water	0.0000	---

Appendix B.2

ClosureTurf® Final Cover HELP Model Results

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: CWLP Dallman Ash Pond (ClosureTurf) **Simulated On:** 7/15/2025 14:08

Layer 1

Type 1 - Vertical Percolation Layer (Cover Soil)
Engineered Turf
Material Texture Number 46

Thickness	=	0.5	inches
Porosity	=	0.437	vol/vol
Field Capacity	=	0.062	vol/vol
Wilting Point	=	0.024	vol/vol
Initial Soil Water Content	=	0.3342	vol/vol
Effective Sat. Hyd. Conductivity	=	2.50E-02	cm/sec

Note: 100% of drainage collected from Layer 2 is recirculated into this layer.

Layer 2

Type 2 - Lateral Drainage Layer
Drainage Net (0.5 cm)
Material Texture Number 20

Thickness	=	0.13	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.8487	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E+01	cm/sec
Slope	=	3	%
Drainage Length	=	500	ft

Note: 100% of drainage collected from this layer is recirculated into Layer 1.

Layer 3

Type 4 - Flexible Membrane Liner
LDPE Membrane
Material Texture Number 36

Thickness	=	0.04	inches
Effective Sat. Hyd. Conductivity	=	4.00E-13	cm/sec
FML Pinhole Density	=	5	Holes/Acre
FML Installation Defects	=	1	Holes/Acre
FML Placement Quality		3	Good

Layer 4

Type 1 - Vertical Percolation Layer

Coal Combustion Residuals

Material Texture Number 45

Thickness	=	360	inches
Porosity	=	0.52	vol/vol
Field Capacity	=	0.39	vol/vol
Wilting Point	=	0.065	vol/vol
Initial Soil Water Content	=	0.39	vol/vol
Effective Sat. Hyd. Conductivity	=	7.00E-04	cm/sec

Layer 5

Type 3 - Barrier Soil Liner

SiCL - Silty Clay Loam

Material Texture Number 12

Thickness	=	36	inches
Porosity	=	0.471	vol/vol
Field Capacity	=	0.342	vol/vol
Wilting Point	=	0.21	vol/vol
Initial Soil Water Content	=	0.471	vol/vol
Effective Sat. Hyd. Conductivity	=	4.20-05	cm/sec

Note: initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	90.1	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	0.6	inches
Initial Water in Evaporative Zone	=	0.252	inches
Upper Limit of Evaporative Storage	=	0.304	inches
Lower Limit of Evaporative Storage	=	0.012	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	157.633	inches
Total Initial Water	=	157.633	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
39.2	43.3	50.1	60.5	70.3	81
84.3	82.1	74.2	61.7	54	43

Evapotranspiration and Weather Data

Station Latitude	=	39.77	Degrees
Maximum Leaf Area Index	=	3.3	
Start of Growing Season (Julian Date)	=	103	days
End of Growing Season (Julian Date)	=	286	days
Average Wind Speed	=	10	mph
Average 1st Quarter Relative Humidity	=	72	%
Average 2nd Quarter Relative Humidity	=	66	%
Average 3rd Quarter Relative Humidity	=	73	%
Average 4th Quarter Relative Humidity	=	65	%

Note: Evapotranspiration data was obtained for Springfield, Illinois

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
2.336523	2.34694	3.65042	3.899823	4.906736	4.019345
3.485628	3.062774	3.110144	3.335429	4.510665	3.737905

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 39.77/-89.6

Annual Totals for Year 1			
	inches	cubic feet	percent
Precipitation	51.42	186,651.9	100.00
Runoff	22.974	83,395.4	44.68
Evapotranspiration	28.416	103,151.0	55.26
Recirculation into Layer 1	77.5691	281,575.7	150.86
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	77.5691	281,575.7	150.86
Percolation/Leakage through Layer 3	0.028822	104.6	0.06
Average Head on Top of Layer 3	0.1414	---	---
Percolation/Leakage through Layer 5	0.028822	104.6	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.0002	0.8561	0.00
Soil Water at Start of Year	162.3134	589,197.7	315.67
Soil Water at End of Year	162.3137	589,198.6	315.67
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-77.5690	-281,575.6	-150.86

Annual Totals for Year 2			
	inches	cubic feet	percent
Precipitation	45.78	166,165.5	100.00
Runoff	22.278	80,869.0	48.67
Evapotranspiration	23.563	85,534.8	51.48
Recirculation into Layer 1	76.8010	278,787.8	167.78
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	76.8010	278,787.8	167.78
Percolation/Leakage through Layer 3	0.031700	115.1	0.07
Average Head on Top of Layer 3	0.1629	---	---
Percolation/Leakage through Layer 5	0.031700	115.1	0.07
Average Head on Top of Layer 5	0.0001	---	---

Change in Water Storage	-0.0544	-197.6	-0.12
Soil Water at Start of Year	162.3137	589,198.6	354.59
Soil Water at End of Year	162.2492	588,964.6	354.44
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0100	36.4	0.02
Annual Water Budget Balance	-76.8440	-278,943.6	-167.87

Annual Totals for Year 3			
	inches	cubic feet	percent
Precipitation	50.58	183,615.9	100.00
Runoff	23.643	85,824.2	46.74
Evapotranspiration	27.527	99,923.9	54.42
Recirculation into Layer 1	63.5644	230,738.8	125.66
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	63.5644	230,738.8	125.66
Percolation/Leakage through Layer 3	0.022754	82.6	0.04
Average Head on Top of Layer 3	0.1089	---	---
Percolation/Leakage through Layer 5	0.022754	82.6	0.04
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.2096	-761.0	-0.41
Soil Water at Start of Year	162.2492	588,964.6	320.76
Soil Water at End of Year	162.0496	588,240.0	320.36
Snow Water at Start of Year	0.0100	36.4	0.02
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-63.9649	-232,192.6	-126.46

Annual Totals for Year 4			
	inches	cubic feet	percent
Precipitation	34.72	126,016.0	100.00
Runoff	11.180	40,582.3	32.20
Evapotranspiration	22.992	83,459.1	66.23
Recirculation into Layer 1	54.5332	197,955.3	157.09

Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	54.5332	197,955.3	157.09
Percolation/Leakage through Layer 3	0.017950	65.2	0.05
Average Head on Top of Layer 3	0.0815	---	---
Percolation/Leakage through Layer 5	0.017950	65.2	0.05
Average Head on Top of Layer 5	0.0000	---	---
Change in Water Storage	0.1819	660.3	0.52
Soil Water at Start of Year	162.0496	588,240.0	466.80
Soil Water at End of Year	162.2315	588,900.3	467.32
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-54.1890	-196,706.2	-156.10

Annual Totals for Year 5

	inches	cubic feet	percent
Precipitation	52.20	189,495.8	100.00
Runoff	24.426	88,668.0	46.79
Evapotranspiration	27.856	101,119.1	53.36
Recirculation into Layer 1	62.4582	226,723.1	119.65
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	62.4582	226,723.1	119.65
Percolation/Leakage through Layer 3	0.024304	88.2	0.05
Average Head on Top of Layer 3	0.1194	---	---
Percolation/Leakage through Layer 5	0.024304	88.2	0.05
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.1083	393.2	0.21
Soil Water at Start of Year	162.2315	588,900.3	310.77
Soil Water at End of Year	162.3398	589,293.5	310.98
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-62.6710	-227,495.8	-120.05

Annual Totals for Year 6			
	inches	cubic feet	percent
Precipitation	44.51	161,585.5	100.00
Runoff	18.290	66,392.5	41.09
Evapotranspiration	26.136	94,875.1	58.72
Recirculation into Layer 1	70.7274	256,740.3	158.89
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	70.7274	256,740.3	158.89
Percolation/Leakage through Layer 3	0.027704	100.6	0.06
Average Head on Top of Layer 3	0.1392	---	---
Percolation/Leakage through Layer 5	0.027704	100.6	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.1237	-449.1	-0.28
Soil Water at Start of Year	162.3398	589,293.5	364.69
Soil Water at End of Year	162.2161	588,844.4	364.42
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-70.5438	-256,073.9	-158.48

Annual Totals for Year 7			
	inches	cubic feet	percent
Precipitation	33.25	120,687.9	100.00
Runoff	10.272	37,288.3	30.90
Evapotranspiration	21.882	79,430.9	65.82
Recirculation into Layer 1	53.7395	195,074.3	161.64
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	53.7395	195,074.3	161.64
Percolation/Leakage through Layer 3	0.021671	78.7	0.07
Average Head on Top of Layer 3	0.1083	---	---
Percolation/Leakage through Layer 5	0.021671	78.7	0.07
Average Head on Top of Layer 5	0.0001	---	---

Change in Water Storage	1.0889	3,952.6	3.28
Soil Water at Start of Year	162.2161	588,844.4	487.91
Soil Water at End of Year	162.3648	589,384.3	488.35
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.9401	3,412.6	2.83
Annual Water Budget Balance	-53.7567	-195,136.8	-161.69

Annual Totals for Year 8			
	inches	cubic feet	percent
Precipitation	42.21	153,222.7	100.00
Runoff	19.638	71,287.3	46.53
Evapotranspiration	23.895	86,739.1	56.61
Recirculation into Layer 1	78.4475	284,764.3	185.85
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	78.4475	284,764.3	185.85
Percolation/Leakage through Layer 3	0.037555	136.3	0.09
Average Head on Top of Layer 3	0.2007	---	---
Percolation/Leakage through Layer 5	0.037555	136.3	0.09
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-1.1640	-4,225.5	-2.76
Soil Water at Start of Year	162.3648	589,384.3	384.66
Soil Water at End of Year	162.1409	588,571.4	384.13
Snow Water at Start of Year	0.9401	3,412.6	2.23
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-78.6443	-285,478.9	-186.32

Annual Totals for Year 9			
	inches	cubic feet	percent
Precipitation	38.49	139,731.6	100.00
Runoff	13.804	50,108.3	35.86
Evapotranspiration	24.628	89,399.4	63.98
Recirculation into Layer 1	69.8075	253,401.1	181.35

Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	69.8075	253,401.1	181.35
Percolation/Leakage through Layer 3	0.025841	93.8	0.07
Average Head on Top of Layer 3	0.1258	---	---
Percolation/Leakage through Layer 5	0.025841	93.8	0.07
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.0198	71.8	0.05
Soil Water at Start of Year	162.1409	588,571.4	421.22
Soil Water at End of Year	162.1607	588,643.2	421.27
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-69.7914	-253,342.7	-181.31

Annual Totals for Year 10			
	inches	cubic feet	percent
Precipitation	37.06	134,541.3	100.00
Runoff	13.731	49,842.8	37.05
Evapotranspiration	22.729	82,506.1	61.32
Recirculation into Layer 1	64.9789	235,873.2	175.32
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	64.9789	235,873.2	175.32
Percolation/Leakage through Layer 3	0.028712	104.2	0.08
Average Head on Top of Layer 3	0.1497	---	---
Percolation/Leakage through Layer 5	0.028712	104.2	0.08
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.3091	1,122.0	0.83
Soil Water at Start of Year	162.1607	588,643.2	437.52
Soil Water at End of Year	162.3575	589,357.7	438.05
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.1122	407.5	0.30
Annual Water Budget Balance	-64.7127	-234,907.0	-174.60

Annual Totals for Year 11			
	inches	cubic feet	percent
Precipitation	46.90	170,246.5	100.00
Runoff	22.989	83,451.6	49.02
Evapotranspiration	23.974	87,025.9	51.12
Recirculation into Layer 1	70.4246	255,641.2	150.16
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	70.4246	255,641.2	150.16
Percolation/Leakage through Layer 3	0.032182	116.8	0.07
Average Head on Top of Layer 3	0.1729	---	---
Percolation/Leakage through Layer 5	0.032182	116.8	0.07
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.1574	-571.4	-0.34
Soil Water at Start of Year	162.3575	589,357.7	346.18
Soil Water at End of Year	162.3123	589,193.8	346.08
Snow Water at Start of Year	0.1122	407.5	0.24
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-70.3630	-255,417.6	-150.03

Annual Totals for Year 12			
	inches	cubic feet	percent
Precipitation	43.97	159,605.3	100.00
Runoff	18.245	66,229.8	41.50
Evapotranspiration	25.863	93,881.2	58.82
Recirculation into Layer 1	61.1421	221,945.8	139.06
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	61.1421	221,945.8	139.06
Percolation/Leakage through Layer 3	0.022575	81.9	0.05
Average Head on Top of Layer 3	0.1213	---	---
Percolation/Leakage through Layer 5	0.022575	81.9	0.05
Average Head on Top of Layer 5	0.0001	---	---

Change in Water Storage	-0.0794	-288.3	-0.18
Soil Water at Start of Year	162.3123	589,193.8	369.16
Soil Water at End of Year	162.2329	588,905.5	368.98
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-61.2246	-222,245.1	-139.25

Annual Totals for Year 13			
	inches	cubic feet	percent
Precipitation	50.32	182,656.5	100.00
Runoff	22.683	82,340.7	45.08
Evapotranspiration	27.575	100,096.5	54.80
Recirculation into Layer 1	81.3165	295,178.8	161.60
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	81.3165	295,178.8	161.60
Percolation/Leakage through Layer 3	0.031355	113.8	0.06
Average Head on Top of Layer 3	0.1558	---	---
Percolation/Leakage through Layer 5	0.031355	113.8	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.0039	14.0	0.01
Soil Water at Start of Year	162.2329	588,905.5	322.41
Soil Water at End of Year	162.2368	588,919.5	322.42
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-81.2913	-295,087.3	-161.55

Annual Totals for Year 14			
	inches	cubic feet	percent
Precipitation	32.31	117,286.9	100.00
Runoff	6.922	25,126.4	21.42
Evapotranspiration	25.394	92,181.0	78.59
Recirculation into Layer 1	50.2261	182,320.8	155.45

Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	50.2261	182,320.8	155.45
Percolation/Leakage through Layer 3	0.017227	62.5	0.05
Average Head on Top of Layer 3	0.0779	---	---
Percolation/Leakage through Layer 5	0.017227	62.5	0.05
Average Head on Top of Layer 5	0.0000	---	---
Change in Water Storage	-0.0034	-12.5	-0.01
Soil Water at Start of Year	162.2368	588,919.5	502.12
Soil Water at End of Year	162.2333	588,907.0	502.11
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-50.2455	-182,391.3	-155.51

Annual Totals for Year 15			
	inches	cubic feet	percent
Precipitation	35.13	127,507.3	100.00
Runoff	12.540	45,519.9	35.70
Evapotranspiration	22.356	81,152.7	63.65
Recirculation into Layer 1	59.5417	216,136.4	169.51
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	59.5417	216,136.4	169.51
Percolation/Leakage through Layer 3	0.021607	78.4	0.06
Average Head on Top of Layer 3	0.1027	---	---
Percolation/Leakage through Layer 5	0.021607	78.4	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.1315	477.3	0.37
Soil Water at Start of Year	162.2333	588,907.0	461.86
Soil Water at End of Year	162.3648	589,384.3	462.24
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-59.4648	-215,857.4	-169.29

Annual Totals for Year 16			
	inches	cubic feet	percent
Precipitation	46.97	170,507.5	100.00
Runoff	19.937	72,371.4	42.44
Evapotranspiration	27.263	98,966.3	58.04
Recirculation into Layer 1	75.7767	275,069.4	161.32
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	75.7767	275,069.4	161.32
Percolation/Leakage through Layer 3	0.027015	98.1	0.06
Average Head on Top of Layer 3	0.1301	---	---
Percolation/Leakage through Layer 5	0.027015	98.1	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.1403	-509.2	-0.30
Soil Water at Start of Year	162.3648	589,384.3	345.66
Soil Water at End of Year	162.2246	588,875.2	345.37
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-75.8921	-275,488.5	-161.57

Annual Totals for Year 17			
	inches	cubic feet	percent
Precipitation	52.69	191,267.7	100.00
Runoff	19.375	70,330.5	36.77
Evapotranspiration	31.471	114,238.5	59.73
Recirculation into Layer 1	75.8281	275,256.1	143.91
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	75.8281	275,256.1	143.91
Percolation/Leakage through Layer 3	0.027093	98.3	0.05
Average Head on Top of Layer 3	0.1304	---	---
Percolation/Leakage through Layer 5	0.027093	98.3	0.05
Average Head on Top of Layer 5	0.0001	---	---

Change in Water Storage	1.8728	6,798.1	3.55
Soil Water at Start of Year	162.2246	588,875.2	307.88
Soil Water at End of Year	162.2188	588,854.4	307.87
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	1.8785	6,818.9	3.57
Annual Water Budget Balance	-75.8826	-275,453.9	-144.01

Annual Totals for Year 18			
	inches	cubic feet	percent
Precipitation	43.84	159,156.7	100.00
Runoff	18.913	68,655.2	43.14
Evapotranspiration	26.836	97,413.3	61.21
Recirculation into Layer 1	71.3584	259,030.8	162.75
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	71.3584	259,030.8	162.75
Percolation/Leakage through Layer 3	0.027732	100.7	0.06
Average Head on Top of Layer 3	0.1364	---	---
Percolation/Leakage through Layer 5	0.027732	100.7	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-1.8886	-6,855.6	-4.31
Soil Water at Start of Year	162.2188	588,854.4	369.98
Soil Water at End of Year	162.2087	588,817.8	369.96
Snow Water at Start of Year	1.8785	6,818.9	4.28
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-71.4016	-259,187.7	-162.85

Annual Totals for Year 19			
	inches	cubic feet	percent
Precipitation	38.79	140,797.2	100.00
Runoff	14.263	51,775.0	36.77
Evapotranspiration	24.301	88,214.4	62.65
Recirculation into Layer 1	69.2743	251,465.9	178.60

Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	69.2743	251,465.9	178.60
Percolation/Leakage through Layer 3	0.027119	98.4	0.07
Average Head on Top of Layer 3	0.1353	---	---
Percolation/Leakage through Layer 5	0.027119	98.4	0.07
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.1027	373.0	0.26
Soil Water at Start of Year	162.2087	588,817.8	418.20
Soil Water at End of Year	162.3115	589,190.7	418.47
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-69.1817	-251,129.5	-178.36

Annual Totals for Year 20			
	inches	cubic feet	percent
Precipitation	36.71	133,246.2	100.00
Runoff	13.541	49,153.4	36.89
Evapotranspiration	23.402	84,949.3	63.75
Recirculation into Layer 1	69.1579	251,043.1	188.41
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	69.1579	251,043.1	188.41
Percolation/Leakage through Layer 3	0.027278	99.0	0.07
Average Head on Top of Layer 3	0.1443	---	---
Percolation/Leakage through Layer 5	0.027278	99.0	0.07
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.1245	-451.8	-0.34
Soil Water at Start of Year	162.3115	589,190.7	442.18
Soil Water at End of Year	162.1870	588,739.0	441.84
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-69.2967	-251,547.0	-188.78

Annual Totals for Year 21			
	inches	cubic feet	percent
Precipitation	44.49	161,487.2	100.00
Runoff	21.283	77,257.5	47.84
Evapotranspiration	22.371	81,208.1	50.29
Recirculation into Layer 1	77.3767	280,877.4	173.93
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	77.3767	280,877.4	173.93
Percolation/Leakage through Layer 3	0.033531	121.7	0.08
Average Head on Top of Layer 3	0.1745	---	---
Percolation/Leakage through Layer 5	0.033531	121.7	0.08
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.7289	2,645.8	1.64
Soil Water at Start of Year	162.1870	588,739.0	364.57
Soil Water at End of Year	162.3524	589,339.1	364.94
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.5635	2,045.6	1.27
Annual Water Budget Balance	-77.3067	-280,623.3	-173.77

Annual Totals for Year 22			
	inches	cubic feet	percent
Precipitation	45.43	164,920.9	100.00
Runoff	16.175	58,713.5	35.60
Evapotranspiration	28.979	105,194.6	63.78
Recirculation into Layer 1	73.4854	266,752.2	161.75
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	73.4854	266,752.2	161.75
Percolation/Leakage through Layer 3	0.026479	96.1	0.06
Average Head on Top of Layer 3	0.1269	---	---
Percolation/Leakage through Layer 5	0.026479	96.1	0.06
Average Head on Top of Layer 5	0.0001	---	---

Change in Water Storage	0.0628	227.9	0.14
Soil Water at Start of Year	162.3524	589,339.1	357.35
Soil Water at End of Year	162.3648	589,384.3	357.37
Snow Water at Start of Year	0.5635	2,045.6	1.24
Snow Water at End of Year	0.6139	2,228.4	1.35
Annual Water Budget Balance	-73.2957	-266,063.3	-161.33

Annual Totals for Year 23			
	inches	cubic feet	percent
Precipitation	43.25	157,010.6	100.00
Runoff	18.585	67,462.5	42.97
Evapotranspiration	24.879	90,311.5	57.52
Recirculation into Layer 1	63.6163	230,927.2	147.08
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	63.6163	230,927.2	147.08
Percolation/Leakage through Layer 3	0.026499	96.2	0.06
Average Head on Top of Layer 3	0.1330	---	---
Percolation/Leakage through Layer 5	0.026499	96.2	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.1590	577.2	0.37
Soil Water at Start of Year	162.3648	589,384.3	375.38
Soil Water at End of Year	162.1182	588,489.1	374.81
Snow Water at Start of Year	0.6139	2,228.4	1.42
Snow Water at End of Year	1.0195	3,700.9	2.36
Annual Water Budget Balance	-64.0121	-232,363.9	-147.99

Annual Totals for Year 24			
	inches	cubic feet	percent
Precipitation	35.29	128,113.1	100.00
Runoff	13.232	48,033.4	37.49
Evapotranspiration	22.846	82,931.9	64.73
Recirculation into Layer 1	61.4847	223,189.3	174.21

Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	61.4847	223,189.3	174.21
Percolation/Leakage through Layer 3	0.020811	75.5	0.06
Average Head on Top of Layer 3	0.0956	---	---
Percolation/Leakage through Layer 5	0.020811	75.5	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.9374	-3,402.8	-2.66
Soil Water at Start of Year	162.1182	588,489.1	459.35
Soil Water at End of Year	162.2003	588,787.1	459.58
Snow Water at Start of Year	1.0195	3,700.9	2.89
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-61.3538	-222,714.2	-173.84

Annual Totals for Year 25			
	inches	cubic feet	percent
Precipitation	49.03	177,975.2	100.00
Runoff	21.483	77,981.7	43.82
Evapotranspiration	27.161	98,593.1	55.40
Recirculation into Layer 1	82.5481	299,649.7	168.37
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	82.5481	299,649.7	168.37
Percolation/Leakage through Layer 3	0.028808	104.6	0.06
Average Head on Top of Layer 3	0.1388	---	---
Percolation/Leakage through Layer 5	0.028808	104.6	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.0929	337.3	0.19
Soil Water at Start of Year	162.2003	588,787.1	330.83
Soil Water at End of Year	162.2932	589,124.3	331.01
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-82.2841	-298,691.2	-167.83

Annual Totals for Year 26			
	inches	cubic feet	percent
Precipitation	38.33	139,125.2	100.00
Runoff	12.892	46,796.2	33.64
Evapotranspiration	25.445	92,363.8	66.39
Recirculation into Layer 1	65.6984	238,485.3	171.42
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	65.6984	238,485.3	171.42
Percolation/Leakage through Layer 3	0.022495	81.7	0.06
Average Head on Top of Layer 3	0.1053	---	---
Percolation/Leakage through Layer 5	0.022495	81.7	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.0317	-115.0	-0.08
Soil Water at Start of Year	162.2932	589,124.3	423.45
Soil Water at End of Year	162.2615	589,009.3	423.37
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-65.6988	-238,486.6	-171.42

Annual Totals for Year 27			
	inches	cubic feet	percent
Precipitation	33.69	122,301.7	100.00
Runoff	11.498	41,738.1	34.13
Evapotranspiration	22.195	80,566.9	65.88
Recirculation into Layer 1	55.6752	202,101.0	165.25
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	55.6752	202,101.0	165.25
Percolation/Leakage through Layer 3	0.019125	69.4	0.06
Average Head on Top of Layer 3	0.0888	---	---
Percolation/Leakage through Layer 5	0.019125	69.4	0.06
Average Head on Top of Layer 5	0.0001	---	---

Change in Water Storage	0.0706	256.4	0.21
Soil Water at Start of Year	162.2615	589,009.3	481.60
Soil Water at End of Year	162.2364	588,918.1	481.53
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0957	347.6	0.28
Annual Water Budget Balance	-55.7659	-202,430.2	-165.52

Annual Totals for Year 28			
	inches	cubic feet	percent
Precipitation	51.63	187,402.1	100.00
Runoff	22.407	81,337.9	43.40
Evapotranspiration	29.189	105,957.2	56.54
Recirculation into Layer 1	75.2914	273,307.8	145.84
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	75.2914	273,307.8	145.84
Percolation/Leakage through Layer 3	0.028731	104.3	0.06
Average Head on Top of Layer 3	0.1414	---	---
Percolation/Leakage through Layer 5	0.028731	104.3	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.0713	-258.7	-0.14
Soil Water at Start of Year	162.2364	588,918.1	314.25
Soil Water at End of Year	162.2609	589,007.0	314.30
Snow Water at Start of Year	0.0957	347.6	0.19
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-75.2194	-273,046.5	-145.70

Annual Totals for Year 29			
	inches	cubic feet	percent
Precipitation	45.56	165,377.9	100.00
Runoff	17.818	64,679.3	39.11
Evapotranspiration	27.699	100,547.9	60.80
Recirculation into Layer 1	64.2708	233,302.8	141.07

Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	64.2708	233,302.8	141.07
Percolation/Leakage through Layer 3	0.023830	86.5	0.05
Average Head on Top of Layer 3	0.1139	---	---
Percolation/Leakage through Layer 5	0.023830	86.5	0.05
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.0010	-3.6202	0.00
Soil Water at Start of Year	162.2609	589,007.0	356.16
Soil Water at End of Year	162.2599	589,003.4	356.16
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-64.2521	-233,235.0	-141.03

Annual Totals for Year 30			
	inches	cubic feet	percent
Precipitation	44.94	163,118.7	100.00
Runoff	18.874	68,512.6	42.00
Evapotranspiration	26.549	96,374.4	59.08
Recirculation into Layer 1	70.0199	254,172.4	155.82
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	70.0199	254,172.4	155.82
Percolation/Leakage through Layer 3	0.026168	95.0	0.06
Average Head on Top of Layer 3	0.1263	---	---
Percolation/Leakage through Layer 5	0.026168	95.0	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.1349	-489.6	-0.30
Soil Water at Start of Year	162.2599	589,003.4	361.09
Soil Water at End of Year	162.1250	588,513.8	360.79
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-70.3984	-255,546.0	-156.66

Annual Totals for Year 31			
	inches	cubic feet	percent
Precipitation	34.31	124,551.9	100.00
Runoff	12.507	45,399.5	36.45
Evapotranspiration	21.447	77,853.8	62.51
Recirculation into Layer 1	56.8683	206,431.9	165.74
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	56.8683	206,431.9	165.74
Percolation/Leakage through Layer 3	0.021321	77.4	0.06
Average Head on Top of Layer 3	0.1049	---	---
Percolation/Leakage through Layer 5	0.021321	77.4	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.2398	870.5	0.70
Soil Water at Start of Year	162.1250	588,513.8	472.50
Soil Water at End of Year	162.3648	589,384.3	473.20
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-56.7717	-206,081.2	-165.46

Annual Totals for Year 32			
	inches	cubic feet	percent
Precipitation	48.06	174,469.3	100.00
Runoff	23.049	83,668.1	47.96
Evapotranspiration	24.421	88,648.0	50.81
Recirculation into Layer 1	72.8340	264,387.3	151.54
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	72.8340	264,387.3	151.54
Percolation/Leakage through Layer 3	0.030583	111.0	0.06
Average Head on Top of Layer 3	0.1610	---	---
Percolation/Leakage through Layer 5	0.030583	111.0	0.06
Average Head on Top of Layer 5	0.0001	---	---

Change in Water Storage	0.3429	1,244.7	0.71
Soil Water at Start of Year	162.3648	589,384.3	337.82
Soil Water at End of Year	162.3557	589,351.1	337.80
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.3521	1,278.0	0.73
Annual Water Budget Balance	-72.6143	-263,589.9	-151.08

Annual Totals for Year 33			
	inches	cubic feet	percent
Precipitation	41.70	151,354.2	100.00
Runoff	16.995	61,691.6	40.76
Evapotranspiration	24.949	90,563.2	59.84
Recirculation into Layer 1	73.4440	266,601.9	176.14
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	73.4440	266,601.9	176.14
Percolation/Leakage through Layer 3	0.031698	115.1	0.08
Average Head on Top of Layer 3	0.1634	---	---
Percolation/Leakage through Layer 5	0.031698	115.1	0.08
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.3432	-1,245.8	-0.82
Soil Water at Start of Year	162.3557	589,351.1	389.39
Soil Water at End of Year	162.3645	589,383.3	389.41
Snow Water at Start of Year	0.3521	1,278.0	0.84
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-73.3807	-266,371.8	-175.99

Annual Totals for Year 34			
	inches	cubic feet	percent
Precipitation	37.40	135,757.9	100.00
Runoff	13.474	48,910.3	36.03
Evapotranspiration	23.999	87,115.2	64.17
Recirculation into Layer 1	70.2102	254,862.9	187.73

Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	70.2102	254,862.9	187.73
Percolation/Leakage through Layer 3	0.030508	110.7	0.08
Average Head on Top of Layer 3	0.1570	---	---
Percolation/Leakage through Layer 5	0.030508	110.7	0.08
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.1018	-369.5	-0.27
Soil Water at Start of Year	162.3645	589,383.3	434.14
Soil Water at End of Year	162.2627	589,013.7	433.87
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-70.2126	-254,871.7	-187.74

Annual Totals for Year 35			
	inches	cubic feet	percent
Precipitation	40.58	147,295.2	100.00
Runoff	15.815	57,407.7	38.97
Evapotranspiration	24.934	90,511.9	61.45
Recirculation into Layer 1	67.3249	244,389.3	165.92
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	67.3249	244,389.3	165.92
Percolation/Leakage through Layer 3	0.026165	95.0	0.06
Average Head on Top of Layer 3	0.1293	---	---
Percolation/Leakage through Layer 5	0.026165	95.0	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.0555	-201.6	-0.14
Soil Water at Start of Year	162.2627	589,013.7	399.89
Soil Water at End of Year	162.2072	588,812.2	399.75
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-67.4675	-244,907.1	-166.27

Annual Totals for Year 36			
	inches	cubic feet	percent
Precipitation	35.09	127,386.5	100.00
Runoff	13.432	48,758.9	38.28
Evapotranspiration	22.037	79,995.5	62.80
Recirculation into Layer 1	54.6032	198,209.6	155.60
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	54.6032	198,209.6	155.60
Percolation/Leakage through Layer 3	0.018850	68.4	0.05
Average Head on Top of Layer 3	0.0870	---	---
Percolation/Leakage through Layer 5	0.018850	68.4	0.05
Average Head on Top of Layer 5	0.0000	---	---
Change in Water Storage	-0.1052	-381.9	-0.30
Soil Water at Start of Year	162.2072	588,812.2	462.22
Soil Water at End of Year	162.1020	588,430.3	461.93
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-54.8937	-199,264.1	-156.42

Annual Totals for Year 37			
	inches	cubic feet	percent
Precipitation	33.08	120,090.1	100.00
Runoff	10.361	37,610.2	31.32
Evapotranspiration	21.912	79,539.2	66.23
Recirculation into Layer 1	39.1936	142,272.8	118.47
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	39.1936	142,272.8	118.47
Percolation/Leakage through Layer 3	0.012861	46.7	0.04
Average Head on Top of Layer 3	0.0571	---	---
Percolation/Leakage through Layer 5	0.012861	46.7	0.04
Average Head on Top of Layer 5	0.0000	---	---

Change in Water Storage	0.6750	2,450.2	2.04
Soil Water at Start of Year	162.1020	588,430.3	489.99
Soil Water at End of Year	162.1707	588,679.5	490.20
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.6063	2,201.0	1.83
Annual Water Budget Balance	-39.0714	-141,829.0	-118.10

Annual Totals for Year 38			
	inches	cubic feet	percent
Precipitation	39.77	144,368.2	100.00
Runoff	13.893	50,431.3	34.93
Evapotranspiration	26.243	95,260.5	65.98
Recirculation into Layer 1	59.8282	217,176.5	150.43
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	59.8282	217,176.5	150.43
Percolation/Leakage through Layer 3	0.020386	74.0	0.05
Average Head on Top of Layer 3	0.0968	---	---
Percolation/Leakage through Layer 5	0.020386	74.0	0.05
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.4122	-1,496.2	-1.04
Soil Water at Start of Year	162.1707	588,679.5	407.76
Soil Water at End of Year	162.3648	589,384.3	408.25
Snow Water at Start of Year	0.6063	2,201.0	1.52
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-59.8011	-217,077.9	-150.36

Annual Totals for Year 39			
	inches	cubic feet	percent
Precipitation	47.81	173,553.6	100.00
Runoff	20.917	75,928.2	43.75
Evapotranspiration	26.950	97,828.0	56.37
Recirculation into Layer 1	59.7622	216,936.9	125.00

Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	59.7622	216,936.9	125.00
Percolation/Leakage through Layer 3	0.023909	86.8	0.05
Average Head on Top of Layer 3	0.1226	---	---
Percolation/Leakage through Layer 5	0.023909	86.8	0.05
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.1511	-548.6	-0.32
Soil Water at Start of Year	162.3648	589,384.3	339.60
Soil Water at End of Year	162.2137	588,835.7	339.28
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-59.6908	-216,677.5	-124.85

Annual Totals for Year 40			
	inches	cubic feet	percent
Precipitation	43.52	157,986.7	100.00
Runoff	19.767	71,753.6	45.42
Evapotranspiration	22.946	83,292.2	52.72
Recirculation into Layer 1	73.1890	265,675.9	168.16
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	73.1890	265,675.9	168.16
Percolation/Leakage through Layer 3	0.026651	96.7	0.06
Average Head on Top of Layer 3	0.1330	---	---
Percolation/Leakage through Layer 5	0.026651	96.7	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.5737	2,082.6	1.32
Soil Water at Start of Year	162.2137	588,835.7	372.71
Soil Water at End of Year	162.2635	589,016.4	372.83
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.5239	1,901.8	1.20
Annual Water Budget Balance	-72.9792	-264,914.4	-167.68

Annual Totals for Year 41			
	inches	cubic feet	percent
Precipitation	36.01	130,711.6	100.00
Runoff	15.190	55,139.0	42.18
Evapotranspiration	21.975	79,768.9	61.03
Recirculation into Layer 1	61.5551	223,445.2	170.95
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	61.5551	223,445.2	170.95
Percolation/Leakage through Layer 3	0.022704	82.4	0.06
Average Head on Top of Layer 3	0.1118	---	---
Percolation/Leakage through Layer 5	0.022704	82.4	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.7384	-2,680.5	-2.05
Soil Water at Start of Year	162.2635	589,016.4	450.62
Soil Water at End of Year	162.0490	588,237.8	450.03
Snow Water at Start of Year	0.5239	1,901.8	1.45
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-61.9954	-225,043.4	-172.17

Annual Totals for Year 42			
	inches	cubic feet	percent
Precipitation	42.90	155,735.9	100.00
Runoff	15.086	54,763.2	35.16
Evapotranspiration	26.911	97,687.8	62.73
Recirculation into Layer 1	75.3102	273,376.0	175.54
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	75.3102	273,376.0	175.54
Percolation/Leakage through Layer 3	0.028098	102.0	0.07
Average Head on Top of Layer 3	0.1375	---	---
Percolation/Leakage through Layer 5	0.028098	102.0	0.07
Average Head on Top of Layer 5	0.0001	---	---

Change in Water Storage	0.4332	1,572.6	1.01
Soil Water at Start of Year	162.0490	588,237.8	377.71
Soil Water at End of Year	162.3302	589,258.7	378.37
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.1520	551.7	0.35
Annual Water Budget Balance	-74.8666	-271,765.8	-174.50

Annual Totals for Year 43			
	inches	cubic feet	percent
Precipitation	41.90	152,095.6	100.00
Runoff	15.520	56,336.1	37.04
Evapotranspiration	26.470	96,084.5	63.17
Recirculation into Layer 1	69.1623	251,059.3	165.07
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	69.1623	251,059.3	165.07
Percolation/Leakage through Layer 3	0.028177	102.3	0.07
Average Head on Top of Layer 3	0.1408	---	---
Percolation/Leakage through Layer 5	0.028177	102.3	0.07
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.1194	-433.3	-0.28
Soil Water at Start of Year	162.3302	589,258.7	387.43
Soil Water at End of Year	162.3628	589,377.1	387.50
Snow Water at Start of Year	0.1520	551.7	0.36
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-69.1607	-251,053.3	-165.06

Annual Totals for Year 44			
	inches	cubic feet	percent
Precipitation	54.28	197,049.3	100.00
Runoff	25.508	92,595.3	46.99
Evapotranspiration	28.799	104,541.3	53.05
Recirculation into Layer 1	85.5266	310,461.5	157.56

Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	85.5266	310,461.5	157.56
Percolation/Leakage through Layer 3	0.039270	142.5	0.07
Average Head on Top of Layer 3	0.2111	---	---
Percolation/Leakage through Layer 5	0.039270	142.5	0.07
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.0008	-3.0620	0.00
Soil Water at Start of Year	162.3628	589,377.1	299.10
Soil Water at End of Year	162.3620	589,374.0	299.10
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-85.5890	-310,688.2	-157.67

Annual Totals for Year 45			
	inches	cubic feet	percent
Precipitation	44.24	160,601.5	100.00
Runoff	20.796	75,488.0	47.00
Evapotranspiration	23.643	85,822.8	53.44
Recirculation into Layer 1	84.5572	306,942.7	191.12
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	84.5572	306,942.7	191.12
Percolation/Leakage through Layer 3	0.037603	136.5	0.08
Average Head on Top of Layer 3	0.1982	---	---
Percolation/Leakage through Layer 5	0.037603	136.5	0.08
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.1525	-553.7	-0.34
Soil Water at Start of Year	162.3620	589,374.0	366.98
Soil Water at End of Year	162.2095	588,820.4	366.63
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-84.6377	-307,234.8	-191.30

Annual Totals for Year 46			
	inches	cubic feet	percent
Precipitation	41.66	151,210.6	100.00
Runoff	15.374	55,806.0	36.91
Evapotranspiration	25.857	93,862.6	62.07
Recirculation into Layer 1	68.5129	248,701.7	164.47
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	68.5129	248,701.7	164.47
Percolation/Leakage through Layer 3	0.024937	90.5	0.06
Average Head on Top of Layer 3	0.1204	---	---
Percolation/Leakage through Layer 5	0.024937	90.5	0.06
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.6911	2,508.6	1.66
Soil Water at Start of Year	162.2095	588,820.4	389.40
Soil Water at End of Year	162.1052	588,441.9	389.15
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.7953	2,887.1	1.91
Annual Water Budget Balance	-68.8041	-249,758.8	-165.17

Annual Totals for Year 47			
	inches	cubic feet	percent
Precipitation	40.01	145,247.7	100.00
Runoff	15.888	57,672.8	39.71
Evapotranspiration	24.387	88,524.6	60.95
Recirculation into Layer 1	67.9107	246,516.0	169.72
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	67.9107	246,516.0	169.72
Percolation/Leakage through Layer 3	0.026315	95.5	0.07
Average Head on Top of Layer 3	0.1307	---	---
Percolation/Leakage through Layer 5	0.026315	95.5	0.07
Average Head on Top of Layer 5	0.0001	---	---

Change in Water Storage	-0.6647	-2,412.8	-1.66
Soil Water at Start of Year	162.1052	588,441.9	405.13
Soil Water at End of Year	162.2359	588,916.1	405.46
Snow Water at Start of Year	0.7953	2,887.1	1.99
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-67.5340	-245,148.4	-168.78

Annual Totals for Year 48			
	inches	cubic feet	percent
Precipitation	37.82	137,281.1	100.00
Runoff	16.447	59,703.2	43.49
Evapotranspiration	20.451	74,238.4	54.08
Recirculation into Layer 1	78.5712	285,213.5	207.76
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	78.5712	285,213.5	207.76
Percolation/Leakage through Layer 3	0.033868	122.9	0.09
Average Head on Top of Layer 3	0.1751	---	---
Percolation/Leakage through Layer 5	0.033868	122.9	0.09
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	0.8287	3,008.2	2.19
Soil Water at Start of Year	162.2359	588,916.1	428.99
Soil Water at End of Year	162.3648	589,384.3	429.33
Snow Water at Start of Year	0.0000	0.0000	0.00
Snow Water at End of Year	0.6997	2,540.0	1.85
Annual Water Budget Balance	-78.5138	-285,005.1	-207.61

Annual Totals for Year 49			
	inches	cubic feet	percent
Precipitation	44.19	160,407.9	100.00
Runoff	20.475	74,322.8	46.33
Evapotranspiration	24.309	88,241.1	55.01
Recirculation into Layer 1	62.0531	225,252.7	140.42

Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	62.0531	225,252.7	140.42
Percolation/Leakage through Layer 3	0.023874	86.7	0.05
Average Head on Top of Layer 3	0.1185	---	---
Percolation/Leakage through Layer 5	0.023874	86.7	0.05
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.2873	-1,043.0	-0.65
Soil Water at Start of Year	162.3648	589,384.3	367.43
Soil Water at End of Year	162.3590	589,363.0	367.42
Snow Water at Start of Year	0.6997	2,540.0	1.58
Snow Water at End of Year	0.4183	1,518.4	0.95
Annual Water Budget Balance	-62.3836	-226,452.3	-141.17

Annual Totals for Year 50			
	inches	cubic feet	percent
Precipitation	46.29	168,044.1	100.00
Runoff	19.214	69,745.6	41.50
Evapotranspiration	27.250	98,917.6	58.86
Recirculation into Layer 1	53.9767	195,935.4	116.60
Drainage Collected from Layer 2	0.0000	0.0000	0.00
Recirculation from Layer 2	53.9767	195,935.4	116.60
Percolation/Leakage through Layer 3	0.021042	76.4	0.05
Average Head on Top of Layer 3	0.1113	---	---
Percolation/Leakage through Layer 5	0.021042	76.4	0.05
Average Head on Top of Layer 5	0.0001	---	---
Change in Water Storage	-0.5208	-1,890.5	-1.12
Soil Water at Start of Year	162.3590	589,363.0	350.72
Soil Water at End of Year	162.2565	588,990.9	350.50
Snow Water at Start of Year	0.4183	1,518.4	0.90
Snow Water at End of Year	0.0000	0.0000	0.00
Annual Water Budget Balance	-53.6475	-194,740.4	-115.89

Average Annual Totals Summary

Title: CWLP Dallman Ash Pond (ClosureTurf)
Simulated on: 7/15/2025 14:10

	Average Annual Totals for Years 1 - 50*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	42.40	[5.89]	153,920.5	100.00
Runoff	17.272	[4.309]	62,697.1	40.73
Evapotranspiration	25.105	[2.416]	91,132.1	59.21
Subprofile1				
Recirculation into Layer 1	67.6107	[9.5551]	245,426.7	159.45
Lateral drainage collected from Layer 2	0.0000	[0]	0.0000	0.00
Drainage recirculated from Layer 2	67.6107	[9.5551]	245,426.7	159.45
Percolation/leakage through Layer 3	0.026270	[0.005351]	95.4	0.06
Average Head on Top of Layer 3	0.1311	[0.0314]	---	---
Subprofile2				
Percolation/leakage through Layer 5	0.026270	[0.005351]	95.4	0.06
Average Head on Top of Layer 5	0.0001	[0]	---	---
Water storage				
Change in water storage	-0.0011	[0.5609]	-4.1365	0.00

Peak Values Summary

Title: CWLP Dallman Ash Pond (ClosureTurf)
Simulated on: 7/15/2025 14:10

	Peak Values for Years 1 - 50*	
	(inches)	(cubic feet)
Precipitation	4.06	14,750.3
Runoff	3.641	13,218.4
Subprofile1		
Drainage Recirculated into Layer 1	0.4454	1,616.7
Drainage collected from Layer 2	0.0000	0.0000
Drainage recirculated from Layer 2	0.4454	1,616.7
Percolation/leakage through Layer 3	0.000293	1.0629
Average head on Layer 3	0.6298	---
Maximum head on Layer 3	1.2245	---
Location of maximum head in Layer 2	13.51 (feet from drain)	
Subprofile2		
Percolation/leakage through Layer 5	0.000293	1.0629
Average head on Layer 5	0.0003	
Other Parameters		
Snow water	4.2388	15,386.8
Maximum vegetation soil water	0.5058 (vol/vol)	
Minimum vegetation soil water	0.0208 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: CWLP Dallman Ash Pond (ClosureTurf)
Simulated on: 7/15/2025 14:11
Simulation period: 50 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	0.1101	0.2202
2	0.1103	0.8487
3	0.0000	0.0000
4	140.4000	0.3900
5	16.9560	0.4710
Snow water	0.0000	---

Appendix C

CQA Plan Table C.1

Construction Quality Assurance Plan Table C.1

Testing	Property/Test Method	Requirement/Specification	Frequency	Responsibility
SOILS - PREQUALIFICATION TESTING	FOUNDATION FILL & BERMS			CQA Officer
	Standard Proctor Curve - ASTM D698		Per soil type (See Note 1)	
	Atterberg Limits - ASTM D4318	PI > 5, LL > 20%	Per soil type	
	Grain Size Analysis - ASTM D422	- 200 Sieve > 50% or meets soil liner specifications	Per soil type	
	Hydraulic Conductivity - ASTM D5084	See Note 1	Per soil type	

Note 1: "Soil Type" refers to differences in soil color and/or textural consistency that would be indicative of differences in soil characteristics.

SOILS - MATERIAL PLACEMENT TESTING	FOUNDATION			CQA Officer
	Survey	0 to -0.4 feet Design Grade	100-foot grid	
	FOUNDATION FILL & BERMS			CQA Officer
	Density/Moisture - ASTM D2922 and D3017	95% Standard Proctor Density and -2% to +2% Optimum Moisture Content	1 per 10,000 cubic yards (minimum 1 per compacted lift)	
	Strength	0.5 tsf (hand-held penetrometer)	1 per 10,000 cubic yards (minimum 1 per compacted lift)	
	Hydraulic Conductivity - ASTM D5084	See Note 2	1 per 25,000 cubic yards	
	Sieve and Hydrometer Analysis of Soils - ASTM D422	- 200 Sieve > 50% or meets soil liner specifications	Per Soil Type	
	Liquid Limit, Plastic Limit and Plasticity Index (Atterberg Limits) - ASTM D4318	PI > 5, LL > 20	Per Soil Type	

Note 2: There is no specific requirement for hydraulic conductivity for the foundations and berms. The contractor will attempt to utilize the most impermeable materials available (as identified visually) when constructing foundation fill and berms. For purposes of a complete construction record, samples of placed foundation fill and side berms will be collected and tested in the lab for hydraulic conductivity at a rate of one test per each 25,000 cubic yards of material placed. No specific threshold values are required.

GEOSYNTHETICS - PREQUALIFICATION TESTING	GEOMEMBRANES (textured, 40 mil and 60 mil)			Installer
	Puncture Resistance - ASTM D4833	Manufacturer's List of Guaranteed Properties	See Note 4	
	Tear Resistance - ASTM D1004	Manufacturer's List of Guaranteed Properties	See Note 4	
	Thickness - ASTM D5994	Manufacturer's List of Guaranteed Properties	See Note 4	
	Tensile Strength and Elongation - ASTM D638 (Modified) or D6693	Manufacturer's List of Guaranteed Properties	See Note 4	
	GEOTEXTILES (non-woven, 4 oz., 6 oz., 10 oz., and 16 oz.)			Installer
	Mass per Unit Area - ASTM D3776/D5261	Manufacturer's List of Guaranteed Properties	See Note 5	
	Grab Tensile Strength - ASTM D4632	Manufacturer's List of Guaranteed Properties	See Note 5	
	Trapezoidal Tear Strength - ASTM D4533	Manufacturer's List of Guaranteed Properties	See Note 5	
	Apparent Opening Size - ASTM D4751 (see Note 3)	Manufacturer's List of Guaranteed Properties	See Note 5	
	Puncture Resistance - ASTM D4833/D6241	Manufacturer's List of Guaranteed Properties	See Note 5	
	Permittivity - ASTM D4491 (see Note 4)	Manufacturer's List of Guaranteed Properties	See Note 5	
	SYNTHETIC TURF			Installer
	Yarn Weight - ASTM D5261	Manufacturer's List of Guaranteed Properties	See Note 5	
	Yarn Tensile Strength - ASTM D2256	Manufacturer's List of Guaranteed Properties	See Note 5	
	CBR Puncture - ASTM D6241	Manufacturer's List of Guaranteed Properties	See Note 5	

Note 3: Permittivity and apparent opening size are not required for 10 oz. geotextile when used for cushioning only.

Note 4: 1 per 100,000 square feet or per raw material batch, whichever is greater. Sample 3 feet wide by the full roll width.

Note 5: 1 per lot or one per 100,000 square feet, whichever is greater. Sample 3 feet wide by the full roll width.

Construction Quality Assurance Plan Table C.1

Testing	Property/Test Method	Requirement/Specification	Frequency	Responsibility
GEOSYNTHETICS - MATERIAL PLACEMENT TESTING	GEOMEMBRANES (textured, 40 mil and 60 mil)			
	Seam Overlap	3" (Minimum)	All Seams	Installer
	Non-Destructive Testing	As per Section 5.5.3.1d of CQA Plan	All Seams	
	Destructive Testing	As per Section 5.5.3.1e of CQA Plan	One each day for each welding unit	
	GEOTEXTILES (non-woven, 4 oz., 6 oz., 10 oz., and 16 oz.)			
	Seam Overlap	3" (Minimum)	All Seams	Installer
	Installation	Physical Installation per Section 5.5.3.2c of the Closure Plan	None	
	SYNTHETIC TURF			
	Seam Overlap	5" (Minimum)	All Seams	Installer
	Seaming Method	Sewn or Fusion Weld	All Seams	
	Installation	Physical Installation per Section 5.5.3.2c of the Closure Plan	None	
GRANULAR MEDIA - PREQUALIFICATION TESTING	COARSE AGGREGATE			
	Hydraulic Conductivity - ASTM D2434	1.0×10^{-1} cm/sec (Minimum)	One Test per Source	CQA Officer
	Grain Size Analysis - ASTM D422	Field Established Based on Hydraulic Conductivity (Fines Passing #200 < 5%)	One Test per Source	
	SPECIFIED AGGRAGATE INFILL			
	Grain Size Analysis - ASTM D422	Per Table 1 in SECTION 31 05 16	One Test per Source	CQA Officer
	Specific Gravity - ASTM C128	Oven-dry specific gravity ≥ 2.40	One Test per Source	
	Fine Aggregate Angularity - ASTM C1252	Uncompacted void content >40%	One Test per Source	
GRANULAR MEDIA - MATERIAL PLACEMENT TESTING	COARSE AGGREGATE			
	Gradation - ASTM D422	Field Established Based on Hydraulic Conductivity (Fines Passing #200 < 5%)	1 per 3,000 cubic yards	CQA Officer
	Hydraulic Conductivity - ASTM D2434	1.0×10^{-1} cm/sec (Minimum)	1 per 10,000 cubic yards	
	SPECIFIED AGGRAGATE INFILL			
	Grain Size Analysis - ASTM D422	Field Established Based on Hydraulic Conductivity (Fines Passing #200 < 5%)	One Test per 175 cu. yd. to bew installed	CQA Officer
	Survey	Elevation ± 0.1 feet with no adverse slopes. Plan location ± 0.5 feet.	Every 100 feet and connections	CQA Officer
	Welds and Connections	Visual Inspection	Each connection	
	SURFACE WATER MANAGEMENT SYSTEM			
	Survey	Field established for positive drainage (± 0.4 feet)	Inlet and Outlet, and every 100 lineal feet along ditch channel	CQA Officer
	CONCRETE			
	Slump - ASTM C143	4 in. maximum; a tolerance up to 1 in. above the maximum allowed for one of every five (5) batches tested	1 per 25 cubic yards or minimum 1 per day	CQA Officer
	Air Entrainment - ASTM C231	5% to 7% at time of placement	1 per 100 cubic yards or minimum 1 per day	
	Compressive Strength - ASTM C31 and C39	4,000 psi at 28 days	2 cylinders per 50 cubic yards or minimum 2 cylinders per day	
	Delivery Time - ASTM C94	Total mixing and delivery time less than 1.5 hours	Each Delivery	

Appendix D

1,000-year Storm Drainage Calculations

1. Introduction

1.1 Regulatory Requirements

The closed facility must meet the following requirement of 40 CFR 257.82-Hydrologic and hydraulic capacity requirements for CCR surface impoundments:

- 40 CFR 257.82(a) The owner or operator of an existing or new CCR surface impoundment, legacy CCR surface impoundment, or any lateral expansion of a CCR surface impoundment must design, construct, operate, and maintain an inflow design flood control system as specified in paragraphs (a)(1) and (2) of this section.

- 40 CFR 257.82(a)(1) The inflow design flood control system must adequately manage flow into the CCR unit during and following the peak discharge of the inflow design flood specified in paragraph 40 CFR 257.82(a)(3).

- 40 CFR 257.82(a)(2) The inflow design flood control system must adequately manage flow from the CCR unit to collect and control the peak discharge resulting from the inflow design flood specified in paragraph 40 CFR 257.82(a)(3).

- 40 CFR 257.82(a)(3) The inflow design flood is: 40 CFR 257.82(a)(ii) For a significant hazard potential CCR surface impoundment, as determined under 40 CFR 257.73(a)(2) or 40 CFR 257.74(a)(2), the 1,000-year flood.

- 40 CFR 257.82(b) Discharge from the CCR unit must be handled in accordance with the surface water requirements under 40 CFR 257.3-3.

This report details the hydrologic analysis and drainage design for the proposed closure system for the CWLP Ash Ponds. The analysis is based on the 1000-year critical duration rainfall event, using data from the Illinois State Water Survey (ISWS) Bulletin 75 and appropriate Huff Distributions. The objective is to evaluate proposed drainage conditions and to design proposed drainage infrastructure that safely conveys storm runoff from the site.

2. Site Background

The CWLP ash ponds are in Section 12 R.5W, T.15N of the Third Principal Meridian in Springfield, Sangamon County, Illinois. The Site is in the Springfield Plain of the Central Lowland Province Physiographic Division of Illinois (Leighton et al., 1948). For the purposes of this report, the inflow drainage system is divided into the following areas of study.

2.1 Lakeside Ash Pond

The older of the two (2) impoundments is Lakeside Ash Pond (LAP). LAP has a footprint of approximately 36 acres and contains approximately 1,565,000 cubic yards (cu. yd.) of CCR along with water treatment plant sludge. The Lakeside Ash Pond is being closed by removal of CCR for this design scenario, and no longer discharges stormwater into inflow drainage system.

2.2 Dallman Ash Pond

Dallman Ash Pond (DAP) has a footprint of approximately 36 acres and currently contains approximately 1,217,000 cu. yd. of CCR. The Dallman Ash Pond in will be divided into four quarters and capped in place with a ClosureTurf synthetic alternative cover system. The cover drainage system for each quarter will collect stormwater at the top of the slope and at the outer perimeter to safely convey the discharges out of the cover system through a box culvert.

2.3 Clarification Pond

The site Clarification Pond collects runoff from the Dallman Ash Pond, the Lime Treatment Facility east of the Lakeside Ash Pond, and a portion of the CCR Landfill cover east of the Dallman Ash Pond. This pond also collects base process water flows from the CCR Landfill leachate collection system as well as the Lime Treatment Facility located on the east side of the facility. All flows from this pond controlled by an outlet structure consisting of a weir consisting of 6' wide stoplogs and then into a pump station structure with a 36-inch diameter outfall pipe to Sugar Creek on the west side of the facility. This final outfall structure is regulated as an NPDES outfall point.

3. Hydrologic Methodology

3.1 Hydrologic Model

The hydrologic analysis was performed using hydrograph routing methodology. The model was developed using the following parameters:

- Rainfall Data: Bulletin 75 rainfall depth-duration-frequency (DDF) data for Geographic Section 6 (West Southwest) of Illinois.

- Rainfall Distribution: Huff rainfall distributions, with the specific quartile and probability level determined by the critical duration analysis.

- Runoff Hydrograph Development: The TR-55 methodology is a widely used U.S. approach for hydrologic analysis of small to medium-sized watersheds that provides simplified procedures for calculating storm runoff volume, peak discharge rates, and hydrographs. It employs the SCS runoff equation to determine runoff depth from rainfall and the NRCS unit hydrograph method to transform runoff into a discharge hydrograph over time. Key components of the method include the Curve Number (CN) method for runoff calculation and a velocity method for determining Time of Concentration (Tc).

- Rainfall-Runoff Relationship: Curve Number (CN): The TR-55 methodology begins by using the NRCS (formerly SCS) runoff curve number (CN) to convert a given rainfall event into an excess runoff depth based on factors like soil type, land cover, and antecedent moisture conditions. The Curve Numbers were selected for this analysis:

Pond Surfaces	98
Grass Cover (CCR Landfill)	74
Concrete surfaces	98
ClosureTurf synthetic cover	95

- Hydrograph Generation:
    - Time of Concentration (Tc): The calculated time it takes for runoff to travel from the farthest point of the watershed to a specific outlet is determined. TR-55 uses a velocity method that breaks Tc into components:
        - Sheet Flow: Water movement over a plane surface.
        - Shallow Concentrated Flow: The flow between sheet flow and open channels.
        - Open Channel Flow: Water flowing in a defined channel.
        - Unit Hydrograph: A standard unit hydrograph shape is used to transform the calculated runoff volume and peak flow rate into a hydrograph representing the discharge over time. This analysis develops synthetic unit hydrographs from the appropriate Huff rainfall distribution.

- Output Products:
- Calculations were Runoff Volume and Peak Discharge: The procedure calculates the total volume of runoff and the peak flow rate for the watershed.
- Hydrographs: It generates detailed hydrographs, which show how discharge changes over time.
- Storage Volumes: TR-55 can also be used to estimate the storage volumes needed for floodwater reservoirs.

3.2 1,000-Year Event Derivation

Bulletin 75 provides precipitation frequency estimates up to the 500-year recurrence interval. To derive the 1,000-year event, the following steps were taken:

1. DDF Data Extraction: Rainfall depths for the 1-year to 500-year events were extracted from Bulletin 75 for all relevant durations (e.g., 1, 2, 3, 6, 12, 24 hours).
2. Extrapolation: The DDF curve was extrapolated to the 1,000-year recurrence interval using an established statistical method, such as a log-Pearson Type III distribution.
3. Critical Duration Analysis: The hydrologic model was run for the 1,000-year rainfall depths across all durations to determine the "critical duration"—the storm length that produces the highest peak flow for the site.

4. Huff Distribution Analysis

The temporal distribution of rainfall plays a crucial role in determining peak runoff. The Huff distribution curves, based on statistical analysis of heavy rainstorms in Illinois, represent the typical timing of peak rainfall intensity.

4.1 Quartile Selection

A critical duration analysis was performed using all four Huff quartiles (1st, 2nd, 3rd, and 4th) to simulate various storm types.

- First Quartile: Represents intense, short-duration storms where the majority of rainfall occurs in the first quarter.
- Second Quartile: For storms of moderate duration (6–12 hours).
- Third Quartile: Applies to storms of moderate-to-long duration (12–24 hours).
- Fourth Quartile: For long-duration storms (greater than 24 hours).

4.2 Critical Quartile Determination

The analysis showed that the First Quartile storm produced the highest peak flow for the 1,000-year event with the critical duration of 30 minutes. This finding indicates that the drainage system is most sensitive to rainfall events where the highest intensity occurs within the first quarter of the storm.

In addition to the peak flow event, 12-hour event was determined to create highest peak water surface elevation in the facility clarification pond.

5. Drainage Analysis and Findings

5.1 1,000-Year Storm Event Parameters to determine critical duration peak flows.

- Return Period: 1,000-year
- Critical Duration: 30-minutes
- Rainfall Depth: 3.57 inches
- Huff Distribution: First Quartile

5.2 1,000-Year Storm Event Parameters to determine the critical duration peak water surface elevation in the Clarification Pond.

- Return Period: 1,000-year
- Critical Duration: 12-hours
- Rainfall Depth: 8.42 inches
- Huff Distribution: Second Quartile

5.3 Hydrologic Modeling Results

The hydrologic model was used to simulate the 1,000-year critical duration storm event. The calculations were performed using HydroCAD software Dynamic Storage-Indication (DSI) routing method, which accounts for the influence of downstream conditions, such as tailwater, on upstream nodes by calculating all nodes simultaneously within each time step. DSI is crucial for analyzing interconnected ponds, catch basins, or other systems where a downstream node's tailwater directly affects the outflow and storage of an upstream pond or structure.

Key Aspects of DSI Methodology

- Simultaneous Calculation: Unlike the step-by-step storage-indication method, DSI calculates all nodes in a network at each time step. This allows for the dynamic interaction between nodes.
- Variable Tailwater: The primary benefit of DSI is its ability to model how changing tailwater conditions from downstream nodes influence the performance of upstream nodes.
- Interconnected Systems: DSI is ideal for "coupled ponds," such as multiple catch basins or a road crossing with a ponding area on both sides of the road, where the discharge from one influences the next.
- Automatic Tailwater: In a DSI model, the tailwater for each node is automatically determined from the conditions at the next downstream node in the network.

Hydrograph results for the 1000-year, 30-minute storm event are included in Appendix D-1.

5.4 Upper Diversion Ditches

The upper diversion ditches prevent surface water from the upper cover from entering the steeper sideslope of the cover system. The upper diversion ditches will be stabilized by a cement stabilized version of ClosureTurf called HydroTurf. Watershed Geo, the manufacturer of HydroTurf, utilized the large-scale flume testing facility at Colorado State University. Tests were conducted in accordance with ASTM D-7277, the standard test method for ACB revetment systems. The results were analyzed according to ASTM D-7276. HydroTurf performed without damage or instability at the maximum flow velocity the flume could generate at over 29 ft/sec. For the purposes of this report, the maximum allowable velocity for the HydroTurf system will be 19 ft/sec using a factor of safety of 1.5. All diversion ditches safely pass the flow for the 1000-year event without overtopping.

NODE	NAME	PEAK DISCHARGE (CFS)	PEAK FLOW DEPTH (INCHES)	FREEBOARD AT PEAK FLOW DEPTH (INCHES)	PEAK VELOCITY (FT/SEC)
1A-D	1A-DIVERSION	10.73	5.0	7.0	3.19
1B-D	1B-DIVERSION	20.98	7.2	4.8	3.17
2A-D	2A-DIVERSION	42.22	9.8	2.2	3.64
2B-D	2B-DIVERSION	16.08	6.0	6.0	3.40
3A-D	3A-DIVERSION	16.55	6.7	5.3	2.82
3B-D	3B-DIVERSION	24.92	7.2	4.8	3.77
4A-D	4A-DIVERSION	23.98	7.4	4.6	3.33
4B-D	4B-DIVERSION	17.41	6.8	5.2	2.86

5.5 Cover Down Chutes

The cover down chutes convey surface water from the upper diversion ditches into the discharge culverts in the perimeter berm. The cover down chutes will be stabilized using HydroTurf. All cover down chutes safely pass the flow for the 1000-year event.

NODE	NAME	PEAK DISCHARGE (CFS)	PEAK FLOW DEPTH (INCHES)	FREEBOARD AT PEAK FLOW DEPTH (INCHES)	PEAK VELOCITY (FT/SEC)
CS1	1-COVER CHUTE	31.64	2.6	9.4	13.01
CS2	2-COVER CHUTE	61.58	4.0	8.0	16.48
CS3	3-COVER CHUTE	41.54	3.2	8.8	14.08
CS4	4-COVER CHUTE	41.43	3.2	8.8	14.04

5.6 Perimeter Ditches

The perimeter ditches are location around the inside perimeter of the CCR pond containment berm. They convey surface water from the perimeter cover side slopes to the discharge culverts in the perimeter berm. Since these ditches act as storage for the discharge culverts during heavy rain events, freeboard has been determine using the culvert maximum headwater elevation with respect to the perimeter berm. The perimeter ditches are stabilized with HydroTurf. All perimeter ditches safely pass the flow for the 1000-year event.

NODE	NAME	PEAK DISCHARGE (CFS)	PEAK FLOW DEPTH (INCHES)	FREEBOARD AT PEAK FLOW DEPTH (INCHES)	PEAK VELOCITY (FT/SEC)
1A1-P	1A1-PERIMETER	16.38	7.9	35.3	3.24
1A2-P	1A2-PERIMETER	16.63	4.9	35.3	6.09
1B-P	1B-PERIMETER	34.45	11.6	52.3	3.98
2A-P	2A-PERIMETER	43.48	13.1	52.3	4.27
2B1-P	2B1-PERIMETER	22.72	9.4	52.3	3.56
2B2-P	2B2-PERIMETER	23.02	5.9	52.3	6.72
3A-P	3A-PERIMETER	23.27	9.5	24.1	3.58
3B-P	3B-PERIMETER	15.22	5.9	24.1	4.42
4A-P	4A-PERIMETER	17.61	7.0	29.4	4.19
4B-P	4B-PERIMETER	24.69	9.8	29.4	3.62

5.7 Discharge Culverts

The discharge culverts are outlets that will be installed into the perimeter berm of the CCR pond to discharge clean storm water to either Sugar Creek on the north and west sides of the unit, or to the Clarification Pond on the south side of the unit. The culverts will be installed with cast-in-place concrete flared end sections constructed per Illinois Department of Transportation (IDOT) standard plans. The culverts were sized accounting for headwater and tailwater conditions at each time step interval. All discharge culverts safely pass the flow for the 1000-year event.

NODE	NAME	PEAK DISCHARGE (CFS)	BOX CULVERT SIZE	HEADWATER FREEBOARD AT PEAK FLOW DEPTH (INCHES)	PEAK VELOCITY (FT/SEC)
C1	BOX CULVERT 1	60.38	48"W x 24"H	35.3	7.55
C2	BOX CULVERT 2	88.24	60"W x 24"H	52.3	8.82
C3	BOX CULVERT 3	56.62	48"W x 24"H	24.1	7.08
C4	BOX CULVERT 4	57.71	48"W x 24"H	29.4	7.21

5.8 Exterior Rock Chutes

The exterior rock chutes convey stormwater from the perimeter box culverts down the existing sideslope. The rock chutes were designed using an Excel spreadsheet distributed by the USDA Natural Resources Conservation Service, that uses the design methodology "Design of Rock Chutes" published by Robinson, Rice, and Kadavy in the 1998 American Society of Agricultural Engineers (ASAE) journal. The design is iteratively solved by determining proper riprap sizes and plunge pool depths to prevent the movement during a design storm event. A factor of safety of 1.5 was used in the calculation. A corresponding riprap gradation was then selected using the D50 results. Rock Chute calculations are included in Appendix D-2.

NAME	CHUTE WIDTH (FT)	OUTLET APRON SIZE (FT)	OUTLET APRON POOL DEPTH (FT)	MINIMUM D50 SIZE (INCHES)	IDOT RIPRAP GRADATION	MINIMUM RIPRAP THICKNESS (INCHES)
RS2	13.0	20'L x 13'W	1.0	16.4	RR7	32.7
RS3	13.0	16'L x 13'W	1.0	13.1	RR6	26.2
RS4	13.0	17'L x 13'W	1.0	13.2	RR6	26.5

5.9 Clarification Pond

The clarification pond collects stormwater from the southeast quarter of the final cover system, a portion of the existing capped CCR Landfill, and the Lime Treatment Facility. The CCR Landfill and Lime Treatment Facility also contribute continuous base flows from leachate collection and process water. The pond is operated at a continuous water surface elevation of by a discharge structure consisting of 6' wide stoplogs. The stoplog maintain a constant operating water surface elevation of 546.09. Stage storage curves were determined by the existing pond geometry. Final discharge from the out of the discharge structure is a 36-inch diameter culvert that drains to Sugar Creek. The lowest elevation of the clarification pond perimeter berm is 552.2.

The critical design event for the pond was the event that produced the highest peak water surface elevation. This event was determined to be the 1000-year, 12-hour event. The peak water surface during this event was elevation 547.18. HydroCAD results for the 1000-year, 12-hour event are included in Appendix D-3.

To determine proper freeboard for this event, wave runup was also considered. The ASCE Design Hazard Report lists a 700-year return interval maximum wind speed for this area of 108 mph. This wind speed, with a fetch length of 1230 feet in the longest direction and a pond depth of 15 feet result in a maximum wave runup of 2.03 feet (peak elevation 549.21). The resulting freeboard is 2.99 feet. Wave runup calculations are included in Appendix D-4.

Appendix E

Settlement and Slope Stability Calculations

Date: 9/12/2025
To: City Water, Light and Power (CWLP)
From: Kip Chepkoit, Ph.D., P.E., Hanson Professional Services Inc.
Project No.: 25E0006
Project Name: Dallman and Lakeside Ash Ponds
Subject: Assessment of Corrective Measures

1.0 Introduction

1.1 Purpose and Scope

The objectives of this memorandum are to present a summary assessment of the corrective measures associated with the closure of the Dallman Ash Pond.

Four key components of the Coal Combustion Residual (CCR) surface impoundment were reviewed, evaluated and analyzed.

- Structural Stability: review and analyze the ability of the coal ash and the underlying soil to support the surcharge loads from the final cover system and any future loads.
- Long-Term CCR Stability: determine if the CCR material at the site will remain stable long term.
- Slope Stability: analyze the slopes' stability, making sure they can support the weight of any new soil or foundation layers added for the final cover system.
- Settlement Evaluation: assess how the CCR and underlying soils might settle or compress over time once the final cover is placed.

1.2 Site Description

The CWLP Dallman Ash Ponds (DAP) is in Section 12 R.5W, T.15N of the Third Principal Meridian in Springfield, Sangamon County, Illinois. The Site is in the Springfield Plain of the Central Lowland Province Physiographic Division of Illinois (Leighton et al., 1948).

Dallman Ash Pond has a footprint of approximately 36 acres and contains approximately 1,217,000 cu. yds. of CCR. The floor of DAP slopes from the south to the northeast corner (from elevation 525 ft. to about 523 ft.

1.3 Project Description

The selected closure procedure for the DAP entails the implementation of a geotube confinement system as the primary method to consolidate Lakeside Ash Pond (LAP) into DAP. This system will utilize geotubes as containment vessels. These geotubes will be filled with a mixture of fly ash sourced from the LAP and water treatment plant sludge. The filling procedure will target a nominal height of 6 to 8 feet per tube. Successive layers will be vertically stacked with a lateral offset of 50 feet between each level. The final configuration will achieve a total vertical elevation of approximately 45 feet above the existing in-situ ash substrate within DAP.

2.0 Field exploration

Data from geotechnical explorations performed by Hanson and others at the DAP were reviewed and used to determine the subsurface condition at the site. The identification and general

information regarding the borings are presented in Table 1. All borings were advanced 1.0 ft to 1.5 ft past the ash layer and into the natural cohesive material. Split-spoon sampling was performed within both the natural cohesive and ash strata encountered. Supplemental data from a geotechnical exploration performed by Andrews Engineering, Inc. (AEI) at the same site was also reviewed to support the findings.

Table 1: Summary of Boring Data

Boring ID	Grade (ft)	Drilled Depth (ft)	Northing (ft)	Easting (ft)	Date Drilled
DB-01	563.801	39.0	1129829.03	2455470.48	8/13/2024
DB-02	556.861	35.5	1130338.40	2456184.51	8/13/2024
DB-03	554.734	31.0	1129517.42	2455963.38	8/14/2024
DB-04	553.706	31.0	1129163.19	2455379.61	8/19/2024
DB-05	553.237	28.5	1129181.97	2456241.37	8/15/2024
B-10CCR*	555.350	24.5	1129518.55	2455869.56	10/20/2023
B-11U*	552.270	29.5	1128891.26	2456234.99	10/18/2023
B-5*	553.620	39.5	1129302.48	2455281.11	10/16/2023
B-5CCR*	552.590	19.5	1129333.75	2455341.56	10/3/2023
B-5L*	534.000	19.5	1129295.29	2455215.62	10/3/2023
B-6*	553.930	40.0	1130094.72	2455316.59	10/5/2023
B-6CCR*	553.320	24.5	1130067.17	2455388.17	10/20/2023
B-6L*	531.190	23.5	1130126.84	2455243.51	10/2/2023
B-7*	552.560	39.5	1130413.91	2455917.71	10/4/2023
B-7CCR*	552.200	19.5	1130310.33	2455947.06	10/19/2023
B-7L*	533.200	20.0	1130467.06	2455885.37	10/2/2023
B-8L*	530.620	24.5	1130109.51	2456566.64	10/4/2023
B-8U*	551.700	33.5	1130083.21	2456391.16	10/19/2023
B-9CCR*	553.970	19.5	1129680.19	2456242.16	10/18/2023
B-9L*	524.100	19.5	1129778.29	2456635.89	10/4/2023
B-9U*	552.150	40.0	1129690.26	2456402.29	10/19/2023

*AEI Report

The data from the AEI exploration is contained in a report titled Geotechnical Investigation Report for Unstable Areas Demonstration, Safety Factor and Liquefaction Analysis for Coal Combustion Residual Surface Impoundments, dated June 2024.

Figures 1 and 2 in Appendix A show the project location and soil boring locations, respectively. A log of the borehole performed by Hanson and is provided in Appendix B.

3.0 Laboratory Testing

The laboratory testing of samples consisted of moisture contents (ASTM D2216), Specific Gravity of Soil Solid by Displacement Method (ASTM D854), Consolidated-Undrained Triaxial Compression Test (ASTM D4767), Hydraulic Conductivity of Saturated Porous Materials (ASTM D5084), and Density (Unit Weight) of Soil Specimen (ASTM D7263), Particle-Size Analyses (ASTM D7928), and Standard Proctor (ASTM D698). Note Hanson laboratory testing focus primarily on the CCR Ash material encountered.

Results of the Laboratory tests are provided in Appendix C.

4.0 Subsurface Soil Profile, and Design Parameters

4.1 Subsurface Soil Profile

Based on field observations and laboratory classification tests, the subsurface profile around the Dallman Ash Pond can be characterizes as generally consisting of three distinct soil layers.

Stratum I_A CCR Ash wet/dry which covers the pond area varies in thickness from 27.5 ft to 38.0 ft.

Stratum I_B Fill – silty clay with clayey silt and silt pocket (stiff to hard consistency)

Stratum II Clay (CL) and some silt (natural material) underlie the CCR at the site and was present to the boring termination depth.

The subsurface profile within the Dallman Ash Pond is presented on Figure 3. The leachate levels below the ash pond surface ranged from 10 ft at boring DB-02 to 18 ft at boring DB-01.

4.2 Design Parameters

Generalized soil parameters are provided in the subsequent sections.

It should be noted, geotechnical data from previous explorations (field and laboratory) were reviewed and used as the basis for the design parameters. Soil parameters used in the analysis are based on, correlation and typical values (from available literature) selected based on subsurface material description and characteristics.

Bedrock was not encountered during the subsurface exploration. Based on general geology within this region of Illinois, bedrock Unit (BU) consists primarily of Pennsylvanian age gray shales with some coal seams. Bedrock elevation ranges from 490 ft to 560.

5.0 Engineering Analysis

5.1 Slope Stability

Two cross sections of the pond (West to East and North to South) were analyzed.

The Slope stability analysis was performed using GeoStudio Slope/W 2025.1 version of (GEO-SLOPE Ltd). The analyses were carried out using drained and undrained soil parameters provided in the table below. Spencer's Method of limit equilibrium analysis was the method selected for the result output. The program's optimized circular search routines were utilized to determine the critical failure surface for the section analyzed.

Table 2: Slope Stability Design Parameters

Material Type	Elevation* (ft)	Unit Weight (pcf)	S- Case (Drained)		Q-Case (Undrained)	
			C (psf)	Phi (deg)	C (psf)	Phi (deg)
Cover	595	120	200	27	1000	0
CCR from Lakeside	595	115	0	40	200	30
CCR from Dallman	550	120	140	33	0	28
Fill Silty Clay**	550	115	270	28	1800	0
Native Soil	528	115	0	28	750	0
Shale	500	130	3500	10	3500	10

* Top elevation **AEI report

General notes and assumption:

- The geotubes were modeled in the analysis as geosynthetic, with tensile capacity equal to 6000 lb/ft and reduction factor of 2.5.
- The tubes are estimated to be filled to a height of 7.5 feet.

Summary results of the slope stability analysis are provided in Table 3. Detail graphical presentation is presented in Appendix D.

Table 3: Slope Stability Result

Case	Undrained	Drained
	Permissible ≥ 1.3	Permissible ≥ 1.5
North to South	1.5	2.6
East to West	1.6	2.7

All factors of safety values meet or exceed the factor of safety requirements by the Illinois Administrative Code, Part 845. The requirements are as follows:

- Static Factor of safety under the end of construction loading condition = 1.30
- Static Factor of safety under long term loading condition = 1.50

5.2 Settlement Analysis

The settlement analysis was completed using RocScience Settle3 software. In the analysis, the subsurface material (clay layers) is assumed to be normal consolidated. Soil parameters used in the settlement analysis are based on correlation and typical values (from available literature) selected based on subsurface material description and characteristics. Soil parameters used in the settlement analysis are summarized in the table below.

Table 4: Settlement Analysis Soil Parameter

Material Type	Y (psf)	Es (ksf)	Cc	Cr	OCR	E_0	Cv(in^2/s)
CCR from Lakeside	115	144	-	-	-	-	-
CCR from Dallman	120	-	-	-	-	-	-
Native Soil	115	118	0.25	0.03	1	1	$8.66x10^{-04}$
Cc – compression index; Cr – coefficient of recompression; Es – Elastic Modulus OCR – Overconsolidation ratio; Eo – initial void ratio; Cv – coefficient of consolidation							

Results of the settlement analysis indicate maximum total settlement of 34 inches; 19 inches immediate and 19 inches long-term consolidation settlement. The geotubes should be designed to accommodate a 10 percent differential settlement. If differential settlement of 10 percent is not attainable, options such as installing heavy duty geogrid between lower layers of geotubes may be explored. The use of geogrid at the interface of the bottom 3 to 4 rows of geotubes will help to reduce differential settlement. The geotube connections should be designed to resist sagging which could lead to tear.

5.3 Bearing Capacity

The ash pond closure cover system is expected to have a maximum height of 45 ft, which will impart a surcharge load of more than 5,175 psf on the in-situ coal ash and the underlying soil (assuming fill unit weight of 115 pcf).

The in-situ bearing soil (CCR material) with an effective internal angle of friction of 28 degrees will provide adequate nominal bearing capacity to support the surcharge loading from the final covering system.

Localized punching shear failure is not a concern given the fairly uniform subsurface condition throughout the site.

5.4 Seismicity

The project site is located in a region of low seismic activity, which is caused primarily by earthquakes in the New Madrid Fault Zone, 225 miles south of the site and Wabash Valley seismic zone, 200 miles southeast of the site. Seismic design parameters for the project site using the USGS Unified Hazard Tool are listed in the table below.

Table 5: Seismic Design Parameters

Peak Ground Acceleration (PGA)	0.097
0.20 Second Spectral Acceleration (S_S)	0.199
1.00 Second Spectral Acceleration (S_1)	0.091

The CCR material found at the site are susceptible to liquefaction. However, the possibility of liquefaction is minimal given the low PGA, the confining pressure of the impoundment fill and the dewatering of the CCR. In addition, a liquefaction analysis based on CPT indicates liquefaction is not to be a concern.

6.0 Conclusion

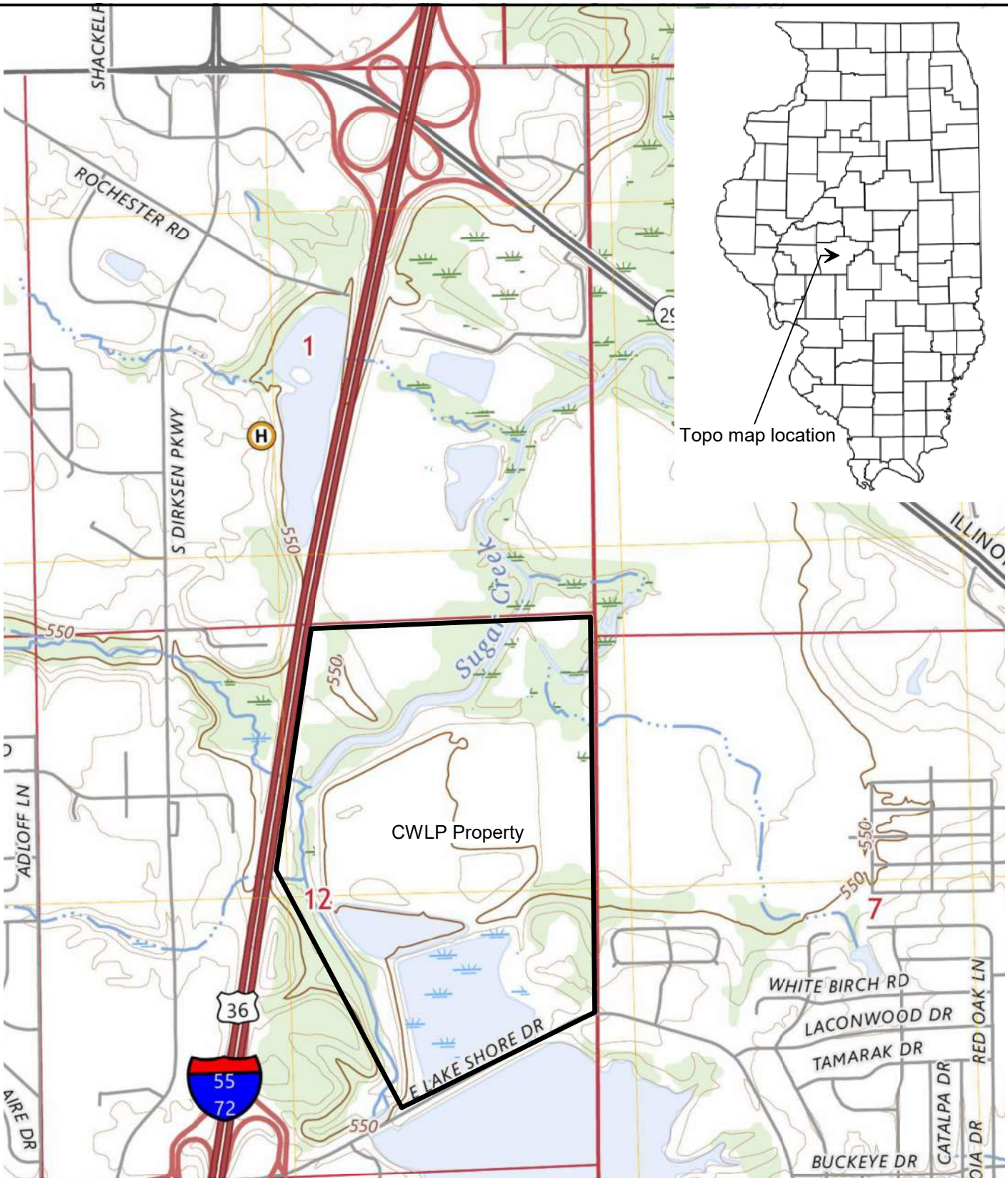
Based on computational analysis and review of available geotechnical data the following conclusion can be drawn.

- Structural Stability: Bearing capacity analysis was performed. The bearing capacity of the in-situ material exceeds the expected surcharge load. In addition, local and punching shear failure were checked and was determined not to be a concern. Bearing capacity computations are provided in Section 1 of Appendix E of this report.
- Long-Term CCR Stability: Review of available geotechnical data and assessment of the long-term stability of CCR was performed. Long-term stability included global slope stability, localized bearing capacity and settlement using drained soil parameters. In view of the project geographic location and construction method, liquefaction due to seismic loading is not a concern at the project site. Computations are provided in Appendix E of this report.
- Slope Stability: slope stability analysis was performed on critical section of the pond. Resulting factor of safety exceeds requirement set forth in Illinois Administrative Code, Part 845. Computations are provided in Section 3 of Appendix E of this report.
- Settlement Evaluation: settlement analysis was performed to assess how the CCR, and underlying soils might settle or compress over time once the final cover is placed. Computations are provided in Section 4 of Appendix E of this report.

Calculation package for the analysis performed for the project including geotechnical data used to develop soil parameters are included in appendix D of this report.

Appendix A

Figures



SCALE: 1 inch equals 400 feet

0 400 800 1200

CONTOUR INTERVAL = 10 feet

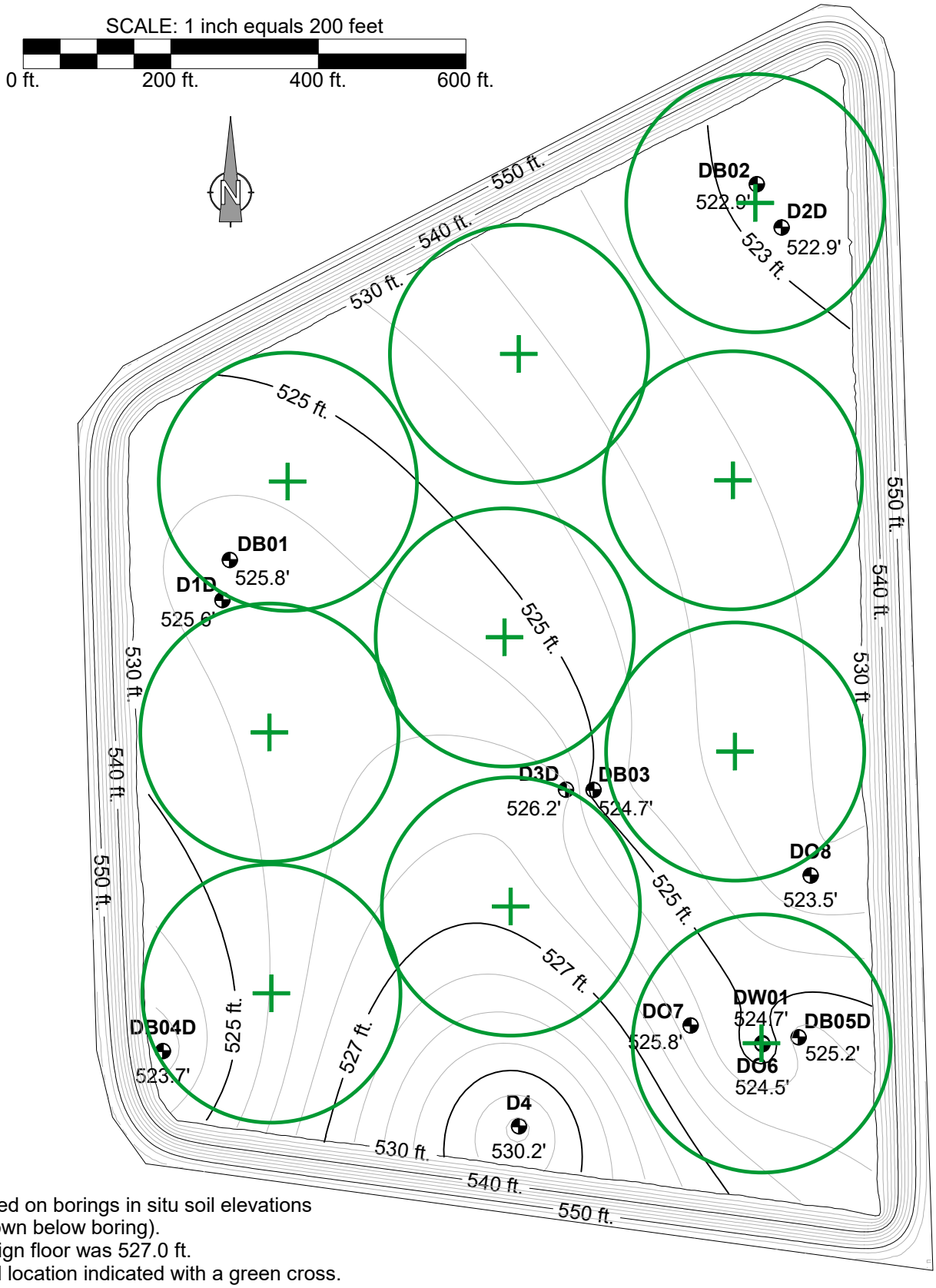
© Copyright Hanson Professional Services Inc. 2025

HANSON

Site Location Map

Dallman and Lakeside Ash Ponds
City Water, Light and Power
Springfield, Sangamon Co., Illinois

HANSON NO. 25E0006.00 FIGURE 1



Based on borings in situ soil elevations
(shown below boring).
Design floor was 527.0 ft.
Well location indicated with a green cross.
Green circles are the well radius of influence.

Copyright Hanson Professional Services Inc. 2025

Contour Interval
Floor = 0.5 ft.
Sidewall = 2 ft.

HANSON

Dallman Dewatering Well Location Map

Dallman and Lakeside Ash Ponds
City Water, Light and Power
Springfield, Sangamon Co., Illinois

HANSON NO. 25E0006.00 FIGURE 2

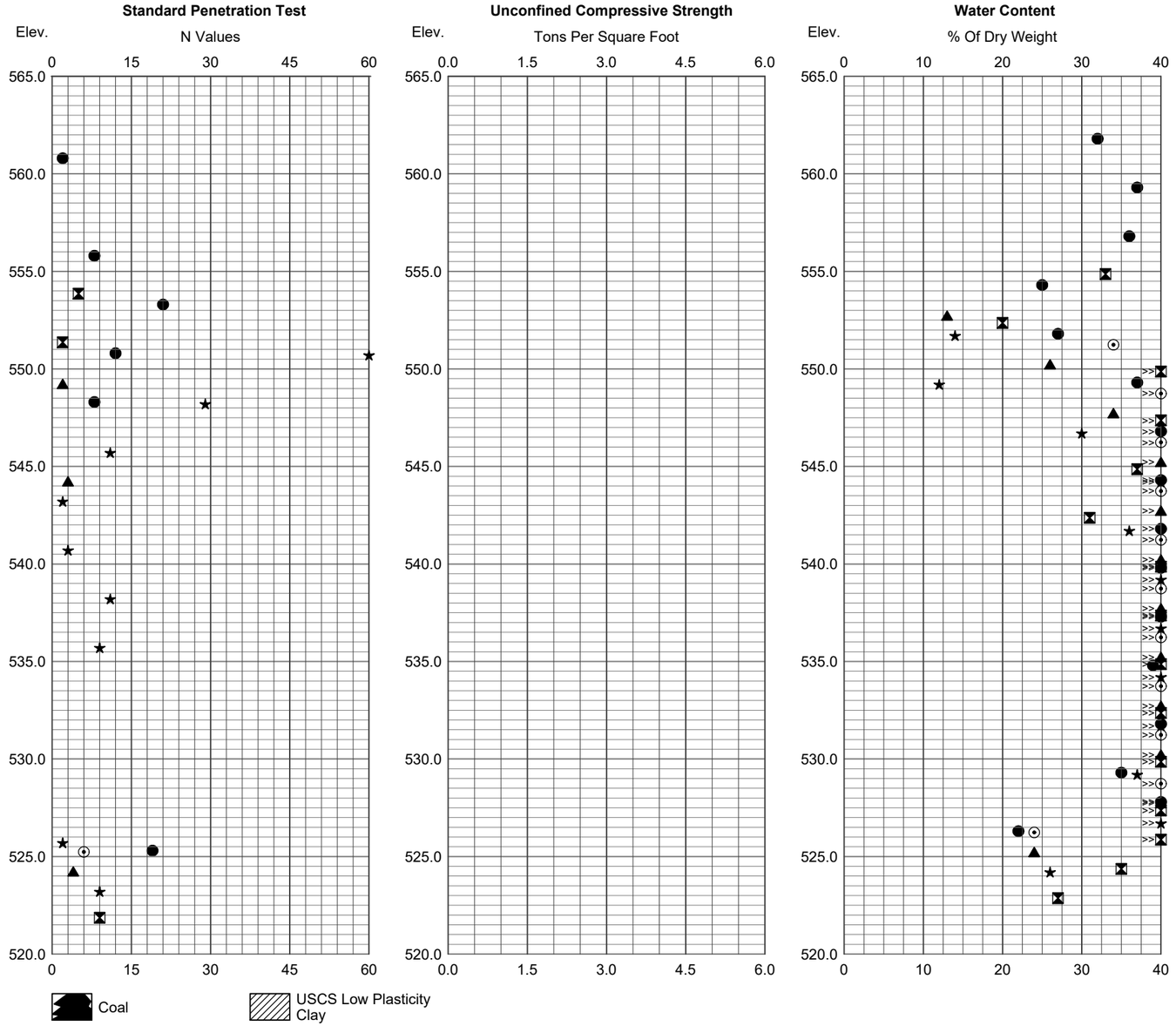
I:\25jobs\25E0006_00Admin\14-Reports\CPPCP/DallmanDWellMap_20250711.srf



Groundwater level while drilling

Groundwater level at completion of boring

Groundwater level hrs. after completion of boring.



1. THE SUBSURFACE CONDITIONS SHOWN ON THIS DRAWING EXIST ONLY AT THE SPECIFIC LOCATION OF EACH SOIL TEST BORING AT THE TIME OF THE INVESTIGATION. CROSS SECTION IS NOT TO SCALE HORIZONTALLY.
2. THE WATER LEVELS SHOWN ON THIS DRAWING ARE BASED UPON WATER LEVEL READINGS IN THE DRILL HOLES AT THE TIMES AND UNDER CONDITIONS STATED ON THE FIELD BORING LOGS. FLUCTUATIONS IN THE LEVEL OF THE GROUND WATER MAY OCCUR DUE TO VARIATIONS IN RAINFALL, INFILTRATION, AND OTHER FACTORS.
3. THE STRATUM LINES ON THIS DRAWING ARE BASED UPON INTERPOLATION BETWEEN BORINGS AND MAY NOT REPRESENT ACTUAL SUBSURFACE CONDITIONS AT INTERMEDIATE LOCATIONS.
4. SEE TEXT OF REPORT FOR STRATA DESCRIPTIONS.

FOUNDATION SUMMARY

HANSON™

Dallman Ash Pond Closure
CWLP
City Water, Light and Power

JOB NO. 25E0006 **FIGURE 3**

FOUNDATION_SUMMARY_2018_24E0022 - CWLP BORING LOGS.GPJ 2010 HANSON.GDT 9/14/25

Appendix B

Hanson Boring Logs

Project No. 24E0022

LOG OF BOREHOLE NO. DB-01

CLIENT: **CWLP**

ENGINEER/GEOLOGIST: **Hanson Professional Services Inc.**

SITE: **CWLP**

PROJECT: **CWLP Ash Pond Dewatering**

N 1129829.025 E 2455470.48

Surface Elevation: **563.8 ft**

DEPTH (ft)	GRAPHIC LOG	SAMPLES: BLOWS/6in N - VALUE RQD	SAMPLES: TYPE NUMBER	SAMPLES: RECOVERED (in) LTH SMPLD (in)	TESTS: MOISTURE, %	TESTS: DRY DENSITY (lb/ft³)	TESTS: Qu (tsf) FAILURE TYPE	ADDITIONAL DATA REMARKS
Ash, (Silt like), Very Soft, Dark Gray (10Y 3/1), Moist								
2		1-1-1 N=2	SPT-1	12/18 67%	32			
4		1-WH-WH	SPT-2	14/18 78%	37			
6								
8		2-4-4 N=8	SPT-3	18/18 100%	36			
10.0 553.8		8-11-10 N=21	SPT-4	12/18 67%	25			
Ash, (Silt like), Medium Stiff, Dark Gray (10Y 3/1), Moist, 1 inch wet seam at 12.4								
12		3-6-6 N=12	SPT-5	12/18 67%	27			
14								
15.0 548.8		4-4-4 N=8	SPT-6	12/18 67%	37			
Ash, Med Grained, Loose, Black (10G 2.5/1), Moist								
16								
17.0 546.8								
Ash, (Silt like), Very Soft, Dark Gray (10Y 3/1), Wet ▼		WR-WR-WR	SPT-7	18/18 100%	45			
18								
20		WR-WR-1	SPT-8	18/18	52			

Continued Next Page

WATER LEVEL OBSERVATIONS

WL	▼ 18.0 -During Drilling

HANSON

STARTED	8/13/2024	FINISHED	8/13/2024
DRILL CO.	Skinner	DRILL RIG	CME-550 ATV Drill
DRILLER	T. Skinner	ASS'T DRILLER	
LOGGED BY		APPROVED	

Project No. 24E0022

LOG OF BOREHOLE NO. DB-01

CLIENT: **CWLP**

ENGINEER/GEOLOGIST: **Hanson Professional Services Inc.**

SITE: **CWLP**

PROJECT: **CWLP Ash Pond Dewatering**

N 1129829.025 E 2455470.48

(continued)

		GRAPHIC LOG	DEPTH (ft)	SAMPLES: BLOWS/6in N - VALUE RQD	SAMPLES: TYPE NUMBER	SAMPLES: RECOVERED (in) LTH SMPLD (in)	TESTS: MOISTURE, %	TESTS: DRY DENSITY (lb/ft³)	TESTS: Qu (tsf) FAILURE TYPE	ADDITIONAL DATA REMARKS
	Ash, (Silt like), Very Soft, Dark Gray (10Y 3/1), Wet *(continued)*					100%				
			22	WR-WR-WH	SPT-9	14/18 78%	49			
			24	WH-WH-WH	SPT-10	16/18 89%	85			
			26	WH-WH-WH	SPT-11	18/18 100%	56			
			28	WH-WH-WH	SPT-12	18/18 100%	39			
			30	WR-WR-WH	SPT-13	18/18 100%	40			
			32	WH-WH-WH	SPT-14	18/18 100%	35			
			34	WR-WR-WH	SPT-15	16/18 89%	41			
38.0		525.8	36	7-8-11 N=19	SPT-16	14/18 78%	22			
	Clay, Silty, Med Stiff, Moist, Dark Greenish Gray (5G 4/1)		38							
39.0		524.8								
	E.O.B.									

WATER LEVEL OBSERVATIONS	
WL	▼ 18.0 -During Drilling

HANSON

STARTED	8/13/2024	FINISHED	8/13/2024
DRILL CO.	Skinner	DRILL RIG	CME-550 ATV Drill
DRILLER	T. Skinner	ASS'T DRILLER	
LOGGED BY		APPROVED	

Project No. 24E0022

LOG OF BOREHOLE NO. DB-02

CLIENT: **CWLP**

ENGINEER/GEOLOGIST: **Hanson Professional Services Inc.**

SITE: **CWLP**

PROJECT: **CWLP Ash Pond Dewatering**

N 1130338.397 E 2456184.506

Surface Elevation: **556.9 ft**

DEPTH (ft)	GRAPHIC LOG	SAMPLES: BLOWS/6in N - VALUE RQD	SAMPLES: TYPE NUMBER	SAMPLES: RECOVERED (in) LTH SMPLD (in)	TESTS: MOISTURE, %	TESTS: DRY DENSITY (lb/ft³)	TESTS: Qu (tsf) FAILURE TYPE	ADDITIONAL DATA REMARKS
Ash, (Silt like), Soft-Very Soft, Greenish Black (5G 2.5/1), Moist								
2		2-3-2 N=5	SPT-1	4/18 22%	33			
4		1-1-1 N=2	SPT-2	6/18 33%	20			
6								
7.0 — 549.9								
Ash, (Silt like), Very Soft, Dark Gray (10Y 3/1), Moist		WH-WH-WH	SPT-3	14/18 78%	53			
8								
10.0 — ▼ 546.9		WH-WH-WH	SPT-4	18/18 100%	53			
Ash, (Silt like), Very Soft, Dark Gray (10Y 3/1), Wet								
10								
12		WH-WH-WH	SPT-5	18/18 100%	37			
14								
		WR-WR-WH	SPT-6	18/18 100%	31			
16								
		WR-WR-WH	SPT-7	18/18 100%	52			
18								
19.5 — 537.4								
Ash, (Silt like), Very Soft, Bluish Black (5B 2.5/1), Wet		WR-WR-WH	SPT-8	18/18	48			
20								

Continued Next Page

WATER LEVEL OBSERVATIONS	
WL	▼ 10.0 -During Drilling

HANSON

STARTED	8/13/2024	FINISHED	8/13/2024
DRILL CO.	Skinner	DRILL RIG	CME-550 ATV Drill
DRILLER	T. Skinner	ASS'T DRILLER	
LOGGED BY		APPROVED	

Project No. 24E0022

LOG OF BOREHOLE NO. DB-02

CLIENT **CWLP**

ENGINEER/GEOLOGIST **Hanson Professional Services Inc.**

SITE **CWLP**

PROJECT **CWLP Ash Pond Dewatering**

N 1130338.397 E 2456184.506

(continued)

	GRAPHIC LOG	DEPTH (ft)	SAMPLES: BLOWS/6in N - VALUE RQD	SAMPLES: TYPE NUMBER	SAMPLES: RECOVERED (in) LTH SMPLD (in)	TESTS: MOISTURE, %	TESTS: DRY DENSITY (lb/ft³)	TESTS: Qu (tsf) FAILURE TYPE	ADDITIONAL DATA REMARKS
Ash, (Silt like), Very Soft, Bluish Black (5B 2.5/1), Wet *(continued)*					100%				
		22	WH-WH-WS	SPT-9	18/18 100%	49			
		24	WH-WH-WS	SPT-10	18/18 100%	50			
		26	WR-WR-WS	SPT-11	18/18 100%	53			
		28	WR-WR-WS	SPT-12	18/18 100%	60			
		30	WR-WR-WS	SPT-13	14/18 78%	46			
		32	WR-WR-2	SPT-14	18/18 100%	35			
34.0 522.9									
Clay, Silty, Soft, Light Greenish Gray (5G 7/1) w/ brown mottling, High Plasticity, Moist		34	3-4-5 N=9	SPT-15	18/18 100%	27			
35.5 521.4									
E.O.B.									

WATER LEVEL OBSERVATIONS	
WL	▼ 10.0 -During Drilling

HANSON

STARTED	8/13/2024	FINISHED	8/13/2024
DRILL CO.	Skinner	DRILL RIG	CME-550 ATV Drill
DRILLER	T. Skinner	ASS'T DRILLER	
LOGGED BY		APPROVED	

Project No. 24E0022	**LOG OF BOREHOLE NO. DB-03**	Sheet 1 of 2

CLIENT	ENGINEER/GEOLOGIST
CWLP	**Hanson Professional Services Inc.**
SITE	PROJECT
CWLP	**CWLP Ash Pond Dewatering**

N 1129517.423 E 2455963.383

Surface Elevation: **554.7 ft**

DEPTH (ft)	GRAPHIC LOG	SAMPLES: BLOWS/6in N - VALUE RQD	SAMPLES: TYPE NUMBER	SAMPLES: RECOVERED (in) LTH SMPLD (in)	TESTS: MOISTURE, %	TESTS: DRY DENSITY (lb/ft³)	TESTS: Qu (tsf) FAILURE TYPE	ADDITIONAL DATA REMARKS
Ash (Sand Like), Med Grained, Poorly Graded, Light Greenish Gray (5G 7/1), Moist								
2		1-WH-WH	SPT-1	4/18 22%	13			
4		1-1-1 N=2	SPT-2	18/18 100%	26			
6								
7.0 / 547.7								
Ash (Silt Like), Very Soft, Greenish Black (10GY 2.5/1), Wet, Trace Coarse Grains								
8		WH-WH-1	SPT-3	14/18 78%	34			
10		WH-1-2 N=3	SPT-4	16/18 89%	48			
12		WH-WH-WH	SPT-5	18/18 100%	52			
14								
16		WH-WH-WH	SPT-6	18/18 100%	51			
18		WH-WH-WH	SPT-7	18/18 100%	50			
19.5 / 535.2								
20		WH-WH-WH	SPT-8	18/18	47			

Continued Next Page

WATER LEVEL OBSERVATIONS					
		STARTED	8/14/2024	FINISHED	8/14/2024
		DRILL CO.	Skinner	DRILL RIG	CME-550 ATV Drill
		DRILLER	T. Skinner	ASS'T DRILLER	
		LOGGED BY		APPROVED	

HANSON

Project No. 24E0022

LOG OF BOREHOLE NO. DB-03

Sheet 2 of 2

CLIENT: **CWLP**

ENGINEER/GEOLOGIST: **Hanson Professional Services Inc.**

SITE: **CWLP**

PROJECT: **CWLP Ash Pond Dewatering**

N 1129517.423 E 2455963.383

(continued)

	GRAPHIC LOG	DEPTH (ft)	SAMPLES: BLOWS/6in N - VALUE RQD	SAMPLES: TYPE NUMBER	SAMPLES: RECOVERED (in) LTH SMPLD (in)	TESTS: MOISTURE, %	TESTS: DRY DENSITY (lb/ft³)	TESTS: Qu (tsf) FAILURE TYPE	ADDITIONAL DATA REMARKS
Ash (Sand Like), Fine Grained w/ trace coarse, Very Loose, Light Greenish Gray (5G 7/1), Wet *(continued)*					100%				
22.0 — 532.7									
Ash (Silt Like), Very Soft, Greenish Black (10GY 2.5/1), No Plasticity, Wet		22	WR-WR-WS	SPT-9	18/18 100%	56			
		24	WR-WR-WS	SPT-10	18/18 100%	49			
		26	WR-WR-WS	SPT-11	18/18 100%	41			
		28							
30.0 — 524.7									
Clay, Silty, Soft, High Plasticity, Moist, Light Reddish Brown (2.5YR 6/4) w/ Gray Mottling		30	WH-2-2 N=4	SPT-12	18/18 100%	24			
31.0 — 523.7									
E.O.B.									

WATER LEVEL OBSERVATIONS

HANSON

STARTED	8/14/2024	FINISHED	8/14/2024
DRILL CO.	Skinner	DRILL RIG	CME-550 ATV Drill
DRILLER	T. Skinner	ASS'T DRILLER	
LOGGED BY		APPROVED	

Project No. 24E0022

LOG OF BOREHOLE NO. DB-04

CLIENT: **CWLP**

ENGINEER/GEOLOGIST: **Hanson Professional Services Inc.**

SITE: **CWLP**

PROJECT: **CWLP Ash Pond Dewatering**

N 1129163.191 E 2455379.61

Surface Elevation: **553.7 ft**

DEPTH (ft)	GRAPHIC LOG	SAMPLES: BLOWS/6in N - VALUE RQD	SAMPLES: TYPE NUMBER	SAMPLES: RECOVERED (in) LTH SMPLD (in)	TESTS: MOISTURE, %	TESTS: DRY DENSITY (lb/ft³)	TESTS: Qu (tsf) FAILURE TYPE	ADDITIONAL DATA REMARKS
Ash (Sand Like), Medium Grained, Poorly Graded, Greenish Black (10GY 2.5/1), Medium Dense, Moist								
2		14-24-36 N=60	SPT-1	12/18 67%	14			
4		10-15-14 N=29	SPT-2	12/18 67%	12			
6								
7.5 — 546.2		4-7-4 N=11	SPT-3	14/18 78%	30			
Ash (Sand Like), Medium Grained, Poorly Graded, Greenish Black (10GY 2.5/1), Loose, Wet								
8								
10.0 — 543.7		1-1-1 N=2	SPT-4	18/18 100%	59			
10								
Ash (Silt Like) w/ trace sand, Very Soft, Greenish Black (10GY 2.5/1), Wet								
12.0 — 541.7		1-1-2 N=3	SPT-5	4/18 22%	36			
12								
Ash (Sand Like), Medium Grained, Poorly Graded, Greenish Black (10GY 2.5/1), Loose, Wet								
14								
15.5 — 538.2		4-5-6 N=11	SPT-6	10/18 56%	50			
16								
Ash (Silt Like) w/ trace sand, Very Soft, Light Greenish Gray (5G 7/1), Wet								
18		3-4-5 N=9	SPT-7	18/18 100%	49			
19.5 — 534.2								
20		WH-WH-WH	SPT-8	14/18	48			

Continued Next Page

WATER LEVEL OBSERVATIONS

HANSON

STARTED	8/19/2024	FINISHED	8/19/2024
DRILL CO.	Skinner	DRILL RIG	CME-550 ATV Drill
DRILLER	T. Skinner	ASS'T DRILLER	
LOGGED BY		APPROVED	

Project No. 24E0022

LOG OF BOREHOLE NO. DB-04

CLIENT: **CWLP**

ENGINEER/GEOLOGIST: **Hanson Professional Services Inc.**

SITE: **CWLP**

PROJECT: **CWLP Ash Pond Dewatering**

N 1129163.191 E 2455379.61

(continued)

			GRAPHIC LOG	DEPTH (ft)	SAMPLES: BLOWS/6in N - VALUE RQD	SAMPLES: TYPE NUMBER	SAMPLES: RECOVERED (in) LTH SMPLD (in)	TESTS: MOISTURE, %	TESTS: DRY DENSITY (lb/ft³)	TESTS: Qu (tsf) FAILURE TYPE	ADDITIONAL DATA REMARKS
	Ash (Silt Like), Very Soft, Greenish Black (10GY 2.5/1), Wet Sandy @ 27 *(continued)*						78%				
				22	WH-WH-WH	SPT-9	18/18 100%	41			
				24	WH-WH-WH	SPT-10	18/18 100%	37			
				26							
				28	1-1-1 N=2	SPT-11	18/18 100%	44			
30.0		523.7									
	Clay, Silty, Medium Stiff, Moist, Light Reddish Brown (2.5YR 6/4) w/ Gray Mottling			30	2-4-5 N=9	SPT-12	18/18 100%	26			
31.0		522.7									
	E.O.B.										

WATER LEVEL OBSERVATIONS

HANSON

STARTED	8/19/2024	FINISHED	8/19/2024
DRILL CO.	Skinner	DRILL RIG	CME-550 ATV Drill
DRILLER	T. Skinner	ASS'T DRILLER	
LOGGED BY		APPROVED	

Project No. 24E0022

LOG OF BOREHOLE NO. DB-05

CLIENT: **CWLP**

ENGINEER/GEOLOGIST: **Hanson Professional Services Inc.**

SITE: **CWLP**

PROJECT: **CWLP Ash Pond Dewatering**

N 1129181.966 E 2456241.368

Surface Elevation: **553.2 ft**

DEPTH (ft)	GRAPHIC LOG	SAMPLES: BLOWS/6in N - VALUE RQD	SAMPLES: TYPE NUMBER	SAMPLES: RECOVERED (in) LTH SMPLD (in)	TESTS: MOISTURE, %	TESTS: DRY DENSITY (lb/ft³)	TESTS: Qu (tsf) FAILURE TYPE	ADDITIONAL DATA REMARKS
								ASH (Silt Like) w/ trace fine sand, Very Soft, Greenish Black (10GY 2.5/1), Moist
2		WH-WH-WH	SPT-1	18/18 100%	34			
4								
4.5								548.7
								ASH (Silt Like) w/ trace sand, Very Soft, Greenish Black (10GY 2.5/1), Wet
		WH-WH-WH	SPT-2	18/18 100%	41			
6								
		WH-WH-WH	SPT-3	18/18 100%	44			
8								
		WH-WH-WH	SPT-4	18/18 100%	47			
10								
12.0								541.2
								ASH (Silt Like), Very Soft, Dark Greenish Gray (5GY 4/1), Wet
12		WH-WH-WH	SPT-5	18/18 100%	53			
14								
		WH-WH-WH	SPT-6	18/18 100%	52			
16								
		WH-WH-WH	SPT-7	18/18 100%	47			
18								
19.5								533.7
20		WH-WH-WH	SPT-8	18/18	41			

Continued Next Page

WATER LEVEL OBSERVATIONS

HANSON

STARTED	8/15/2024	FINISHED	8/15/2024
DRILL CO.	Skinner	DRILL RIG	CME-550 ATV Drill
DRILLER	T. Skinner	ASS'T DRILLER	
LOGGED BY		APPROVED	

Project No. 24E0022

LOG OF BOREHOLE NO. DB-05

Sheet 2 of 2

CLIENT: **CWLP**

ENGINEER/GEOLOGIST: **Hanson Professional Services Inc.**

SITE: **CWLP**

PROJECT: **CWLP Ash Pond Dewatering**

N 1129181.966 E 2456241.368

(continued)	GRAPHIC LOG	DEPTH (ft)	SAMPLES: BLOWS/6in N - VALUE RQD	SAMPLES: TYPE NUMBER	SAMPLES: RECOVERED (in) LTH SMPLD (in)	TESTS: MOISTURE, %	TESTS: DRY DENSITY (lb/ft^3)	TESTS: Qu (tsf) FAILURE TYPE	ADDITIONAL DATA REMARKS
ASH (Silt Like), Very Soft, Greenish Black (10GY 2.5/1), Wet *(continued)*					100%				
		22	WH-WH-WH	SPT-9	18/18 100%	43			
		24	WH-WH-WH	SPT-10	18/18 100%	55			
		26							
27.5 525.7 Clay, Silty, Medium Stiff, Moist, Light Reddish Brown (2.5YR 6/4) w/ Gray Mottling, High Plasticity			WH-2-4 N=6	SPT-11	18/18 100%	24			
28.5 524.7 E.O.B.		28							

WATER LEVEL OBSERVATIONS

HANSON

STARTED	8/15/2024	FINISHED	8/15/2024
DRILL CO.	Skinner	DRILL RIG	CME-550 ATV Drill
DRILLER	T. Skinner	ASS'T DRILLER	
LOGGED BY		APPROVED	

Appendix C

Hanson Laboratory Results

Via email: nwendling@metgeotech.com

© 2024 Geotechnology, LLC, dba UES
November 12, 2024

Mr. Nick Wendling, P.E.
Midwest Engineering and Testing, Inc.
501 Mercury Drive
Champaign, Illinois 61822

Re: Summary of Laboratory Testing Services
CWLP Ash Pond Samples
Springfield, Illinois – C43128
UES Job No. J040516.06.6404

Dear Mr. Wendling:

Included in this report are test results of five bulk samples of pond ash received in our laboratory on September 24, 2024. The samples were tested in general accordance with the test methods listed below.

Test to Determine	Method of Test
Specific Gravity of Soil Solids by Displacement Water Method	ASTM D 854
Water (Moisture) Content of Soils	ASTM D2216
Identification of Soils (Visual-Manual Procedures)	ASTM D2488
Consolidated-Undrained Triaxial Compression Test	ASTM D4767
Hydraulic Conductivity of Saturated Porous Materials	ASTM D5084
Density (Unit Weight) of Soil Specimens	ASTM D7263

This report has been prepared for the exclusive use of Midwest Engineering and Testing, Inc. Our scope of services was limited to performing specific tests on provided samples and did not include engineering or interpretation of the test results.

* * * *

We trust this is the information you require. Please contact the undersigned if you have any questions regarding this report.

Respectfully submitted,

UES



Janet M. May
Illinois Laboratory Manager

JMM/LPH:jmm

Attachments: Appendix A - Test Result Summary (3)
Appendix B – Triax CU Results (5)
Appendix C - Hydraulic Conductivity Data (38)
Appendix D - Test Assignments (44)

© 2024 Geotechnology, LLC, dba UES

APPENDIX A

SUMMARY OF LABORATORY TEST RESULTS

MET Job C43128

		ASTM D854
Boring Number	Depth, feet	Specific Gravity
DB-01	7.0-10.0	2.53
DB-04	1.0-5.0	2.57
DB-05	2.0-5.0	2.46
LB-01	1.0-5.0	2.54
LB-03	1.0-5.0	2.57

		ASTM D698			ASTM D2216	ASTM D7263	ASTM D5084	
Boring Number	Depth, feet	Optimum Moisture Content, %	Maximum Dry Unit Weight, pcf	Percent Compact	Moisture Content, %	Dry Unit Weight, pcf	Hydraulic Conductivity, cm/sec	Range of Hydraulic Gradient
DB-01	7.0-10.0	12.5	110.9	95.7	12.4	106.1	5.0×10^{-5}	0.6 – 0.9
DB-04	1.0-5.0	12.7	117.7	95.0	11.8	111.8	2.6×10^{-4}	0.9 – 1.1
DB-05	2.0-5.0	16.0	98.0	96.8	16.5	94.9	1.6×10^{-5}	0.6 – 0.8
LB-01	1.0-5.0	13.9	104.1	96.7	13.8	100.7	6.0×10^{-5}	0.3 – 0.4
LB-03	1.0-5.0	18.2	93.0	98.4	18.0	91.5	2.7×10^{-4}	1.0 – 1.2

Notes and abbreviations:
% - Percent
cm/sec - Centimeters per second
pcf - Pounds per cubic foot

© 2024 Geotechnology, LLC, dba UES

SUMMARY OF LABORATORY TEST RESULTS

MET Job C43128

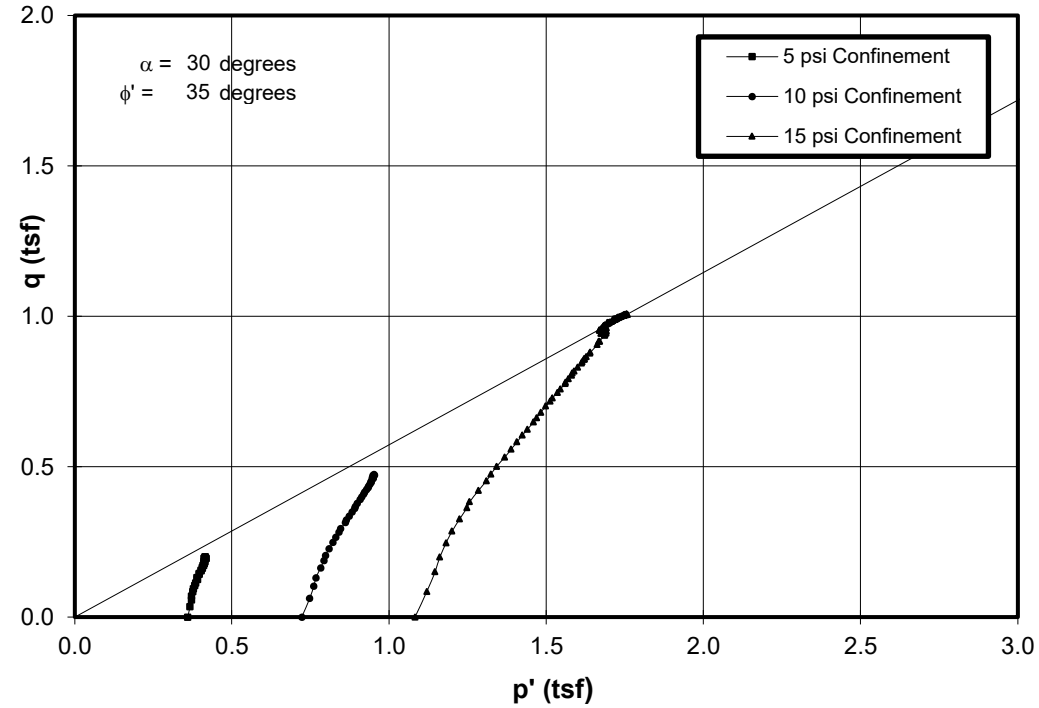
		ASTM D698			ASTM D2216	ASTM D7263	ASTM D4767	
Boring Number	Depth, feet	Optimum Moisture Content, %	Maximum Dry Unit Weight, pcf	Percent Compact	Moisture Content, %	Dry Unit Weight, pcf	Max Shear Strength, tsf	Confining Pressure, psi
DB-01	7.0-10.0	12.5	110.9	96.0	12.8	106.5	0.20*	5
							0.47*	10
							0.99	15
DB-04	1.0-5.0	12.7	117.7	96.0	11.8	113.0	2.34*	5
							3.05*	10
							4.12	15
DB-05	2.0-5.0	16.0	98.0	96.8	16.2	94.9	0.68*	5
							0.87*	10
							1.23	15
LB-01	1.0-5.0	13.9	104.1	96.7	13.7	100.7	0.37*	5
							0.67*	10
							0.83	15
LB-03	1.0-5.0	18.2	93.0	99.1	18.0	92.2	0.18*	5
							0.36*	10
							0.54	15

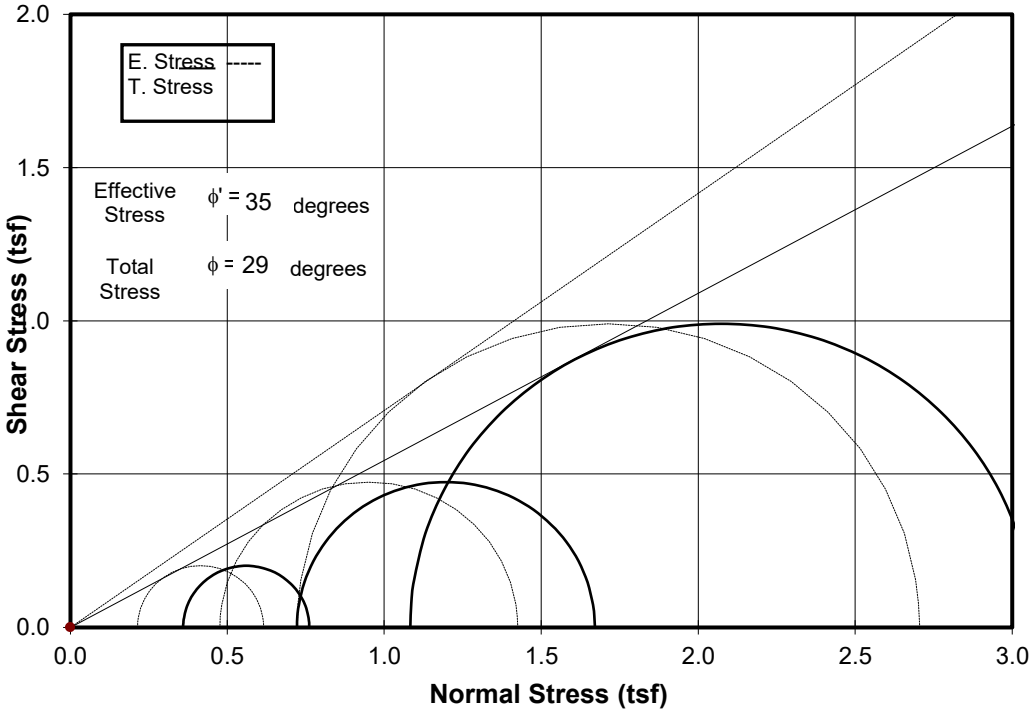
Notes and Abbreviations:
* Staged specimen. Not tested to 15% strain.
% - Percent
pcf - Pounds per cubic foot
psi – Pounds per square inch
tsf – Tons per square foot

© 2024 Geotechnology, LLC, dba UES

APPENDIX B

Triax CU Results





SAMPLE INFORMATION

Boring: DB-01 Sample: -- Depth: 7.0-10.0 feet

SAMPLE DATA

Average Moisture Content (%):	12.8
Average Dry Unit Weight (pcf):	106.5

RESULTS

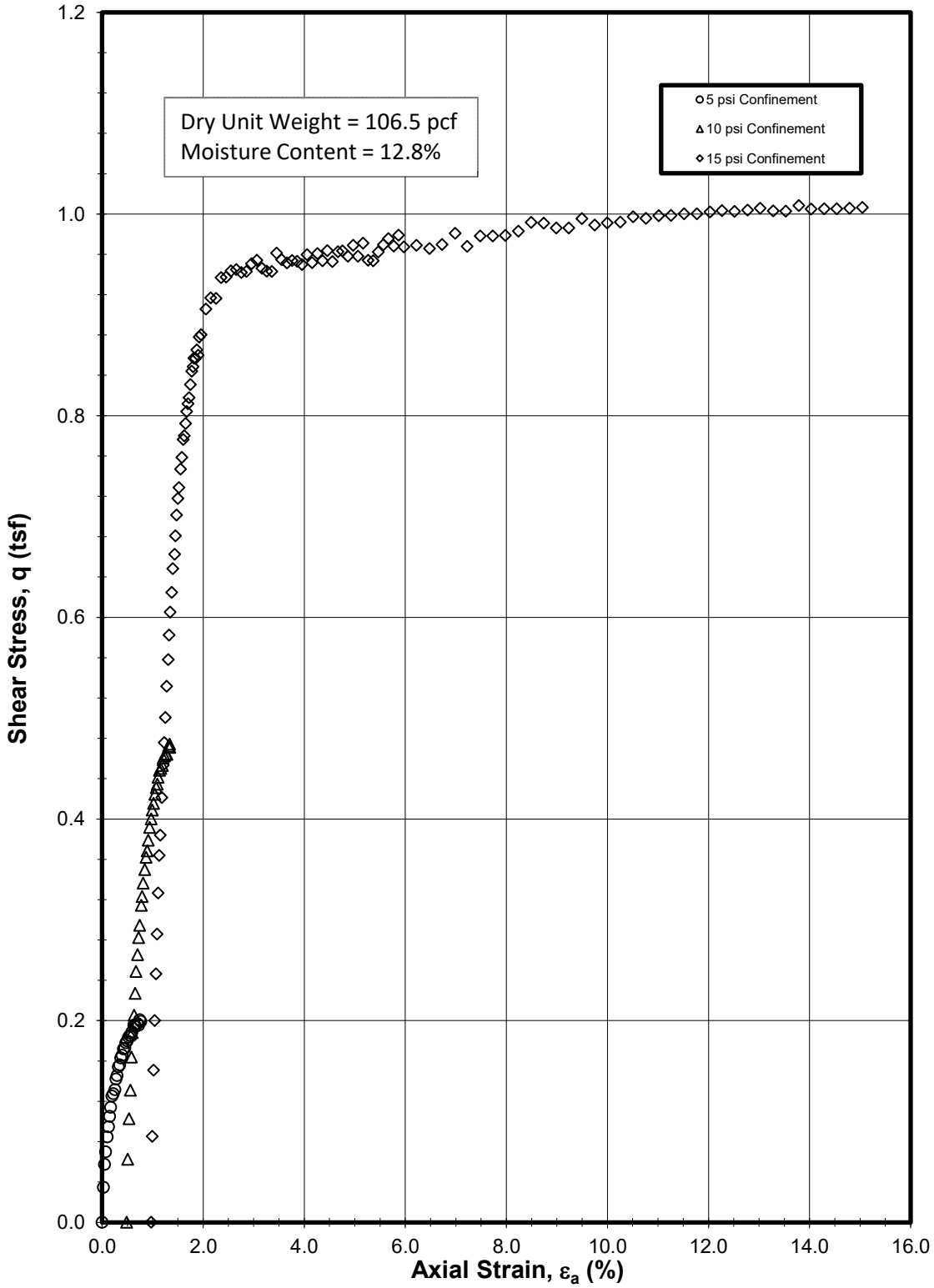
Total Friction Angle (degrees):	29
Effective Friction Angle (degrees):	35
Effective Cohesion (tsf):	0.0

Tested By: JMM	Calc'd By: JMM	Check'd By: CKK
Date: 10/15/2024	Date: 11/8/2024	Date: 11/11/2024

CWLP Ash Pond Samples
Springfield, Illinois
C43128

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ASTM D4767

Project Number: J040516.06.6404



CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST

ASTM D 4767

Project No.: J040516.06.6404

Boring: DB-01

Sample: LSN-6056 - Depth: 7.0-10.0

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-01
Sample No.: LSN-6056 Specimen No.: A
Depth (ft.): 7.0-10.0

Initial Height., H_o (in): 6.079 Confining Pressure (psi): 5.00
Initial Diameter, D_o (in): 2.881 Initial Volume, V_o (in^3): 39.64
Membrane Thickness (in): 0.02 Initial Area, A_o (in^2): 6.52
Ht Change at End of Consol.,ΔH_o (in): 0.001 H_c 6.078 Area after Consol., A_c (in^2): 6.51
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 0.86 0.05246 in^3

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	90.00	95.00	0.000	6.513	0.00	0.00	4.99	4.99	1.00	0.00	0.000	0.359
1.50	0.00	6.28	90.39	95.00	0.024	6.514	0.00	0.07	4.60	5.57	1.21	0.03	0.035	0.366
3.02	0.00	10.39	90.64	95.00	0.046	6.516	0.00	0.11	4.36	5.96	1.37	0.05	0.057	0.371
4.52	0.00	12.66	90.82	94.99	0.070	6.517	0.00	0.14	4.18	6.13	1.46	0.06	0.070	0.371
6.02	0.01	15.36	90.96	95.00	0.100	6.519	0.00	0.17	4.04	6.39	1.58	0.07	0.085	0.376
7.52	0.01	17.16	91.07	95.00	0.128	6.521	0.01	0.19	3.93	6.56	1.67	0.08	0.095	0.378
9.02	0.01	19.05	91.15	95.00	0.145	6.522	0.01	0.21	3.84	6.76	1.76	0.08	0.105	0.382
10.52	0.01	20.70	91.24	95.00	0.169	6.524	0.01	0.23	3.76	6.93	1.84	0.09	0.114	0.385
12.03	0.01	22.70	91.31	95.00	0.197	6.526	0.01	0.25	3.69	7.17	1.94	0.09	0.125	0.391
13.53	0.01	23.12	91.36	94.99	0.223	6.527	0.01	0.25	3.63	7.18	1.97	0.10	0.128	0.389
15.03	0.02	23.85	91.43	95.00	0.253	6.529	0.01	0.26	3.57	7.22	2.02	0.10	0.131	0.388
16.53	0.02	25.81	91.48	95.00	0.273	6.531	0.01	0.28	3.52	7.47	2.12	0.11	0.142	0.396
18.03	0.02	26.40	91.52	94.99	0.296	6.532	0.01	0.29	3.48	7.52	2.16	0.11	0.145	0.396
19.55	0.02	28.01	91.56	95.00	0.321	6.534	0.01	0.31	3.44	7.73	2.25	0.11	0.154	0.402
21.05	0.02	28.35	91.59	95.00	0.348	6.536	0.01	0.31	3.41	7.74	2.27	0.11	0.156	0.401
22.55	0.02	29.62	91.63	94.99	0.368	6.537	0.02	0.33	3.37	7.90	2.35	0.12	0.163	0.406
24.05	0.02	30.08	91.67	95.00	0.398	6.539	0.02	0.33	3.33	7.93	2.38	0.12	0.166	0.405
25.57	0.03	31.24	91.69	94.99	0.423	6.541	0.02	0.34	3.30	8.08	2.45	0.12	0.172	0.410
27.07	0.03	31.38	91.73	94.99	0.447	6.542	0.02	0.34	3.27	8.07	2.47	0.12	0.173	0.408
28.57	0.03	32.40	91.75	95.00	0.471	6.544	0.02	0.36	3.25	8.20	2.53	0.13	0.178	0.412
30.08	0.03	32.73	91.78	94.98	0.498	6.545	0.02	0.36	3.22	8.22	2.55	0.13	0.180	0.412
31.58	0.03	33.43	91.80	95.00	0.523	6.547	0.02	0.37	3.20	8.30	2.60	0.13	0.184	0.414
33.10	0.03	33.69	91.83	94.99	0.549	6.549	0.02	0.37	3.17	8.31	2.63	0.13	0.185	0.413
34.60	0.03	33.61	91.85	94.99	0.573	6.550	0.02	0.37	3.14	8.27	2.63	0.13	0.185	0.411
36.10	0.04	34.39	91.88	95.00	0.590	6.552	0.02	0.38	3.12	8.37	2.68	0.14	0.189	0.413
37.60	0.04	35.61	91.90	94.99	0.626	6.554	0.03	0.39	3.09	8.53	2.76	0.14	0.196	0.418
39.10	0.04	35.42	91.93	94.98	0.648	6.555	0.03	0.39	3.07	8.48	2.76	0.14	0.195	0.416
40.60	0.04	35.39	91.95	94.99	0.666	6.557	0.03	0.39	3.04	8.44	2.77	0.14	0.194	0.414
42.12	0.04	35.94	91.97	94.99	0.699	6.559	0.03	0.39	3.02	8.50	2.81	0.14	0.197	0.415
43.62	0.04	35.64	92.00	94.98	0.721	6.560	0.03	0.39	3.00	8.43	2.81	0.14	0.196	0.411
45.12	0.05	36.60	92.02	94.98	0.745	6.562	0.03	0.40	2.98	8.55	2.87	0.15	0.201	0.415
45.98	0.05	36.36	92.02	94.99	0.767	6.563	0.03	0.40	2.98	8.52	2.86	0.14	0.199	0.414

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-01
Sample No.: LSN-6056 Specimen No.: A
Depth (ft.): 7.0-10.0

Initial Height., H_o (in):	6.079	Confining Pressure (psi):	10.00
Initial Diameter, D_o (in):	2.881	Initial Volume, V_o (in^3):	39.64
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.52
Ht Change at End of Consol., ΔH_o (in):	0.030 H_c 6.049	Area after Consol., A_c (in^2):	6.51
Ht Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
Volume change during Consol. V_c (cc^3):	3.99 0.24339 in^3		

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.03	0.00	90.02	100.05	0.484	6.545	0.02	0.00	10.03	10.03	1.00	0.00	0.00	0.72
1.50	0.03	11.36	90.53	100.06	0.508	6.546	0.02	0.12	9.51	11.25	1.18	0.04	0.06	0.75
3.00	0.03	18.68	90.91	100.05	0.532	6.548	0.02	0.20	9.13	11.99	1.31	0.06	0.10	0.76
4.50	0.03	23.83	91.21	100.06	0.561	6.550	0.02	0.26	8.83	12.47	1.41	0.09	0.13	0.77
6.00	0.04	29.80	91.46	100.05	0.581	6.551	0.02	0.33	8.59	13.14	1.53	0.10	0.16	0.78
7.50	0.04	34.28	91.65	100.04	0.599	6.552	0.02	0.37	8.39	13.62	1.62	0.12	0.19	0.79
9.00	0.04	37.40	91.82	100.02	0.635	6.554	0.03	0.41	8.22	13.93	1.69	0.13	0.21	0.80
10.50	0.04	41.34	91.96	100.03	0.654	6.556	0.03	0.45	8.08	14.39	1.78	0.14	0.23	0.81
12.00	0.04	45.31	92.09	100.03	0.673	6.557	0.03	0.50	7.95	14.86	1.87	0.15	0.25	0.82
13.50	0.04	48.39	92.20	100.02	0.703	6.559	0.03	0.53	7.85	15.23	1.94	0.16	0.27	0.83
15.00	0.04	51.48	92.30	100.01	0.725	6.560	0.03	0.56	7.75	15.59	2.01	0.16	0.28	0.84
16.50	0.05	53.69	92.39	100.01	0.747	6.562	0.03	0.59	7.66	15.84	2.07	0.17	0.29	0.85
18.00	0.05	57.35	92.46	100.01	0.776	6.564	0.03	0.63	7.59	16.33	2.15	0.18	0.31	0.86
19.50	0.05	58.94	92.53	100.00	0.793	6.565	0.03	0.64	7.51	16.49	2.20	0.18	0.32	0.86
21.02	0.05	61.36	92.59	100.00	0.816	6.566	0.03	0.67	7.45	16.80	2.25	0.19	0.34	0.87
22.52	0.05	63.86	92.66	100.01	0.845	6.568	0.04	0.70	7.39	17.11	2.32	0.19	0.35	0.88
24.02	0.05	66.07	92.71	100.00	0.871	6.570	0.04	0.72	7.33	17.39	2.37	0.19	0.36	0.89
25.52	0.05	67.22	92.77	99.99	0.890	6.571	0.04	0.73	7.28	17.51	2.41	0.20	0.37	0.89
27.02	0.06	69.19	92.82	99.99	0.911	6.573	0.04	0.76	7.22	17.75	2.46	0.20	0.38	0.90
28.52	0.06	71.55	92.88	99.99	0.939	6.575	0.04	0.78	7.16	18.05	2.52	0.21	0.39	0.91
30.02	0.06	73.10	92.92	99.99	0.970	6.577	0.04	0.80	7.12	18.24	2.56	0.21	0.40	0.91
31.52	0.06	74.73	92.96	99.98	0.995	6.578	0.04	0.81	7.08	18.44	2.60	0.21	0.41	0.92
33.02	0.06	75.95	93.01	99.99	1.017	6.580	0.04	0.83	7.04	18.58	2.64	0.22	0.42	0.92
34.52	0.06	77.60	93.05	99.99	1.043	6.582	0.04	0.85	7.00	18.79	2.68	0.22	0.42	0.93
36.02	0.06	78.85	93.07	99.99	1.070	6.583	0.04	0.86	6.97	18.95	2.72	0.22	0.43	0.93
37.52	0.07	79.50	93.11	99.98	1.091	6.585	0.05	0.87	6.94	19.01	2.74	0.22	0.43	0.93
39.02	0.07	80.76	93.15	99.99	1.109	6.586	0.05	0.88	6.90	19.16	2.78	0.23	0.44	0.94
40.52	0.07	82.01	93.18	99.99	1.134	6.588	0.05	0.89	6.86	19.31	2.81	0.23	0.45	0.94
42.02	0.07	82.38	93.22	99.98	1.163	6.590	0.05	0.90	6.83	19.33	2.83	0.23	0.45	0.94
43.52	0.07	82.96	93.24	99.98	1.191	6.591	0.05	0.90	6.81	19.40	2.85	0.23	0.45	0.94
45.02	0.07	84.30	93.26	99.98	1.210	6.593	0.05	0.92	6.78	19.57	2.88	0.23	0.46	0.95
46.52	0.07	84.76	93.29	99.98	1.236	6.594	0.05	0.92	6.75	19.61	2.90	0.24	0.46	0.95
48.02	0.08	85.08	93.31	99.97	1.266	6.596	0.05	0.92	6.73	19.63	2.92	0.24	0.46	0.95
49.52	0.08	85.06	93.34	99.97	1.284	6.598	0.05	0.92	6.70	19.60	2.92	0.24	0.46	0.95
51.03	0.08	86.59	93.36	99.98	1.313	6.600	0.05	0.94	6.68	19.80	2.96	0.24	0.47	0.95
52.53	0.08	86.95	93.42	100.01	1.334	6.601	0.06	0.94	6.62	19.79	2.99	0.25	0.47	0.95
52.73	0.08	86.35	93.41	100.00	1.339	6.601	0.06	0.94	6.64	19.72	2.97	0.24	0.47	0.95

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-01
Sample No.: LSN-6056 Specimen No.: A
Depth (ft.): 7.0-10.0

Initial Height., H_o (in): 6.079
Initial Diameter, D_o (in): 2.881
Membr. Thickness (in): 0.02
t Change at End of Consol.,ΔH_o (in): 0.060 H_c 6.020
Change at End of Saturation, H_s (in): 0.000
ume change during Consol. V_c (cc^3): 6.67 0.40687 in^3

Confining Pressure (psi): 15.00
Initial Volume, V_o (in^3): 39.64
Initial Area, A_o (in^2): 6.52
Area after Consol., A_c (in^2): 6.52
Piston Correction (lbs): 0.0

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.059	0.00	89.96	104.99	0.973	6.582	0.04	0.00	15.03	15.03	1.00	0.00	0.00	1.08
1.50	0.060	15.59	90.62	104.97	0.995	6.583	0.04	0.17	14.37	16.74	1.16	0.05	0.09	1.12
3.00	0.061	27.58	91.17	104.98	1.021	6.585	0.04	0.30	13.82	18.01	1.30	0.09	0.15	1.15
4.50	0.062	36.60	91.64	104.99	1.038	6.586	0.04	0.40	13.35	18.91	1.42	0.12	0.20	1.16
6.00	0.064	45.09	92.01	104.98	1.068	6.588	0.04	0.49	12.98	19.83	1.53	0.15	0.25	1.18
7.50	0.066	52.34	92.30	104.98	1.088	6.589	0.05	0.57	12.69	20.64	1.63	0.17	0.29	1.20
9.00	0.067	59.80	92.52	104.98	1.109	6.591	0.05	0.65	12.47	21.54	1.73	0.18	0.33	1.22
10.50	0.068	66.64	92.71	104.99	1.132	6.592	0.05	0.72	12.28	22.39	1.82	0.20	0.36	1.25
12.00	0.069	70.31	92.88	104.97	1.151	6.594	0.05	0.76	12.11	22.78	1.88	0.21	0.38	1.26
13.50	0.071	77.20	93.00	104.97	1.181	6.596	0.05	0.84	11.99	23.69	1.98	0.22	0.42	1.28
15.00	0.073	83.08	93.10	104.98	1.208	6.597	0.05	0.90	11.89	24.48	2.06	0.23	0.45	1.31
16.52	0.074	87.19	93.21	104.97	1.229	6.599	0.05	0.95	11.78	24.99	2.12	0.23	0.48	1.32
18.02	0.075	91.82	93.30	104.96	1.253	6.600	0.05	1.00	11.69	25.60	2.19	0.24	0.50	1.34
19.52	0.077	97.48	93.38	104.96	1.277	6.602	0.05	1.06	11.61	26.37	2.27	0.25	0.53	1.37
21.02	0.079	102.39	93.46	104.97	1.309	6.604	0.05	1.11	11.53	27.03	2.35	0.25	0.56	1.39
22.52	0.080	106.88	93.54	104.98	1.326	6.605	0.06	1.16	11.45	27.63	2.41	0.26	0.58	1.41
24.02	0.081	111.06	93.62	104.94	1.347	6.607	0.06	1.21	11.37	28.18	2.48	0.26	0.61	1.42
25.52	0.083	114.67	93.66	104.96	1.377	6.609	0.06	1.25	11.33	28.68	2.53	0.27	0.62	1.44
27.02	0.084	119.05	93.72	104.96	1.399	6.610	0.06	1.29	11.27	29.28	2.60	0.27	0.65	1.46
28.52	0.086	121.70	93.78	104.96	1.435	6.613	0.06	1.32	11.21	29.61	2.64	0.28	0.66	1.47
30.02	0.087	125.06	93.86	104.94	1.451	6.614	0.06	1.36	11.13	30.04	2.70	0.28	0.68	1.48
31.52	0.089	128.89	93.92	104.95	1.472	6.615	0.06	1.40	11.07	30.55	2.76	0.29	0.70	1.50
33.02	0.090	131.96	93.96	104.95	1.502	6.617	0.06	1.43	11.03	30.98	2.81	0.29	0.72	1.51
34.52	0.092	133.97	94.01	104.95	1.520	6.618	0.06	1.45	10.98	31.23	2.84	0.29	0.73	1.52
36.02	0.093	137.35	94.04	104.94	1.550	6.620	0.06	1.49	10.95	31.70	2.89	0.29	0.75	1.54
37.52	0.095	139.53	94.07	104.94	1.580	6.622	0.07	1.51	10.92	31.99	2.93	0.30	0.76	1.54
39.02	0.097	142.83	94.10	104.95	1.604	6.624	0.07	1.55	10.89	32.45	2.98	0.30	0.78	1.56
40.53	0.098	143.58	94.14	104.93	1.625	6.625	0.07	1.56	10.85	32.52	3.00	0.30	0.78	1.56
42.03	0.099	145.83	94.18	104.94	1.652	6.627	0.07	1.58	10.81	32.82	3.04	0.30	0.79	1.57
43.53	0.101	148.07	94.21	104.92	1.675	6.629	0.07	1.60	10.78	33.12	3.07	0.31	0.80	1.58
45.03	0.102	149.50	94.28	104.97	1.699	6.630	0.07	1.62	10.71	33.26	3.11	0.31	0.81	1.58
46.53	0.104	150.66	94.29	104.98	1.723	6.632	0.07	1.63	10.70	33.42	3.12	0.31	0.82	1.59
48.03	0.105	153.11	94.32	104.98	1.750	6.634	0.07	1.66	10.67	33.76	3.16	0.31	0.83	1.60
49.53	0.107	155.56	94.32	104.98	1.772	6.635	0.07	1.68	10.67	34.11	3.20	0.31	0.84	1.61
51.03	0.108	156.43	94.35	104.96	1.799	6.637	0.07	1.69	10.64	34.20	3.22	0.32	0.85	1.61
52.53	0.109	158.05	94.38	104.98	1.819	6.638	0.08	1.71	10.61	34.42	3.24	0.32	0.86	1.62
54.03	0.111	158.03	94.39	104.98	1.848	6.640	0.08	1.71	10.60	34.40	3.25	0.32	0.86	1.62
55.55	0.113	159.66	94.41	104.97	1.876	6.642	0.08	1.73	10.58	34.62	3.27	0.32	0.87	1.63
57.05	0.114	158.69	94.42	104.96	1.899	6.644	0.08	1.71	10.57	34.46	3.26	0.32	0.86	1.62
58.55	0.116	162.05	94.43	104.98	1.923	6.645	0.08	1.75	10.56	34.95	3.31	0.32	0.88	1.64
60.05	0.118	162.55	94.44	104.97	1.958	6.648	0.08	1.75	10.55	35.00	3.32	0.32	0.88	1.64
66.05	0.124	167.42	94.48	104.97	2.055	6.654	0.09	1.81	10.51	35.67	3.39	0.33	0.91	1.66
72.05	0.129	169.65	94.54	104.96	2.149	6.661	0.09	1.83	10.45	35.92	3.44	0.33	0.92	1.67
78.05	0.136	169.72	94.56	104.95	2.254	6.668	0.09	1.83	10.43	35.88	3.44	0.33	0.92	1.67
84.05	0.142	173.75	94.58	104.96	2.357	6.675	0.10	1.87	10.41	36.44	3.50	0.33	0.94	1.69
90.05	0.148	174.02	94.60	104.96	2.453	6.682	0.10	1.87	10.39	36.43	3.51	0.33	0.94	1.69
96.07	0.154	175.32	94.64	104.95	2.551	6.688	0.11	1.88	10.35	36.56	3.53	0.34	0.94	1.69
102.07	0.160	175.75	94.64	104.95	2.658	6.696	0.11	1.88	10.35	36.59	3.54	0.34	0.94	1.69
108.07	0.166	175.39	94.69	104.94	2.755	6.702	0.11	1.88	10.30	36.47	3.54	0.34	0.94	1.68
114.07	0.172	175.76	94.70	104.93	2.856	6.709	0.12	1.88	10.29	36.49	3.55	0.34	0.94	1.68
120.07	0.178	177.36	94.70	104.92	2.956	6.716	0.12	1.89	10.29	36.69	3.57	0.34	0.95	1.69
126.07	0.185	178.22	94.78	104.98	3.065	6.724	0.13	1.90	10.21	36.72	3.60	0.35	0.95	1.69
132.07	0.190	176.90	94.77	104.96	3.162	6.730	0.13	1.88	10.22	36.50	3.57	0.35	0.95	1.68
138.07	0.196	176.53	94.83	104.96	3.260	6.737	0.14	1.88	10.16	36.36	3.58	0.35	0.94	1.67
144.07	0.202	176.68	94.84	104.96	3.361	6.744	0.14	1.88	10.15	36.34	3.58	0.35	0.94	1.67

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-01
Sample No.: LSN-6056 Specimen No.: A
Depth (ft.): 7.0-10.0

Initial Height., H_o (in): 6.079
Confining Pressure (psi): 15.00
Initial Diameter, D_o (in): 2.881
Initial Volume, V_o (in^3): 39.64
Membr. Thickness (in): 0.02
Initial Area, A_o (in^2): 6.52
t Change at End of Consol.,ΔH_o (in): 0.060 H_c 6.020
Area after Consol., A_c (in^2): 6.52
Change at End of Saturation, H_s (in): 0.000
Piston Correction (lbs): 0.0
ume change during Consol. V_c (cc^3): 6.67 0.40687 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
150.07	0.208	180.24	94.84	104.96	3.452	6.751	0.14	1.91	10.15	36.85	3.63	0.35	0.96	1.69
156.07	0.214	179.19	94.86	104.97	3.553	6.758	0.15	1.90	10.13	36.65	3.62	0.35	0.95	1.68
162.07	0.220	178.79	94.88	104.94	3.660	6.765	0.15	1.89	10.11	36.54	3.61	0.35	0.95	1.68
168.07	0.226	179.47	94.91	104.93	3.761	6.772	0.16	1.90	10.08	36.58	3.63	0.36	0.95	1.68
174.08	0.232	179.46	94.91	104.95	3.858	6.779	0.16	1.89	10.08	36.55	3.63	0.36	0.95	1.68
180.08	0.238	179.03	94.91	104.94	3.954	6.786	0.16	1.89	10.08	36.46	3.62	0.36	0.95	1.68
186.08	0.244	181.09	94.92	104.94	4.055	6.793	0.17	1.91	10.07	36.73	3.65	0.36	0.96	1.68
192.08	0.250	179.76	94.92	104.92	4.154	6.800	0.17	1.89	10.07	36.50	3.63	0.36	0.95	1.68
198.08	0.256	181.68	94.93	104.92	4.260	6.808	0.18	1.91	10.06	36.75	3.65	0.36	0.96	1.69
204.08	0.263	180.55	94.94	104.90	4.363	6.815	0.18	1.89	10.05	36.55	3.64	0.36	0.95	1.68
210.08	0.268	182.59	94.99	104.96	4.457	6.822	0.19	1.91	10.00	36.77	3.68	0.36	0.96	1.68
216.08	0.274	180.74	95.02	104.96	4.555	6.829	0.19	1.89	9.97	36.44	3.65	0.36	0.95	1.67
222.08	0.281	182.81	95.04	104.97	4.667	6.837	0.19	1.91	9.95	36.69	3.69	0.37	0.96	1.68
228.08	0.286	183.16	95.03	104.96	4.759	6.843	0.20	1.91	9.96	36.73	3.69	0.37	0.96	1.68
234.08	0.293	182.33	95.03	104.96	4.865	6.851	0.20	1.90	9.96	36.57	3.67	0.37	0.96	1.68
240.08	0.299	184.59	95.04	104.96	4.966	6.858	0.21	1.92	9.95	36.87	3.70	0.37	0.97	1.69
246.08	0.305	182.70	95.03	104.95	5.066	6.865	0.21	1.90	9.96	36.57	3.67	0.37	0.96	1.67
252.08	0.311	185.40	95.05	104.96	5.163	6.872	0.22	1.93	9.94	36.92	3.71	0.37	0.97	1.69
258.10	0.317	182.35	95.06	104.95	5.266	6.880	0.22	1.89	9.93	36.43	3.67	0.37	0.95	1.67
264.10	0.323	182.44	95.05	104.94	5.367	6.887	0.22	1.89	9.94	36.43	3.66	0.37	0.95	1.67
270.10	0.329	184.30	95.04	104.93	5.466	6.894	0.23	1.91	9.95	36.69	3.69	0.37	0.96	1.68
276.10	0.335	185.89	95.02	104.93	5.567	6.902	0.23	1.92	9.97	36.90	3.70	0.36	0.97	1.69
282.10	0.341	187.26	95.01	104.91	5.665	6.909	0.24	1.93	9.98	37.08	3.72	0.36	0.98	1.69
288.10	0.347	186.00	95.06	104.96	5.770	6.917	0.24	1.92	9.93	36.82	3.71	0.37	0.97	1.68
294.10	0.353	188.31	95.05	104.96	5.867	6.924	0.24	1.94	9.94	37.14	3.74	0.37	0.98	1.69
300.10	0.360	186.27	95.06	104.95	5.972	6.932	0.25	1.92	9.93	36.80	3.71	0.37	0.97	1.68
315.10	0.374	187.05	95.05	104.95	6.220	6.950	0.26	1.92	9.94	36.86	3.71	0.37	0.97	1.68
330.10	0.390	186.95	95.05	104.95	6.482	6.969	0.27	1.91	9.94	36.77	3.70	0.37	0.97	1.68
345.10	0.405	188.21	95.02	104.94	6.727	6.988	0.28	1.92	9.97	36.90	3.70	0.36	0.97	1.69
360.10	0.421	190.94	94.99	104.91	6.986	7.007	0.29	1.94	10.00	37.25	3.72	0.36	0.98	1.70
375.10	0.435	188.88	95.02	104.95	7.225	7.025	0.30	1.91	9.97	36.85	3.70	0.36	0.97	1.69
390.10	0.450	191.42	95.02	104.95	7.483	7.045	0.31	1.93	9.97	37.14	3.73	0.36	0.98	1.70
405.12	0.465	191.93	94.98	104.96	7.730	7.064	0.32	1.93	10.01	37.18	3.72	0.36	0.98	1.70
420.12	0.480	192.58	94.98	104.94	7.981	7.083	0.33	1.93	10.01	37.20	3.72	0.36	0.98	1.70
435.12	0.496	193.96	94.93	104.93	8.235	7.103	0.34	1.94	10.06	37.37	3.72	0.36	0.98	1.71
450.12	0.511	196.22	94.90	104.91	8.489	7.122	0.35	1.96	10.09	37.64	3.73	0.36	0.99	1.72
465.12	0.526	196.61	94.95	104.97	8.740	7.142	0.36	1.96	10.04	37.57	3.74	0.36	0.99	1.71
480.12	0.541	196.18	94.92	104.96	8.989	7.161	0.37	1.95	10.07	37.46	3.72	0.36	0.99	1.71
495.12	0.556	196.71	94.91	104.95	9.236	7.181	0.38	1.94	10.08	37.48	3.72	0.36	0.99	1.71
510.12	0.572	199.12	94.86	104.94	9.497	7.202	0.40	1.96	10.13	37.78	3.73	0.35	1.00	1.72
525.13	0.587	198.44	94.85	104.92	9.749	7.222	0.41	1.95	10.14	37.61	3.71	0.35	0.99	1.72
540.13	0.602	199.37	94.87	104.97	9.997	7.242	0.42	1.95	10.12	37.65	3.72	0.35	0.99	1.72
555.13	0.617	200.14	94.83	104.96	10.253	7.262	0.43	1.95	10.16	37.72	3.71	0.35	0.99	1.72
570.13	0.633	201.76	94.83	104.96	10.511	7.283	0.44	1.96	10.16	37.87	3.73	0.35	1.00	1.73
585.13	0.648	201.97	94.79	104.95	10.759	7.303	0.45	1.96	10.20	37.85	3.71	0.35	1.00	1.73
600.13	0.663	203.10	94.75	104.94	11.013	7.324	0.46	1.96	10.24	37.97	3.71	0.35	1.00	1.74
615.13	0.678	203.72	94.77	104.97	11.260	7.345	0.47	1.96	10.22	37.96	3.71	0.35	1.00	1.73
630.13	0.693	204.63	94.75	104.97	11.517	7.366	0.48	1.97	10.24	38.02	3.71	0.35	1.00	1.74
645.15	0.709	205.25	94.74	104.97	11.771	7.387	0.49	1.97	10.25	38.03	3.71	0.34	1.00	1.74
660.15	0.724	206.25	94.72	104.96	12.030	7.409	0.50	1.97	10.27	38.11	3.71	0.34	1.00	1.74
675.15	0.739	207.03	94.70	104.95	12.268	7.429	0.51	1.97	10.29	38.16	3.71	0.34	1.00	1.74
690.15	0.753	207.45	94.66	104.93	12.512	7.450	0.52	1.97	10.33	38.17	3.70	0.34	1.00	1.75
705.15	0.769	208.36	94.69	104.97	12.775	7.472	0.53	1.97	10.30	38.18	3.71	0.34	1.00	1.75
720.15	0.784	209.37	94.68	104.98	13.022	7.493	0.54	1.97	10.31	38.25	3.71	0.34	1.01	1.75
735.15	0.800	209.43	94.66	104.97	13.282	7.516	0.55	1.97	10.33	38.19	3.70	0.34	1.00	1.75

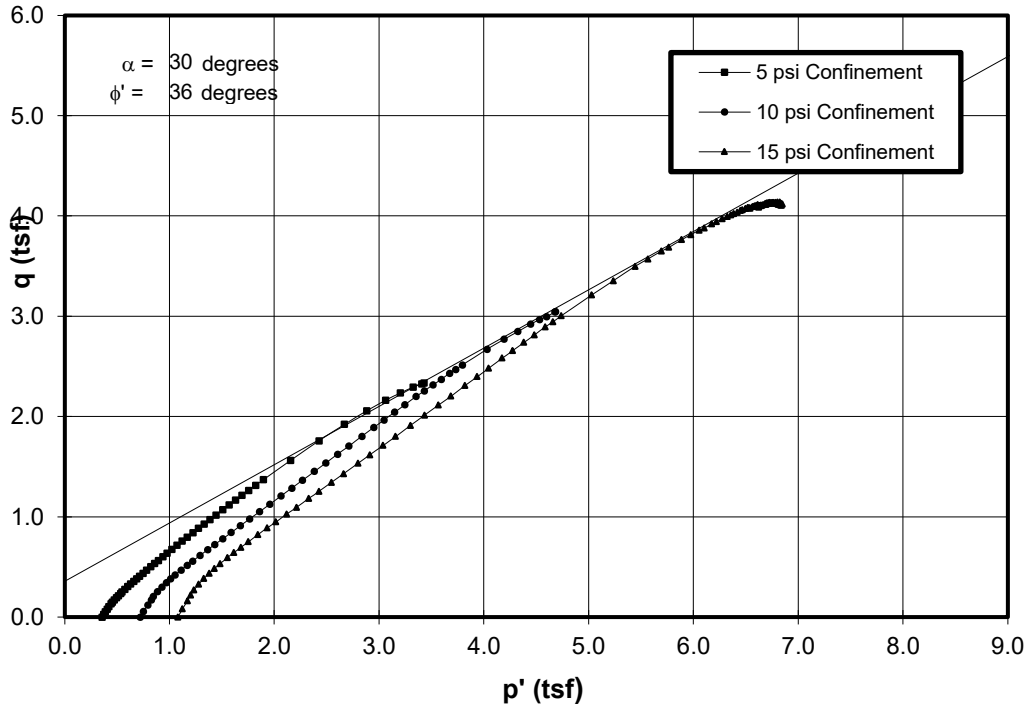
Report No.:

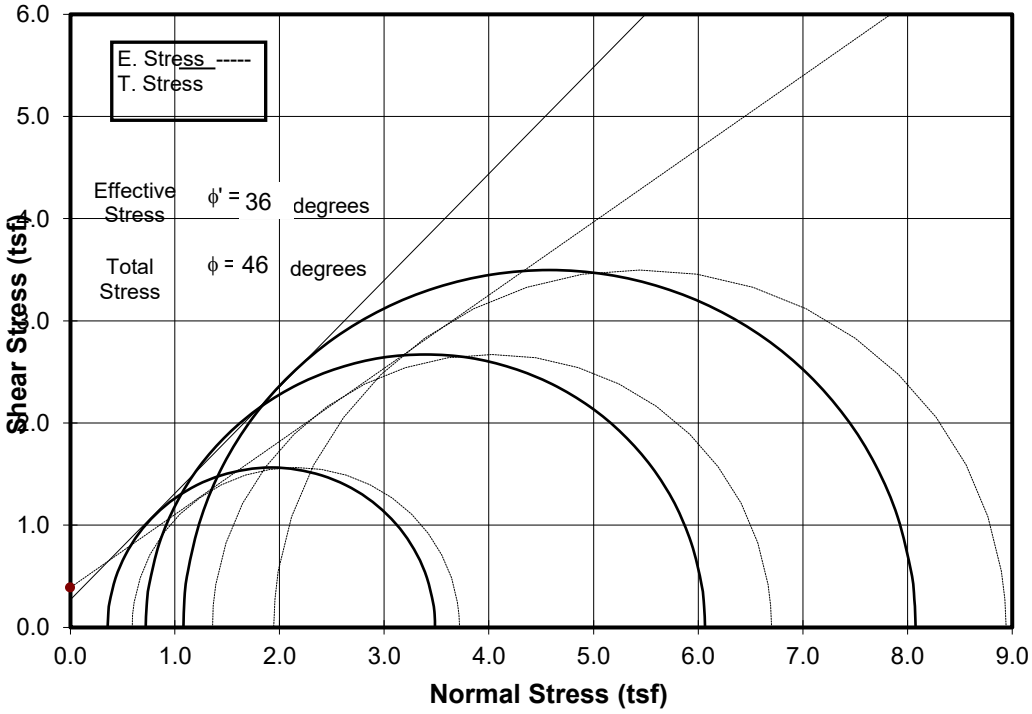
CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-01
Sample No.: LSN-6056 Specimen No.: A
Depth (ft.): 7.0-10.0

Initial Height., H_o (in):	6.079	Confining Pressure (psi):	15.00
Initial Diameter, D_o (in):	2.881	Initial Volume, V_o (in^3):	39.64
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.52
t Change at End of Consol., ΔH_o (in):	0.060 H_c 6.020	Area after Consol., A_c (in^2):	6.52
Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
ume change during Consol. V_c (cc^3):	6.67 0.40687 in^3		

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
750.15	0.815	209.96	94.66	104.96	13.531	7.538	0.56	1.96	10.33	38.19	3.70	0.34	1.00	1.75
765.15	0.830	211.74	94.61	104.95	13.785	7.560	0.57	1.98	10.38	38.39	3.70	0.34	1.01	1.76
780.15	0.845	211.61	94.64	104.97	14.030	7.581	0.58	1.97	10.35	38.26	3.70	0.34	1.00	1.75
795.15	0.860	212.32	94.61	104.98	14.288	7.604	0.60	1.97	10.38	38.30	3.69	0.34	1.01	1.75
810.15	0.875	212.93	94.59	104.97	14.538	7.626	0.61	1.97	10.40	38.32	3.69	0.33	1.01	1.75
825.15	0.890	213.73	94.59	104.97	14.793	7.649	0.62	1.97	10.40	38.34	3.69	0.33	1.01	1.75
840.17	0.906	214.50	94.55	104.96	15.046	7.672	0.63	1.97	10.44	38.40	3.68	0.33	1.01	1.76





SAMPLE INFORMATION			
Boring: DB-04	Sample: --	Depth:	1.0-5.0 feet

SAMPLE DATA	
Average Moisture Content (%):	11.8
Average Dry Unit Weight (pcf):	113.0

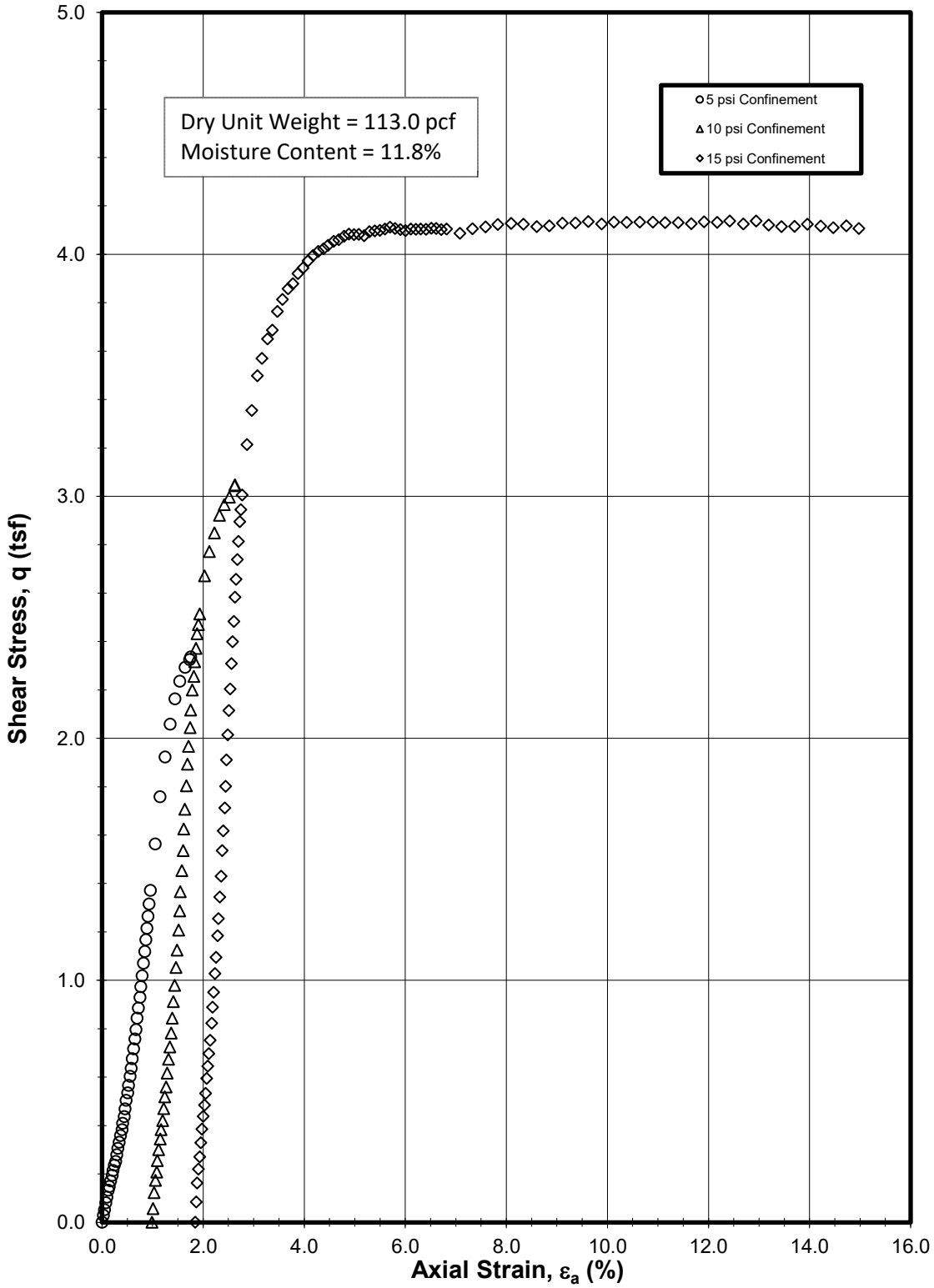
RESULTS	
Total Friction Angle (degrees):	46
Effective Friction Angle (degrees):	36
Effective Cohesion (tsf):	0.39

Tested By: JMM	Calc'd By: JMM	Check'd By: CKK
Date: 10/2/2024	Date: 11/11/2024	Date: 11/11/2024

CWLP Ash Pond Samples
Springfield, Illinois
C43128

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ASTM D4767

Project Number: J040516.06.6404



CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST

ASTM D 4767

Project No.: J040516.06.6404

Boring: DB-04

Sample: LSN-6055 - Depth: 1.0-5.0

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-04
Sample No.: LSN-6055 Specimen No.: A
Depth (ft.): 1.0-5.0

Initial Height., H_o (in): 6.055
Initial Diameter, D_o (in): 2.884
Membrane Thickness (in): 0.02
Ht Change at End of Consol.,ΔH_o (in): 0.019 H_c 6.036
Ht Change at End of Saturation, H_s (in): 0.000
Volume change during Consol. V_c (cc^3): 0.07 0.00427 in^3

Confining Pressure (psi): 5.00
Initial Volume, V_o (in^3): 39.55
Initial Area, A_o (in^2): 6.53
Area after Consol., A_c (in^2): 6.55
Piston Correction (lbs): 0.0

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	80.03	84.98	0.000	6.553	0.00	0.00	4.95	4.95	1.00	0.00	0.000	0.356
1.52	0.00	5.30	80.21	84.97	0.024	6.554	0.00	0.06	4.77	5.58	1.17	0.01	0.029	0.373
3.02	0.00	9.58	80.35	84.98	0.049	6.556	0.00	0.11	4.63	6.09	1.32	0.02	0.053	0.386
4.52	0.00	14.72	80.48	84.98	0.076	6.558	0.00	0.16	4.51	6.75	1.50	0.03	0.081	0.405
6.02	0.01	19.04	80.58	84.98	0.096	6.559	0.00	0.21	4.40	7.30	1.66	0.04	0.105	0.421
7.52	0.01	24.12	80.67	84.98	0.122	6.561	0.01	0.26	4.31	7.99	1.85	0.05	0.132	0.443
9.02	0.01	27.11	80.74	84.98	0.143	6.562	0.01	0.30	4.24	8.37	1.97	0.05	0.149	0.454
10.52	0.01	31.29	80.79	84.98	0.171	6.564	0.01	0.34	4.19	8.96	2.14	0.05	0.172	0.473
12.02	0.01	35.37	80.83	84.98	0.201	6.566	0.01	0.39	4.15	9.54	2.30	0.06	0.194	0.493
13.52	0.01	39.18	80.86	84.98	0.218	6.567	0.01	0.43	4.13	10.09	2.45	0.06	0.215	0.512
15.02	0.01	43.13	80.87	84.97	0.242	6.569	0.01	0.47	4.11	10.68	2.60	0.06	0.236	0.532
16.52	0.02	45.98	80.89	84.96	0.270	6.570	0.01	0.50	4.09	11.09	2.71	0.06	0.252	0.547
18.02	0.02	50.92	80.89	84.97	0.291	6.572	0.01	0.56	4.10	11.84	2.89	0.06	0.279	0.574
19.52	0.02	55.84	80.88	84.97	0.314	6.573	0.01	0.61	4.10	12.59	3.07	0.06	0.306	0.601
21.02	0.02	60.42	80.86	84.98	0.336	6.575	0.01	0.66	4.12	13.31	3.23	0.06	0.331	0.628
22.52	0.02	65.44	80.82	84.97	0.366	6.577	0.02	0.72	4.16	14.11	3.39	0.06	0.358	0.658
24.02	0.02	70.00	80.79	84.97	0.395	6.579	0.02	0.76	4.19	14.83	3.54	0.05	0.383	0.685
25.52	0.02	74.83	80.75	84.97	0.409	6.580	0.02	0.82	4.24	15.61	3.69	0.05	0.409	0.714
27.02	0.03	79.95	80.69	84.97	0.440	6.582	0.02	0.87	4.29	16.44	3.83	0.05	0.437	0.746
28.53	0.03	85.76	80.63	84.98	0.454	6.583	0.02	0.94	4.35	17.38	4.00	0.04	0.469	0.782
30.03	0.03	92.29	80.58	84.98	0.474	6.584	0.02	1.01	4.41	18.42	4.18	0.04	0.505	0.822
31.53	0.03	97.83	80.52	84.98	0.509	6.586	0.02	1.07	4.46	19.32	4.33	0.03	0.535	0.856
33.03	0.03	103.59	80.44	84.97	0.525	6.587	0.02	1.13	4.54	20.27	4.46	0.03	0.566	0.893
34.53	0.03	110.44	80.35	84.98	0.556	6.589	0.02	1.21	4.63	21.39	4.62	0.02	0.603	0.937
36.03	0.03	116.52	80.28	84.97	0.576	6.591	0.02	1.27	4.71	22.39	4.76	0.02	0.636	0.975
37.53	0.04	123.85	80.17	84.98	0.598	6.592	0.02	1.35	4.81	23.60	4.90	0.01	0.676	1.023
39.03	0.04	131.40	80.06	84.97	0.625	6.594	0.03	1.43	4.93	24.85	5.05	0.00	0.717	1.072
40.53	0.04	138.84	79.94	84.98	0.649	6.595	0.03	1.51	5.04	26.10	5.17	-0.01	0.758	1.121
42.03	0.04	145.92	79.82	84.97	0.670	6.597	0.03	1.59	5.16	27.28	5.29	-0.02	0.796	1.168
43.53	0.04	154.66	79.69	84.97	0.693	6.598	0.03	1.69	5.29	28.73	5.43	-0.02	0.844	1.225
45.03	0.04	162.38	79.55	84.97	0.721	6.600	0.03	1.77	5.43	30.03	5.53	-0.03	0.886	1.277
46.53	0.05	170.43	79.40	84.97	0.747	6.602	0.03	1.86	5.58	31.40	5.63	-0.05	0.929	1.331
48.03	0.05	178.53	79.25	84.97	0.764	6.603	0.03	1.94	5.73	32.76	5.72	-0.06	0.973	1.386
49.53	0.05	186.87	79.09	84.97	0.794	6.605	0.03	2.03	5.89	34.19	5.80	-0.07	1.019	1.443
51.03	0.05	196.43	78.91	84.97	0.817	6.607	0.03	2.14	6.07	35.81	5.90	-0.08	1.070	1.508
52.53	0.05	205.52	78.73	84.97	0.843	6.608	0.04	2.24	6.25	37.35	5.97	-0.09	1.120	1.570
54.03	0.05	214.38	78.55	84.98	0.865	6.610	0.04	2.33	6.43	38.86	6.04	-0.11	1.168	1.631
55.53	0.05	223.18	78.36	84.97	0.890	6.612	0.04	2.43	6.62	40.38	6.10	-0.12	1.215	1.692
57.03	0.05	232.31	78.15	84.97	0.911	6.613	0.04	2.53	6.83	41.96	6.14	-0.14	1.265	1.756
58.53	0.06	241.63	77.95	84.97	0.929	6.614	0.04	2.63	7.03	43.57	6.19	-0.15	1.315	1.822
60.03	0.06	252.07	77.71	84.97	0.954	6.616	0.04	2.74	7.27	45.37	6.24	-0.17	1.372	1.895
66.03	0.06	287.69	76.76	84.98	1.053	6.622	0.04	3.12	8.22	51.66	6.29	-0.24	1.564	2.156
72.05	0.07	323.80	75.70	84.98	1.146	6.629	0.05	3.51	9.28	58.13	6.26	-0.31	1.759	2.427
78.05	0.08	354.43	74.62	84.98	1.249	6.636	0.05	3.84	10.36	63.77	6.16	-0.39	1.923	2.669
84.05	0.08	379.73	73.53	84.99	1.344	6.642	0.06	4.11	11.46	68.63	5.99	-0.47	2.058	2.883
90.05	0.09	399.60	72.49	84.96	1.443	6.649	0.06	4.32	12.49	72.60	5.81	-0.54	2.164	3.063
96.05	0.09	413.40	71.55	84.96	1.534	6.655	0.06	4.47	13.44	75.56	5.62	-0.61	2.236	3.204
102.05	0.10	424.32	70.67	84.97	1.642	6.662	0.07	4.58	14.31	78.00	5.45	-0.67	2.293	3.323
108.05	0.10	430.65	69.94	84.97	1.734	6.668	0.07	4.64	15.04	79.62	5.29	-0.73	2.325	3.408
109.05	0.11	432.87	69.80	84.97	1.752	6.670	0.07	4.67	15.18	80.08	5.28	-0.74	2.337	3.430

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-04
Sample No.: LSN-6055 Specimen No.: A
Depth (ft.): 1.0-5.0

Initial Height., H_o (in):	6.055	Confining Pressure (psi):	10.00
Initial Diameter, D_o (in):	2.884	Initial Volume, V_o (in^3):	39.55
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.53
Ht Change at End of Consol.,ΔH_o (in):	0.078 H_c 5.976	Area after Consol., A_c (in^2):	6.62
Ht Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
Volume change during Consol. V_c (cc^3):	0.12 0.00732 in^3		

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.06	0.00	79.99	90.00	0.988	6.683	0.04	0.00	10.01	10.01	1.00	0.00	0.00	0.72
1.50	0.06	10.58	80.35	89.99	1.008	6.684	0.04	0.11	9.64	11.23	1.16	0.03	0.06	0.75
3.00	0.06	22.75	80.67	89.99	1.031	6.686	0.04	0.24	9.32	12.73	1.37	0.05	0.12	0.79
4.50	0.06	32.28	80.93	89.98	1.056	6.688	0.04	0.34	9.06	13.89	1.53	0.07	0.17	0.83
6.00	0.06	38.49	81.12	89.98	1.080	6.689	0.04	0.41	8.88	14.63	1.65	0.08	0.21	0.85
7.50	0.07	47.31	81.23	89.98	1.094	6.690	0.05	0.51	8.76	15.83	1.81	0.09	0.25	0.89
9.02	0.07	55.89	81.31	89.99	1.118	6.692	0.05	0.60	8.69	17.04	1.96	0.10	0.30	0.93
10.52	0.07	63.95	81.31	90.00	1.149	6.694	0.05	0.68	8.68	18.24	2.10	0.10	0.34	0.97
12.02	0.07	71.14	81.28	89.99	1.168	6.695	0.05	0.76	8.72	19.34	2.22	0.09	0.38	1.01
13.52	0.07	78.30	81.20	89.98	1.199	6.697	0.05	0.84	8.79	20.48	2.33	0.09	0.42	1.05
15.02	0.07	87.46	81.10	90.00	1.219	6.699	0.05	0.94	8.89	21.95	2.47	0.08	0.47	1.11
16.52	0.07	96.47	80.96	89.99	1.240	6.700	0.05	1.03	9.03	23.43	2.59	0.07	0.52	1.17
18.02	0.08	104.21	80.81	90.00	1.269	6.702	0.05	1.12	9.18	24.73	2.69	0.06	0.56	1.22
19.52	0.08	114.87	80.62	89.99	1.287	6.703	0.05	1.23	9.38	26.52	2.83	0.05	0.62	1.29
21.02	0.08	125.55	80.41	89.99	1.313	6.705	0.05	1.34	9.59	28.31	2.95	0.03	0.67	1.36
22.52	0.08	134.98	80.18	89.99	1.341	6.707	0.06	1.45	9.81	29.94	3.05	0.01	0.72	1.43
24.02	0.08	145.78	79.93	89.98	1.365	6.709	0.06	1.56	10.07	31.80	3.16	0.00	0.78	1.51
25.52	0.08	157.36	79.66	89.99	1.388	6.710	0.06	1.68	10.33	33.78	3.27	-0.02	0.84	1.59
27.02	0.08	170.09	79.39	89.99	1.410	6.712	0.06	1.82	10.60	35.95	3.39	-0.04	0.91	1.68
28.52	0.09	182.69	79.09	90.00	1.437	6.713	0.06	1.95	10.91	38.12	3.50	-0.06	0.98	1.76
30.02	0.09	196.36	78.78	90.00	1.462	6.715	0.06	2.10	11.21	40.46	3.61	-0.09	1.05	1.86
31.52	0.09	209.97	78.46	90.00	1.483	6.717	0.06	2.25	11.54	42.80	3.71	-0.11	1.13	1.96
33.02	0.09	225.45	78.12	90.01	1.513	6.719	0.06	2.41	11.88	45.44	3.82	-0.13	1.21	2.06
34.52	0.09	240.17	77.78	89.99	1.535	6.720	0.06	2.57	12.21	47.95	3.93	-0.16	1.29	2.17
36.02	0.09	255.01	77.45	90.00	1.550	6.721	0.06	2.73	12.55	50.49	4.02	-0.18	1.37	2.27
37.53	0.09	271.42	77.09	90.00	1.580	6.723	0.07	2.90	12.90	53.27	4.13	-0.21	1.45	2.38
39.03	0.10	287.03	76.74	90.00	1.605	6.725	0.07	3.07	13.25	55.93	4.22	-0.23	1.54	2.49
40.53	0.10	303.60	76.41	89.99	1.618	6.726	0.07	3.25	13.58	58.72	4.32	-0.26	1.63	2.60
42.03	0.10	318.92	76.05	89.99	1.639	6.727	0.07	3.41	13.95	61.36	4.40	-0.28	1.71	2.71
43.53	0.10	337.19	75.68	90.00	1.671	6.729	0.07	3.60	14.32	64.42	4.50	-0.31	1.80	2.83
45.03	0.10	353.91	75.32	90.00	1.692	6.731	0.07	3.78	14.68	67.26	4.58	-0.34	1.89	2.95
46.53	0.10	367.77	74.99	89.99	1.711	6.732	0.07	3.93	15.01	69.63	4.64	-0.36	1.97	3.05
48.03	0.10	382.51	74.67	90.00	1.744	6.734	0.07	4.08	15.33	72.13	4.71	-0.38	2.04	3.15
49.53	0.10	396.17	74.35	90.00	1.755	6.735	0.07	4.23	15.65	74.47	4.76	-0.41	2.12	3.24
51.03	0.11	411.75	74.01	90.00	1.783	6.737	0.07	4.40	15.98	77.10	4.82	-0.43	2.20	3.35
52.53	0.11	422.24	73.69	90.01	1.815	6.739	0.08	4.51	16.31	78.96	4.84	-0.45	2.26	3.43
54.03	0.11	433.82	73.36	89.99	1.834	6.741	0.08	4.63	16.63	80.99	4.87	-0.48	2.32	3.51
55.53	0.11	444.20	73.03	89.99	1.857	6.742	0.08	4.74	16.96	82.85	4.88	-0.50	2.37	3.59
57.03	0.11	455.69	72.76	89.99	1.879	6.744	0.08	4.86	17.24	84.81	4.92	-0.52	2.43	3.67
58.53	0.11	462.73	72.49	90.00	1.905	6.746	0.08	4.93	17.50	86.10	4.92	-0.54	2.47	3.73
60.03	0.12	471.26	72.22	90.00	1.933	6.747	0.08	5.02	17.78	87.62	4.93	-0.56	2.51	3.79
66.03	0.12	501.22	71.14	89.98	2.030	6.754	0.08	5.34	18.85	93.06	4.94	-0.64	2.67	4.03
72.03	0.13	520.61	70.27	89.99	2.122	6.760	0.09	5.54	19.73	96.73	4.90	-0.70	2.77	4.19
78.03	0.13	535.49	69.51	89.99	2.225	6.768	0.09	5.69	20.48	99.61	4.86	-0.75	2.85	4.32
84.05	0.14	549.86	68.83	89.98	2.323	6.774	0.10	5.84	21.17	102.34	4.83	-0.80	2.92	4.45
90.05	0.14	558.73	68.28	89.96	2.418	6.781	0.10	5.93	21.71	104.11	4.79	-0.84	2.97	4.53
96.05	0.15	565.08	67.76	89.98	2.518	6.788	0.10	5.99	22.24	105.49	4.74	-0.88	3.00	4.60
102.05	0.16	574.62	67.32	89.99	2.625	6.795	0.11	6.08	22.67	107.23	4.73	-0.91	3.04	4.68
102.63	0.16	575.22	67.28	89.99	2.629	6.796	0.11	6.09	22.71	107.36	4.73	-0.91	3.05	4.68

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-04
Sample No.: LSN-6055 Specimen No.: A
Depth (ft.): 1.0-5.0

Initial Height., H_o (in): 6.055
Initial Diameter, D_o (in): 2.884
Membr. Thickness (in): 0.02
t Change at End of Consol., ΔH_o (in): 0.129 H_c 5.926
Change at End of Saturation, H_s (in): 0.000
ume change during Consol. V_c (cc^3): 0.96 0.05856 in^3

Confining Pressure (psi): 15.00
Initial Volume, V_o (in^3): 39.55
Initial Area, A_o (in^2): 6.53
Area after Consol., A_c (in^2): 6.66
Piston Correction (lbs): 0.0

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.109	0.00	79.94	94.93	1.843	6.790	0.08	-0.01	14.99	14.99	1.00	0.00	0.00	1.08
1.50	0.110	15.85	80.48	94.92	1.863	6.791	0.08	0.16	14.45	16.79	1.16	0.04	0.08	1.12
3.02	0.111	30.76	80.93	94.92	1.880	6.792	0.08	0.32	14.00	18.53	1.32	0.07	0.16	1.17
4.52	0.113	41.42	81.29	94.91	1.907	6.794	0.08	0.43	13.64	19.73	1.45	0.10	0.22	1.20
6.02	0.115	51.13	81.56	94.93	1.932	6.796	0.08	0.54	13.37	20.89	1.56	0.12	0.27	1.23
7.52	0.116	62.09	81.74	94.92	1.954	6.797	0.08	0.65	13.19	22.33	1.69	0.13	0.33	1.28
9.02	0.117	72.69	81.84	94.93	1.977	6.799	0.08	0.76	13.09	23.79	1.82	0.14	0.38	1.33
10.52	0.118	82.81	81.87	94.92	1.999	6.800	0.08	0.87	13.06	25.23	1.93	0.14	0.44	1.38
12.02	0.120	91.60	81.84	94.92	2.028	6.802	0.08	0.96	13.09	26.55	2.03	0.14	0.48	1.43
13.52	0.122	100.79	81.75	94.91	2.051	6.804	0.09	1.06	13.18	28.00	2.12	0.13	0.53	1.48
15.02	0.123	112.35	81.61	94.92	2.071	6.805	0.09	1.18	13.32	29.83	2.24	0.12	0.59	1.55
16.52	0.124	122.06	81.46	94.93	2.090	6.807	0.09	1.28	13.47	31.40	2.33	0.11	0.65	1.62
18.02	0.125	131.77	81.26	94.92	2.112	6.808	0.09	1.39	13.67	33.03	2.42	0.09	0.70	1.68
19.52	0.127	142.25	81.03	94.92	2.141	6.810	0.09	1.50	13.91	34.79	2.50	0.08	0.75	1.75
21.02	0.129	155.64	80.76	94.93	2.170	6.812	0.09	1.64	14.17	37.02	2.61	0.06	0.82	1.84
22.52	0.130	168.30	80.45	94.91	2.188	6.814	0.09	1.77	14.48	39.18	2.71	0.04	0.89	1.93
24.02	0.131	179.95	80.15	94.91	2.210	6.815	0.09	1.89	14.79	41.19	2.79	0.01	0.95	2.02
25.52	0.132	194.69	79.79	94.90	2.234	6.817	0.09	2.05	15.14	43.70	2.89	-0.01	1.03	2.12
27.02	0.134	207.42	79.42	94.91	2.253	6.818	0.09	2.18	15.51	45.93	2.96	-0.04	1.10	2.21
28.52	0.135	224.31	79.04	94.91	2.285	6.820	0.10	2.36	15.89	48.78	3.07	-0.06	1.18	2.33
30.02	0.137	237.71	78.65	94.91	2.304	6.822	0.10	2.50	16.28	51.13	3.14	-0.09	1.25	2.43
31.52	0.138	254.74	78.25	94.91	2.328	6.823	0.10	2.68	16.68	54.02	3.24	-0.12	1.34	2.55
33.02	0.139	271.07	77.83	94.93	2.353	6.825	0.10	2.85	17.10	56.81	3.32	-0.15	1.43	2.66
34.53	0.141	291.28	77.38	94.92	2.375	6.827	0.10	3.06	17.55	60.22	3.43	-0.18	1.54	2.80
36.03	0.142	306.84	76.96	94.92	2.396	6.828	0.10	3.23	17.97	62.91	3.50	-0.21	1.62	2.91
37.53	0.144	324.88	76.51	94.91	2.427	6.830	0.10	3.42	18.42	65.98	3.58	-0.25	1.71	3.04
39.03	0.145	341.87	76.09	94.92	2.443	6.831	0.10	3.60	18.84	68.88	3.66	-0.28	1.80	3.16
40.53	0.146	362.71	75.66	94.90	2.461	6.833	0.10	3.81	19.27	72.36	3.75	-0.31	1.91	3.30
42.03	0.148	382.51	75.21	94.91	2.489	6.835	0.10	4.02	19.72	75.68	3.84	-0.34	2.01	3.43
43.53	0.149	401.54	74.79	94.92	2.509	6.836	0.10	4.22	20.14	78.88	3.92	-0.37	2.11	3.56
45.03	0.150	418.66	74.36	94.93	2.537	6.838	0.11	4.40	20.57	81.80	3.98	-0.40	2.20	3.69
46.53	0.152	438.71	73.96	94.92	2.561	6.840	0.11	4.61	20.97	85.11	4.06	-0.43	2.31	3.82
48.03	0.153	455.84	73.59	94.92	2.583	6.841	0.11	4.79	21.34	87.97	4.12	-0.46	2.40	3.94
49.53	0.155	471.90	73.21	94.93	2.607	6.843	0.11	4.96	21.72	90.68	4.18	-0.48	2.48	4.05
51.03	0.156	491.09	72.83	94.90	2.631	6.845	0.11	5.16	22.10	93.85	4.25	-0.51	2.58	4.17
52.53	0.157	505.41	72.46	94.92	2.651	6.846	0.11	5.31	22.47	96.29	4.29	-0.54	2.66	4.28
54.03	0.159	521.05	72.12	94.90	2.676	6.848	0.11	5.47	22.81	98.90	4.34	-0.56	2.74	4.38
55.53	0.160	535.35	71.78	94.92	2.698	6.849	0.11	5.62	23.15	101.31	4.38	-0.59	2.81	4.48
57.03	0.161	550.95	71.43	94.91	2.725	6.851	0.11	5.78	23.50	103.92	4.42	-0.61	2.90	4.59
58.53	0.163	560.58	71.14	94.92	2.744	6.853	0.11	5.88	23.79	105.59	4.44	-0.63	2.95	4.66
60.03	0.164	572.25	70.86	94.93	2.771	6.854	0.12	6.00	24.07	107.56	4.47	-0.65	3.01	4.74
66.03	0.170	612.46	69.72	94.92	2.866	6.861	0.12	6.42	25.21	114.48	4.54	-0.74	3.21	5.03
72.03	0.176	639.96	68.80	94.92	2.962	6.868	0.12	6.70	26.13	119.31	4.57	-0.80	3.35	5.24
78.05	0.182	668.13	67.93	94.93	3.073	6.876	0.13	6.99	27.00	124.17	4.60	-0.87	3.50	5.44
84.05	0.187	682.56	67.24	94.93	3.163	6.882	0.13	7.13	27.69	126.87	4.58	-0.91	3.57	5.56
90.05	0.194	698.64	66.54	94.92	3.271	6.890	0.14	7.29	28.39	129.79	4.57	-0.97	3.65	5.69
96.05	0.200	706.38	66.06	94.92	3.367	6.897	0.14	7.36	28.87	131.29	4.55	-1.00	3.69	5.77
102.05	0.205	721.94	65.45	94.91	3.468	6.904	0.14	7.52	29.48	134.05	4.55	-1.04	3.76	5.89
108.05	0.211	732.03	64.91	94.91	3.568	6.911	0.15	7.62	30.02	135.94	4.53	-1.08	3.81	5.97
114.07	0.218	741.53	64.43	94.91	3.678	6.919	0.15	7.71	30.50	137.67	4.51	-1.12	3.86	6.05
120.07	0.224	746.27	64.04	94.89	3.775	6.926	0.16	7.75	30.89	138.64	4.49	-1.15	3.88	6.10
126.07	0.230	755.14	63.65	94.92	3.875	6.933	0.16	7.83	31.29	140.20	4.48	-1.17	3.92	6.17
132.07	0.236	760.28	63.31	94.91	3.974	6.940	0.17	7.88	31.62	141.17	4.46	-1.20	3.94	6.22
138.07	0.242	766.92	62.98	94.92	4.078	6.948	0.17	7.94	31.95	142.33	4.45	-1.22	3.97	6.27
144.07	0.248	771.98	62.62	94.90	4.178	6.955	0.17	7.98	32.31	143.30	4.44	-1.25	4.00	6.32

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-04
Sample No.: LSN-6055 Specimen No.: A
Depth (ft.): 1.0-5.0

Initial Height., H_o (in): 6.055 Confining Pressure (psi): 15.00
Initial Diameter, D_o (in): 2.884 Initial Volume, V_o (in^3): 39.55
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
t Change at End of Consol.,ΔH_o (in): 0.129 H_c 5.926 Area after Consol., A_c (in^2): 6.66
Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
ume change during Consol. V_c (cc^3): 0.96 0.05856 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
150.07	0.253	775.92	62.36	94.91	4.277	6.962	0.18	8.01	32.57	144.01	4.42	-1.27	4.01	6.36
156.08	0.260	778.86	62.14	94.90	4.383	6.970	0.18	8.03	32.79	144.54	4.41	-1.28	4.02	6.38
162.08	0.265	782.41	61.89	94.90	4.472	6.976	0.19	8.06	33.04	145.19	4.39	-1.30	4.04	6.42
168.08	0.272	786.51	61.68	94.91	4.582	6.985	0.19	8.09	33.25	145.86	4.39	-1.32	4.05	6.45
174.08	0.278	788.70	61.51	94.91	4.684	6.992	0.19	8.11	33.42	146.22	4.38	-1.33	4.06	6.47
180.08	0.284	792.22	61.30	94.90	4.788	7.000	0.20	8.13	33.63	146.81	4.37	-1.34	4.07	6.50
186.08	0.289	794.74	61.12	94.91	4.882	7.007	0.20	8.15	33.81	147.24	4.36	-1.36	4.08	6.52
192.08	0.295	795.27	61.00	94.90	4.985	7.014	0.21	8.15	33.93	147.31	4.34	-1.36	4.08	6.52
198.08	0.301	796.22	60.84	94.90	5.081	7.021	0.21	8.15	34.09	147.49	4.33	-1.38	4.08	6.54
204.08	0.307	796.15	60.74	94.88	5.186	7.029	0.22	8.14	34.19	147.45	4.31	-1.38	4.08	6.54
210.08	0.314	800.22	60.62	94.90	5.293	7.037	0.22	8.17	34.31	148.03	4.31	-1.39	4.09	6.56
216.08	0.320	801.78	60.47	94.90	5.394	7.045	0.22	8.18	34.46	148.27	4.30	-1.40	4.10	6.58
222.08	0.326	802.87	60.38	94.90	5.495	7.052	0.23	8.18	34.55	148.40	4.30	-1.41	4.10	6.59
228.08	0.332	804.90	60.30	94.90	5.597	7.060	0.23	8.19	34.63	148.65	4.29	-1.41	4.10	6.60
234.10	0.338	807.28	60.20	94.89	5.699	7.067	0.24	8.21	34.73	148.96	4.29	-1.42	4.11	6.61
240.10	0.344	807.16	60.15	94.89	5.799	7.075	0.24	8.20	34.79	148.87	4.28	-1.43	4.11	6.61
246.10	0.350	807.02	60.07	94.88	5.904	7.083	0.25	8.19	34.86	148.81	4.27	-1.43	4.10	6.61
252.10	0.356	807.21	60.08	94.89	6.005	7.090	0.25	8.18	34.85	148.70	4.27	-1.43	4.10	6.61
258.10	0.362	809.23	59.99	94.89	6.108	7.098	0.25	8.19	34.94	148.95	4.26	-1.44	4.10	6.62
264.10	0.368	810.05	59.95	94.89	6.208	7.106	0.26	8.19	34.99	148.99	4.26	-1.44	4.10	6.62
270.10	0.374	810.92	59.90	94.89	6.304	7.113	0.26	8.19	35.03	149.04	4.25	-1.44	4.10	6.63
276.10	0.380	811.62	59.84	94.90	6.408	7.121	0.27	8.19	35.09	149.07	4.25	-1.45	4.10	6.63
282.10	0.386	813.43	59.75	94.88	6.515	7.129	0.27	8.20	35.18	149.29	4.24	-1.45	4.11	6.64
288.10	0.392	814.01	59.70	94.88	6.611	7.136	0.28	8.19	35.23	149.30	4.24	-1.46	4.11	6.64
294.10	0.398	814.04	59.63	94.87	6.714	7.144	0.28	8.18	35.30	149.25	4.23	-1.46	4.10	6.64
300.10	0.404	815.41	59.65	94.90	6.819	7.152	0.28	8.19	35.28	149.29	4.23	-1.46	4.10	6.64
315.10	0.420	814.35	59.72	94.90	7.081	7.172	0.29	8.15	35.21	148.75	4.22	-1.46	4.09	6.62
330.10	0.434	820.21	59.60	94.89	7.328	7.192	0.30	8.19	35.33	149.38	4.23	-1.46	4.11	6.65
345.12	0.450	824.00	59.50	94.88	7.588	7.212	0.32	8.20	35.43	149.69	4.22	-1.47	4.11	6.66
360.12	0.464	828.21	59.37	94.89	7.833	7.231	0.33	8.22	35.56	150.09	4.22	-1.48	4.12	6.68
375.12	0.480	831.41	59.23	94.89	8.094	7.251	0.34	8.23	35.70	150.35	4.21	-1.49	4.13	6.70
390.12	0.494	833.03	59.23	94.90	8.340	7.271	0.35	8.22	35.70	150.27	4.21	-1.49	4.12	6.69
405.12	0.510	833.47	59.20	94.91	8.603	7.292	0.36	8.20	35.73	150.03	4.20	-1.49	4.11	6.69
420.12	0.525	836.28	59.17	94.90	8.851	7.312	0.37	8.21	35.76	150.13	4.20	-1.50	4.12	6.69
435.12	0.540	840.96	59.11	94.91	9.111	7.333	0.38	8.23	35.82	150.51	4.20	-1.50	4.13	6.71
450.12	0.555	843.69	59.00	94.90	9.368	7.353	0.39	8.23	35.93	150.66	4.19	-1.51	4.13	6.72
465.12	0.570	847.18	58.94	94.91	9.620	7.374	0.40	8.24	35.99	150.88	4.19	-1.51	4.14	6.73
480.12	0.586	847.45	58.93	94.91	9.883	7.395	0.41	8.22	36.00	150.59	4.18	-1.51	4.13	6.72
495.12	0.600	851.31	58.79	94.91	10.127	7.415	0.42	8.24	36.14	150.94	4.18	-1.52	4.13	6.73
510.13	0.615	853.64	58.64	94.89	10.381	7.436	0.43	8.23	36.29	151.09	4.16	-1.53	4.13	6.75
525.13	0.630	856.21	58.59	94.91	10.638	7.458	0.44	8.23	36.34	151.15	4.16	-1.54	4.13	6.75
540.13	0.646	858.85	58.44	94.92	10.900	7.480	0.45	8.23	36.49	151.31	4.15	-1.55	4.13	6.76
555.13	0.660	860.56	58.40	94.90	11.140	7.500	0.46	8.23	36.53	151.27	4.14	-1.55	4.13	6.76
570.13	0.676	863.16	58.32	94.92	11.402	7.522	0.47	8.23	36.61	151.36	4.13	-1.56	4.13	6.77
585.13	0.691	864.68	58.26	94.90	11.661	7.544	0.49	8.22	36.67	151.29	4.13	-1.56	4.13	6.77
600.13	0.706	868.88	58.16	94.88	11.915	7.566	0.50	8.23	36.77	151.61	4.12	-1.57	4.13	6.78
615.13	0.721	870.96	58.07	94.90	12.169	7.588	0.51	8.23	36.86	151.64	4.11	-1.57	4.13	6.79
630.15	0.736	874.57	57.93	94.91	12.422	7.610	0.52	8.24	37.00	151.92	4.11	-1.58	4.14	6.80
645.15	0.752	874.62	57.86	94.90	12.687	7.633	0.53	8.21	37.07	151.66	4.09	-1.59	4.13	6.79
660.15	0.767	879.89	57.64	94.92	12.942	7.655	0.54	8.24	37.29	152.23	4.08	-1.61	4.14	6.82
675.15	0.782	878.81	57.60	94.89	13.191	7.677	0.55	8.20	37.33	151.80	4.07	-1.61	4.12	6.81
690.15	0.797	880.10	57.52	94.89	13.445	7.700	0.56	8.19	37.41	151.71	4.06	-1.61	4.11	6.81
705.15	0.812	882.95	57.43	94.91	13.705	7.723	0.57	8.19	37.50	151.83	4.05	-1.62	4.12	6.82
720.15	0.827	887.45	57.28	94.91	13.956	7.745	0.58	8.21	37.65	152.22	4.04	-1.63	4.12	6.84
735.15	0.843	888.55	57.16	94.92	14.219	7.769	0.59	8.19	37.77	152.14	4.03	-1.64	4.12	6.84

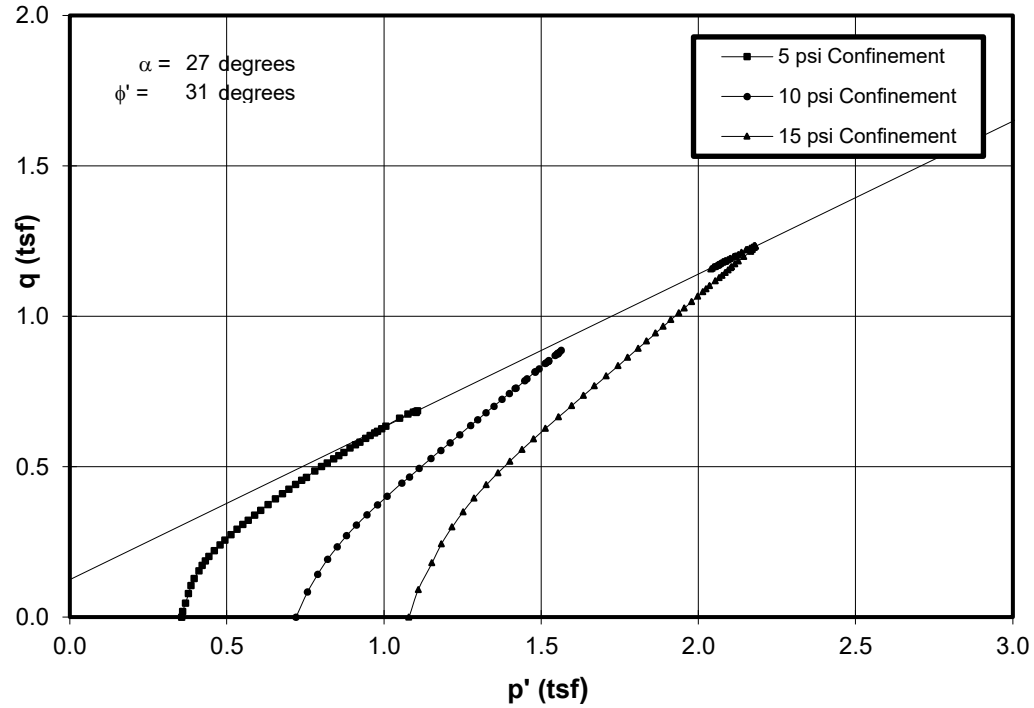
Report No.:

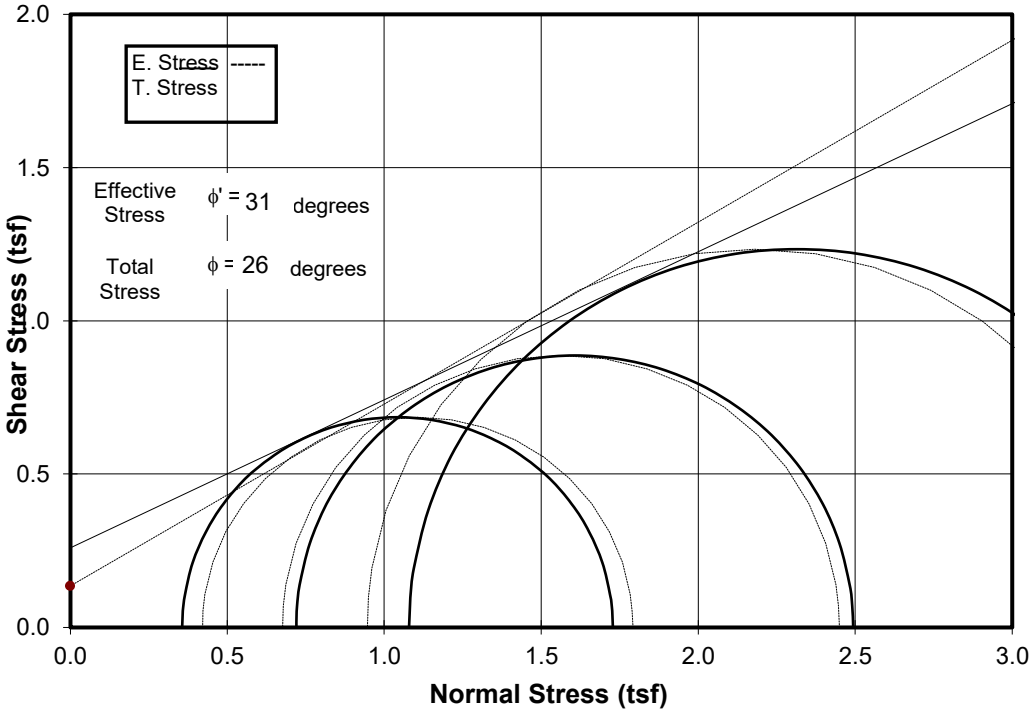
CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-04
Sample No.: LSN-6055 Specimen No.: A
Depth (ft.): 1.0-5.0

Initial Height., H_o (in):	6.055	Confining Pressure (psi):	15.00
Initial Diameter, D_o (in):	2.884	Initial Volume, V_o (in^3):	39.55
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.53
t Change at End of Consol.,ΔH_o (in):	0.129 H_c 5.926	Area after Consol., A_c (in^2):	6.66
Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
ume change during Consol. V_c (cc^3):	0.96 0.05856 in^3		

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
750.15	0.858	889.51	57.17	94.93	14.470	7.792	0.60	8.18	37.76	151.92	4.02	-1.64	4.11	6.83
765.15	0.873	894.05	57.01	94.92	14.726	7.815	0.61	8.19	37.92	152.32	4.02	-1.65	4.12	6.85
780.15	0.888	894.21	56.98	94.91	14.976	7.838	0.62	8.17	37.95	152.03	4.01	-1.65	4.11	6.84





SAMPLE INFORMATION

Boring: DB-05 Sample: -- Depth: 2.0-5.0 feet

SAMPLE DATA

Average Moisture Content (%):	16.2
Average Dry Unit Weight (pcf):	94.9

RESULTS

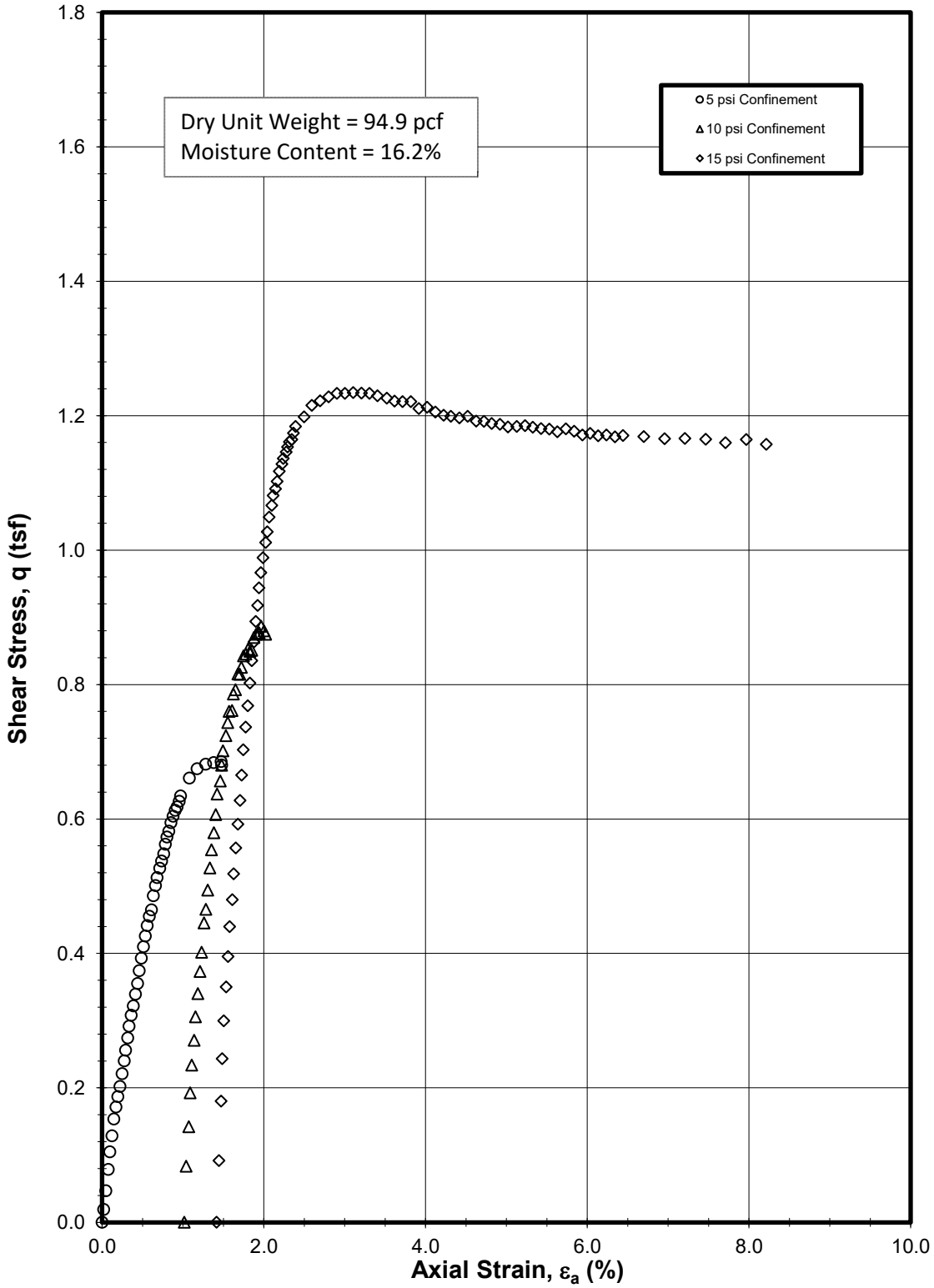
Total Friction Angle (degrees):	26
Effective Friction Angle (degrees):	31
Effective Cohesion (tsf):	0.14

Tested By: JMM	Calc'd By: JMM	Check'd By: CKK
Date: 10/26/2024	Date: 11/8/2024	Date: 11/11/2024

CWLP Ash Pond Samples
Springfield, Illinois
C43128

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ASTM D4767

Project Number: J040516.06.6404



CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST
ASTM D 4767
Project No.: J040516.06.6404
Boring: DB-05
Sample: LSN-6054 - Depth: 2.0-5.0

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-05
Sample No.: LSN-6054 Specimen No.: A
Depth (ft.): 2.0-5.0

Initial Height., H_o (in): 6.046
Initial Diameter, D_o (in): 2.883
Membrane Thickness (in): 0.02
Ht Change at End of Consol.,ΔH_o (in): 0.002 H_c 6.044
Ht Change at End of Saturation, H_s (in): 0.000
Volume change during Consol. V_c (cc^3): 0.69 0.04209 in^3

Confining Pressure (psi): 5.00
Initial Volume, V_o (in^3): 39.46
Initial Area, A_o (in^2): 6.53
Area after Consol., A_c (in^2): 6.52
Piston Correction (lbs): 0.0

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	60.04	64.99	0.000	6.522	0.00	0.00	4.95	4.95	1.00	0.00	0.000	0.357
1.50	0.00	3.49	60.27	64.99	0.021	6.523	0.00	0.04	4.72	5.25	1.11	0.02	0.019	0.359
3.02	0.00	8.52	60.53	64.98	0.047	6.525	0.00	0.09	4.46	5.77	1.29	0.04	0.047	0.368
4.52	0.00	14.25	60.84	64.98	0.077	6.527	0.00	0.16	4.15	6.34	1.53	0.06	0.079	0.378
6.02	0.01	19.04	61.09	64.98	0.095	6.528	0.00	0.21	3.90	6.82	1.75	0.08	0.105	0.386
7.52	0.01	23.35	61.28	64.98	0.121	6.530	0.01	0.26	3.71	7.28	1.96	0.09	0.129	0.396
9.03	0.01	27.91	61.42	64.98	0.147	6.531	0.01	0.31	3.57	7.84	2.20	0.10	0.154	0.411
10.53	0.01	31.18	61.53	64.98	0.172	6.533	0.01	0.34	3.46	8.23	2.38	0.11	0.172	0.421
12.03	0.01	33.95	61.60	64.97	0.195	6.535	0.01	0.37	3.39	8.58	2.53	0.11	0.187	0.431
13.55	0.01	36.69	61.64	64.96	0.220	6.536	0.01	0.40	3.35	8.96	2.68	0.12	0.202	0.443
15.05	0.01	40.18	61.68	64.98	0.247	6.538	0.01	0.44	3.31	9.46	2.85	0.12	0.221	0.460
16.55	0.02	43.62	61.69	64.98	0.275	6.540	0.01	0.48	3.30	9.97	3.02	0.12	0.240	0.478
18.05	0.02	46.55	61.69	64.98	0.290	6.541	0.01	0.51	3.30	10.42	3.16	0.12	0.256	0.494
19.55	0.02	49.88	61.68	64.98	0.317	6.543	0.01	0.55	3.31	10.93	3.30	0.12	0.274	0.513
21.05	0.02	53.07	61.66	64.97	0.332	6.544	0.01	0.58	3.33	11.44	3.43	0.12	0.292	0.532
22.55	0.02	56.00	61.62	64.97	0.361	6.546	0.02	0.61	3.37	11.92	3.54	0.11	0.308	0.551
24.07	0.02	58.59	61.58	64.97	0.387	6.547	0.02	0.64	3.41	12.36	3.62	0.11	0.322	0.568
25.57	0.02	61.72	61.53	64.97	0.413	6.549	0.02	0.68	3.46	12.88	3.73	0.11	0.339	0.588
27.07	0.03	64.69	61.49	64.97	0.439	6.551	0.02	0.71	3.50	13.38	3.82	0.10	0.356	0.608
28.57	0.03	68.14	61.43	64.97	0.459	6.552	0.02	0.75	3.56	13.96	3.92	0.10	0.374	0.630
30.07	0.03	71.56	61.37	64.98	0.486	6.554	0.02	0.78	3.62	14.54	4.01	0.10	0.393	0.654
31.57	0.03	74.66	61.29	64.98	0.511	6.555	0.02	0.82	3.70	15.09	4.08	0.09	0.410	0.676
33.08	0.03	77.57	61.23	64.97	0.535	6.557	0.02	0.85	3.76	15.59	4.14	0.09	0.426	0.697
34.58	0.03	80.39	61.14	64.97	0.556	6.558	0.02	0.88	3.85	16.11	4.18	0.08	0.441	0.718
36.08	0.04	82.98	61.06	64.96	0.583	6.560	0.02	0.91	3.93	16.58	4.22	0.07	0.455	0.738
37.60	0.04	84.76	60.99	64.96	0.611	6.562	0.03	0.93	4.00	16.92	4.23	0.07	0.465	0.753
39.10	0.04	88.61	60.91	64.97	0.632	6.563	0.03	0.97	4.08	17.58	4.31	0.06	0.486	0.780
40.60	0.04	91.36	60.83	64.97	0.660	6.565	0.03	1.00	4.16	18.07	4.35	0.06	0.501	0.800
42.10	0.04	93.59	60.74	64.97	0.681	6.567	0.03	1.02	4.25	18.50	4.35	0.05	0.513	0.819
43.62	0.04	96.13	60.65	64.97	0.712	6.569	0.03	1.05	4.34	18.98	4.37	0.04	0.527	0.840
45.12	0.04	98.09	60.57	64.96	0.736	6.570	0.03	1.07	4.42	19.35	4.38	0.04	0.537	0.856
46.62	0.05	100.08	60.49	64.96	0.761	6.572	0.03	1.09	4.50	19.73	4.38	0.03	0.548	0.872
48.12	0.05	102.67	60.42	64.97	0.782	6.573	0.03	1.12	4.58	20.19	4.41	0.03	0.562	0.892
49.63	0.05	104.72	60.33	64.97	0.802	6.575	0.03	1.14	4.66	20.58	4.42	0.02	0.573	0.909
51.13	0.05	106.29	60.26	64.96	0.827	6.576	0.03	1.16	4.74	20.90	4.41	0.02	0.582	0.923
52.63	0.05	108.66	60.17	64.96	0.851	6.578	0.04	1.19	4.82	21.34	4.43	0.01	0.595	0.942
54.13	0.05	110.42	60.10	64.96	0.877	6.580	0.04	1.21	4.89	21.67	4.43	0.00	0.604	0.956
55.65	0.05	112.02	60.04	64.96	0.904	6.581	0.04	1.22	4.96	21.98	4.43	0.00	0.613	0.970
57.15	0.06	113.00	59.97	64.96	0.929	6.583	0.04	1.23	5.02	22.18	4.42	0.00	0.618	0.979
58.65	0.06	114.55	59.92	64.97	0.953	6.585	0.04	1.25	5.07	22.47	4.43	-0.01	0.626	0.992
60.15	0.06	116.08	59.85	64.97	0.971	6.586	0.04	1.27	5.14	22.77	4.43	-0.01	0.635	1.005
66.15	0.07	121.07	59.61	64.96	1.078	6.593	0.04	1.32	5.38	23.75	4.41	-0.03	0.661	1.049
72.15	0.07	123.74	59.42	64.96	1.175	6.599	0.05	1.35	5.57	24.32	4.37	-0.04	0.675	1.076
78.15	0.08	125.08	59.28	64.95	1.279	6.606	0.05	1.36	5.71	24.65	4.31	-0.05	0.682	1.093
84.17	0.08	125.62	59.20	64.96	1.379	6.613	0.06	1.36	5.79	24.78	4.28	-0.06	0.684	1.101
90.17	0.09	126.05	59.15	64.96	1.472	6.619	0.06	1.37	5.85	24.89	4.26	-0.06	0.686	1.106
90.55	0.09	125.13	59.14	64.95	1.478	6.620	0.06	1.36	5.85	24.75	4.23	-0.06	0.681	1.102

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-05
Sample No.: LSN-6054 Specimen No.: A
Depth (ft.): 2.0-5.0

Initial Height., H_o (in):	6.046	Confining Pressure (psi):	10.00
Initial Diameter, D_o (in):	2.883	Initial Volume, V_o (in^3):	39.46
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.53
Ht Change at End of Consol., ΔH_o (in):	0.063 H_c 5.983	Area after Consol., A_c (in^2):	6.56
Ht Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
Volume change during Consol. V_c (cc^3):	3.06 0.18666 in^3		

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.06	0.00	60.00	69.99	1.017	6.632	0.04	0.00	9.99	9.99	1.00	0.00	0.00	0.72
1.50	0.06	15.40	60.65	69.99	1.041	6.633	0.04	0.16	9.34	11.66	1.25	0.05	0.08	0.76
3.00	0.06	26.24	61.01	70.00	1.073	6.635	0.04	0.28	8.98	12.93	1.44	0.07	0.14	0.79
4.50	0.07	35.49	61.27	69.98	1.089	6.636	0.05	0.38	8.72	14.07	1.61	0.09	0.19	0.82
6.00	0.07	43.13	61.42	70.00	1.108	6.638	0.05	0.46	8.57	15.07	1.76	0.10	0.23	0.85
7.50	0.07	49.96	61.52	70.00	1.138	6.640	0.05	0.54	8.47	15.99	1.89	0.11	0.27	0.88
9.02	0.07	56.42	61.57	70.00	1.154	6.641	0.05	0.61	8.42	16.91	2.01	0.11	0.31	0.91
10.52	0.07	62.76	61.59	69.99	1.184	6.643	0.05	0.68	8.40	17.85	2.12	0.11	0.34	0.95
12.02	0.07	68.91	61.58	69.99	1.211	6.645	0.05	0.74	8.41	18.78	2.23	0.11	0.37	0.98
13.52	0.07	74.16	61.55	69.99	1.231	6.646	0.05	0.80	8.44	19.60	2.32	0.11	0.40	1.01
15.02	0.08	82.29	61.51	69.99	1.259	6.648	0.05	0.89	8.48	20.86	2.46	0.11	0.45	1.06
16.52	0.08	86.04	61.46	69.99	1.285	6.650	0.05	0.93	8.53	21.47	2.52	0.11	0.47	1.08
18.02	0.08	91.30	61.42	70.00	1.308	6.651	0.05	0.98	8.57	22.30	2.60	0.10	0.49	1.11
19.52	0.08	97.42	61.36	69.99	1.333	6.653	0.06	1.05	8.63	23.27	2.70	0.10	0.53	1.15
21.02	0.08	102.47	61.30	70.00	1.354	6.654	0.06	1.10	8.69	24.09	2.77	0.09	0.55	1.18
22.52	0.08	107.17	61.24	70.01	1.383	6.656	0.06	1.16	8.75	24.85	2.84	0.09	0.58	1.21
24.02	0.08	112.20	61.19	69.99	1.405	6.658	0.06	1.21	8.80	25.65	2.92	0.09	0.61	1.24
25.52	0.09	117.88	61.13	70.01	1.424	6.659	0.06	1.27	8.86	26.56	3.00	0.08	0.64	1.27
27.02	0.09	121.46	61.09	69.99	1.461	6.662	0.06	1.31	8.90	27.14	3.05	0.08	0.66	1.30
28.52	0.09	125.83	61.05	70.00	1.477	6.663	0.06	1.36	8.94	27.83	3.11	0.08	0.68	1.32
30.02	0.09	129.80	60.99	69.99	1.496	6.664	0.06	1.40	9.00	28.48	3.16	0.07	0.70	1.35
31.52	0.09	134.10	60.95	70.00	1.530	6.666	0.06	1.44	9.04	29.15	3.23	0.07	0.72	1.37
33.03	0.09	137.67	60.90	69.99	1.554	6.668	0.06	1.48	9.09	29.74	3.27	0.06	0.74	1.40
34.53	0.09	140.79	60.87	69.99	1.573	6.669	0.07	1.52	9.12	30.23	3.31	0.06	0.76	1.42
36.03	0.10	141.09	60.85	69.99	1.606	6.671	0.07	1.52	9.14	30.29	3.31	0.06	0.76	1.42
37.53	0.10	145.66	60.81	69.99	1.624	6.673	0.07	1.57	9.18	31.01	3.38	0.06	0.79	1.45
39.03	0.10	146.87	60.80	69.99	1.651	6.674	0.07	1.58	9.19	31.20	3.39	0.06	0.79	1.45
40.53	0.10	151.30	60.77	70.00	1.680	6.676	0.07	1.63	9.22	31.89	3.46	0.06	0.82	1.48
42.03	0.10	151.20	60.75	69.98	1.703	6.678	0.07	1.63	9.24	31.88	3.45	0.05	0.82	1.48
43.53	0.10	153.15	60.72	70.00	1.724	6.679	0.07	1.65	9.27	32.20	3.47	0.05	0.83	1.49
45.03	0.10	156.42	60.70	69.99	1.750	6.681	0.07	1.68	9.29	32.70	3.52	0.05	0.84	1.51
46.53	0.11	156.96	60.69	69.99	1.780	6.683	0.07	1.69	9.30	32.78	3.53	0.05	0.85	1.51
48.03	0.11	158.32	60.67	69.99	1.804	6.685	0.08	1.70	9.32	33.00	3.54	0.05	0.85	1.52
49.53	0.11	157.79	60.66	69.98	1.828	6.686	0.08	1.69	9.33	32.93	3.53	0.05	0.85	1.52
51.03	0.11	158.10	60.65	69.99	1.851	6.688	0.08	1.70	9.34	32.98	3.53	0.05	0.85	1.52
52.53	0.11	161.66	60.63	69.99	1.878	6.690	0.08	1.73	9.36	33.53	3.58	0.05	0.87	1.54
54.03	0.11	162.60	60.61	69.99	1.903	6.692	0.08	1.74	9.38	33.68	3.59	0.04	0.87	1.55
55.53	0.12	162.88	60.61	69.99	1.931	6.693	0.08	1.75	9.39	33.72	3.59	0.04	0.88	1.55
57.03	0.12	163.06	60.60	69.98	1.943	6.694	0.08	1.75	9.39	33.75	3.59	0.04	0.88	1.55
58.55	0.12	164.93	60.60	69.98	1.967	6.696	0.08	1.77	9.39	34.02	3.62	0.04	0.89	1.56
60.05	0.12	163.76	60.59	69.98	2.002	6.698	0.08	1.75	9.40	33.85	3.60	0.04	0.88	1.56
61.18	0.12	162.81	60.57	69.96	2.022	6.700	0.08	1.74	9.42	33.72	3.58	0.04	0.87	1.55

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-05
Sample No.: LSN-6054 Specimen No.: A
Depth (ft.): 2.0-5.0

Initial Height., H_o (in): 6.046
Initial Diameter, D_o (in): 2.883
Membr. Thickness (in): 0.02
t Change at End of Consol.,ΔH_o (in): 0.086 H_c 5.960
Change at End of Saturation, H_s (in): 0.000
ume change during Consol. V_c (cc^3): 5.20 0.3172 in^3

Confining Pressure (psi): 15.00
Initial Volume, V_o (in^3): 39.46
Initial Area, A_o (in^2): 6.53
Area after Consol., A_c (in^2): 6.57
Piston Correction (lbs): 0.0

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.084	0.00	60.01	75.00	1.416	6.662	0.06	0.00	14.99	14.99	1.00	0.00	0.00	1.08
1.50	0.086	17.01	60.87	75.01	1.447	6.664	0.06	0.18	14.13	16.68	1.18	0.06	0.09	1.11
3.00	0.088	33.41	61.50	75.01	1.472	6.666	0.06	0.36	13.50	18.51	1.37	0.11	0.18	1.15
4.50	0.088	45.06	61.96	75.00	1.485	6.667	0.06	0.48	13.04	19.80	1.52	0.14	0.24	1.18
6.00	0.090	55.51	62.27	75.01	1.505	6.668	0.06	0.59	12.73	21.05	1.65	0.16	0.30	1.22
7.50	0.092	64.89	62.48	75.01	1.536	6.670	0.06	0.70	12.51	22.24	1.78	0.18	0.35	1.25
9.00	0.093	73.27	62.62	75.01	1.556	6.671	0.06	0.79	12.37	23.35	1.89	0.19	0.40	1.29
10.50	0.094	81.55	62.70	75.01	1.577	6.673	0.07	0.88	12.30	24.52	1.99	0.19	0.44	1.33
12.00	0.096	88.99	62.74	75.01	1.611	6.675	0.07	0.96	12.26	25.59	2.09	0.20	0.48	1.36
13.50	0.097	96.14	62.75	75.01	1.626	6.676	0.07	1.03	12.25	26.65	2.18	0.20	0.52	1.40
15.00	0.099	103.31	62.75	75.02	1.653	6.678	0.07	1.11	12.25	27.72	2.26	0.20	0.56	1.44
16.50	0.100	109.89	62.73	75.01	1.681	6.680	0.07	1.18	12.27	28.72	2.34	0.20	0.59	1.48
18.00	0.102	116.46	62.69	75.01	1.705	6.682	0.07	1.25	12.31	29.74	2.42	0.19	0.63	1.51
19.52	0.103	123.50	62.64	75.01	1.726	6.683	0.07	1.33	12.36	30.84	2.50	0.19	0.67	1.55
21.02	0.104	130.55	62.58	75.01	1.748	6.684	0.07	1.40	12.41	31.94	2.57	0.19	0.70	1.60
22.52	0.106	136.83	62.53	75.01	1.775	6.686	0.07	1.47	12.46	32.93	2.64	0.18	0.74	1.63
24.02	0.107	142.77	62.48	75.01	1.803	6.688	0.08	1.53	12.51	33.86	2.71	0.18	0.77	1.67
25.52	0.109	149.07	62.43	75.02	1.828	6.690	0.08	1.60	12.57	34.85	2.77	0.17	0.80	1.71
27.02	0.110	155.30	62.37	75.01	1.851	6.692	0.08	1.67	12.62	35.83	2.84	0.17	0.84	1.74
28.52	0.112	160.55	62.34	75.01	1.878	6.693	0.08	1.72	12.66	36.64	2.90	0.17	0.86	1.77
30.02	0.113	166.23	62.30	75.02	1.902	6.695	0.08	1.78	12.70	37.53	2.96	0.16	0.89	1.81
31.52	0.115	170.73	62.26	75.02	1.923	6.696	0.08	1.83	12.74	38.24	3.00	0.16	0.92	1.84
33.02	0.116	175.61	62.23	75.02	1.941	6.698	0.08	1.88	12.77	38.99	3.05	0.16	0.94	1.86
34.52	0.117	179.87	62.20	75.02	1.964	6.699	0.08	1.93	12.80	39.65	3.10	0.16	0.97	1.89
36.02	0.119	184.07	62.17	75.01	1.991	6.701	0.08	1.97	12.82	40.29	3.14	0.16	0.99	1.91
37.52	0.121	188.32	62.14	75.02	2.022	6.703	0.08	2.02	12.86	40.95	3.18	0.15	1.01	1.94
39.02	0.122	191.32	62.11	75.02	2.043	6.705	0.09	2.05	12.88	41.42	3.21	0.15	1.03	1.95
40.52	0.123	195.39	62.08	75.02	2.067	6.706	0.09	2.09	12.91	42.05	3.26	0.15	1.05	1.98
42.02	0.125	198.74	62.07	75.02	2.097	6.708	0.09	2.13	12.93	42.55	3.29	0.15	1.07	2.00
43.53	0.126	201.54	62.03	75.01	2.116	6.710	0.09	2.16	12.96	43.00	3.32	0.15	1.08	2.01
45.03	0.128	203.46	62.04	75.02	2.147	6.712	0.09	2.18	12.96	43.27	3.34	0.15	1.09	2.02
46.53	0.129	205.55	62.03	75.02	2.165	6.713	0.09	2.20	12.97	43.59	3.36	0.15	1.10	2.04
48.03	0.131	208.42	62.00	75.01	2.193	6.715	0.09	2.23	13.00	44.04	3.39	0.14	1.12	2.05
49.53	0.133	210.50	61.97	75.01	2.225	6.717	0.09	2.25	13.02	44.36	3.41	0.14	1.13	2.07
51.03	0.134	212.07	61.96	75.02	2.241	6.718	0.09	2.27	13.03	44.60	3.42	0.14	1.14	2.07
52.53	0.136	213.93	61.95	75.01	2.276	6.721	0.09	2.29	13.04	44.87	3.44	0.14	1.15	2.08
54.03	0.137	215.37	61.93	75.01	2.292	6.722	0.10	2.30	13.07	45.11	3.45	0.14	1.15	2.09
55.53	0.138	216.83	61.92	75.01	2.316	6.723	0.10	2.32	13.08	45.33	3.47	0.14	1.16	2.10
57.03	0.140	217.59	61.92	75.01	2.346	6.725	0.10	2.32	13.07	45.43	3.47	0.14	1.16	2.11
58.53	0.141	219.36	61.91	75.02	2.366	6.727	0.10	2.34	13.08	45.69	3.49	0.14	1.17	2.12
60.03	0.143	221.28	61.89	75.02	2.394	6.729	0.10	2.36	13.10	45.99	3.51	0.14	1.18	2.13
66.05	0.149	224.22	61.86	75.01	2.498	6.736	0.10	2.39	13.14	46.42	3.53	0.13	1.20	2.14
72.05	0.155	227.66	61.78	75.01	2.595	6.743	0.11	2.42	13.21	46.98	3.56	0.13	1.22	2.17
78.05	0.161	229.15	61.81	75.01	2.697	6.750	0.11	2.44	13.19	47.14	3.57	0.13	1.22	2.17
84.05	0.167	230.50	61.80	75.01	2.803	6.757	0.12	2.45	13.20	47.31	3.58	0.13	1.23	2.18
90.05	0.173	231.71	61.81	75.00	2.905	6.764	0.12	2.46	13.18	47.44	3.60	0.13	1.23	2.18
96.05	0.179	231.96	61.84	75.00	3.002	6.771	0.12	2.46	13.15	47.41	3.60	0.13	1.23	2.18
102.05	0.185	232.40	61.86	75.01	3.106	6.778	0.13	2.46	13.14	47.42	3.61	0.13	1.23	2.18
108.05	0.191	232.52	61.88	75.01	3.209	6.785	0.13	2.46	13.12	47.38	3.61	0.13	1.23	2.18
114.05	0.197	232.70	61.91	75.01	3.305	6.792	0.14	2.46	13.09	47.35	3.62	0.14	1.23	2.18
120.05	0.203	232.27	61.94	75.02	3.408	6.799	0.14	2.45	13.05	47.21	3.62	0.14	1.23	2.17
126.05	0.210	231.85	61.98	75.02	3.520	6.807	0.15	2.44	13.02	47.07	3.62	0.14	1.23	2.16
132.05	0.216	231.21	62.01	75.01	3.617	6.814	0.15	2.43	12.99	46.92	3.61	0.14	1.22	2.16
138.07	0.222	231.34	62.05	75.01	3.717	6.821	0.15	2.43	12.94	46.86	3.62	0.15	1.22	2.15
144.07	0.228	231.54	62.07	75.01	3.819	6.828	0.16	2.43	12.93	46.83	3.62	0.15	1.22	2.15

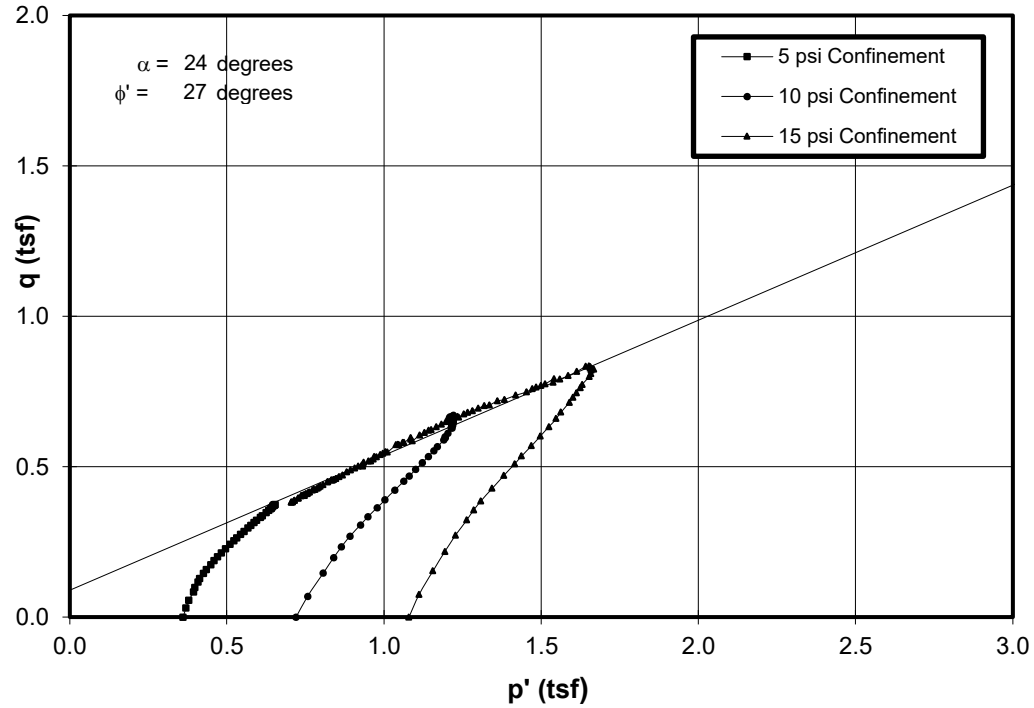
Report No.:

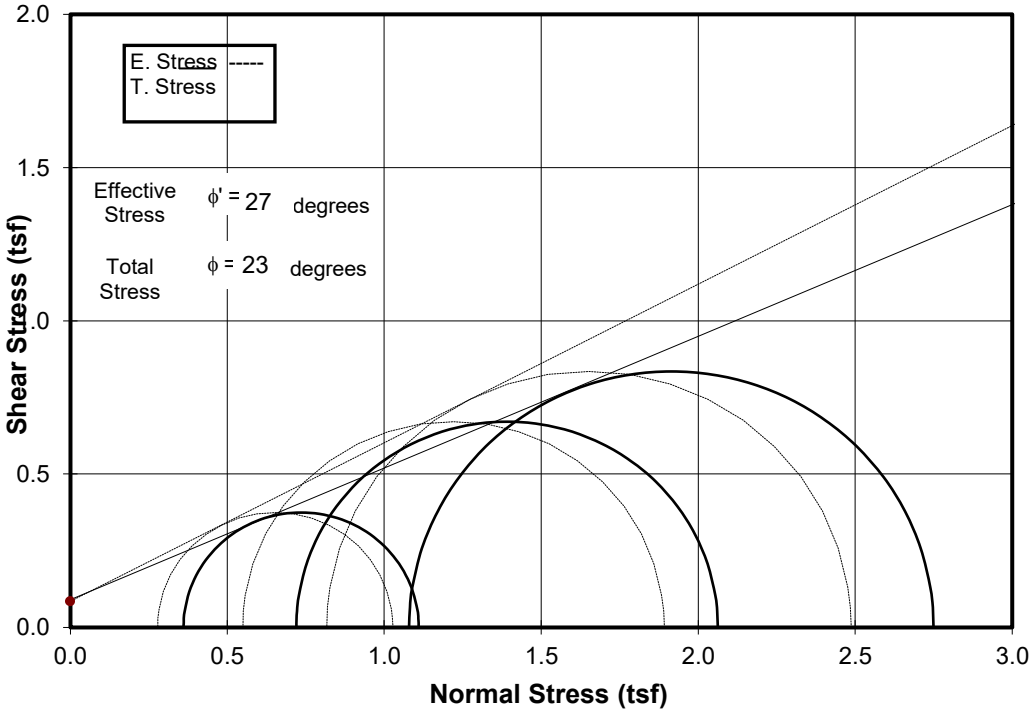
CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: DB-05
Sample No.: LSN-6054 Specimen No.: A
Depth (ft.): 2.0-5.0

Initial Height., H_o (in): 6.046 Confining Pressure (psi): 15.00
Initial Diameter, D_o (in): 2.883 Initial Volume, V_o (in^3): 39.46
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
t Change at End of Consol., ΔH_o (in): 0.086 H_c 5.960 Area after Consol., A_c (in^2): 6.57
Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
ume change during Consol. V_c (cc^3): 5.20 0.3172 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
150.07	0.234	229.85	62.14	75.01	3.919	6.836	0.16	2.41	12.85	46.48	3.62	0.15	1.21	2.14
156.07	0.239	230.51	62.15	75.01	4.019	6.843	0.17	2.41	12.84	46.53	3.62	0.15	1.21	2.14
162.07	0.246	229.37	62.19	75.01	4.121	6.850	0.17	2.40	12.81	46.29	3.61	0.16	1.21	2.13
168.07	0.252	228.74	62.23	75.00	4.226	6.857	0.18	2.39	12.76	46.12	3.61	0.16	1.20	2.12
174.07	0.257	228.64	62.27	75.00	4.313	6.864	0.18	2.39	12.73	46.04	3.62	0.16	1.20	2.12
180.07	0.263	228.45	62.30	75.01	4.419	6.871	0.18	2.38	12.69	45.94	3.62	0.17	1.20	2.11
186.07	0.269	229.08	62.31	75.00	4.521	6.879	0.19	2.38	12.68	45.99	3.63	0.17	1.20	2.11
192.07	0.276	227.99	62.36	75.01	4.626	6.886	0.19	2.37	12.64	45.74	3.62	0.17	1.19	2.10
198.07	0.281	228.16	62.39	75.01	4.723	6.893	0.20	2.37	12.61	45.71	3.63	0.17	1.19	2.10
204.07	0.287	227.76	62.41	75.01	4.820	6.900	0.20	2.36	12.58	45.59	3.62	0.17	1.19	2.09
210.07	0.293	227.82	62.42	75.02	4.921	6.908	0.20	2.36	12.57	45.55	3.62	0.17	1.19	2.09
216.07	0.299	227.23	62.45	75.01	5.021	6.915	0.21	2.35	12.55	45.41	3.62	0.18	1.18	2.09
222.07	0.306	227.72	62.47	75.01	5.129	6.923	0.21	2.35	12.53	45.42	3.63	0.18	1.18	2.09
228.08	0.312	228.15	62.49	75.01	5.230	6.930	0.22	2.35	12.51	45.43	3.63	0.18	1.19	2.09
234.08	0.317	227.91	62.50	75.01	5.326	6.937	0.22	2.35	12.50	45.35	3.63	0.18	1.18	2.08
240.08	0.324	227.82	62.52	75.01	5.430	6.945	0.23	2.35	12.48	45.28	3.63	0.18	1.18	2.08
246.08	0.330	227.89	62.53	75.01	5.532	6.952	0.23	2.34	12.46	45.24	3.63	0.18	1.18	2.08
252.08	0.336	227.36	62.57	75.00	5.631	6.960	0.23	2.34	12.42	45.09	3.63	0.18	1.18	2.07
258.08	0.342	228.46	62.55	75.01	5.736	6.967	0.24	2.34	12.45	45.24	3.63	0.18	1.18	2.08
264.08	0.348	227.97	62.58	75.00	5.837	6.975	0.24	2.34	12.41	45.10	3.63	0.19	1.18	2.07
270.08	0.354	227.19	62.59	75.00	5.941	6.982	0.25	2.32	12.41	44.94	3.62	0.19	1.17	2.06
276.08	0.360	227.90	62.59	75.00	6.038	6.990	0.25	2.33	12.40	45.01	3.63	0.19	1.17	2.07
282.08	0.366	227.39	62.63	75.00	6.136	6.997	0.26	2.32	12.37	44.87	3.63	0.19	1.17	2.06
288.08	0.372	227.90	62.62	75.01	6.237	7.005	0.26	2.32	12.38	44.91	3.63	0.19	1.17	2.06
294.08	0.378	227.63	62.64	75.00	6.342	7.012	0.26	2.32	12.36	44.82	3.63	0.19	1.17	2.06
300.08	0.384	228.24	62.62	75.00	6.441	7.020	0.27	2.32	12.38	44.89	3.63	0.19	1.17	2.06
315.08	0.399	228.56	62.65	75.00	6.699	7.039	0.28	2.32	12.35	44.82	3.63	0.19	1.17	2.06
330.10	0.415	228.58	62.67	75.01	6.956	7.059	0.29	2.31	12.33	44.71	3.63	0.19	1.17	2.05
345.10	0.430	229.26	62.67	75.00	7.207	7.078	0.30	2.31	12.32	44.71	3.63	0.19	1.17	2.05
360.10	0.445	229.66	62.68	74.99	7.465	7.097	0.31	2.31	12.31	44.67	3.63	0.19	1.16	2.05
375.10	0.459	229.24	62.72	75.01	7.710	7.116	0.32	2.30	12.27	44.49	3.62	0.20	1.16	2.04
390.10	0.475	230.84	62.73	75.02	7.968	7.136	0.33	2.31	12.26	44.61	3.64	0.20	1.16	2.05
404.70	0.490	230.04	62.75	75.01	8.214	7.155	0.34	2.29	12.25	44.40	3.62	0.20	1.16	2.04





SAMPLE INFORMATION

Boring: LB-01 Sample: -- Depth: 1.0-5.0 feet

SAMPLE DATA

Average Moisture Content (%):	13.7
Average Dry Unit Weight (pcf):	100.7

RESULTS

Total Friction Angle (degrees):	23
Effective Friction Angle (degrees):	27
Effective Cohesion (tsf):	0.09

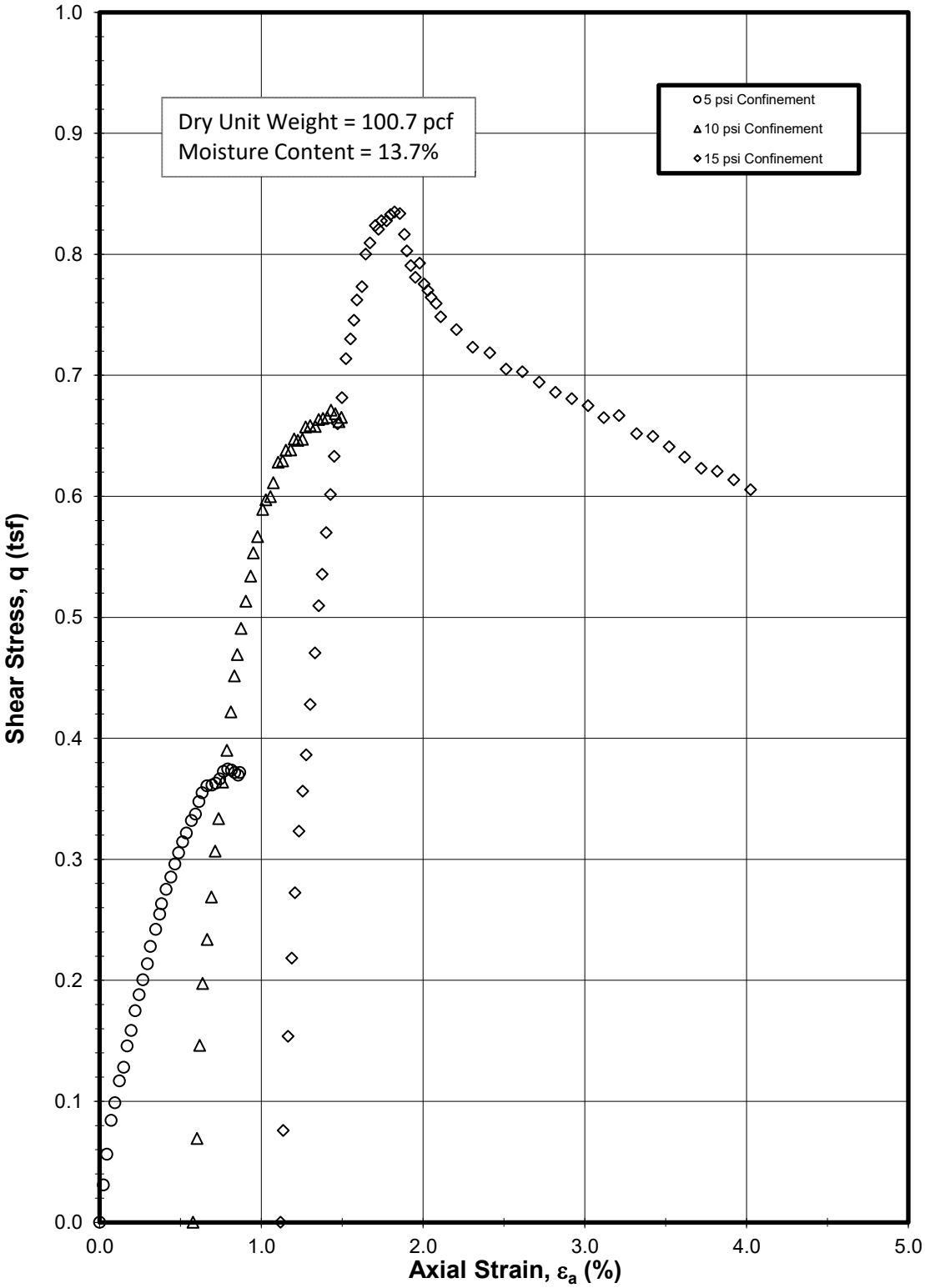
Tested By: JMM	Calc'd By: JMM	Check'd By: CKK
Date: 10/9/2024	Date: 11/11/2024	Date: 11/11/2024

UES™

CWLP Ash Pond Samples
Springfield, Illinois
C43128

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ASTM D4767

Project Number: J040516.06.6404



CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST

ASTM D 4767

Project No.: J040516.06.6404

Boring: LB-01

Sample: LSN-6057 - Depth: 1.0-5.0

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: LB-01
Sample No.: LSN-6057 Specimen No.: A
Depth (ft.): 1.0-5.0

Initial Height., H_o (in): 6.003
Initial Diameter, D_o (in): 2.882
Membrane Thickness (in): 0.02
Ht Change at End of Consol.,ΔH_o (in): 0.002 H_c 6.001
Ht Change at End of Saturation, H_s (in): 0.000
Volume change during Consol. V_c (cc^3): 0.69 0.04209 in^3

Confining Pressure (psi): 5.00
Initial Volume, V_o (in^3): 39.17
Initial Area, A_o (in^2): 6.52
Area after Consol., A_c (in^2): 6.52
Piston Correction (lbs): 0.0

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	90.00	95.00	0.000	6.520	0.00	0.00	5.01	5.01	1.00	0.00	0.000	0.360
1.50	0.00	5.59	90.30	95.00	0.023	6.522	0.00	0.06	4.70	5.56	1.18	0.02	0.031	0.370
3.00	0.00	10.22	90.53	94.99	0.044	6.523	0.00	0.11	4.47	6.04	1.35	0.04	0.056	0.378
4.52	0.00	15.29	90.70	95.00	0.072	6.525	0.00	0.17	4.30	6.64	1.54	0.05	0.084	0.394
6.02	0.01	17.92	90.85	95.00	0.094	6.526	0.00	0.20	4.15	6.90	1.66	0.06	0.099	0.398
7.52	0.01	21.21	90.97	95.00	0.123	6.528	0.01	0.23	4.04	7.28	1.81	0.07	0.117	0.408
9.02	0.01	23.26	91.05	94.99	0.148	6.530	0.01	0.26	3.95	7.52	1.90	0.08	0.128	0.413
10.53	0.01	26.46	91.12	94.99	0.171	6.531	0.01	0.29	3.89	7.94	2.04	0.08	0.146	0.426
12.03	0.01	28.77	91.17	94.98	0.195	6.533	0.01	0.32	3.84	8.24	2.15	0.08	0.159	0.435
13.53	0.01	31.74	91.20	94.99	0.220	6.535	0.01	0.35	3.80	8.66	2.28	0.09	0.175	0.448
15.03	0.01	34.15	91.24	94.99	0.245	6.536	0.01	0.38	3.76	8.99	2.39	0.09	0.188	0.459
16.53	0.02	36.42	91.26	95.00	0.268	6.538	0.01	0.40	3.74	9.31	2.49	0.09	0.201	0.470
18.03	0.02	38.84	91.27	94.99	0.295	6.540	0.01	0.43	3.73	9.67	2.59	0.09	0.214	0.483
19.55	0.02	41.42	91.28	94.99	0.313	6.541	0.01	0.46	3.72	10.05	2.70	0.09	0.228	0.496
21.05	0.02	44.03	91.29	94.99	0.346	6.543	0.01	0.48	3.71	10.44	2.81	0.09	0.242	0.509
22.55	0.02	46.29	91.29	94.99	0.371	6.545	0.02	0.51	3.71	10.78	2.91	0.09	0.255	0.522
24.07	0.02	47.87	91.29	94.99	0.384	6.545	0.02	0.53	3.71	11.03	2.97	0.09	0.263	0.531
25.57	0.02	50.06	91.28	94.99	0.410	6.547	0.02	0.55	3.72	11.37	3.06	0.09	0.275	0.543
27.07	0.03	51.90	91.27	94.99	0.441	6.549	0.02	0.57	3.74	11.66	3.12	0.09	0.285	0.554
28.57	0.03	53.90	91.25	94.98	0.465	6.551	0.02	0.59	3.75	11.98	3.19	0.09	0.296	0.566
30.07	0.03	55.59	91.25	94.98	0.489	6.552	0.02	0.61	3.75	12.24	3.26	0.09	0.305	0.576
31.57	0.03	57.24	91.23	94.99	0.514	6.554	0.02	0.63	3.77	12.51	3.32	0.09	0.314	0.586
33.08	0.03	58.60	91.22	94.98	0.537	6.556	0.02	0.64	3.78	12.72	3.36	0.09	0.322	0.594
34.58	0.03	60.49	91.19	94.99	0.567	6.558	0.02	0.66	3.81	13.03	3.42	0.09	0.332	0.606
36.10	0.04	61.48	91.18	94.98	0.592	6.559	0.02	0.67	3.82	13.19	3.45	0.09	0.337	0.613
37.60	0.04	63.40	91.16	94.97	0.614	6.561	0.03	0.69	3.84	13.50	3.52	0.08	0.348	0.624
39.10	0.04	64.73	91.15	94.98	0.633	6.562	0.03	0.71	3.86	13.72	3.56	0.08	0.355	0.633
40.60	0.04	65.79	91.14	94.98	0.663	6.564	0.03	0.72	3.86	13.89	3.59	0.08	0.361	0.639
42.10	0.04	65.92	91.13	94.98	0.694	6.566	0.03	0.72	3.87	13.91	3.59	0.08	0.361	0.640
43.62	0.04	66.23	91.14	94.99	0.718	6.568	0.03	0.72	3.86	13.95	3.61	0.08	0.363	0.641
45.12	0.04	66.90	91.14	94.99	0.742	6.569	0.03	0.73	3.87	14.05	3.63	0.08	0.367	0.645
46.62	0.05	68.02	91.13	94.99	0.765	6.571	0.03	0.74	3.87	14.22	3.67	0.08	0.373	0.651
48.12	0.05	68.39	91.14	94.99	0.793	6.572	0.03	0.75	3.86	14.27	3.69	0.08	0.375	0.653
49.62	0.05	68.26	91.14	94.99	0.815	6.574	0.03	0.75	3.86	14.24	3.69	0.08	0.374	0.652
51.12	0.05	67.92	91.16	94.99	0.835	6.575	0.03	0.74	3.85	14.18	3.68	0.08	0.372	0.649
52.63	0.05	67.54	91.16	94.99	0.857	6.577	0.04	0.74	3.84	14.11	3.67	0.08	0.370	0.646
53.33	0.05	67.92	91.17	94.99	0.866	6.577	0.04	0.74	3.83	14.16	3.69	0.08	0.372	0.648

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: LB-01
Sample No.: LSN-6057 Specimen No.: A
Depth (ft.): 1.0-5.0

Initial Height., H_o (in):	6.003	Confining Pressure (psi):	10.00
Initial Diameter, D_o (in):	2.882	Initial Volume, V_o (in^3):	39.17
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.52
Ht Change at End of Consol., ΔH_o (in):	0.063 H_c 5.940	Area after Consol., A_c (in^2):	6.56
Ht Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
Volume change during Consol. V_c (cc^3):	3.06 0.18666 in^3		

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.03	0.00	90.01	100.00	0.577	6.601	0.02	0.00	9.99	9.99	1.00	0.00	0.00	0.72
1.52	0.04	12.71	90.46	100.00	0.602	6.603	0.03	0.14	9.55	11.47	1.20	0.03	0.07	0.76
3.02	0.04	26.84	90.84	100.00	0.619	6.604	0.03	0.29	9.16	13.23	1.44	0.06	0.15	0.81
4.52	0.04	36.23	91.09	100.01	0.637	6.605	0.03	0.39	8.91	14.40	1.62	0.08	0.20	0.84
6.02	0.04	42.90	91.25	100.00	0.666	6.607	0.03	0.47	8.75	15.25	1.74	0.09	0.23	0.86
7.52	0.04	49.35	91.36	100.00	0.691	6.609	0.03	0.54	8.64	16.11	1.86	0.10	0.27	0.89
9.02	0.04	56.31	91.42	100.00	0.714	6.610	0.03	0.61	8.58	17.10	1.99	0.10	0.31	0.92
10.52	0.04	61.29	91.47	100.01	0.737	6.612	0.03	0.67	8.54	17.81	2.09	0.10	0.33	0.95
12.02	0.05	66.83	91.48	100.00	0.761	6.613	0.03	0.73	8.52	18.63	2.19	0.11	0.36	0.98
13.52	0.05	71.70	91.49	99.99	0.788	6.615	0.03	0.78	8.51	19.35	2.27	0.11	0.39	1.00
15.02	0.05	77.55	91.51	100.01	0.812	6.617	0.03	0.84	8.49	20.21	2.38	0.11	0.42	1.03
16.52	0.05	83.01	91.51	100.00	0.834	6.618	0.03	0.90	8.49	21.03	2.48	0.11	0.45	1.06
18.03	0.05	86.27	91.52	100.00	0.852	6.619	0.04	0.94	8.48	21.51	2.54	0.11	0.47	1.08
19.53	0.05	90.27	91.54	99.99	0.874	6.621	0.04	0.98	8.46	22.09	2.61	0.11	0.49	1.10
21.03	0.05	94.44	91.56	100.00	0.905	6.623	0.04	1.02	8.44	22.70	2.69	0.11	0.51	1.12
22.53	0.06	98.29	91.58	99.99	0.933	6.625	0.04	1.07	8.42	23.26	2.76	0.11	0.53	1.14
24.03	0.06	101.85	91.60	99.99	0.951	6.626	0.04	1.10	8.40	23.77	2.83	0.11	0.55	1.16
25.53	0.06	104.34	91.63	99.99	0.977	6.628	0.04	1.13	8.37	24.12	2.88	0.12	0.57	1.17
27.03	0.06	108.51	91.66	99.99	1.008	6.630	0.04	1.18	8.34	24.71	2.96	0.12	0.59	1.19
28.53	0.06	109.99	91.71	100.01	1.028	6.631	0.04	1.19	8.30	24.88	3.00	0.12	0.60	1.19
30.03	0.06	110.50	91.75	100.00	1.055	6.633	0.04	1.20	8.25	24.91	3.02	0.13	0.60	1.19
31.53	0.06	112.65	91.79	100.00	1.074	6.634	0.04	1.22	8.21	25.19	3.07	0.13	0.61	1.20
33.03	0.07	115.80	91.84	100.00	1.104	6.636	0.05	1.25	8.16	25.61	3.14	0.13	0.63	1.22
34.53	0.07	116.05	91.90	100.00	1.131	6.638	0.05	1.26	8.10	25.58	3.16	0.14	0.63	1.21
36.03	0.07	117.68	91.95	100.00	1.152	6.639	0.05	1.27	8.06	25.78	3.20	0.14	0.64	1.22
37.53	0.07	117.78	92.00	99.99	1.182	6.641	0.05	1.27	8.01	25.74	3.22	0.14	0.64	1.21
39.03	0.07	119.48	92.05	100.00	1.203	6.643	0.05	1.29	7.95	25.94	3.26	0.15	0.65	1.22
40.53	0.07	119.27	92.10	99.99	1.226	6.644	0.05	1.29	7.90	25.85	3.27	0.15	0.65	1.22
42.05	0.07	119.49	92.13	99.98	1.255	6.646	0.05	1.29	7.87	25.85	3.28	0.15	0.65	1.21
43.55	0.08	121.40	92.18	100.01	1.275	6.648	0.05	1.31	7.82	26.08	3.33	0.16	0.66	1.22
45.05	0.08	121.63	92.23	100.01	1.303	6.650	0.05	1.31	7.78	26.07	3.35	0.16	0.66	1.22
46.55	0.08	121.52	92.26	100.01	1.333	6.652	0.06	1.31	7.74	26.01	3.36	0.16	0.66	1.22
48.05	0.08	122.61	92.28	100.01	1.354	6.653	0.06	1.32	7.73	26.15	3.39	0.16	0.66	1.22
49.55	0.08	122.81	92.31	100.02	1.381	6.655	0.06	1.32	7.69	26.14	3.40	0.17	0.66	1.22
51.05	0.08	123.00	92.35	100.02	1.408	6.657	0.06	1.33	7.65	26.13	3.42	0.17	0.67	1.22
52.55	0.08	124.16	92.37	100.02	1.430	6.658	0.06	1.34	7.63	26.28	3.44	0.17	0.67	1.22
54.05	0.09	123.63	92.40	100.02	1.457	6.660	0.06	1.33	7.61	26.17	3.44	0.17	0.67	1.22
55.55	0.09	122.45	92.43	100.02	1.480	6.662	0.06	1.32	7.58	25.96	3.43	0.17	0.66	1.21
56.57	0.09	123.12	92.45	100.02	1.495	6.663	0.06	1.33	7.55	26.03	3.45	0.18	0.67	1.21

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: LB-01
Sample No.: LSN-6057 Specimen No.: A
Depth (ft.): 1.0-5.0

Initial Height., H_o (in): 6.003 Confining Pressure (psi): 15.00
Initial Diameter, D_o (in): 2.882 Initial Volume, V_o (in^3): 39.17
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.52
t Change at End of Consol.,ΔH_o (in): 0.086 H_c 5.917 Area after Consol., A_c (in^2): 6.57
Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
ume change during Consol. V_c (cc^3): 5.20 0.3172 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.066	0.00	90.00	104.98	1.120	6.641	0.05	0.00	14.98	14.98	1.00	0.00	0.00	1.08
1.50	0.067	13.99	90.60	105.00	1.135	6.642	0.05	0.15	14.38	16.49	1.15	0.04	0.08	1.11
3.00	0.069	28.38	91.07	104.99	1.165	6.644	0.05	0.30	13.91	18.18	1.31	0.08	0.15	1.16
4.50	0.070	40.30	91.44	104.98	1.189	6.645	0.05	0.43	13.54	19.61	1.45	0.10	0.22	1.19
6.00	0.071	50.28	91.73	104.99	1.207	6.647	0.05	0.54	13.26	20.82	1.57	0.12	0.27	1.23
7.50	0.073	59.71	91.93	104.98	1.233	6.648	0.05	0.64	13.05	22.03	1.69	0.14	0.32	1.26
9.00	0.074	65.84	92.08	104.98	1.255	6.650	0.05	0.71	12.90	22.80	1.77	0.15	0.36	1.29
10.52	0.076	71.40	92.19	104.98	1.277	6.651	0.05	0.77	12.80	23.53	1.84	0.16	0.39	1.31
12.02	0.077	79.11	92.27	104.97	1.302	6.653	0.05	0.85	12.71	24.60	1.94	0.16	0.43	1.34
13.52	0.079	87.00	92.35	104.98	1.331	6.655	0.06	0.94	12.64	25.71	2.03	0.17	0.47	1.38
15.02	0.080	94.22	92.40	104.96	1.355	6.657	0.06	1.02	12.59	26.74	2.12	0.17	0.51	1.42
16.52	0.081	99.05	92.46	104.96	1.376	6.658	0.06	1.07	12.53	27.40	2.19	0.18	0.54	1.44
18.02	0.083	105.45	92.50	104.96	1.401	6.660	0.06	1.14	12.49	28.32	2.27	0.18	0.57	1.47
19.52	0.084	111.32	92.55	104.96	1.428	6.662	0.06	1.20	12.43	29.14	2.34	0.18	0.60	1.50
21.02	0.086	117.18	92.61	104.96	1.451	6.663	0.06	1.26	12.38	29.97	2.42	0.19	0.63	1.52
22.52	0.087	122.17	92.66	104.95	1.471	6.664	0.06	1.32	12.33	30.66	2.49	0.19	0.66	1.55
24.02	0.089	126.23	92.75	105.00	1.498	6.666	0.06	1.36	12.23	31.17	2.55	0.20	0.68	1.56
25.52	0.090	132.20	92.82	105.00	1.523	6.668	0.06	1.42	12.16	31.99	2.63	0.20	0.71	1.59
27.02	0.092	135.28	92.89	105.01	1.550	6.670	0.06	1.46	12.09	32.38	2.68	0.21	0.73	1.60
28.52	0.093	138.16	92.95	105.02	1.572	6.671	0.07	1.49	12.03	32.74	2.72	0.21	0.75	1.61
30.02	0.094	141.27	93.02	105.01	1.591	6.673	0.07	1.52	11.97	33.14	2.77	0.22	0.76	1.62
31.52	0.096	143.38	93.08	105.02	1.622	6.675	0.07	1.54	11.90	33.38	2.81	0.22	0.77	1.63
33.03	0.097	148.41	93.14	105.02	1.645	6.676	0.07	1.60	11.84	34.07	2.88	0.23	0.80	1.65
34.53	0.099	150.15	93.20	105.01	1.672	6.678	0.07	1.61	11.79	34.27	2.91	0.23	0.81	1.66
36.03	0.101	152.88	93.28	105.01	1.705	6.680	0.07	1.64	11.71	34.59	2.96	0.24	0.82	1.67
37.53	0.102	152.33	93.34	105.02	1.725	6.682	0.07	1.64	11.64	34.44	2.96	0.24	0.82	1.66
39.03	0.103	153.68	93.43	105.01	1.743	6.683	0.07	1.65	11.55	34.55	2.99	0.25	0.83	1.66
40.53	0.105	153.70	93.49	105.00	1.774	6.685	0.07	1.65	11.50	34.49	3.00	0.25	0.83	1.66
42.03	0.106	154.71	93.56	105.02	1.798	6.687	0.07	1.66	11.43	34.57	3.02	0.26	0.83	1.66
43.53	0.108	155.14	93.64	105.02	1.823	6.688	0.08	1.66	11.34	34.54	3.04	0.26	0.84	1.65
45.03	0.110	154.94	93.76	105.00	1.856	6.691	0.08	1.66	11.23	34.38	3.06	0.27	0.83	1.64
46.53	0.111	151.79	93.92	105.00	1.884	6.693	0.08	1.63	11.06	33.74	3.05	0.28	0.82	1.61
48.03	0.112	149.26	94.12	105.02	1.900	6.694	0.08	1.60	10.87	33.17	3.05	0.30	0.80	1.59
49.53	0.114	147.07	94.32	105.01	1.925	6.695	0.08	1.58	10.67	32.63	3.06	0.31	0.79	1.56
51.03	0.115	145.31	94.47	105.01	1.952	6.697	0.08	1.56	10.51	32.21	3.06	0.32	0.78	1.54
52.53	0.117	147.52	94.59	105.01	1.979	6.699	0.08	1.58	10.39	32.41	3.12	0.33	0.79	1.54
54.03	0.119	144.34	94.74	105.00	2.006	6.701	0.08	1.54	10.24	31.78	3.10	0.34	0.78	1.51
55.53	0.120	143.39	94.87	105.01	2.030	6.702	0.08	1.53	10.12	31.51	3.11	0.35	0.77	1.50
57.05	0.121	142.34	94.99	105.01	2.050	6.704	0.09	1.52	9.99	31.22	3.13	0.36	0.76	1.48
58.55	0.123	141.47	95.10	105.00	2.080	6.706	0.09	1.51	9.89	30.98	3.13	0.37	0.76	1.47
60.05	0.125	139.43	95.19	105.00	2.110	6.708	0.09	1.49	9.79	30.58	3.12	0.37	0.75	1.45
66.05	0.131	137.61	95.53	104.98	2.206	6.715	0.09	1.47	9.45	29.95	3.17	0.40	0.74	1.42
72.05	0.136	135.03	95.83	104.97	2.307	6.721	0.10	1.44	9.16	29.25	3.19	0.42	0.72	1.38
78.05	0.143	134.32	96.07	105.01	2.413	6.729	0.10	1.43	8.91	28.87	3.24	0.44	0.72	1.36
84.05	0.149	131.94	96.23	105.01	2.513	6.736	0.10	1.40	8.75	28.34	3.24	0.45	0.71	1.34
90.05	0.155	131.66	96.42	105.01	2.614	6.743	0.11	1.40	8.56	28.09	3.28	0.46	0.70	1.32
96.07	0.161	130.17	96.58	105.01	2.718	6.750	0.11	1.38	8.40	27.69	3.30	0.47	0.69	1.30
102.07	0.167	128.74	96.72	105.01	2.818	6.757	0.12	1.36	8.26	27.32	3.31	0.48	0.69	1.28
108.07	0.173	127.88	96.85	104.99	2.918	6.764	0.12	1.35	8.13	27.04	3.32	0.49	0.68	1.27
114.07	0.179	126.97	96.94	104.98	3.020	6.771	0.13	1.34	8.04	26.80	3.33	0.50	0.68	1.25
120.07	0.184	125.23	97.04	104.97	3.117	6.778	0.13	1.32	7.94	26.42	3.33	0.51	0.67	1.24
126.07	0.190	125.66	97.12	104.97	3.212	6.784	0.13	1.32	7.86	26.39	3.35	0.51	0.67	1.23
132.07	0.196	122.99	97.28	105.01	3.321	6.792	0.14	1.29	7.70	25.81	3.35	0.52	0.65	1.21
138.07	0.202	122.67	97.38	105.00	3.420	6.799	0.14	1.29	7.61	25.65	3.37	0.53	0.65	1.20
144.07	0.208	121.20	97.47	105.00	3.521	6.806	0.15	1.27	7.52	25.32	3.37	0.54	0.64	1.18

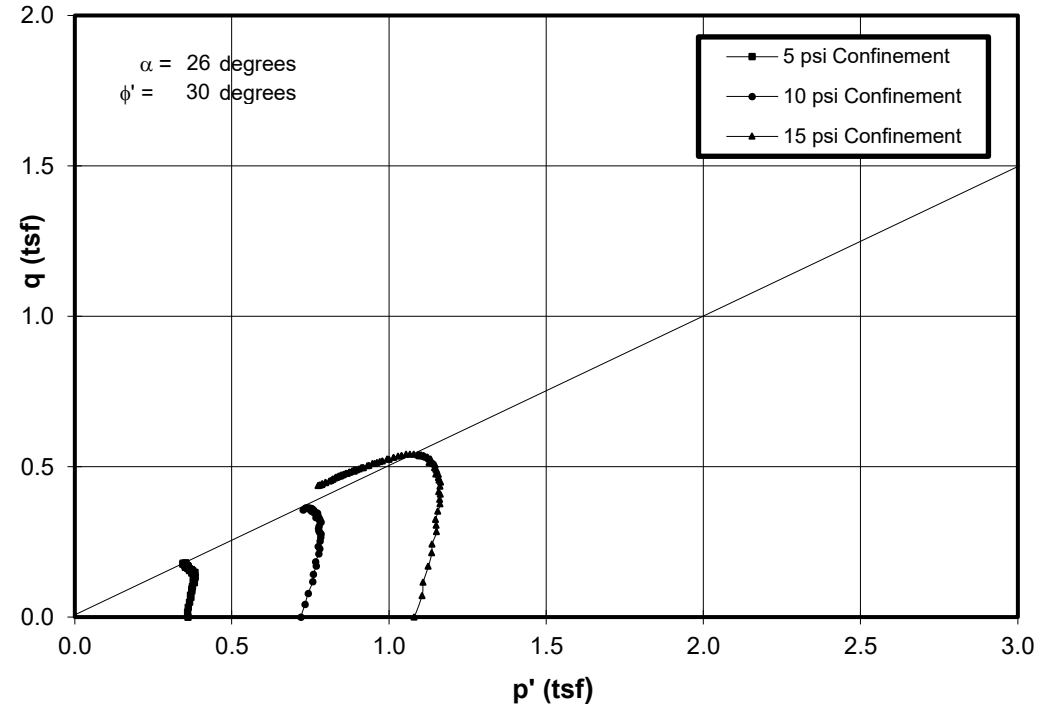
Report No.:

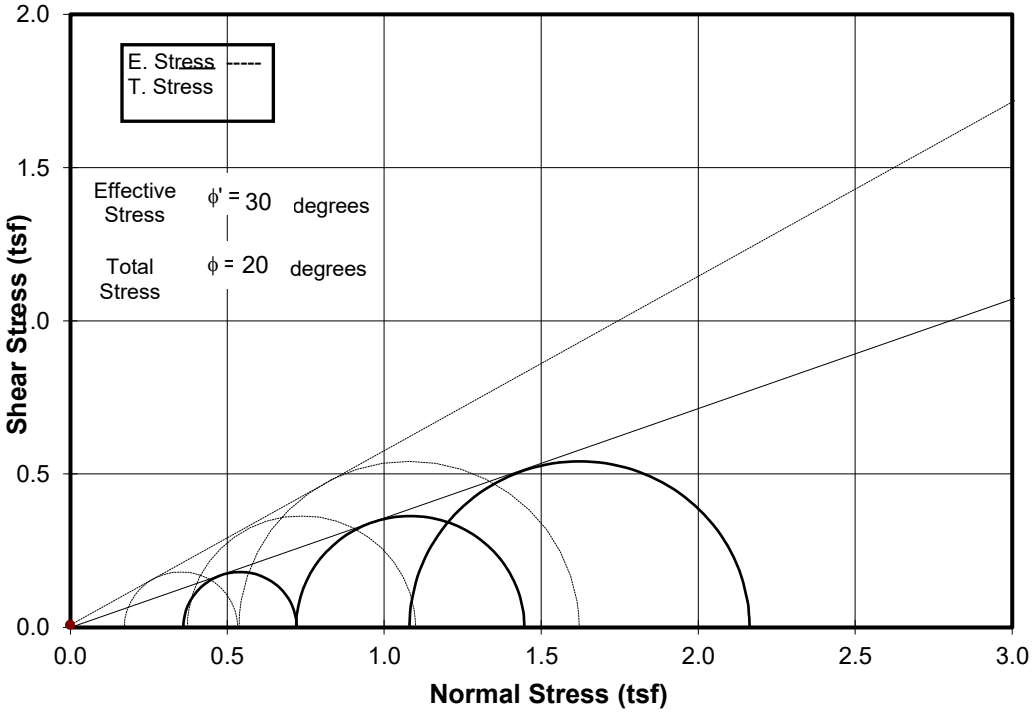
CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: LB-01
Sample No.: LSN-6057 Specimen No.: A
Depth (ft.): 1.0-5.0

Initial Height., H_o (in):	6.003	Confining Pressure (psi):	15.00
Initial Diameter, D_o (in):	2.882	Initial Volume, V_o (in^3):	39.17
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.52
t Change at End of Consol.,ΔH_o (in):	0.086 H_c 5.917	Area after Consol., A_c (in^2):	6.57
Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
ume change during Consol. V_c (cc^3):	5.20 0.3172 in^3		

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
150.07	0.214	119.69	97.57	105.00	3.617	6.813	0.15	1.25	7.41	24.98	3.37	0.55	0.63	1.17
156.07	0.220	118.07	97.67	105.00	3.720	6.820	0.15	1.24	7.31	24.63	3.37	0.55	0.62	1.15
162.07	0.226	117.74	97.75	104.97	3.819	6.827	0.16	1.23	7.24	24.48	3.38	0.56	0.62	1.14
168.07	0.232	116.52	97.84	104.98	3.921	6.834	0.16	1.22	7.14	24.19	3.39	0.56	0.61	1.13
174.07	0.238	115.09	97.93	104.97	4.025	6.842	0.17	1.20	7.05	23.87	3.39	0.57	0.61	1.11





SAMPLE INFORMATION

Boring: LB-03 Sample: -- Depth: 1.0-5.0 feet

SAMPLE DATA

Average Moisture Content (%):	18.0
Average Dry Unit Weight (pcf):	92.2

RESULTS

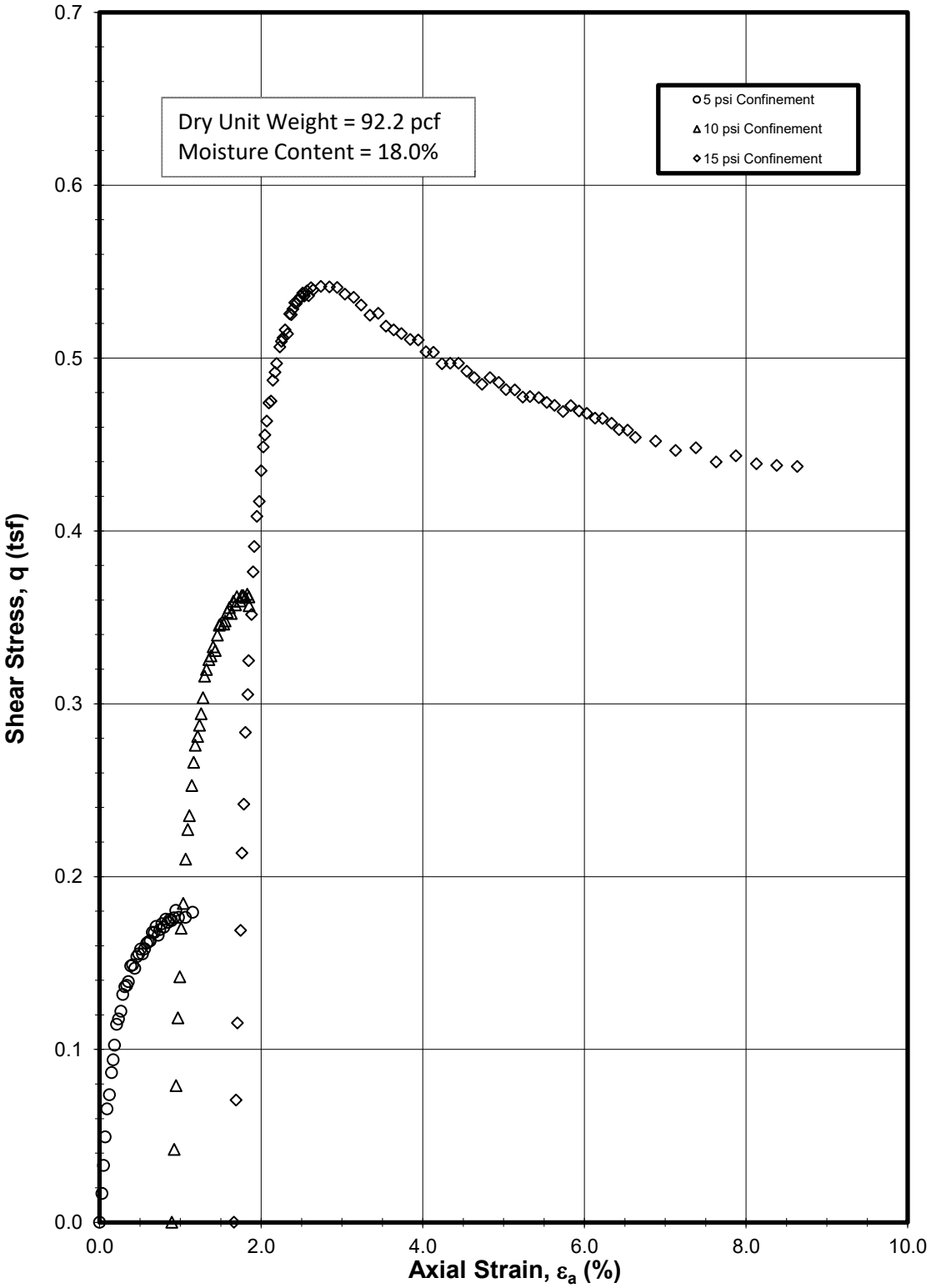
Total Friction Angle (degrees):	20
Effective Friction Angle (degrees):	30
Effective Cohesion (tsf):	0.0

Tested By: JMM	Calc'd By: JMM	Check'd By: CKK
Date: 10/22/2024	Date: 11/8/2024	Date: 11/11/2024

CWLP Ash Pond Samples
Springfield, Illinois
C43128

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ASTM D4767

Project Number: J040516.06.6404



CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST
ASTM D 4767
Project No.: J040516.06.6404
Boring: LB-03
Sample: LSN-6058 - Depth: 1.0-5.0

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: LB-03
Sample No.: LSN-6058 Specimen No.: A
Depth (ft.): 1.0-5.0

Initial Height., H_o (in): 5.929
Initial Diameter, D_o (in): 2.883
Membrane Thickness (in): 0.02
Ht Change at End of Consol.,ΔH_o (in): 0.002 H_c 5.927
Ht Change at End of Saturation, H_s (in): 0.000
Volume change during Consol. V_c (cc^3): 0.69 0.04209 in^3

Confining Pressure (psi): 5.00
Initial Volume, V_o (in^3): 38.71
Initial Area, A_o (in^2): 6.53
Area after Consol., A_c (in^2): 6.52
Piston Correction (lbs): 0.0

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	70.00	75.00	0.000	6.525	0.00	0.00	5.00	5.00	1.00	0.00	0.000	0.360
1.50	0.00	3.03	70.25	74.99	0.028	6.527	0.00	0.03	4.75	5.22	1.10	0.02	0.017	0.359
3.00	0.00	5.97	70.44	74.99	0.049	6.528	0.00	0.07	4.56	5.47	1.20	0.03	0.033	0.361
4.50	0.00	8.98	70.62	74.99	0.069	6.529	0.00	0.10	4.38	5.75	1.31	0.04	0.050	0.365
6.02	0.01	11.90	70.77	75.00	0.093	6.531	0.00	0.13	4.22	6.04	1.43	0.06	0.066	0.370
7.52	0.01	13.38	70.91	74.98	0.121	6.533	0.01	0.15	4.09	6.13	1.50	0.07	0.074	0.368
9.02	0.01	15.73	71.03	74.99	0.148	6.534	0.01	0.17	3.96	6.37	1.61	0.07	0.087	0.372
10.52	0.01	17.07	71.14	74.99	0.167	6.536	0.01	0.19	3.86	6.47	1.68	0.08	0.094	0.372
12.02	0.01	18.62	71.22	74.98	0.186	6.537	0.01	0.20	3.77	6.62	1.75	0.09	0.103	0.374
13.52	0.01	20.80	71.31	74.99	0.213	6.539	0.01	0.23	3.69	6.87	1.86	0.09	0.115	0.380
15.02	0.01	21.39	71.39	74.99	0.236	6.540	0.01	0.23	3.61	6.88	1.91	0.10	0.118	0.378
16.53	0.02	22.20	71.45	74.98	0.266	6.542	0.01	0.24	3.55	6.94	1.96	0.10	0.122	0.378
18.03	0.02	23.97	71.52	74.99	0.287	6.544	0.01	0.26	3.48	7.15	2.05	0.11	0.132	0.383
19.53	0.02	24.79	71.58	74.99	0.312	6.545	0.01	0.27	3.41	7.20	2.11	0.11	0.136	0.382
21.03	0.02	24.94	71.63	74.98	0.337	6.547	0.01	0.27	3.36	7.17	2.13	0.12	0.137	0.379
22.55	0.02	25.34	71.69	74.98	0.357	6.548	0.01	0.28	3.30	7.17	2.17	0.12	0.139	0.377
24.05	0.02	27.00	71.75	74.98	0.386	6.550	0.02	0.30	3.24	7.37	2.27	0.13	0.148	0.382
25.57	0.02	27.11	71.81	74.99	0.409	6.552	0.02	0.30	3.18	7.32	2.30	0.13	0.149	0.378
27.07	0.03	26.76	71.87	74.98	0.434	6.553	0.02	0.29	3.13	7.21	2.30	0.13	0.147	0.372
28.58	0.03	28.01	71.93	74.98	0.462	6.555	0.02	0.31	3.07	7.34	2.39	0.14	0.154	0.375
30.08	0.03	28.30	71.99	74.99	0.485	6.557	0.02	0.31	3.01	7.33	2.43	0.14	0.155	0.372
31.58	0.03	28.80	72.04	74.98	0.509	6.558	0.02	0.31	2.96	7.35	2.49	0.15	0.158	0.371
33.10	0.03	28.31	72.09	74.97	0.530	6.560	0.02	0.31	2.91	7.23	2.48	0.15	0.155	0.365
34.60	0.03	28.84	72.13	74.98	0.558	6.561	0.02	0.31	2.86	7.26	2.54	0.15	0.158	0.364
36.10	0.03	29.45	72.19	74.98	0.583	6.563	0.02	0.32	2.81	7.30	2.60	0.16	0.162	0.364
37.62	0.04	29.59	72.23	74.99	0.605	6.565	0.03	0.32	2.76	7.27	2.63	0.16	0.162	0.361
39.12	0.04	29.71	72.27	74.98	0.628	6.566	0.03	0.32	2.73	7.25	2.66	0.16	0.163	0.359
40.62	0.04	30.61	72.31	74.98	0.654	6.568	0.03	0.33	2.68	7.34	2.74	0.17	0.168	0.361
42.12	0.04	30.61	72.35	74.98	0.677	6.569	0.03	0.33	2.65	7.31	2.76	0.17	0.168	0.358
43.63	0.04	31.24	72.38	74.98	0.699	6.571	0.03	0.34	2.62	7.37	2.82	0.17	0.171	0.360
45.13	0.04	30.33	72.42	74.97	0.727	6.573	0.03	0.33	2.58	7.19	2.79	0.17	0.166	0.352
46.63	0.04	30.92	72.44	74.98	0.747	6.574	0.03	0.34	2.55	7.26	2.84	0.18	0.169	0.353
48.13	0.05	31.56	72.46	74.98	0.773	6.576	0.03	0.34	2.54	7.34	2.89	0.18	0.173	0.355
49.63	0.05	31.19	72.49	74.97	0.794	6.577	0.03	0.34	2.51	7.25	2.89	0.18	0.171	0.351
51.13	0.05	32.04	72.51	74.98	0.819	6.579	0.03	0.35	2.48	7.35	2.96	0.18	0.175	0.354
52.63	0.05	31.72	72.53	74.97	0.845	6.580	0.04	0.34	2.47	7.29	2.95	0.18	0.174	0.351
54.13	0.05	32.05	72.56	74.98	0.870	6.582	0.04	0.35	2.44	7.31	3.00	0.18	0.175	0.351
55.65	0.05	31.93	72.57	74.98	0.890	6.583	0.04	0.35	2.42	7.27	3.00	0.19	0.175	0.349
57.15	0.05	32.23	72.59	74.98	0.922	6.586	0.04	0.35	2.41	7.30	3.03	0.19	0.176	0.349
58.65	0.06	33.03	72.60	74.98	0.943	6.587	0.04	0.36	2.40	7.41	3.09	0.19	0.181	0.353
60.17	0.06	32.30	72.62	74.99	0.977	6.589	0.04	0.35	2.37	7.28	3.07	0.19	0.176	0.347
66.17	0.06	32.33	72.67	74.98	1.063	6.595	0.04	0.35	2.32	7.23	3.11	0.19	0.176	0.344
70.98	0.07	32.91	72.71	74.98	1.151	6.601	0.05	0.36	2.29	7.28	3.18	0.20	0.179	0.344

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: LB-03
Sample No.: LSN-6058 Specimen No.: A
Depth (ft.): 1.0-5.0

Initial Height., H_o (in):	5.929	Confining Pressure (psi):	10.00
Initial Diameter, D_o (in):	2.883	Initial Volume, V_o (in^3):	38.71
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.53
Ht Change at End of Consol., ΔH_o (in):	0.063 H_c 5.866	Area after Consol., A_c (in^2):	6.57
Ht Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
Volume change during Consol. V_c (cc^3):	3.06 0.18666 in^3		

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.05	0.00	70.00	79.99	0.896	6.627	0.04	0.00	9.99	9.99	1.00	0.00	0.00	0.72
1.50	0.05	7.78	70.41	79.98	0.922	6.629	0.04	0.08	9.58	10.76	1.12	0.03	0.04	0.73
3.00	0.06	14.57	70.78	79.99	0.947	6.631	0.04	0.16	9.21	11.41	1.24	0.06	0.08	0.74
4.50	0.06	21.78	71.11	79.99	0.971	6.632	0.04	0.23	8.88	12.16	1.37	0.08	0.12	0.76
6.00	0.06	26.18	71.42	79.99	0.994	6.634	0.04	0.28	8.57	12.52	1.46	0.10	0.14	0.76
7.50	0.06	31.35	71.69	79.99	1.009	6.635	0.04	0.34	8.30	13.03	1.57	0.12	0.17	0.77
9.00	0.06	34.01	71.92	79.99	1.038	6.637	0.04	0.37	8.07	13.20	1.63	0.14	0.18	0.77
10.50	0.06	38.73	72.12	79.98	1.065	6.639	0.04	0.42	7.87	13.70	1.74	0.15	0.21	0.78
12.00	0.06	41.92	72.32	79.99	1.091	6.640	0.05	0.45	7.67	13.98	1.82	0.17	0.23	0.78
13.50	0.07	43.42	72.50	79.98	1.112	6.642	0.05	0.47	7.49	14.03	1.87	0.18	0.24	0.77
15.02	0.07	46.65	72.66	79.99	1.141	6.644	0.05	0.50	7.33	14.35	1.96	0.19	0.25	0.78
16.52	0.07	49.12	72.81	80.00	1.166	6.646	0.05	0.53	7.18	14.57	2.03	0.20	0.27	0.78
18.02	0.07	50.96	72.95	79.99	1.184	6.647	0.05	0.55	7.04	14.71	2.09	0.21	0.28	0.78
19.52	0.07	51.92	73.07	79.99	1.216	6.649	0.05	0.56	6.92	14.73	2.13	0.22	0.28	0.78
21.02	0.07	53.12	73.20	79.98	1.237	6.650	0.05	0.57	6.79	14.78	2.18	0.23	0.29	0.78
22.52	0.07	54.35	73.31	79.99	1.257	6.652	0.05	0.58	6.68	14.85	2.22	0.24	0.29	0.78
24.02	0.08	56.08	73.41	80.00	1.280	6.653	0.05	0.60	6.58	15.01	2.28	0.25	0.30	0.78
25.52	0.08	58.41	73.50	79.99	1.301	6.655	0.05	0.63	6.49	15.27	2.35	0.25	0.32	0.78
27.02	0.08	59.12	73.60	79.99	1.324	6.656	0.06	0.64	6.39	15.27	2.39	0.26	0.32	0.78
28.52	0.08	60.22	73.69	80.00	1.352	6.658	0.06	0.65	6.30	15.35	2.43	0.27	0.33	0.78
30.02	0.08	60.62	73.77	79.99	1.381	6.660	0.06	0.65	6.23	15.33	2.46	0.27	0.33	0.78
31.53	0.08	61.63	73.85	80.00	1.406	6.662	0.06	0.66	6.14	15.40	2.51	0.28	0.33	0.78
33.03	0.08	61.24	73.92	79.99	1.431	6.663	0.06	0.66	6.07	15.26	2.51	0.28	0.33	0.77
34.53	0.09	62.91	73.99	80.00	1.459	6.665	0.06	0.68	6.00	15.44	2.57	0.29	0.34	0.77
36.03	0.09	63.97	74.06	80.00	1.481	6.667	0.06	0.69	5.93	15.52	2.62	0.29	0.35	0.77
37.53	0.09	64.13	74.13	79.99	1.500	6.668	0.06	0.69	5.86	15.48	2.64	0.30	0.35	0.77
39.03	0.09	64.12	74.19	80.00	1.537	6.671	0.06	0.69	5.80	15.41	2.66	0.30	0.35	0.76
40.53	0.09	64.49	74.26	80.00	1.556	6.672	0.06	0.69	5.74	15.40	2.69	0.31	0.35	0.76
42.03	0.09	65.44	74.32	80.00	1.581	6.674	0.07	0.70	5.67	15.48	2.73	0.31	0.35	0.76
43.53	0.09	65.94	74.38	80.00	1.608	6.675	0.07	0.71	5.62	15.49	2.76	0.31	0.36	0.76
45.03	0.10	65.34	74.43	79.99	1.630	6.677	0.07	0.70	5.56	15.35	2.76	0.32	0.35	0.75
46.53	0.10	66.68	74.49	80.00	1.658	6.679	0.07	0.71	5.50	15.49	2.81	0.32	0.36	0.76
48.03	0.10	66.29	74.54	80.00	1.683	6.680	0.07	0.71	5.45	15.37	2.82	0.33	0.36	0.75
49.53	0.10	67.18	74.58	80.00	1.701	6.682	0.07	0.72	5.41	15.46	2.86	0.33	0.36	0.75
51.03	0.10	66.76	74.63	80.00	1.740	6.684	0.07	0.71	5.36	15.35	2.86	0.33	0.36	0.75
52.53	0.10	67.33	74.67	80.00	1.759	6.686	0.07	0.72	5.32	15.39	2.89	0.34	0.36	0.75
54.03	0.10	67.36	74.72	80.01	1.779	6.687	0.07	0.72	5.27	15.34	2.91	0.34	0.36	0.74
55.53	0.11	67.17	74.76	80.01	1.804	6.689	0.08	0.72	5.23	15.27	2.92	0.34	0.36	0.74
57.03	0.11	67.53	74.81	80.00	1.828	6.690	0.08	0.72	5.18	15.28	2.95	0.35	0.36	0.74
58.53	0.11	67.27	74.84	80.01	1.849	6.692	0.08	0.72	5.15	15.20	2.95	0.35	0.36	0.73
58.68	0.11	66.30	74.85	79.99	1.852	6.692	0.08	0.71	5.14	15.05	2.93	0.35	0.36	0.73

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: LB-03
Sample No.: LSN-6058 Specimen No.: A
Depth (ft.): 1.0-5.0

Initial Height., H_o (in): 5.929
Initial Diameter, D_o (in): 2.883
Membr. Thickness (in): 0.02
t Change at End of Consol., ΔH_o (in): 0.086 H_c 5.843
Change at End of Saturation, H_s (in): 0.000
ume change during Consol. V_c (cc^3): 5.20 0.3172 in^3

Confining Pressure (psi): 15.00
Initial Volume, V_o (in^3): 38.71
Initial Area, A_o (in^2): 6.53
Area after Consol., A_c (in^2): 6.57
Piston Correction (lbs): 0.0

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.097	0.00	69.96	84.96	1.664	6.683	0.07	0.00	15.00	15.00	1.00	0.00	0.00	1.08
1.50	0.099	13.14	70.60	84.97	1.691	6.685	0.07	0.14	14.36	16.33	1.14	0.05	0.07	1.10
3.00	0.100	21.43	71.17	84.95	1.705	6.686	0.07	0.23	13.80	17.00	1.23	0.09	0.12	1.11
4.52	0.102	31.39	71.69	84.97	1.747	6.688	0.07	0.33	13.28	17.97	1.35	0.12	0.17	1.12
6.02	0.103	39.71	72.15	84.97	1.763	6.689	0.07	0.42	12.81	18.74	1.46	0.16	0.21	1.14
7.52	0.104	44.97	72.54	84.96	1.785	6.691	0.07	0.48	12.43	19.15	1.54	0.19	0.24	1.14
9.02	0.105	52.69	72.91	84.97	1.804	6.692	0.08	0.56	12.05	19.93	1.65	0.21	0.28	1.15
10.52	0.107	56.77	73.24	84.96	1.834	6.694	0.08	0.61	11.73	20.21	1.72	0.24	0.31	1.15
12.02	0.108	60.42	73.53	84.96	1.846	6.695	0.08	0.64	11.44	20.46	1.79	0.26	0.32	1.15
13.52	0.110	65.41	73.80	84.97	1.881	6.698	0.08	0.70	11.16	20.93	1.87	0.28	0.35	1.16
15.03	0.111	70.03	74.04	84.96	1.901	6.699	0.08	0.75	10.92	21.37	1.96	0.29	0.38	1.16
16.53	0.112	72.78	74.27	84.95	1.916	6.700	0.08	0.78	10.69	21.55	2.02	0.31	0.39	1.16
18.03	0.114	76.03	74.49	84.97	1.947	6.702	0.08	0.81	10.48	21.82	2.08	0.33	0.41	1.16
19.53	0.115	77.67	74.68	84.95	1.976	6.704	0.08	0.83	10.28	21.87	2.13	0.34	0.42	1.16
21.03	0.117	80.98	74.85	84.96	1.999	6.706	0.08	0.86	10.11	22.19	2.19	0.35	0.43	1.16
22.53	0.118	83.58	75.02	84.96	2.026	6.707	0.08	0.89	9.94	22.40	2.25	0.36	0.45	1.16
24.03	0.120	84.88	75.18	84.96	2.046	6.709	0.09	0.90	9.78	22.43	2.29	0.38	0.46	1.16
25.53	0.121	86.41	75.33	84.96	2.070	6.710	0.09	0.92	9.63	22.50	2.34	0.39	0.46	1.16
27.03	0.123	88.39	75.48	84.97	2.097	6.712	0.09	0.94	9.48	22.65	2.39	0.40	0.47	1.16
28.53	0.124	88.62	75.60	84.95	2.122	6.714	0.09	0.94	9.36	22.56	2.41	0.41	0.48	1.15
30.05	0.125	90.86	75.73	84.96	2.146	6.716	0.09	0.97	9.24	22.77	2.47	0.42	0.49	1.15
31.55	0.127	91.76	75.84	84.96	2.171	6.717	0.09	0.98	9.12	22.78	2.50	0.42	0.49	1.15
33.05	0.128	92.72	75.95	84.95	2.191	6.719	0.09	0.99	9.01	22.81	2.53	0.43	0.50	1.15
34.55	0.130	94.56	76.06	84.96	2.230	6.721	0.09	1.01	8.90	22.97	2.58	0.44	0.51	1.15
36.05	0.132	95.18	76.16	84.96	2.252	6.723	0.09	1.01	8.80	22.96	2.61	0.45	0.51	1.14
37.55	0.133	95.57	76.26	84.95	2.272	6.724	0.09	1.02	8.70	22.91	2.63	0.45	0.51	1.14
39.05	0.134	96.46	76.36	84.96	2.297	6.726	0.10	1.03	8.60	22.94	2.67	0.46	0.52	1.14
40.55	0.136	96.07	76.44	84.95	2.326	6.728	0.10	1.02	8.52	22.80	2.68	0.47	0.51	1.13
42.05	0.138	98.25	76.53	84.96	2.353	6.730	0.10	1.04	8.43	23.03	2.73	0.47	0.53	1.13
43.55	0.139	98.18	76.60	84.95	2.372	6.731	0.10	1.04	8.36	22.95	2.74	0.48	0.53	1.13
45.05	0.140	98.81	76.68	84.95	2.393	6.733	0.10	1.05	8.28	22.96	2.77	0.48	0.53	1.12
46.57	0.141	99.52	76.76	84.96	2.417	6.734	0.10	1.06	8.21	22.98	2.80	0.49	0.53	1.12
48.07	0.142	99.45	76.83	84.95	2.437	6.736	0.10	1.06	8.14	22.90	2.81	0.49	0.53	1.12
49.57	0.144	99.91	76.89	84.96	2.468	6.738	0.10	1.06	8.07	22.90	2.84	0.50	0.53	1.11
51.07	0.145	100.27	76.96	84.95	2.490	6.739	0.10	1.06	8.00	22.88	2.86	0.50	0.54	1.11
52.57	0.147	100.67	77.02	84.96	2.515	6.741	0.10	1.07	7.95	22.88	2.88	0.51	0.54	1.11
54.07	0.148	100.36	77.08	84.95	2.536	6.743	0.11	1.06	7.89	22.77	2.89	0.51	0.54	1.10
55.57	0.150	100.95	77.13	84.95	2.567	6.745	0.11	1.07	7.83	22.79	2.91	0.52	0.54	1.10
57.07	0.151	100.44	77.19	84.95	2.588	6.746	0.11	1.06	7.78	22.66	2.91	0.52	0.54	1.10
58.57	0.153	101.36	77.25	84.96	2.617	6.748	0.11	1.07	7.71	22.73	2.95	0.52	0.54	1.10
60.07	0.154	101.16	77.30	84.96	2.642	6.750	0.11	1.07	7.66	22.65	2.96	0.53	0.54	1.09
66.07	0.160	101.63	77.49	84.96	2.738	6.757	0.11	1.07	7.47	22.51	3.01	0.54	0.54	1.08
72.07	0.166	101.68	77.67	84.95	2.845	6.764	0.12	1.07	7.30	22.33	3.06	0.55	0.54	1.07
78.08	0.172	101.72	77.83	84.96	2.941	6.771	0.12	1.07	7.13	22.15	3.11	0.57	0.54	1.05
84.08	0.177	101.10	77.98	84.96	3.035	6.777	0.13	1.06	6.98	21.90	3.14	0.58	0.54	1.04
90.08	0.184	100.86	78.11	84.96	3.144	6.785	0.13	1.06	6.85	21.72	3.17	0.59	0.54	1.03
96.08	0.189	100.10	78.24	84.96	3.237	6.791	0.13	1.05	6.72	21.46	3.19	0.60	0.53	1.01
102.08	0.195	99.11	78.35	84.96	3.345	6.799	0.14	1.04	6.61	21.19	3.21	0.60	0.52	1.00
108.08	0.201	99.42	78.46	84.97	3.447	6.806	0.14	1.04	6.50	21.11	3.25	0.61	0.53	0.99
114.08	0.207	98.13	78.56	84.96	3.544	6.813	0.15	1.03	6.40	20.80	3.25	0.62	0.52	0.98
120.08	0.213	97.82	78.65	84.96	3.639	6.820	0.15	1.02	6.31	20.65	3.27	0.63	0.52	0.97
126.08	0.218	97.49	78.74	84.96	3.736	6.827	0.16	1.02	6.22	20.50	3.30	0.63	0.51	0.96
132.08	0.225	96.97	78.81	84.95	3.845	6.834	0.16	1.01	6.16	20.34	3.30	0.64	0.51	0.95
138.10	0.230	96.99	78.89	84.96	3.943	6.841	0.16	1.01	6.07	20.25	3.34	0.64	0.51	0.95
144.10	0.236	95.81	78.96	84.96	4.040	6.848	0.17	1.00	6.00	19.99	3.33	0.65	0.50	0.94

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J040516.06.6404 Boring No.: LB-03
Sample No.: LSN-6058 Specimen No.: A
Depth (ft.): 1.0-5.0

Initial Height., H_o (in): 5.929
Initial Diameter, D_o (in): 2.883
Membr. Thickness (in): 0.02
t Change at End of Consol.,ΔH_o (in): 0.086 H_c 5.843
Change at End of Saturation, H_s (in): 0.000
ume change during Consol. V_c (cc^3): 5.20 0.3172 in^3

Confining Pressure (psi): 15.00
Initial Volume, V_o (in^3): 38.71
Initial Area, A_o (in^2): 6.53
Area after Consol., A_c (in^2): 6.57
Piston Correction (lbs): 0.0

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
150.10	0.241	95.84	79.02	84.97	4.132	6.855	0.17	0.99	5.94	19.92	3.35	0.65	0.50	0.93
156.10	0.248	94.69	79.10	84.96	4.236	6.862	0.18	0.98	5.87	19.67	3.35	0.66	0.50	0.92
162.10	0.253	94.86	79.14	84.97	4.338	6.870	0.18	0.98	5.82	19.63	3.37	0.66	0.50	0.92
168.10	0.260	94.95	79.20	84.97	4.443	6.877	0.18	0.98	5.76	19.57	3.40	0.67	0.50	0.91
174.10	0.266	94.17	79.24	84.96	4.545	6.884	0.19	0.97	5.72	19.40	3.39	0.67	0.49	0.90
180.10	0.271	93.55	79.31	84.97	4.638	6.891	0.19	0.96	5.66	19.23	3.40	0.67	0.49	0.90
186.10	0.276	92.91	79.35	84.96	4.732	6.898	0.20	0.96	5.61	19.08	3.40	0.68	0.48	0.89
192.12	0.282	93.73	79.40	84.97	4.832	6.905	0.20	0.96	5.57	19.14	3.44	0.68	0.49	0.89
198.12	0.289	93.30	79.44	84.96	4.940	6.913	0.21	0.96	5.52	19.02	3.44	0.68	0.49	0.88
204.12	0.294	92.58	79.48	84.96	5.031	6.920	0.21	0.95	5.48	18.86	3.44	0.69	0.48	0.88
210.12	0.300	92.67	79.52	84.96	5.139	6.928	0.21	0.95	5.44	18.82	3.46	0.69	0.48	0.87
216.12	0.306	91.97	79.55	84.95	5.238	6.935	0.22	0.94	5.41	18.67	3.45	0.69	0.48	0.87
222.12	0.311	92.11	79.60	84.96	5.328	6.941	0.22	0.94	5.37	18.64	3.47	0.69	0.48	0.86
228.12	0.318	92.11	79.61	84.95	5.435	6.949	0.23	0.94	5.35	18.60	3.48	0.69	0.48	0.86
234.13	0.323	91.65	79.67	84.97	5.536	6.957	0.23	0.93	5.29	18.47	3.49	0.70	0.47	0.86
240.13	0.329	91.42	79.70	84.97	5.630	6.964	0.23	0.93	5.26	18.39	3.49	0.70	0.47	0.85
246.13	0.335	90.85	79.74	84.96	5.737	6.972	0.24	0.92	5.22	18.26	3.49	0.70	0.47	0.85
252.13	0.341	91.60	79.76	84.97	5.832	6.979	0.24	0.93	5.21	18.33	3.52	0.71	0.47	0.85
258.13	0.347	91.08	79.79	84.96	5.934	6.986	0.25	0.92	5.17	18.21	3.52	0.71	0.47	0.84
264.13	0.352	90.92	79.82	84.97	6.028	6.993	0.25	0.92	5.14	18.14	3.53	0.71	0.47	0.84
270.13	0.358	90.46	79.84	84.96	6.132	7.001	0.26	0.91	5.12	18.05	3.52	0.71	0.47	0.83
276.15	0.364	90.53	79.87	84.97	6.224	7.008	0.26	0.91	5.09	18.01	3.54	0.71	0.47	0.83
282.15	0.370	90.11	79.89	84.96	6.337	7.016	0.26	0.91	5.08	17.92	3.53	0.71	0.46	0.83
288.15	0.376	89.48	79.91	84.96	6.428	7.023	0.27	0.90	5.06	17.80	3.52	0.72	0.46	0.82
294.15	0.382	89.51	79.93	84.95	6.533	7.031	0.27	0.90	5.03	17.76	3.53	0.72	0.46	0.82
300.15	0.387	88.78	79.95	84.95	6.631	7.038	0.28	0.89	5.01	17.62	3.52	0.72	0.45	0.81
315.15	0.402	88.59	79.99	84.95	6.881	7.057	0.29	0.88	4.97	17.52	3.53	0.72	0.45	0.81
330.15	0.416	87.77	80.06	84.96	7.128	7.076	0.30	0.87	4.90	17.30	3.53	0.73	0.45	0.80
345.15	0.431	88.32	80.11	84.96	7.379	7.095	0.31	0.87	4.86	17.30	3.56	0.73	0.45	0.80
360.15	0.446	86.93	80.15	84.95	7.629	7.114	0.32	0.86	4.81	17.03	3.54	0.73	0.44	0.79
375.17	0.460	87.87	80.18	84.96	7.876	7.133	0.33	0.86	4.79	17.10	3.57	0.74	0.44	0.79
390.17	0.475	87.19	80.21	84.95	8.128	7.153	0.34	0.85	4.75	16.94	3.57	0.74	0.44	0.78
405.17	0.490	87.26	80.25	84.96	8.379	7.173	0.35	0.85	4.71	16.88	3.58	0.74	0.44	0.78
420.17	0.504	87.35	80.28	84.97	8.634	7.193	0.36	0.85	4.68	16.83	3.59	0.74	0.44	0.77

APPENDIX C

Hydraulic Conductivity Results

HYDRAULIC CONDUCTIVITY TEST DATA

(ASTM D 5084, Method A)

				Initial Unit Weight		Unit Weight as Tested	
JOB NO.:	J040515.06.6404			WET UNIT WEIGHT, pcf:	119.3	WET UNIT WEIGHT, pcf:	119.3
SAMPLE ID:	LSN-6056	ASTM D698 Results		DRY UNIT WEIGHT, pcf:	106.1	DRY UNIT WEIGHT, pcf:	--
LOCATION:	CWLP Ash Pond Samples	Maximum Dry Unit Weight, pcf:	110.9	**Percent Compact:**	**95.7%**		
MATERIAL:	DB-01, 7'-10'	Optimum Water Content, %	12.5				

	Initial	As Tested**		Initial	As Tested	INITIAL MOISTURE CONTENT		FINAL MOISTURE CONTENT	
LENGTH, in.:	6.070	6.070	LENGTH, cm:	15.418	15.418	WET WT SPLE+TARE	1541.96	WET WT SPLE+TARE	
DIAMETER, in.:	2.882	2.882	DIAMETER, cm	7.320	7.320	DRY WT SPLE+TARE	1404.93	DRY WT SPLE+TARE	
WET WT., gms.:	1239.62	1239.62				TARE WEIGHT	302.34	TARE WEIGHT	
AREA, sq.in.:	6.523	6.523	AREA, sq cm:	42.087	42.087	**% MOISTURE**	12.4	% MOISTURE	Not determined

B VALUE (before Permeation): 95% Cell / Back Pressure, psi: 88 / 85 Percent Wet of Optimum: -0.1

HEAD (PSI)	DATE (YR,MO,DY)	TIME (HR,MN,SC)	TEMP °C	ELAPSED MINUTES	BOTTOM BURETTE	TOP BURETTE	Q (CC)	K CM/SEC	HYDRAULIC GRADIENT	HYDRAULIC HEAD	HEAD LOSS,%	k (in/sec)
0.0	07-Nov-24	02:31 PM	21.9	0	9.03	23.03			0.91	14.00		
0.0	07-Nov-24	02:34 PM	21.9	3	9.32	22.67	0.29	5.1E-05	0.87	13.35	4.64	2.0E-05
0.0	07-Nov-24	02:37 PM	21.9	3	9.60	22.30	0.28	5.3E-05	0.82	12.70	4.87	2.1E-05
0.0	07-Nov-24	02:47 PM	21.9	0	10.43	21.20			0.70	10.77		
0.0	07-Nov-24	02:50 PM	21.9	3	10.69	20.93	0.26	5.4E-05	0.66	10.24	4.92	2.1E-05
0.0	07-Nov-24	02:52 PM	21.9	2	10.83	20.75	0.14	5.1E-05	0.64	9.92	3.13	2.0E-05

Average Temp. = 21.9

AVERAGE K = 5.2E-05 AVERAGE K = 2.1E-05

Corrected K for 20ºC = 5.0E-05 Corrected K for 20ºC = 2.0E-05

** Measurements at end of test not possible.

HYDRAULIC CONDUCTIVITY TEST DATA

(ASTM D 5084, Method A)

				Initial Unit Weight		Unit Weight as Tested	
JOB NO.:	J040515.06.6404			WET UNIT WEIGHT, pcf:	124.9	WET UNIT WEIGHT, pcf:	124.9
SAMPLE ID:	LSN-6055	ASTM D698 Results		DRY UNIT WEIGHT, pcf:	111.8	DRY UNIT WEIGHT, pcf:	--
LOCATION:	CWLP Ash Pond Samples	Maximum Dry Unit Weight, pcf:	117.7	**Percent Compact:**	**95.0%**		
MATERIAL:	DB-04, 1'-5'	Optimum Water Content, %	12.7				

	Initial	As Tested**		Initial	As Tested	INITIAL MOISTURE CONTENT		FINAL MOISTURE CONTENT	
LENGTH, in.:	6.036	6.036	LENGTH, cm:	15.331	15.331	WET WT SPLE+TARE	1586.25	WET WT SPLE+TARE	
DIAMETER, in.:	2.895	2.895	DIAMETER, cm	7.353	7.353	DRY WT SPLE+TARE	1448.90	DRY WT SPLE+TARE	
WET WT., gms.:	1303.01	1303.01				TARE WEIGHT	283.24	TARE WEIGHT	
AREA, sq.in.:	6.582	6.582	AREA, sq cm:	42.467	42.467	**% MOISTURE**	11.8	% MOISTURE	Not determined

B VALUE (before Permeation): 95% Cell / Back Pressure, psi: 93 / 90 Percent From of Optimum: -0.9

HEAD (PSI)	DATE (YR,MO,DY)	TIME (HR,MN,SC)	TEMP °C	ELAPSED MINUTES	BOTTOM BURETTE	TOP BURETTE	Q (CC)	K CM/SEC	HYDRAULIC GRADIENT	HYDRAULIC HEAD	HEAD LOSS,%	k (in/sec)
0.0	07-Nov-24	03:30 PM	21.8	0	6.64	23.27			1.08	16.63		
0.0	07-Nov-24	03:30 PM	21.8	0.5	6.92	22.90	0.28	2.5E-04	1.04	15.98	3.91	9.9E-05
0.0	07-Nov-24	03:31 PM	21.8	0.5	7.25	22.56	0.33	2.7E-04	1.00	15.31	4.19	1.1E-04
0.0	07-Nov-24	03:31 PM	21.8	0.5	7.59	22.21	0.34	2.9E-04	0.95	14.62	4.51	1.1E-04
0.0	07-Nov-24	03:32 PM	21.8	0.5	7.90	21.92	0.31	2.6E-04	0.91	14.02	4.10	1.0E-04

Average Temp. = 21.8 **AVERAGE K =** 2.7E-04 AVERAGE K = 1.1E-04

Corrected K for 20ºC = 2.6E-04 Corrected K for 20ºC = 1.0E-04

** Measurements at end of test not possible.

HYDRAULIC CONDUCTIVITY TEST DATA

(ASTM D 5084, Method A)

				Initial Unit Weight		Unit Weight as Tested	
JOB NO.:	J040515.06.6404			WET UNIT WEIGHT, pcf:	110.5	WET UNIT WEIGHT, pcf:	110.5
SAMPLE ID:	LSN-6054	ASTM D698 Results		DRY UNIT WEIGHT, pcf:	94.9	DRY UNIT WEIGHT, pcf:	--
LOCATION:	CWLP Ash Pond Samples	Maximum Dry Unit Weight, pcf:	98.0	**Percent Compact:**	**96.8%**		
MATERIAL:	DB-05, 2'-5'	Optimum Water Content, %	16.0				

	Initial	As Tested**		Initial	As Tested	INITIAL MOISTURE CONTENT		FINAL MOISTURE CONTENT	
LENGTH, in.:	6.055	6.055	LENGTH, cm:	15.380	15.380	WET WT SPLE+TARE	1423.60	WET WT SPLE+TARE	
DIAMETER, in.:	2.882	2.882	DIAMETER, cm	7.320	7.320	DRY WT SPLE+TARE	1261.77	DRY WT SPLE+TARE	
WET WT., gms.:	1145.30	1145.30				TARE WEIGHT	278.30	TARE WEIGHT	
AREA, sq.in.:	6.523	6.523	AREA, sq cm:	42.087	42.087	**% MOISTURE**	16.5	% MOISTURE	Not determined

B VALUE (before Permeation): 96% Cell / Back Pressure, psi: 63 / 60 Percent From of Optimum: 0.5

HEAD (PSI)	DATE (YR,MO,DY)	TIME (HR,MN,SC)	TEMP °C	ELAPSED MINUTES	BOTTOM BURETTE	TOP BURETTE	Q (CC)	K CM/SEC	HYDRAULIC GRADIENT	HYDRAULIC HEAD	HEAD LOSS,%	k (in/sec)
0.0	30-Nov-24	11:52 AM	22.8	0	12.04	23.73			0.76	11.69		
0.0	30-Nov-24	12:00 PM	22.8	8	12.24	23.47	0.20	1.6E-05	0.73	11.23	3.93	6.3E-06
0.0	30-Nov-24	12:11 PM	22.7	0	12.57	23.14			0.69	10.57		
0.0	30-Nov-24	12:20 PM	22.7	9	12.81	22.88	0.24	1.7E-05	0.65	10.07	4.73	6.8E-06
0.0	30-Nov-24	12:29 PM	22.7	9	13.05	22.65	0.24	1.7E-05	0.62	9.60	4.67	6.7E-06
0.0	30-Nov-24	12:38 PM	22.6	9	13.26	22.43	0.21	1.6E-05	0.60	9.17	4.48	6.4E-06
0.0	30-Nov-24	12:47 PM	22.6	9	13.48	22.21	0.22	1.7E-05	0.57	8.73	4.80	6.9E-06
		Average Temp. =	**22.7**				**AVERAGE K =**	**1.7E-05**			AVERAGE K =	6.6E-06
							Corrected K for 20ºC =	**1.6E-05**			Corrected K for 20ºC =	6.2E-06

** Measurements at end of test not possible.

HYDRAULIC CONDUCTIVITY TEST DATA

(ASTM D 5084, Method A)

				Initial Unit Weight		Unit Weight as Tested	
JOB NO.:	J040515.06.6404			WET UNIT WEIGHT, pcf:	114.5	WET UNIT WEIGHT, pcf:	114.4
SAMPLE ID:	LSN-6057	ASTM D698 Results		DRY UNIT WEIGHT, pcf:	100.7	DRY UNIT WEIGHT, pcf:	--
LOCATION:	CWLP Ash Pond Samples	Maximum Dry Unit Weight, pcf:	104.1	**Percent Compact:**	**96.7%**		
MATERIAL:	LB-01, 1'-5'	Optimum Water Content, %	13.9				

	Initial	As Tested**		Initial	As Tested	INITIAL MOISTURE CONTENT		FINAL MOISTURE CONTENT	
LENGTH, in.:	3.000	3.000	LENGTH, cm:	7.620	7.620	WET WT SPLE+TARE	871.21	WET WT SPLE+TARE	
DIAMETER, in.:	2.881	2.883	DIAMETER, cm	7.318	7.323	DRY WT SPLE+TARE	800.08	DRY WT SPLE+TARE	
WET WT., gms.:	587.93	587.93				TARE WEIGHT	283.28	TARE WEIGHT	
AREA, sq.in.:	6.519	6.528	AREA, sq cm:	42.058	42.116	**% MOISTURE**	13.8	% MOISTURE	Not determined

B VALUE (before Permeation): 95% Cell / Back Pressure, psi: 93 / 90 Percent Wet of Optimum: -0.1

HEAD (PSI)	DATE (YR,MO,DY)	TIME (HR,MN,SC)	TEMP °C	ELAPSED MINUTES	BOTTOM BURETTE	TOP BURETTE	Q (CC)	K CM/SEC	HYDRAULIC GRADIENT	HYDRAULIC HEAD	HEAD LOSS,%	k (in/sec)
0.0	09-Oct-24	11:42 AM	20.8	0	11.35	14.13			0.36	2.78		
0.0	09-Oct-24	11:43 AM	20.8	1	11.39	14.08	0.04	5.2E-05	0.35	2.69	3.24	2.1E-05
0.0	09-Oct-24	11:44 AM	20.8	1	11.43	14.03	0.04	5.4E-05	0.34	2.60	3.35	2.1E-05
0.0	09-Oct-24	11:45 AM	20.7	1	11.49	13.98	0.06	6.8E-05	0.33	2.49	4.23	2.7E-05
0.0	09-Oct-24	11:46 AM	20.8	1	11.55	13.93	0.06	7.2E-05	0.31	2.38	4.42	2.8E-05

Average Temp. = 20.8 **AVERAGE K = 6.1E-05** AVERAGE K = 2.4E-05

Corrected K for 20ºC = 6.0E-05 Corrected K for 20ºC = 2.4E-05

** Measurements at end of test not possible.

HYDRAULIC CONDUCTIVITY TEST DATA

(ASTM D 5084, Method A)

				Initial Unit Weight		Unit Weight as Tested	
JOB NO.:	J040515.06.6404			WET UNIT WEIGHT, pcf:	108.0	WET UNIT WEIGHT, pcf:	108.0
SAMPLE ID:	LSN-6058	ASTM D698 Results		DRY UNIT WEIGHT, pcf:	91.5	DRY UNIT WEIGHT, pcf:	--
LOCATION:	CWLP Ash Pond Samples	Maximum Dry Unit Weight, pcf:	93.0	**Percent Compact:**	**98.4%**		
MATERIAL:	LB-03, 1'-5'	Optimum Water Content, %	18.2				

	Initial	As Tested**		Initial	As Tested	INITIAL MOISTURE CONTENT		FINAL MOISTURE CONTENT	
LENGTH, in.:	5.989	5.989	LENGTH, cm:	15.212	15.212	WET WT SPLE+TARE	838.36	WET WT SPLE+TARE	
DIAMETER, in.:	2.878	2.878	DIAMETER, cm	7.310	7.310	DRY WT SPLE+TARE	754.24	DRY WT SPLE+TARE	
WET WT., gms.:	1104.22	1104.22				TARE WEIGHT	286.25	TARE WEIGHT	
AREA, sq.in.:	6.505	6.505	AREA, sq cm:	41.970	41.970	**% MOISTURE**	18.0	% MOISTURE	Not determined

B VALUE (before Permeation): 99% Cell / Back Pressure, psi: 63 / 60 Percent Wet of Optimum: -0.2

HEAD (PSI)	DATE (YR,MO,DY)	TIME (HR,MN,SC)	TEMP °C	ELAPSED MINUTES	BOTTOM BURETTE	TOP BURETTE	Q (CC)	K CM/SEC	HYDRAULIC GRADIENT	HYDRAULIC HEAD	HEAD LOSS.%	k (in/sec)
0.0	07-Nov-24	03:37 PM	21.5	0	4.00	22.76			1.23	18.76		
0.0	07-Nov-24	03:37 PM	21.5	0.5	4.46	22.37	0.46	2.9E-04	1.18	17.91	4.53	1.2E-04
0.0	07-Nov-24	03:38 PM	21.5	0.5	4.87	21.93	0.41	3.1E-04	1.12	17.06	4.75	1.2E-04
0.0	07-Nov-24	03:38 PM	21.5	0.5	5.16	21.60	0.29	2.3E-04	1.08	16.44	3.63	9.2E-05
0.0	07-Nov-24	03:39 PM	21.5	0.5	5.50	21.27	0.34	2.6E-04	1.04	15.77	4.08	1.0E-04
0.0	07-Nov-24	03:39 PM	21.5	0.5	5.83	20.95	0.33	2.7E-04	0.99	15.12	4.12	1.1E-04
0.0	07-Nov-24	03:40 PM	21.5	0.5	6.14	20.60	0.31	2.8E-04	0.95	14.46	4.37	1.1E-04

Average Temp. = 21.5

AVERAGE K = 2.8E-04 AVERAGE K = 1.1E-04

Corrected K for 20ºC = 2.7E-04 Corrected K for 20ºC = 1.0E-04

** Measurements at end of test not possible.

APPENDIX D

Test Assignments

Janet May

From: Nicholas Wendling <nwendling@metgeotech.com>
Sent: Tuesday, September 24, 2024 10:15 AM
To: Janet May
Subject: Bucket Sample Testing
Attachments: C43128 Proctor 2 - DB01-1 7-10, 9-13-2024.pdf; C43128 Proctor 3 - LB-3 1-5, 9-13-2024.pdf; C43128 Proctor 4 - LB01 1-5 9-13-2024.pdf; C43128 Proctor 5 - DB05 2-5, 9-13-2024.pdf; C43128 Proctor 1 - DB04 1-5, 9-12-2024.pdf

This Message Is From an External Sender
This message came from outside your organization.

Janet,

My tech will also be bringing 5 bulk samples for testing as well, consisting of 2 buckets per sample. We are looking for hydraulic conductivity (D5084), CU multi stage triaxial testing at 5, 10, 15 psi confining pressures, and specific gravity testing (D854) for each sample. I have attached standard proctor curves for your use, and samples are to be molded between 95 and 100 percent of maximum DD, at OMC.

Project: CWLP Ash Pond Samples
Springfield, Illinois
MET Project C43128

Thanks,
Nick Wendling, PE
Geotechnical Department Manager
Cell:217-621-0417
Email:nwendling@metgeotech.com

Midwest Engineering and Testing, Inc.
501 Mercury Drive, Champaign, IL 61822
Ph:217-359-2128|Fax:217-359-8446

HANSON
Engineering | Planning | Allied Services

Hanson Professional Services Inc.
1525 South Sixth Street
Springfield, Illinois 62703
(217) 788-2450
fax (217) 788-2503
www.hanson-inc.com

February 15, 2022

Mr. Bill Antonacci
Project and Construction
City Water, Light and Power
3100 Stevenson Drive
Springfield, IL 62703
bill.antonacci@cwlp.com

RE: Summary Memorandum
Lime Pond Cap Stability Assessment
Lakeside and Dallman Ash ponds
Hanson Project 21E0080

Dear Mr. Antonacci:

This memorandum summarizes the results of our study to evaluate the lime pond sludge currently in place, along with a series of lime pond sludge/ash mixtures to determine the stability of the material under a proposed capping scenario as required by IL EPA requirements.

It should be noted that the IL EPA ash pond closure requirements include a seismic stability analysis to determine any potential hazards due to seismic movement. This evaluation is not included in this memorandum, but only the in-situ lime pond sludge and ash combination mixtures for stability in a static environment with construction loads only.

Hanson obtained the following samples from the Lakeside Ash Pond Area in 5-gallon buckets:

- In-situ lime pond sludge – 20 buckets
- In-situ ash – 15 buckets

The following mixtures were prepared by the laboratory for analysis:

1. 100% lime pond sludge
2. 70% lime pond sludge/30% ash
3. 50% lime pond sludge/50% ash
4. 30% lime pond sludge/70% ash

The following tests for the mixtures identified were performed to assist in determining the stability of the material under a capped scenario.

- ASTM D698 – Compaction test – Standard Proctor
- ASTM D4767 - CU Triaxial test envelope
- ASTM D1140 & D7928 - Grain size analysis (combined)
- ASTM D4318 – Atterberg Limits
- Total Porosity Test

- Field Capacity Test
- Wilting Point Test

Hanson assumed that the cap will consist of a sheet of 40-mil HPDE plastic and three feet thick final protective layer [35 IAC 845.750(c)(1)(B) & 750(c)(2).

The results of the laboratory testing performed on the lime sludge and sludge-ash mixtures is provided in the table below:

Test	Property	% Sludge (% S) and % Ash (% A)			
		100% S	70% S - 30% A	50% S - 50% A	30% S - 70% A
ASTM D4318	LL	NP	NP	NP	NP
	PL	NP	NP	NP	NP
	PI	NP	NP	NP	NP
ASTM D1140	% Pass # 200	85.8	61.6	50.7	42.9
ASTM D698	Max DD (pcf)	87.6	90.1	99	102.9
	Optimum %w	21.5	21.7	16.5	15.9
ASTM D4767	ϕ degrees	39	30	41	38
	ϕ' degrees	40	40	40	38
	c (psf)	250	200	0	300
	c' (psf)	0	0	200	300
Porosity	%	62.1	54.8	49.7	47.5
Field Capacity	%w	44.2	31.3	25.0	21.8
Wilting Point	%w	16.4	11.0	8.6	6.5

Discussion of laboratory testing results

The lime sludge and sludge-ash mixtures are non-plastic and have a reduced percentage of fines with higher ash content. For constructability, the silt and clay sized portions of the material is most important when considering moisture density relationships, moisture conditioning, compaction, and compactive effort with earth moving equipment. In general, materials with greater than 65% silt content may be difficult to compact unless the moisture content is relatively close to optimum. Since the clay size fraction is non-plastic, it will also contribute to difficulties in compaction.

The maximum dry density increases with increased ash content and the optimum water content decreases in the mixtures containing 50% or more ash. The shape of the moisture-density curves is consistent with materials that will generally react to field compaction manipulation and densify with compactive effort.

The shear strength of the mixtures containing ash does not appear to vary with ash content. The total stress phi value for the 70% sludge-30% ash sample appears to be anomalous when compared to the other mixtures and the 100% sludge sample tested. The low cohesion values

shown in the table and lab test results can be due to normal irregularities and inconsistencies inherent in preparation of reconstituted samples of essentially granular materials for the test method and the curve fitting required for calculation of the phi angles. The cohesion value is 0 for all tests.

The porosity of a material is the percentage of void space within the material by volume. The field capacity of a material is the percentage of water remaining in the material after it has been thoroughly saturated and allowed to drain freely. The wilting point of a material is minimum point of soils moisture when most plant begin to wilt. These conditions are represented in the laboratory by applying 1/3 bar pressure to a sample that represents the field capacity and 15 bar pressure to represent the wilting point.

The porosity, field capacity, and wilting point of the mixtures tested decrease with increased ash content. The results of these tests indicate that there are less pore spaces in the bulk material and that the mixtures containing ash retain less water within the pore spaces under free drainage conditions. Based on these results, mixtures containing ash and increased percentages of ash would be expected to dry quicker than mixtures with less ash or no ash when other conditions are the same.

Conclusions and recommendations

Based on the observations made during sample collection, the results of the laboratory tests, and our experience with other sludge materials with similar consistency, it appears that the in-situ sludge that is present in the ash ponds may not support bridge materials deposited on the surface, or the sludge material will squeeze during bridging operations and create a wave or pile of material ahead of the bridging operation that could be a few feet to several feet in height. The pile would then create an uneven surface for capping where the bridging operation is completed.

Since the bulk density of the sludge material is less than water, most CCB combustion products, and HDPE, field testing with the proposed capping materials will be required to determine if bridging is feasible. One test would be to cover an area of sludge materials with the proposed cap material to determine if the sludge will support the cap materials or if the cap material will sink into the sludge. A second test would be to cover an aera of sludge material with the proposed HDPE liner and cover with cap materials to determine if the sludge lined with HDPE will support the cap, and if so, the magnitude of squeeze and wave developed due to loading the HDPE cover material. If the above tests are successful in a limited area, bridging of the entire pond surface may be feasible. The scale of the test area and loading with respect to the size and loading of the entire pond should be carefully considered prior to planning bridging operations for the entire pond. If field testing determines that bridging over the sludge material is not feasible, or economical, then mixing drying, or both should be considered.

The in-situ sludge material will probably require mixing with ash, drying, or a combination of mixing with ash and drying in order to be workable with earth moving equipment. The drying and/or mixing will need to result in a material with a moisture content relatively close to the optimum moisture content of the compacted samples in order for the material to be workable and support construction traffic.

Air drying of the in-situ (100%) sludge does not appear to be feasible based on the particle size, field capacity and difficulties consolidating lab specimens reported during the CU testing. The small particle size and high porosity within the in-situ sludge appear to induce an affinity for water within the pore spaces and result in a high surface tension and minimal propensity for free

drainage. If air-drying is possible, it would likely require a large amount of time and large area for the material to be dispersed for drying to be effective. Any precipitation on the material during air drying would slow the process.

Air drying of mixtures with increasing percentage of ash may be effective. Increased ash content appears to indicate increased air drying effectiveness.

Mechanical drying such as filter pressing of the in-situ (100%) sludge may be difficult due to the small particle size. Water may not be separated at an acceptable rate for this reason.

Mechanical drying of mixtures with increasing percentage of ash may be effective. Increased ash content appears to indicate increased mechanical drying effectiveness due to increased pore size and decreased field capacity.

Drying using heat will probably be feasible but also cost prohibitive if there is time and space available to employ other methods of mixing and/or drying.

The above observations are mostly qualitative. It is not possible to indicate the quantitative effect that the addition of ash will have on the constructability of the material.

It is recommended that field testing for workability be performed on one or more of the above materials to determine the best methods for mixing, any drying necessary, and the final material to use for closure. Field testing should be performed in an area with conditions as close to those within the ponds or within the ponds.

It is our opinion that the in-situ (100%) sludge will be the least likely to be economical for use during closure. This is due to the probable difficulties with reducing the moisture content of the material to a point where it will be workable and support construction traffic.

Of the mixtures tested, we recommend that field testing be performed with the intent of mixing to obtain a 70% sludge-30% ash mixture. The properties of the 70% sludge-30% ash mixture increase significantly from the 100% sludge material. Increasing returns appear to decrease with higher percentages of ash. If a workable material cannot be obtained using 30% ash, then the ash content should be increased and the new material field tested.

We appreciate the opportunity to provide this information and look forward to working with City Water, Light and Power to provide continued support and assistance related to your technical challenges. Please contact me at (217) 747-9380 if you have any questions concerning this information or wish to discuss it further.

Sincerely,

HANSON PROFESSIONAL SERVICES INC.



James P. Knutelski
Senior Geotechnical Engineer

Attachments:
Laboratory test results
Agvise laboratory test report

GEOTECHNOLOGY
A Universal Engineering Sciences Company

Via email: mheyen@hanson-inc.com

January 25, 2022

Mr. Matt Heyen, P.E.
Hanson Professional Services, Inc.
1525 S. Sixth Street
Springfield, Illinois 62703

Re: Laboratory Testing Services
CWLP Lime Pond Final Cover Stability
Geotechnology Project No. J039671.01.6000

Dear Mr. Heyen:

Included in this report are the test results for lime pond sludge and coal ash samples received in our laboratory on November 10, 2021. The samples were tested in general accordance with the test methods listed below.

Test to Determine	Method of Test
Particle-Size Analysis of Soil	ASTM D422
Laboratory Compaction of Soil Using Standard Effort	ASTM D698
Water (Moisture) Content of Soil	ASTM D2216
Liquid Limit, Plastic Limit and Plasticity Index of Soils	ASTM D4318
Consolidated-Undrained Triaxial Compression Test	ASTM D4767
Density (Unit Weight) of Soil Specimens	ASTM D7263

This report has been prepared for the exclusive use of Hanson Professional Services, Inc. Our scope of services was limited to performing specific tests on provided samples and did not include engineering or interpretation of the test results.

We trust this is the information you require. Please contact the undersigned if you have any questions regarding this report.

* * * * *

Respectfully submitted,

GEOTECHNOLOGY, LLC



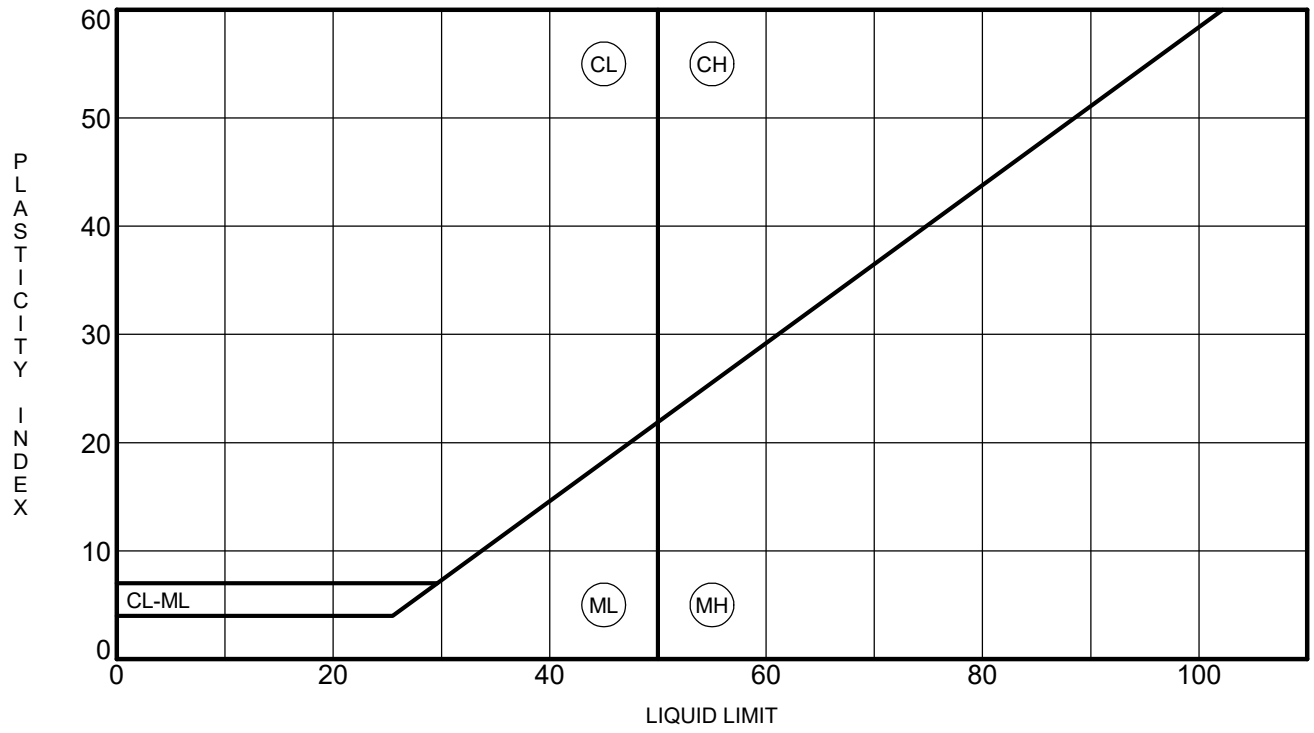
Janet M. May
Illinois Laboratory Manager

JMM/LPH:jmm

Attachments: Appendix A – Atterberg Limits' Results
Appendix B – Grain Size Distribution
Appendix C – Moisture-Density Relationship
Appendix D – Triaxial Results
Appendix E – Chain of Custody Form

APPENDIX A

Atterberg Limits' Results



	Specimen Identification	LL	PL	PI	Fines	Classification
●	**LSN-4149; Sludge**	**NP**	**NP**	**NP**	**85.8**	**100% Lime Pond Sludge**
⊠	**LSN-4149/50 A 70%/30%**	**NP**	**NP**	**NP**	**61.6**	**70% Lime Pond Sludge/30% Ash**
▲	**LSN-4149/50 B 50%/50%**	**NP**	**NP**	**NP**	**50.7**	**50% Lime Pond Sludge/50% Ash**
★	**LSN-4149/50 C 30%/70%**	**NP**	**NP**	**NP**	**42.9**	**30% Lime Pond Sludge/70% Ash**

GEOTECHNOLOGY
A Universal Engineering Sciences Company

ATTERBERG LIMITS' RESULTS

Project Number: J039671.01.6001

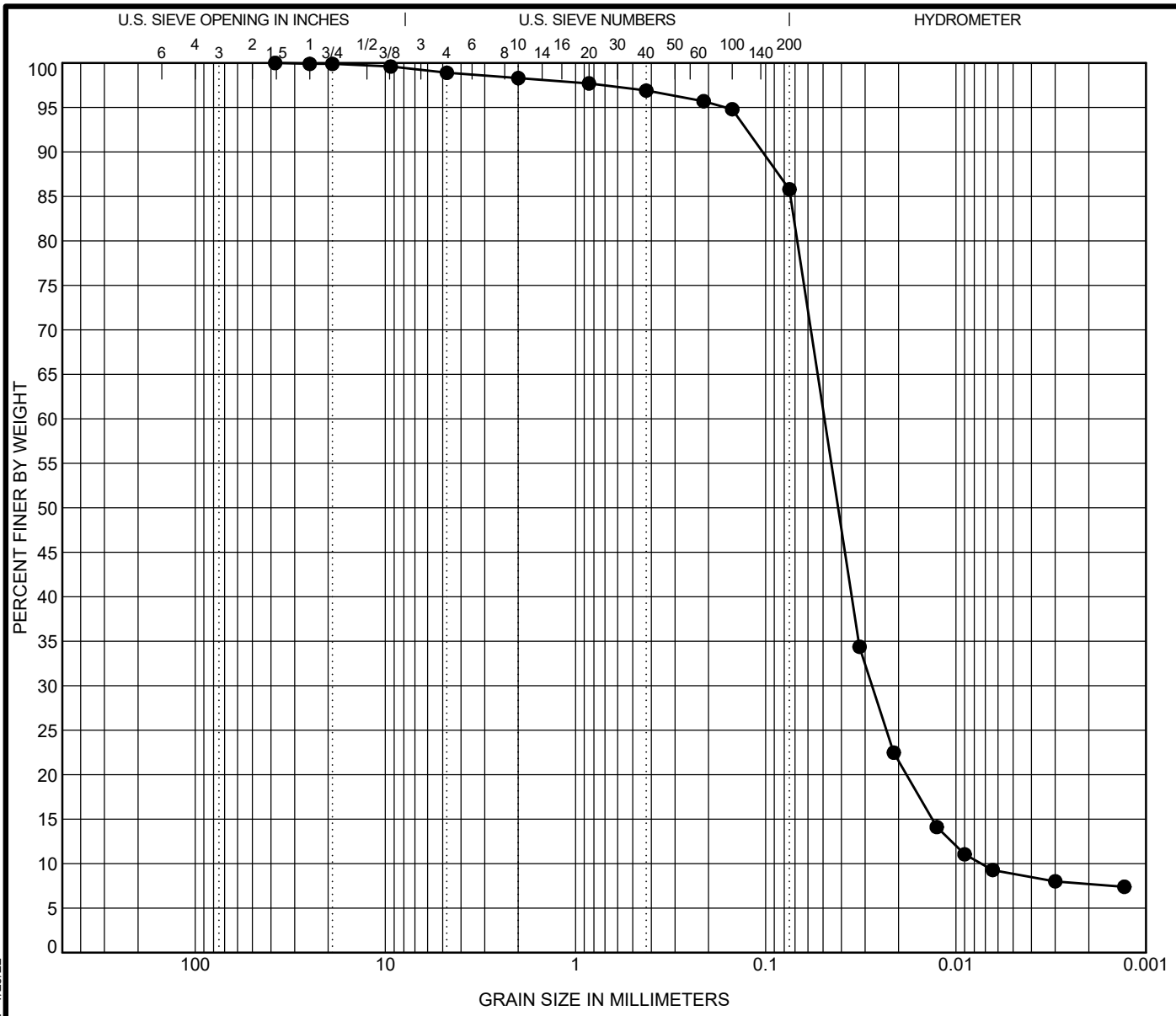
Project: CWLP Lime Pond Sludge /

Location: Coal Ash Stability Evaluation

US ATTERBERG LIMITS J039671.01.6001 LAB RESULTS.GPJ GEOTECHNOLOGY.GDT 1/25/22

APPENDIX B

Grain Size Distribution



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification	Classification	LL	PL	PI	Cc	Cu
●	**LSN-4149; Sludge**	**100% Lime Pond Sludge**	**NP**	**NP**	**NP**	**2.11**	**6.67**

	Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**LSN-4149; Sludge**	**38**	**0.049**	**0.028**	**0.007**	**1.1**	**13.1**	**76.9**	**8.9**

GEOTECHNOLOGY
A Universal Engineering Sciences Company

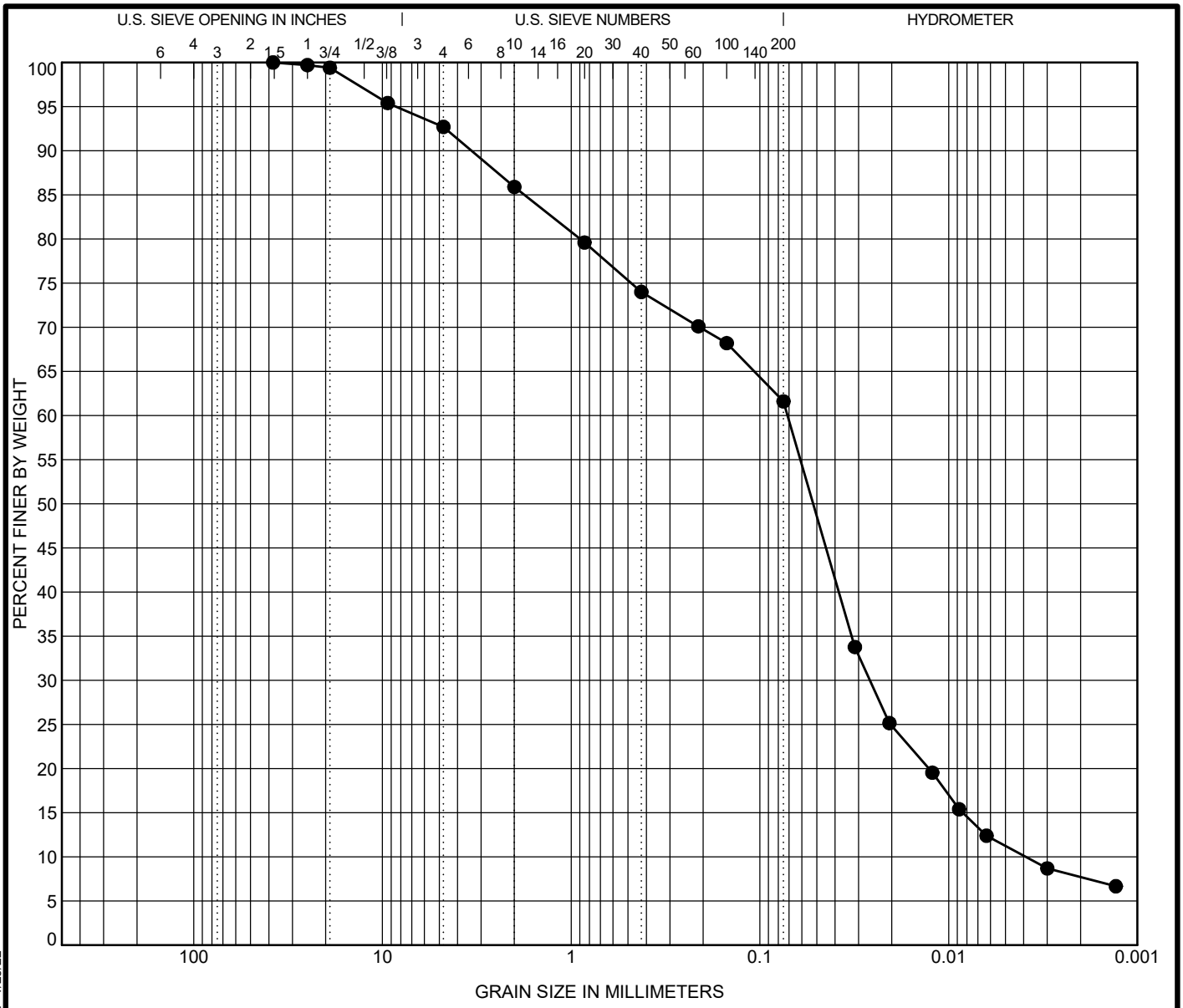
GRAIN SIZE DISTRIBUTION

Project Number: J039671.01.6001

Project: CWLP Lime Pond Sludge /

Location: Coal Ash Stability Evaluation

GRAIN SIZE WIDER IDENTIFICATION J039671.01.6001 LAB RESULTS.GPJ GEOTECHNOLOGY.GDT 1/25/22



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification	Classification	LL	PL	PI	Cc	Cu
●	**LSN-4149/50 A 70%/30%**	**70% Lime Pond Sludge/30% Ash**	**NP**	**NP**	**NP**	**2.45**	**18.29**

	Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**LSN-4149/50 A 70%/30%**	**38**	**0.071**	**0.026**	**0.004**	**7.3**	**31.1**	**50.4**	**11.2**

GEOTECHNOLOGY
A Universal Engineering Sciences Company

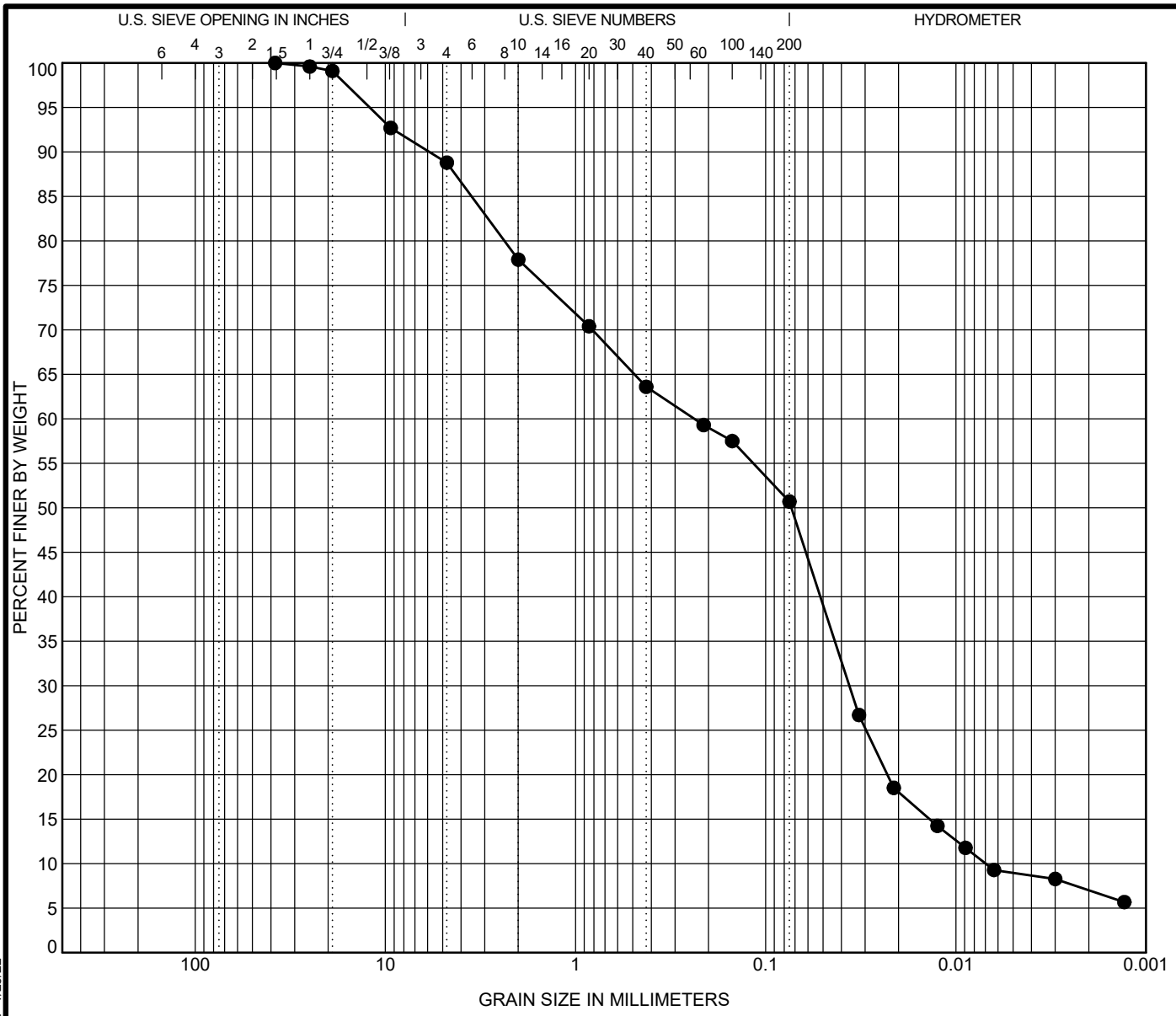
GRAIN SIZE DISTRIBUTION

Project Number: J039671.01.6001

Project: CWLP Lime Pond Sludge /

Location: Coal Ash Stability Evaluation

GRAIN SIZE WIDER IDENTIFICATION J039671.01.6001 LAB RESULTS.GPJ GEOTECHNOLOGY.GDT 1/25/22



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification	Classification	LL	PL	PI	Cc	Cu
●	**LSN-4149/50 B 50%/50%**	**50% Lime Pond Sludge/50% Ash**	**NP**	**NP**	**NP**	**0.80**	**34.12**

	Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**LSN-4149/50 B 50%/50%**	**38**	**0.237**	**0.036**	**0.007**	**11.2**	**38.1**	**41.7**	**9.0**

GEOTECHNOLOGY
A Universal Engineering Sciences Company

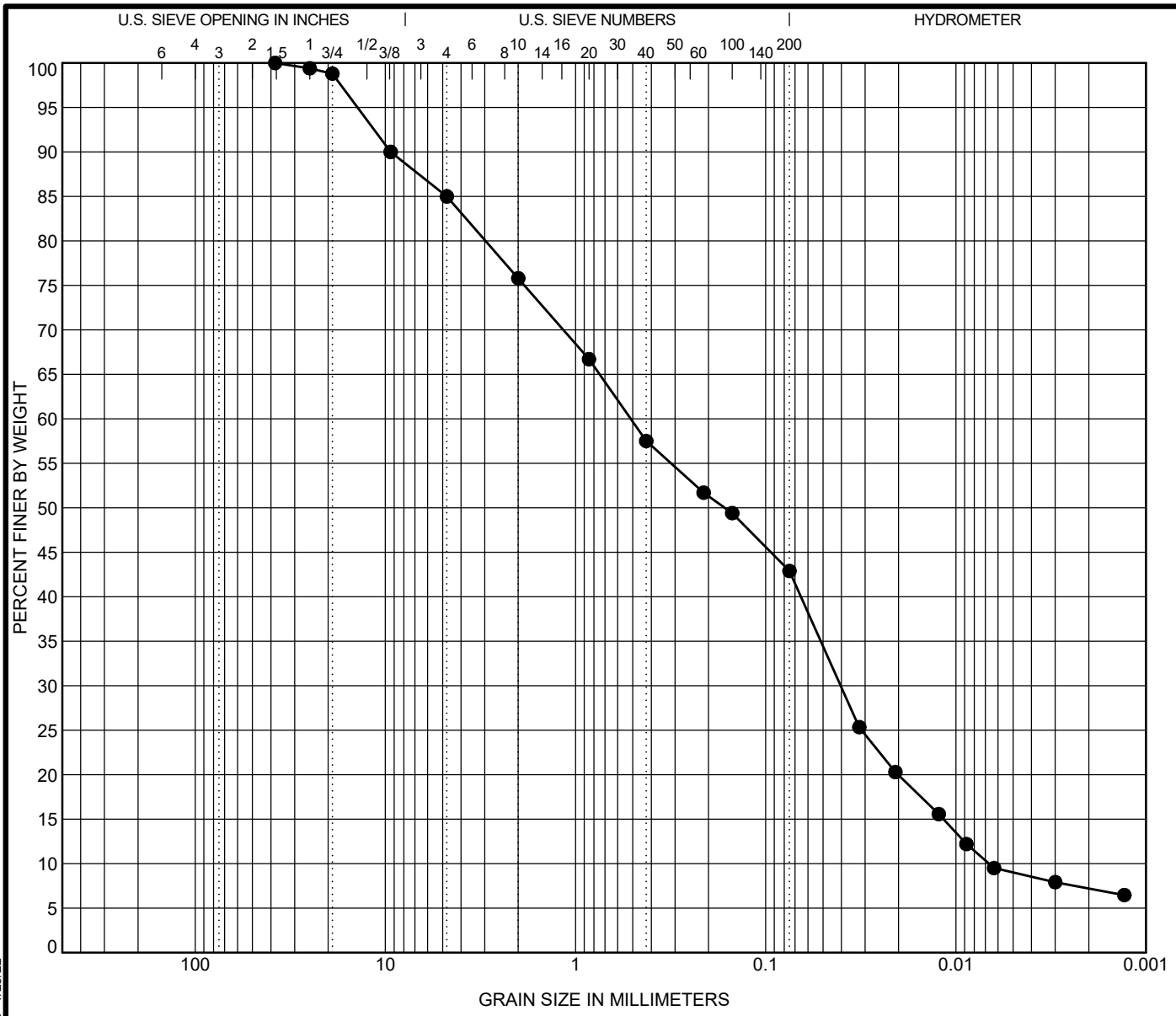
GRAIN SIZE DISTRIBUTION

Project Number: J039671.01.6001

Project: CWLP Lime Pond Sludge /

Location: Coal Ash Stability Evaluation

GRAIN SIZE WIDER IDENTIFICATION J039671.01.6001 LAB RESULTS.GPJ GEOTECHNOLOGY.GDT 1/25/22



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification	Classification	LL	PL	PI	Cc	Cu
●	**LSN-4149/50 C 30%/70%**	**30% Lime Pond Sludge/70% Ash**	**NP**	**NP**	**NP**	**0.47**	**76.58**

	Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**LSN-4149/50 C 30%/70%**	**38**	**0.513**	**0.04**	**0.007**	**15.0**	**42.1**	**33.9**	**9.0**

GEOTECHNOLOGY
A Universal Engineering Sciences Company

GRAIN SIZE DISTRIBUTION

Project Number: J039671.01.6001

Project: CWLP Lime Pond Sludge /

Location: Coal Ash Stability Evaluation

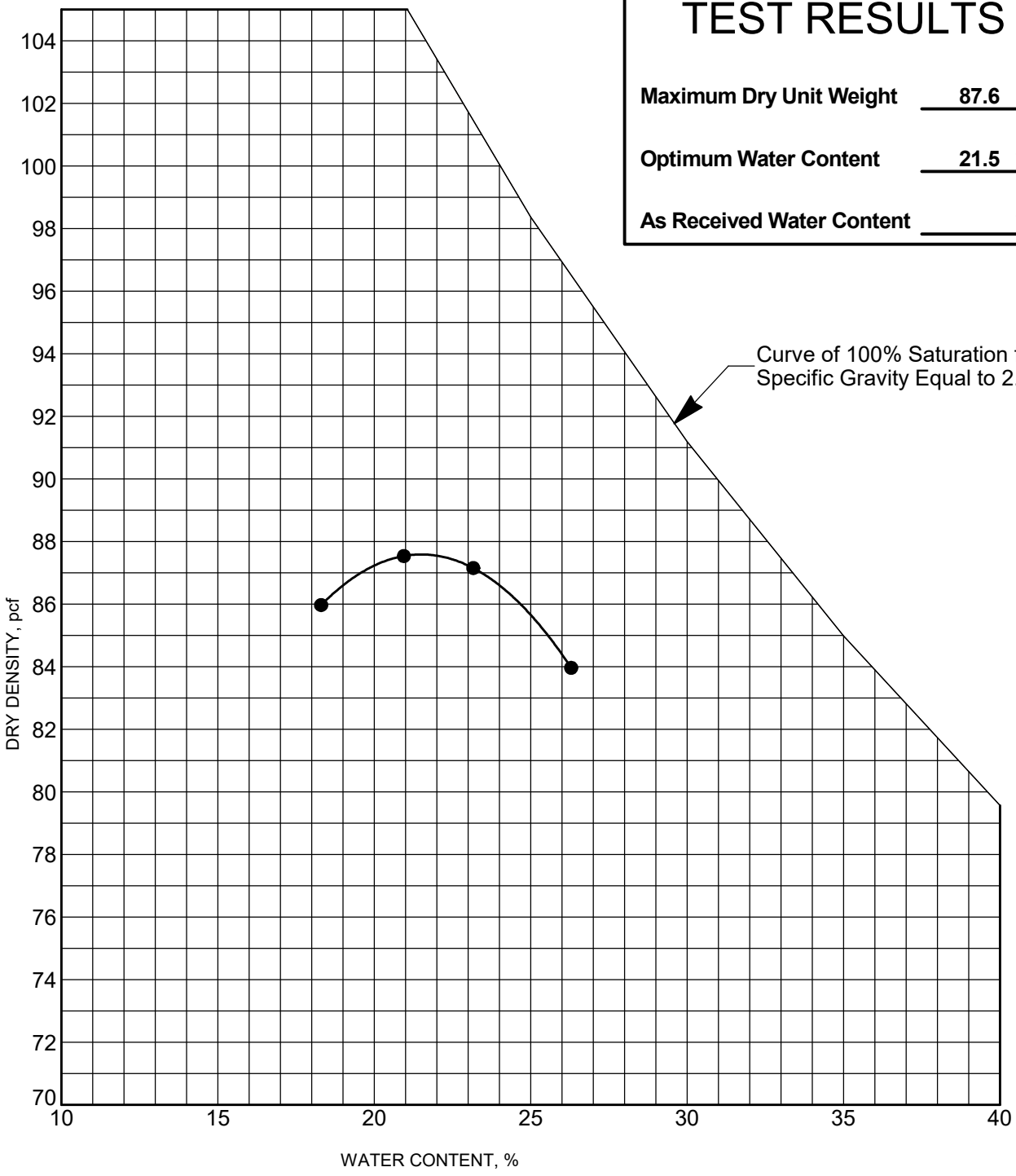
GRAIN SIZE WIDER IDENTIFICATION J039671.01.6001 LAB RESULTS.GPJ GEOTECHNOLOGY.GDT 1/25/22

APPENDIX C

Moisture-Density Relationship

TEST RESULTS

Maximum Dry Unit Weight	**87.6 PCF**
Optimum Water Content	**21.5 %**
As Received Water Content	**%**



Sample No. **LSN-4149; Sludge**
Depth **--**
Test Method **ASTM D698-A (Standard)**

Source of Material
Description of Material **100% Lime Pond Sludge**

GEOTECHNOLOGY
A Universal Engineering Sciences Company

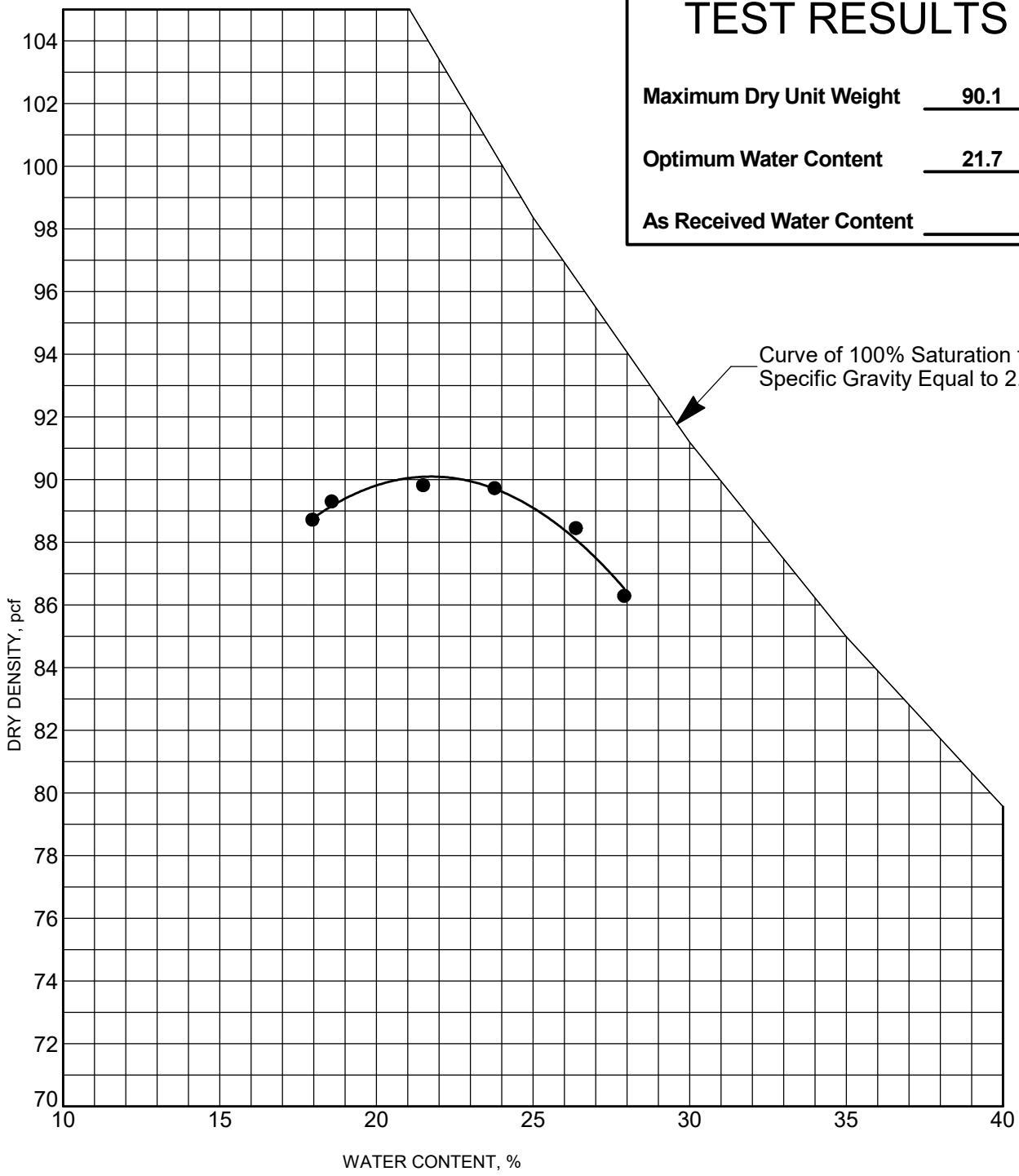
MOISTURE-DENSITY RELATIONSHIP

Project Number: J039671.01.6001
Project: CWLP Lime Pond Sludge /
Coal Ash Stability Evaluation

PROCTOR CURVE 70 TO 110 PCF 10 TO 40 MC J039671.01.6001 LAB RESULTS.GPJ GEOTECHNOLOGY.GDT 12/20/21

TEST RESULTS

Maximum Dry Unit Weight	**90.1 PCF**
Optimum Water Content	**21.7 %**
As Received Water Content	**%**



Sample No. **LSN-4149/50 A 70%/30%**
Depth **--**
Test Method **ASTM D698-B (Standard)**

Source of Material
Description of Material **70% Lime Pond Sludge/30% Ash**

GEOTECHNOLOGY
A Universal Engineering Sciences Company

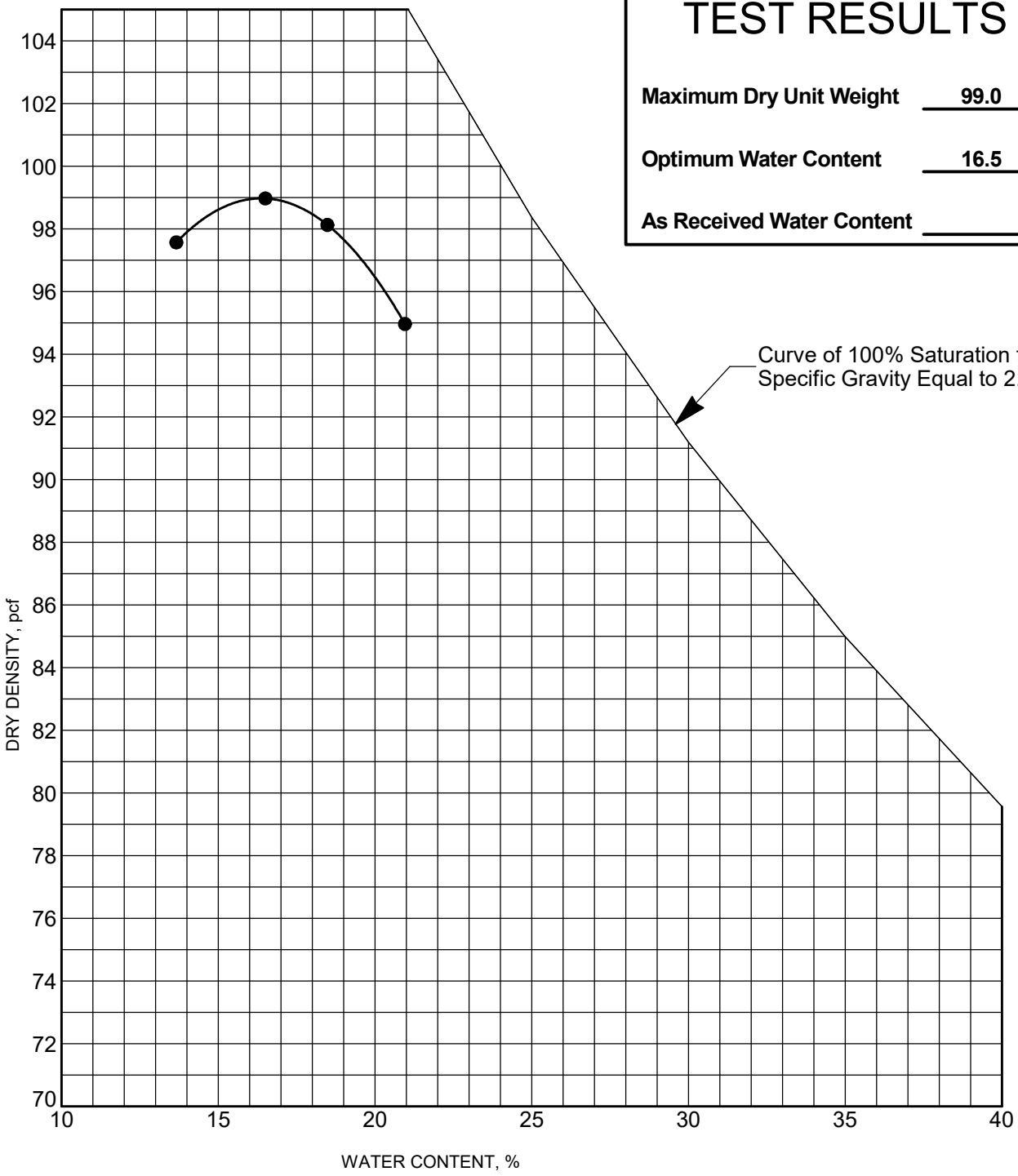
MOISTURE-DENSITY RELATIONSHIP

Project Number: J039671.01.6001
Project: CWLP Lime Pond Sludge /
Coal Ash Stability Evaluation

PROCTOR CURVE 70 TO 110 PCF 10 TO 40 MC J039671.01.6001 LAB RESULTS.GPJ GEOTECHNOLOGY.GDT 12/20/21

TEST RESULTS

Maximum Dry Unit Weight	**99.0 PCF**
Optimum Water Content	**16.5 %**
As Received Water Content	**%**



Sample No. **LSN-4149/50 B 50%/50%**
Depth **--**
Test Method **ASTM D698-B (Standard)**

Source of Material
Description of Material **50% Lime Pond Sludge/50% Ash**

GEOTECHNOLOGY
A Universal Engineering Sciences Company

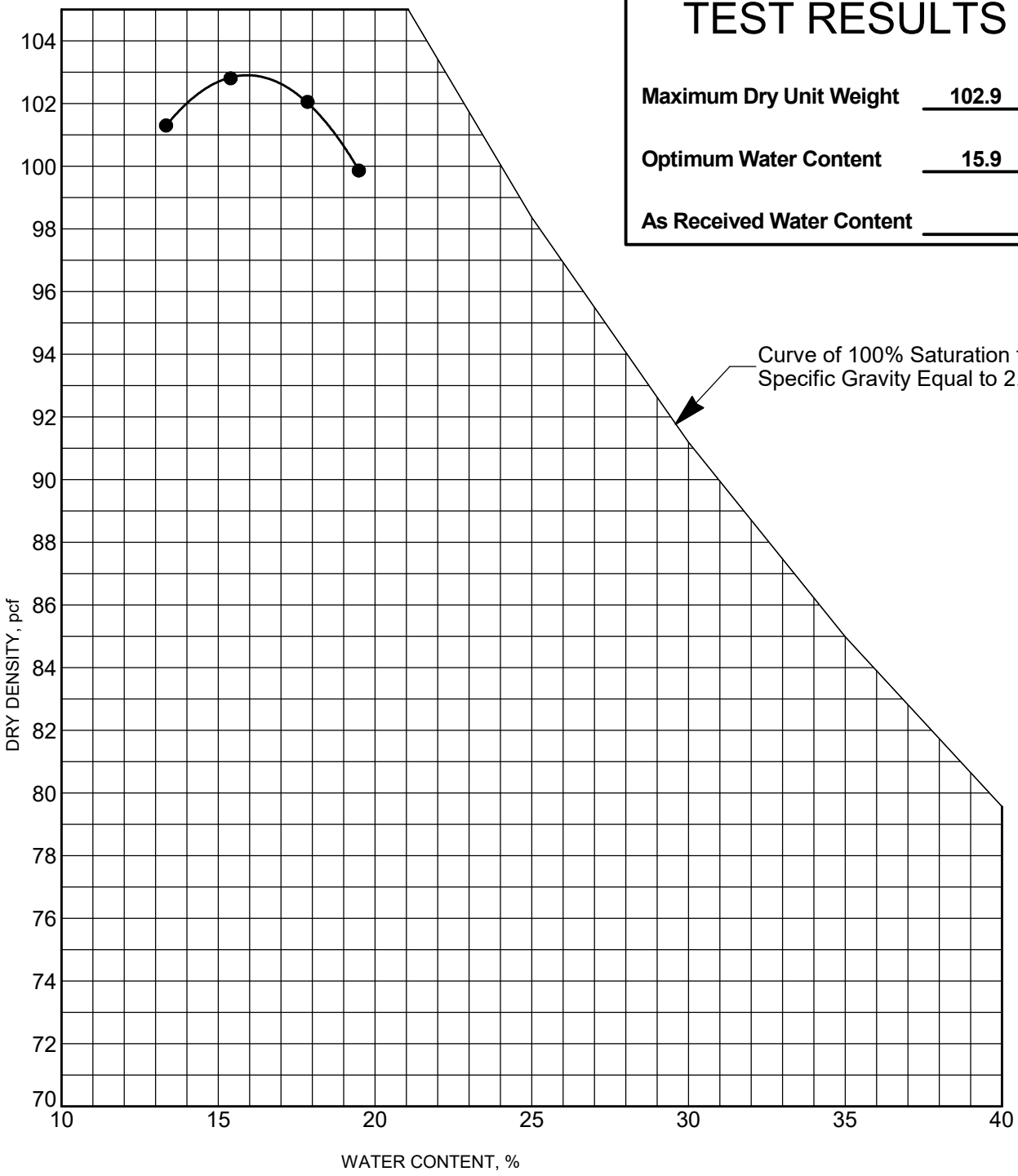
MOISTURE-DENSITY RELATIONSHIP

Project Number: J039671.01.6001
Project: CWLP Lime Pond Sludge /
Coal Ash Stability Evaluation

PROCTOR CURVE 70 TO 110 PCF 10 TO 40 MC J039671.01.6001 LAB RESULTS.GPJ GEOTECHNOLOGY.GDT 12/20/21

TEST RESULTS

Maximum Dry Unit Weight	**102.9 PCF**
Optimum Water Content	**15.9 %**
As Received Water Content	**%**



Sample No. **LSN-4149/50 C 30%/70%**
Depth **--**
Test Method **ASTM D698-B (Standard)**

Source of Material
Description of Material **30% Lime Pond Sludge/70% Ash**

GEOTECHNOLOGY
A Universal Engineering Sciences Company

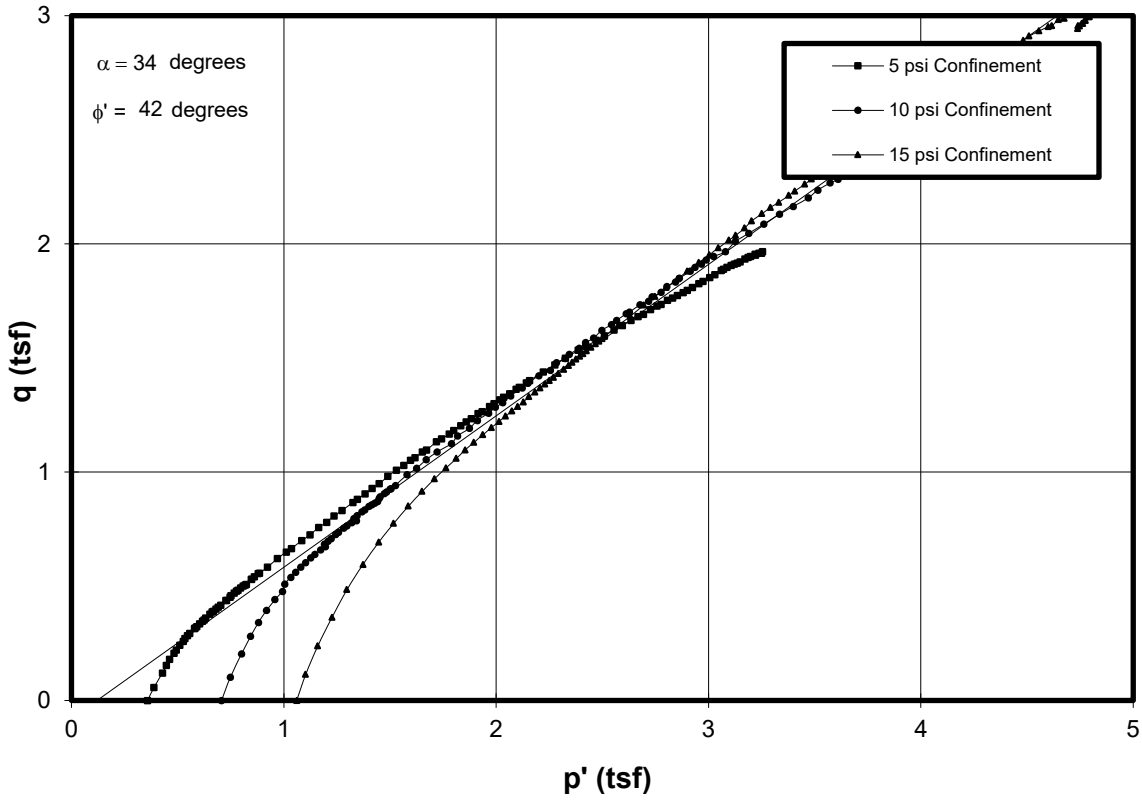
MOISTURE-DENSITY RELATIONSHIP

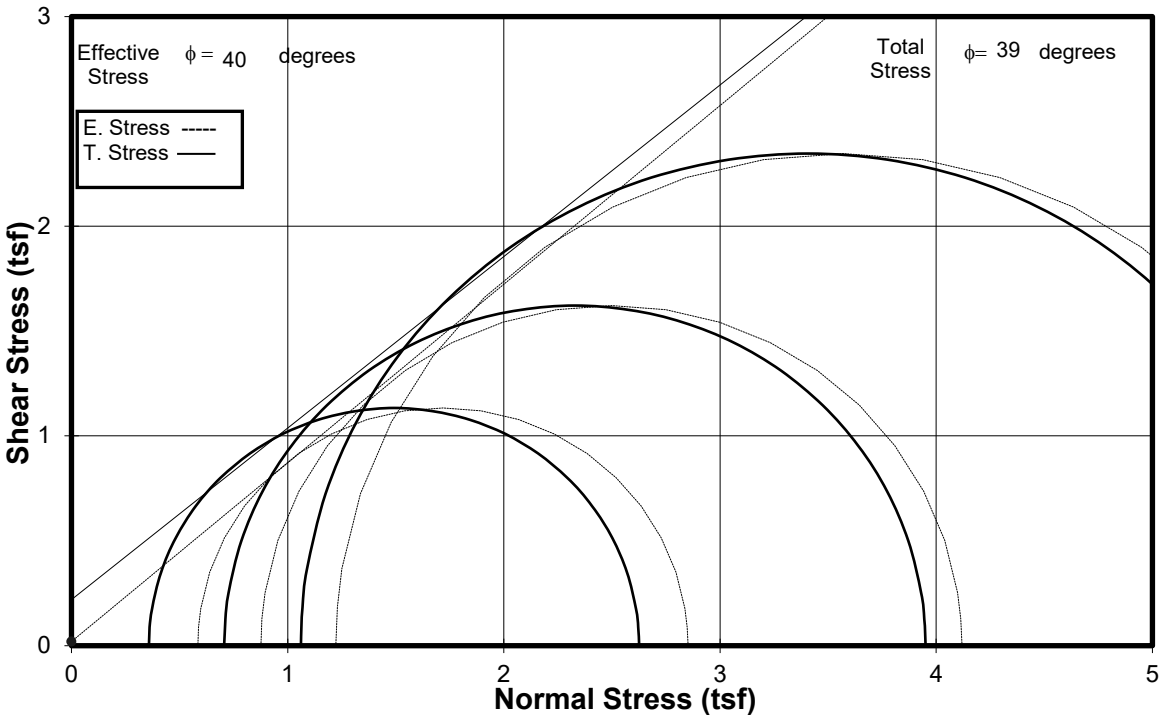
Project Number: J039671.01.6001
Project: CWLP Lime Pond Sludge / Coal Ash Stability Evaluation

PROCTOR CURVE 70 TO 110 PCF 10 TO 40 MC J039671.01.6001 LAB RESULTS.GPJ GEOTECHNOLOGY.GDT 12/20/21

APPENDIX D

Triaxial Results





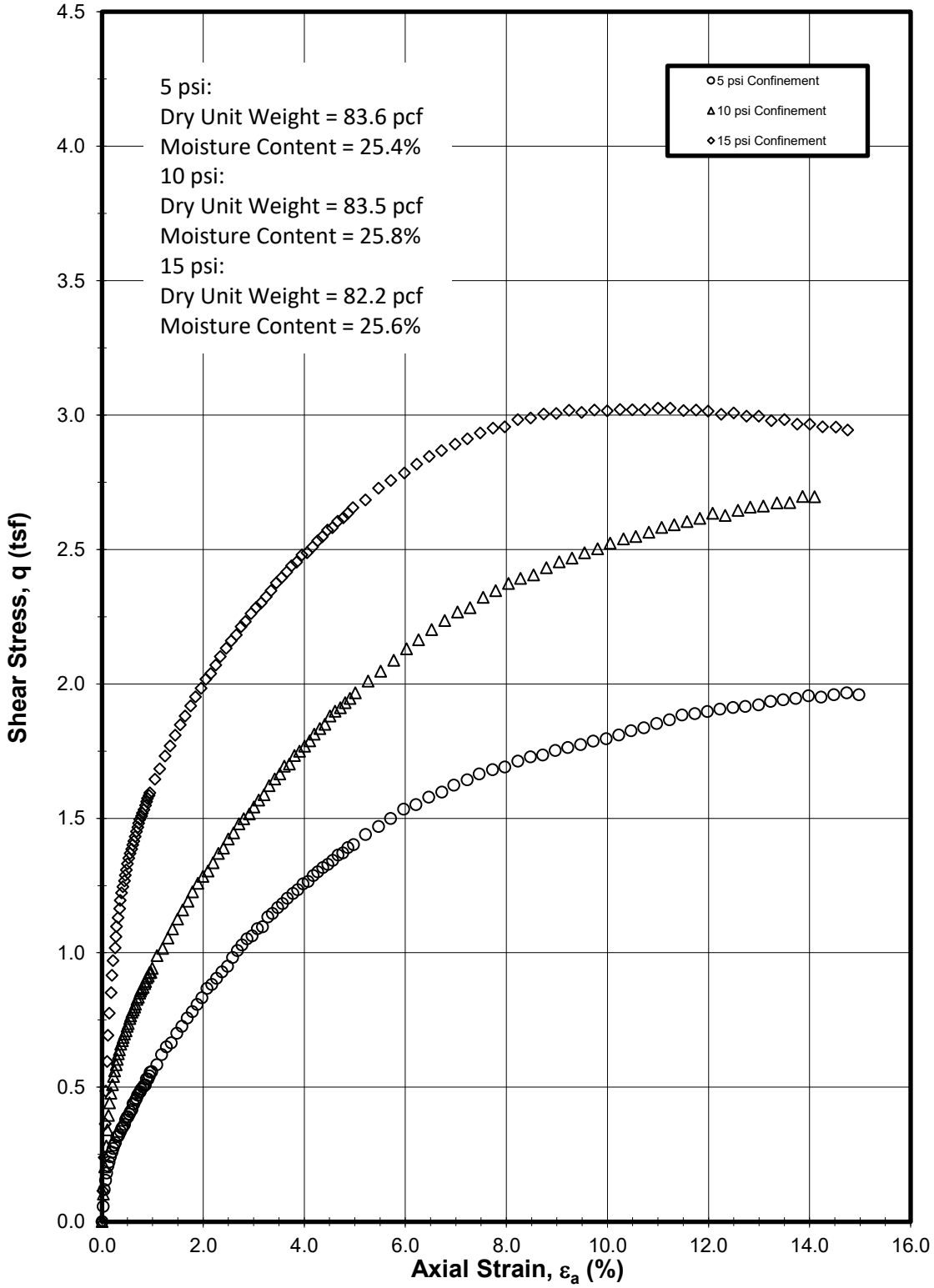
CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST

ASTM D 4767

Project No.: J039697.01

Sample: 100% Lime Pond Sludge

GEOTECHNOLOGY
A Universal Engineering Sciences Company



CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST
ASTM D 4767
Project No.: J039697.01
Sample: 100% Lime Pond Sludge

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: 100% Lime Pond Sludge
Sample No.: 0 Specimen No.: A
Depth (ft.): 0

Initial Height., H_o (in): 5.825 Confining Pressure (psi): 5.00
Initial Diameter, D_o (in): 2.880 Initial Volume, V_o (in^3): 37.95
Membrane Thickness (in): 0.02 Initial Area, A_o (in^2): 6.51
Ht Change at End of Consol.,ΔH_o (in): 0.014 H_c 5.812 Area after Consol., A_c (in^2): 6.487
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 4.11 0.25071 in^3

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	85.12	90.08	0.000	6.487	0.00	0.00	4.97	4.97	1.00	0.00	0.000	0.358
1.52	0.00	10.28	85.49	90.08	0.022	6.488	0.00	0.11	4.59	6.18	1.34	0.03	0.057	0.388
3.02	0.00	21.60	85.81	90.07	0.044	6.490	0.00	0.24	4.27	7.60	1.78	0.05	0.120	0.428
4.52	0.00	27.78	86.02	90.07	0.071	6.491	0.00	0.31	4.06	8.34	2.05	0.07	0.154	0.446
6.02	0.01	32.57	86.18	90.06	0.090	6.492	0.00	0.36	3.91	8.92	2.28	0.08	0.181	0.462
7.52	0.01	37.39	86.26	90.06	0.115	6.494	0.00	0.41	3.82	9.58	2.51	0.08	0.207	0.483
9.02	0.01	39.96	86.31	90.04	0.139	6.496	0.01	0.44	3.77	9.92	2.63	0.09	0.221	0.493
10.52	0.01	43.57	86.36	90.05	0.165	6.497	0.01	0.48	3.73	10.43	2.80	0.09	0.241	0.510
12.02	0.01	46.67	86.37	90.03	0.193	6.499	0.01	0.52	3.71	10.89	2.93	0.09	0.259	0.526
13.52	0.01	49.13	86.46	90.09	0.218	6.501	0.01	0.54	3.63	11.18	3.08	0.10	0.272	0.533
15.02	0.01	51.28	86.45	90.09	0.240	6.502	0.01	0.57	3.63	11.52	3.17	0.10	0.284	0.546
16.52	0.02	53.09	86.44	90.09	0.263	6.504	0.01	0.59	3.65	11.81	3.24	0.10	0.294	0.556
18.02	0.02	57.00	86.42	90.09	0.288	6.505	0.01	0.63	3.66	12.42	3.39	0.09	0.315	0.579
19.52	0.02	57.36	86.41	90.08	0.314	6.507	0.01	0.63	3.67	12.49	3.40	0.09	0.317	0.582
21.02	0.02	58.43	86.39	90.07	0.333	6.508	0.01	0.65	3.69	12.67	3.43	0.09	0.323	0.589
22.52	0.02	60.79	86.38	90.07	0.364	6.510	0.02	0.67	3.71	13.04	3.52	0.09	0.336	0.603
24.02	0.02	62.84	86.34	90.05	0.392	6.512	0.02	0.69	3.74	13.39	3.58	0.09	0.347	0.617
25.52	0.02	63.81	86.31	90.05	0.414	6.514	0.02	0.70	3.77	13.57	3.60	0.09	0.353	0.624
27.02	0.03	65.37	86.33	90.08	0.444	6.516	0.02	0.72	3.76	13.79	3.67	0.09	0.361	0.632
28.52	0.03	68.45	86.30	90.09	0.466	6.517	0.02	0.75	3.78	14.29	3.78	0.09	0.378	0.650
30.03	0.03	70.24	86.27	90.10	0.493	6.519	0.02	0.77	3.81	14.59	3.83	0.08	0.388	0.662
31.53	0.03	70.64	86.23	90.07	0.513	6.520	0.02	0.78	3.85	14.69	3.81	0.08	0.390	0.667
33.03	0.03	72.44	86.20	90.06	0.539	6.522	0.02	0.80	3.88	14.99	3.86	0.08	0.400	0.679
34.53	0.03	74.14	86.17	90.05	0.562	6.523	0.02	0.82	3.91	15.28	3.91	0.08	0.409	0.691
36.03	0.03	75.52	86.12	90.05	0.593	6.525	0.02	0.83	3.96	15.53	3.92	0.07	0.417	0.702
37.53	0.04	79.57	86.09	90.03	0.612	6.527	0.03	0.88	4.00	16.19	4.05	0.07	0.439	0.727
39.03	0.04	79.47	86.04	90.02	0.630	6.528	0.03	0.87	4.04	16.22	4.01	0.07	0.438	0.729
40.53	0.04	82.01	85.99	90.01	0.658	6.530	0.03	0.90	4.09	16.65	4.07	0.06	0.452	0.747
42.03	0.04	83.30	86.04	90.06	0.679	6.531	0.03	0.92	4.04	16.80	4.15	0.07	0.459	0.750
43.53	0.04	85.42	86.00	90.05	0.702	6.533	0.03	0.94	4.09	17.16	4.20	0.06	0.471	0.765
45.03	0.04	87.03	85.96	90.08	0.736	6.535	0.03	0.96	4.12	17.44	4.23	0.06	0.479	0.776
46.53	0.04	87.81	85.92	90.06	0.756	6.536	0.03	0.97	4.17	17.60	4.22	0.06	0.484	0.784
48.03	0.04	89.50	85.87	90.05	0.769	6.537	0.03	0.98	4.21	17.90	4.25	0.05	0.493	0.796
49.53	0.05	90.99	85.82	90.05	0.808	6.539	0.03	1.00	4.26	18.17	4.27	0.05	0.501	0.808
51.03	0.05	91.98	85.77	90.05	0.831	6.541	0.03	1.01	4.31	18.37	4.26	0.05	0.506	0.817
52.53	0.05	92.46	85.73	90.02	0.853	6.542	0.04	1.01	4.35	18.49	4.25	0.04	0.509	0.822
54.03	0.05	96.52	85.69	90.02	0.879	6.544	0.04	1.06	4.40	19.15	4.35	0.04	0.531	0.848
55.55	0.05	96.42	85.68	90.06	0.908	6.546	0.04	1.06	4.41	19.14	4.34	0.04	0.530	0.847
57.05	0.05	98.52	85.66	90.08	0.935	6.548	0.04	1.08	4.42	19.47	4.40	0.04	0.542	0.860
58.55	0.06	101.07	85.60	90.08	0.950	6.549	0.04	1.11	4.49	19.92	4.44	0.03	0.556	0.879
60.05	0.06	101.57	85.55	90.07	0.981	6.551	0.04	1.11	4.53	20.04	4.42	0.03	0.558	0.884
66.05	0.06	106.42	85.39	90.05	1.080	6.557	0.04	1.17	4.69	20.92	4.46	0.02	0.584	0.922
72.05	0.07	113.36	85.26	90.09	1.178	6.564	0.05	1.24	4.82	22.10	4.58	0.01	0.622	0.969
78.05	0.07	118.69	85.08	90.06	1.272	6.570	0.05	1.30	5.00	23.07	4.61	0.00	0.650	1.010
84.05	0.08	121.59	84.94	90.09	1.368	6.577	0.06	1.33	5.14	23.63	4.60	-0.01	0.666	1.036
90.05	0.09	128.24	84.77	90.09	1.479	6.584	0.06	1.40	5.32	24.80	4.66	-0.03	0.701	1.084
96.05	0.09	132.98	84.58	90.06	1.580	6.591	0.07	1.45	5.51	25.68	4.66	-0.04	0.726	1.123
102.05	0.10	138.79	84.45	90.10	1.685	6.598	0.07	1.51	5.64	26.67	4.73	-0.05	0.757	1.163
108.05	0.10	143.28	84.26	90.05	1.787	6.605	0.07	1.56	5.83	27.52	4.72	-0.06	0.781	1.200
114.07	0.11	148.34	84.14	90.08	1.877	6.611	0.08	1.61	5.94	28.38	4.78	-0.07	0.808	1.236
120.07	0.11	153.10	83.96	90.05	1.975	6.617	0.08	1.66	6.13	29.26	4.78	-0.08	0.833	1.274
126.07	0.12	159.64	83.74	90.03	2.075	6.624	0.09	1.73	6.34	30.44	4.80	-0.10	0.868	1.324
132.07	0.13	162.44	83.64	90.07	2.168	6.630	0.09	1.76	6.45	30.95	4.80	-0.11	0.882	1.346
138.07	0.13	166.93	83.47	90.05	2.267	6.637	0.09	1.80	6.62	31.77	4.80	-0.12	0.905	1.382
144.07	0.14	171.53	83.35	90.10	2.369	6.644	0.10	1.85	6.74	32.55	4.83	-0.13	0.929	1.414
150.07	0.14	175.45	83.16	90.07	2.482	6.652	0.10	1.89	6.93	33.30	4.81	-0.14	0.950	1.448

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: 100% Lime Pond Sludge
Sample No.: 0 Specimen No.: A
Depth (ft.): 0

Initial Height., H_o (in): 5.825 Confining Pressure (psi): 5.00
Initial Diameter, D_o (in): 2.880 Initial Volume, V_o (in^3): 37.95
Membrane Thickness (in): 0.02 Initial Area, A_o (in^2): 6.51
Ht Change at End of Consol., ΔH_o (in): 0.014 H_c 5.812 Area after Consol., A_c (in^2): 6.487
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 4.11 0.25071 in^3

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
156.08	0.15	181.71	83.04	90.09	2.580	6.658	0.11	1.96	7.04	34.33	4.87	-0.15	0.982	1.490
162.08	0.16	186.70	82.86	90.07	2.677	6.665	0.11	2.01	7.23	35.24	4.87	-0.16	1.008	1.529
168.08	0.16	190.82	82.67	90.03	2.768	6.671	0.12	2.05	7.42	36.02	4.86	-0.18	1.030	1.564
174.08	0.17	195.25	82.55	90.06	2.869	6.678	0.12	2.10	7.54	36.77	4.88	-0.18	1.053	1.595
180.08	0.17	197.39	82.38	90.05	2.969	6.685	0.12	2.12	7.70	37.23	4.83	-0.20	1.063	1.617
186.08	0.18	202.50	82.27	90.09	3.075	6.692	0.13	2.17	7.81	38.07	4.87	-0.20	1.089	1.652
192.10	0.18	204.12	82.11	90.08	3.176	6.699	0.13	2.18	7.97	38.44	4.82	-0.22	1.097	1.671
198.10	0.19	211.17	81.97	90.09	3.279	6.706	0.14	2.26	8.11	39.60	4.88	-0.23	1.134	1.718
204.10	0.20	213.67	81.81	90.06	3.370	6.713	0.14	2.28	8.28	40.11	4.85	-0.24	1.146	1.742
210.10	0.20	218.03	81.62	90.03	3.472	6.720	0.14	2.33	8.47	40.91	4.83	-0.25	1.168	1.778
216.10	0.21	221.05	81.52	90.06	3.571	6.727	0.15	2.36	8.57	41.43	4.84	-0.26	1.183	1.800
222.12	0.21	225.07	81.35	90.04	3.667	6.734	0.15	2.40	8.73	42.16	4.83	-0.27	1.203	1.832
228.12	0.22	228.64	81.24	90.08	3.775	6.741	0.16	2.43	8.85	42.76	4.83	-0.28	1.221	1.858
234.12	0.23	231.43	81.09	90.07	3.872	6.748	0.16	2.46	9.00	43.29	4.81	-0.29	1.235	1.883
240.12	0.23	235.80	80.96	90.11	3.975	6.755	0.17	2.50	9.12	44.03	4.83	-0.30	1.257	1.913
246.12	0.24	237.71	80.81	90.08	4.075	6.762	0.17	2.52	9.27	44.43	4.79	-0.31	1.265	1.933
252.12	0.24	242.10	80.64	90.06	4.175	6.769	0.17	2.56	9.45	45.21	4.79	-0.32	1.288	1.968
258.12	0.25	244.87	80.54	90.10	4.267	6.776	0.18	2.59	9.55	45.69	4.79	-0.33	1.301	1.988
264.12	0.25	248.16	80.37	90.09	4.369	6.783	0.18	2.62	9.71	46.30	4.77	-0.34	1.317	2.016
270.12	0.26	250.63	80.28	90.12	4.469	6.790	0.19	2.64	9.80	46.72	4.76	-0.35	1.329	2.035
276.12	0.27	253.77	80.10	90.09	4.564	6.797	0.19	2.67	9.98	47.32	4.74	-0.36	1.344	2.063
282.12	0.27	257.74	79.96	90.09	4.668	6.804	0.19	2.71	10.13	48.01	4.74	-0.37	1.364	2.093
288.12	0.28	259.57	79.86	90.11	4.764	6.811	0.20	2.73	10.23	48.34	4.73	-0.38	1.372	2.108
294.12	0.28	263.51	79.67	90.09	4.862	6.818	0.20	2.77	10.41	49.06	4.71	-0.39	1.391	2.141
300.13	0.29	265.83	79.60	90.12	4.972	6.826	0.21	2.79	10.49	49.43	4.71	-0.40	1.402	2.157
315.13	0.30	273.72	79.23	90.13	5.212	6.843	0.22	2.86	10.85	50.85	4.69	-0.42	1.440	2.221
330.13	0.32	280.24	78.91	90.13	5.470	6.862	0.23	2.92	11.18	52.02	4.65	-0.45	1.470	2.275
345.13	0.33	286.48	78.61	90.13	5.708	6.879	0.24	2.98	11.47	53.12	4.63	-0.47	1.499	2.325
360.13	0.35	293.99	78.25	90.14	5.967	6.898	0.25	3.05	11.83	54.45	4.60	-0.49	1.534	2.386
375.13	0.36	297.95	77.99	90.14	6.211	6.916	0.26	3.08	12.10	55.18	4.56	-0.51	1.551	2.422
390.13	0.38	304.08	77.70	90.14	6.463	6.935	0.27	3.14	12.39	56.23	4.54	-0.53	1.579	2.470
405.13	0.39	308.70	77.43	90.13	6.722	6.954	0.28	3.18	12.65	57.04	4.51	-0.55	1.598	2.509
420.13	0.40	314.43	77.15	90.13	6.958	6.972	0.29	3.23	12.93	58.03	4.49	-0.57	1.624	2.555
435.13	0.42	319.08	76.89	90.13	7.225	6.992	0.30	3.26	13.20	58.83	4.46	-0.59	1.643	2.593
450.15	0.43	324.27	76.64	90.13	7.463	7.010	0.31	3.31	13.45	59.71	4.44	-0.61	1.665	2.634
465.15	0.45	328.36	76.39	90.12	7.724	7.030	0.32	3.34	13.70	60.41	4.41	-0.63	1.682	2.668
480.15	0.46	331.17	76.18	90.12	7.969	7.048	0.33	3.36	13.90	60.89	4.38	-0.64	1.692	2.693
495.15	0.48	336.35	76.02	90.19	8.225	7.068	0.34	3.40	14.06	61.65	4.38	-0.65	1.713	2.726
510.15	0.49	340.34	75.81	90.19	8.474	7.087	0.35	3.43	14.27	62.29	4.37	-0.67	1.729	2.756
525.15	0.51	342.57	75.64	90.19	8.720	7.106	0.36	3.44	14.44	62.65	4.34	-0.68	1.735	2.775
540.17	0.52	346.96	75.45	90.19	8.969	7.126	0.37	3.48	14.63	63.32	4.33	-0.70	1.753	2.806
555.17	0.54	349.99	75.26	90.19	9.217	7.145	0.38	3.50	14.82	63.80	4.31	-0.71	1.763	2.830
570.17	0.55	353.07	75.10	90.18	9.468	7.165	0.39	3.52	14.99	64.27	4.29	-0.72	1.774	2.853
586.17	0.56	356.66	74.91	90.18	9.717	7.185	0.40	3.54	15.17	64.82	4.27	-0.73	1.787	2.880
601.17	0.58	359.59	74.77	90.18	9.972	7.205	0.42	3.56	15.31	65.22	4.26	-0.74	1.797	2.899
616.18	0.59	363.22	74.61	90.17	10.225	7.225	0.43	3.59	15.48	65.75	4.25	-0.76	1.810	2.924
631.18	0.61	367.49	74.42	90.17	10.467	7.245	0.44	3.62	15.67	66.39	4.24	-0.77	1.826	2.954
646.18	0.62	370.69	74.30	90.16	10.722	7.266	0.45	3.64	15.78	66.80	4.23	-0.78	1.837	2.973
661.18	0.64	375.04	74.08	90.16	10.975	7.286	0.46	3.67	16.00	67.47	4.22	-0.79	1.853	3.005
676.18	0.65	378.78	73.94	90.13	11.227	7.307	0.47	3.70	16.14	67.98	4.21	-0.80	1.866	3.028
691.18	0.67	383.51	73.77	90.12	11.473	7.327	0.48	3.73	16.31	68.65	4.21	-0.82	1.884	3.059
706.18	0.68	385.57	73.68	90.18	11.726	7.348	0.49	3.74	16.41	68.88	4.20	-0.82	1.889	3.070
721.18	0.70	388.36	73.57	90.19	11.977	7.369	0.50	3.76	16.52	69.22	4.19	-0.83	1.897	3.086
736.18	0.71	391.25	73.42	90.19	12.225	7.390	0.51	3.78	16.66	69.61	4.18	-0.84	1.906	3.106
751.20	0.73	393.68	73.29	90.19	12.484	7.412	0.52	3.79	16.80	69.91	4.16	-0.85	1.912	3.121
766.20	0.74	395.60	73.17	90.19	12.726	7.432	0.53	3.79	16.92	70.14	4.15	-0.86	1.916	3.134

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: 100% Lime Pond Sludge
Sample No.: 0 Specimen No.: A
Depth (ft.): 0

Initial Height., H_o (in):	5.825	Confining Pressure (psi):	5.00
Initial Diameter, D_o (in):	2.880	Initial Volume, V_o (in^3):	37.95
Membrane Thickness (in):	0.02	Initial Area, A_o (in^2):	6.51
Ht Change at End of Consol.,ΔH_o (in):	0.014 H_c 5.812	Area after Consol., A_c (in^2):	6.487
Ht Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
Volume change during Consol. V_c (cc^3):	4.11 0.25071 in^3		

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
781.20	0.75	397.99	73.05	90.17	12.988	7.455	0.54	3.80	17.03	70.42	4.13	-0.87	1.922	3.148
796.20	0.77	401.73	72.92	90.15	13.227	7.475	0.55	3.83	17.17	70.91	4.13	-0.88	1.935	3.171
811.20	0.78	404.21	72.79	90.15	13.478	7.497	0.56	3.84	17.30	71.21	4.12	-0.89	1.941	3.186
826.20	0.80	406.43	72.69	90.16	13.725	7.519	0.57	3.85	17.39	71.45	4.11	-0.89	1.946	3.198
841.20	0.81	409.70	72.54	90.16	13.979	7.541	0.58	3.87	17.55	71.88	4.10	-0.91	1.956	3.219
856.22	0.83	409.91	72.47	90.16	14.228	7.563	0.59	3.86	17.62	71.82	4.08	-0.91	1.951	3.220
871.22	0.84	412.84	72.35	90.15	14.481	7.585	0.60	3.88	17.73	72.16	4.07	-0.92	1.959	3.236
886.22	0.86	415.70	72.22	90.12	14.733	7.607	0.61	3.89	17.87	72.51	4.06	-0.93	1.967	3.254
901.20	0.87	415.35	72.17	90.11	14.976	7.629	0.62	3.87	17.91	72.35	4.04	-0.93	1.960	3.250

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: 100% Lime Pond Sludge
Sample No.: 0 Specimen No.: B
Depth (ft.): 0

Initial Height., H_o (in): 5.806 Confining Pressure (psi): 10.00
Initial Diameter, D_o (in): 2.880 Initial Volume, V_o (in^3): 37.82
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.51
Ht Change at End of Consol., ΔH_o (in): 0.064 H_c 5.742 Area after Consol., A_c (in^2): 6.48
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 9.97 0.60817 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	94.27	104.07	0.000	6.481	0.00	0.00	9.80	9.80	1.00	0.00	0.00	0.71
1.52	0.00	18.45	95.12	104.05	0.029	6.483	0.00	0.20	8.96	11.81	1.32	0.06	0.10	0.75
3.02	0.00	36.67	95.79	104.05	0.051	6.484	0.00	0.41	8.28	13.94	1.68	0.11	0.20	0.80
4.52	0.00	50.69	96.27	104.04	0.083	6.486	0.00	0.56	7.80	15.61	2.00	0.14	0.28	0.84
6.02	0.01	61.50	96.60	104.02	0.104	6.487	0.00	0.68	7.47	16.95	2.27	0.17	0.34	0.88
7.52	0.01	71.19	96.80	103.99	0.127	6.489	0.01	0.79	7.27	18.24	2.51	0.18	0.39	0.92
9.02	0.01	79.67	96.91	103.95	0.150	6.490	0.01	0.88	7.16	19.44	2.71	0.19	0.44	0.96
10.52	0.01	86.15	96.92	103.86	0.173	6.492	0.01	0.95	7.15	20.43	2.85	0.19	0.48	0.99
12.02	0.01	91.96	97.22	104.11	0.205	6.494	0.01	1.02	6.85	21.01	3.07	0.21	0.51	1.00
13.53	0.01	97.37	97.23	104.09	0.228	6.495	0.01	1.08	6.84	21.83	3.19	0.21	0.54	1.03
15.03	0.01	101.25	97.22	104.07	0.248	6.497	0.01	1.12	6.85	22.44	3.27	0.21	0.56	1.05
16.53	0.02	105.44	97.19	104.05	0.279	6.499	0.01	1.17	6.88	23.11	3.36	0.21	0.58	1.08
18.03	0.02	108.94	97.16	104.03	0.303	6.500	0.01	1.21	6.91	23.67	3.42	0.21	0.60	1.10
19.53	0.02	112.77	97.11	103.99	0.322	6.502	0.01	1.25	6.96	24.31	3.49	0.20	0.62	1.13
21.03	0.02	115.56	97.05	103.96	0.345	6.503	0.01	1.28	7.03	24.80	3.53	0.20	0.64	1.15
22.53	0.02	119.30	96.96	103.91	0.369	6.505	0.02	1.32	7.12	25.46	3.58	0.19	0.66	1.17
24.03	0.02	121.68	96.82	103.81	0.400	6.507	0.02	1.35	7.26	25.96	3.58	0.18	0.67	1.20
25.53	0.02	123.84	97.06	104.08	0.416	6.508	0.02	1.37	7.02	26.05	3.71	0.20	0.69	1.19
27.03	0.03	126.18	97.01	104.06	0.441	6.509	0.02	1.39	7.06	26.45	3.74	0.20	0.70	1.21
28.53	0.03	128.31	96.96	104.04	0.475	6.512	0.02	1.42	7.11	26.82	3.77	0.19	0.71	1.22
30.03	0.03	131.48	96.91	104.03	0.498	6.513	0.02	1.45	7.17	27.35	3.82	0.19	0.73	1.24
31.55	0.03	133.29	96.84	104.01	0.519	6.514	0.02	1.47	7.23	27.70	3.83	0.19	0.74	1.26
33.05	0.03	136.74	96.77	103.99	0.547	6.516	0.02	1.51	7.31	28.29	3.87	0.18	0.76	1.28
34.55	0.03	138.50	96.69	103.95	0.566	6.518	0.02	1.53	7.38	28.63	3.88	0.17	0.76	1.30
36.05	0.03	141.11	96.59	103.89	0.591	6.519	0.02	1.56	7.49	29.13	3.89	0.17	0.78	1.32
37.55	0.04	142.59	96.38	103.72	0.620	6.521	0.03	1.57	7.70	29.56	3.84	0.15	0.79	1.34
39.05	0.04	144.54	96.70	104.09	0.642	6.523	0.03	1.59	7.38	29.54	4.00	0.17	0.80	1.33
40.55	0.04	146.68	96.64	104.07	0.661	6.524	0.03	1.62	7.43	29.92	4.02	0.17	0.81	1.34
42.05	0.04	149.81	96.57	104.05	0.690	6.526	0.03	1.65	7.50	30.46	4.06	0.17	0.83	1.37
43.55	0.04	151.42	96.50	104.04	0.719	6.528	0.03	1.67	7.57	30.77	4.06	0.16	0.84	1.38
45.05	0.04	154.14	96.43	104.02	0.743	6.529	0.03	1.70	7.65	31.26	4.09	0.16	0.85	1.40
46.55	0.04	155.53	96.36	103.99	0.762	6.530	0.03	1.71	7.72	31.53	4.09	0.15	0.86	1.41
48.05	0.04	156.98	96.28	103.95	0.781	6.532	0.03	1.73	7.80	31.83	4.08	0.14	0.87	1.43
49.55	0.05	158.18	96.18	103.89	0.814	6.534	0.03	1.74	7.89	32.10	4.07	0.14	0.87	1.44
51.05	0.05	160.80	96.26	104.02	0.845	6.536	0.04	1.77	7.81	32.42	4.15	0.14	0.89	1.45
52.55	0.05	162.13	96.30	104.09	0.862	6.537	0.04	1.78	7.78	32.58	4.19	0.15	0.89	1.45
54.05	0.05	164.71	96.23	104.07	0.885	6.539	0.04	1.81	7.84	33.03	4.21	0.14	0.91	1.47
55.55	0.05	165.93	96.17	104.06	0.912	6.540	0.04	1.82	7.90	33.27	4.21	0.14	0.91	1.48
57.05	0.05	168.24	96.10	104.04	0.941	6.542	0.04	1.85	7.97	33.69	4.23	0.13	0.93	1.50
58.55	0.06	168.51	96.05	104.03	0.966	6.544	0.04	1.85	8.02	33.77	4.21	0.13	0.93	1.50
60.05	0.06	171.23	95.98	104.00	0.992	6.546	0.04	1.88	8.09	34.25	4.23	0.12	0.94	1.52
66.07	0.06	180.02	95.88	104.10	1.089	6.552	0.05	1.97	8.20	35.67	4.35	0.12	0.99	1.58
72.07	0.07	185.25	95.64	104.04	1.198	6.559	0.05	2.03	8.44	36.68	4.35	0.10	1.02	1.62
78.07	0.07	192.49	95.53	104.13	1.303	6.566	0.05	2.11	8.54	37.86	4.43	0.09	1.06	1.67
84.07	0.08	198.75	95.30	104.03	1.396	6.572	0.06	2.17	8.77	39.02	4.45	0.07	1.09	1.72
90.07	0.09	205.73	94.87	103.80	1.495	6.579	0.06	2.25	9.20	40.47	4.40	0.04	1.13	1.79
96.07	0.09	212.13	94.93	104.04	1.595	6.586	0.07	2.31	9.14	41.35	4.52	0.05	1.16	1.82
102.07	0.10	218.32	94.62	103.90	1.699	6.593	0.07	2.38	9.46	42.57	4.50	0.03	1.19	1.87
108.07	0.10	224.87	94.58	104.07	1.792	6.599	0.07	2.45	9.49	43.57	4.59	0.02	1.23	1.91
114.08	0.11	230.92	94.29	103.96	1.893	6.606	0.08	2.51	9.78	44.74	4.57	0.00	1.26	1.96
120.08	0.11	235.93	94.21	104.09	1.995	6.613	0.08	2.56	9.86	45.54	4.62	0.00	1.28	1.99
126.08	0.12	239.80	93.99	104.02	2.098	6.620	0.09	2.60	10.08	46.31	4.59	-0.02	1.30	2.03
132.08	0.13	245.64	93.90	104.12	2.197	6.626	0.09	2.66	10.17	47.24	4.64	-0.03	1.33	2.07
138.08	0.13	252.35	93.62	104.04	2.304	6.634	0.10	2.73	10.46	48.50	4.64	-0.05	1.37	2.12
144.08	0.14	256.34	93.53	104.13	2.402	6.640	0.10	2.77	10.55	49.15	4.66	-0.05	1.39	2.15
150.08	0.14	262.68	93.28	104.06	2.495	6.646	0.10	2.84	10.79	50.32	4.66	-0.07	1.42	2.20
156.08	0.15	267.30	92.86	103.80	2.603	6.654	0.11	2.88	11.22	51.39	4.58	-0.10	1.45	2.25

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: 100% Lime Pond Sludge
Sample No.: 0 Specimen No.: B
Depth (ft.): 0

Initial Height., H_o (in): 5.806 Confining Pressure (psi): 10.00
Initial Diameter, D_o (in): 2.880 Initial Volume, V_o (in^3): 37.82
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.51
Ht Change at End of Consol., ΔH_o (in): 0.064 H_c 5.742 Area after Consol., A_c (in^2): 6.48
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 9.97 0.60817 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
162.08	0.16	273.83	92.91	104.09	2.710	6.661	0.11	2.95	11.16	52.27	4.68	-0.10	1.48	2.28
168.08	0.16	277.52	92.61	103.94	2.805	6.668	0.12	2.99	11.46	53.09	4.63	-0.12	1.50	2.32
174.08	0.17	281.24	92.59	104.12	2.915	6.675	0.12	3.02	11.48	53.61	4.67	-0.12	1.52	2.34
180.08	0.17	286.31	92.31	103.99	3.005	6.681	0.13	3.08	11.77	54.62	4.64	-0.14	1.54	2.39
186.10	0.18	291.27	92.23	104.11	3.101	6.688	0.13	3.13	11.85	55.40	4.68	-0.15	1.57	2.42
192.10	0.18	295.26	91.99	104.03	3.205	6.695	0.13	3.17	12.09	56.19	4.65	-0.16	1.59	2.46
198.10	0.19	301.92	91.92	104.14	3.305	6.702	0.14	3.23	12.15	57.20	4.71	-0.17	1.62	2.50
204.10	0.20	306.94	91.65	104.06	3.415	6.710	0.14	3.28	12.43	58.17	4.68	-0.19	1.65	2.54
210.10	0.20	310.70	91.57	104.16	3.517	6.717	0.15	3.32	12.51	58.76	4.70	-0.19	1.67	2.57
216.10	0.21	316.41	91.34	104.07	3.606	6.723	0.15	3.38	12.74	59.80	4.70	-0.21	1.69	2.61
222.10	0.21	318.10	91.22	104.13	3.706	6.730	0.15	3.39	12.85	60.12	4.68	-0.22	1.70	2.63
228.10	0.22	324.48	90.98	104.11	3.808	6.737	0.16	3.46	13.09	61.26	4.68	-0.24	1.73	2.68
234.12	0.22	327.72	90.63	103.90	3.906	6.744	0.16	3.49	13.45	62.04	4.61	-0.26	1.75	2.72
240.12	0.23	331.64	90.66	104.12	4.008	6.751	0.17	3.52	13.41	62.53	4.66	-0.26	1.77	2.73
246.12	0.24	335.67	90.37	103.99	4.108	6.758	0.17	3.56	13.71	63.38	4.62	-0.28	1.79	2.78
252.12	0.24	340.70	90.33	104.14	4.199	6.765	0.17	3.61	13.74	64.11	4.66	-0.28	1.81	2.80
258.12	0.25	344.96	90.05	104.02	4.308	6.772	0.18	3.65	14.03	64.96	4.63	-0.30	1.83	2.84
264.13	0.25	348.40	90.02	104.15	4.411	6.780	0.18	3.69	14.05	65.44	4.66	-0.31	1.85	2.86
270.13	0.26	354.48	89.73	104.06	4.511	6.787	0.19	3.75	14.34	66.57	4.64	-0.33	1.88	2.91
276.13	0.26	358.25	89.67	104.17	4.608	6.794	0.19	3.78	14.41	67.14	4.66	-0.33	1.90	2.94
282.13	0.27	361.06	89.43	104.09	4.714	6.801	0.20	3.81	14.65	67.74	4.62	-0.35	1.91	2.97
288.13	0.28	364.99	89.37	104.18	4.808	6.808	0.20	3.85	14.71	68.32	4.65	-0.35	1.93	2.99
294.13	0.28	368.39	89.11	104.10	4.905	6.815	0.20	3.88	14.96	69.02	4.61	-0.37	1.95	3.02
300.13	0.29	372.69	88.63	103.78	5.012	6.823	0.21	3.92	15.45	70.07	4.54	-0.41	1.97	3.08
315.13	0.30	382.08	88.59	104.17	5.265	6.841	0.22	4.01	15.49	71.34	4.61	-0.41	2.01	3.13
330.13	0.32	389.98	88.21	104.15	5.514	6.859	0.23	4.08	15.86	72.72	4.58	-0.44	2.05	3.19
345.13	0.33	398.84	87.79	104.13	5.769	6.877	0.24	4.16	16.28	74.27	4.56	-0.47	2.09	3.26
360.13	0.35	408.08	87.37	104.10	6.024	6.896	0.25	4.24	16.71	75.88	4.54	-0.50	2.13	3.33
375.13	0.36	415.64	86.94	104.06	6.264	6.914	0.26	4.31	17.14	77.25	4.51	-0.53	2.16	3.40
390.13	0.37	424.03	86.48	103.98	6.520	6.933	0.27	4.38	17.60	78.76	4.48	-0.56	2.20	3.47
405.13	0.39	431.73	86.32	104.17	6.780	6.952	0.28	4.45	17.75	79.86	4.50	-0.57	2.24	3.51
420.13	0.40	439.06	85.95	104.18	7.035	6.971	0.29	4.51	18.12	81.10	4.48	-0.60	2.27	3.57
435.15	0.42	443.25	85.66	104.15	7.281	6.990	0.30	4.54	18.41	81.83	4.44	-0.62	2.28	3.61
450.15	0.43	452.05	85.29	104.12	7.540	7.009	0.31	4.62	18.79	83.28	4.43	-0.65	2.32	3.67
465.15	0.45	458.10	84.92	104.09	7.791	7.028	0.32	4.67	19.15	84.33	4.40	-0.67	2.35	3.73
480.15	0.46	464.60	84.61	104.03	8.042	7.047	0.34	4.72	19.47	85.39	4.39	-0.70	2.37	3.77
495.15	0.48	469.59	84.11	103.85	8.282	7.066	0.35	4.76	19.96	86.42	4.33	-0.73	2.39	3.83
510.15	0.49	473.41	84.20	104.20	8.539	7.086	0.36	4.78	19.87	86.68	4.36	-0.72	2.41	3.84
525.15	0.50	480.01	83.90	104.17	8.793	7.105	0.37	4.84	20.17	87.73	4.35	-0.75	2.43	3.88
540.15	0.52	485.73	83.60	104.15	9.048	7.125	0.38	4.88	20.48	88.65	4.33	-0.77	2.45	3.93
555.15	0.53	489.73	83.36	104.12	9.299	7.145	0.39	4.91	20.71	89.25	4.31	-0.79	2.47	3.96
570.15	0.55	495.07	83.07	104.07	9.548	7.165	0.40	4.95	21.01	90.10	4.29	-0.81	2.49	4.00
585.15	0.56	499.58	82.75	103.97	9.806	7.185	0.41	4.98	21.33	90.85	4.26	-0.83	2.50	4.04
600.17	0.58	505.08	82.75	104.21	10.054	7.205	0.42	5.02	21.32	91.42	4.29	-0.83	2.52	4.06
615.17	0.59	509.66	82.51	104.18	10.316	7.226	0.43	5.05	21.56	92.09	4.27	-0.85	2.54	4.09
630.17	0.61	512.91	82.29	104.16	10.564	7.246	0.44	5.06	21.78	92.57	4.25	-0.86	2.55	4.12
645.17	0.62	517.56	82.08	104.14	10.820	7.267	0.45	5.10	21.99	93.22	4.24	-0.88	2.56	4.15
660.17	0.64	522.65	81.83	104.09	11.071	7.287	0.46	5.13	22.25	93.97	4.22	-0.90	2.58	4.18
675.17	0.65	526.10	81.57	104.01	11.323	7.308	0.47	5.15	22.51	94.49	4.20	-0.91	2.59	4.21
690.17	0.66	530.17	81.59	104.22	11.577	7.329	0.48	5.17	22.48	94.82	4.22	-0.91	2.60	4.22
705.17	0.68	534.16	81.44	104.21	11.831	7.350	0.49	5.20	22.64	95.31	4.21	-0.92	2.62	4.25
720.18	0.69	539.43	81.19	104.18	12.083	7.371	0.50	5.23	22.88	96.06	4.20	-0.94	2.63	4.28
735.18	0.71	539.28	81.06	104.16	12.330	7.392	0.51	5.22	23.01	95.97	4.17	-0.95	2.63	4.28
750.18	0.72	544.77	80.85	104.11	12.584	7.414	0.52	5.25	23.22	96.70	4.16	-0.97	2.65	4.32
765.18	0.74	548.75	80.57	104.05	12.829	7.434	0.53	5.28	23.50	97.31	4.14	-0.99	2.66	4.35
780.18	0.75	551.23	80.58	104.15	13.087	7.456	0.55	5.28	23.49	97.42	4.15	-0.99	2.66	4.35
795.18	0.77	555.33	80.51	104.20	13.353	7.479	0.56	5.31	23.56	97.81	4.15	-0.99	2.67	4.37

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: 100% Lime Pond Sludge
Sample No.: 0 Specimen No.: B
Depth (ft.): 0

Initial Height., H_o (in):	5.806	Confining Pressure (psi):	10.00
Initial Diameter, D_o (in):	2.880	Initial Volume, V_o (in^3):	37.82
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.51
Ht Change at End of Consol., ΔH_o (in):	0.064 H_c 5.742	Area after Consol., A_c (in^2):	6.48
Ht Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
Volume change during Consol. V_c (cc^3):	9.97 0.60817 in^3		

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
810.18	0.78	557.24	80.39	104.13	13.609	7.502	0.57	5.31	23.68	97.96	4.14	-1.00	2.67	4.38
825.18	0.80	563.55	80.26	104.05	13.860	7.523	0.58	5.35	23.82	98.72	4.14	-1.01	2.70	4.41
840.18	0.81	564.90	80.15	104.00	14.097	7.544	0.59	5.35	23.92	98.80	4.13	-1.02	2.70	4.42

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: 100% Lime Pond Sludge
Sample No.: Ash 50% Specimen No.: C
Depth (ft.): 0

Initial Height., H_o (in): 5.881 Confining Pressure (psi): 15.00
Initial Diameter, D_o (in): 2.880 Initial Volume, V_o (in^3): 38.31
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.51
t Change at End of Consol.,ΔH_o (in): 0.035 H_c 5.846 Area after Consol., A_c (in^2): 5.94
Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
ume change during Consol. V_c (cc^3): 58.45 3.56545 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	80.14	94.87	0.000	5.944	0.00	0.00	14.72	14.72	1.00	0.00	0.00	1.06
1.52	0.001	18.88	81.14	94.87	0.015	5.945	0.00	0.23	13.72	16.90	1.23	0.07	0.11	1.10
3.02	0.002	39.47	82.09	94.87	0.041	5.946	0.00	0.48	12.78	19.42	1.52	0.14	0.24	1.16
4.52	0.004	60.04	82.89	94.87	0.061	5.947	0.00	0.73	11.98	22.08	1.84	0.20	0.36	1.23
6.03	0.004	80.23	83.60	94.93	0.071	5.948	0.00	0.97	11.26	24.75	2.20	0.25	0.49	1.30
7.53	0.006	98.49	84.09	94.94	0.100	5.950	0.00	1.19	10.78	27.33	2.54	0.28	0.60	1.37
9.03	0.007	114.55	84.40	94.94	0.118	5.951	0.00	1.39	10.47	29.72	2.84	0.31	0.69	1.45
10.55	0.008	128.24	84.58	94.94	0.144	5.952	0.01	1.55	10.28	31.83	3.10	0.32	0.78	1.52
12.07	0.011	140.83	84.67	94.94	0.180	5.954	0.01	1.70	10.20	33.85	3.32	0.33	0.85	1.59
13.57	0.011	151.59	84.67	94.94	0.196	5.955	0.01	1.83	10.20	35.65	3.50	0.33	0.92	1.65
15.08	0.013	160.69	84.62	94.94	0.215	5.957	0.01	1.94	10.25	37.23	3.63	0.32	0.97	1.71
16.58	0.015	168.61	84.53	94.94	0.259	5.959	0.01	2.04	10.33	38.63	3.74	0.32	1.02	1.76
18.08	0.016	175.54	84.43	94.93	0.275	5.960	0.01	2.12	10.44	39.89	3.82	0.31	1.06	1.81
19.58	0.017	181.73	84.37	94.98	0.286	5.961	0.01	2.19	10.49	40.98	3.90	0.30	1.10	1.85
21.10	0.019	187.25	84.26	94.99	0.318	5.963	0.01	2.26	10.61	42.01	3.96	0.30	1.13	1.89
22.60	0.020	192.90	84.14	94.98	0.346	5.964	0.01	2.33	10.73	43.07	4.01	0.29	1.16	1.94
24.10	0.021	198.08	84.01	94.98	0.361	5.965	0.02	2.39	10.86	44.06	4.06	0.28	1.20	1.98
25.62	0.022	202.62	83.89	94.98	0.384	5.967	0.02	2.44	10.97	44.93	4.09	0.27	1.22	2.01
27.13	0.024	206.52	83.78	94.98	0.414	5.968	0.02	2.49	11.08	45.69	4.12	0.26	1.25	2.04
28.63	0.026	210.25	83.68	94.98	0.442	5.970	0.02	2.53	11.19	46.40	4.15	0.25	1.27	2.07
30.13	0.027	213.60	83.58	94.97	0.458	5.971	0.02	2.57	11.29	47.06	4.17	0.25	1.29	2.10
31.63	0.028	216.95	83.48	94.96	0.482	5.973	0.02	2.61	11.39	47.71	4.19	0.24	1.31	2.13
33.13	0.029	220.83	83.43	95.02	0.502	5.974	0.02	2.66	11.43	48.40	4.23	0.24	1.33	2.15
34.63	0.031	224.28	83.34	95.02	0.529	5.975	0.02	2.70	11.53	49.06	4.26	0.23	1.35	2.18
36.13	0.032	227.34	83.24	95.02	0.553	5.977	0.02	2.74	11.62	49.66	4.27	0.22	1.37	2.21
37.63	0.034	230.07	83.16	95.01	0.584	5.979	0.02	2.77	11.71	50.19	4.29	0.22	1.39	2.23
39.13	0.035	232.77	83.08	95.01	0.606	5.980	0.03	2.80	11.79	50.71	4.30	0.21	1.40	2.25
40.65	0.037	235.21	83.00	95.01	0.626	5.981	0.03	2.83	11.86	51.19	4.31	0.21	1.42	2.27
42.15	0.038	238.04	82.92	95.01	0.652	5.983	0.03	2.86	11.94	51.73	4.33	0.20	1.43	2.29
43.67	0.040	241.24	82.84	95.00	0.679	5.984	0.03	2.90	12.03	52.34	4.35	0.19	1.45	2.32
45.17	0.041	243.92	82.74	94.99	0.706	5.986	0.03	2.93	12.12	52.87	4.36	0.19	1.47	2.34
46.68	0.042	246.46	82.71	95.04	0.722	5.987	0.03	2.96	12.15	53.32	4.39	0.19	1.48	2.36
48.18	0.044	248.79	82.65	95.04	0.747	5.988	0.03	2.99	12.21	53.76	4.40	0.18	1.50	2.38
49.68	0.046	250.96	82.58	95.04	0.781	5.990	0.03	3.01	12.28	54.18	4.41	0.18	1.51	2.39
51.18	0.047	252.89	82.52	95.04	0.800	5.992	0.03	3.04	12.34	54.55	4.42	0.17	1.52	2.41
52.68	0.049	255.10	82.46	95.04	0.831	5.994	0.03	3.06	12.40	54.97	4.43	0.17	1.53	2.43
54.20	0.050	257.78	82.39	95.04	0.861	5.995	0.04	3.09	12.48	55.48	4.45	0.16	1.55	2.45
55.70	0.051	260.23	82.31	95.03	0.880	5.997	0.04	3.12	12.56	55.95	4.46	0.16	1.56	2.47
57.22	0.053	262.25	82.24	95.02	0.900	5.998	0.04	3.15	12.63	56.35	4.46	0.15	1.57	2.48
58.73	0.054	264.15	82.18	95.01	0.927	5.999	0.04	3.17	12.69	56.72	4.47	0.15	1.59	2.50
60.23	0.055	265.88	82.17	95.06	0.946	6.001	0.04	3.19	12.70	57.01	4.49	0.15	1.60	2.51
66.23	0.061	274.45	81.94	95.06	1.045	6.007	0.04	3.29	12.93	58.62	4.53	0.13	1.64	2.58
72.25	0.067	281.18	81.70	95.03	1.140	6.012	0.05	3.36	13.17	59.93	4.55	0.11	1.68	2.63
78.25	0.073	289.52	81.51	95.07	1.244	6.019	0.05	3.46	13.36	61.46	4.60	0.10	1.73	2.69
84.25	0.079	296.18	81.29	95.06	1.346	6.025	0.06	3.54	13.58	62.74	4.62	0.08	1.77	2.75
90.25	0.085	303.11	81.10	95.09	1.448	6.031	0.06	3.61	13.76	64.02	4.65	0.07	1.81	2.80
96.25	0.090	309.89	80.88	95.08	1.548	6.037	0.06	3.69	13.98	65.31	4.67	0.05	1.85	2.85
102.27	0.096	315.65	80.72	95.11	1.643	6.043	0.07	3.76	14.15	66.38	4.69	0.04	1.88	2.90
108.27	0.102	322.37	80.49	95.10	1.751	6.050	0.07	3.83	14.38	67.66	4.71	0.03	1.92	2.95
114.27	0.108	328.32	80.27	95.06	1.848	6.056	0.08	3.90	14.60	68.82	4.71	0.01	1.95	3.00
120.27	0.115	333.98	80.11	95.11	1.959	6.062	0.08	3.96	14.76	69.84	4.73	0.00	1.98	3.05
126.27	0.120	340.06	79.89	95.08	2.052	6.068	0.09	4.03	14.97	71.01	4.74	-0.02	2.02	3.10
132.27	0.126	343.94	79.74	95.07	2.152	6.074	0.09	4.07	15.13	71.75	4.74	-0.03	2.04	3.13
138.27	0.131	349.60	79.59	94.97	2.248	6.080	0.09	4.13	15.28	72.77	4.76	-0.04	2.07	3.17
144.27	0.137	355.24	79.57	95.02	2.339	6.086	0.10	4.20	15.30	73.67	4.82	-0.04	2.10	3.20

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: 100% Lime Pond Sludge
Sample No.: Ash 50% Specimen No.: C
Depth (ft.): 0

Initial Height., H_o (in): 5.881 Confining Pressure (psi): 15.00
Initial Diameter, D_o (in): 2.880 Initial Volume, V_o (in^3): 38.31
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.51
t Change at End of Consol.,ΔH_o (in): 0.035 H_c 5.846 Area after Consol., A_c (in^2): 5.94
Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
ume change during Consol. V_c (cc^3): 58.45 3.56545 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
150.28	0.144	361.03	79.34	95.03	2.457	6.093	0.10	4.26	15.53	74.78	4.81	-0.06	2.13	3.25
156.30	0.149	366.05	79.16	95.08	2.555	6.100	0.11	4.31	15.71	75.72	4.82	-0.07	2.16	3.29
162.30	0.155	370.16	78.93	95.07	2.659	6.106	0.11	4.36	15.93	76.56	4.80	-0.09	2.18	3.33
168.30	0.161	375.63	78.69	95.05	2.751	6.112	0.11	4.42	16.17	77.63	4.80	-0.10	2.21	3.38
174.30	0.166	379.24	78.57	95.10	2.837	6.117	0.12	4.46	16.30	78.29	4.80	-0.11	2.23	3.41
180.32	0.172	384.78	78.33	95.07	2.945	6.124	0.12	4.51	16.54	79.37	4.80	-0.13	2.26	3.45
186.32	0.178	389.01	78.21	95.11	3.052	6.131	0.13	4.56	16.66	80.11	4.81	-0.14	2.28	3.48
192.32	0.184	392.34	78.00	95.03	3.146	6.137	0.13	4.59	16.87	80.80	4.79	-0.15	2.30	3.52
198.32	0.190	396.62	78.00	95.00	3.250	6.143	0.14	4.64	16.87	81.43	4.83	-0.15	2.32	3.54
204.33	0.195	400.92	77.89	95.01	3.343	6.149	0.14	4.68	16.98	82.17	4.84	-0.16	2.35	3.57
210.33	0.202	406.31	77.67	95.05	3.448	6.156	0.14	4.74	17.20	83.20	4.84	-0.18	2.38	3.61
216.33	0.208	410.07	77.47	95.06	3.556	6.163	0.15	4.78	17.40	83.93	4.82	-0.19	2.40	3.65
222.35	0.214	414.08	77.22	95.04	3.655	6.169	0.15	4.82	17.65	84.77	4.80	-0.21	2.42	3.69
228.35	0.219	418.40	77.07	95.09	3.750	6.175	0.16	4.87	17.80	85.55	4.81	-0.22	2.44	3.72
234.35	0.225	421.12	76.89	95.08	3.847	6.182	0.16	4.89	17.97	86.10	4.79	-0.23	2.45	3.75
240.37	0.231	426.23	76.72	95.12	3.955	6.189	0.16	4.95	18.14	87.02	4.80	-0.25	2.48	3.79
246.37	0.237	428.07	76.58	95.02	4.056	6.195	0.17	4.96	18.29	87.39	4.78	-0.26	2.49	3.80
252.37	0.244	432.40	76.55	94.99	4.166	6.202	0.17	5.01	18.32	88.04	4.81	-0.26	2.51	3.83
258.38	0.250	436.79	76.45	95.01	4.268	6.209	0.18	5.05	18.42	88.77	4.82	-0.27	2.53	3.86
264.38	0.255	439.81	76.28	95.05	4.359	6.215	0.18	5.08	18.59	89.36	4.81	-0.28	2.55	3.89
270.38	0.261	444.48	76.06	95.07	4.462	6.221	0.19	5.13	18.81	90.25	4.80	-0.29	2.57	3.93
276.40	0.266	446.51	75.86	95.05	4.557	6.228	0.19	5.15	19.01	90.71	4.77	-0.31	2.58	3.95
282.42	0.273	451.06	75.68	95.09	4.662	6.234	0.19	5.20	19.19	91.54	4.77	-0.32	2.60	3.99
288.42	0.279	453.82	75.51	95.08	4.774	6.242	0.20	5.22	19.35	92.06	4.76	-0.33	2.62	4.01
294.42	0.284	457.18	75.38	95.11	4.863	6.248	0.20	5.25	19.49	92.66	4.75	-0.34	2.63	4.04
300.42	0.290	461.30	75.19	95.09	4.962	6.254	0.21	5.30	19.67	93.43	4.75	-0.36	2.66	4.07
315.40	0.305	467.55	75.06	94.99	5.210	6.270	0.22	5.35	19.81	94.37	4.76	-0.37	2.68	4.11
330.42	0.320	476.42	74.59	95.04	5.471	6.288	0.23	5.44	20.28	96.05	4.74	-0.40	2.73	4.19
345.42	0.334	482.66	74.23	95.10	5.716	6.304	0.24	5.50	20.63	97.19	4.71	-0.43	2.76	4.24
360.42	0.350	488.96	73.97	95.03	5.982	6.322	0.25	5.55	20.89	98.24	4.70	-0.44	2.78	4.29
375.42	0.364	496.06	73.81	95.06	6.223	6.338	0.26	5.62	21.05	99.32	4.72	-0.46	2.82	4.33
390.42	0.378	502.41	73.40	95.09	6.474	6.355	0.27	5.67	21.46	100.52	4.68	-0.49	2.85	4.39
405.43	0.393	507.61	73.08	95.11	6.719	6.372	0.28	5.72	21.79	101.45	4.66	-0.51	2.87	4.44
420.43	0.408	513.35	72.78	95.11	6.987	6.390	0.29	5.76	22.08	102.42	4.64	-0.53	2.89	4.48
435.43	0.423	518.13	72.68	95.01	7.231	6.407	0.30	5.80	22.19	103.06	4.64	-0.54	2.91	4.51
450.43	0.438	523.45	72.33	95.06	7.484	6.425	0.31	5.84	22.53	104.01	4.62	-0.56	2.93	4.56
465.43	0.452	528.16	71.99	95.08	7.736	6.442	0.32	5.88	22.88	104.86	4.58	-0.59	2.95	4.60
480.45	0.466	530.34	71.81	94.98	7.970	6.458	0.33	5.89	23.05	105.17	4.56	-0.60	2.96	4.62
495.45	0.481	536.62	71.74	95.07	8.226	6.476	0.34	5.94	23.13	105.98	4.58	-0.60	2.98	4.65
510.45	0.496	539.14	71.46	95.11	8.479	6.494	0.35	5.95	23.41	106.43	4.55	-0.63	2.99	4.67
525.45	0.511	543.33	71.19	95.12	8.737	6.513	0.36	5.98	23.68	107.11	4.52	-0.64	3.00	4.71
540.45	0.525	545.16	71.19	95.04	8.989	6.531	0.37	5.98	23.68	107.15	4.53	-0.64	3.01	4.71
555.47	0.540	548.88	70.93	95.10	9.242	6.549	0.39	6.01	23.93	107.74	4.50	-0.66	3.02	4.74
570.47	0.555	549.08	70.80	95.11	9.492	6.567	0.40	5.99	24.07	107.68	4.47	-0.67	3.01	4.74
585.47	0.569	552.12	70.85	95.01	9.741	6.585	0.41	6.01	24.02	107.86	4.49	-0.67	3.02	4.75
600.47	0.584	553.16	70.65	95.07	9.996	6.604	0.42	6.00	24.21	107.98	4.46	-0.68	3.02	4.76
615.48	0.599	555.71	70.49	95.09	10.248	6.622	0.43	6.01	24.38	108.29	4.44	-0.70	3.02	4.78
630.48	0.613	556.92	70.42	95.16	10.493	6.641	0.44	6.01	24.44	108.31	4.43	-0.70	3.02	4.78
645.48	0.628	558.62	70.41	95.02	10.742	6.659	0.45	6.01	24.45	108.34	4.43	-0.70	3.02	4.78
660.50	0.643	561.20	70.28	95.10	10.997	6.678	0.46	6.02	24.58	108.62	4.42	-0.71	3.03	4.80
675.50	0.657	562.85	70.15	95.13	11.242	6.697	0.47	6.02	24.71	108.76	4.40	-0.72	3.03	4.81
690.50	0.673	562.83	70.06	95.04	11.507	6.717	0.48	6.00	24.80	108.60	4.38	-0.73	3.02	4.80
705.50	0.687	564.76	70.13	95.07	11.755	6.736	0.49	6.00	24.73	108.58	4.39	-0.72	3.02	4.80
720.52	0.701	565.48	69.97	95.10	11.994	6.754	0.50	5.99	24.90	108.63	4.36	-0.73	3.01	4.81
735.52	0.716	564.94	69.95	95.06	12.250	6.774	0.51	5.97	24.92	108.32	4.35	-0.73	3.00	4.80

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: 100% Lime Pond Sludge

Sample No.: Ash 50% Specimen No.: C

Depth (ft.): 0

Initial Height., H_o (in): 5.881 Confining Pressure (psi): 15.00

Initial Diameter, D_o (in): 2.880 Initial Volume, V_o (in^3): 38.31

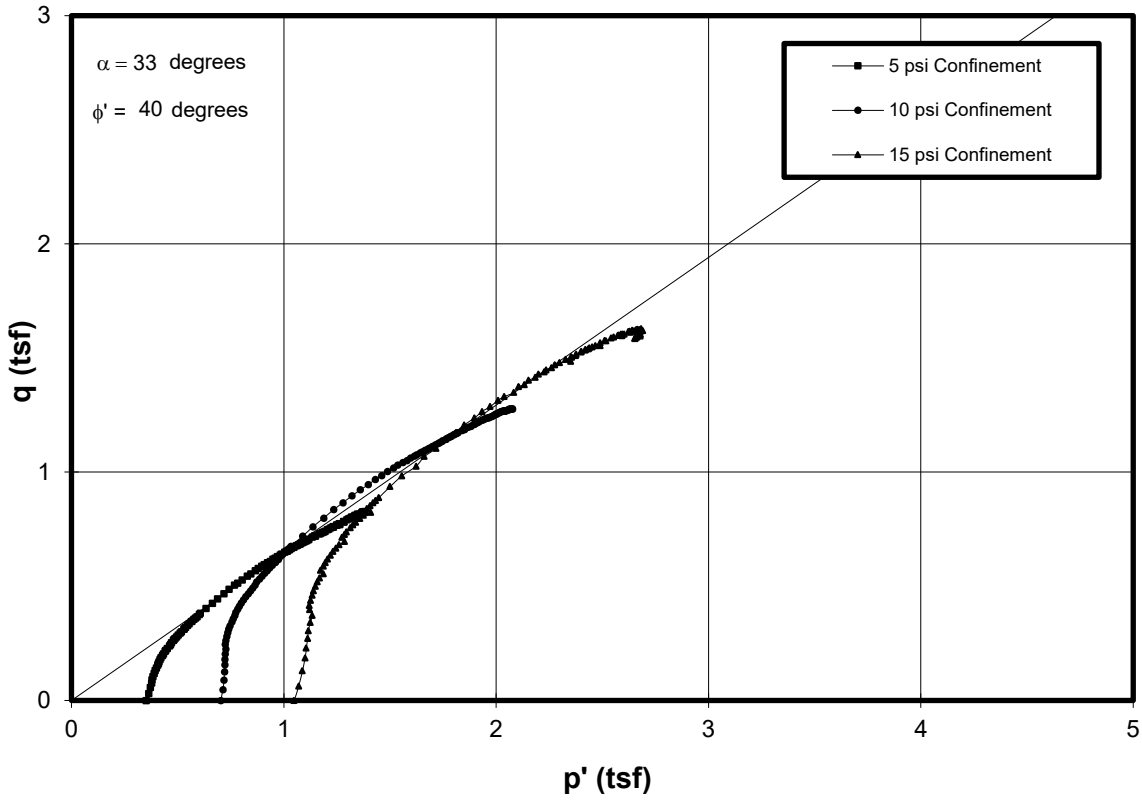
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.51

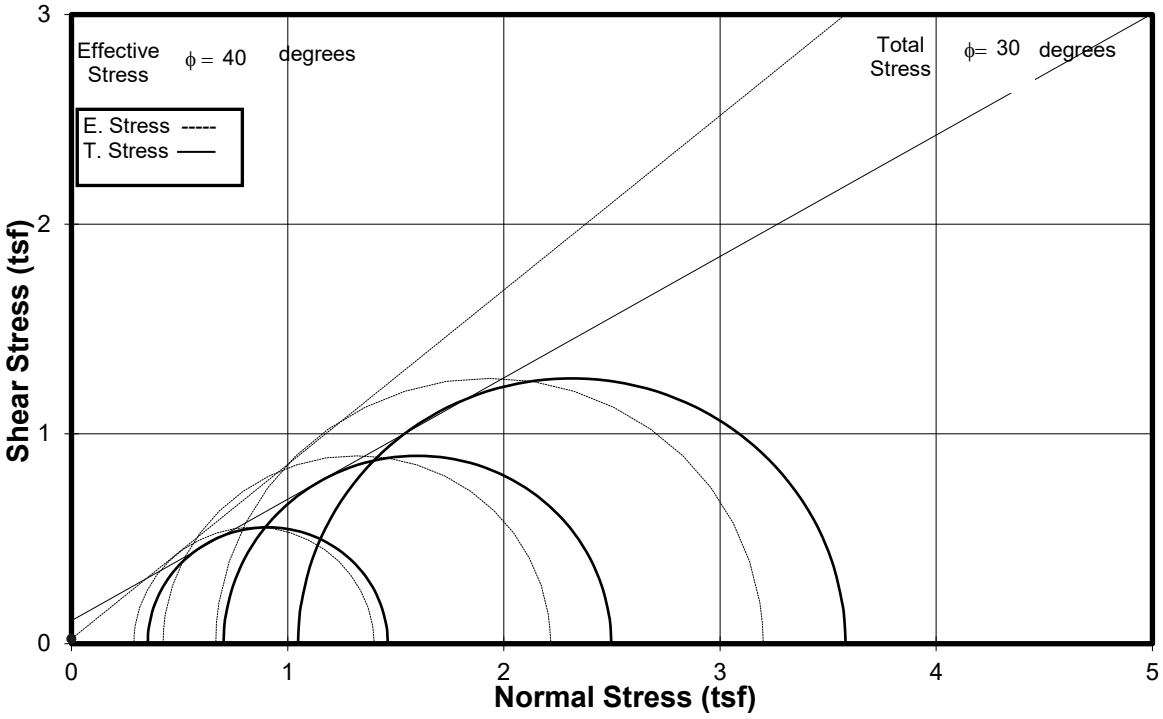
t Change at End of Consol.,ΔH_o (in): 0.035 H_c 5.846 Area after Consol., A_c (in^2): 5.94

Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0

ume change during Consol. V_c (cc^3): 58.45 3.56545 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
750.63	0.731	567.43	70.02	95.04	12.497	6.793	0.52	5.98	24.85	108.39	4.36	-0.73	3.01	4.80
765.63	0.745	566.96	69.93	95.08	12.750	6.812	0.53	5.95	24.94	108.16	4.34	-0.74	3.00	4.79
780.65	0.760	568.46	69.92	95.16	12.995	6.831	0.54	5.95	24.95	108.16	4.34	-0.74	3.00	4.79
795.65	0.774	566.94	69.94	95.12	13.244	6.851	0.55	5.92	24.93	107.68	4.32	-0.73	2.98	4.77
810.65	0.789	569.32	70.02	95.09	13.503	6.872	0.56	5.92	24.85	107.70	4.33	-0.73	2.98	4.77
825.65	0.804	567.75	69.99	95.14	13.754	6.892	0.57	5.89	24.87	107.26	4.31	-0.73	2.97	4.76
840.65	0.819	569.51	69.93	95.14	14.005	6.912	0.58	5.89	24.94	107.33	4.30	-0.74	2.97	4.76
855.65	0.834	569.15	70.10	95.07	14.259	6.932	0.59	5.87	24.77	106.87	4.31	-0.72	2.96	4.74
870.65	0.849	570.73	69.97	95.12	14.520	6.953	0.61	5.87	24.90	106.98	4.30	-0.73	2.95	4.75
885.67	0.863	570.23	69.96	95.14	14.756	6.973	0.61	5.84	24.91	106.69	4.28	-0.73	2.94	4.74



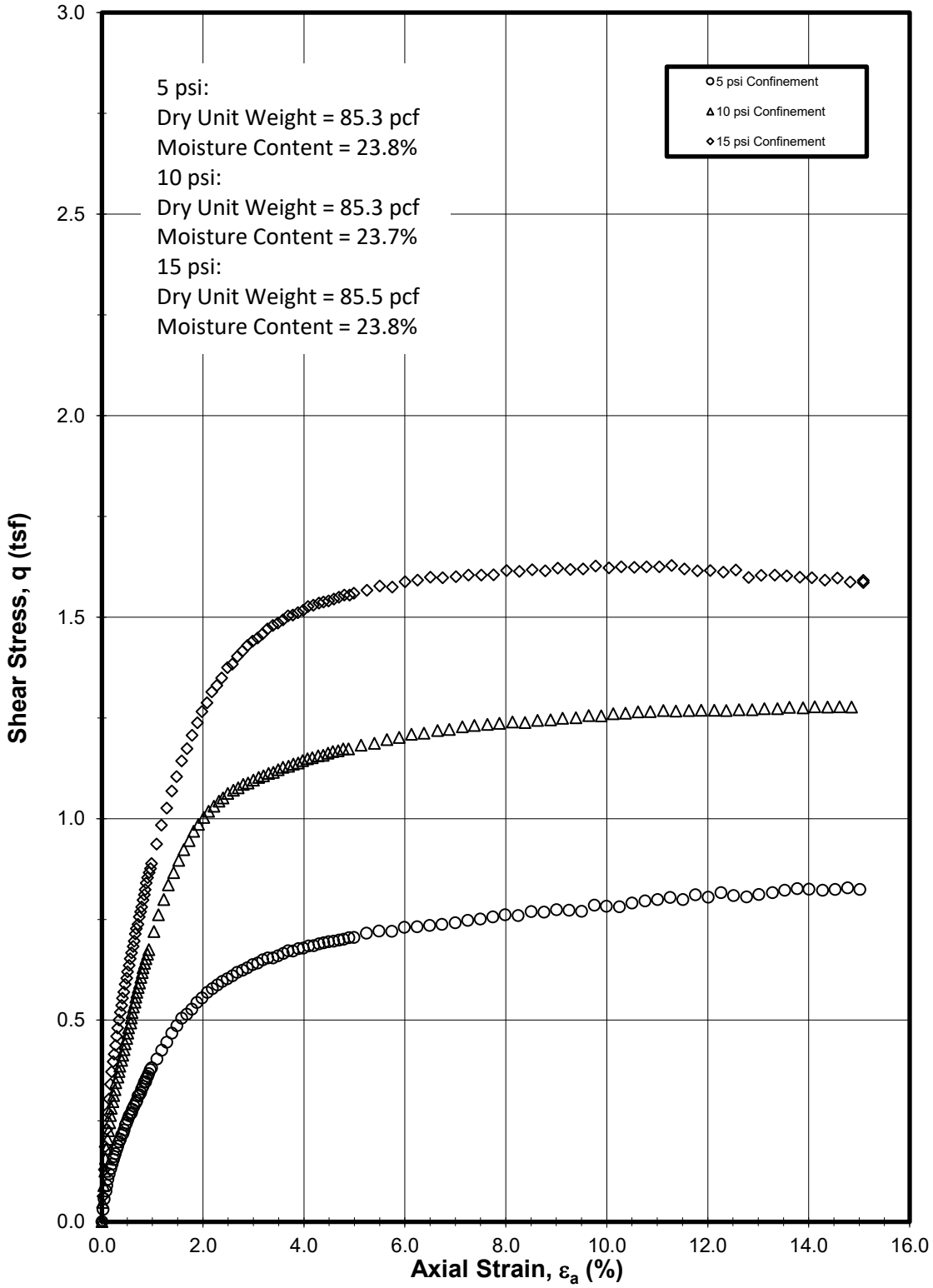


CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST

ASTM D 4767

Project No.: J039697.01

Boring: 70% Lime Pond Sludge / 30% Ash



CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST

ASTM D 4767

Project No.: J039697.01

Boring: 70% Lime Pond Sludge / 30% Ash

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime Pond Sludge
Sample No.: 30% Ash Specimen No.: A
Depth (ft.): 0

Initial Height., H_o (in): 5.854 Confining Pressure (psi): 5.00
Initial Diameter, D_o (in): 2.883 Initial Volume, V_o (in^3): 38.21
Membrane Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
Ht Change at End of Consol.,ΔH_o (in): 0.023 H_c 5.831 Area after Consol., A_c (in^2): 6.531
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 2.17 0.13237 in^3

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	80.12	85.01	0.000	6.531	0.00	0.00	4.89	4.89	1.00	0.00	0.000	0.352
1.50	0.00	5.52	80.38	84.99	0.022	6.532	0.00	0.06	4.62	5.47	1.18	0.02	0.030	0.363
3.00	0.00	10.30	80.64	85.02	0.042	6.534	0.00	0.11	4.36	5.94	1.36	0.04	0.057	0.371
4.50	0.00	13.89	80.84	85.02	0.077	6.536	0.00	0.15	4.16	6.29	1.51	0.05	0.076	0.376
6.00	0.01	16.34	81.00	85.01	0.096	6.537	0.00	0.18	4.01	6.51	1.62	0.06	0.090	0.378
7.52	0.01	19.09	81.14	85.02	0.117	6.539	0.00	0.21	3.86	6.78	1.76	0.07	0.105	0.383
9.02	0.01	21.51	81.26	85.01	0.144	6.540	0.01	0.24	3.75	7.04	1.88	0.08	0.118	0.388
10.52	0.01	23.94	81.37	85.01	0.175	6.542	0.01	0.26	3.64	7.30	2.01	0.09	0.132	0.394
12.02	0.01	26.03	81.45	85.01	0.200	6.544	0.01	0.29	3.55	7.53	2.12	0.10	0.143	0.399
13.53	0.01	28.11	81.53	85.00	0.227	6.546	0.01	0.31	3.48	7.77	2.23	0.10	0.155	0.405
15.03	0.01	29.44	81.59	85.00	0.242	6.547	0.01	0.32	3.41	7.91	2.32	0.11	0.162	0.408
16.53	0.02	30.76	81.64	85.01	0.264	6.548	0.01	0.34	3.36	8.06	2.40	0.11	0.169	0.411
18.03	0.02	32.64	81.73	85.04	0.292	6.550	0.01	0.36	3.28	8.26	2.52	0.12	0.179	0.415
19.55	0.02	34.07	81.77	85.03	0.311	6.551	0.01	0.37	3.23	8.44	2.61	0.12	0.187	0.420
21.05	0.02	36.02	81.81	85.03	0.337	6.553	0.01	0.39	3.20	8.69	2.72	0.12	0.198	0.428
22.57	0.02	37.27	81.85	85.02	0.362	6.555	0.02	0.41	3.16	8.85	2.80	0.12	0.205	0.432
24.07	0.02	39.17	81.88	85.03	0.390	6.557	0.02	0.43	3.13	9.10	2.91	0.13	0.215	0.440
25.57	0.02	39.97	81.90	85.03	0.416	6.558	0.02	0.44	3.10	9.20	2.96	0.13	0.219	0.443
27.07	0.03	41.51	81.92	85.01	0.436	6.560	0.02	0.45	3.09	9.42	3.05	0.13	0.228	0.450
28.57	0.03	43.64	81.93	85.01	0.465	6.562	0.02	0.48	3.07	9.72	3.16	0.13	0.239	0.461
30.08	0.03	44.71	81.95	85.00	0.487	6.563	0.02	0.49	3.06	9.87	3.23	0.13	0.245	0.465
31.58	0.03	46.21	81.99	85.04	0.511	6.565	0.02	0.51	3.02	10.06	3.33	0.13	0.253	0.471
33.08	0.03	48.00	82.00	85.03	0.541	6.567	0.02	0.52	3.00	10.31	3.43	0.14	0.263	0.479
34.60	0.03	48.78	82.01	85.04	0.564	6.568	0.02	0.53	2.99	10.42	3.48	0.14	0.267	0.483
36.10	0.03	49.47	82.01	85.03	0.584	6.569	0.02	0.54	3.00	10.53	3.51	0.14	0.271	0.487
37.60	0.04	50.91	82.01	85.01	0.603	6.571	0.03	0.56	3.00	10.74	3.59	0.14	0.279	0.495
39.12	0.04	52.30	82.01	85.02	0.635	6.573	0.03	0.57	3.00	10.95	3.66	0.14	0.286	0.502
40.62	0.04	53.95	82.01	85.02	0.670	6.575	0.03	0.59	3.00	11.20	3.74	0.14	0.295	0.511
42.13	0.04	54.89	82.00	85.02	0.692	6.577	0.03	0.60	3.00	11.35	3.78	0.14	0.300	0.517
43.63	0.04	56.92	81.99	85.01	0.713	6.578	0.03	0.62	3.01	11.67	3.87	0.13	0.312	0.528
45.13	0.04	57.61	82.01	85.03	0.740	6.580	0.03	0.63	3.00	11.75	3.92	0.14	0.315	0.531
46.63	0.04	58.53	82.00	85.03	0.765	6.581	0.03	0.64	3.00	11.90	3.96	0.14	0.320	0.536
48.13	0.05	60.25	82.00	85.03	0.787	6.583	0.03	0.66	3.01	12.16	4.04	0.14	0.329	0.546
49.63	0.05	61.49	81.99	85.03	0.812	6.584	0.03	0.67	3.02	12.36	4.09	0.13	0.336	0.554
51.13	0.05	63.29	81.97	85.03	0.841	6.586	0.04	0.69	3.03	12.64	4.17	0.13	0.346	0.564
52.63	0.05	63.64	81.96	85.02	0.864	6.588	0.04	0.69	3.05	12.71	4.17	0.13	0.348	0.567
54.13	0.05	65.10	81.94	85.03	0.879	6.589	0.04	0.71	3.06	12.94	4.23	0.13	0.356	0.576
55.65	0.05	66.05	81.92	85.02	0.901	6.590	0.04	0.72	3.08	13.10	4.25	0.13	0.361	0.583
57.15	0.05	67.29	81.91	85.02	0.925	6.592	0.04	0.73	3.09	13.30	4.30	0.13	0.367	0.590
58.65	0.06	69.07	81.89	85.01	0.953	6.594	0.04	0.75	3.11	13.59	4.36	0.13	0.377	0.601
60.17	0.06	70.00	81.90	85.04	0.983	6.596	0.04	0.76	3.10	13.71	4.42	0.13	0.382	0.605
66.17	0.06	74.09	81.82	85.04	1.087	6.603	0.05	0.80	3.19	14.41	4.52	0.12	0.404	0.633
72.17	0.07	78.08	81.71	85.01	1.184	6.609	0.05	0.85	3.29	15.11	4.59	0.11	0.425	0.663
78.17	0.07	81.84	81.65	85.03	1.282	6.616	0.05	0.89	3.35	15.72	4.69	0.11	0.445	0.687
84.17	0.08	86.03	81.55	85.02	1.385	6.623	0.06	0.93	3.46	16.45	4.75	0.10	0.468	0.717
90.17	0.09	89.63	81.47	85.05	1.482	6.629	0.06	0.97	3.54	17.06	4.82	0.10	0.487	0.741
96.17	0.09	93.12	81.36	85.03	1.580	6.636	0.07	1.01	3.65	17.68	4.85	0.09	0.505	0.768
102.17	0.10	94.97	81.29	85.05	1.681	6.643	0.07	1.02	3.72	18.01	4.85	0.08	0.515	0.782
108.17	0.10	97.47	81.18	85.03	1.780	6.649	0.07	1.05	3.83	18.49	4.83	0.08	0.528	0.803
114.17	0.11	100.62	81.07	85.02	1.882	6.656	0.08	1.08	3.93	19.05	4.84	0.07	0.544	0.827
120.17	0.12	102.78	81.00	85.04	1.981	6.663	0.08	1.10	4.00	19.43	4.85	0.06	0.555	0.844
126.18	0.12	105.49	80.89	85.03	2.085	6.670	0.09	1.13	4.12	19.93	4.84	0.06	0.569	0.866
132.18	0.13	107.28	80.83	85.05	2.186	6.677	0.09	1.15	4.18	20.25	4.85	0.05	0.578	0.879
138.18	0.13	109.11	80.74	85.04	2.284	6.684	0.10	1.17	4.27	20.59	4.82	0.04	0.588	0.895
144.18	0.14	110.76	80.67	85.05	2.384	6.691	0.10	1.18	4.33	20.88	4.82	0.04	0.596	0.908
150.20	0.14	112.20	80.58	85.04	2.482	6.697	0.10	1.20	4.43	21.18	4.78	0.03	0.603	0.922

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime Pond Sludge
Sample No.: 30% Ash Specimen No.: A
Depth (ft.): 0

Initial Height., H_o (in): 5.854 Confining Pressure (psi): 5.00
Initial Diameter, D_o (in): 2.883 Initial Volume, V_o (in^3): 38.21
Membrane Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
Ht Change at End of Consol.,ΔH_o (in): 0.023 H_c 5.831 Area after Consol., A_c (in^2): 6.531
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 2.17 0.13237 in^3

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
156.20	0.15	113.57	80.48	85.02	2.582	6.704	0.11	1.21	4.53	21.47	4.74	0.03	0.610	0.936
162.20	0.16	115.33	80.43	85.05	2.679	6.711	0.11	1.23	4.58	21.76	4.76	0.02	0.619	0.948
168.20	0.16	116.42	80.35	85.03	2.780	6.718	0.12	1.24	4.65	21.98	4.72	0.02	0.624	0.959
174.20	0.17	117.67	80.30	85.05	2.879	6.725	0.12	1.25	4.70	22.20	4.72	0.01	0.630	0.969
180.20	0.17	119.32	80.22	85.03	2.984	6.732	0.12	1.27	4.79	22.51	4.70	0.01	0.638	0.983
186.22	0.18	120.13	80.18	85.06	3.086	6.739	0.13	1.27	4.82	22.65	4.69	0.00	0.642	0.989
192.22	0.19	121.80	80.10	85.04	3.183	6.746	0.13	1.29	4.91	22.97	4.68	0.00	0.650	1.004
198.22	0.19	122.71	80.02	85.03	3.283	6.753	0.14	1.30	4.98	23.16	4.65	-0.01	0.654	1.013
204.22	0.20	122.87	79.99	85.05	3.386	6.760	0.14	1.30	5.02	23.19	4.62	-0.01	0.654	1.015
210.23	0.20	123.96	79.93	85.04	3.484	6.767	0.15	1.31	5.08	23.40	4.61	-0.01	0.660	1.025
216.23	0.21	125.32	79.90	85.06	3.593	6.774	0.15	1.32	5.11	23.61	4.62	-0.02	0.666	1.034
222.23	0.21	126.60	79.82	85.04	3.684	6.781	0.15	1.33	5.18	23.86	4.60	-0.02	0.672	1.045
228.23	0.22	126.64	79.80	85.06	3.782	6.788	0.16	1.33	5.20	23.86	4.59	-0.02	0.672	1.046
234.23	0.23	127.94	79.73	85.05	3.893	6.796	0.16	1.34	5.27	24.10	4.57	-0.03	0.678	1.057
240.25	0.23	128.29	79.67	85.03	3.988	6.802	0.17	1.35	5.34	24.20	4.54	-0.03	0.679	1.063
246.25	0.24	129.44	79.65	85.05	4.092	6.810	0.17	1.36	5.36	24.37	4.55	-0.03	0.684	1.070
252.25	0.24	129.71	79.59	85.04	4.192	6.817	0.17	1.36	5.42	24.45	4.51	-0.04	0.685	1.075
258.25	0.25	130.65	79.57	85.06	4.296	6.824	0.18	1.37	5.44	24.58	4.52	-0.04	0.689	1.081
264.25	0.26	131.35	79.51	85.04	4.392	6.831	0.18	1.37	5.49	24.72	4.50	-0.04	0.692	1.088
270.27	0.26	132.00	79.49	85.06	4.490	6.838	0.19	1.38	5.51	24.81	4.50	-0.05	0.695	1.092
276.27	0.27	132.37	79.43	85.06	4.590	6.845	0.19	1.38	5.58	24.91	4.47	-0.05	0.696	1.098
282.27	0.27	132.95	79.41	85.05	4.693	6.853	0.20	1.38	5.60	25.00	4.47	-0.05	0.698	1.101
288.27	0.28	133.54	79.36	85.04	4.785	6.859	0.20	1.39	5.64	25.11	4.45	-0.05	0.701	1.107
294.27	0.29	134.38	79.31	85.03	4.889	6.867	0.20	1.39	5.70	25.27	4.43	-0.06	0.704	1.115
300.28	0.29	134.73	79.30	85.06	4.992	6.874	0.21	1.40	5.70	25.30	4.44	-0.06	0.706	1.116
315.28	0.31	137.12	79.21	85.06	5.236	6.892	0.22	1.42	5.79	25.69	4.43	-0.07	0.716	1.133
330.28	0.32	138.46	79.13	85.05	5.486	6.910	0.23	1.43	5.88	25.91	4.41	-0.07	0.721	1.145
345.28	0.33	138.63	79.05	85.05	5.741	6.929	0.24	1.42	5.95	25.96	4.36	-0.08	0.720	1.149
360.28	0.35	140.92	78.97	85.06	5.989	6.947	0.25	1.44	6.04	26.32	4.36	-0.08	0.730	1.165
375.30	0.36	141.58	78.90	85.05	6.242	6.966	0.26	1.44	6.11	26.43	4.33	-0.09	0.732	1.171
390.30	0.38	142.66	78.83	85.04	6.492	6.984	0.27	1.45	6.18	26.60	4.31	-0.09	0.735	1.180
405.30	0.39	143.53	78.76	85.04	6.735	7.003	0.28	1.46	6.24	26.74	4.28	-0.10	0.738	1.187
420.32	0.41	144.65	78.73	85.07	6.994	7.022	0.29	1.46	6.28	26.88	4.28	-0.10	0.742	1.194
435.32	0.42	146.29	78.67	85.06	7.243	7.041	0.30	1.47	6.34	27.11	4.28	-0.10	0.748	1.204
450.32	0.44	147.30	78.60	85.07	7.493	7.060	0.31	1.48	6.40	27.27	4.26	-0.11	0.751	1.212
465.33	0.45	148.67	78.54	85.07	7.741	7.079	0.32	1.49	6.46	27.46	4.25	-0.11	0.756	1.221
480.33	0.47	150.18	78.48	85.07	7.986	7.098	0.33	1.50	6.53	27.69	4.24	-0.12	0.762	1.232
495.33	0.48	150.21	78.44	85.06	8.243	7.118	0.34	1.49	6.57	27.67	4.21	-0.12	0.760	1.233
510.35	0.50	152.57	78.35	85.05	8.500	7.138	0.35	1.51	6.65	28.03	4.21	-0.13	0.770	1.248
525.35	0.51	152.71	78.32	85.06	8.757	7.158	0.36	1.51	6.69	28.02	4.19	-0.13	0.768	1.250
540.35	0.52	154.38	78.25	85.06	9.002	7.177	0.37	1.52	6.75	28.26	4.19	-0.13	0.774	1.260
555.35	0.54	154.55	78.22	85.06	9.252	7.197	0.39	1.52	6.79	28.26	4.16	-0.14	0.773	1.262
570.37	0.55	154.37	78.16	85.05	9.497	7.216	0.40	1.51	6.85	28.24	4.12	-0.14	0.770	1.263
585.37	0.57	157.86	78.12	85.07	9.753	7.237	0.41	1.54	6.89	28.70	4.17	-0.14	0.785	1.281
600.37	0.58	157.74	78.08	85.08	9.991	7.256	0.42	1.54	6.92	28.66	4.14	-0.15	0.783	1.281
615.37	0.60	158.00	78.04	85.08	10.250	7.277	0.43	1.53	6.96	28.68	4.12	-0.15	0.782	1.283
630.38	0.61	160.32	78.00	85.07	10.499	7.297	0.44	1.55	7.01	28.98	4.13	-0.15	0.791	1.296
645.38	0.63	161.80	77.95	85.07	10.754	7.318	0.45	1.56	7.05	29.16	4.13	-0.16	0.796	1.304
660.38	0.64	162.90	77.89	85.06	11.004	7.339	0.46	1.57	7.12	29.31	4.12	-0.16	0.799	1.311
675.38	0.66	164.45	77.86	85.07	11.254	7.359	0.47	1.58	7.15	29.49	4.13	-0.16	0.804	1.319
690.40	0.67	163.89	77.82	85.06	11.507	7.380	0.48	1.56	7.19	29.40	4.09	-0.17	0.799	1.317
705.40	0.69	166.73	77.75	85.06	11.754	7.401	0.49	1.59	7.25	29.78	4.11	-0.17	0.811	1.333
720.40	0.70	165.97	77.72	85.06	12.009	7.422	0.50	1.57	7.29	29.65	4.07	-0.17	0.805	1.330
735.40	0.72	168.78	77.66	85.06	12.264	7.444	0.51	1.60	7.35	30.02	4.09	-0.18	0.816	1.345
750.40	0.73	167.81	77.66	85.08	12.511	7.465	0.52	1.58	7.34	29.82	4.06	-0.18	0.809	1.338
765.42	0.74	167.55	77.60	85.08	12.769	7.487	0.53	1.57	7.40	29.78	4.02	-0.18	0.806	1.339

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime Pond Sludge
Sample No.: 30% Ash Specimen No.: A
Depth (ft.): 0

Initial Height., H_o (in):	5.854	Confining Pressure (psi):	5.00
Initial Diameter, D_o (in):	2.883	Initial Volume, V_o (in^3):	38.21
Membrane Thickness (in):	0.02	Initial Area, A_o (in^2):	6.53
Ht Change at End of Consol.,ΔH_o (in):	0.023 H_c 5.831	Area after Consol., A_c (in^2):	6.531
Ht Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
Volume change during Consol. V_c (cc^3):	2.17 0.13237 in^3		

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
780.42	0.76	169.35	77.57	85.08	13.010	7.508	0.54	1.59	7.44	29.99	4.03	-0.18	0.812	1.348
795.43	0.77	170.85	77.54	85.06	13.278	7.531	0.55	1.59	7.47	30.15	4.04	-0.19	0.817	1.354
810.43	0.79	172.59	77.46	85.01	13.525	7.553	0.56	1.60	7.55	30.40	4.03	-0.19	0.823	1.366
825.43	0.80	173.84	77.45	85.01	13.771	7.574	0.57	1.61	7.56	30.51	4.04	-0.19	0.826	1.370
840.43	0.82	174.09	77.41	85.02	14.006	7.595	0.58	1.61	7.59	30.51	4.02	-0.19	0.825	1.372
855.45	0.83	174.05	77.40	85.03	14.271	7.618	0.59	1.60	7.60	30.45	4.00	-0.20	0.822	1.370
870.45	0.85	174.96	77.36	84.99	14.521	7.640	0.60	1.61	7.64	30.54	4.00	-0.20	0.824	1.375
885.45	0.86	176.33	77.33	84.99	14.771	7.663	0.61	1.61	7.67	30.68	4.00	-0.20	0.828	1.381
900.02	0.88	175.95	77.30	84.98	15.014	7.685	0.62	1.60	7.70	30.60	3.97	-0.20	0.824	1.379

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 70%
Sample No.: Ash 30% Specimen No.: B
Depth (ft.): 0

Initial Height., H_o (in): 5.951 Confining Pressure (psi): 10.00
Initial Diameter, D_o (in): 2.881 Initial Volume, V_o (in^3): 38.80
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.52
Ht Change at End of Consol., ΔH_o (in): 0.004 H_c 5.947 Area after Consol., A_c (in^2): 6.48
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 3.99 0.24339 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	85.25	95.01	0.000	6.484	0.00	0.00	9.76	9.76	1.00	0.00	0.00	0.70
1.52	0.00	8.62	85.79	95.01	0.011	6.485	0.00	0.10	9.23	10.56	1.14	0.04	0.05	0.71
3.02	0.00	16.17	86.29	95.01	0.037	6.487	0.00	0.18	8.72	11.21	1.29	0.08	0.09	0.72
4.52	0.00	22.63	86.76	95.00	0.058	6.488	0.00	0.25	8.26	11.75	1.42	0.11	0.13	0.72
6.02	0.00	28.19	87.16	95.00	0.070	6.489	0.00	0.31	7.86	12.20	1.55	0.14	0.16	0.72
7.52	0.01	32.62	87.50	94.99	0.086	6.490	0.00	0.36	7.52	12.54	1.67	0.16	0.18	0.72
9.03	0.01	36.85	87.80	94.98	0.110	6.491	0.00	0.41	7.21	12.89	1.79	0.18	0.20	0.72
10.53	0.01	40.73	88.07	94.96	0.132	6.493	0.01	0.45	6.95	13.22	1.90	0.20	0.23	0.73
12.05	0.01	44.32	88.37	95.02	0.151	6.494	0.01	0.49	6.64	13.47	2.03	0.22	0.25	0.72
13.55	0.01	47.56	88.58	95.02	0.169	6.495	0.01	0.53	6.43	13.75	2.14	0.24	0.26	0.73
15.05	0.01	50.74	88.77	95.02	0.183	6.496	0.01	0.56	6.24	14.05	2.25	0.25	0.28	0.73
16.55	0.01	53.73	88.94	95.01	0.215	6.498	0.01	0.59	6.08	14.34	2.36	0.27	0.30	0.74
18.05	0.01	56.49	89.07	95.00	0.231	6.499	0.01	0.63	5.94	14.63	2.46	0.28	0.31	0.74
19.55	0.02	59.23	89.21	95.00	0.256	6.501	0.01	0.66	5.81	14.92	2.57	0.28	0.33	0.75
21.07	0.02	62.24	89.32	94.99	0.276	6.502	0.01	0.69	5.69	15.26	2.68	0.29	0.34	0.75
22.57	0.02	64.77	89.42	94.98	0.315	6.505	0.01	0.72	5.59	15.55	2.78	0.30	0.36	0.76
24.08	0.02	67.32	89.51	94.97	0.338	6.506	0.01	0.74	5.51	15.85	2.88	0.31	0.37	0.77
25.58	0.02	69.78	89.64	95.02	0.356	6.507	0.01	0.77	5.37	16.09	3.00	0.32	0.39	0.77
27.10	0.02	72.41	89.72	95.02	0.393	6.510	0.02	0.80	5.29	16.42	3.10	0.32	0.40	0.78
28.60	0.02	74.73	89.78	95.02	0.414	6.511	0.02	0.83	5.23	16.70	3.20	0.33	0.41	0.79
30.12	0.03	77.25	89.84	95.01	0.436	6.513	0.02	0.85	5.17	17.03	3.29	0.33	0.43	0.80
31.62	0.03	79.85	89.89	95.00	0.462	6.514	0.02	0.88	5.12	17.38	3.39	0.33	0.44	0.81
33.13	0.03	82.27	89.93	95.00	0.492	6.516	0.02	0.91	5.08	17.70	3.49	0.34	0.45	0.82
34.63	0.03	84.76	89.97	94.99	0.510	6.517	0.02	0.93	5.04	18.05	3.58	0.34	0.47	0.83
36.15	0.03	87.08	90.00	94.98	0.530	6.519	0.02	0.96	5.02	18.37	3.66	0.34	0.48	0.84
37.65	0.03	89.36	90.02	94.97	0.570	6.521	0.02	0.98	5.00	18.70	3.74	0.34	0.49	0.85
39.17	0.03	91.58	90.05	94.98	0.581	6.522	0.02	1.01	4.96	19.00	3.83	0.35	0.51	0.86
40.67	0.04	94.04	90.11	95.02	0.597	6.523	0.02	1.04	4.90	19.32	3.94	0.35	0.52	0.87
42.17	0.04	96.51	90.12	95.01	0.625	6.525	0.03	1.06	4.89	19.68	4.02	0.35	0.53	0.88
43.67	0.04	98.75	90.13	95.01	0.656	6.527	0.03	1.09	4.88	20.01	4.10	0.35	0.54	0.90
45.17	0.04	101.04	90.13	95.00	0.673	6.528	0.03	1.11	4.88	20.36	4.17	0.35	0.56	0.91
46.67	0.04	103.17	90.13	95.00	0.690	6.529	0.03	1.14	4.88	20.68	4.24	0.35	0.57	0.92
48.17	0.04	105.36	90.13	94.99	0.720	6.531	0.03	1.16	4.88	21.02	4.30	0.35	0.58	0.93
49.68	0.04	107.50	90.12	94.99	0.744	6.533	0.03	1.18	4.89	21.35	4.36	0.35	0.59	0.94
51.18	0.05	109.97	90.10	94.97	0.772	6.535	0.03	1.21	4.91	21.74	4.43	0.35	0.61	0.96
52.70	0.05	112.19	90.08	94.96	0.796	6.536	0.03	1.23	4.93	22.09	4.48	0.35	0.62	0.97
54.20	0.05	114.36	90.13	95.02	0.813	6.537	0.03	1.26	4.88	22.38	4.58	0.35	0.63	0.98
55.70	0.05	116.52	90.11	95.01	0.845	6.539	0.04	1.28	4.90	22.72	4.63	0.35	0.64	0.99
57.22	0.05	118.59	90.09	95.01	0.874	6.541	0.04	1.30	4.92	23.05	4.68	0.35	0.65	1.01
58.72	0.05	120.58	90.07	95.01	0.902	6.543	0.04	1.32	4.95	23.38	4.73	0.35	0.66	1.02
60.23	0.06	122.75	90.04	95.00	0.929	6.545	0.04	1.35	4.97	23.72	4.77	0.35	0.68	1.03
66.23	0.06	130.97	89.90	94.96	1.032	6.552	0.04	1.44	5.12	25.11	4.91	0.33	0.72	1.09
72.23	0.07	138.70	89.81	95.01	1.122	6.558	0.05	1.52	5.21	26.36	5.06	0.33	0.76	1.14
78.25	0.07	145.71	89.63	94.98	1.224	6.565	0.05	1.59	5.39	27.58	5.12	0.32	0.80	1.19
84.25	0.08	152.55	89.49	95.01	1.317	6.571	0.05	1.67	5.53	28.74	5.20	0.30	0.84	1.23
90.25	0.08	158.27	89.30	94.99	1.418	6.578	0.06	1.73	5.72	29.78	5.21	0.29	0.87	1.28
96.25	0.09	163.99	89.14	95.02	1.521	6.584	0.06	1.79	5.88	30.78	5.24	0.28	0.90	1.32
102.25	0.10	168.95	88.95	95.01	1.623	6.591	0.07	1.84	6.07	31.70	5.23	0.27	0.92	1.36
108.25	0.10	173.24	88.74	94.97	1.725	6.598	0.07	1.89	6.27	32.53	5.18	0.25	0.95	1.40
114.25	0.11	177.67	88.59	95.01	1.817	6.604	0.08	1.93	6.42	33.32	5.19	0.24	0.97	1.43
120.25	0.11	180.97	88.41	94.98	1.914	6.611	0.08	1.97	6.60	33.98	5.15	0.23	0.99	1.46
126.25	0.12	184.39	88.28	95.02	2.018	6.618	0.08	2.00	6.73	34.59	5.14	0.22	1.00	1.49
132.27	0.13	187.41	88.11	94.99	2.114	6.624	0.09	2.03	6.90	35.19	5.10	0.21	1.02	1.52
138.27	0.13	189.89	88.00	95.02	2.219	6.631	0.09	2.06	7.02	35.65	5.08	0.20	1.03	1.54
144.27	0.14	192.35	87.84	95.00	2.316	6.638	0.10	2.08	7.17	36.15	5.04	0.19	1.04	1.56
150.28	0.14	194.05	87.69	94.97	2.397	6.643	0.10	2.10	7.32	36.53	4.99	0.18	1.05	1.58
156.28	0.15	196.29	87.61	95.01	2.493	6.650	0.10	2.12	7.40	36.92	4.99	0.17	1.06	1.60

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 70%
Sample No.: Ash 30% Specimen No.: B
Depth (ft.): 0

Initial Height., H_o (in): 5.951 Confining Pressure (psi): 10.00
Initial Diameter, D_o (in): 2.881 Initial Volume, V_o (in^3): 38.80
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.52
Ht Change at End of Consol., ΔH_o (in): 0.004 H_c 5.947 Area after Consol., A_c (in^2): 6.48
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 3.99 0.24339 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
162.28	0.15	198.02	87.48	94.98	2.603	6.657	0.11	2.13	7.54	37.28	4.95	0.16	1.07	1.61
168.28	0.16	199.27	87.40	95.01	2.696	6.664	0.11	2.14	7.61	37.51	4.93	0.15	1.08	1.62
174.28	0.17	201.02	87.28	94.99	2.797	6.671	0.12	2.16	7.73	37.86	4.90	0.15	1.08	1.64
180.27	0.17	201.93	87.21	95.00	2.895	6.678	0.12	2.17	7.80	38.04	4.88	0.14	1.09	1.65
186.27	0.18	203.41	87.12	95.00	3.000	6.685	0.12	2.18	7.89	38.32	4.86	0.13	1.10	1.66
192.27	0.18	204.86	87.01	94.97	3.103	6.692	0.13	2.19	8.00	38.61	4.83	0.13	1.10	1.68
198.28	0.19	205.78	86.98	95.02	3.200	6.699	0.13	2.20	8.03	38.75	4.82	0.12	1.11	1.68
204.28	0.20	207.12	86.88	95.00	3.299	6.705	0.14	2.21	8.14	39.03	4.80	0.12	1.11	1.70
210.30	0.20	207.81	86.85	95.03	3.395	6.712	0.14	2.22	8.16	39.12	4.79	0.12	1.11	1.70
216.30	0.21	209.27	86.76	95.02	3.492	6.719	0.15	2.23	8.25	39.40	4.77	0.11	1.12	1.72
222.32	0.21	210.54	86.69	95.01	3.583	6.725	0.15	2.24	8.32	39.63	4.76	0.10	1.13	1.73
228.32	0.22	211.37	86.64	95.03	3.695	6.733	0.15	2.25	8.37	39.76	4.75	0.10	1.13	1.73
234.33	0.23	212.49	86.55	95.01	3.790	6.740	0.16	2.26	8.46	39.99	4.73	0.09	1.14	1.74
240.33	0.23	213.20	86.55	95.05	3.885	6.746	0.16	2.26	8.47	40.07	4.73	0.09	1.14	1.75
246.33	0.24	214.55	86.45	95.02	3.974	6.753	0.17	2.28	8.56	40.33	4.71	0.09	1.14	1.76
252.33	0.24	215.62	86.43	95.05	4.072	6.759	0.17	2.28	8.58	40.48	4.72	0.08	1.15	1.77
258.35	0.25	216.42	86.36	95.04	4.168	6.766	0.17	2.29	8.65	40.64	4.70	0.08	1.15	1.77
264.35	0.25	217.44	86.27	94.99	4.282	6.774	0.18	2.30	8.75	40.84	4.67	0.07	1.16	1.79
270.35	0.26	218.02	86.28	95.05	4.383	6.781	0.18	2.30	8.73	40.88	4.68	0.07	1.16	1.79
276.35	0.27	219.20	86.19	95.03	4.477	6.788	0.19	2.31	8.82	41.11	4.66	0.07	1.16	1.80
282.37	0.27	220.13	86.18	95.07	4.574	6.795	0.19	2.32	8.83	41.23	4.67	0.07	1.17	1.80
288.38	0.28	220.76	86.11	95.04	4.676	6.802	0.19	2.32	8.90	41.36	4.64	0.06	1.17	1.81
294.38	0.28	221.85	86.08	95.07	4.778	6.810	0.20	2.33	8.93	41.51	4.65	0.06	1.17	1.82
300.38	0.29	222.16	86.03	95.06	4.886	6.817	0.20	2.33	8.98	41.57	4.63	0.06	1.17	1.82
315.38	0.31	224.53	85.91	95.06	5.134	6.835	0.21	2.35	9.10	41.95	4.61	0.05	1.18	1.84
330.40	0.32	226.01	85.81	95.06	5.397	6.854	0.22	2.36	9.21	42.18	4.58	0.04	1.19	1.85
345.38	0.34	228.35	85.69	95.06	5.643	6.872	0.24	2.38	9.32	42.55	4.56	0.03	1.20	1.87
360.38	0.35	229.92	85.58	95.05	5.889	6.890	0.25	2.39	9.43	42.80	4.54	0.02	1.20	1.88
375.38	0.36	232.06	85.47	95.04	6.128	6.908	0.26	2.40	9.54	43.13	4.52	0.02	1.21	1.90
390.38	0.38	233.22	85.45	95.10	6.377	6.926	0.27	2.41	9.56	43.24	4.52	0.01	1.21	1.90
405.40	0.40	235.08	85.38	95.11	6.647	6.946	0.28	2.42	9.63	43.48	4.51	0.01	1.22	1.91
420.40	0.41	236.23	85.32	95.10	6.880	6.963	0.29	2.42	9.69	43.62	4.50	0.00	1.22	1.92
435.40	0.42	238.14	85.24	95.10	7.141	6.983	0.30	2.43	9.78	43.88	4.49	0.00	1.23	1.93
450.42	0.44	239.36	85.17	95.09	7.377	7.001	0.31	2.44	9.84	44.03	4.48	-0.01	1.23	1.94
465.40	0.45	240.64	85.11	95.09	7.633	7.020	0.32	2.45	9.91	44.18	4.46	-0.01	1.23	1.95
480.42	0.47	241.71	85.06	95.09	7.875	7.039	0.33	2.45	9.96	44.30	4.45	-0.01	1.24	1.95
495.42	0.48	243.03	84.99	95.09	8.134	7.058	0.34	2.45	10.03	44.46	4.43	-0.02	1.24	1.96
510.43	0.50	243.52	84.93	95.08	8.380	7.077	0.35	2.45	10.08	44.49	4.41	-0.02	1.24	1.96
525.43	0.51	245.15	84.87	95.07	8.629	7.097	0.36	2.46	10.15	44.69	4.40	-0.03	1.24	1.97
540.43	0.53	246.08	84.81	95.06	8.889	7.117	0.37	2.46	10.21	44.78	4.39	-0.03	1.24	1.98
555.45	0.54	247.63	84.74	95.05	9.127	7.135	0.38	2.47	10.27	44.98	4.38	-0.04	1.25	1.99
570.45	0.56	248.60	84.75	95.11	9.391	7.156	0.39	2.47	10.26	45.00	4.39	-0.04	1.25	1.99
585.47	0.57	250.24	84.70	95.11	9.643	7.176	0.40	2.48	10.32	45.19	4.38	-0.04	1.26	2.00
600.47	0.59	250.84	84.65	95.10	9.889	7.196	0.41	2.48	10.36	45.22	4.37	-0.04	1.25	2.00
615.47	0.60	252.58	84.60	95.10	10.126	7.215	0.42	2.49	10.41	45.42	4.36	-0.05	1.26	2.01
630.60	0.62	253.56	84.57	95.09	10.370	7.234	0.43	2.49	10.44	45.49	4.36	-0.05	1.26	2.01
645.62	0.63	254.98	84.52	95.08	10.622	7.255	0.44	2.50	10.49	45.64	4.35	-0.05	1.27	2.02
660.62	0.65	255.72	84.47	95.08	10.861	7.274	0.45	2.50	10.54	45.69	4.34	-0.06	1.27	2.02
675.62	0.66	256.97	84.43	95.07	11.121	7.296	0.46	2.50	10.59	45.81	4.33	-0.06	1.27	2.03
690.62	0.68	257.45	84.39	95.06	11.367	7.316	0.47	2.50	10.63	45.82	4.31	-0.06	1.27	2.03
705.62	0.69	258.55	84.35	95.05	11.629	7.337	0.48	2.50	10.66	45.90	4.30	-0.07	1.27	2.04
720.63	0.71	259.35	84.31	95.04	11.871	7.358	0.49	2.50	10.71	45.96	4.29	-0.07	1.27	2.04
735.63	0.72	260.15	84.32	95.10	12.127	7.379	0.51	2.50	10.69	45.94	4.30	-0.07	1.27	2.04
750.63	0.74	260.68	84.29	95.10	12.368	7.399	0.52	2.50	10.73	45.96	4.28	-0.07	1.27	2.04
765.62	0.75	261.77	84.25	95.10	12.619	7.421	0.53	2.50	10.76	46.03	4.28	-0.07	1.27	2.04
780.63	0.77	262.60	84.22	95.09	12.877	7.443	0.54	2.50	10.80	46.08	4.27	-0.07	1.27	2.05
795.63	0.78	263.86	84.19	95.09	13.120	7.463	0.55	2.51	10.82	46.17	4.27	-0.08	1.27	2.05

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 70%
Sample No.: Ash 30% Specimen No.: B
Depth (ft.): 0

Initial Height., H_o (in):	5.951	Confining Pressure (psi):	10.00
Initial Diameter, D_o (in):	2.881	Initial Volume, V_o (in^3):	38.80
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.52
Ht Change at End of Consol., ΔH_o (in):	0.004	H_c 5.947	Area after Consol., A_c (in^2): 6.48
Ht Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
Volume change during Consol. V_c (cc^3):	3.99	0.24339 in^3	

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
810.65	0.80	264.69	84.15	95.08	13.380	7.486	0.56	2.51	10.86	46.22	4.26	-0.08	1.27	2.05
825.65	0.81	266.16	84.12	95.07	13.619	7.507	0.57	2.51	10.89	46.35	4.26	-0.08	1.28	2.06
840.65	0.83	266.72	84.08	95.07	13.886	7.530	0.58	2.51	10.93	46.35	4.24	-0.08	1.28	2.06
855.67	0.84	268.01	84.05	95.06	14.123	7.551	0.59	2.51	10.97	46.46	4.24	-0.09	1.28	2.07
870.67	0.85	268.62	83.99	95.05	14.374	7.573	0.60	2.51	11.03	46.50	4.22	-0.09	1.28	2.07
885.67	0.87	269.46	83.94	95.03	14.613	7.594	0.61	2.51	11.07	46.56	4.20	-0.09	1.28	2.07
900.10	0.88	270.06	83.91	95.06	14.851	7.615	0.62	2.51	11.10	46.57	4.19	-0.10	1.28	2.08

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 70%
Sample No.: Ash 30% Specimen No.: C
Depth (ft.): 0

Initial Height., H_o (in): 5.881 Confining Pressure (psi): 15.00
Initial Diameter, D_o (in): 2.883 Initial Volume, V_o (in^3): 38.39
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
t Change at End of Consol.,ΔH_o (in): 0.046 H_c 5.835 Area after Consol., A_c (in^2): 6.50
Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
ume change during Consol. V_c (cc^3): 7.39 0.45079 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	90.47	105.02	0.000	6.502	0.00	0.00	14.55	14.55	1.00	0.00	0.00	1.05
1.50	0.001	11.40	91.04	105.04	0.019	6.503	0.00	0.13	13.98	15.73	1.13	0.04	0.06	1.07
3.00	0.003	23.41	91.72	105.02	0.049	6.505	0.00	0.26	13.30	16.90	1.27	0.09	0.13	1.09
4.50	0.004	33.62	92.33	105.00	0.065	6.506	0.00	0.37	12.69	17.86	1.41	0.13	0.19	1.10
6.00	0.005	41.37	92.85	104.99	0.093	6.508	0.00	0.46	12.17	18.53	1.52	0.17	0.23	1.11
7.52	0.007	49.00	93.34	104.96	0.114	6.509	0.00	0.54	11.68	19.20	1.64	0.21	0.27	1.11
9.02	0.008	55.12	93.77	104.93	0.141	6.511	0.01	0.61	11.25	19.72	1.75	0.24	0.30	1.11
10.52	0.010	61.68	94.15	104.88	0.166	6.513	0.01	0.68	10.87	20.34	1.87	0.26	0.34	1.12
12.03	0.011	67.30	94.44	104.80	0.191	6.514	0.01	0.74	10.58	20.91	1.98	0.29	0.37	1.13
13.53	0.013	71.89	94.97	105.03	0.219	6.516	0.01	0.79	10.05	21.08	2.10	0.32	0.40	1.12
15.03	0.014	75.27	95.25	105.04	0.243	6.518	0.01	0.83	9.77	21.32	2.18	0.34	0.42	1.12
16.53	0.016	79.26	95.47	105.02	0.268	6.519	0.01	0.87	9.55	21.70	2.27	0.36	0.44	1.12
18.03	0.017	83.37	95.68	105.00	0.290	6.521	0.01	0.92	9.34	22.12	2.37	0.38	0.46	1.13
19.53	0.018	87.06	95.86	104.98	0.312	6.522	0.01	0.96	9.16	22.50	2.46	0.39	0.48	1.14
21.05	0.020	90.69	96.02	104.96	0.337	6.524	0.01	1.00	9.00	22.90	2.54	0.40	0.50	1.15
22.55	0.021	94.14	96.15	104.93	0.363	6.525	0.02	1.04	8.87	23.29	2.63	0.41	0.52	1.16
24.07	0.023	97.31	96.24	104.87	0.392	6.527	0.02	1.07	8.78	23.68	2.70	0.42	0.54	1.17
25.57	0.024	100.56	96.25	104.75	0.409	6.528	0.02	1.11	8.77	24.17	2.76	0.42	0.55	1.19
27.07	0.025	103.32	96.64	105.05	0.431	6.530	0.02	1.14	8.38	24.20	2.89	0.44	0.57	1.17
28.57	0.027	106.88	96.73	105.03	0.461	6.532	0.02	1.18	8.29	24.65	2.97	0.45	0.59	1.19
30.07	0.029	109.60	96.81	105.02	0.489	6.534	0.02	1.21	8.21	24.98	3.04	0.46	0.60	1.19
31.57	0.030	112.51	96.87	105.00	0.509	6.535	0.02	1.24	8.15	25.36	3.11	0.46	0.62	1.21
33.08	0.031	115.52	96.93	104.98	0.538	6.537	0.02	1.27	8.09	25.76	3.19	0.47	0.64	1.22
34.58	0.033	118.56	96.98	104.95	0.560	6.538	0.02	1.30	8.04	26.18	3.25	0.47	0.65	1.23
36.08	0.034	121.17	97.00	104.92	0.588	6.540	0.02	1.33	8.02	26.55	3.31	0.47	0.67	1.24
37.58	0.036	124.07	97.00	104.87	0.616	6.542	0.03	1.36	8.02	26.99	3.36	0.47	0.68	1.26
39.08	0.037	126.47	96.82	104.63	0.638	6.543	0.03	1.39	8.20	27.53	3.36	0.46	0.70	1.29
40.60	0.038	129.82	97.25	105.05	0.660	6.545	0.03	1.43	7.77	27.60	3.55	0.49	0.71	1.27
42.10	0.040	132.27	97.27	105.03	0.684	6.546	0.03	1.45	7.75	27.96	3.61	0.49	0.73	1.29
43.60	0.042	134.25	97.28	105.01	0.713	6.548	0.03	1.47	7.74	28.24	3.65	0.49	0.74	1.30
45.10	0.043	137.65	97.29	104.99	0.738	6.550	0.03	1.51	7.73	28.75	3.72	0.49	0.76	1.31
46.60	0.045	139.88	97.29	104.98	0.763	6.552	0.03	1.53	7.73	29.08	3.76	0.49	0.77	1.33
48.10	0.046	142.17	97.27	104.95	0.786	6.553	0.03	1.56	7.75	29.44	3.80	0.49	0.78	1.34
49.62	0.047	145.29	97.25	104.92	0.811	6.555	0.03	1.59	7.77	29.94	3.85	0.49	0.80	1.36
51.12	0.049	147.75	97.20	104.85	0.840	6.557	0.03	1.62	7.82	30.36	3.88	0.48	0.81	1.37
52.63	0.050	150.05	96.90	104.54	0.858	6.558	0.04	1.64	8.12	31.00	3.82	0.46	0.82	1.41
54.13	0.051	153.05	97.37	105.04	0.875	6.559	0.04	1.68	7.65	30.98	4.05	0.50	0.84	1.39
55.63	0.053	155.49	97.35	105.02	0.902	6.561	0.04	1.70	7.67	31.37	4.09	0.50	0.85	1.41
57.13	0.054	157.90	97.32	105.01	0.934	6.563	0.04	1.73	7.69	31.75	4.13	0.49	0.87	1.42
58.63	0.056	159.70	97.29	104.99	0.961	6.565	0.04	1.75	7.73	32.05	4.15	0.49	0.88	1.43
60.15	0.057	162.06	97.26	104.97	0.981	6.566	0.04	1.77	7.76	32.44	4.18	0.49	0.89	1.45
66.15	0.063	171.09	97.20	105.00	1.084	6.573	0.05	1.87	7.82	33.85	4.33	0.48	0.94	1.50
72.15	0.069	179.82	97.08	104.99	1.179	6.579	0.05	1.96	7.94	35.27	4.44	0.48	0.98	1.56
78.17	0.075	187.77	96.74	104.79	1.282	6.586	0.05	2.05	8.28	36.79	4.44	0.45	1.03	1.62
84.17	0.081	195.72	96.80	105.00	1.382	6.593	0.06	2.13	8.22	37.91	4.61	0.46	1.07	1.66
90.17	0.086	202.42	96.51	104.87	1.478	6.599	0.06	2.20	8.51	39.18	4.61	0.44	1.10	1.72
96.18	0.092	209.78	96.45	105.01	1.581	6.606	0.07	2.28	8.57	40.32	4.71	0.43	1.14	1.76
102.18	0.098	215.56	96.18	104.92	1.683	6.613	0.07	2.34	8.83	41.43	4.69	0.41	1.17	1.81
108.18	0.104	221.90	96.10	105.02	1.784	6.620	0.07	2.41	8.92	42.44	4.76	0.41	1.21	1.85
114.18	0.110	227.80	95.85	104.91	1.890	6.627	0.08	2.47	9.17	43.54	4.75	0.39	1.24	1.90
120.20	0.116	233.24	95.75	105.00	1.981	6.633	0.08	2.53	9.27	44.43	4.79	0.38	1.27	1.93
126.20	0.121	237.43	95.52	104.93	2.082	6.640	0.09	2.57	9.50	45.26	4.76	0.36	1.29	1.97
132.20	0.127	242.75	95.39	104.97	2.177	6.646	0.09	2.62	9.63	46.15	4.79	0.35	1.31	2.01
138.20	0.133	245.93	95.21	104.94	2.275	6.653	0.09	2.65	9.81	46.77	4.77	0.34	1.33	2.04
144.20	0.138	249.59	94.83	104.73	2.372	6.660	0.10	2.69	10.19	47.66	4.68	0.31	1.35	2.08

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 70%
Sample No.: Ash 30% Specimen No.: C
Depth (ft.): 0

Initial Height., H_o (in): 5.881 Confining Pressure (psi): 15.00
Initial Diameter, D_o (in): 2.883 Initial Volume, V_o (in^3): 38.39
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
t Change at End of Consol.,ΔH_o (in): 0.046 H_c 5.835 Area after Consol., A_c (in^2): 6.50
Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
ume change during Consol. V_c (cc^3): 7.39 0.45079 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
150.20	0.145	254.62	94.88	104.96	2.488	6.668	0.10	2.74	10.14	48.33	4.77	0.32	1.37	2.10
156.20	0.151	256.44	94.62	104.82	2.583	6.674	0.11	2.76	10.40	48.83	4.69	0.30	1.38	2.13
162.22	0.156	260.30	94.61	104.98	2.680	6.681	0.11	2.80	10.41	49.37	4.74	0.30	1.40	2.15
168.22	0.162	262.97	94.36	104.88	2.783	6.688	0.12	2.82	10.66	49.98	4.69	0.28	1.42	2.18
174.22	0.168	265.87	94.33	105.00	2.884	6.695	0.12	2.85	10.69	50.40	4.72	0.28	1.43	2.20
180.22	0.174	268.06	94.11	104.92	2.986	6.702	0.12	2.87	10.91	50.91	4.67	0.26	1.44	2.23
186.22	0.180	269.92	94.09	105.02	3.084	6.709	0.13	2.89	10.93	51.16	4.68	0.26	1.45	2.24
192.23	0.186	272.01	93.88	104.94	3.179	6.715	0.13	2.91	11.14	51.64	4.64	0.25	1.46	2.26
198.23	0.191	274.62	93.84	105.03	3.279	6.722	0.14	2.93	11.18	52.03	4.65	0.24	1.47	2.28
204.23	0.197	276.54	93.65	104.96	3.384	6.729	0.14	2.95	11.37	52.46	4.62	0.23	1.48	2.30
210.23	0.203	277.90	93.00	104.38	3.485	6.736	0.15	2.96	12.02	53.27	4.43	0.18	1.49	2.35
216.25	0.209	279.74	93.46	104.98	3.586	6.744	0.15	2.98	11.56	53.05	4.59	0.22	1.49	2.33
222.25	0.215	281.89	93.19	104.82	3.686	6.751	0.15	3.00	11.83	53.59	4.53	0.20	1.50	2.35
228.25	0.221	282.46	93.26	105.00	3.782	6.757	0.16	3.00	11.76	53.56	4.55	0.20	1.50	2.35
234.25	0.227	283.95	93.04	104.88	3.883	6.764	0.16	3.01	11.98	53.96	4.50	0.19	1.51	2.37
240.27	0.232	285.31	93.09	105.02	3.984	6.772	0.17	3.02	11.93	54.06	4.53	0.19	1.52	2.38
246.27	0.238	287.36	92.89	104.92	4.082	6.778	0.17	3.04	12.13	54.53	4.49	0.17	1.53	2.40
252.27	0.244	288.30	92.92	105.03	4.186	6.786	0.17	3.05	12.10	54.59	4.51	0.18	1.53	2.40
258.27	0.251	289.62	92.74	104.95	4.300	6.794	0.18	3.06	12.28	54.91	4.47	0.16	1.53	2.42
264.28	0.256	290.40	92.75	105.04	4.386	6.800	0.18	3.06	12.27	54.97	4.48	0.16	1.54	2.42
270.28	0.262	291.21	92.60	104.97	4.491	6.807	0.19	3.07	12.42	55.19	4.45	0.15	1.54	2.43
276.28	0.268	292.43	92.62	105.05	4.594	6.815	0.19	3.08	12.40	55.31	4.46	0.15	1.54	2.44
282.30	0.274	293.57	92.49	104.99	4.694	6.822	0.20	3.08	12.53	55.56	4.43	0.15	1.55	2.45
288.30	0.280	294.94	92.04	104.60	4.802	6.830	0.20	3.09	12.98	56.17	4.33	0.11	1.55	2.49
294.30	0.286	295.31	92.35	105.01	4.906	6.837	0.20	3.10	12.67	55.86	4.41	0.14	1.55	2.47
300.30	0.291	296.37	92.14	104.84	4.992	6.843	0.21	3.10	12.87	56.18	4.36	0.12	1.56	2.49
315.32	0.306	298.59	92.20	105.06	5.246	6.862	0.22	3.12	12.82	56.34	4.39	0.12	1.57	2.49
330.32	0.321	301.43	92.05	105.05	5.501	6.880	0.23	3.14	12.97	56.78	4.38	0.11	1.58	2.51
345.32	0.335	301.75	91.93	105.03	5.749	6.898	0.24	3.13	13.09	56.83	4.34	0.11	1.57	2.52
360.33	0.350	305.05	91.78	105.01	6.006	6.917	0.25	3.16	13.24	57.34	4.33	0.09	1.59	2.54
375.33	0.365	306.59	91.66	104.97	6.252	6.935	0.26	3.16	13.36	57.56	4.31	0.09	1.59	2.55
390.33	0.380	308.88	91.50	104.92	6.506	6.954	0.27	3.18	13.51	57.93	4.29	0.07	1.60	2.57
405.35	0.394	309.46	91.21	104.72	6.750	6.972	0.28	3.18	13.81	58.19	4.21	0.05	1.60	2.59
420.35	0.409	310.84	91.46	105.06	7.012	6.992	0.29	3.18	13.56	58.02	4.28	0.07	1.60	2.58
435.35	0.424	312.38	91.37	105.05	7.259	7.011	0.30	3.19	13.65	58.21	4.26	0.06	1.60	2.59
450.37	0.439	313.28	91.26	105.01	7.516	7.030	0.31	3.19	13.76	58.32	4.24	0.06	1.60	2.59
464.22	0.452	314.23	91.16	104.99	7.754	7.048	0.32	3.19	13.86	58.45	4.22	0.05	1.60	2.60
479.22	0.468	317.20	91.03	104.95	8.018	7.068	0.33	3.21	13.99	58.86	4.21	0.04	1.62	2.62
494.23	0.482	317.68	90.88	104.84	8.267	7.088	0.34	3.20	14.14	58.97	4.17	0.03	1.61	2.63
509.23	0.497	319.37	90.98	105.04	8.523	7.108	0.35	3.21	14.04	58.97	4.20	0.04	1.62	2.63
524.23	0.512	319.68	90.96	105.05	8.780	7.128	0.37	3.20	14.06	58.91	4.19	0.04	1.61	2.63
539.23	0.527	321.84	90.87	105.03	9.029	7.147	0.38	3.22	14.15	59.19	4.18	0.03	1.62	2.64
554.23	0.541	322.13	90.81	105.00	9.277	7.167	0.39	3.21	14.21	59.16	4.16	0.02	1.62	2.64
569.23	0.556	323.25	90.72	104.97	9.531	7.187	0.40	3.21	14.30	59.28	4.14	0.02	1.62	2.65
584.25	0.571	325.59	90.60	104.90	9.781	7.207	0.41	3.22	14.42	59.60	4.13	0.01	1.63	2.66
599.25	0.586	325.70	90.66	105.01	10.043	7.228	0.42	3.21	14.36	59.43	4.14	0.01	1.62	2.66
614.25	0.600	327.13	90.65	105.06	10.285	7.247	0.43	3.22	14.37	59.51	4.14	0.01	1.63	2.66
629.25	0.615	327.71	90.61	105.04	10.545	7.268	0.44	3.21	14.41	59.50	4.13	0.01	1.62	2.66
644.27	0.630	328.94	90.54	105.02	10.790	7.288	0.45	3.22	14.48	59.61	4.12	0.01	1.62	2.67
659.27	0.644	329.80	90.44	104.99	11.042	7.309	0.46	3.22	14.58	59.70	4.10	0.00	1.62	2.67
674.27	0.659	331.44	90.38	104.93	11.286	7.329	0.47	3.22	14.64	59.86	4.09	-0.01	1.63	2.68
689.27	0.673	330.65	90.14	104.73	11.540	7.350	0.48	3.20	14.88	59.86	4.02	-0.02	1.62	2.69
704.28	0.688	330.71	90.43	105.05	11.796	7.371	0.49	3.19	14.59	59.46	4.07	0.00	1.62	2.67
719.28	0.703	331.78	90.39	105.05	12.052	7.393	0.50	3.20	14.63	59.51	4.07	-0.01	1.62	2.67
734.28	0.718	331.87	90.34	105.02	12.309	7.414	0.51	3.19	14.68	59.44	4.05	-0.01	1.61	2.67

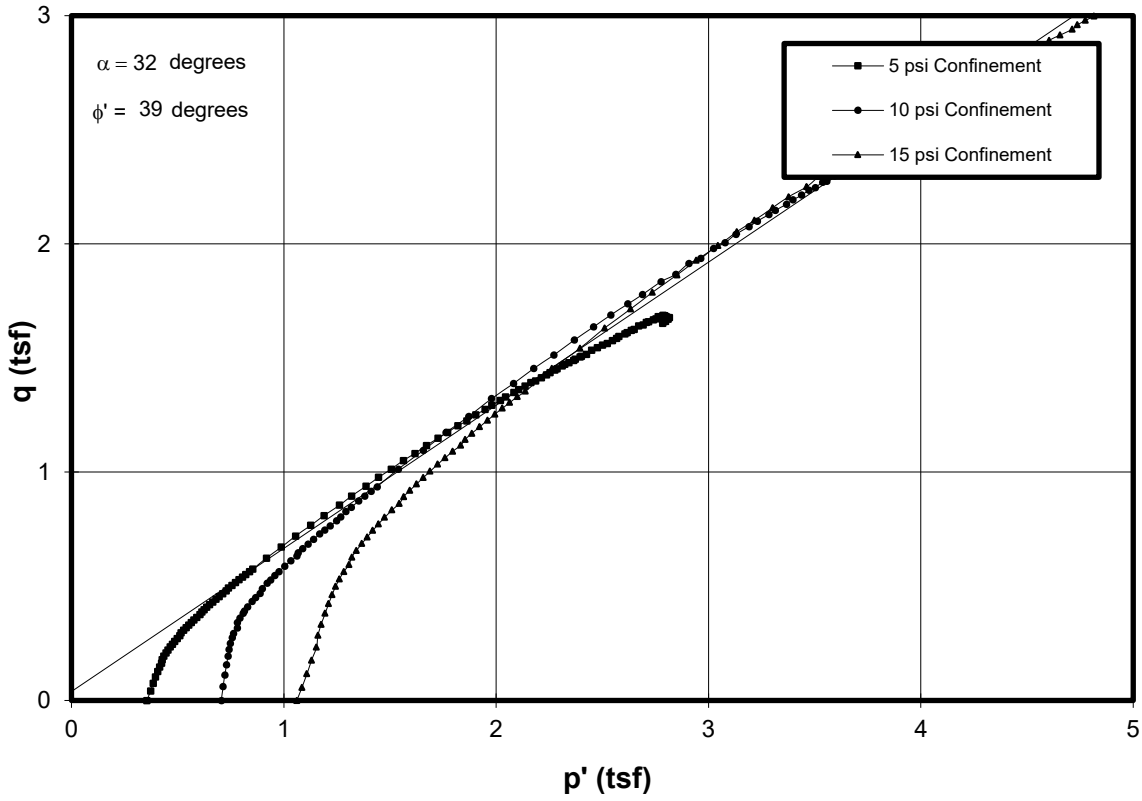
Report No.:

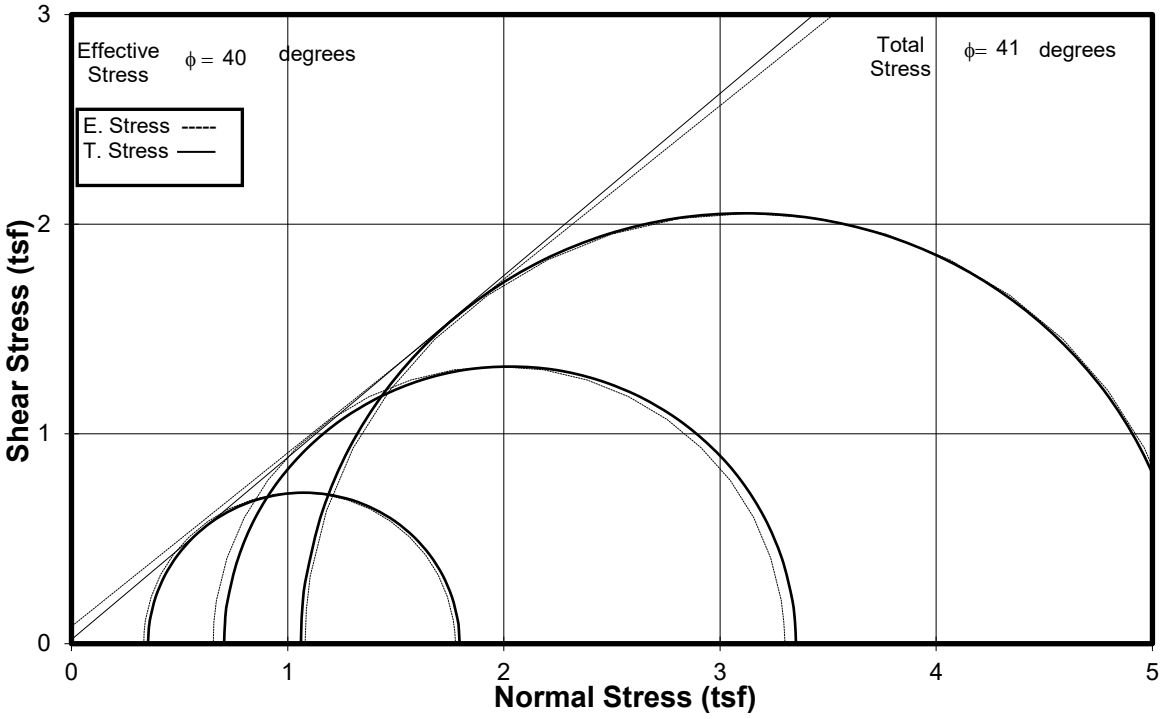
CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 70%
Sample No.: Ash 30% Specimen No.: C
Depth (ft.): 0

Initial Height., H_o (in):	5.881	Confining Pressure (psi):	15.00
Initial Diameter, D_o (in):	2.883	Initial Volume, V_o (in^3):	38.39
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.53
t Change at End of Consol., ΔH_o (in):	0.046 H_c 5.835	Area after Consol., A_c (in^2):	6.50
Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
ume change during Consol. V_c (cc^3):	7.39 0.45079 in^3		

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
749.28	0.733	333.88	90.29	105.01	12.557	7.435	0.52	3.20	14.73	59.64	4.05	-0.01	1.62	2.68
764.30	0.747	331.13	90.21	104.96	12.809	7.457	0.53	3.16	14.81	59.22	4.00	-0.02	1.60	2.67
779.30	0.762	333.11	90.08	104.80	13.058	7.478	0.54	3.17	14.94	59.49	3.98	-0.03	1.60	2.68
794.32	0.778	334.31	90.30	105.07	13.330	7.502	0.55	3.17	14.72	59.28	4.03	-0.01	1.60	2.66
809.32	0.792	334.77	90.27	105.05	13.565	7.522	0.56	3.16	14.75	59.25	4.02	-0.01	1.60	2.66
824.32	0.807	335.10	90.25	105.04	13.826	7.545	0.58	3.16	14.77	59.19	4.01	-0.02	1.60	2.66
839.32	0.820	335.74	90.20	105.00	14.061	7.566	0.59	3.15	14.82	59.19	4.00	-0.02	1.60	2.66
854.32	0.836	335.46	90.14	104.97	14.319	7.588	0.60	3.14	14.88	59.09	3.97	-0.02	1.59	2.66
869.33	0.850	337.54	90.01	104.85	14.568	7.610	0.61	3.15	15.01	59.36	3.96	-0.03	1.60	2.68
884.33	0.865	336.47	90.22	105.09	14.821	7.633	0.62	3.13	14.80	58.89	3.98	-0.02	1.59	2.65
899.33	0.880	338.33	90.19	105.06	15.079	7.656	0.63	3.14	14.83	59.02	3.98	-0.02	1.59	2.66
899.37	0.880	337.25	90.18	105.06	15.080	7.656	0.63	3.13	14.84	58.88	3.97	-0.02	1.59	2.65



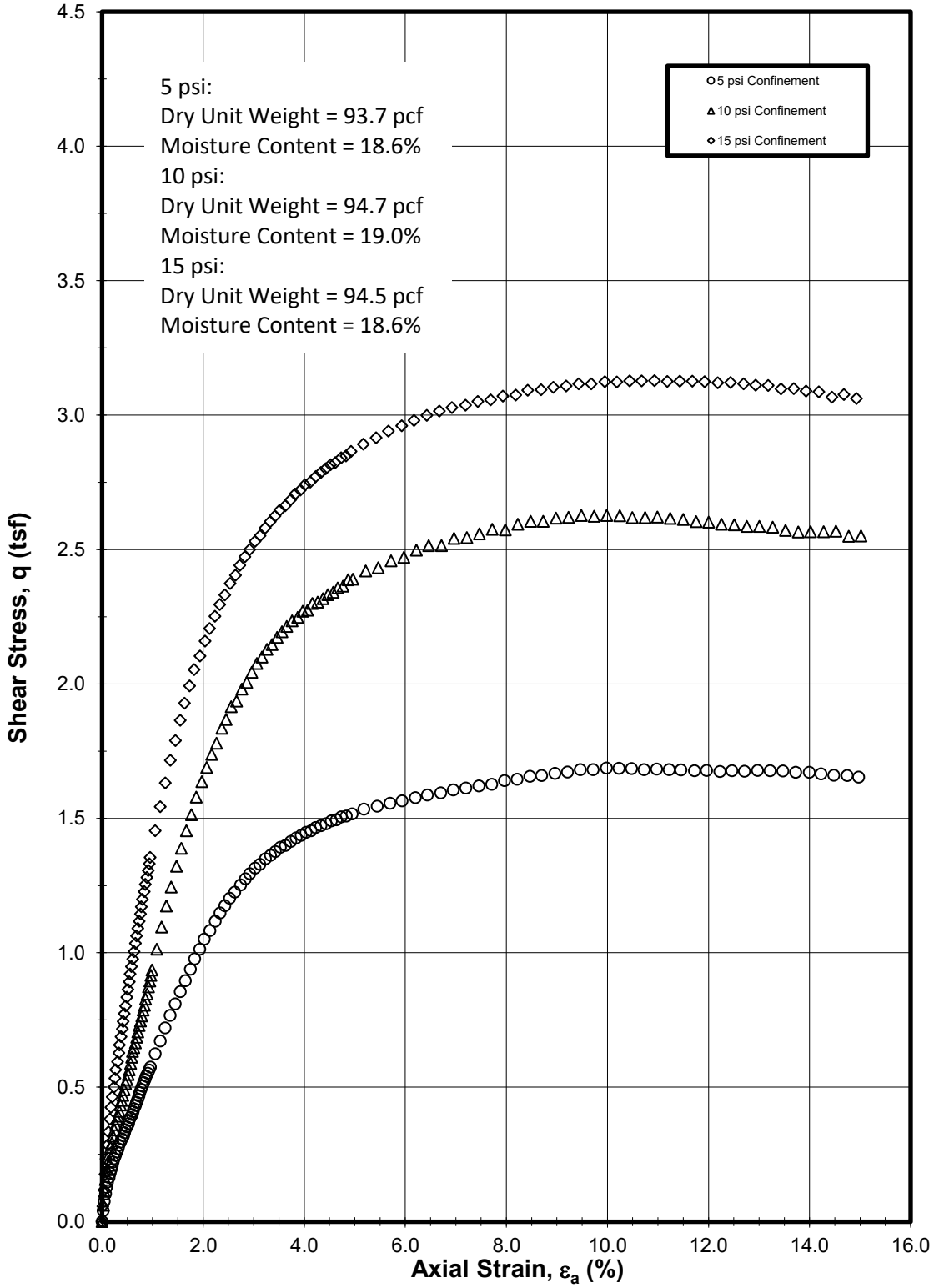


CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST

ASTM D 4767

Project No.: J039697.01

Sample: 50% Lime Pond Sludge / 50% Ash



CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST

ASTM D 4767

Project No.: J039697.01

Sample: 50% Lime Pond Sludge / 50% Ash

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime Pond Sludge
Sample No.: 50% Ash Specimen No.: A
Depth (ft.): 0

Initial Height., H_o (in): 5.933 Confining Pressure (psi): 5.00
Initial Diameter, D_o (in): 2.884 Initial Volume, V_o (in^3): 38.76
Membrane Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
Ht Change at End of Consol.,ΔH_o (in): 0.019 H_c 5.915 Area after Consol., A_c (in^2): 6.538
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 1.45 0.08845 in^3

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	90.18	95.09	0.000	6.538	0.00	0.00	4.91	4.91	1.00	0.00	0.000	0.353
1.50	0.00	7.50	90.50	95.09	0.023	6.540	0.00	0.08	4.59	5.73	1.25	0.02	0.041	0.372
3.00	0.00	13.69	90.80	95.08	0.044	6.541	0.00	0.15	4.29	6.39	1.49	0.04	0.075	0.385
4.52	0.00	18.81	91.04	95.08	0.068	6.543	0.00	0.21	4.05	6.93	1.71	0.06	0.103	0.395
6.02	0.00	23.08	91.23	95.07	0.084	6.544	0.00	0.25	3.86	7.39	1.91	0.08	0.127	0.405
7.53	0.01	26.69	91.38	95.06	0.108	6.545	0.00	0.29	3.71	7.79	2.10	0.09	0.147	0.414
9.03	0.01	29.84	91.50	95.05	0.138	6.547	0.01	0.33	3.59	8.15	2.27	0.09	0.164	0.423
10.53	0.01	32.67	91.66	95.11	0.161	6.549	0.01	0.36	3.43	8.42	2.45	0.11	0.180	0.427
12.05	0.01	35.30	91.75	95.11	0.181	6.550	0.01	0.39	3.34	8.73	2.61	0.11	0.194	0.435
13.55	0.01	37.91	91.81	95.11	0.200	6.551	0.01	0.42	3.28	9.06	2.77	0.12	0.208	0.444
15.07	0.01	40.34	91.86	95.10	0.218	6.553	0.01	0.44	3.23	9.38	2.91	0.12	0.222	0.454
16.57	0.01	42.70	91.90	95.10	0.240	6.554	0.01	0.47	3.19	9.70	3.04	0.12	0.235	0.464
18.07	0.02	44.91	91.93	95.09	0.263	6.555	0.01	0.49	3.16	10.01	3.17	0.13	0.247	0.474
19.58	0.02	47.25	91.95	95.08	0.292	6.557	0.01	0.52	3.14	10.35	3.29	0.13	0.259	0.486
21.08	0.02	49.43	91.96	95.07	0.319	6.559	0.01	0.54	3.13	10.67	3.41	0.13	0.271	0.497
22.60	0.02	51.71	91.95	95.05	0.333	6.560	0.01	0.57	3.14	11.02	3.51	0.13	0.284	0.510
24.10	0.02	54.02	92.04	95.13	0.366	6.562	0.02	0.59	3.05	11.28	3.70	0.13	0.296	0.516
25.62	0.02	56.17	92.04	95.13	0.388	6.564	0.02	0.61	3.05	11.61	3.81	0.13	0.308	0.528
27.12	0.02	58.21	92.04	95.12	0.420	6.566	0.02	0.64	3.05	11.92	3.90	0.13	0.319	0.539
28.62	0.03	60.28	92.03	95.11	0.443	6.567	0.02	0.66	3.06	12.24	4.00	0.13	0.330	0.551
30.13	0.03	62.33	92.01	95.10	0.461	6.569	0.02	0.68	3.08	12.56	4.08	0.13	0.342	0.563
31.63	0.03	64.39	91.99	95.09	0.492	6.571	0.02	0.70	3.10	12.90	4.17	0.13	0.353	0.576
33.13	0.03	66.57	91.96	95.08	0.524	6.573	0.02	0.73	3.13	13.25	4.24	0.13	0.365	0.590
34.63	0.03	68.66	91.93	95.07	0.534	6.573	0.02	0.75	3.16	13.61	4.30	0.13	0.376	0.604
36.13	0.03	70.80	91.96	95.13	0.561	6.575	0.02	0.77	3.13	13.90	4.44	0.13	0.388	0.613
37.65	0.04	72.76	91.96	95.14	0.595	6.577	0.02	0.79	3.13	14.19	4.53	0.13	0.398	0.624
39.17	0.04	74.69	91.93	95.13	0.611	6.578	0.03	0.82	3.16	14.51	4.59	0.13	0.409	0.636
40.67	0.04	76.75	91.89	95.13	0.628	6.580	0.03	0.84	3.20	14.86	4.65	0.12	0.420	0.650
42.17	0.04	78.93	91.86	95.12	0.660	6.582	0.03	0.86	3.24	15.23	4.71	0.12	0.432	0.665
43.68	0.04	81.15	91.81	95.11	0.683	6.583	0.03	0.89	3.28	15.61	4.75	0.12	0.444	0.680
45.18	0.04	83.31	91.76	95.10	0.705	6.585	0.03	0.91	3.33	15.98	4.80	0.11	0.455	0.695
46.68	0.04	85.59	91.70	95.09	0.730	6.586	0.03	0.93	3.39	16.38	4.84	0.11	0.468	0.712
48.20	0.04	87.84	91.64	95.07	0.746	6.587	0.03	0.96	3.45	16.78	4.87	0.11	0.480	0.728
49.70	0.05	90.16	91.67	95.15	0.772	6.589	0.03	0.98	3.42	17.10	5.01	0.11	0.493	0.739
51.20	0.05	92.30	91.62	95.15	0.799	6.591	0.03	1.01	3.47	17.48	5.03	0.10	0.504	0.754
52.70	0.05	94.65	91.56	95.14	0.826	6.593	0.03	1.03	3.53	17.89	5.06	0.10	0.517	0.771
54.22	0.05	96.86	91.49	95.13	0.851	6.594	0.04	1.05	3.60	18.29	5.08	0.09	0.529	0.788
55.72	0.05	99.10	91.43	95.12	0.873	6.596	0.04	1.08	3.66	18.68	5.11	0.09	0.541	0.804
57.23	0.05	101.21	91.36	95.11	0.901	6.598	0.04	1.10	3.73	19.07	5.12	0.09	0.552	0.821
58.75	0.05	103.40	91.29	95.10	0.927	6.599	0.04	1.13	3.80	19.46	5.13	0.08	0.564	0.837
60.25	0.06	105.50	91.22	95.09	0.955	6.601	0.04	1.15	3.87	19.85	5.13	0.08	0.575	0.854
66.25	0.06	114.54	91.02	95.14	1.048	6.607	0.04	1.25	4.07	21.41	5.26	0.06	0.624	0.917
72.25	0.07	123.43	90.71	95.11	1.149	6.614	0.05	1.34	4.38	23.04	5.26	0.04	0.672	0.987
78.25	0.07	132.51	90.46	95.16	1.246	6.621	0.05	1.44	4.63	24.65	5.32	0.02	0.721	1.054
84.25	0.08	141.33	90.11	95.12	1.344	6.627	0.06	1.53	4.98	26.30	5.29	0.00	0.768	1.126
90.25	0.09	149.36	89.84	95.15	1.449	6.634	0.06	1.62	5.25	27.77	5.28	-0.02	0.810	1.189
96.25	0.09	157.91	89.46	95.08	1.548	6.641	0.06	1.71	5.63	29.41	5.22	-0.05	0.856	1.262
102.25	0.10	165.45	89.22	95.15	1.650	6.648	0.07	1.79	5.87	30.76	5.24	-0.07	0.896	1.319
108.25	0.10	173.54	88.87	95.13	1.747	6.654	0.07	1.87	6.22	32.30	5.19	-0.09	0.939	1.387
114.25	0.11	180.91	88.61	95.18	1.832	6.660	0.08	1.95	6.48	33.65	5.19	-0.11	0.978	1.445
120.27	0.11	187.73	88.27	95.15	1.934	6.667	0.08	2.02	6.82	34.98	5.13	-0.14	1.014	1.505
126.27	0.12	194.88	88.00	95.19	2.025	6.673	0.08	2.10	7.09	36.30	5.12	-0.16	1.051	1.562
132.28	0.13	200.89	87.68	95.16	2.136	6.681	0.09	2.16	7.41	37.48	5.06	-0.18	1.082	1.616
138.28	0.13	207.59	87.40	95.20	2.237	6.688	0.09	2.23	7.69	38.73	5.04	-0.20	1.117	1.671
144.28	0.14	213.57	87.09	95.17	2.332	6.694	0.10	2.29	8.00	39.91	4.99	-0.22	1.148	1.725
150.28	0.14	218.72	86.81	95.17	2.429	6.701	0.10	2.34	8.28	40.92	4.94	-0.24	1.175	1.771

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime Pond Sludge
Sample No.: 50% Ash Specimen No.: A
Depth (ft.): 0

Initial Height., H_o (in): 5.933 Confining Pressure (psi): 5.00
Initial Diameter, D_o (in): 2.884 Initial Volume, V_o (in^3): 38.76
Membrane Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
Ht Change at End of Consol.,ΔH_o (in): 0.019 H_c 5.915 Area after Consol., A_c (in^2): 6.538
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 1.45 0.08845 in^3

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
156.28	0.15	224.21	86.54	95.18	2.524	6.708	0.11	2.40	8.55	41.97	4.91	-0.26	1.203	1.819
162.30	0.16	228.55	86.25	95.14	2.626	6.715	0.11	2.44	8.84	42.88	4.85	-0.28	1.225	1.862
168.30	0.16	233.79	86.04	95.19	2.740	6.722	0.11	2.50	9.05	43.83	4.84	-0.30	1.252	1.904
174.32	0.17	238.32	85.76	95.15	2.837	6.729	0.12	2.54	9.33	44.75	4.79	-0.32	1.275	1.947
180.32	0.17	242.04	85.58	95.20	2.921	6.735	0.12	2.58	9.51	45.45	4.78	-0.33	1.294	1.978
186.32	0.18	246.21	85.31	95.16	3.027	6.742	0.13	2.62	9.78	46.29	4.73	-0.35	1.315	2.019
192.33	0.18	249.20	85.17	95.20	3.119	6.749	0.13	2.65	9.92	46.85	4.72	-0.36	1.329	2.044
198.33	0.19	253.28	84.90	95.17	3.232	6.757	0.13	2.69	10.19	47.67	4.68	-0.38	1.350	2.083
204.33	0.20	256.03	84.78	95.21	3.331	6.764	0.14	2.72	10.31	48.17	4.67	-0.39	1.363	2.105
210.33	0.20	258.96	84.55	95.18	3.428	6.770	0.14	2.74	10.54	48.79	4.63	-0.41	1.377	2.136
216.35	0.21	262.13	84.40	95.22	3.528	6.777	0.15	2.77	10.69	49.37	4.62	-0.42	1.392	2.162
222.35	0.21	263.77	84.19	95.14	3.630	6.785	0.15	2.79	10.90	49.78	4.57	-0.43	1.400	2.184
228.35	0.22	266.84	84.02	95.10	3.733	6.792	0.16	2.82	11.07	50.36	4.55	-0.44	1.414	2.212
234.35	0.23	269.48	83.85	95.07	3.839	6.799	0.16	2.84	11.24	50.88	4.53	-0.46	1.427	2.236
240.35	0.23	271.72	83.77	95.15	3.942	6.807	0.16	2.86	11.32	51.24	4.53	-0.46	1.437	2.252
246.35	0.24	274.10	83.60	95.13	4.033	6.813	0.17	2.88	11.49	51.73	4.50	-0.47	1.448	2.276
252.37	0.24	275.36	83.53	95.18	4.132	6.820	0.17	2.89	11.56	51.94	4.49	-0.48	1.454	2.286
258.37	0.25	277.93	83.35	95.15	4.224	6.827	0.18	2.92	11.74	52.45	4.47	-0.49	1.466	2.311
264.38	0.26	279.50	83.28	95.19	4.330	6.834	0.18	2.93	11.81	52.70	4.46	-0.50	1.472	2.322
270.38	0.26	281.28	83.13	95.17	4.432	6.841	0.18	2.95	11.97	53.08	4.44	-0.51	1.480	2.342
276.40	0.27	283.52	82.95	95.12	4.538	6.849	0.19	2.97	12.14	53.53	4.41	-0.52	1.490	2.364
282.40	0.27	284.70	82.91	95.18	4.636	6.856	0.19	2.98	12.18	53.70	4.41	-0.52	1.495	2.372
288.40	0.28	287.00	82.75	95.14	4.733	6.863	0.20	3.00	12.34	54.16	4.39	-0.54	1.505	2.394
294.40	0.29	287.81	82.69	95.16	4.834	6.870	0.20	3.00	12.40	54.29	4.38	-0.54	1.508	2.401
300.42	0.29	289.75	82.48	95.03	4.949	6.879	0.21	3.02	12.61	54.73	4.34	-0.55	1.516	2.424
315.42	0.31	293.86	82.38	95.15	5.183	6.896	0.22	3.05	12.71	55.32	4.35	-0.56	1.534	2.449
330.42	0.32	296.86	82.17	95.17	5.442	6.915	0.23	3.07	12.92	55.85	4.32	-0.58	1.546	2.476
345.43	0.34	299.77	82.00	95.18	5.696	6.933	0.24	3.10	13.09	56.33	4.30	-0.59	1.557	2.499
360.43	0.35	302.07	81.78	95.14	5.934	6.951	0.25	3.11	13.31	56.77	4.27	-0.60	1.565	2.523
375.43	0.37	305.25	81.62	95.07	6.200	6.970	0.26	3.13	13.47	57.26	4.25	-0.62	1.577	2.546
390.43	0.38	307.99	81.48	95.09	6.436	6.988	0.27	3.15	13.61	57.68	4.24	-0.63	1.587	2.567
405.43	0.40	310.47	81.44	95.19	6.703	7.008	0.28	3.17	13.65	57.95	4.25	-0.63	1.595	2.578
420.45	0.41	313.42	81.21	95.09	6.948	7.026	0.29	3.19	13.88	58.49	4.21	-0.65	1.606	2.606
435.45	0.43	315.54	81.14	95.11	7.198	7.045	0.30	3.20	13.95	58.73	4.21	-0.65	1.612	2.617
450.45	0.44	318.11	81.00	95.13	7.457	7.065	0.31	3.22	14.09	59.12	4.19	-0.66	1.621	2.636
465.58	0.46	320.00	80.88	95.13	7.707	7.084	0.32	3.23	14.21	59.38	4.18	-0.67	1.626	2.649
480.60	0.47	323.76	80.79	95.21	7.961	7.104	0.33	3.26	14.30	59.87	4.19	-0.68	1.641	2.670
495.60	0.49	325.65	80.58	95.07	8.209	7.123	0.34	3.27	14.51	60.23	4.15	-0.69	1.646	2.691
510.60	0.50	328.56	80.50	95.13	8.465	7.143	0.35	3.29	14.59	60.59	4.15	-0.70	1.656	2.707
525.62	0.51	330.07	80.39	95.15	8.695	7.161	0.36	3.29	14.70	60.79	4.14	-0.70	1.659	2.717
540.62	0.53	332.62	80.20	95.08	8.962	7.182	0.37	3.31	14.89	61.21	4.11	-0.72	1.667	2.740
555.62	0.54	334.57	80.10	95.06	9.209	7.201	0.38	3.32	14.99	61.45	4.10	-0.73	1.673	2.752
570.62	0.56	337.27	80.08	95.17	9.463	7.222	0.39	3.33	15.01	61.71	4.11	-0.73	1.681	2.762
585.63	0.57	338.08	79.94	95.10	9.715	7.242	0.40	3.33	15.15	61.83	4.08	-0.74	1.681	2.771
600.63	0.59	340.43	79.85	95.10	9.980	7.263	0.42	3.34	15.24	62.11	4.08	-0.74	1.687	2.785
615.63	0.60	341.02	79.81	95.13	10.229	7.283	0.43	3.34	15.28	62.11	4.06	-0.75	1.686	2.786
630.63	0.62	341.92	79.71	95.12	10.477	7.303	0.44	3.34	15.38	62.20	4.04	-0.75	1.685	2.793
645.63	0.63	341.91	79.70	95.12	10.727	7.324	0.45	3.33	15.39	62.07	4.03	-0.75	1.681	2.789
660.63	0.65	343.43	79.65	95.12	10.972	7.344	0.46	3.33	15.44	62.20	4.03	-0.76	1.683	2.795
675.63	0.66	343.86	79.64	95.15	11.221	7.365	0.47	3.33	15.45	62.14	4.02	-0.76	1.681	2.793
690.65	0.68	344.68	79.53	95.09	11.452	7.384	0.48	3.33	15.56	62.24	4.00	-0.77	1.681	2.801
705.65	0.69	345.09	79.51	95.07	11.725	7.407	0.49	3.32	15.58	62.17	3.99	-0.77	1.677	2.799
720.65	0.71	346.18	79.47	95.08	11.962	7.427	0.50	3.32	15.62	62.24	3.98	-0.77	1.678	2.803
735.65	0.72	346.38	79.47	95.08	12.223	7.449	0.51	3.31	15.62	62.12	3.98	-0.77	1.674	2.798
750.65	0.74	348.02	79.47	95.11	12.462	7.469	0.52	3.32	15.62	62.22	3.98	-0.77	1.677	2.802
765.65	0.75	348.63	79.46	95.14	12.712	7.490	0.53	3.31	15.63	62.17	3.98	-0.77	1.676	2.801

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime Pond Sludge
Sample No.: 50% Ash Specimen No.: A
Depth (ft.): 0

Initial Height., H_o (in):	5.933	Confining Pressure (psi):	5.00
Initial Diameter, D_o (in):	2.884	Initial Volume, V_o (in^3):	38.76
Membrane Thickness (in):	0.02	Initial Area, A_o (in^2):	6.53
Ht Change at End of Consol.,ΔH_o (in):	0.019 H_c 5.915	Area after Consol., A_c (in^2):	6.538
Ht Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
Volume change during Consol. V_c (cc^3):	1.45 0.08845 in^3		

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
780.67	0.77	350.17	79.39	95.12	12.971	7.513	0.54	3.32	15.70	62.31	3.97	-0.78	1.678	2.808
795.67	0.78	351.09	79.30	95.03	13.217	7.534	0.55	3.32	15.79	62.39	3.95	-0.78	1.678	2.815
810.67	0.80	351.76	79.39	95.15	13.472	7.556	0.56	3.31	15.70	62.25	3.97	-0.78	1.676	2.806
825.68	0.81	351.74	79.29	95.00	13.726	7.578	0.57	3.30	15.80	62.21	3.94	-0.78	1.671	2.808
840.68	0.83	352.81	79.58	94.93	13.992	7.602	0.58	3.30	15.51	61.92	3.99	-0.76	1.671	2.787
855.68	0.84	352.52	79.43	95.03	14.223	7.622	0.59	3.29	15.66	61.91	3.95	-0.77	1.665	2.792
870.68	0.86	352.57	79.30	94.99	14.479	7.645	0.60	3.28	15.79	61.91	3.92	-0.78	1.660	2.797
885.68	0.87	353.43	79.44	94.94	14.741	7.669	0.61	3.27	15.65	61.74	3.94	-0.77	1.659	2.786
899.63	0.89	353.09	79.39	95.08	14.969	7.689	0.62	3.26	15.70	61.62	3.92	-0.78	1.653	2.784

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 50%
Sample No.: Ash 50% Specimen No.: B
Depth (ft.): 0

Initial Height., H_o (in): 5.849 Confining Pressure (psi): 10.00
Initial Diameter, D_o (in): 2.884 Initial Volume, V_o (in^3): 38.21
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
Ht Change at End of Consol., ΔH_o (in): 0.036 H_c 5.814 Area after Consol., A_c (in^2): 6.54
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 3.06 0.18666 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	93.12	102.91	0.000	6.540	0.00	0.00	9.79	9.79	1.00	0.00	0.00	0.71
1.50	0.00	11.09	93.85	103.03	0.025	6.542	0.00	0.12	9.06	10.76	1.19	0.05	0.06	0.71
3.00	0.00	20.36	94.45	103.04	0.046	6.543	0.00	0.22	8.46	11.57	1.37	0.10	0.11	0.72
4.50	0.00	28.37	94.96	103.03	0.065	6.545	0.00	0.31	7.96	12.29	1.54	0.13	0.16	0.73
6.02	0.01	35.29	95.38	103.02	0.102	6.547	0.00	0.39	7.53	12.92	1.72	0.16	0.19	0.74
7.52	0.01	40.60	95.72	103.01	0.124	6.549	0.01	0.45	7.19	13.39	1.86	0.19	0.22	0.74
9.03	0.01	45.48	96.01	103.00	0.141	6.550	0.01	0.50	6.90	13.85	2.01	0.21	0.25	0.75
10.53	0.01	50.24	96.23	102.97	0.171	6.552	0.01	0.55	6.68	14.35	2.15	0.22	0.28	0.76
12.03	0.01	53.38	96.39	102.94	0.194	6.553	0.01	0.59	6.52	14.67	2.25	0.24	0.29	0.76
13.53	0.01	57.85	96.49	102.85	0.217	6.555	0.01	0.63	6.43	15.25	2.37	0.24	0.32	0.78
15.03	0.01	62.14	96.81	103.05	0.245	6.556	0.01	0.68	6.10	15.58	2.55	0.27	0.34	0.78
16.53	0.02	65.71	96.92	103.04	0.268	6.558	0.01	0.72	6.00	16.02	2.67	0.27	0.36	0.79
18.05	0.02	69.71	97.00	103.03	0.292	6.560	0.01	0.76	5.91	16.54	2.80	0.28	0.38	0.81
19.55	0.02	71.56	97.06	103.01	0.318	6.561	0.01	0.78	5.86	16.76	2.86	0.28	0.39	0.81
21.05	0.02	74.76	97.11	103.00	0.344	6.563	0.01	0.82	5.81	17.20	2.96	0.29	0.41	0.83
22.55	0.02	79.11	97.13	102.98	0.365	6.564	0.02	0.87	5.78	17.83	3.08	0.29	0.43	0.85
24.05	0.02	82.18	97.14	102.94	0.385	6.566	0.02	0.90	5.78	18.29	3.17	0.29	0.45	0.87
25.55	0.02	85.65	97.10	102.88	0.410	6.567	0.02	0.94	5.82	18.86	3.24	0.29	0.47	0.89
27.05	0.03	89.55	97.26	103.05	0.440	6.569	0.02	0.98	5.65	19.28	3.41	0.30	0.49	0.90
28.55	0.03	93.77	97.26	103.04	0.463	6.571	0.02	1.03	5.66	19.93	3.52	0.30	0.51	0.92
30.05	0.03	96.47	97.24	103.04	0.491	6.573	0.02	1.06	5.67	20.35	3.59	0.30	0.53	0.94
31.55	0.03	99.97	97.22	103.02	0.515	6.574	0.02	1.09	5.69	20.90	3.67	0.30	0.55	0.96
33.05	0.03	103.16	97.19	103.00	0.540	6.576	0.02	1.13	5.73	21.42	3.74	0.29	0.56	0.98
34.57	0.03	107.54	97.14	102.99	0.567	6.578	0.02	1.18	5.77	22.12	3.83	0.29	0.59	1.00
36.07	0.03	111.77	97.07	102.95	0.585	6.579	0.02	1.22	5.84	22.83	3.91	0.28	0.61	1.03
37.57	0.04	115.77	96.98	102.91	0.604	6.580	0.03	1.26	5.93	23.52	3.97	0.28	0.63	1.06
39.08	0.04	118.30	97.08	103.05	0.628	6.582	0.03	1.29	5.84	23.81	4.08	0.28	0.65	1.07
40.58	0.04	121.70	97.04	103.05	0.659	6.584	0.03	1.33	5.88	24.36	4.14	0.28	0.67	1.09
42.08	0.04	125.43	96.97	103.04	0.686	6.586	0.03	1.37	5.94	24.99	4.20	0.28	0.69	1.11
43.58	0.04	129.12	96.90	103.03	0.707	6.587	0.03	1.41	6.01	25.61	4.26	0.27	0.71	1.14
45.10	0.04	133.52	96.82	103.02	0.734	6.589	0.03	1.46	6.10	26.36	4.32	0.27	0.73	1.17
46.60	0.04	136.68	96.73	103.01	0.762	6.591	0.03	1.49	6.18	26.92	4.35	0.26	0.75	1.19
48.10	0.05	140.12	96.64	102.99	0.785	6.592	0.03	1.53	6.28	27.53	4.39	0.25	0.77	1.22
49.62	0.05	144.11	96.52	102.95	0.813	6.594	0.03	1.57	6.40	28.25	4.42	0.24	0.79	1.25
51.12	0.05	147.45	96.48	102.99	0.839	6.596	0.03	1.61	6.43	28.78	4.48	0.24	0.80	1.27
52.62	0.05	151.68	96.48	103.06	0.860	6.597	0.04	1.65	6.43	29.42	4.57	0.24	0.83	1.29
54.13	0.05	155.20	96.38	103.06	0.892	6.599	0.04	1.69	6.53	30.05	4.60	0.23	0.85	1.32
55.63	0.05	160.25	96.28	103.04	0.920	6.601	0.04	1.75	6.64	30.91	4.66	0.23	0.87	1.35
57.13	0.05	164.12	96.17	103.02	0.945	6.603	0.04	1.79	6.75	31.60	4.68	0.22	0.89	1.38
58.65	0.06	168.06	96.05	103.00	0.966	6.604	0.04	1.83	6.86	32.31	4.71	0.21	0.92	1.41
60.15	0.06	171.80	95.94	102.97	0.988	6.606	0.04	1.87	6.98	32.98	4.73	0.20	0.94	1.44
66.15	0.06	186.14	95.63	103.02	1.082	6.612	0.05	2.02	7.29	35.44	4.86	0.18	1.01	1.54
72.15	0.07	201.39	95.13	102.96	1.178	6.618	0.05	2.19	7.78	38.21	4.91	0.14	1.10	1.66
78.15	0.07	216.01	94.74	103.03	1.272	6.625	0.05	2.34	8.18	40.78	4.99	0.12	1.17	1.76
84.15	0.08	229.24	94.23	102.97	1.368	6.631	0.06	2.49	8.68	43.25	4.98	0.08	1.24	1.87
90.15	0.09	243.84	93.82	103.04	1.473	6.638	0.06	2.64	9.09	45.83	5.04	0.05	1.32	1.98
96.15	0.09	256.30	93.30	102.98	1.567	6.645	0.07	2.77	9.61	48.18	5.01	0.01	1.39	2.08
102.15	0.10	268.70	92.90	103.05	1.670	6.651	0.07	2.90	10.02	50.41	5.03	-0.02	1.45	2.18
108.15	0.10	279.91	92.40	103.00	1.769	6.658	0.07	3.02	10.51	52.55	5.00	-0.05	1.51	2.27
114.15	0.11	292.37	91.97	103.06	1.863	6.665	0.08	3.15	10.94	54.81	5.01	-0.08	1.58	2.37
120.17	0.11	303.38	91.51	103.02	1.974	6.672	0.08	3.27	11.40	56.87	4.99	-0.12	1.64	2.46
126.17	0.12	313.39	91.10	103.05	2.068	6.679	0.09	3.37	11.81	58.74	4.97	-0.15	1.69	2.54
132.17	0.13	322.66	90.66	103.03	2.172	6.686	0.09	3.47	12.25	60.51	4.94	-0.18	1.74	2.62
138.17	0.13	330.69	90.27	103.03	2.267	6.692	0.09	3.55	12.64	62.05	4.91	-0.20	1.78	2.69
144.17	0.14	341.47	89.85	103.03	2.371	6.699	0.10	3.66	13.06	64.03	4.90	-0.24	1.83	2.78
150.17	0.14	347.80	89.34	102.89	2.454	6.705	0.10	3.73	13.58	65.45	4.82	-0.27	1.87	2.85
156.17	0.15	357.05	89.14	103.04	2.557	6.712	0.11	3.82	13.77	66.97	4.86	-0.29	1.92	2.91

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 50%
Sample No.: Ash 50% Specimen No.: B
Depth (ft.): 0

Initial Height., H_o (in): 5.849 Confining Pressure (psi): 10.00
Initial Diameter, D_o (in): 2.884 Initial Volume, V_o (in^3): 38.21
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
Ht Change at End of Consol., ΔH_o (in): 0.036 H_c 5.814 Area after Consol., A_c (in^2): 6.54
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 3.06 0.18666 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
162.17	0.15	361.46	88.66	102.92	2.663	6.719	0.11	3.87	14.25	68.04	4.78	-0.32	1.94	2.96
168.17	0.16	370.15	88.43	103.05	2.767	6.727	0.12	3.95	14.48	69.51	4.80	-0.34	1.98	3.02
174.17	0.17	375.10	88.03	102.94	2.863	6.733	0.12	4.00	14.88	70.59	4.74	-0.37	2.01	3.08
180.17	0.17	382.47	87.84	103.07	2.964	6.740	0.12	4.08	15.07	71.81	4.77	-0.38	2.04	3.13
186.17	0.18	389.06	87.44	102.98	3.061	6.747	0.13	4.14	15.48	73.14	4.73	-0.41	2.08	3.19
192.18	0.18	394.00	87.24	103.08	3.161	6.754	0.13	4.19	15.68	74.01	4.72	-0.42	2.10	3.23
198.18	0.19	399.82	86.87	102.99	3.265	6.761	0.14	4.25	16.04	75.17	4.69	-0.45	2.13	3.28
204.18	0.20	403.61	86.71	103.08	3.365	6.768	0.14	4.28	16.20	75.83	4.68	-0.46	2.15	3.31
210.18	0.20	409.08	86.35	103.00	3.465	6.775	0.14	4.34	16.56	76.94	4.65	-0.49	2.17	3.37
216.20	0.21	413.27	86.21	103.08	3.559	6.782	0.15	4.38	16.70	77.64	4.65	-0.50	2.19	3.40
222.20	0.21	417.55	85.92	103.01	3.656	6.789	0.15	4.42	17.00	78.50	4.62	-0.52	2.21	3.44
228.20	0.22	421.92	85.73	103.09	3.761	6.796	0.16	4.46	17.18	79.26	4.61	-0.53	2.24	3.47
234.22	0.22	424.70	85.49	103.02	3.869	6.804	0.16	4.48	17.43	79.85	4.58	-0.55	2.25	3.50
240.22	0.23	429.61	85.33	103.09	3.970	6.811	0.17	4.53	17.58	80.66	4.59	-0.56	2.27	3.54
246.22	0.24	430.78	85.12	103.03	4.063	6.817	0.17	4.54	17.80	80.98	4.55	-0.58	2.27	3.56
252.22	0.24	435.82	84.94	103.10	4.162	6.824	0.17	4.59	17.97	81.83	4.55	-0.59	2.30	3.59
258.22	0.25	437.33	84.73	103.04	4.269	6.832	0.18	4.60	18.18	82.19	4.52	-0.60	2.30	3.61
264.22	0.25	440.26	84.63	103.10	4.371	6.839	0.18	4.62	18.29	82.66	4.52	-0.61	2.32	3.63
270.22	0.26	443.41	84.41	103.05	4.468	6.846	0.19	4.65	18.50	83.27	4.50	-0.63	2.33	3.66
276.22	0.27	445.65	84.31	103.11	4.572	6.854	0.19	4.67	18.60	83.62	4.50	-0.63	2.34	3.68
282.22	0.27	449.04	84.09	103.05	4.664	6.860	0.19	4.70	18.82	84.28	4.48	-0.65	2.36	3.71
288.22	0.28	450.96	84.01	103.11	4.770	6.868	0.20	4.71	18.90	84.56	4.47	-0.66	2.36	3.72
294.23	0.28	455.98	83.79	103.06	4.867	6.875	0.20	4.76	19.12	85.45	4.47	-0.67	2.39	3.76
300.23	0.29	456.72	83.72	103.12	4.966	6.882	0.21	4.76	19.19	85.56	4.46	-0.68	2.39	3.77
315.23	0.30	463.96	83.34	103.10	5.216	6.900	0.22	4.83	19.58	86.81	4.43	-0.70	2.42	3.83
330.23	0.32	467.49	83.04	103.08	5.464	6.918	0.23	4.85	19.88	87.45	4.40	-0.73	2.43	3.86
345.23	0.33	473.65	82.68	103.04	5.719	6.937	0.24	4.90	20.24	88.51	4.37	-0.75	2.46	3.92
360.23	0.35	477.47	82.36	102.94	5.972	6.956	0.25	4.92	20.56	89.20	4.34	-0.77	2.47	3.95
375.23	0.36	483.87	82.24	103.12	6.222	6.974	0.26	4.98	20.68	90.06	4.36	-0.78	2.50	3.99
390.25	0.38	488.33	81.97	103.10	6.465	6.992	0.27	5.01	20.95	90.78	4.33	-0.80	2.51	4.02
405.25	0.39	489.67	81.77	103.07	6.718	7.011	0.28	5.01	21.14	90.98	4.30	-0.82	2.51	4.04
420.25	0.40	496.24	81.49	103.02	6.963	7.030	0.29	5.06	21.42	92.01	4.30	-0.84	2.54	4.08
435.25	0.42	498.28	81.42	103.13	7.221	7.049	0.30	5.07	21.50	92.18	4.29	-0.84	2.54	4.09
450.27	0.43	502.35	81.23	103.12	7.468	7.068	0.31	5.09	21.68	92.75	4.28	-0.86	2.56	4.12
465.27	0.45	506.92	81.03	103.09	7.721	7.088	0.32	5.13	21.89	93.41	4.27	-0.87	2.57	4.15
480.27	0.46	507.92	80.91	103.06	7.981	7.108	0.33	5.12	22.01	93.47	4.25	-0.88	2.57	4.16
495.27	0.48	513.49	80.64	102.97	8.229	7.127	0.34	5.16	22.28	94.33	4.23	-0.90	2.59	4.20
510.28	0.49	517.13	80.63	103.13	8.478	7.146	0.35	5.18	22.29	94.65	4.25	-0.90	2.61	4.21
525.28	0.51	518.52	80.49	103.11	8.726	7.166	0.36	5.18	22.43	94.79	4.23	-0.91	2.61	4.22
540.28	0.52	522.32	80.28	103.09	8.985	7.186	0.37	5.21	22.63	95.31	4.21	-0.92	2.62	4.25
555.28	0.54	524.36	80.16	103.04	9.228	7.205	0.38	5.21	22.76	95.53	4.20	-0.93	2.62	4.26
570.28	0.55	527.23	79.98	103.05	9.482	7.226	0.39	5.23	22.94	95.90	4.18	-0.95	2.63	4.28
585.28	0.57	528.16	79.96	103.13	9.735	7.246	0.41	5.22	22.96	95.85	4.18	-0.95	2.62	4.28
600.28	0.58	530.05	79.83	103.11	9.984	7.266	0.42	5.22	23.09	96.04	4.16	-0.96	2.63	4.29
615.30	0.60	531.43	79.68	103.07	10.244	7.287	0.43	5.22	23.24	96.17	4.14	-0.97	2.63	4.30
630.30	0.61	531.44	79.57	103.03	10.492	7.307	0.44	5.21	23.34	96.07	4.12	-0.98	2.62	4.30
645.30	0.62	533.00	79.56	103.15	10.744	7.328	0.45	5.20	23.35	96.09	4.11	-0.98	2.62	4.30
660.32	0.64	534.92	79.50	103.13	10.990	7.348	0.46	5.21	23.41	96.21	4.11	-0.98	2.62	4.31
675.32	0.65	535.39	79.44	103.11	11.244	7.369	0.47	5.20	23.47	96.13	4.10	-0.98	2.62	4.31
690.32	0.67	536.14	79.37	103.07	11.501	7.390	0.48	5.19	23.55	96.09	4.08	-0.99	2.61	4.31
705.32	0.68	536.00	79.29	102.96	11.752	7.411	0.49	5.17	23.62	95.94	4.06	-1.00	2.60	4.30
720.33	0.70	537.21	79.40	103.15	12.002	7.432	0.50	5.17	23.51	95.79	4.07	-0.99	2.60	4.29
735.33	0.71	537.12	79.41	103.12	12.255	7.454	0.51	5.15	23.51	95.57	4.07	-0.99	2.59	4.29
750.33	0.73	538.19	79.33	103.09	12.509	7.476	0.52	5.15	23.59	95.58	4.05	-0.99	2.59	4.29
765.33	0.74	538.53	79.26	103.04	12.758	7.497	0.53	5.13	23.65	95.49	4.04	-1.00	2.59	4.29
780.35	0.76	539.96	79.35	103.14	13.004	7.518	0.54	5.13	23.56	95.39	4.05	-0.99	2.59	4.28
795.35	0.77	541.14	79.33	103.13	13.268	7.541	0.55	5.13	23.58	95.34	4.04	-0.99	2.58	4.28

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 50%
Sample No.: Ash 50% Specimen No.: B
Depth (ft.): 0

Initial Height., H_o (in):	5.849	Confining Pressure (psi):	10.00
Initial Diameter, D_o (in):	2.884	Initial Volume, V_o (in^3):	38.21
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.53
Ht Change at End of Consol., ΔH_o (in):	0.036 H_c 5.814	Area after Consol., A_c (in^2):	6.54
Ht Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
Volume change during Consol. V_c (cc^3):	3.06 0.18666 in^3		

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
810.35	0.79	540.22	79.34	103.12	13.524	7.563	0.56	5.10	23.57	95.00	4.03	-0.99	2.57	4.27
825.35	0.80	540.46	79.29	103.03	13.778	7.586	0.57	5.09	23.62	94.87	4.02	-1.00	2.56	4.27
840.35	0.82	542.25	79.27	102.92	14.022	7.607	0.58	5.09	23.65	94.93	4.01	-1.00	2.57	4.27
855.37	0.83	543.85	79.42	103.01	14.281	7.630	0.59	5.09	23.49	94.77	4.03	-0.99	2.57	4.26
870.37	0.84	545.76	79.40	102.96	14.521	7.651	0.60	5.09	23.51	94.84	4.03	-0.99	2.57	4.26
885.38	0.86	543.51	79.53	102.97	14.774	7.674	0.61	5.05	23.38	94.21	4.03	-0.98	2.55	4.23
900.05	0.87	545.19	79.49	102.91	15.020	7.696	0.62	5.06	23.42	94.26	4.02	-0.98	2.55	4.24

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 50%
Sample No.: Ash 50% Specimen No.: C
Depth (ft.): 0

Initial Height., H_o (in): 5.912 Confining Pressure (psi): 15.00
Initial Diameter, D_o (in): 2.883 Initial Volume, V_o (in^3): 38.60
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
t Change at End of Consol.,ΔH_o (in): 0.011 H_c 5.901 Area after Consol., A_c (in^2): 6.49
Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
ume change during Consol. V_c (cc^3): 4.57 0.27877 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	90.29	105.02	0.000	6.493	0.00	0.00	14.73	14.73	1.00	0.00	0.00	1.06
1.50	0.001	10.22	90.74	104.99	0.017	6.494	0.00	0.11	14.27	15.85	1.11	0.03	0.06	1.08
3.00	0.002	21.11	91.25	104.95	0.035	6.495	0.00	0.23	13.76	17.01	1.24	0.07	0.12	1.11
4.50	0.003	31.73	91.77	104.90	0.058	6.497	0.00	0.35	13.25	18.13	1.37	0.11	0.18	1.13
6.02	0.005	42.23	92.24	104.81	0.081	6.498	0.00	0.47	12.77	19.27	1.51	0.14	0.23	1.15
7.53	0.007	51.57	92.87	104.96	0.111	6.500	0.00	0.57	12.14	20.07	1.65	0.19	0.29	1.16
9.03	0.008	60.27	93.33	104.95	0.128	6.501	0.01	0.67	11.69	20.96	1.79	0.22	0.33	1.18
10.53	0.009	68.92	93.73	104.93	0.152	6.503	0.01	0.76	11.28	21.88	1.94	0.25	0.38	1.19
12.03	0.010	76.77	94.10	104.93	0.175	6.504	0.01	0.85	10.92	22.72	2.08	0.27	0.42	1.21
13.55	0.012	83.85	94.42	104.93	0.200	6.506	0.01	0.93	10.59	23.48	2.22	0.30	0.46	1.23
15.05	0.014	90.41	94.69	104.93	0.237	6.508	0.01	1.00	10.33	24.22	2.34	0.32	0.50	1.24
16.57	0.015	96.34	94.89	104.92	0.253	6.509	0.01	1.06	10.12	24.92	2.46	0.33	0.53	1.26
18.08	0.016	102.14	95.05	104.90	0.271	6.511	0.01	1.13	9.96	25.65	2.57	0.34	0.56	1.28
19.58	0.018	107.64	95.14	104.84	0.309	6.513	0.01	1.19	9.87	26.40	2.67	0.35	0.59	1.31
21.10	0.020	113.50	95.40	104.99	0.331	6.515	0.01	1.25	9.61	27.04	2.81	0.37	0.63	1.32
22.60	0.020	118.96	95.51	105.00	0.342	6.515	0.01	1.31	9.50	27.76	2.92	0.38	0.66	1.34
24.10	0.022	124.47	95.58	105.00	0.373	6.517	0.02	1.37	9.43	28.53	3.02	0.38	0.69	1.37
25.60	0.024	129.73	95.63	104.99	0.401	6.519	0.02	1.43	9.38	29.28	3.12	0.38	0.72	1.39
27.10	0.025	134.92	95.67	104.99	0.417	6.520	0.02	1.49	9.35	30.04	3.21	0.39	0.74	1.42
28.60	0.026	140.17	95.68	104.97	0.437	6.521	0.02	1.55	9.33	30.82	3.30	0.39	0.77	1.45
30.10	0.028	145.37	95.68	104.96	0.467	6.523	0.02	1.60	9.33	31.61	3.39	0.39	0.80	1.47
31.62	0.029	151.24	95.65	104.93	0.494	6.525	0.02	1.67	9.37	32.54	3.47	0.39	0.83	1.51
33.12	0.030	156.49	95.57	104.86	0.512	6.526	0.02	1.72	9.45	33.43	3.54	0.38	0.86	1.54
34.63	0.032	161.87	95.70	105.02	0.538	6.528	0.02	1.78	9.32	34.11	3.66	0.39	0.89	1.56
36.15	0.033	167.01	95.68	105.03	0.556	6.529	0.02	1.84	9.34	34.91	3.74	0.39	0.92	1.59
37.65	0.034	172.18	95.63	105.02	0.582	6.531	0.02	1.90	9.38	35.75	3.81	0.38	0.95	1.62
39.17	0.036	177.26	95.58	105.02	0.606	6.533	0.03	1.95	9.44	36.57	3.88	0.38	0.98	1.66
40.67	0.038	182.32	95.52	105.01	0.636	6.535	0.03	2.01	9.50	37.40	3.94	0.38	1.00	1.69
42.17	0.039	187.89	95.44	104.99	0.658	6.536	0.03	2.07	9.57	38.32	4.00	0.37	1.03	1.72
43.67	0.040	193.11	95.35	104.98	0.679	6.537	0.03	2.12	9.66	39.20	4.06	0.36	1.06	1.76
45.17	0.042	198.20	95.25	104.95	0.708	6.539	0.03	2.18	9.77	40.08	4.10	0.36	1.09	1.79
46.68	0.043	203.13	95.10	104.87	0.733	6.541	0.03	2.23	9.92	40.97	4.13	0.35	1.12	1.83
48.18	0.045	207.95	95.17	105.04	0.760	6.543	0.03	2.29	9.84	41.63	4.23	0.35	1.14	1.85
49.70	0.046	212.79	95.09	105.05	0.775	6.544	0.03	2.34	9.92	42.44	4.28	0.35	1.17	1.89
51.20	0.047	218.04	94.98	105.04	0.799	6.545	0.03	2.40	10.03	43.34	4.32	0.34	1.20	1.92
52.70	0.049	223.35	94.87	105.03	0.834	6.548	0.03	2.45	10.15	44.26	4.36	0.33	1.23	1.96
54.22	0.050	228.21	94.75	105.02	0.854	6.549	0.04	2.51	10.27	45.11	4.39	0.32	1.25	1.99
55.72	0.052	233.00	94.63	105.01	0.886	6.551	0.04	2.56	10.39	45.96	4.42	0.31	1.28	2.03
57.22	0.054	237.71	94.50	104.99	0.914	6.553	0.04	2.61	10.52	46.79	4.45	0.30	1.31	2.06
58.72	0.055	242.32	94.35	104.95	0.933	6.554	0.04	2.66	10.66	47.63	4.47	0.29	1.33	2.10
60.22	0.056	246.72	94.15	104.86	0.953	6.555	0.04	2.71	10.86	48.50	4.46	0.28	1.35	2.14
66.23	0.062	265.04	93.80	105.00	1.051	6.562	0.04	2.90	11.22	51.61	4.60	0.25	1.45	2.26
72.23	0.068	281.55	93.19	104.84	1.150	6.569	0.05	3.08	11.82	54.69	4.63	0.21	1.54	2.39
78.23	0.074	298.08	92.81	104.98	1.252	6.575	0.05	3.26	12.20	57.53	4.72	0.18	1.63	2.51
84.25	0.080	313.73	92.28	104.94	1.354	6.582	0.06	3.43	12.74	60.40	4.74	0.14	1.72	2.63
90.25	0.086	327.38	91.86	105.03	1.453	6.589	0.06	3.57	13.15	62.84	4.78	0.11	1.79	2.74
96.25	0.091	341.56	91.32	104.99	1.549	6.595	0.06	3.72	13.69	65.48	4.78	0.07	1.86	2.85
102.27	0.096	353.59	90.94	105.06	1.633	6.601	0.07	3.85	14.08	67.65	4.80	0.05	1.93	2.94
108.27	0.102	365.80	90.41	105.02	1.731	6.607	0.07	3.98	14.60	69.97	4.79	0.01	1.99	3.04
114.27	0.108	377.25	90.02	105.08	1.824	6.614	0.08	4.10	14.99	72.03	4.80	-0.02	2.05	3.13
120.27	0.114	386.98	89.56	105.04	1.940	6.621	0.08	4.20	15.45	73.89	4.78	-0.05	2.10	3.22
126.28	0.120	397.52	89.15	105.08	2.040	6.628	0.08	4.31	15.87	75.84	4.78	-0.08	2.16	3.30
132.28	0.125	406.58	88.76	105.07	2.126	6.634	0.09	4.41	16.25	77.54	4.77	-0.11	2.21	3.38
138.28	0.132	415.34	88.20	104.90	2.232	6.641	0.09	4.50	16.81	79.35	4.72	-0.15	2.25	3.46
144.28	0.137	423.83	88.00	105.09	2.327	6.648	0.10	4.58	17.01	80.77	4.75	-0.16	2.30	3.52

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 50%
Sample No.: Ash 50% Specimen No.: C
Depth (ft.): 0

Initial Height., H_o (in): 5.912 Confining Pressure (psi): 15.00
Initial Diameter, D_o (in): 2.883 Initial Volume, V_o (in^3): 38.60
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
t Change at End of Consol.,ΔH_o (in): 0.011 H_c 5.901 Area after Consol., A_c (in^2): 6.49
Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
ume change during Consol. V_c (cc^3): 4.57 0.27877 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
150.30	0.143	430.88	87.55	105.00	2.430	6.655	0.10	4.65	17.46	82.21	4.71	-0.20	2.33	3.59
156.30	0.150	439.29	87.28	105.11	2.535	6.662	0.11	4.74	17.73	83.67	4.72	-0.22	2.37	3.65
162.30	0.156	445.36	86.91	105.04	2.638	6.669	0.11	4.80	18.10	84.89	4.69	-0.24	2.40	3.71
168.30	0.161	452.58	86.63	105.12	2.723	6.675	0.11	4.87	18.38	86.19	4.69	-0.26	2.44	3.76
174.30	0.167	459.03	86.26	105.06	2.824	6.682	0.12	4.94	18.75	87.45	4.66	-0.29	2.47	3.82
180.30	0.172	464.36	86.03	105.13	2.923	6.689	0.12	4.99	18.99	88.41	4.66	-0.31	2.50	3.87
186.32	0.179	470.64	85.68	105.08	3.028	6.696	0.13	5.05	19.33	89.62	4.64	-0.33	2.53	3.92
192.32	0.185	475.08	85.48	105.14	3.127	6.703	0.13	5.09	19.54	90.42	4.63	-0.35	2.55	3.96
198.32	0.190	480.91	85.14	105.10	3.227	6.710	0.13	5.15	19.88	91.55	4.61	-0.37	2.58	4.01
204.33	0.196	485.82	84.92	105.14	3.325	6.716	0.14	5.20	20.10	92.43	4.60	-0.39	2.60	4.05
210.33	0.202	490.17	84.63	105.12	3.421	6.723	0.14	5.24	20.38	93.29	4.58	-0.41	2.62	4.09
216.35	0.207	494.70	84.19	104.91	3.515	6.730	0.15	5.28	20.83	94.34	4.53	-0.44	2.65	4.15
222.35	0.214	498.24	84.17	105.14	3.622	6.737	0.15	5.31	20.84	94.80	4.55	-0.44	2.66	4.16
228.35	0.220	503.10	83.78	105.00	3.735	6.745	0.16	5.36	21.23	95.82	4.51	-0.47	2.69	4.21
234.37	0.225	507.38	83.69	105.14	3.815	6.751	0.16	5.40	21.33	96.49	4.52	-0.47	2.71	4.24
240.37	0.231	510.77	83.38	105.05	3.923	6.758	0.16	5.43	21.63	97.21	4.49	-0.50	2.72	4.28
246.37	0.237	514.99	83.26	105.15	4.012	6.764	0.17	5.47	21.76	97.89	4.50	-0.51	2.74	4.31
252.37	0.243	517.42	83.02	105.08	4.118	6.772	0.17	5.49	21.99	98.40	4.47	-0.52	2.75	4.33
258.37	0.250	521.93	82.86	105.16	4.232	6.780	0.18	5.53	22.16	99.14	4.47	-0.54	2.77	4.37
264.38	0.256	525.21	82.63	105.10	4.330	6.787	0.18	5.56	22.39	99.77	4.46	-0.55	2.79	4.40
270.38	0.261	528.45	82.48	105.16	4.425	6.794	0.18	5.59	22.54	100.32	4.45	-0.56	2.80	4.42
276.38	0.267	531.87	82.26	105.12	4.521	6.800	0.19	5.62	22.75	100.96	4.44	-0.58	2.82	4.45
282.38	0.272	533.75	82.16	105.17	4.617	6.807	0.19	5.63	22.86	101.27	4.43	-0.59	2.82	4.47
288.40	0.279	537.91	81.92	105.14	4.730	6.815	0.20	5.67	23.09	102.02	4.42	-0.60	2.84	4.50
294.40	0.285	539.76	81.62	104.97	4.826	6.822	0.20	5.68	23.40	102.51	4.38	-0.62	2.85	4.53
300.40	0.291	543.43	81.62	105.15	4.929	6.830	0.21	5.71	23.40	102.97	4.40	-0.62	2.86	4.55
315.40	0.305	550.04	81.25	105.14	5.170	6.847	0.22	5.77	23.77	104.10	4.38	-0.65	2.89	4.60
330.42	0.320	555.98	80.86	105.09	5.422	6.865	0.23	5.81	24.16	105.14	4.35	-0.68	2.92	4.65
345.42	0.334	562.23	80.41	104.95	5.667	6.883	0.24	5.86	24.61	106.29	4.32	-0.71	2.94	4.71
360.42	0.350	567.53	80.34	105.19	5.932	6.902	0.25	5.90	24.68	106.90	4.33	-0.72	2.96	4.74
375.42	0.364	572.80	80.09	105.19	6.172	6.920	0.26	5.94	24.93	107.70	4.32	-0.73	2.98	4.77
390.42	0.379	577.91	79.79	105.16	6.428	6.939	0.27	5.98	25.23	108.51	4.30	-0.76	3.00	4.81
405.42	0.394	582.63	79.49	105.05	6.674	6.957	0.28	6.01	25.52	109.26	4.28	-0.78	3.01	4.85
420.43	0.409	586.68	79.26	105.05	6.924	6.976	0.29	6.03	25.75	109.85	4.27	-0.79	3.03	4.88
435.43	0.424	590.15	78.97	104.95	7.190	6.996	0.30	6.05	26.04	110.40	4.24	-0.81	3.04	4.91
450.43	0.439	594.36	78.92	105.17	7.435	7.015	0.31	6.08	26.10	110.83	4.25	-0.82	3.05	4.93
465.43	0.454	597.15	78.75	105.15	7.689	7.034	0.32	6.09	26.27	111.17	4.23	-0.83	3.06	4.95
480.43	0.468	601.49	78.51	105.15	7.929	7.052	0.33	6.12	26.50	111.79	4.22	-0.85	3.07	4.98
495.43	0.483	603.91	78.35	105.14	8.185	7.072	0.34	6.12	26.67	112.06	4.20	-0.86	3.07	4.99
510.43	0.497	608.94	78.11	105.11	8.421	7.090	0.35	6.16	26.90	112.79	4.19	-0.88	3.09	5.03
525.43	0.513	611.12	77.89	105.01	8.686	7.111	0.36	6.16	27.13	113.07	4.17	-0.89	3.09	5.05
540.43	0.527	614.47	77.86	105.18	8.927	7.130	0.37	6.18	27.15	113.34	4.17	-0.89	3.10	5.06
555.58	0.542	617.24	77.68	105.06	9.183	7.150	0.38	6.19	27.33	113.66	4.16	-0.91	3.11	5.08
570.58	0.557	620.52	77.59	105.11	9.433	7.169	0.39	6.20	27.43	113.98	4.16	-0.91	3.12	5.09
585.58	0.571	622.18	77.48	105.11	9.682	7.189	0.40	6.20	27.54	114.08	4.14	-0.92	3.12	5.10
600.58	0.587	625.71	77.33	105.09	9.947	7.210	0.41	6.22	27.68	114.46	4.13	-0.93	3.12	5.12
615.60	0.601	627.09	77.19	105.05	10.188	7.230	0.42	6.21	27.83	114.57	4.12	-0.94	3.12	5.13
630.60	0.616	629.64	76.85	104.82	10.442	7.250	0.43	6.22	28.17	115.01	4.08	-0.97	3.13	5.15
645.60	0.630	631.27	77.07	105.17	10.677	7.269	0.44	6.22	27.94	114.79	4.11	-0.95	3.13	5.14
660.60	0.645	633.37	76.92	105.08	10.932	7.290	0.46	6.22	28.10	114.98	4.09	-0.96	3.13	5.15
675.60	0.660	634.57	76.81	105.05	11.186	7.311	0.47	6.22	28.21	115.01	4.08	-0.97	3.12	5.16
690.60	0.675	636.45	76.76	105.07	11.433	7.331	0.48	6.22	28.25	115.07	4.07	-0.97	3.13	5.16
705.62	0.689	638.28	76.66	105.05	11.682	7.352	0.49	6.22	28.36	115.18	4.06	-0.98	3.13	5.17
720.62	0.704	639.69	76.53	104.96	11.926	7.372	0.50	6.21	28.49	115.26	4.05	-0.99	3.12	5.17
735.62	0.719	640.70	76.61	105.15	12.185	7.394	0.51	6.20	28.40	115.05	4.05	-0.98	3.12	5.16

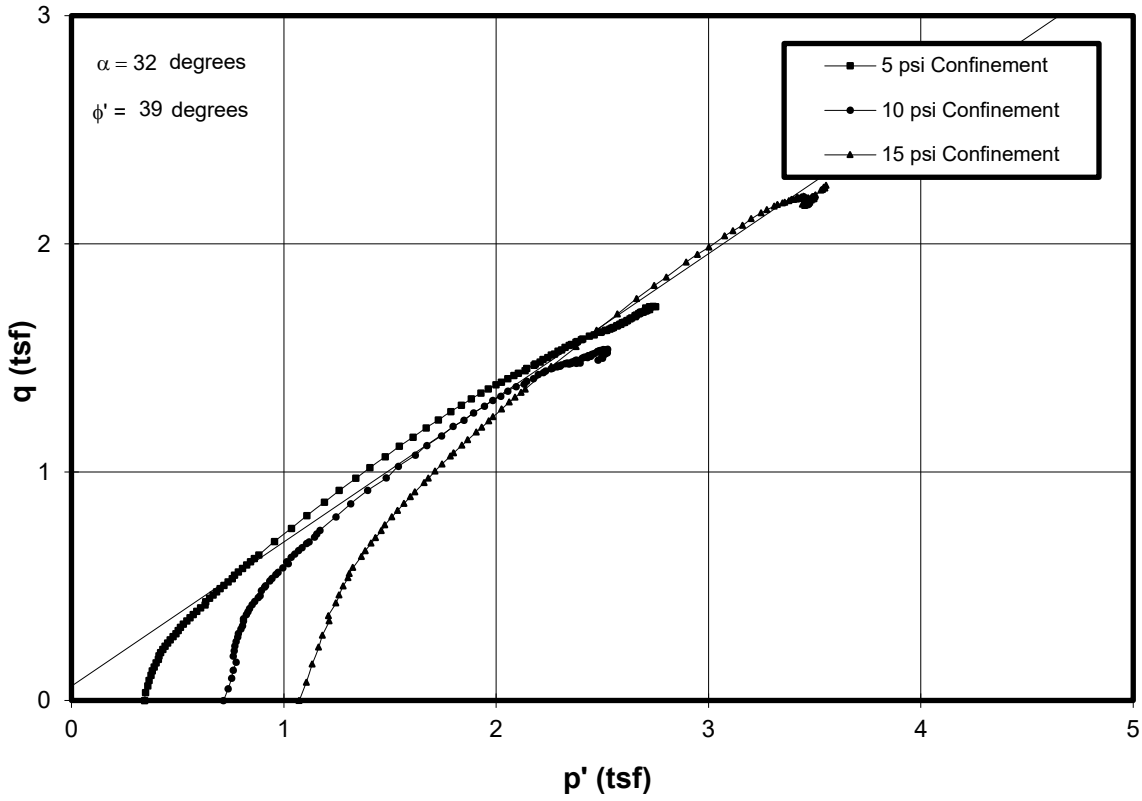
Report No.:

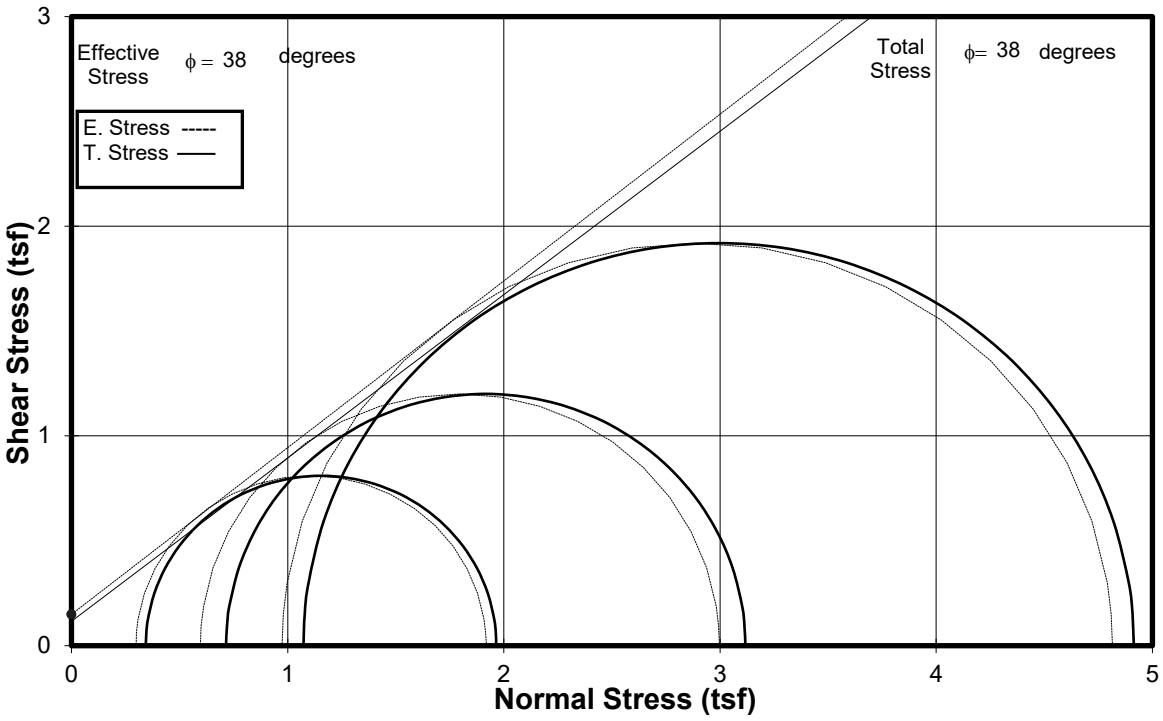
CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 50%
Sample No.: Ash 50% Specimen No.: C
Depth (ft.): 0

Initial Height., H_o (in):	5.912	Confining Pressure (psi):	15.00
Initial Diameter, D_o (in):	2.883	Initial Volume, V_o (in^3):	38.60
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.53
t Change at End of Consol., ΔH_o (in):	0.011 H_c 5.901	Area after Consol., A_c (in^2):	6.49
Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
ume change during Consol. V_c (cc^3):	4.57 0.27877 in^3		

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
750.62	0.734	642.75	76.52	105.03	12.433	7.415	0.52	6.20	28.50	115.18	4.04	-0.99	3.12	5.17
765.62	0.749	643.72	76.51	105.08	12.692	7.437	0.53	6.19	28.51	115.06	4.04	-0.99	3.12	5.17
780.62	0.763	644.39	76.48	105.08	12.934	7.458	0.54	6.18	28.53	114.94	4.03	-0.99	3.11	5.16
795.63	0.778	646.12	76.40	105.07	13.179	7.479	0.55	6.18	28.62	115.01	4.02	-1.00	3.11	5.17
810.63	0.793	645.14	76.29	104.89	13.433	7.501	0.56	6.15	28.73	114.74	3.99	-1.01	3.10	5.16
825.63	0.808	647.24	76.31	105.02	13.686	7.523	0.57	6.15	28.71	114.75	4.00	-1.01	3.10	5.16
840.63	0.822	647.37	76.40	105.11	13.932	7.544	0.58	6.14	28.62	114.43	4.00	-1.00	3.09	5.15
855.63	0.837	648.53	76.32	105.11	14.183	7.566	0.59	6.13	28.69	114.41	3.99	-1.01	3.09	5.15
870.65	0.852	646.35	76.28	105.03	14.440	7.589	0.60	6.09	28.73	113.90	3.96	-1.01	3.07	5.13
885.67	0.866	650.26	76.20	105.00	14.682	7.610	0.61	6.11	28.81	114.25	3.97	-1.01	3.08	5.15
900.10	0.881	649.04	76.23	105.01	14.927	7.632	0.62	6.08	28.79	113.83	3.95	-1.01	3.06	5.13



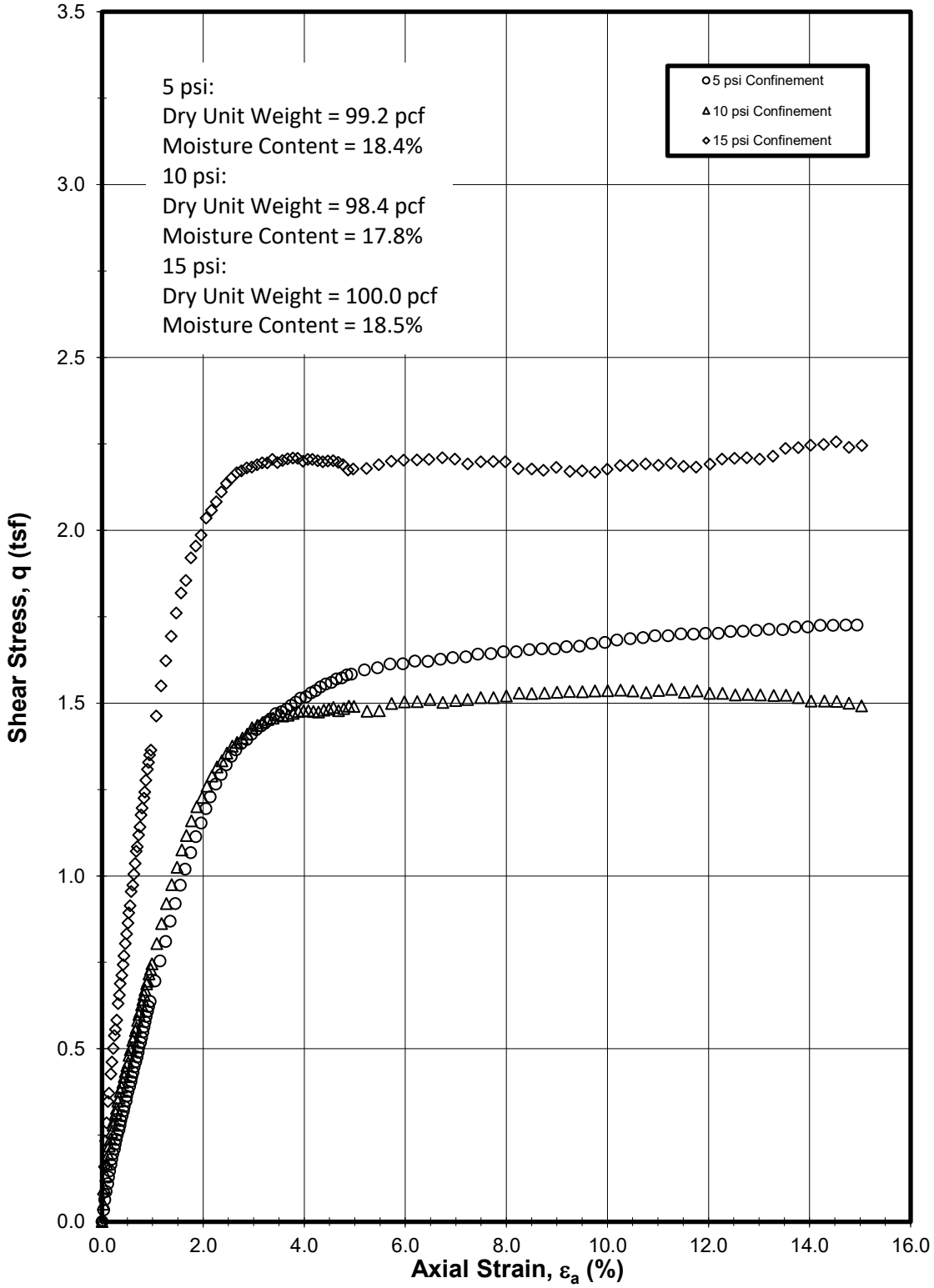


CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST

ASTM D 4767

Project No.: J039697.01

Sample: 30% Lime Pond Sludge / 70% Ash



CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST

ASTM D 4767

Project No.: J039697.01

Sample: 30% Lime Pond Sludge / 70% Ash

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime Pond Sludge
Sample No.: 70% Ash Specimen No.: A
Depth (ft.): 0

Initial Height., H_o (in): 5.741 Confining Pressure (psi): 5.00
Initial Diameter, D_o (in): 2.884 Initial Volume, V_o (in^3): 37.50
Membrane Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
Ht Change at End of Consol.,ΔH_o (in): 0.016 H_c 5.725 Area after Consol., A_c (in^2): 6.535
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 1.48 0.09028 in^3

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	98.12	102.89	0.000	6.535	0.00	0.00	4.77	4.77	1.00	0.00	0.000	0.343
1.50	0.00	6.16	98.53	103.03	0.032	6.537	0.00	0.07	4.36	5.30	1.22	0.03	0.034	0.348
3.00	0.00	11.60	98.81	103.02	0.054	6.538	0.00	0.13	4.08	5.86	1.43	0.05	0.064	0.358
4.52	0.00	15.95	99.04	103.02	0.082	6.540	0.00	0.18	3.86	6.29	1.63	0.07	0.088	0.365
6.03	0.01	19.98	99.24	103.01	0.110	6.542	0.00	0.22	3.66	6.71	1.84	0.08	0.110	0.373
7.53	0.01	23.51	99.40	103.00	0.128	6.543	0.01	0.26	3.49	7.08	2.03	0.09	0.129	0.380
9.05	0.01	26.76	99.54	102.99	0.146	6.544	0.01	0.29	3.35	7.44	2.22	0.10	0.147	0.388
10.55	0.01	30.03	99.65	102.97	0.173	6.546	0.01	0.33	3.24	7.83	2.42	0.11	0.165	0.398
12.05	0.01	32.90	99.72	102.93	0.192	6.547	0.01	0.36	3.17	8.19	2.58	0.12	0.181	0.409
13.55	0.01	35.67	99.90	103.03	0.213	6.549	0.01	0.39	2.99	8.43	2.82	0.13	0.196	0.411
15.05	0.01	38.27	99.98	103.03	0.241	6.551	0.01	0.42	2.91	8.75	3.01	0.13	0.210	0.420
16.55	0.01	40.84	100.04	103.02	0.258	6.552	0.01	0.45	2.85	9.09	3.18	0.14	0.224	0.430
18.05	0.02	43.30	100.08	103.02	0.278	6.553	0.01	0.47	2.81	9.42	3.35	0.14	0.238	0.441
19.57	0.02	45.92	100.11	103.01	0.303	6.555	0.01	0.50	2.78	9.79	3.52	0.14	0.252	0.453
21.07	0.02	48.39	100.13	103.00	0.331	6.556	0.01	0.53	2.76	10.14	3.67	0.14	0.266	0.465
22.58	0.02	50.87	100.14	102.98	0.352	6.558	0.01	0.56	2.75	10.51	3.82	0.15	0.279	0.477
24.08	0.02	53.36	100.13	102.95	0.371	6.559	0.02	0.58	2.76	10.89	3.95	0.14	0.293	0.491
25.58	0.02	55.91	100.18	102.99	0.394	6.561	0.02	0.61	2.71	11.23	4.14	0.15	0.307	0.502
27.10	0.02	58.41	100.23	103.04	0.422	6.562	0.02	0.64	2.66	11.56	4.35	0.15	0.320	0.512
28.60	0.03	60.89	100.23	103.03	0.437	6.563	0.02	0.67	2.67	11.94	4.48	0.15	0.334	0.526
30.12	0.03	63.63	100.21	103.02	0.473	6.566	0.02	0.70	2.68	12.37	4.62	0.15	0.349	0.542
31.62	0.03	66.23	100.20	103.02	0.488	6.567	0.02	0.72	2.70	12.78	4.74	0.15	0.363	0.557
33.13	0.03	68.83	100.17	103.01	0.512	6.568	0.02	0.75	2.72	13.20	4.86	0.15	0.377	0.573
34.63	0.03	71.41	100.14	102.99	0.544	6.571	0.02	0.78	2.75	13.62	4.96	0.15	0.391	0.589
36.13	0.03	74.05	100.10	102.97	0.570	6.572	0.02	0.81	2.79	14.06	5.04	0.14	0.406	0.607
37.63	0.03	76.50	99.98	102.87	0.587	6.573	0.02	0.84	2.91	14.55	5.00	0.13	0.419	0.628
39.13	0.04	79.04	100.13	103.04	0.614	6.575	0.03	0.86	2.76	14.78	5.36	0.14	0.433	0.631
40.63	0.04	81.82	100.10	103.03	0.636	6.577	0.03	0.89	2.79	15.24	5.45	0.14	0.448	0.649
42.13	0.04	84.48	100.06	103.03	0.667	6.579	0.03	0.92	2.83	15.67	5.54	0.14	0.462	0.666
43.63	0.04	87.03	100.02	103.02	0.690	6.580	0.03	0.95	2.87	16.09	5.61	0.14	0.476	0.683
45.13	0.04	89.60	99.98	103.01	0.712	6.582	0.03	0.98	2.91	16.52	5.68	0.13	0.490	0.699
46.63	0.04	92.31	99.94	103.00	0.726	6.583	0.03	1.01	2.95	16.98	5.75	0.13	0.505	0.718
48.13	0.04	94.97	99.88	102.98	0.762	6.585	0.03	1.04	3.01	17.44	5.79	0.13	0.519	0.736
49.65	0.04	97.54	99.78	102.92	0.781	6.586	0.03	1.06	3.11	17.92	5.76	0.12	0.533	0.757
51.17	0.05	100.42	99.86	103.05	0.809	6.588	0.03	1.10	3.03	18.27	6.03	0.13	0.549	0.767
52.67	0.05	103.18	99.81	103.04	0.826	6.589	0.03	1.13	3.08	18.74	6.08	0.12	0.564	0.786
54.18	0.05	105.93	99.75	103.03	0.850	6.591	0.04	1.15	3.14	19.21	6.12	0.12	0.579	0.805
55.68	0.05	108.76	99.69	103.03	0.872	6.592	0.04	1.19	3.20	19.69	6.16	0.11	0.594	0.824
57.20	0.05	111.49	99.64	103.02	0.898	6.594	0.04	1.21	3.25	20.16	6.19	0.11	0.609	0.843
58.70	0.05	113.99	99.57	103.01	0.918	6.595	0.04	1.24	3.32	20.60	6.21	0.10	0.622	0.861
60.22	0.05	116.72	99.50	102.99	0.949	6.597	0.04	1.27	3.39	21.08	6.21	0.10	0.637	0.881
66.22	0.06	127.75	99.30	103.04	1.047	6.604	0.04	1.39	3.59	22.94	6.38	0.08	0.696	0.955
72.22	0.07	138.52	99.00	103.00	1.145	6.610	0.05	1.51	3.89	24.85	6.38	0.06	0.754	1.035
78.23	0.07	148.98	98.76	103.05	1.259	6.618	0.05	1.62	4.14	26.65	6.44	0.05	0.810	1.108
84.23	0.08	159.93	98.42	103.02	1.345	6.624	0.06	1.73	4.47	28.61	6.40	0.02	0.869	1.191
90.23	0.08	169.47	98.16	103.06	1.445	6.631	0.06	1.84	4.73	30.29	6.41	0.00	0.920	1.260
96.23	0.09	179.49	97.82	103.03	1.548	6.638	0.06	1.94	5.07	32.11	6.33	-0.02	0.973	1.339
102.23	0.09	188.23	97.56	103.07	1.640	6.644	0.07	2.04	5.33	33.66	6.32	-0.04	1.020	1.404
108.25	0.10	197.22	97.21	103.04	1.751	6.651	0.07	2.13	5.68	35.33	6.22	-0.07	1.067	1.477
114.25	0.11	205.94	96.93	103.08	1.854	6.658	0.08	2.22	5.96	36.89	6.19	-0.09	1.113	1.543
120.27	0.11	213.54	96.59	103.05	1.959	6.665	0.08	2.30	6.31	38.34	6.08	-0.11	1.153	1.607
126.27	0.12	221.38	96.30	103.08	2.052	6.672	0.09	2.38	6.59	39.77	6.03	-0.13	1.195	1.669
132.27	0.12	227.88	95.97	103.05	2.140	6.678	0.09	2.45	6.92	41.05	5.93	-0.16	1.229	1.727
138.27	0.13	235.09	95.68	103.09	2.251	6.685	0.09	2.53	7.21	42.37	5.88	-0.18	1.266	1.785
144.27	0.13	240.42	95.37	103.06	2.357	6.692	0.10	2.58	7.52	43.44	5.78	-0.20	1.293	1.835
150.27	0.14	245.89	95.11	103.09	2.455	6.699	0.10	2.64	7.78	44.49	5.72	-0.22	1.321	1.882

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime Pond Sludge
Sample No.: 70% Ash Specimen No.: A
Depth (ft.): 0

Initial Height., H_o (in): 5.741 Confining Pressure (psi): 5.00
Initial Diameter, D_o (in): 2.884 Initial Volume, V_o (in^3): 37.50
Membrane Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
Ht Change at End of Consol.,ΔH_o (in): 0.016 H_c 5.725 Area after Consol., A_c (in^2): 6.535
Ht Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
Volume change during Consol. V_c (cc^3): 1.48 0.09028 in^3

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
156.28	0.15	250.76	94.82	103.06	2.555	6.706	0.11	2.68	8.07	45.46	5.63	-0.24	1.346	1.927
162.28	0.15	254.40	94.60	103.10	2.647	6.712	0.11	2.72	8.29	46.20	5.57	-0.25	1.364	1.962
168.28	0.16	258.11	94.35	103.07	2.750	6.720	0.11	2.76	8.54	46.96	5.50	-0.27	1.383	1.998
174.28	0.16	260.69	94.16	103.09	2.862	6.727	0.12	2.78	8.73	47.48	5.44	-0.29	1.395	2.024
180.28	0.17	263.80	93.95	103.08	2.958	6.734	0.12	2.81	8.94	48.11	5.38	-0.30	1.410	2.054
186.30	0.17	266.51	93.73	103.03	3.054	6.741	0.13	2.84	9.16	48.70	5.32	-0.32	1.423	2.083
192.30	0.18	268.75	93.60	103.08	3.146	6.747	0.13	2.86	9.29	49.12	5.29	-0.33	1.434	2.103
198.30	0.19	271.07	93.31	102.93	3.245	6.754	0.14	2.88	9.58	49.72	5.19	-0.35	1.445	2.135
204.32	0.19	273.09	93.32	103.08	3.334	6.760	0.14	2.90	9.57	49.97	5.22	-0.35	1.454	2.144
210.32	0.20	276.24	93.05	102.97	3.439	6.768	0.14	2.93	9.84	50.66	5.15	-0.37	1.469	2.178
216.33	0.20	277.58	93.04	103.08	3.546	6.775	0.15	2.94	9.85	50.82	5.16	-0.37	1.475	2.184
222.33	0.21	279.36	92.84	103.00	3.649	6.782	0.15	2.95	10.05	51.24	5.10	-0.38	1.483	2.207
228.33	0.21	281.70	92.81	103.08	3.739	6.789	0.16	2.98	10.08	51.58	5.12	-0.38	1.494	2.220
234.33	0.22	283.61	92.61	103.01	3.831	6.795	0.16	2.99	10.28	52.01	5.06	-0.40	1.503	2.242
240.33	0.22	286.11	92.55	103.08	3.925	6.802	0.16	3.02	10.34	52.40	5.07	-0.40	1.514	2.259
246.33	0.23	287.18	92.40	103.03	4.033	6.809	0.17	3.02	10.49	52.67	5.02	-0.41	1.518	2.274
252.33	0.24	289.73	92.32	103.09	4.135	6.817	0.17	3.05	10.57	53.07	5.02	-0.42	1.530	2.291
258.33	0.24	291.12	92.17	103.04	4.226	6.823	0.18	3.06	10.72	53.39	4.98	-0.43	1.536	2.308
264.35	0.25	293.43	92.09	103.09	4.321	6.830	0.18	3.08	10.80	53.76	4.98	-0.43	1.547	2.324
270.35	0.25	295.33	91.94	103.04	4.423	6.837	0.18	3.10	10.95	54.14	4.94	-0.44	1.555	2.343
276.35	0.26	296.65	91.88	103.09	4.534	6.845	0.19	3.11	11.01	54.35	4.93	-0.45	1.560	2.353
282.35	0.27	298.85	91.71	103.05	4.635	6.852	0.19	3.13	11.18	54.79	4.90	-0.46	1.570	2.375
288.35	0.27	299.69	91.67	103.10	4.742	6.860	0.20	3.13	11.23	54.91	4.89	-0.46	1.573	2.381
294.37	0.28	301.63	91.50	103.05	4.844	6.867	0.20	3.15	11.39	55.31	4.86	-0.48	1.581	2.401
300.37	0.28	302.41	91.47	103.10	4.931	6.874	0.21	3.15	11.43	55.42	4.85	-0.48	1.584	2.406
315.38	0.30	305.63	91.20	103.09	5.193	6.893	0.22	3.18	11.69	56.03	4.79	-0.50	1.596	2.438
330.38	0.31	307.68	90.98	103.07	5.449	6.911	0.23	3.19	11.91	56.43	4.74	-0.51	1.603	2.460
345.38	0.33	310.51	90.72	103.01	5.696	6.929	0.24	3.21	12.17	56.98	4.68	-0.53	1.613	2.489
360.38	0.34	311.52	90.67	103.11	5.949	6.948	0.25	3.21	12.22	57.05	4.67	-0.54	1.614	2.494
375.40	0.35	313.83	90.51	103.10	6.188	6.966	0.26	3.23	12.38	57.43	4.64	-0.55	1.622	2.513
390.40	0.37	314.55	90.41	103.09	6.448	6.985	0.27	3.22	12.48	57.51	4.61	-0.56	1.621	2.520
405.42	0.38	316.49	90.28	103.06	6.695	7.004	0.28	3.23	12.61	57.80	4.58	-0.56	1.627	2.535
420.42	0.40	318.27	90.22	103.11	6.939	7.022	0.29	3.24	12.67	58.00	4.58	-0.57	1.632	2.544
435.55	0.41	319.59	90.16	103.11	7.196	7.041	0.30	3.25	12.73	58.12	4.56	-0.57	1.634	2.551
450.55	0.43	321.92	90.06	103.09	7.435	7.060	0.31	3.26	12.83	58.43	4.55	-0.58	1.642	2.566
465.55	0.44	323.07	90.00	103.08	7.693	7.079	0.32	3.26	12.89	58.53	4.54	-0.58	1.643	2.571
480.57	0.45	325.02	89.87	103.02	7.942	7.099	0.33	3.27	13.02	58.81	4.52	-0.59	1.648	2.586
495.57	0.47	325.91	89.93	103.12	8.197	7.118	0.34	3.27	12.96	58.75	4.53	-0.59	1.648	2.582
510.58	0.48	328.12	89.85	103.11	8.452	7.138	0.35	3.28	13.04	59.01	4.52	-0.60	1.655	2.594
525.58	0.50	329.45	89.78	103.10	8.702	7.158	0.36	3.29	13.11	59.14	4.51	-0.60	1.657	2.601
540.58	0.51	330.30	89.73	103.07	8.952	7.177	0.37	3.29	13.16	59.18	4.50	-0.60	1.657	2.604
555.58	0.53	332.46	89.68	103.10	9.189	7.196	0.38	3.30	13.21	59.41	4.50	-0.61	1.663	2.614
570.58	0.54	333.78	89.67	103.12	9.447	7.216	0.39	3.30	13.22	59.48	4.50	-0.61	1.665	2.617
585.58	0.55	336.20	89.59	103.11	9.692	7.236	0.40	3.32	13.30	59.76	4.49	-0.61	1.673	2.630
600.60	0.57	337.83	89.54	103.09	9.949	7.257	0.41	3.32	13.35	59.90	4.49	-0.62	1.676	2.637
615.60	0.58	340.05	89.41	103.02	10.187	7.276	0.42	3.33	13.48	60.22	4.47	-0.63	1.682	2.653
630.60	0.60	341.88	89.45	103.12	10.449	7.297	0.43	3.34	13.44	60.29	4.49	-0.62	1.687	2.654
645.60	0.61	343.39	89.42	103.11	10.702	7.318	0.45	3.35	13.48	60.40	4.48	-0.63	1.689	2.659
660.62	0.63	345.43	89.35	103.10	10.942	7.338	0.46	3.36	13.55	60.62	4.48	-0.63	1.695	2.670
675.60	0.64	346.54	89.30	103.07	11.201	7.359	0.47	3.36	13.59	60.68	4.46	-0.64	1.695	2.674
690.62	0.66	348.64	89.28	103.11	11.454	7.380	0.48	3.37	13.61	60.85	4.47	-0.64	1.701	2.681
705.62	0.67	349.36	89.27	103.12	11.703	7.401	0.49	3.36	13.62	60.82	4.47	-0.64	1.699	2.680
720.62	0.68	350.73	89.22	103.11	11.938	7.421	0.50	3.37	13.67	60.94	4.46	-0.64	1.701	2.686
735.63	0.70	351.76	89.15	103.09	12.191	7.442	0.51	3.37	13.74	61.00	4.44	-0.65	1.702	2.691
750.63	0.71	353.88	89.03	103.02	12.436	7.463	0.52	3.38	13.86	61.28	4.42	-0.65	1.707	2.705
765.63	0.73	355.01	89.09	103.14	12.684	7.484	0.53	3.38	13.80	61.23	4.44	-0.65	1.708	2.701

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime Pond Sludge
Sample No.: 70% Ash Specimen No.: A
Depth (ft.): 0

Initial Height., H_o (in):	5.741	Confining Pressure (psi):	5.00
Initial Diameter, D_o (in):	2.884	Initial Volume, V_o (in^3):	37.50
Membrane Thickness (in):	0.02	Initial Area, A_o (in^2):	6.53
Ht Change at End of Consol.,ΔH_o (in):	0.016 H_c 5.725	Area after Consol., A_c (in^2):	6.535
Ht Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
Volume change during Consol. V_c (cc^3):	1.48 0.09028 in^3		

Elasped Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
780.63	0.74	356.68	89.03	103.12	12.943	7.506	0.54	3.38	13.86	61.38	4.43	-0.65	1.711	2.709
795.65	0.76	358.27	88.90	102.99	13.194	7.528	0.55	3.39	14.00	61.59	4.40	-0.66	1.713	2.721
810.65	0.77	359.30	89.02	102.85	13.464	7.551	0.56	3.39	13.87	61.45	4.43	-0.66	1.713	2.712
825.65	0.79	361.89	89.24	102.90	13.713	7.573	0.57	3.40	13.65	61.44	4.50	-0.64	1.720	2.703
840.67	0.80	362.93	89.00	102.99	13.964	7.595	0.58	3.40	13.89	61.67	4.44	-0.66	1.720	2.720
855.65	0.81	364.91	89.00	102.89	14.211	7.617	0.59	3.41	13.89	61.79	4.45	-0.66	1.725	2.724
870.67	0.83	366.01	89.04	102.94	14.463	7.640	0.60	3.41	13.85	61.76	4.46	-0.65	1.725	2.722
885.67	0.84	367.39	88.83	102.94	14.715	7.662	0.61	3.41	14.06	62.01	4.41	-0.67	1.726	2.738
899.70	0.86	368.28	88.67	102.75	14.940	7.683	0.62	3.41	14.22	62.16	4.37	-0.68	1.726	2.750

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 50%
Sample No.: Ash 50% Specimen No.: B
Depth (ft.): 0

Initial Height., H_o (in): 5.808
Initial Diameter, D_o (in): 2.884
Membr. Thickness (in): 0.02
Ht Change at End of Consol., ΔH_o (in): 0.027 H_c 5.781
Ht Change at End of Saturation, H_s (in): 0.000
Volume change during Consol. V_c (cc^3): 5.19 0.31659 in^3

Confining Pressure (psi): 10.00
Initial Volume, V_o (in^3): 37.94
Initial Area, A_o (in^2): 6.53
Area after Consol., A_c (in^2): 6.51
Piston Correction (lbs): 0.0

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	93.54	103.47	0.000	6.508	0.00	0.00	9.93	9.93	1.00	0.00	0.00	0.71
1.52	0.00	9.18	93.95	103.46	0.026	6.510	0.00	0.10	9.53	10.94	1.15	0.03	0.05	0.74
3.02	0.00	17.74	94.37	103.43	0.047	6.511	0.00	0.20	9.10	11.82	1.30	0.06	0.10	0.75
4.52	0.00	24.08	94.76	103.39	0.072	6.513	0.00	0.27	8.71	12.41	1.42	0.09	0.13	0.76
6.02	0.01	30.24	95.04	103.29	0.095	6.514	0.00	0.33	8.43	13.07	1.55	0.11	0.17	0.77
7.52	0.01	35.12	95.60	103.53	0.119	6.516	0.00	0.39	7.87	13.26	1.68	0.15	0.19	0.76
9.03	0.01	39.57	95.88	103.52	0.145	6.518	0.01	0.44	7.59	13.66	1.80	0.17	0.22	0.77
10.53	0.01	43.30	96.12	103.50	0.167	6.519	0.01	0.48	7.35	14.00	1.90	0.19	0.24	0.77
12.03	0.01	46.91	96.32	103.49	0.189	6.521	0.01	0.52	7.15	14.35	2.01	0.20	0.26	0.77
13.53	0.01	50.51	96.49	103.47	0.219	6.523	0.01	0.56	6.98	14.73	2.11	0.21	0.28	0.78
15.03	0.01	53.19	96.64	103.45	0.237	6.524	0.01	0.59	6.83	14.99	2.19	0.22	0.29	0.79
16.55	0.02	56.85	96.75	103.42	0.271	6.526	0.01	0.63	6.72	15.43	2.30	0.23	0.31	0.80
18.05	0.02	59.35	96.84	103.37	0.288	6.527	0.01	0.65	6.63	15.72	2.37	0.24	0.33	0.80
19.55	0.02	63.11	97.06	103.49	0.312	6.529	0.01	0.70	6.41	16.08	2.51	0.25	0.35	0.81
21.05	0.02	65.02	97.21	103.52	0.338	6.530	0.01	0.72	6.27	16.22	2.59	0.26	0.36	0.81
22.55	0.02	68.41	97.29	103.51	0.360	6.532	0.01	0.75	6.18	16.66	2.69	0.27	0.38	0.82
24.07	0.02	70.71	97.36	103.50	0.386	6.533	0.02	0.78	6.11	16.93	2.77	0.27	0.39	0.83
25.57	0.02	73.13	97.43	103.49	0.413	6.535	0.02	0.80	6.04	17.23	2.85	0.28	0.40	0.84
27.07	0.03	76.16	97.49	103.46	0.438	6.537	0.02	0.84	5.99	17.64	2.95	0.28	0.42	0.85
28.57	0.03	78.86	97.53	103.44	0.459	6.538	0.02	0.87	5.95	18.01	3.03	0.29	0.43	0.86
30.07	0.03	81.97	97.54	103.41	0.489	6.540	0.02	0.90	5.93	18.47	3.11	0.29	0.45	0.88
31.58	0.03	83.59	97.53	103.35	0.515	6.542	0.02	0.92	5.94	18.72	3.15	0.29	0.46	0.89
33.08	0.03	87.49	97.74	103.53	0.533	6.543	0.02	0.96	5.74	19.11	3.33	0.30	0.48	0.89
34.60	0.03	90.42	97.76	103.51	0.562	6.545	0.02	0.99	5.71	19.53	3.42	0.30	0.50	0.91
36.10	0.03	91.54	97.78	103.50	0.581	6.546	0.02	1.01	5.69	19.67	3.46	0.31	0.50	0.91
37.60	0.04	95.30	97.79	103.49	0.607	6.548	0.03	1.05	5.68	20.24	3.56	0.31	0.52	0.93
39.10	0.04	97.32	97.79	103.47	0.631	6.550	0.03	1.07	5.68	20.54	3.62	0.31	0.53	0.94
40.62	0.04	100.41	97.79	103.46	0.660	6.551	0.03	1.10	5.68	21.01	3.70	0.31	0.55	0.96
42.12	0.04	102.24	97.77	103.43	0.681	6.553	0.03	1.12	5.70	21.30	3.74	0.30	0.56	0.97
43.62	0.04	105.94	97.73	103.39	0.704	6.554	0.03	1.16	5.74	21.90	3.82	0.30	0.58	1.00
45.12	0.04	109.08	97.62	103.28	0.730	6.556	0.03	1.20	5.85	22.49	3.84	0.29	0.60	1.02
46.63	0.04	110.73	97.85	103.52	0.750	6.557	0.03	1.21	5.62	22.51	4.00	0.31	0.61	1.01
48.13	0.05	114.28	97.82	103.52	0.780	6.559	0.03	1.25	5.65	23.07	4.08	0.31	0.63	1.03
49.63	0.05	117.03	97.79	103.53	0.807	6.561	0.03	1.28	5.68	23.52	4.14	0.31	0.64	1.05
51.13	0.05	119.80	97.76	103.49	0.828	6.563	0.03	1.31	5.72	23.97	4.19	0.30	0.66	1.07
52.63	0.05	122.14	97.71	103.50	0.852	6.564	0.04	1.34	5.76	24.37	4.23	0.30	0.67	1.08
54.13	0.05	125.51	97.66	103.45	0.884	6.566	0.04	1.37	5.81	24.93	4.29	0.30	0.69	1.11
55.63	0.05	126.84	97.61	103.44	0.904	6.568	0.04	1.39	5.87	25.18	4.29	0.29	0.70	1.12
57.15	0.05	130.70	97.52	103.38	0.932	6.569	0.04	1.43	5.95	25.84	4.34	0.29	0.72	1.14
58.65	0.06	133.32	97.58	103.51	0.962	6.571	0.04	1.46	5.89	26.17	4.45	0.29	0.73	1.15
60.15	0.06	136.14	97.59	103.55	0.989	6.573	0.04	1.49	5.89	26.60	4.52	0.29	0.75	1.17
66.15	0.06	147.01	97.36	103.48	1.081	6.579	0.04	1.61	6.11	28.46	4.65	0.27	0.80	1.24
72.15	0.07	157.71	97.19	103.55	1.176	6.586	0.05	1.72	6.28	30.23	4.81	0.26	0.86	1.31
78.17	0.07	168.47	96.89	103.49	1.274	6.592	0.05	1.84	6.58	32.14	4.88	0.24	0.92	1.39
84.17	0.08	178.72	96.44	103.32	1.376	6.599	0.06	1.95	7.03	34.12	4.85	0.21	0.97	1.48
90.17	0.09	188.10	96.34	103.50	1.483	6.606	0.06	2.05	7.13	35.61	4.99	0.20	1.03	1.54
96.18	0.09	197.46	95.92	103.39	1.576	6.612	0.07	2.15	7.55	37.41	4.96	0.17	1.08	1.62
102.18	0.10	205.37	95.76	103.51	1.671	6.619	0.07	2.23	7.71	38.74	5.02	0.16	1.12	1.67
108.18	0.10	213.38	95.39	103.43	1.771	6.626	0.07	2.31	8.08	40.29	4.98	0.13	1.16	1.74
114.20	0.11	221.20	95.20	103.53	1.872	6.632	0.08	2.40	8.28	41.63	5.03	0.12	1.20	1.80
120.20	0.11	226.29	94.86	103.47	1.978	6.640	0.08	2.45	8.61	42.69	4.96	0.10	1.23	1.85
126.20	0.12	232.61	94.69	103.54	2.075	6.646	0.09	2.51	8.78	43.78	4.98	0.08	1.26	1.89
132.20	0.13	238.24	94.37	103.50	2.174	6.653	0.09	2.57	9.10	44.91	4.93	0.06	1.29	1.94
138.22	0.13	243.29	94.19	103.56	2.278	6.660	0.09	2.62	9.28	45.81	4.94	0.05	1.32	1.98
144.22	0.14	246.80	93.92	103.50	2.371	6.666	0.10	2.66	9.55	46.57	4.88	0.03	1.33	2.02
150.22	0.14	251.22	93.77	103.58	2.474	6.673	0.10	2.70	9.70	47.35	4.88	0.02	1.36	2.05
156.23	0.15	255.23	93.51	103.52	2.575	6.680	0.11	2.74	9.96	48.17	4.83	0.00	1.38	2.09

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 50%
Sample No.: Ash 50% Specimen No.: B
Depth (ft.): 0

Initial Height., H_o (in): 5.808
Initial Diameter, D_o (in): 2.884
Membr. Thickness (in): 0.02
Ht Change at End of Consol., ΔH_o (in): 0.027 H_c 5.781
Ht Change at End of Saturation, H_s (in): 0.000
Volume change during Consol. V_c (cc^3): 5.19 0.31659 in^3

Confining Pressure (psi): 10.00
Initial Volume, V_o (in^3): 37.94
Initial Area, A_o (in^2): 6.53
Area after Consol., A_c (in^2): 6.51
Piston Correction (lbs): 0.0

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
162.23	0.15	257.57	93.14	103.33	2.674	6.687	0.11	2.77	10.33	48.85	4.73	-0.03	1.39	2.13
168.23	0.16	260.12	93.15	103.54	2.776	6.694	0.12	2.79	10.33	49.19	4.76	-0.03	1.40	2.14
174.23	0.17	262.54	92.86	103.43	2.875	6.701	0.12	2.81	10.61	49.79	4.69	-0.05	1.41	2.17
180.23	0.17	266.20	92.80	103.53	2.970	6.707	0.12	2.85	10.68	50.36	4.72	-0.05	1.43	2.20
186.23	0.18	267.83	92.57	103.44	3.072	6.715	0.13	2.86	10.90	50.79	4.66	-0.07	1.44	2.22
192.25	0.18	269.45	92.51	103.53	3.171	6.721	0.13	2.88	10.96	51.05	4.66	-0.07	1.44	2.23
198.25	0.19	271.52	92.30	103.45	3.277	6.729	0.14	2.90	11.17	51.52	4.61	-0.09	1.45	2.26
204.25	0.20	272.60	92.25	103.54	3.387	6.736	0.14	2.90	11.22	51.69	4.61	-0.09	1.46	2.26
210.25	0.20	274.55	92.06	103.47	3.474	6.742	0.14	2.92	11.41	52.13	4.57	-0.11	1.47	2.29
216.25	0.21	274.18	92.04	103.55	3.576	6.750	0.15	2.91	11.43	52.05	4.55	-0.11	1.46	2.29
222.25	0.21	274.90	91.87	103.48	3.682	6.757	0.15	2.92	11.61	52.29	4.51	-0.12	1.46	2.30
228.25	0.22	276.21	91.87	103.56	3.780	6.764	0.16	2.93	11.61	52.44	4.52	-0.12	1.47	2.31
234.27	0.22	277.63	91.69	103.52	3.888	6.772	0.16	2.94	11.78	52.78	4.48	-0.13	1.48	2.32
240.27	0.23	278.16	91.65	103.54	3.987	6.779	0.17	2.94	11.82	52.85	4.47	-0.14	1.48	2.33
246.27	0.24	278.59	91.56	103.52	4.079	6.785	0.17	2.94	11.91	52.97	4.45	-0.14	1.48	2.34
252.27	0.24	278.46	91.37	103.38	4.184	6.792	0.17	2.94	12.10	53.10	4.39	-0.16	1.48	2.35
258.27	0.25	278.51	91.45	103.53	4.284	6.800	0.18	2.94	12.02	52.98	4.41	-0.15	1.47	2.34
264.28	0.25	279.76	91.30	103.41	4.387	6.807	0.18	2.95	12.17	53.27	4.38	-0.16	1.48	2.36
270.28	0.26	280.68	91.36	103.53	4.488	6.814	0.19	2.95	12.11	53.30	4.40	-0.16	1.48	2.35
276.28	0.26	281.80	91.24	103.45	4.580	6.821	0.19	2.96	12.23	53.55	4.38	-0.17	1.49	2.37
282.28	0.27	280.32	91.30	103.54	4.678	6.828	0.19	2.94	12.18	53.23	4.37	-0.16	1.48	2.35
288.30	0.28	281.84	91.17	103.46	4.782	6.835	0.20	2.95	12.30	53.54	4.35	-0.17	1.48	2.37
294.30	0.28	283.35	91.19	103.55	4.883	6.842	0.20	2.97	12.28	53.69	4.37	-0.17	1.49	2.37
300.30	0.29	283.51	91.10	103.50	4.986	6.850	0.21	2.97	12.37	53.76	4.35	-0.18	1.49	2.38
315.32	0.30	281.77	90.98	103.47	5.242	6.868	0.22	2.94	12.49	53.52	4.28	-0.18	1.48	2.38
330.32	0.32	282.78	90.76	103.32	5.488	6.886	0.23	2.94	12.72	53.78	4.23	-0.20	1.48	2.39
345.32	0.33	287.46	90.91	103.56	5.731	6.904	0.24	2.98	12.56	54.19	4.32	-0.19	1.50	2.40
360.32	0.35	289.06	90.83	103.56	5.985	6.923	0.25	2.99	12.64	54.39	4.30	-0.20	1.50	2.41
375.32	0.36	289.99	90.76	103.56	6.237	6.941	0.26	2.99	12.71	54.49	4.29	-0.20	1.50	2.42
390.33	0.38	291.98	90.67	103.50	6.491	6.960	0.27	3.00	12.80	54.75	4.28	-0.21	1.51	2.43
405.33	0.39	291.19	90.60	103.43	6.744	6.979	0.28	2.98	12.88	54.60	4.24	-0.21	1.50	2.43
420.33	0.40	293.02	90.45	103.37	6.997	6.998	0.29	2.99	13.02	54.89	4.22	-0.22	1.51	2.44
435.35	0.42	294.38	90.61	103.57	7.236	7.016	0.30	3.00	12.86	54.82	4.26	-0.21	1.51	2.44
450.35	0.43	296.24	90.51	103.55	7.493	7.035	0.31	3.01	12.96	55.07	4.25	-0.22	1.52	2.45
465.35	0.45	297.08	90.48	103.54	7.749	7.055	0.32	3.01	13.00	55.11	4.24	-0.22	1.52	2.45
480.35	0.46	298.84	90.40	103.52	8.003	7.074	0.33	3.02	13.07	55.31	4.23	-0.23	1.52	2.46
495.35	0.48	301.24	90.31	103.47	8.253	7.094	0.34	3.03	13.16	55.62	4.23	-0.23	1.53	2.48
510.37	0.49	301.78	90.20	103.39	8.504	7.113	0.35	3.03	13.28	55.70	4.20	-0.24	1.53	2.48
525.37	0.51	303.01	90.31	103.58	8.756	7.133	0.36	3.03	13.16	55.64	4.23	-0.23	1.53	2.48
540.37	0.52	304.19	90.29	103.59	9.005	7.152	0.37	3.04	13.18	55.71	4.23	-0.23	1.53	2.48
555.38	0.53	305.56	90.22	103.55	9.249	7.172	0.38	3.04	13.25	55.86	4.22	-0.24	1.53	2.49
570.38	0.55	306.24	90.16	103.53	9.503	7.192	0.40	3.04	13.31	55.90	4.20	-0.24	1.53	2.49
585.38	0.56	307.56	90.05	103.49	9.756	7.212	0.41	3.04	13.42	56.07	4.18	-0.25	1.54	2.50
600.38	0.58	308.62	89.95	103.42	10.008	7.232	0.42	3.04	13.52	56.20	4.16	-0.26	1.54	2.51
615.40	0.59	309.79	90.07	103.58	10.258	7.252	0.43	3.04	13.40	56.12	4.19	-0.25	1.54	2.50
630.40	0.61	310.14	90.00	103.56	10.505	7.272	0.44	3.04	13.47	56.12	4.17	-0.26	1.54	2.51
645.40	0.62	310.05	89.96	103.55	10.769	7.294	0.45	3.03	13.51	56.02	4.15	-0.26	1.53	2.50
660.42	0.64	312.15	89.89	103.52	11.013	7.314	0.46	3.04	13.59	56.27	4.14	-0.26	1.54	2.51
675.42	0.65	313.67	89.80	103.49	11.271	7.335	0.47	3.05	13.67	56.44	4.13	-0.27	1.54	2.52
690.42	0.67	312.92	89.73	103.42	11.521	7.356	0.48	3.03	13.74	56.28	4.10	-0.27	1.53	2.52
705.42	0.68	314.50	89.83	103.59	11.776	7.377	0.49	3.03	13.65	56.28	4.12	-0.27	1.53	2.52
720.43	0.70	314.05	89.82	103.57	12.026	7.398	0.50	3.02	13.65	56.10	4.11	-0.27	1.53	2.51
735.43	0.71	314.99	89.77	103.56	12.275	7.419	0.51	3.02	13.71	56.16	4.10	-0.27	1.53	2.52
750.43	0.72	314.95	89.73	103.53	12.528	7.440	0.52	3.01	13.74	56.07	4.08	-0.27	1.52	2.51
765.43	0.74	316.19	89.69	103.49	12.778	7.462	0.53	3.01	13.78	56.16	4.07	-0.28	1.53	2.52
780.45	0.75	316.76	89.59	103.44	13.028	7.483	0.54	3.01	13.88	56.21	4.05	-0.28	1.52	2.52
795.45	0.77	317.30	89.66	103.54	13.291	7.506	0.55	3.00	13.81	56.09	4.06	-0.28	1.52	2.52

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 50%
Sample No.: Ash 50% Specimen No.: B
Depth (ft.): 0

Initial Height., H_o (in):	5.808	Confining Pressure (psi):	10.00
Initial Diameter, D_o (in):	2.884	Initial Volume, V_o (in^3):	37.94
Membr. Thickness (in):	0.02	Initial Area, A_o (in^2):	6.53
Ht Change at End of Consol., ΔH_o (in):	0.027 H_c 5.781	Area after Consol., A_c (in^2):	6.51
Ht Change at End of Saturation, H_s (in):	0.000	Piston Correction (lbs):	0.0
Volume change during Consol. V_c (cc^3):	5.19 0.31659 in^3		

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
810.45	0.78	318.31	89.70	103.51	13.533	7.527	0.56	3.00	13.78	56.07	4.07	-0.28	1.52	2.51
825.45	0.80	317.86	89.69	103.49	13.776	7.548	0.57	2.99	13.78	55.90	4.06	-0.28	1.52	2.51
840.45	0.81	316.66	89.72	103.49	14.028	7.570	0.58	2.97	13.75	55.59	4.04	-0.28	1.51	2.50
855.45	0.83	317.72	89.69	103.45	14.294	7.594	0.59	2.97	13.79	55.63	4.03	-0.28	1.51	2.50
870.45	0.84	318.32	89.65	103.39	14.536	7.615	0.60	2.97	13.82	55.62	4.02	-0.28	1.50	2.50
885.47	0.85	318.12	89.58	103.34	14.782	7.637	0.62	2.95	13.89	55.54	4.00	-0.29	1.50	2.50
900.00	0.87	317.42	89.77	103.53	15.031	7.660	0.63	2.94	13.70	55.14	4.02	-0.27	1.49	2.48

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 30%
Sample No.: Ash 70% Specimen No.: C
Depth (ft.): 0

Initial Height., H_o (in): 5.799 Confining Pressure (psi): 15.00
Initial Diameter, D_o (in): 2.884 Initial Volume, V_o (in^3): 37.88
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
t Change at End of Consol.,ΔH_o (in): 0.029 H_c 5.771 Area after Consol., A_c (in^2): 6.50
Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
ume change during Consol. V_c (cc^3): 6.27 0.38247 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
0.00	0.00	0.00	85.09	99.98	0.000	6.497	0.00	0.00	14.89	14.89	1.00	0.00	0.00	1.07
1.52	0.002	14.46	85.73	100.06	0.027	6.499	0.00	0.16	14.24	16.47	1.16	0.05	0.08	1.11
3.02	0.003	28.69	86.45	100.05	0.046	6.500	0.00	0.32	13.53	17.94	1.33	0.10	0.16	1.13
4.52	0.004	42.16	87.05	100.03	0.070	6.502	0.00	0.47	12.93	19.41	1.50	0.14	0.23	1.16
6.02	0.005	51.59	87.54	100.04	0.091	6.503	0.00	0.57	12.44	20.37	1.64	0.18	0.29	1.18
7.52	0.007	62.86	87.96	100.03	0.114	6.505	0.00	0.70	12.02	21.68	1.80	0.21	0.35	1.21
9.03	0.008	67.16	88.33	100.02	0.139	6.506	0.01	0.74	11.65	21.97	1.89	0.23	0.37	1.21
10.53	0.010	77.25	88.62	100.02	0.176	6.509	0.01	0.85	11.36	23.22	2.05	0.25	0.43	1.24
12.03	0.011	83.50	88.89	99.99	0.193	6.510	0.01	0.92	11.09	23.91	2.16	0.27	0.46	1.26
13.55	0.013	90.58	89.17	100.05	0.222	6.512	0.01	1.00	10.81	24.72	2.29	0.29	0.50	1.28
15.05	0.014	97.30	89.36	100.05	0.244	6.513	0.01	1.07	10.62	25.56	2.41	0.31	0.54	1.30
16.55	0.015	100.53	89.53	100.04	0.265	6.515	0.01	1.11	10.45	25.88	2.48	0.32	0.56	1.31
18.05	0.017	105.47	89.67	100.03	0.291	6.516	0.01	1.16	10.31	26.49	2.57	0.33	0.58	1.32
19.57	0.018	114.24	89.78	100.02	0.318	6.518	0.01	1.26	10.20	27.73	2.72	0.34	0.63	1.37
21.07	0.020	118.75	89.88	99.99	0.345	6.520	0.01	1.31	10.10	28.31	2.80	0.34	0.66	1.38
22.57	0.021	124.75	89.95	100.00	0.357	6.521	0.01	1.38	10.03	29.16	2.91	0.35	0.69	1.41
24.07	0.023	129.16	90.00	99.97	0.391	6.523	0.02	1.42	9.97	29.77	2.99	0.35	0.71	1.43
25.57	0.024	134.77	90.04	99.93	0.416	6.525	0.02	1.49	9.94	30.59	3.08	0.36	0.74	1.46
27.08	0.025	139.43	90.16	100.00	0.435	6.526	0.02	1.54	9.81	31.18	3.18	0.37	0.77	1.48
28.58	0.027	145.86	90.19	100.00	0.461	6.528	0.02	1.61	9.78	32.13	3.28	0.37	0.80	1.51
30.08	0.028	150.99	90.21	99.99	0.487	6.529	0.02	1.66	9.77	32.90	3.37	0.37	0.83	1.54
31.60	0.030	156.64	90.22	99.99	0.512	6.531	0.02	1.73	9.76	33.75	3.46	0.37	0.86	1.57
33.10	0.030	162.00	90.21	99.98	0.527	6.532	0.02	1.78	9.77	34.57	3.54	0.37	0.89	1.60
34.62	0.032	165.86	90.21	99.98	0.555	6.534	0.02	1.83	9.77	35.15	3.60	0.37	0.91	1.62
36.12	0.033	173.27	90.17	99.96	0.578	6.535	0.02	1.91	9.81	36.32	3.70	0.37	0.95	1.66
37.62	0.035	176.72	90.15	99.94	0.606	6.537	0.03	1.94	9.83	36.86	3.75	0.36	0.97	1.68
39.13	0.036	182.57	90.16	100.01	0.628	6.539	0.03	2.01	9.81	37.74	3.85	0.37	1.01	1.71
40.63	0.038	188.24	90.14	100.01	0.653	6.540	0.03	2.07	9.84	38.62	3.93	0.36	1.04	1.74
42.13	0.039	194.62	90.07	100.01	0.674	6.542	0.03	2.14	9.91	39.66	4.00	0.36	1.07	1.78
43.63	0.040	197.06	90.05	100.00	0.697	6.543	0.03	2.17	9.93	40.04	4.03	0.36	1.08	1.80
45.13	0.042	203.28	89.97	100.00	0.723	6.545	0.03	2.23	10.01	41.07	4.10	0.35	1.12	1.84
46.65	0.043	207.61	89.92	100.00	0.750	6.547	0.03	2.28	10.05	41.77	4.15	0.35	1.14	1.87
48.15	0.044	213.98	89.83	99.98	0.771	6.548	0.03	2.35	10.14	42.82	4.22	0.34	1.18	1.91
49.65	0.046	217.71	89.77	99.96	0.795	6.549	0.03	2.39	10.21	43.45	4.26	0.34	1.20	1.93
51.15	0.048	222.86	89.70	99.99	0.828	6.552	0.03	2.45	10.27	44.29	4.31	0.33	1.22	1.96
52.65	0.049	226.19	89.67	100.03	0.846	6.553	0.04	2.48	10.31	44.82	4.35	0.33	1.24	1.98
54.17	0.050	232.37	89.58	100.02	0.868	6.554	0.04	2.55	10.40	45.85	4.41	0.32	1.28	2.03
55.67	0.052	238.25	89.51	100.03	0.895	6.556	0.04	2.61	10.47	46.81	4.47	0.32	1.31	2.06
57.17	0.053	241.97	89.41	100.02	0.921	6.558	0.04	2.65	10.56	47.46	4.49	0.31	1.33	2.09
58.67	0.054	246.00	89.33	100.00	0.940	6.559	0.04	2.70	10.65	48.15	4.52	0.31	1.35	2.12
60.17	0.056	248.58	89.25	99.99	0.967	6.561	0.04	2.73	10.73	48.62	4.53	0.30	1.36	2.14
66.18	0.062	266.91	88.93	100.04	1.072	6.568	0.04	2.92	11.05	51.69	4.68	0.28	1.46	2.26
72.18	0.067	282.98	88.48	100.00	1.170	6.574	0.05	3.10	11.49	54.54	4.75	0.24	1.55	2.38
78.18	0.073	296.51	88.16	100.04	1.263	6.581	0.05	3.24	11.82	56.88	4.81	0.22	1.62	2.47
84.18	0.079	309.86	87.79	100.03	1.366	6.587	0.06	3.38	12.19	59.23	4.86	0.19	1.69	2.57
90.20	0.085	322.46	87.47	100.05	1.466	6.594	0.06	3.52	12.51	61.41	4.91	0.17	1.76	2.66
96.20	0.090	333.38	87.11	100.01	1.563	6.601	0.07	3.63	12.87	63.37	4.93	0.15	1.82	2.74
102.20	0.096	340.35	86.83	100.05	1.659	6.607	0.07	3.70	13.15	64.66	4.92	0.12	1.85	2.80
108.20	0.101	352.82	86.45	100.03	1.757	6.614	0.07	3.84	13.52	66.87	4.94	0.10	1.92	2.89
114.22	0.107	359.38	86.19	100.03	1.853	6.620	0.08	3.90	13.79	68.08	4.94	0.08	1.95	2.95
120.22	0.113	365.56	85.87	100.04	1.957	6.627	0.08	3.97	14.11	69.27	4.91	0.06	1.99	3.00
126.22	0.119	375.06	85.52	99.98	2.059	6.634	0.09	4.06	14.45	70.99	4.91	0.03	2.04	3.08
132.22	0.125	379.56	85.30	100.04	2.163	6.641	0.09	4.11	14.68	71.83	4.89	0.02	2.06	3.11
138.23	0.131	384.48	85.01	99.99	2.262	6.648	0.09	4.16	14.96	72.80	4.86	-0.01	2.08	3.16
144.23	0.136	390.11	84.83	100.05	2.359	6.654	0.10	4.21	15.15	73.77	4.87	-0.02	2.11	3.20

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 30%
Sample No.: Ash 70% Specimen No.: C
Depth (ft.): 0

Initial Height., H_o (in): 5.799 Confining Pressure (psi): 15.00
Initial Diameter, D_o (in): 2.884 Initial Volume, V_o (in^3): 37.88
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
t Change at End of Consol.,ΔH_o (in): 0.029 H_c 5.771 Area after Consol., A_c (in^2): 6.50
Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
ume change during Consol. V_c (cc^3): 6.27 0.38247 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
150.23	0.142	395.18	84.54	100.00	2.460	6.661	0.10	4.26	15.44	74.77	4.84	-0.04	2.14	3.25
156.23	0.148	398.24	84.36	100.05	2.557	6.668	0.11	4.29	15.62	75.34	4.82	-0.05	2.15	3.27
162.23	0.154	401.68	84.10	100.00	2.668	6.676	0.11	4.32	15.88	76.05	4.79	-0.07	2.17	3.31
168.25	0.159	403.11	83.96	100.04	2.758	6.682	0.11	4.34	16.01	76.34	4.77	-0.08	2.17	3.32
174.25	0.165	405.07	83.74	100.01	2.862	6.689	0.12	4.35	16.23	76.79	4.73	-0.10	2.18	3.35
180.25	0.171	405.91	83.65	100.05	2.963	6.696	0.12	4.36	16.33	76.95	4.71	-0.10	2.18	3.36
186.25	0.177	407.66	83.46	100.02	3.066	6.703	0.13	4.37	16.51	77.33	4.68	-0.12	2.19	3.38
192.25	0.183	409.11	83.37	100.05	3.167	6.710	0.13	4.38	16.60	77.57	4.67	-0.12	2.19	3.39
198.27	0.189	409.60	83.24	100.03	3.267	6.717	0.14	4.38	16.74	77.72	4.64	-0.13	2.20	3.40
204.27	0.194	411.87	83.16	100.06	3.371	6.724	0.14	4.40	16.82	78.07	4.64	-0.14	2.21	3.42
210.28	0.200	410.56	83.06	100.03	3.472	6.731	0.14	4.38	16.92	77.92	4.60	-0.15	2.20	3.41
216.28	0.206	412.09	82.98	100.06	3.571	6.738	0.15	4.39	16.99	78.15	4.60	-0.15	2.20	3.43
222.28	0.212	413.40	82.89	100.04	3.668	6.745	0.15	4.40	17.09	78.38	4.59	-0.16	2.21	3.44
228.28	0.218	414.34	82.80	100.07	3.777	6.752	0.16	4.41	17.17	78.54	4.57	-0.16	2.21	3.45
234.28	0.223	414.51	82.71	100.03	3.872	6.759	0.16	4.40	17.27	78.60	4.55	-0.17	2.21	3.45
240.28	0.229	413.43	82.71	100.04	3.976	6.766	0.17	4.39	17.26	78.36	4.54	-0.17	2.20	3.44
246.30	0.235	414.83	82.62	100.00	4.073	6.773	0.17	4.40	17.35	78.60	4.53	-0.18	2.20	3.45
252.30	0.240	415.22	82.59	100.01	4.163	6.780	0.17	4.40	17.38	78.63	4.52	-0.18	2.20	3.46
258.30	0.246	415.05	82.54	100.01	4.269	6.787	0.18	4.39	17.44	78.59	4.51	-0.18	2.20	3.46
264.32	0.252	414.86	82.47	99.94	4.366	6.794	0.18	4.38	17.51	78.57	4.49	-0.19	2.20	3.46
270.32	0.258	415.72	82.46	100.01	4.468	6.801	0.19	4.39	17.52	78.65	4.49	-0.19	2.20	3.46
276.32	0.264	416.34	82.37	99.96	4.573	6.809	0.19	4.39	17.61	78.76	4.47	-0.20	2.20	3.47
282.33	0.270	415.84	82.39	100.02	4.673	6.816	0.19	4.38	17.59	78.60	4.47	-0.19	2.20	3.46
288.33	0.275	414.90	82.34	99.98	4.770	6.823	0.20	4.36	17.64	78.45	4.45	-0.20	2.19	3.46
294.33	0.281	412.49	82.38	100.04	4.868	6.830	0.20	4.33	17.60	78.00	4.43	-0.20	2.17	3.44
300.35	0.287	413.56	82.31	100.00	4.970	6.837	0.21	4.34	17.67	78.15	4.42	-0.20	2.18	3.45
315.35	0.302	415.01	82.30	100.06	5.231	6.856	0.22	4.34	17.68	78.21	4.42	-0.20	2.18	3.45
330.35	0.316	417.99	82.24	100.01	5.474	6.874	0.23	4.36	17.74	78.55	4.43	-0.21	2.19	3.47
345.35	0.330	421.05	82.21	100.02	5.726	6.892	0.24	4.38	17.77	78.86	4.44	-0.21	2.20	3.48
360.37	0.344	422.74	82.17	100.02	5.969	6.910	0.25	4.39	17.81	78.98	4.44	-0.21	2.20	3.48
375.37	0.359	424.05	82.06	100.01	6.229	6.929	0.26	4.39	17.91	79.11	4.42	-0.22	2.20	3.49
390.37	0.373	425.47	82.06	100.02	6.471	6.947	0.27	4.39	17.92	79.16	4.42	-0.22	2.20	3.49
405.37	0.389	427.60	82.06	100.02	6.734	6.967	0.28	4.40	17.92	79.30	4.43	-0.22	2.21	3.50
420.37	0.403	427.93	82.03	100.03	6.982	6.985	0.29	4.39	17.95	79.21	4.41	-0.22	2.21	3.50
435.38	0.417	426.51	82.03	100.03	7.235	7.004	0.30	4.36	17.95	78.84	4.39	-0.22	2.19	3.48
450.38	0.432	428.85	81.95	99.98	7.491	7.024	0.31	4.37	18.02	79.08	4.39	-0.23	2.20	3.50
465.38	0.447	430.19	81.96	100.01	7.741	7.043	0.32	4.37	18.02	79.10	4.39	-0.23	2.20	3.50
480.40	0.460	431.11	81.99	100.03	7.979	7.061	0.33	4.37	17.99	79.04	4.39	-0.22	2.20	3.49
495.40	0.475	428.30	82.01	100.04	8.236	7.081	0.34	4.33	17.97	78.46	4.37	-0.22	2.18	3.47
510.40	0.490	429.50	82.01	100.02	8.500	7.101	0.35	4.33	17.97	78.45	4.37	-0.22	2.18	3.47
525.42	0.504	429.85	82.00	99.99	8.734	7.119	0.36	4.32	17.98	78.36	4.36	-0.22	2.17	3.47
540.42	0.519	432.70	82.01	100.03	8.989	7.139	0.37	4.34	17.97	78.58	4.37	-0.22	2.18	3.48
555.42	0.534	431.70	82.06	100.06	9.256	7.160	0.39	4.31	17.92	78.21	4.36	-0.22	2.17	3.46
570.43	0.548	433.18	82.04	100.02	9.499	7.179	0.40	4.32	17.94	78.27	4.36	-0.22	2.17	3.46
585.43	0.563	433.60	82.13	100.01	9.752	7.200	0.41	4.31	17.85	78.07	4.37	-0.21	2.17	3.45
600.43	0.577	436.39	82.08	100.00	9.999	7.219	0.42	4.32	17.90	78.34	4.38	-0.22	2.18	3.46
615.43	0.592	439.90	82.08	99.98	10.257	7.240	0.43	4.34	17.89	78.65	4.40	-0.22	2.19	3.48
630.45	0.606	441.05	82.18	100.03	10.496	7.259	0.44	4.34	17.80	78.55	4.41	-0.21	2.19	3.47
645.45	0.621	443.33	82.17	100.03	10.755	7.280	0.45	4.35	17.80	78.70	4.42	-0.21	2.19	3.47
660.45	0.635	443.70	82.19	100.03	11.011	7.301	0.46	4.34	17.78	78.55	4.42	-0.21	2.19	3.47
675.45	0.650	446.12	82.11	99.98	11.259	7.322	0.47	4.35	17.87	78.80	4.41	-0.21	2.19	3.48
690.47	0.664	445.64	82.08	99.93	11.506	7.342	0.48	4.34	17.90	78.59	4.39	-0.22	2.19	3.47
705.47	0.678	446.35	82.20	100.04	11.756	7.363	0.49	4.33	17.78	78.40	4.41	-0.21	2.18	3.46
720.47	0.694	449.51	82.18	100.02	12.029	7.386	0.50	4.35	17.80	78.66	4.42	-0.21	2.19	3.47
735.47	0.708	453.74	82.17	100.00	12.266	7.406	0.51	4.37	17.80	79.07	4.44	-0.21	2.21	3.49

Report No.:

CU TRIAXIAL TEST: Stress-Strain Data

Project No.: J039697.01 Boring No.: Lime 30%
Sample No.: Ash 70% Specimen No.: C
Depth (ft.): 0

Initial Height., H_o (in): 5.799 Confining Pressure (psi): 15.00
Initial Diameter, D_o (in): 2.884 Initial Volume, V_o (in^3): 37.88
Membr. Thickness (in): 0.02 Initial Area, A_o (in^2): 6.53
t Change at End of Consol., ΔH_o (in): 0.029 H_c 5.771 Area after Consol., A_c (in^2): 6.50
Change at End of Saturation, H_s (in): 0.000 Piston Correction (lbs): 0.0
ume change during Consol. V_c (cc^3): 6.27 0.38247 in^3

Elapsed Time (min)	Vertical Deform. (in)	Vertical Load (lbf)	Pore Pressure (psi)	Cell Pressure (psi)	Axial Strain (%)	Corrected Area (in^2)	Membr. Correct. (psi)	Deviator Stress (tsf)	σ_3' (psi)	σ_1' (psi)	Obliquity	Excess Pore Pr. (tsf)	q (tsf)	p' (tsf)
750.48	0.722	455.45	82.13	100.00	12.512	7.427	0.52	4.38	17.85	79.17	4.44	-0.21	2.21	3.49
765.48	0.736	457.12	82.05	99.96	12.759	7.448	0.53	4.38	17.93	79.31	4.42	-0.22	2.21	3.50
780.48	0.751	457.61	82.13	100.07	13.010	7.469	0.54	4.37	17.84	79.11	4.43	-0.21	2.21	3.49
795.48	0.766	460.75	82.07	100.03	13.275	7.492	0.55	4.39	17.91	79.41	4.43	-0.22	2.21	3.50
810.48	0.780	466.75	82.01	99.96	13.525	7.514	0.56	4.43	17.97	80.09	4.46	-0.22	2.24	3.53
825.50	0.795	468.60	81.96	99.93	13.776	7.536	0.57	4.44	18.02	80.20	4.45	-0.23	2.24	3.54
840.50	0.809	471.40	81.89	99.91	14.020	7.557	0.58	4.45	18.08	80.46	4.45	-0.23	2.25	3.55
855.50	0.824	473.31	81.98	99.98	14.277	7.580	0.59	4.45	17.99	80.44	4.47	-0.22	2.25	3.54
870.50	0.838	476.39	81.95	99.95	14.525	7.602	0.60	4.47	18.03	80.70	4.48	-0.23	2.26	3.55
885.52	0.853	474.28	81.96	99.97	14.783	7.625	0.62	4.43	18.01	80.22	4.45	-0.23	2.24	3.54
900.22	0.867	476.86	81.88	99.92	15.031	7.647	0.63	4.44	18.10	80.46	4.45	-0.23	2.24	3.55

804 Highway 15 West
P.O. Box 510
Northwood, ND 58267

(701) 587-6010
FAX (701) 587-6013

northwoodlab@agvise.com
www.agvise.com

AGVISE GLP Soil Characterization Report

Submitting firm = HANSON PROFESSIONAL SERVI
Protocol or Study No = 2021 AGVISE INTERNAL
Sample ID. = 100% LPS
Trial ID. = NA
Date Received: 12-13-2021 Date Reported: 12-27-2021

AGVISE Lab No: 21-1940 Acct No: HA4628

Bulk Density (disturbed) gm/cc	0.87
Porosity (%)	62.1
% Moisture at 1/3 Bar	44.2
% Moisture at 15 Bar	16.4

These tests were completed in compliance of 40 CFR Part 160.

Laura Simenson
Analytical Investigator

1/6/22
Date

804 Highway 15 West
P.O. Box 510
Northwood, ND 58267

(701) 587-6010
FAX (701) 587-6013

northwoodlab@agvise.com
www.agvise.com

AGVISE GLP Soil Characterization Report

Submitting firm = HANSON PROFESSIONAL SERVI
Protocol or Study No = 2021 AGVISE INTERNAL
Sample ID. = 70% LPS/30% CA
Trial ID. = NA
Date Received: 12-13-2021 Date Reported: 12-27-2021

AGVISE Lab No: 21-1941 Acct No: HA4628

Bulk Density (disturbed) gm/cc	1.03
Porosity (%)	54.8
% Moisture at 1/3 Bar	31.3
% Moisture at 15 Bar	11.0

These tests were completed in compliance of 40 CFR Part 160.

Laura Simenson
Analytical Investigator

1/6/22
Date

804 Highway 15 West
P.O. Box 510
Northwood, ND 58267

(701) 587-6010
FAX (701) 587-6013

northwoodlab@agvise.com
www.agvise.com

AGVISE GLP Soil Characterization Report

Submitting firm = HANSON PROFESSIONAL SERVI
Protocol or Study No = 2021 AGVISE INTERNAL
Sample ID. = 50% LPS/50% CA
Trial ID. = NA
Date Received: 12-13-2021 Date Reported: 12-27-2021

AGVISE Lab No: 21-1942 Acct No: HA4628

Bulk Density (disturbed) gm/cc	1.18
Porosity (%)	49.7
% Moisture at 1/3 Bar	25.0
% Moisture at 15 Bar	8.6

These tests were completed in compliance of 40 CFR Part 160.

Laura Simenson
Analytical Investigator

1/6/22
Date

AGVISE LABORATORIES

804 Highway 15 West
P.O. Box 510
Northwood, ND 58267

(701) 587-6010
FAX (701) 587-6013

northwoodlab@agvise.com
www.agvise.com

AGVISE GLP Soil Characterization Report

Submitting firm = HANSON PROFESSIONAL SERVI
Protocol or Study No = 2021 AGVISE INTERNAL
Sample ID. = 30% LPS/70% CA
Trial ID. = NA
Date Received: 12-13-2021 Date Reported: 12-27-2021

AGVISE Lab No: 21-1943 Acct No: HA4628

Bulk Density (disturbed) gm/cc	1.29
Porosity (%)	47.5
% Moisture at 1/3 Bar	21.8
% Moisture at 15 Bar	6.5

These tests were completed in compliance of 40 CFR Part 160.

Laura Simenson
Analytical Investigator

1/6/22
Date

METHOD SUMMARY FOR SOIL ANALYSIS

TESTING LABORATORY: **AGVISE LABORATORIES, INC.**
P.O. Box 510; 804 Highway 15
Northwood, ND 58267-0510
(701) 587-6010

The following is a summary of analytical methods used by AGVISE Laboratories, Inc. in the determination of soil characteristics and nutrient content. Analytical data of some or all of these analytical methods are presented based upon the testing requested by the firm submitting the soil specimens.

Chemical Properties

Carbonates – Determined by gravimetric loss of Carbon Dioxide (NUT.02.14.).

Cation Exchange Capacity – Determined by summing cations and hydrogen (NUT.02.03.). The cations of Magnesium, Potassium, Calcium, and Sodium are determined by extraction with 1.0 N Ammonium Acetate (NUT.02.12.) or (NUT.02.93.). Hydrogen is determined by measuring the pH of the soil in Adams-Evans Buffer Solution (NUT.02.11.).

Free Iron Oxide in Soil – Determined by measuring Sodium Citrate/Sodium Bicarbonate/Sodium dithionate extractable Fe (NUT.02.106.).

Nitrogen, % Total – Determined by the Kjeldahl method (NUT.02.15.) or Combustion Method (NUT.02.107.).

Nitrogen, Nitrate and/or Nitrite – Determined using an autoanalyzer with Cadmium Reduction (NUT.02.101.).

Nitrogen, Ammoniacal – Determined by the Steam Distillation method (NUT.02.47.).

Organic Carbon % - Determined by the Walkley-Black procedure (NUT.02.20.), Combustion using an Elementar Carbon Analyzer (NUT.02.107.) or Loss of Weight on Ignition procedure (NUT.02.04.).

Organic Matter % - Determined by the Walkley-Black procedure (NUT.02.09.), Combustion using an Elementar Analyzer (NUT.02.107.) or Loss of Weight on Ignition procedure (NUT.02.04.).

pH – Determined with a pH electrode in a 1:1 soil:water suspension (NUT.02.05.). Alternative procedures include: pH in a 1:1 soil: 1 N KCl suspension (NUT.02.55.), pH in a 1:2 soil: 0.01M $CaCl_2$ suspension (NUT.02.80.), pH in a 1:1 soil: 0.01M $CaCl_2$ suspension (NUT.02.98.), or pH in a saturated paste (NUT.02.39.).

Phosphorus – Determined by the Olsen method (NUT.02.07.). Alternative procedure includes determination by the Bray method (NUT.02.52.).

Phosphorus, Total – Determined by ICP analysis (NUT.02.99.) of an acid digestion following EPA Method 3050B (NUT.02.102.).
Soluble Salts – Determined using a conductivity meter in a 1:1 soil:water suspension (NUT.02.19.), a saturated paste (NUT.02.39.) or a saturated paste extract (NUT.02.82.).

Physical Properties

Bulk Density – Disturbed Bulk Density is determined by weighing a known volume of dried and ground soil (NUT.02.10.). Core or Undisturbed Bulk Density is determined by weighing a known volume of an intact, dried soil core (NUT.02.02.).

Percent Gravel – Determined by dry sieving and weighing the fraction over 2 mm (NUT.02.16.).

Percent Sand, Silt, and Clay – Determined by Hydrometer method (NUT.02.06.) or by Pipette method (NUT.02.56.).

Sand Particle Size – Determined by weighing fractions obtained by wet sieving (NUT.02.32.).

Soil Morphology Description (non-glp)– Soil profile described according to the USDA/NRCS System (NUT.02.108.).

Water Holding Capacity and Water Relations

% Moisture - Determined by gravimetric loss upon drying (NUT.02.36.).

Saturated Hydraulic Conductivity – Determined by using the Constant Head method and measuring the rate of flow of water through a saturated soil column (NUT.02.34.).

Water Infiltration Rate – Determined by using the Constant Head method and measuring the length of time from water application to production of a leachate from a soil column (NUT.02.35.).

Water Holding Capacity at 1/3 or 0.10 Bar – Determined by measuring the moisture remaining when saturated soil is placed under 1/3 or 0.10 Bar pressure (NUT.02.08.).

Water Holding Capacity at 15, 5 or 1 Bar – Determined by measuring the moisture remaining when saturated soil is placed under 15, 5 or 1 Bar pressure (NUT.02.13.).

Water Holding Capacity at 1 cm of Water – Determined by measuring the moisture remaining when saturated soil is placed under 1 cm of tension (NUT.02.50.).

Water Holding Capacity at 0 Bar – Determined by measuring the moisture remaining when saturated soil is placed under tension at 0 Bar (NUT.02.67.).

Maximum Water Holding Capacity in Soil – Determined by measuring the moisture held by a soil due to its physical properties following saturation (NUT.02.68.).

Microbial

Soil Microbial Biomass – Determined by the fumigation extraction method (MIC.02.01.).

Soil Microbial Count – Determined by the plate count method (MIC.02.03.).

Soil and Sediment Anaerobic Microbial Count – Determined by the anaerobic plate count method (MIC.02.06.).

Soil Biomass by Solvita – Determined by measuring the CO2 produced during the Haney-Brinton Method Solvita Test (MIC.02.07.).

All of the above methods are detailed in the current analytical SOPs used by AGVISE Laboratories, Inc. Characterization testing laboratory.

NUT.05.01. – Long Term Storage of Soil and Water Characterization Specimens: According to this SOP, soil characterization samples will be retained by AGVISE Laboratories, Inc. for at least two years before disposal and water characterization samples will be retained for a period of 60 days before disposal.

ADM.05.01. – Archivist Duties and Archiving Procedures: This SOP states that copies of soil and water characterization reports, original COC's, original raw data and hard copies generated by computer will be archived within five laboratory working days 90 days after the signature by the Analytical Investigator. Supplemental data will be archived annually.

QAU.08.01. – Quality Assurance Inspections of Facilities, Studies, and Processes for GLP Compliance: Method inspections will be performed on a regular basis at AGVISE Laboratories, Inc.. For soil characterization, two methods will be inspected per month and one water characterization inspection will be conducted per month. An annual facility audit will be performed by AGVISE Laboratories, Inc. Quality Assurance Unit.

All of the above methods are detailed in the current analytical SOP's used in AGVISE Laboratories, Inc. Characterization laboratory.

APPROVED BY
ANALYTICAL INVESTIGATOR: 2/3/21
Amber Storey, Analytical Investigator **Date**

COPY OF ORIGINAL
AGVISE Laboratories, Inc.
Initial MH Date 1-3-22

AGVISE LABORATORIES

804 Highway 15 West
P.O. Box 510
Northwood, ND 58267

(701) 587-6010
FAX (701) 587-6013

northwoodlab@agvise.com
www.agvise.com

The following personnel have been duly trained to perform Plant Analysis, Soil and Water Characterization methods under 40 CFR Part 160 Good Laboratory Practice Standards.

Nutrient Laboratory

Aaland, Allison – Laboratory Technician III
Ahrndt, Zachary – Nutrient Laboratory Analyst
Brevik, Brian – Laboratory Technician I
Carlson, Lori I. – Laboratory Technician I
Craigmile, Cari – Nutrient Laboratory Analyst
Crow, Jolene K. – Laboratory Technician I
Evenstad, S. Katherine – Laboratory Technician I
Fuglestad, R. Edward – Laboratory Technician I
Hime, Sherry L. – Laboratory Technician III
Ivers, Elizabeth M. – Nutrient Laboratory Analyst
Jodock, Alyssa – Nutrient Laboratory Analyst
Klindt, Bradley J. – Nutrient Laboratory Analyst
Schuster, Angela C. – Laboratory Technician I
Simenson, Laura J. – Nutrient Laboratory Manager
Storey, Amber L. – Nutrient Laboratory Director
Trosen, Heidi M. – Nutrient Laboratory Analyst
Wolf, Sheila T.– Laboratory Technician I

Administrative Support

Beine, Patti – Secretary I/Archivist Assistant
Fuglestad, Teresa S. – Secretary II
Hermanson, Mia – Secretary I
Pollert, Emily D. – Administrative Assistant

Quality Control

Krogstad, Heidi A. – Quality Control Specialist/Archivist
Weber, Cheryl – Quality Control I/Archivist Assistant/Laboratory Technician I

Quality Assurance

Johnson, Julie M. – Quality Assurance Manager
Thorsgard, Tara J. – Quality Assurance Specialist

Testing Facility Management

Wallace, Robert J. – Chief Executive Officer/Testing Facility Management

Appendix D

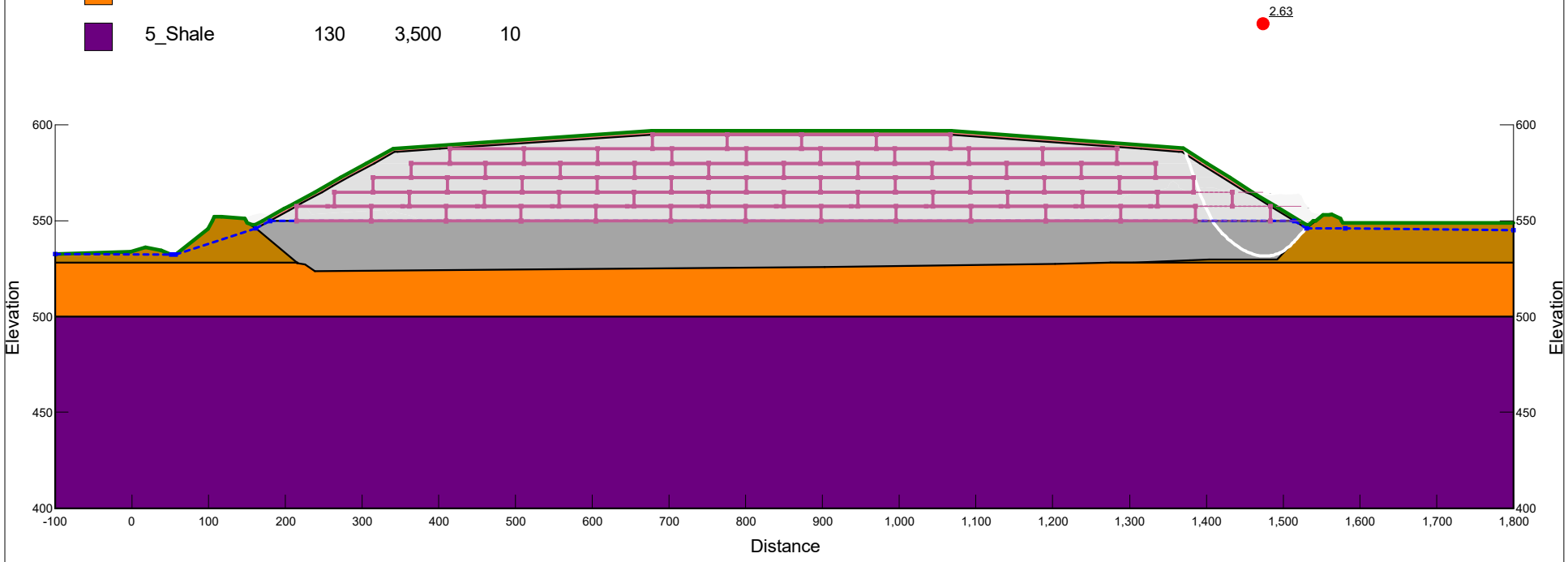
Analysis Result

SECTION 1

GeoStudio Slope Stability Analysis

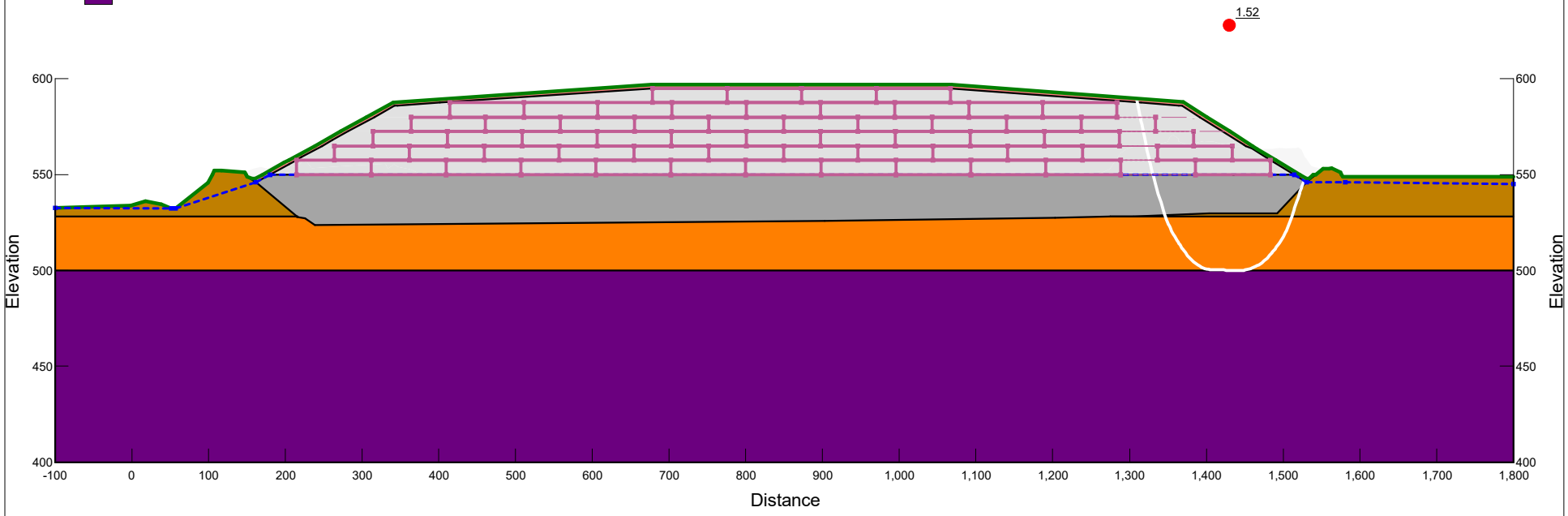


Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	0_CCR Cover (D)	120	200	27
	1_CCR Ash Wet Lakeside (D)	115	0	40
	2_CCR Ash Wet Dallman	120	0	28
	3_Fill (D)	115	270	28
	4_Alluvial (D)	115	0	28
	5_Shale	130	3,500	10



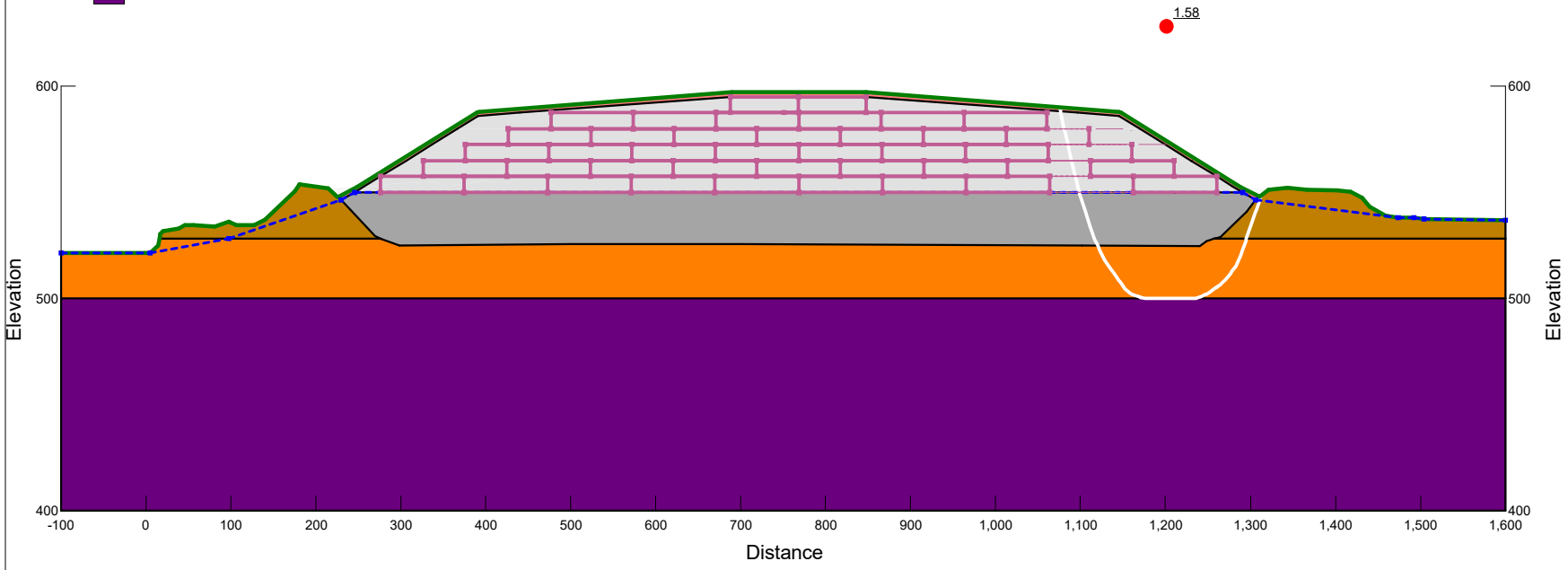
CWLP ASH POND CLOSURE	HANSON™	Name: GT Row 6 Slope Stability (Reinf) (D) (LR)
CITY WATER, LIGHT, AND POWER		Analysis Location: DALLMAN
SPRINGFIELD, SANGAMON COUNTY, ILLINOIS		Kind: SLOPE/W
HANSON PROJECT NUMBER: 25E0006	Last Edited By: Beya Kazadi Date: 09/14/2025	Analysis Type: Spencer
		Additional Note: North - South Cross Section

Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	0_CCR Cover	120	1,000	0
	1_CCR Ash Wet Lakeside	115	200	30
	2_CCR Ash Wet Dallman	120	0	28
	3_Fill	115	1,800	0
	4_Alluvial	115	750	0
	5_Shale	130	3,500	10



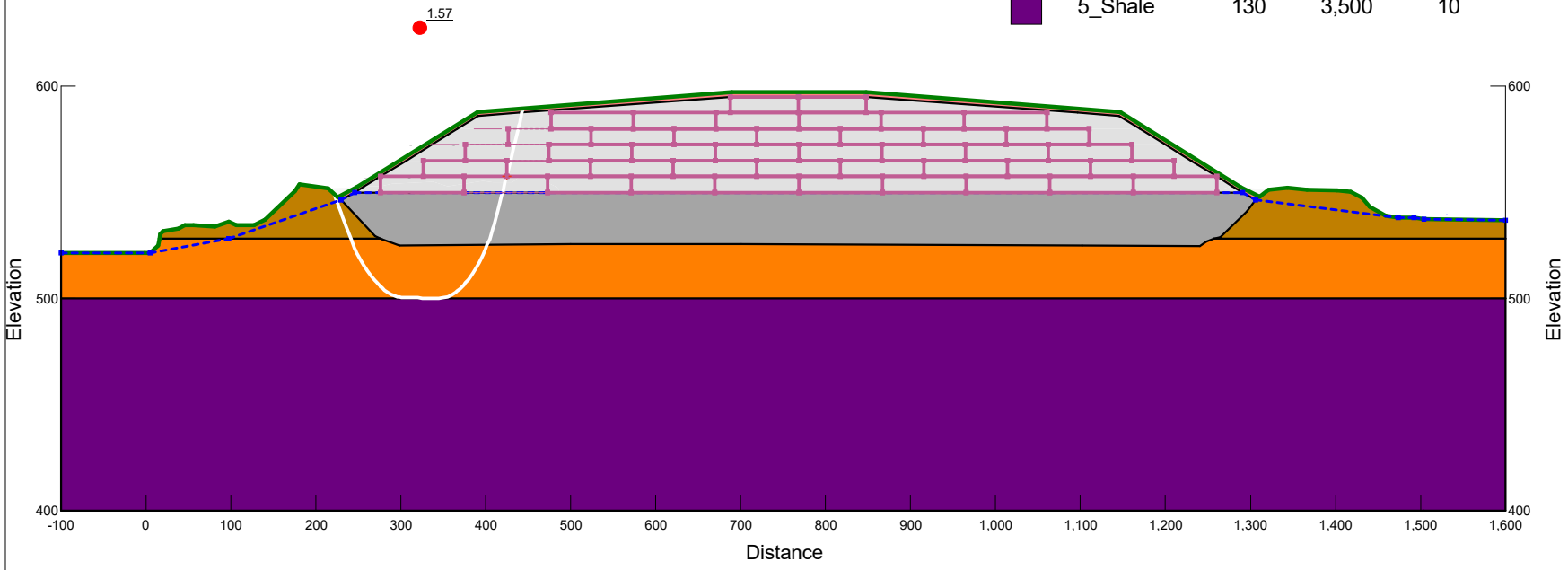
CWLP ASH POND CLOSURE	HANSON™	Name: GT Row 6 Slope Stability (Reinf) (LR)
CITY WATER, LIGHT, AND POWER		Analysis Location: DALLMAN
SPRINGFIELD, SANGAMON COUNTY, ILLINOIS		Kind: SLOPE/W
HANSON PROJECT NUMBER: 25E0006	Last Edited By: Beya Kazadi Date: 09/14/2025	Analysis Type: Spencer
		Additional Note: North - South Cross Section

Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	0_CCR Cover	120	1,000	0
	1_CCR Ash Wet Lakeside	115	200	30
	2_CCR Ash Wet Dallman	120	0	28
	3_Fill	115	1,800	0
	4_Alluvial	115	750	0
	5_Shale	130	3,500	10



CWLP ASH POND CLOSURE	HANSON™	Name: GT Row 6 Slope Stability (Reinf) (LR) (2)
CITY WATER, LIGHT, AND POWER		Analysis Location: DALLMAN
SPRINGFIELD, SANGAMON COUNTY, ILLINOIS		Kind: SLOPE/W
HANSON PROJECT NUMBER: 25E0006	Last Edited By: Beya Kazadi Date: 09/14/2025	Analysis Type: Spencer
		Additional Note: East to West Cross Section

Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	0_CCR Cover	120	1,000	0
	1_CCR Ash Wet Lakeside	115	200	30
	2_CCR Ash Wet Dallman	120	0	28
	3_Fill	115	1,800	0
	4_Alluvial	115	750	0
	5_Shale	130	3,500	10



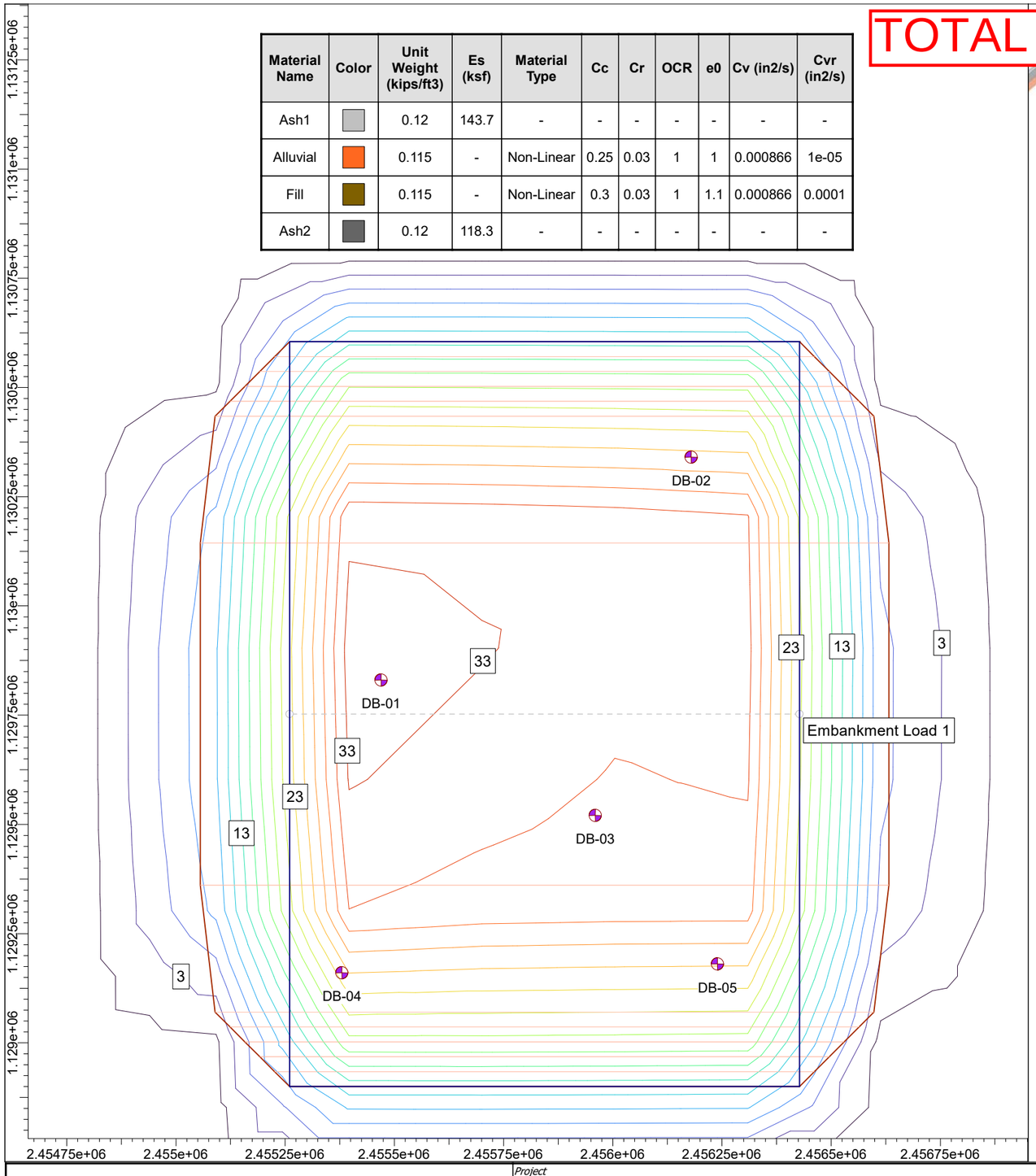
CWLP ASH POND CLOSURE	HANSON™	Name: GT Row 6 Slope Stability (Reinf) (RL) (2)
CITY WATER, LIGHT, AND POWER		Analysis Location: DALLMAN
SPRINGFIELD, SANGAMON COUNTY, ILLINOIS		Kind: SLOPE/W
HANSON PROJECT NUMBER: 25E0006	Last Edited By: Beya Kazadi Date: 09/14/2025	Analysis Type: Spencer
		Additional Note:

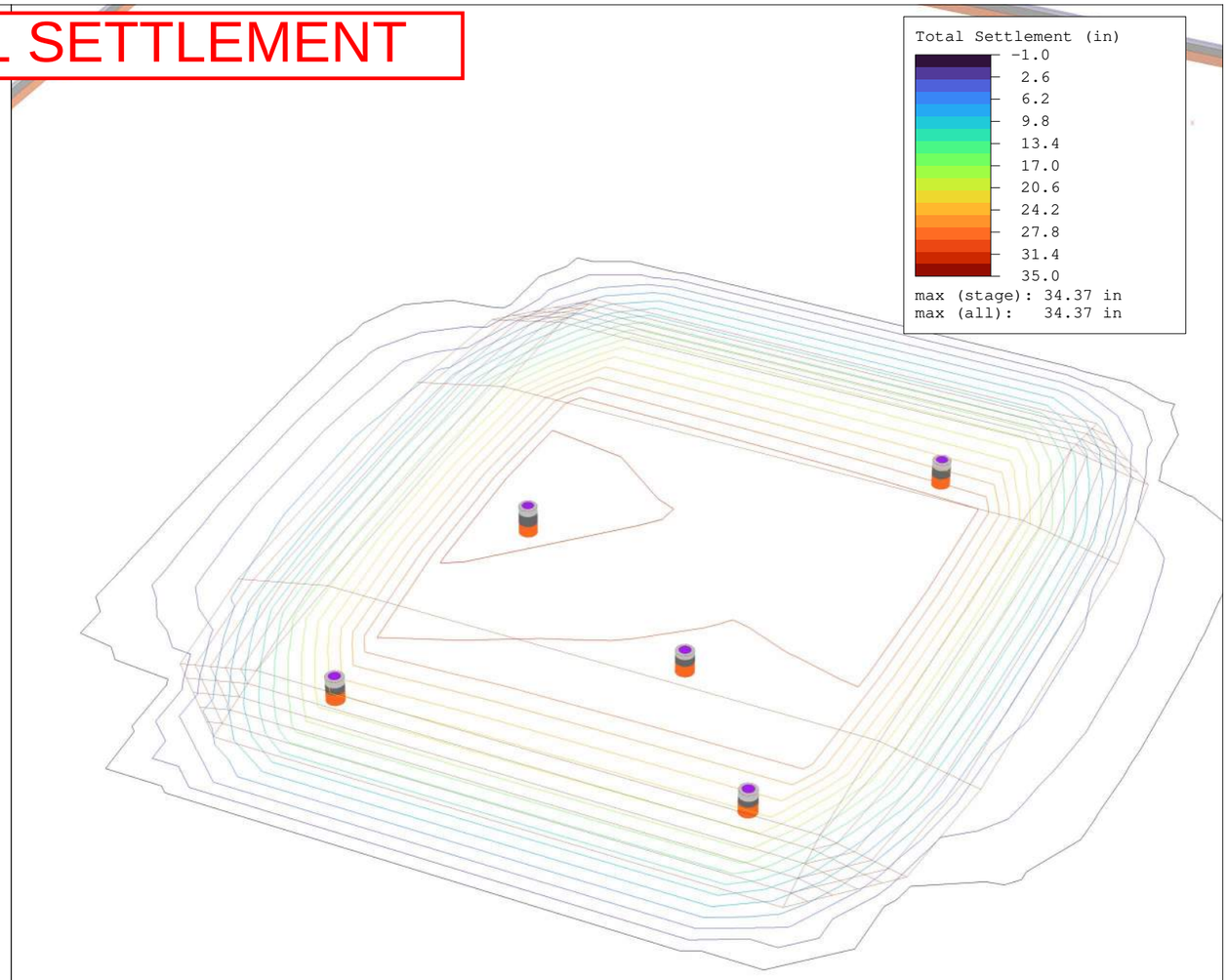
SECTION 2

RocScience Settle3 Settlement Analysis

TOTAL SETTLEMENT

Material Name	Color	Unit Weight (kips/ft3)	Es (ksf)	Material Type	Cc	Cr	OCR	e0	Cv (in2/s)	Cvr (in2/s)
Ash1		0.12	143.7	-	-	-	-	-	-	-
Alluvial		0.115	-	Non-Linear	0.25	0.03	1	1	0.000866	1e-05
Fill		0.115	-	Non-Linear	0.3	0.03	1	1.1	0.000866	0.0001
Ash2		0.12	118.3	-	-	-	-	-	-	-

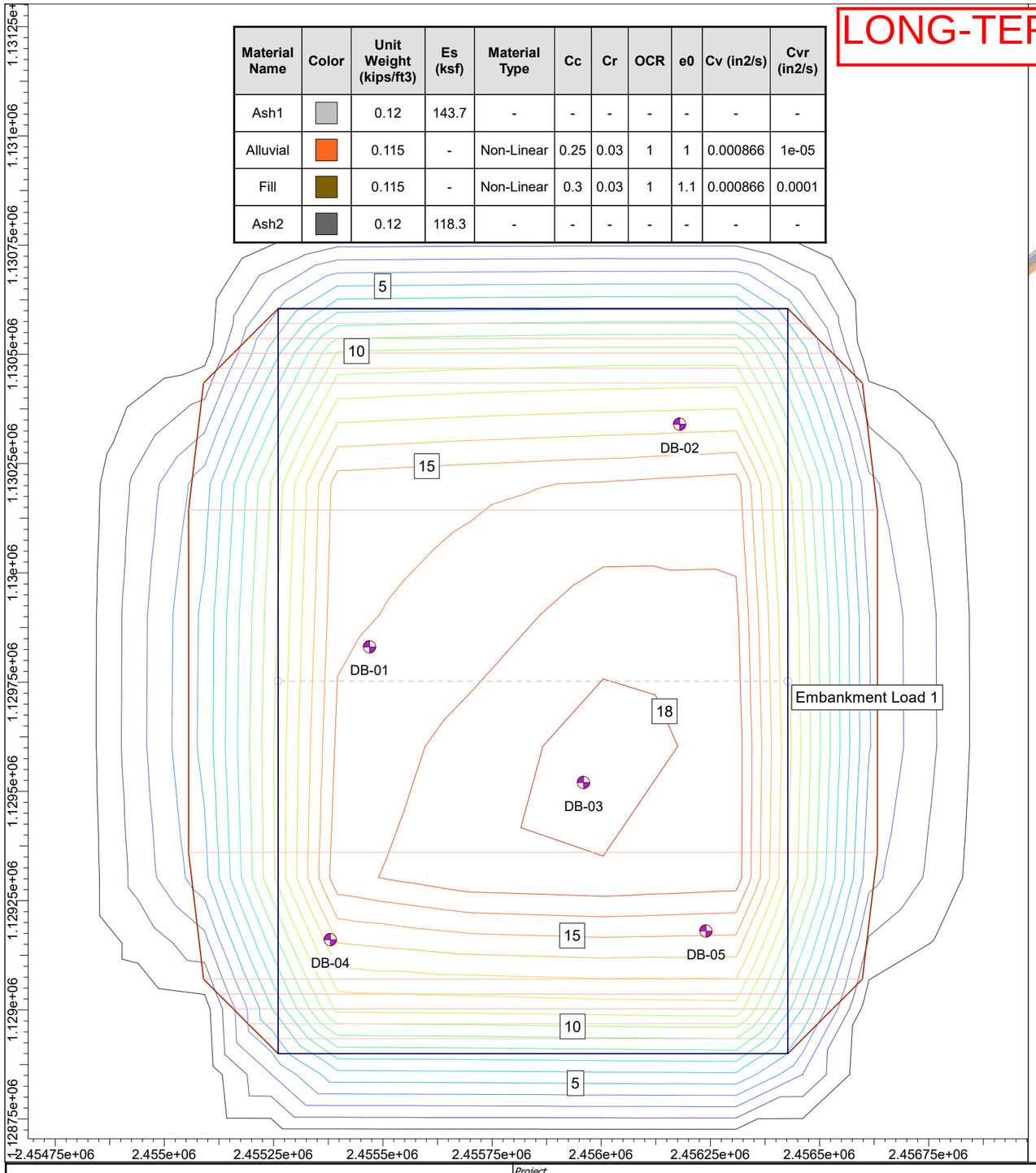


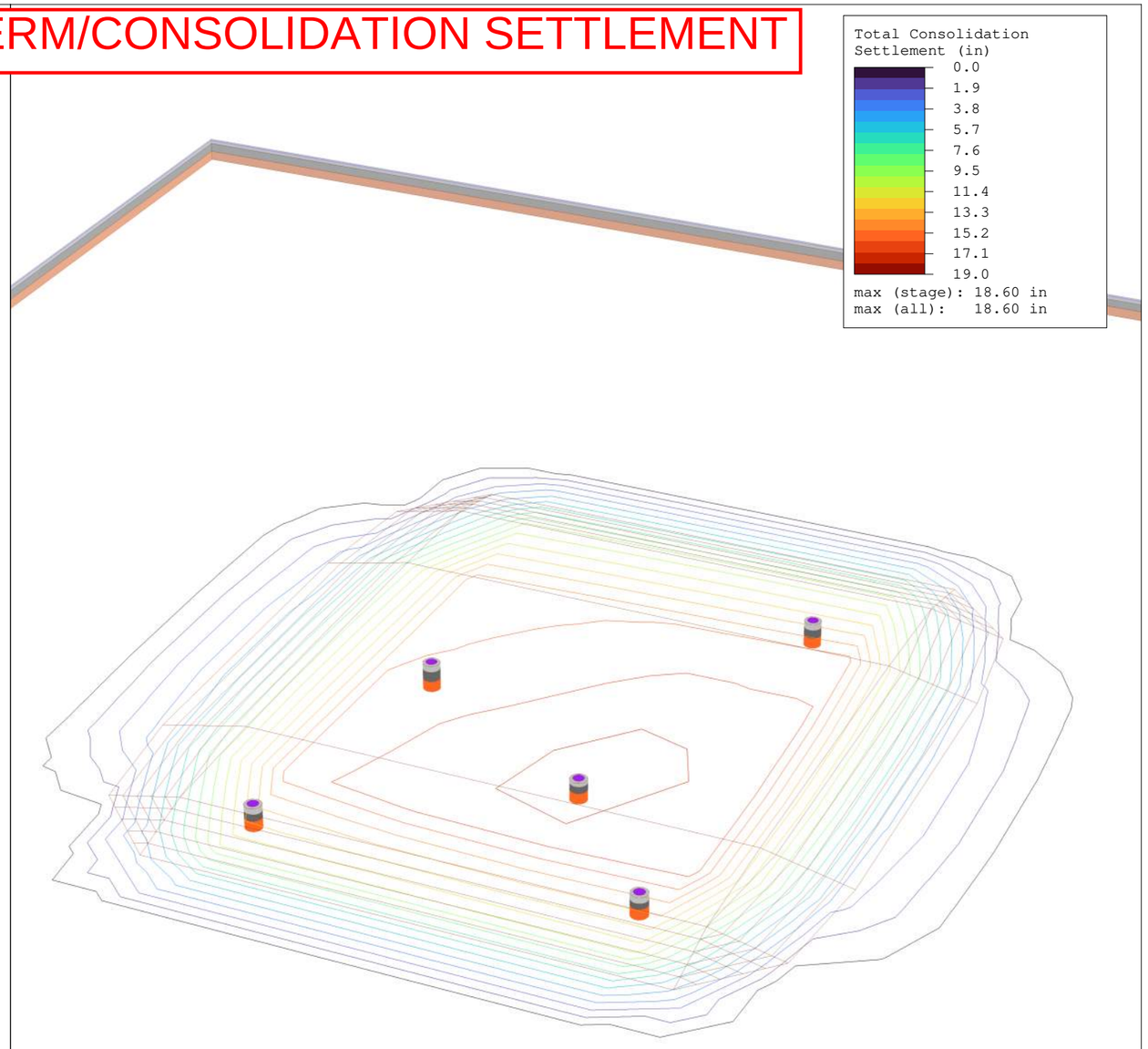


HANSON™	*Project*	CWLP Dallman Ash Pond Closure	
	Analysis Description	Settlement	
	Drawn By	OKO	*Company* Hanson Professional Services
SETTLE3 5.026	*Date*	7/17/2025, 2:11:53 PM	*File Name* 20250804_LoadSettlement_Embankment.s3z

LONG-TERM/CONSOLIDATION SETTLEMENT

Material Name	Color	Unit Weight (kips/ft3)	Es (ksf)	Material Type	Cc	Cr	OCR	e0	Cv (in2/s)	Cvr (in2/s)
Ash1		0.12	143.7	-	-	-	-	-	-	-
Alluvial		0.115	-	Non-Linear	0.25	0.03	1	1	0.000866	1e-05
Fill		0.115	-	Non-Linear	0.3	0.03	1	1.1	0.000866	0.0001
Ash2		0.12	118.3	-	-	-	-	-	-	-



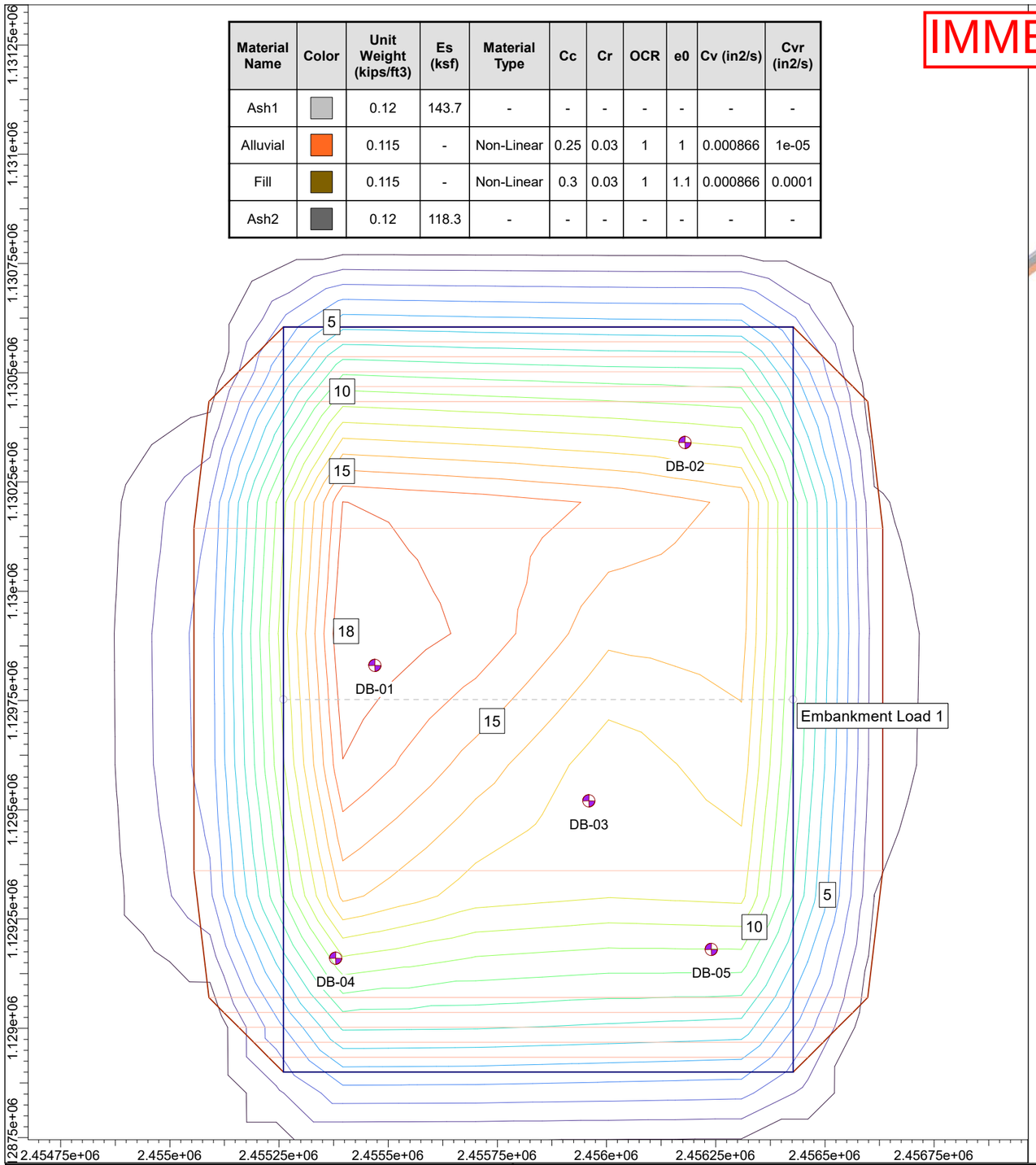


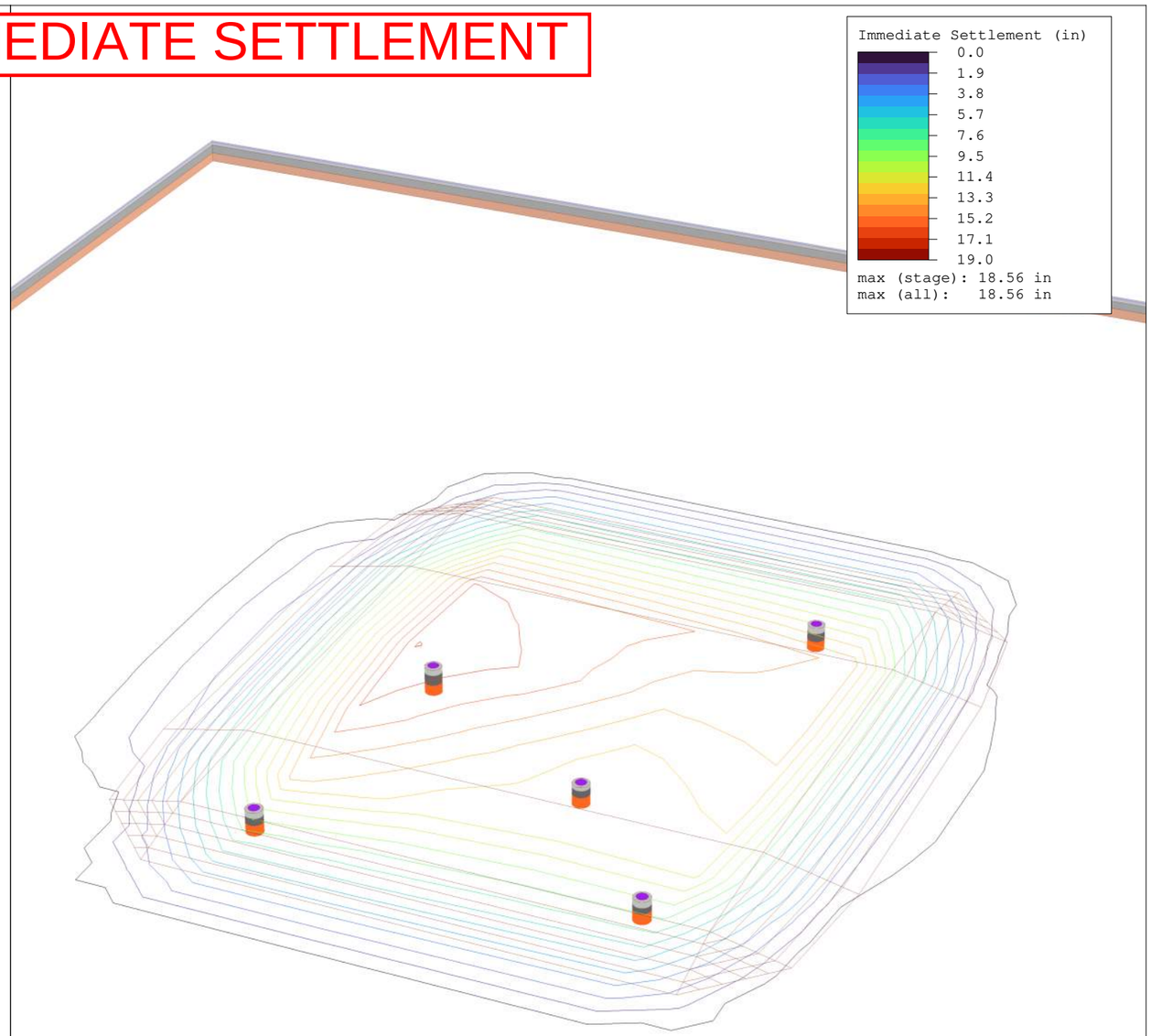
HANSON™	*Project*	CWLP Dallman Ash Pond Closure	
	Analysis Description	Settlement	
	Drawn By	OKO	*Company* Hanson Professional Services
	Date	7/17/2025, 2:11:53 PM	*File Name* 20250804_LoadSettlement_Embankment.s3z

SETTLE3 5.026

IMMEDIATE SETTLEMENT

Material Name	Color	Unit Weight (kips/ft3)	Es (ksf)	Material Type	Cc	Cr	OCR	e0	Cv (in2/s)	Cvr (in2/s)
Ash1		0.12	143.7	-	-	-	-	-	-	-
Alluvial		0.115	-	Non-Linear	0.25	0.03	1	1	0.000866	1e-05
Fill		0.115	-	Non-Linear	0.3	0.03	1	1.1	0.000866	0.0001
Ash2		0.12	118.3	-	-	-	-	-	-	-





HANSON™	*Project*	CWLP Dallman Ash Pond Closure	
	Analysis Description	Settlement	
	Drawn By	OKO	*Company* Hanson Professional Services
SETTLE3 5.026	*Date*	7/17/2025, 2:11:53 PM	*File Name* 20250804_LoadSettlement_Embankment.s3z

Appendix E

Calculation Package

SECTION 1

Bearing Capacity

By: KKC Date: 9/14/25

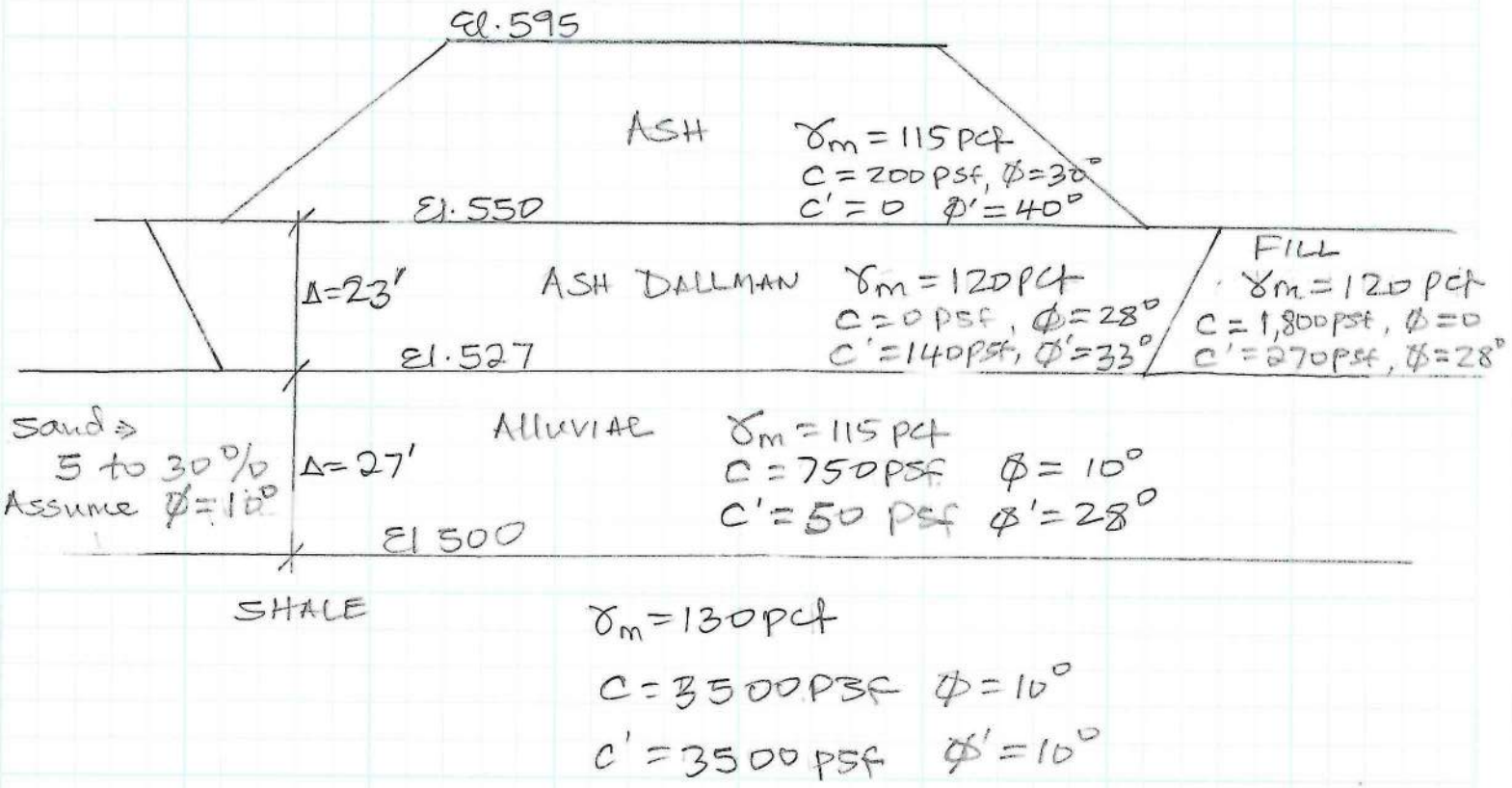
Checked by: BK Date: 9/14/25

HANSON Engineering | Planning | Allied Services

Sheet No.: 1 of: 1

Project No.: 25E0026

CHECK BEARING CAPACITY



GEOMETRY

Fill Area ⇒ 1150 ft X 1450 ft

Foundation Desing by Caduto

Terzaghi Bearing Capacity Equation – Local Shear & Punching Shear

a. Proposed reducing the cohesion and Φ (Terzaghi, 1943 & Vesic, 1975)

$$c'_{adj} = 0.67c' \quad (7.40)$$

$$\phi'_{adj} = \tan^{-1}(0.67 \tan \phi') \quad (7.41)$$

$$\phi'_{adj} = \tan^{-1}[(0.67 + D_r - 0.75D_r^2)\tan \phi'] \quad (7.42)$$

where

c'_{adj} = adjusted effective cohesion

ϕ'_{adj} = adjusted effective friction angle

D_r = relative density of sand, expressed in decimal form ($0 \le D_r \le 67\%$)

➤Use these parameters on bearing capacity

Considering existing Ash & Alluvial layers - Undrained

Project Name: **CCR**

Project Number: **25E0006** By: KKC 9/14/2025 Checked: BK

General Shear Failure - Weighted Average

Foundation Depth (D) =	0	ft
Foundation Width (B) =	1150	ft
Foundation Length (L) =	1450	ft
weighted total cohesion (c) =	405	psf
weighted total phi, ϕ =	18.8	deg
soil total unit weight (Y) =	115	pcf
Vertical effective stress (σ'_{zD}) =	0	psf
FOS =	2	

e_B =	0.0	B' =	1150.0
e_L =	0.0	L' =	1450.0

Groundwater	C_{wq} =	0.5
	C_{wY} =	0.5

$s_c = 1+(B/L)*(N_q/N_c)$ =	1.32	$s_q = 1+(B/L)*\tan(\phi')$ = 1.27	$S_Y = 1-0.4*(B/L)$ = 0.68
N_c =	13.10	N_q = 5.30	N_Y = 4.10
$d_c = 1+0.4*k$ =	1.00	$d_q = 1+2*k*\tan(\phi')*(1-\sin(\phi'))^2$ = 1.000	d_Y = 1.00
		k = 0	

Check for Local Shear, Punching Shear & Lateral Aqueeze

$q_{ult} = c'N_cs_cd_c + C_{wq}\sigma'_{zD}N_qs_qd_q + 0.5\gamma BC_{wY}N_Ys_Yd_Y$ = **99560** psf ***Nominal***

$q_{ult-net} = q_{ult} - \sigma'_{zD}$ = 99560 psf

$q_{ult-net\ (allow)} = q_{net}/FOS$ = **49780 psf**

Wall Height, ft. = 45

Unit Weight, pcf = 115

Y*H, psf = 5175

Cohesion, c, psf= 1800

3*C, psf = 5400

higher than 115*45 = 5175 psf

Considering existing Ash & Alluvial layers - Drained

Project Name: **CCR**

Project Number: **25E0006** By: KKC 9/14/2025 Checked: BK

General Shear Failure - Weighted Average

Foundation Depth (D) =	0	ft
Foundation Width (B) =	1150	ft
Foundation Length (L) =	1450	ft
weighted effective cohesion (c') =	91.4	psf
weighted effective phi, ϕ' =	30.4	deg
soil total unit weight (Y) =	115	pcf
Vertical effective stress (σ'_{zD}) =	0	psf
FOS =	2	

e_B =	0.0	B' =	1150.0
e_L =	0.0	L' =	1450.0

Groundwater	C_{wq} =	0.5
	C_{wY} =	0.5

$s_c = 1+(B/L)*(N_q/N_c)$ =	1.48	$s_q = 1+(B/L)*\tan(\phi')$ = 1.46	$S_Y = 1-0.4*(B/L)$ = 0.68
N_c =	30.10	N_q = 18.40	N_Y = 22.40
$d_c = 1+0.4*k$ =	1.00	$d_q = 1+2*k*\tan(\phi')*(1-\sin(\phi')^2)$ = 1.000	d_Y = 1.00
		k = 0	

Check for Local Shear, Punching Shear & Lateral Aqueeze

$q_{ult} = c'N_c s_c d_c + C_{wq}\sigma'_{zD}N_q s_q d_q + 0.5\gamma B C_{wY}N_Y s_Y d_Y$ = **509736** psf ***Nominal***

$q_{ult-net} = q_{ult} - \sigma'_{zD}$ = 509736 psf

$q_{ult-net\ (allow)} = q_{net}/FOS$ = **254868 psf**

Wall Height, ft. = 45

Unit Weight, pcf = 115

Y*H, psf = 5175

Cohesion, c, psf= 1800

3*C, psf = 5400

higher than 115*45 = 5175 psf

Local/punching shear failure on existing Ash layer - Undrained

Project Name: **CCR**

Project Number: **25E0006** By: KKC 9/14/2025 Checked: BK

Local & Punching Shear Failure

Foundation Depth (D) =	0	ft
Foundation Width (B) =	1150	ft
Foundation Length (L) =	1450	ft
total cohesion (0.67*c) =	0	psf
total phi, $\tan^{-1}(0.67*\tan\phi)$ =	19.6	deg
soil total unit weight (Y) =	120	pcf
Vertical effective stress (σ'_{zD}) =	0	psf
FOS =	2	

e_B =	0.0	B' =	1150.0
e_L =	0.0	L' =	1450.0

Groundwater	C_{wq} =	0.5
	$C_{w\gamma}$ =	0.5

$s_c = 1+(B/L)*(N_q/N_c)$ =	1.33	
N_c =	13.90	
$d_c = 1+0.4*k$ =	1.00	

$s_q = 1+(B/L)*\tan(\phi')$ =	1.28	
N_q =	5.80	
$d_q = 1+2*k*\tan(\phi')*(1-\sin(\phi')^2)$ =	1.000	
k =	0	

$S_\gamma = 1-0.4*(B/L)$ =	0.68	
N_γ =	4.70	
d_γ =	1.00	

Check for Local Shear, Punching Shear & Lateral Aqueeze

$q_{ult} = c'N_cs_cd_c + C_{wq}\sigma'_{zD}N_qs_qd_q + 0.5\gamma BC_{w\gamma}N_\gamma s_\gamma d_\gamma$ =	110709 psf	***Nominal***
$q_{ult-net} = q_{ult} - \sigma'_{zD}$ =	110709 psf	
$q_{ult-net\ (allow)} = q_{net}/FOS$ =	**55355 psf**	

Wall Height, ft. = 45

Unit Weight = 115

Y*H = 5175

Cohesion, c= 1800

3*C' = 5400

#VALUE!

higher than 115*45 = 5175 psf

Local/punching shear failure on existing Ash layer - Drained

Project Name: **CCR**

Project Number: **25E0006** By: KKC 9/14/2025 Checked: BK

Local & Punching Shear Failure

Foundation Depth (D) =	0	ft
Foundation Width (B) =	1150	ft
Foundation Length (L) =	1450	ft
effective cohesion (0.67*c') =	93.8	psf
$\tan^{-1}(0.67*\tan\phi')$ =	23.5	deg
soil total unit weight (Y) =	120	pcf
Vertical effective stress (σ'_{zD}) =	0	psf
FOS =	2	

e_B =	0.0	B' =	1150.0
e_L =	0.0	L' =	1450.0

Groundwater	C_{wq} =	0.5
	$C_{w\gamma}$ =	0.5

$s_c = 1+(B/L)*(N_q/N_c)$ =	1.38	
N_c =	18.00	
$d_c = 1+0.4*k$ =	1.00	

$s_q = 1+(B/L)*\tan(\phi')$ =	1.35	
N_q =	8.70	
$d_q = 1+2*k*\tan(\phi')*(1-\sin(\phi'))^2$ =	1.000	
k =	0	

$S_\gamma = 1-0.4*(B/L)$ =	0.68	
N_γ =	8.20	
d_γ =	1.00	

Check for Local Shear, Punching Shear & Lateral Aqueeze

$q_{ult} = c'N_c s_c d_c + C_{wq}\sigma'_{zD}N_q s_q d_q + 0.5\gamma B C_{w\gamma}N_\gamma s_\gamma d_\gamma$ =	195488 psf	***Nominal***
$q_{ult-net} = q_{ult} - \sigma'_{zD}$ =	195488 psf	
$q_{ult-net\ (allow)} = q_{net}/FOS$ =	**97744 psf**	

Wall Height, ft. = 45

Unit Weight = 115

Y*H = 5175

Cohesion, c= 1800

3*C' = 5400

#VALUE!

higher than 115*45 = 5175 psf

Local/punching shear failure on alluvial layer - Undrained

Project Name: **CCR**

Project Number: **25E0006**

By: KKC 9/14/2025 Checked: BK

Local & Punching Shear Failure

Foundation Depth (D) =	23	ft
Foundation Width (B) =	1150	ft
Foundation Length (L) =	1450	ft
total cohesion (0.67*c) =	502.5	psf
total phi, $\tan^{-1}(0.67*\tan\phi)$ =	6.7	deg
soil total unit weight (Y) =	115	pcf
Vertical effective stress (σ'_{zD}) =	2645	psf
FOS =	2	

e_B =	0.0	B' =	1150.0
e_L =	0.0	L' =	1450.0

Groundwater	C_{wq} =	0.5
	$C_{w\gamma}$ =	0.5

$s_c = 1+(B/L)*(N_q/N_c)$ =	1.20	
N_c =	6.80	
$d_c = 1+0.4*k$ =	1.01	

$s_q = 1+(B/L)*\tan(\phi')$ =	1.09	
N_q =	1.70	
$d_q = 1+2*k*\tan(\phi')*(1-\sin(\phi'))^2$ =	1.004	
k =	0.02	

$S_\gamma = 1-0.4*(B/L)$ =	0.68	
N_γ =	0.60	
d_γ =	1.00	

Check for Local Shear, Punching Shear & Lateral Aqueeze

$q_{ult} = c'N_c s_c d_c + C_{wq}\sigma'_{zD}N_q s_q d_q + 0.5\gamma B C_{w\gamma}N_\gamma s_\gamma d_\gamma$ =	20139 psf	***Nominal***
$q_{ult-net} = q_{ult} - \sigma'_{zD}$ =	17494 psf	
$q_{ult-net\ (allow)} = q_{net}/FOS$ =	**8747 psf**	

Wall Height, ft. = 45

Unit Weight = 115

Y*H = 5175

Cohesion, c= 1800

3*C' = 5400

higher than 115*45 = 5175 psf
FOS = 1.7.
Note design parameters is very conservative. Native (Alluvial) material showed presence of significant sand/clayey silt --- phi of 10 degrees is very conservative. This is supported by good FOS in slope stability analysis.

Local/punching shear failure on alluvial layer - Drained

Project Name: **CCR**

Project Number: **25E0006** By: KKC 9/14/2025 Checked: BK

Local & Punching Shear Failure

Foundation Depth (D) =	23	ft
Foundation Width (B) =	1150	ft
Foundation Length (L) =	1450	ft
effective cohesion (0.67*c') =	33.5	psf
$\tan^{-1}(0.67*\tan\phi')$ =	19.6	deg
soil total unit weight (Y) =	115	pcf
Vertical effective stress (σ'_{zD}) =	2645	psf
FOS =	2	

e_B =	0.0	B' =	1150.0
e_L =	0.0	L' =	1450.0

Groundwater	C_{wq} =	0.5
	$C_{w\gamma}$ =	0.5

$s_c = 1+(B/L)*(N_q/N_c)$ =	1.33	
N_c =	13.90	
$d_c = 1+0.4*k$ =	1.01	

$s_q = 1+(B/L)*\tan(\phi')$ =	1.28	
N_q =	5.80	
$d_q = 1+2*k*\tan(\phi')*(1-\sin(\phi'))^2$ =	1.006	
k =	0.02	

$S_\gamma = 1-0.4*(B/L)$ =	0.68	
N_γ =	4.70	
d_γ =	1.00	

Check for Local Shear, Punching Shear & Lateral Aqueeze

$q_{ult} = c'N_cs_cd_c + C_{wq}\sigma'_{zD}N_qs_qd_q + 0.5\gamma BC_{w\gamma}N_\gamma s_\gamma d_\gamma$ =	116621 psf	***Nominal***
$q_{ult-net} = q_{ult} - \sigma'_{zD}$ =	113976 psf	
$q_{ult-net\ (allow)} = q_{net}/FOS$ =	**56988 psf**	

Wall Height, ft. = 45

Unit Weight = 115

Y*H = 5175

Cohesion, c= 1800

3*C' = 5400

higher than 115*45 = 5175 psf

#VALUE!

Check for heave at the toe due to local failure shows stable 5400 > 5175 psf

SECTION 2

Seismic Review

U.S. Geological Survey - Earthquake Hazards Program

Unified Hazard Tool

Please do not use this tool to obtain ground motion parameter values for the design code reference documents covered by the U.S. Seismic Design Maps web tools (e.g., the International Building Code and the ASCE 7 or 41 Standard). The values returned by the two applications are not identical.

Please also see the new USGS Earthquake Hazard Toolbox for access to the most recent NSHMs for the conterminous U.S. and Hawaii.

Input

Edition

Conterminous U.S. 2014 (v4.0.x)

Spectral Period

Peak Ground Acceleration

Latitude

Decimal degrees

39.767222

Time Horizon

Return period in years

2475

Longitude

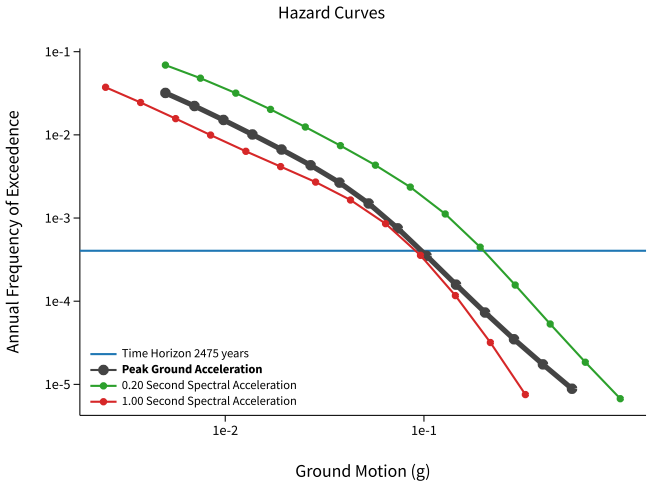
Decimal degrees, negative values for western longitudes

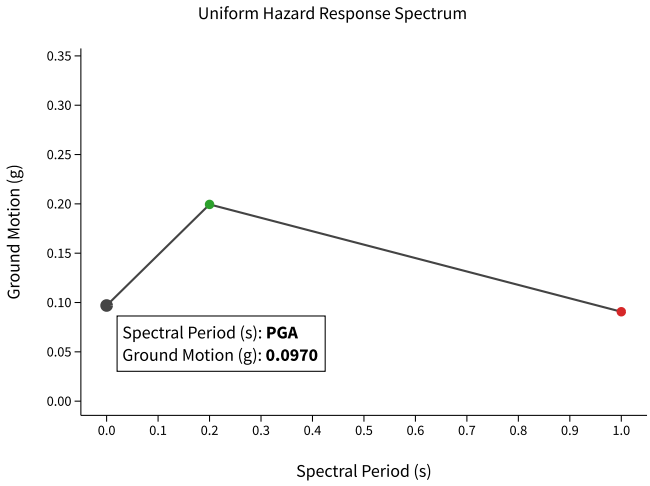
-89.599444

Site Class

760 m/s (B/C boundary)

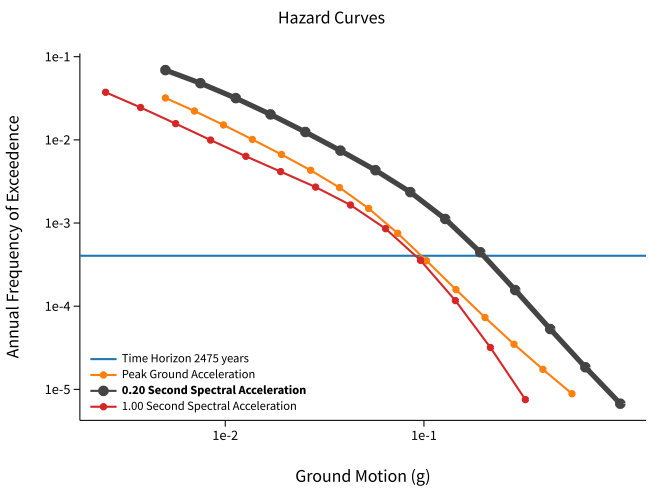
Hazard Curve

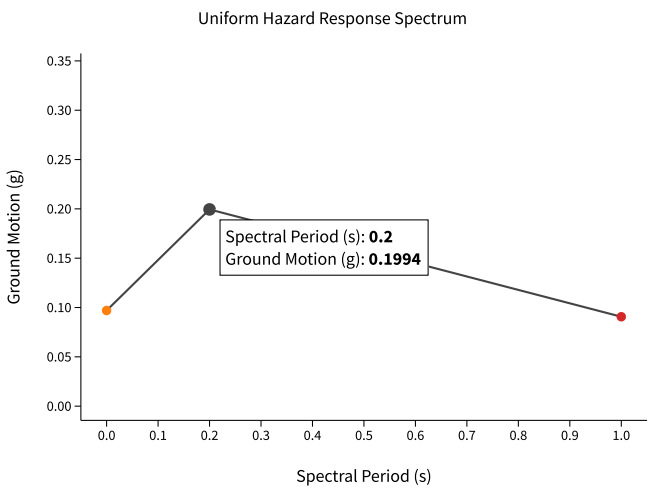




View Raw Data

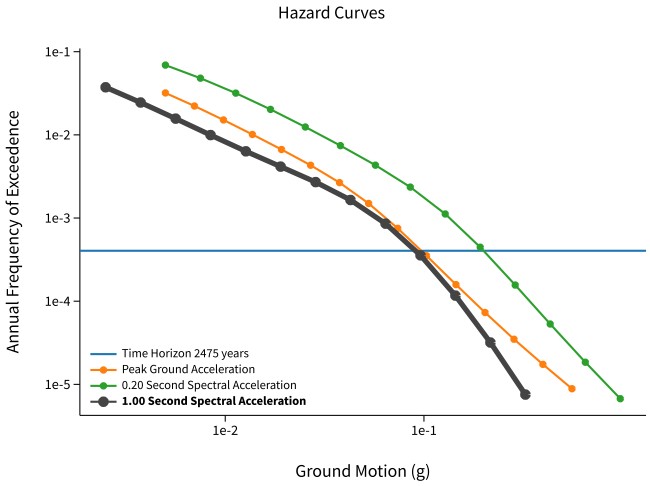
Hazard Curve

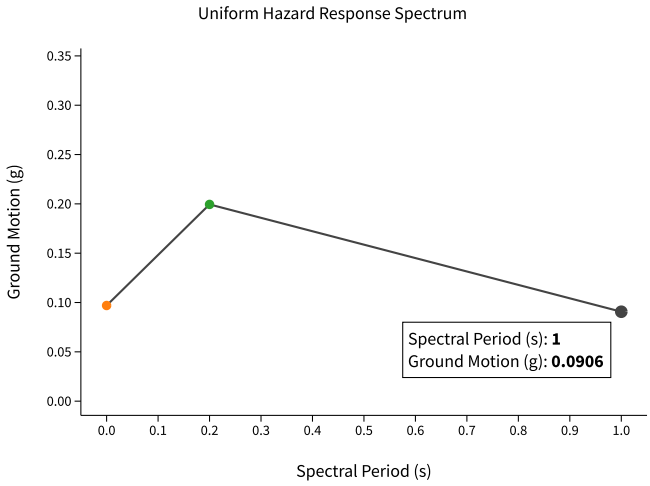




View Raw Data

Hazard Curve





View Raw Data

SECTION 3

GeoStudio Slope Stability Analysis

HANSON™

GT Row 6 Slope Stability (Reinf) (LR)

Report generated using GeoStudio 2025.1.1. Copyright © 2025 Bentley Systems, Incorporated.

File Information

File Version: 11.08
Product Version: 25.1.1.182
Created By: Beya Kazadi
Last Edited By: Beya Kazadi
Revision Number: 373
Date: 09/14/2025
Time: 04:06:39 PM
File Name: CWLP Ash Pond Closure Slope Stabilty.gsz
Directory: I:\25jobs\25E0006_00\Admin\13-Calculations\GEOTECH\Geostudio Model\
Last Solved Date: 09/14/2025
Last Solved Time: 04:16:22 PM

Project Settings

Unit System: U.S. Customary Units

Analysis Settings

GT Row 6 Slope Stability (Reinf) (LR)

Kind: SLOPE/W
Analysis Type: Limit Equilibrium
Settings
- Method: Spencer
- PWP Conditions from: Piezometric Surfaces
- Apply Phreatic Correction: No
- Staged Rapid Drawdown Analysis: No
- Unit Weight of Water: 62.430189 pcf

Slip Surface
- Slip Surface Settings
  - Search Method: Entry and Exit
  - Specify Radius Tangent Lines: No
  - Direction of Movement: Left to Right
  - Use Passive Mode: No
  - No. of Critical Slip Surfaces to Store: 1
- Geometry Settings
  - Minimum Slip Surface Depth: 3 ft
  - Minimum Slip Surface Volume: 35.314667 ft³
  - Number of Columns: 30
- Tension Crack Option: (none)

Optimization
- Optimize Critical Slip Surface: Yes
- Algorithm Settings
  - Algorithm Type: Particle Swarm Optimization
  - No. of Generations: 20
  - No. of Agents: 20
  - Maximum Iterations: 2,000
- Geometry Settings
  - Surface Shape: Spline
  - No. of Points
    - Starting: 8
    - Ending: 16
  - Maximum Concave Angle
    - Driving Side: 5 °
    - Resisting Side: 1 °

Convergence
- Factor of Safety Convergence Settings
  - Maximum Number of Iterations: 100
  - Tolerable Difference in F of S: 0.001
- Under-Relaxation Criteria
  - Initial Rate: 1
  - Minimum Rate: 0.1
  - Rate Reduction Factor: 0.65
  - Reduction Frequency (iterations): 50
- Solution Settings
  - Search Method: Root Finder
  - Tolerable difference between starting and converged F of S: 3
  - Maximum iterations to calculate converged lambda: 20
  - Maximum Absolute Lambda: 2

Materials

3_Fill
Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 115 pcf
Effective Cohesion: 1,800 psf
Effective Friction Angle: 0 °
Phi-B: 0 °
Pore Water Pressure
    Piezometric Surface: 1

4_Alluvial
Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 115 pcf
Effective Cohesion: 750 psf
Effective Friction Angle: 0 °
Phi-B: 0 °
Pore Water Pressure
    Piezometric Surface: 1

2_CCR Ash Wet Dallman
Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 120 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 28 °
Phi-B: 0 °
Pore Water Pressure
    Piezometric Surface: 1

1_CCR Ash Wet Lakeside
Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 115 pcf
Effective Cohesion: 200 psf
Effective Friction Angle: 30 °
Phi-B: 0 °
Pore Water Pressure
    Piezometric Surface: 1

5_Shale
Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 130 pcf
Effective Cohesion: 3,500 psf
Effective Friction Angle: 10 °
Phi-B: 0 °
Pore Water Pressure
    Piezometric Surface: 1

0_CCR Cover
Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 120 pcf
Effective Cohesion: 1,000 psf
Effective Friction Angle: 0 °
Phi-B: 0 °
Pore Water Pressure
    Piezometric Surface: 1

Reinforcements

GeoTube
Type: Geosynthetic
Interface Adhesion: 250 psf
Interface Shear Angle: 33 °
Surface Area Factor: 2
Pullout Resistance Reduction Factor: 1
Tensile Capacity: 6,000 lbf
Tensile Capacity Reduction Factor: 2.5
F of S Dependent: No
Force Distribution: Distributed
Face Anchorage: Yes
Factored Tensile Capacity: 2,400 lbf/ft

Slip Surface Entry and Exit
Left Type: Range
Left-Zone Left Coordinate: (1,284, 590.48868) ft
Left-Zone Right Coordinate: (1,369, 588.00306) ft
Left-Zone Increment: 25
Right Type: Range
Right-Zone Left Coordinate: (1,484.7831, 559.00001) ft

Right-Zone Right Coordinate: (1,578, 549.09417) ft
Right-Zone Increment: 25
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (-100, 532.52639) ft
Right Coordinate: (1,800, 549.06529) ft

Piezometric Surfaces

Piezometric Surface 1

Coordinates

	X	Y
Coordinate 1	-100 ft	532.52639 ft
Coordinate 2	51.3487 ft	532.17002 ft
Coordinate 3	56.7613 ft	532.17002 ft
Coordinate 4	161.9987 ft	546.02071 ft
Coordinate 5	180.1421 ft	550 ft
Coordinate 6	1,514.3403 ft	550 ft
Coordinate 7	1,530.3985 ft	546.05069 ft
Coordinate 8	1,581 ft	546.05069 ft
Coordinate 9	1,800 ft	545 ft

Reinforcement Sets

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,483.8446, 550) ft
  X: 1,483.8446 ft
  Y: 550 ft
Range End: (311.92488, 550) ft
  X: 311.92488 ft
  Y: 550 ft
Orientation Type: Horizontal
Horizontal Direction: Left
Length: 97.659977 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.659977 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,483.8446, 557.4999) ft
  X: 1,483.8446 ft
  Y: 557.4999 ft
Range End: (311.92488, 557.4999) ft
  X: 311.92488 ft
  Y: 557.4999 ft
Orientation Type: Horizontal
Horizontal Direction: Left
Length: 97.659977 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.659977 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,433.8446, 557.5) ft
  X: 1,433.8446 ft
  Y: 557.5 ft
Range End: (361.72987, 557.5) ft
  X: 361.72987 ft
  Y: 557.5 ft
Orientation Type: Horizontal
Horizontal Direction: Left
Length: 97.464975 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.464975 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,433.8446, 564.999) ft
X: 1,433.8446 ft
Y: 564.999 ft
Range End: (361.72987, 564.999) ft
X: 361.72987 ft
Y: 564.999 ft
Orientation Type: Horizontal
Horizontal Direction: Left
Length: 97.464975 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.464975 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,383.8846, 565) ft
X: 1,383.8846 ft
Y: 565 ft
Range End: (411.49942, 565) ft
X: 411.49942 ft
Y: 565 ft
Orientation Type: Horizontal
Horizontal Direction: Left
Length: 97.234518 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.234518 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,383.8846, 572.4999) ft
X: 1,383.8846 ft
Y: 572.4999 ft
Range End: (411.49942, 572.4999) ft
X: 411.49942 ft
Y: 572.4999 ft
Orientation Type: Horizontal
Horizontal Direction: Left
Length: 97.234518 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.234518 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,333.8446, 572.5) ft
X: 1,333.8446 ft
Y: 572.5 ft
Range End: (461.22287, 572.5) ft
X: 461.22287 ft
Y: 572.5 ft
Orientation Type: Horizontal
Horizontal Direction: Left
Length: 96.95797 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 96.95797 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,333.8446, 579.999) ft
X: 1,333.8446 ft
Y: 579.999 ft
Range End: (461.22287, 579.999) ft
X: 461.22287 ft
Y: 579.999 ft
Orientation Type: Horizontal
Horizontal Direction: Left
Length: 96.95797 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 96.95797 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,283.8446, 580) ft
X: 1,283.8446 ft
Y: 580 ft
Range End: (510.88487, 580) ft
X: 510.88487 ft
Y: 580 ft
Orientation Type: Horizontal
Horizontal Direction: Left
Length: 96.619967 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 96.619967 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,283.8446, 587.4999) ft
X: 1,283.8446 ft
Y: 587.4999 ft
Range End: (510.88487, 587.4999) ft
X: 510.88487 ft
Y: 587.4999 ft
Orientation Type: Horizontal
Horizontal Direction: Left
Length: 96.619967 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 96.619967 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,067.0022, 587.5) ft
X: 1,067.0022 ft
Y: 587.5 ft
Range End: (775.70115, 587.5) ft
X: 775.70115 ft
Y: 587.5 ft
Orientation Type: Horizontal
Horizontal Direction: Left
Length: 97.10035 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.10035 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,067.0022, 595) ft
X: 1,067.0022 ft
Y: 595 ft
Range End: (775.70115, 595) ft
X: 775.70115 ft
Y: 595 ft
Orientation Type: Horizontal
Horizontal Direction: Left
Length: 97.10035 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.10035 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,433.8446, 565) ft
X: 1,433.8446 ft
Y: 565 ft
Range End: (264.2649, 565) ft
X: 264.2649 ft
Y: 565 ft
Orientation Type: Vertical
Length: 7.5 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.464975 ft

Reinforcement Sets

Reinforcement: GeoTube

Lock to Ground Surface: No
Range Start: (1,383.8846, 572.5) ft
X: 1,383.8846 ft
Y: 572.5 ft
Range End: (314.2649, 572.5) ft
X: 314.2649 ft
Y: 572.5 ft
Orientation Type: Vertical
Length: 7.5 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.234518 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,333.8446, 580) ft
X: 1,333.8446 ft
Y: 580 ft
Range End: (364.2649, 580) ft
X: 364.2649 ft
Y: 580 ft
Orientation Type: Vertical
Length: 7.5 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 96.95797 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,283.8446, 587.5) ft
X: 1,283.8446 ft
Y: 587.5 ft
Range End: (414.2649, 587.5) ft
X: 414.2649 ft
Y: 587.5 ft
Orientation Type: Vertical
Length: 7.5 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 96.619967 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,067.0022, 595) ft
X: 1,067.0022 ft
Y: 595 ft
Range End: (678.6008, 595) ft
X: 678.6008 ft
Y: 595 ft
Orientation Type: Vertical
Length: 7.5 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.10035 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (1,483.8446, 557.5) ft
X: 1,483.8446 ft
Y: 557.5 ft
Range End: (214.2649, 557.5) ft
X: 214.2649 ft
Y: 557.5 ft
Orientation Type: Vertical
Length: 7.5 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.659977 ft

Reinforcement Lines

	Assigned Reinforcement	Reinforcement Set	Lock to Ground Surface	Outside Point	Inside Point	Length	Trend	Plunge	Slip Surface Intersection	Max. Pullout Force	Available Length	Governing Component	P F
Reinforcement Line 1	GeoTube	587.5 V	No	(1,067.0022, 595)	(1,067.0022, 587.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	

Reinforcement Line 2	GeoTube	587.5 V	No	(969.9018, 595)	(969.9018, 587.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 3	GeoTube	587.5 V	No	(872.8015, 595)	(872.8015, 587.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 4	GeoTube	587.5 V	No	(775.7011, 595)	(775.7011, 587.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 5	GeoTube	587.5 V	No	(678.6008, 595)	(678.6008, 587.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 6	GeoTube	587.5	No	(1,067.0022, 587.5)	(969.9018, 587.5)	97.1004 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 7	GeoTube	587.5	No	(969.9018, 587.5)	(872.8015, 587.5)	97.1003 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 8	GeoTube	587.5	No	(872.8015, 587.5)	(775.7011, 587.5)	97.1004 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 9	GeoTube	587.5	No	(775.7011, 587.5)	(678.6008, 587.5)	97.1003 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 10	GeoTube	587.5 (T)	No	(1,067.0022, 595)	(969.9018, 595)	97.1004 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 11	GeoTube	587.5 (T)	No	(969.9018, 595)	(872.8015, 595)	97.1003 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 12	GeoTube	587.5 (T)	No	(872.8015, 595)	(775.7011, 595)	97.1004 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 13	GeoTube	587.5 (T)	No	(775.7011, 595)	(678.6008, 595)	97.1003 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 14	GeoTube	550 (T)	No	(1,483.8446, 557.4999)	(1,386.1846, 557.4999)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 15	GeoTube	550 (T)	No	(1,386.1846, 557.4999)	(1,288.5246, 557.4999)	97.66 ft	270 °	0 °	(1,325.9904, 557.4999, 0)	2,400 lbf	37.465825 ft	Tensile Capacity	2, lb
Reinforcement Line 16	GeoTube	550 (T)	No	(1,288.5246, 557.4999)	(1,190.8647, 557.4999)	97.6599 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 17	GeoTube	550 (T)	No	(1,190.8647, 557.4999)	(1,093.2047, 557.4999)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 18	GeoTube	550 (T)	No	(1,093.2047, 557.4999)	(995.5447, 557.4999)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 19	GeoTube	550 (T)	No	(995.5447, 557.4999)	(897.8847, 557.4999)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 20	GeoTube	550 (T)	No	(897.8847, 557.4999)	(800.2248, 557.4999)	97.6599 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 21	GeoTube	550 (T)	No	(800.2248, 557.4999)	(702.5648, 557.4999)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 22	GeoTube	550 (T)	No	(702.5648, 557.4999)	(604.9048, 557.4999)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 23	GeoTube	550 (T)	No	(604.9048, 557.4999)	(507.2448, 557.4999)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 24	GeoTube	550 (T)	No	(507.2448, 557.4999)	(409.5849, 557.4999)	97.6599 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 25	GeoTube	550 (T)	No	(409.5849, 557.4999)	(311.9249, 557.4999)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 26	GeoTube	550 (T)	No	(311.9249, 557.4999)	(214.2649, 557.4999)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 27	GeoTube	550	No	(1,483.8446, 550)	(1,386.1846, 550)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 28	GeoTube	550	No	(1,386.1846, 550)	(1,288.5246, 550)	97.66 ft	270 °	0 °	(1,330.4218, 550, 0)	2,400 lbf	41.897234 ft	Tensile Capacity	2, lb
Reinforcement Line 29	GeoTube	550	No	(1,288.5246, 550)	(1,190.8647, 550)	97.6599 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 30	GeoTube	550	No	(1,190.8647, 550)	(1,093.2047, 550)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 31	GeoTube	550	No	(1,093.2047, 550)	(995.5447, 550)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 32	GeoTube	550	No	(995.5447, 550)	(897.8847, 550)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 33	GeoTube	550	No	(897.8847, 550)	(800.2248, 550)	97.6599 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 34	GeoTube	550	No	(800.2248, 550)	(702.5648, 550)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 35	GeoTube	550	No	(702.5648, 550)	(604.9048, 550)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 36	GeoTube	550	No	(604.9048, 550)	(507.2448, 550)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 37	GeoTube	550	No	(507.2448, 550)	(409.5849, 550)	97.6599 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 38	GeoTube	550	No	(409.5849, 550)	(311.9249, 550)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 39	GeoTube	550	No	(311.9249, 550)	(214.2649, 550)	97.66 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 40	GeoTube	550 V	No	(1,483.8446, 557.5)	(1,483.8446, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 41	GeoTube	550 V	No	(1,386.1846, 557.5)	(1,386.1846, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	

Reinforcement Line 42	GeoTube	550 V	No	(1,288.5246, 557.5)	(1,288.5246, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 43	GeoTube	550 V	No	(1,190.8647, 557.5)	(1,190.8647, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 44	GeoTube	550 V	No	(1,093.2047, 557.5)	(1,093.2047, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 45	GeoTube	550 V	No	(995.5447, 557.5)	(995.5447, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 46	GeoTube	550 V	No	(897.8847, 557.5)	(897.8847, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 47	GeoTube	550 V	No	(800.2248, 557.5)	(800.2248, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 48	GeoTube	550 V	No	(702.5648, 557.5)	(702.5648, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 49	GeoTube	550 V	No	(604.9048, 557.5)	(604.9048, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 50	GeoTube	550 V	No	(507.2448, 557.5)	(507.2448, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 51	GeoTube	550 V	No	(409.5849, 557.5)	(409.5849, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 52	GeoTube	550 V	No	(311.9249, 557.5)	(311.9249, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 53	GeoTube	550 V	No	(214.2649, 557.5)	(214.2649, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 54	GeoTube	557.5 (T)	No	(1,433.8446, 564.999)	(1,336.3796, 564.999)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 55	GeoTube	557.5 (T)	No	(1,336.3796, 564.999)	(1,238.9146, 564.999)	97.465 ft	270 °	0 °	(1,321.8399, 564.999, 0)	2,400 lbf	82.925341 ft	Tensile Capacity	2, lb
Reinforcement Line 56	GeoTube	557.5 (T)	No	(1,238.9146, 564.999)	(1,141.4497, 564.999)	97.4649 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 57	GeoTube	557.5 (T)	No	(1,141.4497, 564.999)	(1,043.9847, 564.999)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 58	GeoTube	557.5 (T)	No	(1,043.9847, 564.999)	(946.5197, 564.999)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 59	GeoTube	557.5 (T)	No	(946.5197, 564.999)	(849.0547, 564.999)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 60	GeoTube	557.5 (T)	No	(849.0547, 564.999)	(751.5898, 564.999)	97.4649 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 61	GeoTube	557.5 (T)	No	(751.5898, 564.999)	(654.1248, 564.999)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 62	GeoTube	557.5 (T)	No	(654.1248, 564.999)	(556.6598, 564.999)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 63	GeoTube	557.5 (T)	No	(556.6598, 564.999)	(459.1948, 564.999)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 64	GeoTube	557.5 (T)	No	(459.1948, 564.999)	(361.7299, 564.999)	97.4649 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 65	GeoTube	557.5 (T)	No	(361.7299, 564.999)	(264.2649, 564.999)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 66	GeoTube	557.5	No	(1,433.8446, 557.5)	(1,336.3796, 557.5)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 67	GeoTube	557.5	No	(1,336.3796, 557.5)	(1,238.9146, 557.5)	97.465 ft	270 °	0 °	(1,325.9904, 557.5, 0)	2,400 lbf	87.075769 ft	Tensile Capacity	2, lb
Reinforcement Line 68	GeoTube	557.5	No	(1,238.9146, 557.5)	(1,141.4497, 557.5)	97.4649 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 69	GeoTube	557.5	No	(1,141.4497, 557.5)	(1,043.9847, 557.5)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 70	GeoTube	557.5	No	(1,043.9847, 557.5)	(946.5197, 557.5)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 71	GeoTube	557.5	No	(946.5197, 557.5)	(849.0547, 557.5)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 72	GeoTube	557.5	No	(849.0547, 557.5)	(751.5898, 557.5)	97.4649 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 73	GeoTube	557.5	No	(751.5898, 557.5)	(654.1248, 557.5)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 74	GeoTube	557.5	No	(654.1248, 557.5)	(556.6598, 557.5)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 75	GeoTube	557.5	No	(556.6598, 557.5)	(459.1948, 557.5)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 76	GeoTube	557.5	No	(459.1948, 557.5)	(361.7299, 557.5)	97.4649 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 77	GeoTube	557.5	No	(361.7299, 557.5)	(264.2649, 557.5)	97.465 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 78	GeoTube	557.5 V	No	(1,433.8446, 565)	(1,433.8446, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 79	GeoTube	557.5 V	No	(1,336.3796, 565)	(1,336.3796, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 80	GeoTube	557.5 V	No	(1,238.9147, 565)	(1,238.9147, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 81	GeoTube	557.5 V	No	(1,141.4497, 565)	(1,141.4497, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	

Reinforcement Line 82	GeoTube	557.5 V	No	(1,043.9847, 565)	(1,043.9847, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 83	GeoTube	557.5 V	No	(946.5197, 565)	(946.5197, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 84	GeoTube	557.5 V	No	(849.0547, 565)	(849.0547, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 85	GeoTube	557.5 V	No	(751.5898, 565)	(751.5898, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 86	GeoTube	557.5 V	No	(654.1248, 565)	(654.1248, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 87	GeoTube	557.5 V	No	(556.6598, 565)	(556.6598, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 88	GeoTube	557.5 V	No	(459.1948, 565)	(459.1948, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 89	GeoTube	557.5 V	No	(361.7299, 565)	(361.7299, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 90	GeoTube	557.5 V	No	(264.2649, 565)	(264.2649, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 91	GeoTube	565 (T)	No	(1,383.8846, 572.4999)	(1,286.6501, 572.4999)	97.2345 ft	270 °	0 °	(1,317.8307, 572.4999, 0)	2,400 lbf	31.180635 ft	Tensile Capacity	2, lb
Reinforcement Line 92	GeoTube	565 (T)	No	(1,286.6501, 572.4999)	(1,189.4156, 572.4999)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 93	GeoTube	565 (T)	No	(1,189.4156, 572.4999)	(1,092.181, 572.4999)	97.2346 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 94	GeoTube	565 (T)	No	(1,092.181, 572.4999)	(994.9465, 572.4999)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 95	GeoTube	565 (T)	No	(994.9465, 572.4999)	(897.712, 572.4999)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 96	GeoTube	565 (T)	No	(897.712, 572.4999)	(800.4775, 572.4999)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 97	GeoTube	565 (T)	No	(800.4775, 572.4999)	(703.243, 572.4999)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 98	GeoTube	565 (T)	No	(703.243, 572.4999)	(606.0085, 572.4999)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 99	GeoTube	565 (T)	No	(606.0085, 572.4999)	(508.7739, 572.4999)	97.2346 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 100	GeoTube	565 (T)	No	(508.7739, 572.4999)	(411.5394, 572.4999)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 101	GeoTube	565 (T)	No	(411.5394, 572.4999)	(314.3049, 572.4999)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 102	GeoTube	565	No	(1,383.8846, 565)	(1,286.6501, 565)	97.2345 ft	270 °	0 °	(1,321.8394, 565, 0)	2,400 lbf	35.189301 ft	Tensile Capacity	2, lb
Reinforcement Line 103	GeoTube	565	No	(1,286.6501, 565)	(1,189.4156, 565)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 104	GeoTube	565	No	(1,189.4156, 565)	(1,092.181, 565)	97.2346 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 105	GeoTube	565	No	(1,092.181, 565)	(994.9465, 565)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 106	GeoTube	565	No	(994.9465, 565)	(897.712, 565)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 107	GeoTube	565	No	(897.712, 565)	(800.4775, 565)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 108	GeoTube	565	No	(800.4775, 565)	(703.243, 565)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 109	GeoTube	565	No	(703.243, 565)	(606.0085, 565)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 110	GeoTube	565	No	(606.0085, 565)	(508.7739, 565)	97.2346 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 111	GeoTube	565	No	(508.7739, 565)	(411.5394, 565)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 112	GeoTube	565	No	(411.5394, 565)	(314.3049, 565)	97.2345 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 113	GeoTube	565 V	No	(1,383.8846, 572.5)	(1,383.8846, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 114	GeoTube	565 V	No	(1,286.6501, 572.5)	(1,286.6501, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 115	GeoTube	565 V	No	(1,189.4156, 572.5)	(1,189.4156, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 116	GeoTube	565 V	No	(1,092.181, 572.5)	(1,092.181, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 117	GeoTube	565 V	No	(994.9465, 572.5)	(994.9465, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 118	GeoTube	565 V	No	(897.712, 572.5)	(897.712, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 119	GeoTube	565 V	No	(800.4775, 572.5)	(800.4775, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 120	GeoTube	565 V	No	(703.243, 572.5)	(703.243, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 121	GeoTube	565 V	No	(606.0085, 572.5)	(606.0085, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	

Reinforcement Line 122	GeoTube	565 V	No	(508.7739, 572.5)	(508.7739, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 123	GeoTube	565 V	No	(411.5394, 572.5)	(411.5394, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 124	GeoTube	565 V	No	(314.3049, 572.5)	(314.3049, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 125	GeoTube	572.5 (T)	No	(1,333.8446, 579.999)	(1,236.8866, 579.999)	96.958 ft	270 °	0 °	(1,313.9153, 579.999, 0)	2,400 lbf	77.0287 ft	Tensile Capacity	2, lb
Reinforcement Line 126	GeoTube	572.5 (T)	No	(1,236.8866, 579.999)	(1,139.9287, 579.999)	96.9579 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 127	GeoTube	572.5 (T)	No	(1,139.9287, 579.999)	(1,042.9707, 579.999)	96.958 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 128	GeoTube	572.5 (T)	No	(1,042.9707, 579.999)	(946.0127, 579.999)	96.958 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 129	GeoTube	572.5 (T)	No	(946.0127, 579.999)	(849.0547, 579.999)	96.958 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 130	GeoTube	572.5 (T)	No	(849.0547, 579.999)	(752.0968, 579.999)	96.9579 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 131	GeoTube	572.5 (T)	No	(752.0968, 579.999)	(655.1388, 579.999)	96.958 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 132	GeoTube	572.5 (T)	No	(655.1388, 579.999)	(558.1808, 579.999)	96.958 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 133	GeoTube	572.5 (T)	No	(558.1808, 579.999)	(461.2229, 579.999)	96.9579 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 134	GeoTube	572.5 (T)	No	(461.2229, 579.999)	(364.2649, 579.999)	96.958 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 135	GeoTube	572.5	No	(1,333.8446, 572.5)	(1,236.8866, 572.5)	96.958 ft	270 °	0 °	(1,317.8307, 572.5, 0)	2,400 lbf	80.944082 ft	Tensile Capacity	2, lb
Reinforcement Line 136	GeoTube	572.5	No	(1,236.8866, 572.5)	(1,139.9287, 572.5)	96.9579 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 137	GeoTube	572.5	No	(1,139.9287, 572.5)	(1,042.9707, 572.5)	96.958 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 138	GeoTube	572.5	No	(1,042.9707, 572.5)	(946.0127, 572.5)	96.958 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 139	GeoTube	572.5	No	(946.0127, 572.5)	(849.0547, 572.5)	96.958 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 140	GeoTube	572.5	No	(849.0547, 572.5)	(752.0968, 572.5)	96.9579 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 141	GeoTube	572.5	No	(752.0968, 572.5)	(655.1388, 572.5)	96.958 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 142	GeoTube	572.5	No	(655.1388, 572.5)	(558.1808, 572.5)	96.958 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 143	GeoTube	572.5	No	(558.1808, 572.5)	(461.2229, 572.5)	96.9579 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 144	GeoTube	572.5	No	(461.2229, 572.5)	(364.2649, 572.5)	96.958 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 145	GeoTube	572.5 V	No	(1,333.8446, 580)	(1,333.8446, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 146	GeoTube	572.5 V	No	(1,236.8866, 580)	(1,236.8866, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 147	GeoTube	572.5 V	No	(1,139.9287, 580)	(1,139.9287, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 148	GeoTube	572.5 V	No	(1,042.9707, 580)	(1,042.9707, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 149	GeoTube	572.5 V	No	(946.0127, 580)	(946.0127, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 150	GeoTube	572.5 V	No	(849.0548, 580)	(849.0548, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 151	GeoTube	572.5 V	No	(752.0968, 580)	(752.0968, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 152	GeoTube	572.5 V	No	(655.1388, 580)	(655.1388, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 153	GeoTube	572.5 V	No	(558.1808, 580)	(558.1808, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 154	GeoTube	572.5 V	No	(461.2229, 580)	(461.2229, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 155	GeoTube	572.5 V	No	(364.2649, 580)	(364.2649, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 156	GeoTube	580 (T)	No	(1,283.8446, 587.4999)	(1,187.2246, 587.4999)	96.62 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 157	GeoTube	580 (T)	No	(1,187.2246, 587.4999)	(1,090.6047, 587.4999)	96.6199 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 158	GeoTube	580 (T)	No	(1,090.6047, 587.4999)	(993.9847, 587.4999)	96.62 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 159	GeoTube	580 (T)	No	(993.9847, 587.4999)	(897.3647, 587.4999)	96.62 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 160	GeoTube	580 (T)	No	(897.3647, 587.4999)	(800.7448, 587.4999)	96.6199 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 161	GeoTube	580 (T)	No	(800.7448, 587.4999)	(704.1248, 587.4999)	96.62 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	

Reinforcement Line 162	GeoTube	580 (T)	No	(704.1248, 587.4999)	(607.5048, 587.4999)	96.62 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 163	GeoTube	580 (T)	No	(607.5048, 587.4999)	(510.8849, 587.4999)	96.6199 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 164	GeoTube	580 (T)	No	(510.8849, 587.4999)	(414.2649, 587.4999)	96.62 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 165	GeoTube	580	No	(1,283.8446, 580)	(1,187.2246, 580)	96.62 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 166	GeoTube	580	No	(1,187.2246, 580)	(1,090.6047, 580)	96.6199 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 167	GeoTube	580	No	(1,090.6047, 580)	(993.9847, 580)	96.62 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 168	GeoTube	580	No	(993.9847, 580)	(897.3647, 580)	96.62 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 169	GeoTube	580	No	(897.3647, 580)	(800.7448, 580)	96.6199 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 170	GeoTube	580	No	(800.7448, 580)	(704.1248, 580)	96.62 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 171	GeoTube	580	No	(704.1248, 580)	(607.5048, 580)	96.62 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 172	GeoTube	580	No	(607.5048, 580)	(510.8849, 580)	96.6199 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 173	GeoTube	580	No	(510.8849, 580)	(414.2649, 580)	96.62 ft	270 °	0 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 174	GeoTube	580 V	No	(1,283.8446, 587.5)	(1,283.8446, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 175	GeoTube	580 V	No	(1,187.2246, 587.5)	(1,187.2246, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 176	GeoTube	580 V	No	(1,090.6047, 587.5)	(1,090.6047, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 177	GeoTube	580 V	No	(993.9847, 587.5)	(993.9847, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 178	GeoTube	580 V	No	(897.3647, 587.5)	(897.3647, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 179	GeoTube	580 V	No	(800.7448, 587.5)	(800.7448, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 180	GeoTube	580 V	No	(704.1248, 587.5)	(704.1248, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 181	GeoTube	580 V	No	(607.5048, 587.5)	(607.5048, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 182	GeoTube	580 V	No	(510.8849, 587.5)	(510.8849, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	
Reinforcement Line 183	GeoTube	580 V	No	(414.2649, 587.5)	(414.2649, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft	None	

Geometry

Name: North South Profile

Settings

View: 2D

Element Thickness: 1 ft

Points

	X	Y
Point 1	-100 ft	532.52639 ft
Point 2	-1.3284 ft	533.77631 ft
Point 3	17.9944 ft	536.23773 ft
Point 4	38.8763 ft	534.5275 ft
Point 5	51.3487 ft	532.17002 ft
Point 6	56.7613 ft	532.17002 ft
Point 7	99.5926 ft	545.80069 ft
Point 8	107.7237 ft	551.98231 ft
Point 9	117.0143 ft	552.22296 ft
Point 10	147.6952 ft	551.2307 ft
Point 11	161.9987 ft	546.02071 ft
Point 12	215.5858 ft	527.93508 ft
Point 13	226.0745 ft	527.17684 ft
Point 14	238.4378 ft	523.80851 ft
Point 15	903.1371 ft	525.95454 ft
Point 16	1,203.088 ft	527.39817 ft
Point 17	1,304.9787 ft	528.24967 ft
Point 18	1,378.955 ft	529.2834 ft
Point 19	1,403.3082 ft	529.63559 ft
Point 20	1,492.6242 ft	529.63559 ft
Point 21	1,530.5363 ft	546.11057 ft
Point 22	1,536.3762 ft	548.0397 ft

Point 23	1,551.8672 ft	553.12281 ft
Point 24	1,560.4904 ft	553.12281 ft
Point 25	1,563.5248 ft	553.50664 ft
Point 26	1,574.64 ft	551.0582 ft
Point 27	1,578.0494 ft	549.06529 ft
Point 28	1,800 ft	549.06529 ft
Point 29	1,800 ft	400 ft
Point 30	-100 ft	400 ft
Point 31	150.291 ft	548.93321 ft
Point 32	150.698 ft	551.88293 ft
Point 33	156.094 ft	552.75427 ft
Point 34	168.1675 ft	554.09285 ft
Point 35	174.4613 ft	553.48918 ft
Point 36	177.6054 ft	553.48918 ft
Point 37	184.5848 ft	555.08891 ft
Point 38	198.64 ft	556.15978 ft
Point 39	204.727 ft	555.39206 ft
Point 40	210.9606 ft	554.60466 ft
Point 41	210.9606 ft	554.15091 ft
Point 42	216.1279 ft	554.15091 ft
Point 43	223.0888 ft	557.27789 ft
Point 44	229.388 ft	556.38419 ft
Point 45	234.6636 ft	553.45899 ft
Point 46	275.5124 ft	554.47584 ft
Point 47	330.2738 ft	555.51345 ft
Point 48	333.8827 ft	553.04954 ft
Point 49	341.724 ft	555.36253 ft
Point 50	347.5967 ft	553.96162 ft
Point 51	362.5573 ft	552.72146 ft
Point 52	373.4497 ft	550.79232 ft
Point 53	989.441 ft	550.51881 ft
Point 54	1,201.8289 ft	551.45505 ft
Point 55	1,236.8934 ft	551.16084 ft
Point 56	1,261.2401 ft	551.49757 ft
Point 57	1,264.5495 ft	551.1007 ft
Point 58	1,274.344 ft	552.7644 ft
Point 59	1,287.9775 ft	560.82205 ft
Point 60	1,293.7738 ft	562.87932 ft
Point 61	1,309.6932 ft	565.3856 ft
Point 62	1,318.4263 ft	564.27949 ft
Point 63	1,350.2305 ft	567.18734 ft
Point 64	1,352.9707 ft	569.88025 ft
Point 65	1,357.4064 ft	570.72671 ft
Point 66	1,363.4494 ft	568.71143 ft
Point 67	1,363.4494 ft	567.39994 ft
Point 68	1,375.8447 ft	565.12303 ft
Point 69	1,384.4405 ft	566.16962 ft
Point 70	1,389.4656 ft	566.97707 ft
Point 71	1,397.4671 ft	567.35249 ft
Point 72	1,410.1123 ft	567.18774 ft
Point 73	1,418.0691 ft	566.23196 ft
Point 74	1,420.554 ft	565.94169 ft
Point 75	1,425.8016 ft	566.32274 ft
Point 76	1,427.3794 ft	566.04611 ft
Point 77	1,437.6302 ft	566.7424 ft
Point 78	1,449.3014 ft	565.45348 ft
Point 79	1,459.5025 ft	563.48662 ft
Point 80	1,485.8698 ft	563.4284 ft
Point 81	1,495.1677 ft	563.82023 ft
Point 82	1,503.606 ft	563.5539 ft
Point 83	1,518.0794 ft	563.79841 ft
Point 84	1,519.0905 ft	564.14722 ft
Point 85	1,524.2305 ft	563.15269 ft
Point 86	1,528.7274 ft	558.69946 ft
Point 87	1,537.3124 ft	554.42556 ft
Point 88	1,542.6535 ft	553.62041 ft
Point 89	1,368.64 ft	585.87631 ft
Point 90	1,067.0022 ft	595 ft
Point 91	678.6006 ft	595 ft
Point 92	342.7615 ft	585.89846 ft
Point 93	341.0967 ft	587.77159 ft
Point 94	677.846 ft	596.80939 ft
Point 95	1,067.8526 ft	596.80939 ft
Point 96	1,369.7423 ft	587.98135 ft

Point 97	1,466.2031 ft	563.47182 ft
Point 98	161.2923 ft	547.92314 ft
Point 99	156.8735 ft	548.00979 ft
Point 100	1,530.9628 ft	547.8855 ft
Point 101	1,534.0799 ft	548.0314 ft
Point 102	1,548.5695 ft	553.30091 ft
Point 103	1,530.3985 ft	546.05069 ft
Point 104	-100 ft	528 ft
Point 105	215.3734 ft	528 ft
Point 106	215.3934 ft	528 ft
Point 107	212 ft	529 ft
Point 108	1,800 ft	528 ft
Point 109	1,275.1031 ft	528 ft
Point 110	105.1162 ft	550 ft
Point 111	149.0857 ft	550 ft
Point 112	170.7095 ft	550 ft
Point 113	180.1421 ft	550 ft
Point 114	1,514.3403 ft	550 ft
Point 115	1,522.1773 ft	550 ft
Point 116	1,539.493 ft	550 ft
Point 117	1,542.3503 ft	550 ft
Point 118	1,576.4503 ft	550 ft
Point 119	1,528.4239 ft	559 ft
Point 120	1,284.8946 ft	559 ft
Point 121	221.0521 ft	559 ft
Point 122	261.775 ft	568 ft
Point 123	1,351.0574 ft	568 ft
Point 124	1,363.4494 ft	568 ft
Point 125	1,364.5018 ft	586 ft
Point 126	346.5531 ft	586 ft
Point 127	1,491.0155 ft	557.5 ft
Point 128	1,483.8446 ft	557.5 ft
Point 129	1,282.3566 ft	557.5 ft
Point 130	214.2649 ft	557.5 ft
Point 131	204.6796 ft	557.5 ft
Point 132	214.2649 ft	554.15091 ft
Point 133	214.2649 ft	550 ft
Point 134	1,483.8446 ft	550 ft
Point 135	238.4779 ft	565 ft
Point 136	248.2007 ft	565 ft
Point 137	1,307.2439 ft	565 ft
Point 138	1,312.7376 ft	565 ft
Point 139	1,326.3068 ft	565 ft
Point 140	1,451.6534 ft	565 ft
Point 141	1,460.1887 ft	565 ft
Point 142	264.2649 ft	557.5 ft
Point 143	1,433.8446 ft	557.5 ft
Point 144	272.2762 ft	572.5 ft
Point 145	282.1365 ft	572.5 ft
Point 146	1,421.4706 ft	572.5 ft
Point 147	1,430.6714 ft	572.5 ft
Point 148	306.0745 ft	580 ft
Point 149	316.0723 ft	580 ft
Point 150	1,391.8489 ft	580 ft
Point 151	1,401.1541 ft	580 ft
Point 152	1,383.8446 ft	572.5 ft
Point 153	314.2649 ft	572.5 ft
Point 154	401.8943 ft	587.5 ft
Point 155	1,314.9185 ft	587.5 ft
Point 156	1,333.8446 ft	580 ft
Point 157	364.2649 ft	580 ft
Point 158	678.6006 ft	587.5 ft
Point 159	1,067.0022 ft	587.5 ft
Point 160	-100 ft	500 ft
Point 161	1,800 ft	500 ft
Point 162	1,433.8446 ft	565 ft
Point 163	264.2649 ft	565 ft
Point 164	314.2649 ft	565 ft
Point 165	1,383.8446 ft	566.09707 ft
Point 166	1,383.8446 ft	565 ft
Point 167	364.2649 ft	572.5 ft
Point 168	414.2649 ft	580 ft
Point 169	414.2649 ft	587.5 ft
Point 170	1,333.8446 ft	572.5 ft

Point 171	1,283.8446 ft	580 ft
Point 172	1,283.8446 ft	587.5 ft

Regions

	Material	Points	Area
Region 1	3_Fill	7,6,5,4,3,2,1,104,105,106,11,31,111,10,9,8,110	3,245.9 ft²
Region 2	0_CCR Cover	151,150,146,147	69.398 ft²
Region 3	0_CCR Cover	39,113,112,38	54.899 ft²
Region 4		85,84,83,82,81,80,97,127,115,116,102,88,87,86,119	544.34 ft²
Region 5	4_Alluvial	104,160,161,108,109,16,15,14,13,12,106,105	50,673 ft²
Region 6	3_Fill	22,21,103,20,19,18,17,109,108,28,27,118,26,25,24,23,117	6,391.6 ft²
Region 7		31,99,98,112,38,37,36,35,34,33,32,10,111	144.93 ft²
Region 8	0_CCR Cover	11,31,99,98,112,113	36.812 ft²
Region 9	2_CCR Ash Wet Dallman	11,106,12,13,14,15,16,109,17,18,19,20,103,114,134,133,113	31,469 ft²
Region 10	0_CCR Cover	100,101,116,117,22,21,103,114,115	34.206 ft²
Region 11		101,100,115,116	20.98 ft²
Region 12		102,23,117,116	10.712 ft²
Region 13	0_CCR Cover	114,115,127,128	56.28 ft²
Region 14	1_CCR Ash Wet Lakeside	128,79,140,162,143	259.36 ft²
Region 15	0_CCR Cover	97,79,128,127	41.289 ft²
Region 16	1_CCR Ash Wet Lakeside	39,40,41,132,130	16.608 ft²
Region 17	0_CCR Cover	38,39,130,131	16.5 ft²
Region 18	1_CCR Ash Wet Lakeside	42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,129,142,130,132	6,557.7 ft²
Region 19	1_CCR Ash Wet Lakeside	41,40,39,113,133,132	111.16 ft²
Region 20	1_CCR Ash Wet Lakeside	114,128,134	114.36 ft²
Region 21	0_CCR Cover	131,130,121,136,135	72.406 ft²
Region 22	1_CCR Ash Wet Lakeside	121,130,142,163,136	247.74 ft²
Region 23	1_CCR Ash Wet Lakeside	61,137,138	1.0592 ft²
Region 24	1_CCR Ash Wet Lakeside	62,139,138	4.8884 ft²
Region 25	1_CCR Ash Wet Lakeside	140,78,77,76,75,74,73,72,71,70,69,165,166,162	106.36 ft²
Region 26	0_CCR Cover	79,97,141,140	11.534 ft²
Region 27	0_CCR Cover	135,136,122,145,144	73.437 ft²
Region 28	0_CCR Cover	78,140,141,147,146	68.487 ft²
Region 29	1_CCR Ash Wet Lakeside	75,76,77,78,146,152,165,69,70,71,72,73,74	287.04 ft²
Region 30	0_CCR Cover	144,145,149,148	74.468 ft²
Region 31	1_CCR Ash Wet Lakeside	156,150,89,125,155,172,171	660.51 ft²
Region 32	0_CCR Cover	91,90,155,125,89,150,151,96,95,94,93,148,149,92,126,154	2,067.8 ft²
Region 33	1_CCR Ash Wet Lakeside	145,153,167,157,149	488.7 ft²
Region 34	1_CCR Ash Wet Lakeside	90,159,172,155	929.69 ft²
Region 35	1_CCR Ash Wet Lakeside	154,169,158,91	1,037.6 ft²
Region 36	1_CCR Ash Wet Lakeside	91,158,159,90	2,913 ft²
Region 37	5_Shale	30,29,161,160	1.9e+05 ft²
Region 38	1_CCR Ash Wet Lakeside	143,129,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,43,42,132,133,134,128	2,964.2 ft²
Region 39	1_CCR Ash Wet Lakeside	139,62,138,137,60,59,120,129,143,162,166	1,065.9 ft²
Region 40	1_CCR Ash Wet Lakeside	129,120,59,60,137,164,163,142	7,701 ft²
Region 41	1_CCR Ash Wet Lakeside	145,122,136,163,164,153	368.22 ft²
Region 42	1_CCR Ash Wet Lakeside	153,164,137,61,138,139,63,123,64,65,66,124,67,68,165,152,170,167	7,912.4 ft²
Region 43	1_CCR Ash Wet Lakeside	68,67,124,66,65,64,123,63,139,166,165	108.41 ft²
Region 44	1_CCR Ash Wet Lakeside	152,146,150,156,170	546.11 ft²
Region 45	1_CCR Ash Wet Lakeside	154,126,92,149,157,168,169	567.6 ft²
Region 46	1_CCR Ash Wet Lakeside	168,157,167,170,156,171	7,271.8 ft²
Region 47	1_CCR Ash Wet Lakeside	159,158,169,168,171,172	6,521.8 ft²

Slip Results

Slip Surfaces Analysed: 2520 of 3381 converged

Current Slip Surface

Slip Surface: 3,381
Factor of Safety: 1.52
Volume: 12,274.368 ft³
Weight: 1,431,839.9 lbf
Resisting Moment: 34,157,966 lbf·ft
Activating Moment: 22,403,318 lbf·ft
Resisting Force: 199,951.35 lbf
Activating Force: 131,164.37 lbf
Slip Rank: 1 of 3,381 slip surfaces
Exit: (1,528.8228, 548.40055) ft
Entry: (1,308.9112, 589.76021) ft
Radius: 110.85556 ft
Center: (1,429.7664, 627.80457) ft

Slip Columns

	X	Y	PWP	Base Normal Stress	Frictional Strength	Cohesive Strength	Suction Strength	Column Base Material

Column 1	1,309.4502 ft	588.70467 ft	-2,416.3397 psf	-1,071.9561 psf	0 psf	1,000 psf	0 psf	0_CCR Cover
Column 2	1,311.2236 ft	585.23112 ft	-2,199.4853 psf	151.09659 psf	87.235659 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 3	1,313.1865 ft	581.40656 ft	-1,960.7172 psf	397.34936 psf	229.40976 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 4	1,314.4166 ft	579.03076 ft	-1,812.3956 psf	551.75036 psf	318.55322 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 5	1,315.4619 ft	577.01214 ft	-1,686.3728 psf	679.89194 psf	392.53579 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 6	1,316.9179 ft	574.23138 ft	-1,512.7696 psf	867.04863 psf	500.59076 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 7	1,318.6914 ft	570.86732 ft	-1,302.7507 psf	1,083.5877 psf	625.60964 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 8	1,320.6958 ft	567.11732 ft	-1,068.6375 psf	1,340.7709 psf	774.09444 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 9	1,321.9445 ft	564.80539 ft	-924.30298 psf	1,558.5433 psf	899.82538 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 10	1,322.5744 ft	563.63930 ft	-851.50407 psf	1,576.222 psf	910.03221 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 11	1,324.5447 ft	560.08391 ft	-629.54071 psf	1,831.9755 psf	1,057.6915 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 12	1,326.1486 ft	557.21721 ft	-450.57157 psf	2,088.8576 psf	1,206.0025 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 13	1,326.4764 ft	556.63127 ft	-413.99154 psf	2,122.2269 psf	1,225.2683 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 14	1,328.4195 ft	553.33601 ft	-208.26773 psf	2,337.5971 psf	1,349.6123 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 15	1,330.3074 ft	550.17195 ft	-10.734559 psf	2,798.6627 psf	1,615.8087 psf	200 psf	0 psf	1_CCR Ash Wet Lakeside
Column 16	1,332.0809 ft	547.50675 ft	155.65438 psf	3,137.7486 psf	1,585.6076 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 17	1,335.5134 ft	542.57108 ft	463.78888 psf	3,704.6352 psf	1,723.1886 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 18	1,339.0604 ft	537.79139 ft	762.18582 psf	4,220.9276 psf	1,839.0456 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 19	1,342.6073 ft	533.22195 ft	1,047.4571 psf	4,723.6018 psf	1,954.6408 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 20	1,345.3028 ft	529.90791 ft	1,254.3531 psf	5,138.4563 psf	2,065.2143 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 21	1,346.5768 ft	528.41302 ft	1,347.6794 psf	5,504.296 psf	0 psf	1,800 psf	0 psf	3_Fill
Column 22	1,347.4283 ft	527.41390 ft	1,410.0545 psf	6,366.3179 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 23	1,349.0792 ft	525.73210 ft	1,515.0496 psf	6,693.0461 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 24	1,350.6439 ft	524.24293 ft	1,608.0186 psf	6,860.8672 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 25	1,351.2661 ft	523.65085 ft	1,644.9822 psf	6,935.3098 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 26	1,352.2227 ft	522.84358 ft	1,695.3806 psf	7,103.1627 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 27	1,353.9962 ft	521.40039 ft	1,785.4793 psf	7,257.4141 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 28	1,356.2141 ft	519.69512 ft	1,891.9393 psf	7,500.0333 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 29	1,357.9876 ft	518.39999 ft	1,972.7948 psf	7,643.5496 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 30	1,360.3422 ft	516.78253 ft	2,073.7732 psf	7,854.0592 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 31	1,362.7825 ft	515.16938 ft	2,174.4824 psf	8,062.984 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 32	1,363.9756 ft	514.41781 ft	2,221.4028 psf	8,145.4838 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 33	1,365.0822 ft	513.72070 ft	2,264.9232 psf	8,219.5668 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 34	1,367.1513 ft	512.46705 ft	2,343.1893 psf	8,374.1465 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 35	1,368.9248 ft	511.40913 ft	2,409.2354 psf	8,500.4974 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 36	1,369.4760 ft	511.08990 ft	2,429.1647 psf	8,563.2444 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 37	1,371.2494 ft	510.09557 ft	2,491.2412 psf	8,617.8585 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 38	1,374.3006 ft	508.47827 ft	2,592.2093 psf	8,758.5304 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 39	1,376.0741 ft	507.59124 ft	2,647.5871 psf	8,824.3404 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 40	1,377.6292 ft	506.89355 ft	2,691.1435 psf	8,888.523 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 41	1,379.4027 ft	506.11373 ft	2,739.8281 psf	8,932.3308 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 42	1,381.6240 ft	505.24063 ft	2,794.3356 psf	9,004.576 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 43	1,383.6210 ft	504.49180 ft	2,841.0857 psf	9,092.9658 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 44	1,384.1426 ft	504.32240 ft	2,851.6611 psf	9,085.164 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 45	1,385.6925 ft	503.81900 ft	2,883.0883 psf	9,089.4394 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 46	1,388.2050 ft	503.07186 ft	2,929.7329 psf	9,143.9962 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 47	1,389.9785 ft	502.59280 ft	2,959.6407 psf	9,147.1049 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 48	1,391.1701 ft	502.30684 ft	2,977.4929 psf	9,186.2819 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 49	1,392.9436 ft	501.92168 ft	3,001.5385 psf	9,178.6699 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 50	1,395.8118 ft	501.38978 ft	3,034.7452 psf	9,195.8877 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 51	1,399.3587 ft	500.88970 ft	3,065.965 psf	9,188.6255 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 52	1,401.1431 ft	500.68305 ft	3,078.8667 psf	9,197.9722 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 53	1,402.2312 ft	500.60925 ft	3,083.4739 psf	9,174.6344 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 54	1,403.9937 ft	500.48970 ft	3,090.9376 psf	9,136.8767 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 55	1,406.4527 ft	500.39912 ft	3,096.5923 psf	9,109.0973 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 56	1,409.1692 ft	500.34021 ft	3,100.27 psf	9,043.6561 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 57	1,410.9427 ft	500.31233 ft	3,102.0108 psf	8,995.0573 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 58	1,413.5466 ft	500.27423 ft	3,104.3892 psf	8,924.6207 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 59	1,416.6946 ft	500.23198 ft	3,107.0271 psf	8,838.7533 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 60	1,418.4680 ft	500.20977 ft	3,108.4137 psf	8,789.4986 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 61	1,419.7105 ft	500.19555 ft	3,109.3012 psf	8,756.0647 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 62	1,421.0123 ft	500.18132 ft	3,110.1895 psf	8,719.6691 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 63	1,421.9423 ft	500.17116 ft	3,110.8241 psf	8,693.6682 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 64	1,424.1874 ft	500.14944 ft	3,112.1802 psf	8,631.6923 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 65	1,426.6701 ft	500.12737 ft	3,113.5579 psf	8,563.0049 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 66	1,428.4437 ft	500.11361 ft	3,114.4169 psf	8,512.7698 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 67	1,430.0896 ft	500.10176 ft	3,115.1566 psf	8,467.2466 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 68	1,431.8632 ft	500.09081 ft	3,115.8403 psf	8,416.6859 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 69	1,433.4497 ft	500.08163 ft	3,116.4131 psf	8,372.5751 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 70	1,435.2232 ft	500.07347 ft	3,116.9225 psf	8,321.6926 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 71	1,437.1160 ft	500.06557 ft	3,117.4157 psf	8,268.4807 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 72	1,438.8895 ft	500.06020 ft	3,117.7509 psf	8,217.2733 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 73	1,441.9223 ft	500.05380 ft	3,118.1507 psf	8,130.5625 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 74	1,445.4693 ft	500.06097 ft	3,117.7027 psf	8,031.2925 psf	0 psf	750 psf	0 psf	4_Alluvial

Column 75	1,448.2721 ft	500.11093 ft	3,114.5842 psf	7,968.6331 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 76	1,450.0456 ft	500.18017 ft	3,110.2615 psf	7,908.5412 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 77	1,451.2215 ft	500.24244 ft	3,106.3737 psf	7,894.8027 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 78	1,452.9950 ft	500.37887 ft	3,097.8564 psf	7,826.5822 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 79	1,456.1101 ft	500.68737 ft	3,078.5968 psf	7,727.5373 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 80	1,458.6930 ft	501.01858 ft	3,057.9193 psf	7,642.1384 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 81	1,459.8456 ft	501.19787 ft	3,046.726 psf	7,587.3082 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 82	1,460.8096 ft	501.34784 ft	3,037.3633 psf	7,541.6265 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 83	1,463.2040 ft	501.79274 ft	3,009.5883 psf	7,449.7209 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 84	1,465.5903 ft	502.28707 ft	2,978.7274 psf	7,352.8647 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 85	1,467.3638 ft	502.70968 ft	2,952.3435 psf	7,253.4833 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 86	1,470.2980 ft	503.48516 ft	2,903.9299 psf	7,113.0083 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 87	1,473.8449 ft	504.56132 ft	2,836.7457 psf	6,920.9176 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 88	1,477.3919 ft	505.79633 ft	2,759.6431 psf	6,710.6619 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 89	1,480.9389 ft	507.19444 ft	2,672.3589 psf	6,481.6184 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 90	1,483.2784 ft	508.19242 ft	2,610.0549 psf	6,326.1608 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 91	1,484.8572 ft	508.91085 ft	2,565.2034 psf	6,198.0291 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 92	1,486.0646 ft	509.46027 ft	2,530.9032 psf	6,100.0404 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 93	1,488.0327 ft	510.41995 ft	2,470.9897 psf	5,957.8037 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 94	1,490.4108 ft	511.61527 ft	2,396.3657 psf	5,782.3261 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 95	1,491.8198 ft	512.37087 ft	2,349.1934 psf	5,654.2835 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 96	1,492.9887 ft	512.99769 ft	2,310.0612 psf	5,547.2587 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 97	1,494.2604 ft	513.73290 ft	2,264.1622 psf	5,462.3812 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 98	1,496.0340 ft	514.78798 ft	2,198.2933 psf	5,284.7877 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 99	1,498.6737 ft	516.50157 ft	2,091.3133 psf	5,057.4117 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 100	1,502.0266 ft	518.95894 ft	1,937.8992 psf	4,746.2676 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 101	1,503.8000 ft	520.37276 ft	1,849.6345 psf	4,525.1706 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 102	1,505.7676 ft	522.32094 ft	1,728.0086 psf	4,373.7285 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 103	1,509.3146 ft	526.14511 ft	1,489.2656 psf	3,895.2115 psf	0 psf	750 psf	0 psf	4_Alluvial
Column 104	1,512.7141 ft	530.03395 ft	1,246.4841 psf	4,163.6821 psf	0 psf	1,800 psf	0 psf	3_Fill
Column 105	1,514.4876 ft	532.06052 ft	1,117.703 psf	3,866.744 psf	0 psf	1,800 psf	0 psf	3_Fill
Column 106	1,516.4084 ft	534.25280 ft	951.34616 psf	3,541.3512 psf	0 psf	1,800 psf	0 psf	3_Fill
Column 107	1,518.6362 ft	536.79467 ft	758.45264 psf	3,164.633 psf	0 psf	1,800 psf	0 psf	3_Fill
Column 108	1,520.4097 ft	538.81667 ft	604.98864 psf	2,866.1899 psf	0 psf	1,800 psf	0 psf	3_Fill
Column 109	1,521.9531 ft	540.57614 ft	471.44711 psf	2,605.4106 psf	0 psf	1,800 psf	0 psf	3_Fill
Column 110	1,523.2039 ft	542.00117 ft	363.27752 psf	2,395.0555 psf	0 psf	1,800 psf	0 psf	3_Fill
Column 111	1,524.3721 ft	543.33209 ft	262.25196 psf	2,198.5932 psf	0 psf	1,800 psf	0 psf	3_Fill
Column 112	1,524.8948 ft	543.92759 ft	217.0487 psf	1,011.2496 psf	422.2841 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 113	1,526.3407 ft	545.57428 ft	92.045144 psf	671.88808 psf	308.30796 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 114	1,527.9147 ft	547.36654 ft	-44.013335 psf	952.52607 psf	0 psf	1,000 psf	0 psf	0_CCR Cover
Column 115	1,528.5756 ft	548.11911 ft	-101.14412 psf	839.01206 psf	0 psf	1,000 psf	0 psf	0_CCR Cover
Column 116	1,528.7751 ft	548.34623 ft	-118.38552 psf	804.75488 psf	0 psf	1,000 psf	0 psf	0_CCR Cover

GT Row 6 Slope Stability (Reinf) (RL) (D)

Report generated using GeoStudio 2025.1.1. Copyright © 2025 Bentley Systems, Incorporated.

File Information

File Version: 11.08
Product Version: 25.1.1.182
Created By: Beya Kazadi
Last Edited By: Beya Kazadi
Revision Number: 373
Date: 09/14/2025
Time: 04:06:39 PM
File Name: CWLP Ash Pond Closure Slope Stabilty.gsz
Directory: I:\25jobs\25E0006_00\Admin\13-Calculations\GEOTECH\Geostudio Model\
Last Solved Date: 09/14/2025
Last Solved Time: 04:15:05 PM

Project Settings

Unit System: U.S. Customary Units

Analysis Settings

GT Row 6 Slope Stability (Reinf) (RL) (D)

Kind: SLOPE/W
Analysis Type: Limit Equilibrium
Settings
- Method: Spencer
- PWP Conditions from: Piezometric Surfaces
- Apply Phreatic Correction: No
- Staged Rapid Drawdown Analysis: No
- Unit Weight of Water: 62.430189 pcf

Slip Surface
- Slip Surface Settings
  - Search Method: Entry and Exit
  - Specify Radius Tangent Lines: No
  - Direction of Movement: Right to Left
  - Use Passive Mode: No
  - No. of Critical Slip Surfaces to Store: 1
- Geometry Settings
  - Minimum Slip Surface Depth: 3 ft
  - Minimum Slip Surface Volume: 35.314667 ft³
  - Number of Columns: 30
- Tension Crack Option: (none)

Optimization
- Optimize Critical Slip Surface: Yes
- Algorithm Settings
  - Algorithm Type: Particle Swarm Optimization
  - No. of Generations: 20
  - No. of Agents: 20
  - Maximum Iterations: 2,000
- Geometry Settings
  - Surface Shape: Spline
  - No. of Points
    - Starting: 8
    - Ending: 16
  - Maximum Concave Angle
    - Driving Side: 5 °
    - Resisting Side: 1 °

Convergence
- Factor of Safety Convergence Settings
  - Maximum Number of Iterations: 100
  - Tolerable Difference in F of S: 0.001
- Under-Relaxation Criteria
  - Initial Rate: 1
  - Minimum Rate: 0.1
  - Rate Reduction Factor: 0.65
  - Reduction Frequency (iterations): 50
- Solution Settings
  - Search Method: Root Finder
  - Tolerable difference between starting and converged F of S: 3
  - Maximum iterations to calculate converged lambda: 20
  - Maximum Absolute Lambda: 2

Materials

1_CCR Ash Wet Lakeside (D)

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 115 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 40 °
Phi-B: 0 °
Pore Water Pressure
    Piezometric Surface: 1

3_Fill (D)

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 115 pcf
Effective Cohesion: 270 psf
Effective Friction Angle: 28 °
Phi-B: 0 °
Pore Water Pressure
    Piezometric Surface: 1

4_Alluvial (D)

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 115 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 28 °
Phi-B: 0 °
Pore Water Pressure
    Piezometric Surface: 1

2_CCR Ash Wet Dallman

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 120 pcf
Effective Cohesion: 0 psf
Effective Friction Angle: 28 °
Phi-B: 0 °
Pore Water Pressure
    Piezometric Surface: 1

5_Shale

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 130 pcf
Effective Cohesion: 3,500 psf
Effective Friction Angle: 10 °
Phi-B: 0 °
Pore Water Pressure
    Piezometric Surface: 1

0_CCR Cover (D)

Slope Stability Material Model: Mohr-Coulomb
Unit Weight: 120 pcf
Effective Cohesion: 200 psf
Effective Friction Angle: 27 °
Phi-B: 0 °
Pore Water Pressure
    Piezometric Surface: 1

Reinforcements

GeoTube

Type: Geosynthetic
Interface Adhesion: 250 psf
Interface Shear Angle: 33 °
Surface Area Factor: 2
Pullout Resistance Reduction Factor: 1
Tensile Capacity: 6,000 lbf
Tensile Capacity Reduction Factor: 2.5
F of S Dependent: No
Force Distribution: Distributed
Face Anchorage: Yes
Factored Tensile Capacity: 2,400 lbf/ft

Slip Surface Entry and Exit

Left Type: Range
Left-Zone Left Coordinate: (162, 545.38628) ft
Left-Zone Right Coordinate: (272.9773, 558.71766) ft
Left-Zone Increment: 25
Right Type: Range
Right-Zone Left Coordinate: (353, 578.45962) ft

Right-Zone Right Coordinate: (441.6064, 589.55099) ft
Right-Zone Increment: 25
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (-100, 521.52159) ft
Right Coordinate: (1,600.183, 536.79114) ft

Piezometric Surfaces

Piezometric Surface 1

Coordinates

	X	Y
Coordinate 1	-100 ft	521.52159 ft
Coordinate 2	5.1706 ft	521.52159 ft
Coordinate 3	98 ft	528 ft
Coordinate 4	230.0828 ft	546.22419 ft
Coordinate 5	245.8889 ft	550 ft
Coordinate 6	1,290.84 ft	550 ft
Coordinate 7	1,306.07 ft	546.38067 ft
Coordinate 8	1,473.78 ft	538.02961 ft
Coordinate 9	1,492.58 ft	538.02961 ft
Coordinate 10	1,504.37 ft	537.484 ft
Coordinate 11	1,600.18 ft	536.79114 ft

Reinforcement Sets

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (276.4686, 550) ft
  X: 276.4686 ft
  Y: 550 ft
Range End: (1,161.7877, 550) ft
  X: 1,161.7877 ft
  Y: 550 ft
Orientation Type: Horizontal
Horizontal Direction: Right
Length: 98.36879 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 98.36879 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (276.4686, 557.4999) ft
  X: 276.4686 ft
  Y: 557.4999 ft
Range End: (1,161.7877, 557.4999) ft
  X: 1,161.7877 ft
  Y: 557.4999 ft
Orientation Type: Horizontal
Horizontal Direction: Right
Length: 98.36879 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 98.36879 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (326.4686, 557.5) ft
  X: 326.4686 ft
  Y: 557.5 ft
Range End: (1,111.969, 557.5) ft
  X: 1,111.969 ft
  Y: 557.5 ft
Orientation Type: Horizontal
Horizontal Direction: Right
Length: 98.187544 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 98.187544 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (326.4686, 564.999) ft
X: 326.4686 ft
Y: 564.999 ft
Range End: (1,111.969, 564.999) ft
X: 1,111.969 ft
Y: 564.999 ft
Orientation Type: Horizontal
Horizontal Direction: Right
Length: 98.187544 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 98.187544 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (376.4686, 565) ft
X: 376.4686 ft
Y: 565 ft
Range End: (1,062.1955, 565) ft
X: 1,062.1955 ft
Y: 565 ft
Orientation Type: Horizontal
Horizontal Direction: Right
Length: 97.960988 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.960988 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (376.4686, 572.4999) ft
X: 376.4686 ft
Y: 572.4999 ft
Range End: (1,062.1955, 572.4999) ft
X: 1,062.1955 ft
Y: 572.4999 ft
Orientation Type: Horizontal
Horizontal Direction: Right
Length: 97.960988 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.960988 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (426.4686, 572.5) ft
X: 426.4686 ft
Y: 572.5 ft
Range End: (1,012.4868, 572.5) ft
X: 1,012.4868 ft
Y: 572.5 ft
Orientation Type: Horizontal
Horizontal Direction: Right
Length: 97.6697 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.6697 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (426.4686, 579.999) ft
X: 426.4686 ft
Y: 579.999 ft
Range End: (1,012.4868, 579.999) ft
X: 1,012.4868 ft
Y: 579.999 ft
Orientation Type: Horizontal
Horizontal Direction: Right
Length: 97.6697 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.6697 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (476.4686, 580) ft
  X: 476.4686 ft
  Y: 580 ft
Range End: (962.87518, 580) ft
  X: 962.87518 ft
  Y: 580 ft
Orientation Type: Horizontal
Horizontal Direction: Right
Length: 97.281317 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.281317 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (476.4686, 587.4999) ft
  X: 476.4686 ft
  Y: 587.4999 ft
Range End: (962.87518, 587.4999) ft
  X: 962.87518 ft
  Y: 587.4999 ft
Orientation Type: Horizontal
Horizontal Direction: Right
Length: 97.281317 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.281317 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (687.7869, 587.5) ft
  X: 687.7869 ft
  Y: 587.5 ft
Range End: (767.83865, 587.5) ft
  X: 767.83865 ft
  Y: 587.5 ft
Orientation Type: Horizontal
Horizontal Direction: Right
Length: 80.05175 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 80.05175 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (687.7869, 595) ft
  X: 687.7869 ft
  Y: 595 ft
Range End: (767.83865, 595) ft
  X: 767.83865 ft
  Y: 595 ft
Orientation Type: Horizontal
Horizontal Direction: Right
Length: 80.05175 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 80.05175 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (326.4686, 565) ft
  X: 326.4686 ft
  Y: 565 ft
Range End: (1,210.1565, 565) ft
  X: 1,210.1565 ft
  Y: 565 ft
Orientation Type: Vertical
Length: 7.5 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 98.187544 ft

Reinforcement Sets

Reinforcement: GeoTube

Lock to Ground Surface: No
Range Start: (376.4686, 572.5) ft
X: 376.4686 ft
Y: 572.5 ft
Range End: (1,160.1565, 572.5) ft
X: 1,160.1565 ft
Y: 572.5 ft
Orientation Type: Vertical
Length: 7.5 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.960988 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (426.4686, 580) ft
X: 426.4686 ft
Y: 580 ft
Range End: (1,110.1565, 580) ft
X: 1,110.1565 ft
Y: 580 ft
Orientation Type: Vertical
Length: 7.5 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.6697 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (476.4686, 587.5) ft
X: 476.4686 ft
Y: 587.5 ft
Range End: (1,060.1565, 587.5) ft
X: 1,060.1565 ft
Y: 587.5 ft
Orientation Type: Vertical
Length: 7.5 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 97.281317 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (687.7869, 595) ft
X: 687.7869 ft
Y: 595 ft
Range End: (847.8904, 595) ft
X: 847.8904 ft
Y: 595 ft
Orientation Type: Vertical
Length: 7.5 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 80.05175 ft

Reinforcement Sets

Reinforcement: GeoTube
Lock to Ground Surface: No
Range Start: (276.4686, 557.5) ft
X: 276.4686 ft
Y: 557.5 ft
Range End: (1,260.1565, 557.5) ft
X: 1,260.1565 ft
Y: 557.5 ft
Orientation Type: Vertical
Length: 7.5 ft
Spacing Type: Horizontally
Distribution Type: Specify distance between reinforcements
Distance Between Reinforcements: 98.36879 ft

Reinforcement Lines

	Assigned Reinforcement	Reinforcement Set	Lock to Ground Surface	Outside Point	Inside Point	Length	Trend	Plunge	Slip Surface Intersection	Max. Pullout Force	Available Length	Pullout Force	Shear Force
Reinforcement Line 1	GeoTube	550	No	(276.4686, 550)	(374.8374, 550)	98.3688 ft	90 °	0 °	(351.78812, 550, 0)	2,400 lbf	23.049276 ft	2,400 lbf	0 lbf

Reinforcement Line 2	GeoTube	550	No	(374.8374, 550)	(473.2062, 550)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 3	GeoTube	550	No	(473.2062, 550)	(571.575, 550)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 4	GeoTube	550	No	(571.575, 550)	(669.9438, 550)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 5	GeoTube	550	No	(669.9438, 550)	(768.3125, 550)	98.3687 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 6	GeoTube	550	No	(768.3125, 550)	(866.6813, 550)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 7	GeoTube	550	No	(866.6813, 550)	(965.0501, 550)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 8	GeoTube	550	No	(965.0501, 550)	(1,063.4189, 550)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 9	GeoTube	550	No	(1,063.4189, 550)	(1,161.7877, 550)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 10	GeoTube	550	No	(1,161.7877, 550)	(1,260.1565, 550)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 11	GeoTube	550 (T)	No	(276.4686, 557.4999)	(374.8374, 557.4999)	98.3688 ft	90 °	0 °	(360.7288, 557.4999, 0)	2,400 lbf	14.108603 ft	2,400 lbf	0 lbf
Reinforcement Line 12	GeoTube	550 (T)	No	(374.8374, 557.4999)	(473.2062, 557.4999)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 13	GeoTube	550 (T)	No	(473.2062, 557.4999)	(571.575, 557.4999)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 14	GeoTube	550 (T)	No	(571.575, 557.4999)	(669.9438, 557.4999)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 15	GeoTube	550 (T)	No	(669.9438, 557.4999)	(768.3125, 557.4999)	98.3687 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 16	GeoTube	550 (T)	No	(768.3125, 557.4999)	(866.6813, 557.4999)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 17	GeoTube	550 (T)	No	(866.6813, 557.4999)	(965.0501, 557.4999)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 18	GeoTube	550 (T)	No	(965.0501, 557.4999)	(1,063.4189, 557.4999)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 19	GeoTube	550 (T)	No	(1,063.4189, 557.4999)	(1,161.7877, 557.4999)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 20	GeoTube	550 (T)	No	(1,161.7877, 557.4999)	(1,260.1565, 557.4999)	98.3688 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 21	GeoTube	550 V	No	(276.4686, 557.5)	(276.4686, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 22	GeoTube	550 V	No	(374.8374, 557.5)	(374.8374, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 23	GeoTube	550 V	No	(473.2062, 557.5)	(473.2062, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 24	GeoTube	550 V	No	(571.575, 557.5)	(571.575, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 25	GeoTube	550 V	No	(669.9438, 557.5)	(669.9438, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 26	GeoTube	550 V	No	(768.3125, 557.5)	(768.3125, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 27	GeoTube	550 V	No	(866.6813, 557.5)	(866.6813, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 28	GeoTube	550 V	No	(965.0501, 557.5)	(965.0501, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 29	GeoTube	550 V	No	(1,063.4189, 557.5)	(1,063.4189, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 30	GeoTube	550 V	No	(1,161.7877, 557.5)	(1,161.7877, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 31	GeoTube	550 V	No	(1,260.1565, 557.5)	(1,260.1565, 550)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 32	GeoTube	557.5	No	(326.4686, 557.5)	(424.6561, 557.5)	98.1875 ft	90 °	0 °	(360.7289, 557.5, 0)	2,400 lbf	63.927198 ft	2,400 lbf	0 lbf
Reinforcement Line 33	GeoTube	557.5	No	(424.6561, 557.5)	(522.8437, 557.5)	98.1876 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 34	GeoTube	557.5	No	(522.8437, 557.5)	(621.0312, 557.5)	98.1875 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 35	GeoTube	557.5	No	(621.0312, 557.5)	(719.2188, 557.5)	98.1876 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 36	GeoTube	557.5	No	(719.2188, 557.5)	(817.4063, 557.5)	98.1875 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 37	GeoTube	557.5	No	(817.4063, 557.5)	(915.5939, 557.5)	98.1876 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 38	GeoTube	557.5	No	(915.5939, 557.5)	(1,013.7814, 557.5)	98.1875 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 39	GeoTube	557.5	No	(1,013.7814, 557.5)	(1,111.969, 557.5)	98.1876 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 40	GeoTube	557.5	No	(1,111.969, 557.5)	(1,210.1565, 557.5)	98.1875 ft	90 °	0 °	ft	2,400 lbf	0 ft		

Reinforcement Line 41	GeoTube	557.5 (T)	No	(326.4686, 564.999)	(424.6561, 564.999)	98.1875 ft	90 °	0 °	(368.7294, 564.999, 0)	2,400 lbf	55.9267 ft	2,400 lbf	0 lbf
Reinforcement Line 42	GeoTube	557.5 (T)	No	(424.6561, 564.999)	(522.8437, 564.999)	98.1876 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 43	GeoTube	557.5 (T)	No	(522.8437, 564.999)	(621.0312, 564.999)	98.1875 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 44	GeoTube	557.5 (T)	No	(621.0312, 564.999)	(719.2188, 564.999)	98.1876 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 45	GeoTube	557.5 (T)	No	(719.2188, 564.999)	(817.4063, 564.999)	98.1875 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 46	GeoTube	557.5 (T)	No	(817.4063, 564.999)	(915.5939, 564.999)	98.1876 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 47	GeoTube	557.5 (T)	No	(915.5939, 564.999)	(1,013.7814, 564.999)	98.1875 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 48	GeoTube	557.5 (T)	No	(1,013.7814, 564.999)	(1,111.969, 564.999)	98.1876 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 49	GeoTube	557.5 (T)	No	(1,111.969, 564.999)	(1,210.1565, 564.999)	98.1875 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 50	GeoTube	557.5 V	No	(326.4686, 565)	(326.4686, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 51	GeoTube	557.5 V	No	(424.6561, 565)	(424.6561, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 52	GeoTube	557.5 V	No	(522.8437, 565)	(522.8437, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 53	GeoTube	557.5 V	No	(621.0312, 565)	(621.0312, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 54	GeoTube	557.5 V	No	(719.2188, 565)	(719.2188, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 55	GeoTube	557.5 V	No	(817.4063, 565)	(817.4063, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 56	GeoTube	557.5 V	No	(915.5939, 565)	(915.5939, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 57	GeoTube	557.5 V	No	(1,013.7814, 565)	(1,013.7814, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 58	GeoTube	557.5 V	No	(1,111.969, 565)	(1,111.969, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 59	GeoTube	557.5 V	No	(1,210.1565, 565)	(1,210.1565, 557.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 60	GeoTube	565	No	(376.4686, 565)	(474.4296, 565)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 61	GeoTube	565	No	(474.4296, 565)	(572.3906, 565)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 62	GeoTube	565	No	(572.3906, 565)	(670.3516, 565)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 63	GeoTube	565	No	(670.3516, 565)	(768.3125, 565)	97.9609 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 64	GeoTube	565	No	(768.3125, 565)	(866.2735, 565)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 65	GeoTube	565	No	(866.2735, 565)	(964.2345, 565)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 66	GeoTube	565	No	(964.2345, 565)	(1,062.1955, 565)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 67	GeoTube	565	No	(1,062.1955, 565)	(1,160.1565, 565)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 68	GeoTube	565 (T)	No	(376.4686, 572.4999)	(474.4296, 572.4999)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 69	GeoTube	565 (T)	No	(474.4296, 572.4999)	(572.3906, 572.4999)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 70	GeoTube	565 (T)	No	(572.3906, 572.4999)	(670.3516, 572.4999)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 71	GeoTube	565 (T)	No	(670.3516, 572.4999)	(768.3125, 572.4999)	97.9609 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 72	GeoTube	565 (T)	No	(768.3125, 572.4999)	(866.2735, 572.4999)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 73	GeoTube	565 (T)	No	(866.2735, 572.4999)	(964.2345, 572.4999)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 74	GeoTube	565 (T)	No	(964.2345, 572.4999)	(1,062.1955, 572.4999)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 75	GeoTube	565 (T)	No	(1,062.1955, 572.4999)	(1,160.1565, 572.4999)	97.961 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 76	GeoTube	565 V	No	(376.4686, 572.5)	(376.4686, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 77	GeoTube	565 V	No	(474.4296, 572.5)	(474.4296, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 78	GeoTube	565 V	No	(572.3906, 572.5)	(572.3906, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 79	GeoTube	565 V	No	(670.3516, 572.5)	(670.3516, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 80	GeoTube	565 V	No	(768.3125, 572.5)	(768.3125, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		

Reinforcement Line 81	GeoTube	565 V	No	(866.2735, 572.5)	(866.2735, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 82	GeoTube	565 V	No	(964.2345, 572.5)	(964.2345, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 83	GeoTube	565 V	No	(1,062.1955, 572.5)	(1,062.1955, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 84	GeoTube	565 V	No	(1,160.1565, 572.5)	(1,160.1565, 565)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 85	GeoTube	572.5	No	(426.4686, 572.5)	(524.1383, 572.5)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 86	GeoTube	572.5	No	(524.1383, 572.5)	(621.808, 572.5)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 87	GeoTube	572.5	No	(621.808, 572.5)	(719.4777, 572.5)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 88	GeoTube	572.5	No	(719.4777, 572.5)	(817.1474, 572.5)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 89	GeoTube	572.5	No	(817.1474, 572.5)	(914.8171, 572.5)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 90	GeoTube	572.5	No	(914.8171, 572.5)	(1,012.4868, 572.5)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 91	GeoTube	572.5	No	(1,012.4868, 572.5)	(1,110.1565, 572.5)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 92	GeoTube	572.5 (T)	No	(426.4686, 579.999)	(524.1383, 579.999)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 93	GeoTube	572.5 (T)	No	(524.1383, 579.999)	(621.808, 579.999)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 94	GeoTube	572.5 (T)	No	(621.808, 579.999)	(719.4777, 579.999)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 95	GeoTube	572.5 (T)	No	(719.4777, 579.999)	(817.1474, 579.999)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 96	GeoTube	572.5 (T)	No	(817.1474, 579.999)	(914.8171, 579.999)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 97	GeoTube	572.5 (T)	No	(914.8171, 579.999)	(1,012.4868, 579.999)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 98	GeoTube	572.5 (T)	No	(1,012.4868, 579.999)	(1,110.1565, 579.999)	97.6697 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 99	GeoTube	572.5 V	No	(426.4686, 580)	(426.4686, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 100	GeoTube	572.5 V	No	(524.1383, 580)	(524.1383, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 101	GeoTube	572.5 V	No	(621.808, 580)	(621.808, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 102	GeoTube	572.5 V	No	(719.4777, 580)	(719.4777, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 103	GeoTube	572.5 V	No	(817.1474, 580)	(817.1474, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 104	GeoTube	572.5 V	No	(914.8171, 580)	(914.8171, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 105	GeoTube	572.5 V	No	(1,012.4868, 580)	(1,012.4868, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 106	GeoTube	572.5 V	No	(1,110.1565, 580)	(1,110.1565, 572.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 107	GeoTube	580	No	(476.4686, 580)	(573.7499, 580)	97.2813 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 108	GeoTube	580	No	(573.7499, 580)	(671.0312, 580)	97.2813 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 109	GeoTube	580	No	(671.0312, 580)	(768.3126, 580)	97.2814 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 110	GeoTube	580	No	(768.3126, 580)	(865.5939, 580)	97.2813 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 111	GeoTube	580	No	(865.5939, 580)	(962.8752, 580)	97.2813 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 112	GeoTube	580	No	(962.8752, 580)	(1,060.1565, 580)	97.2813 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 113	GeoTube	580 (T)	No	(476.4686, 587.4999)	(573.7499, 587.4999)	97.2813 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 114	GeoTube	580 (T)	No	(573.7499, 587.4999)	(671.0312, 587.4999)	97.2813 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 115	GeoTube	580 (T)	No	(671.0312, 587.4999)	(768.3126, 587.4999)	97.2814 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 116	GeoTube	580 (T)	No	(768.3126, 587.4999)	(865.5939, 587.4999)	97.2813 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 117	GeoTube	580 (T)	No	(865.5939, 587.4999)	(962.8752, 587.4999)	97.2813 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 118	GeoTube	580 (T)	No	(962.8752, 587.4999)	(1,060.1565, 587.4999)	97.2813 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 119	GeoTube	580 V	No	(476.4686, 587.5)	(476.4686, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 120	GeoTube	580 V	No	(573.7499, 587.5)	(573.7499, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		

Reinforcement Line 121	GeoTube	580 V	No	(671.0312, 587.5)	(671.0312, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 122	GeoTube	580 V	No	(768.3126, 587.5)	(768.3126, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 123	GeoTube	580 V	No	(865.5939, 587.5)	(865.5939, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 124	GeoTube	580 V	No	(962.8752, 587.5)	(962.8752, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 125	GeoTube	580 V	No	(1,060.1565, 587.5)	(1,060.1565, 580)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 126	GeoTube	587.5	No	(687.7869, 587.5)	(767.8386, 587.5)	80.0517 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 127	GeoTube	587.5	No	(767.8386, 587.5)	(847.8904, 587.5)	80.0518 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 128	GeoTube	587.5 (T)	No	(687.7869, 595)	(767.8386, 595)	80.0517 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 129	GeoTube	587.5 (T)	No	(767.8386, 595)	(847.8904, 595)	80.0518 ft	90 °	0 °	ft	2,400 lbf	0 ft		
Reinforcement Line 130	GeoTube	587.5 V	No	(687.7869, 595)	(687.7869, 587.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 131	GeoTube	587.5 V	No	(767.8386, 595)	(767.8386, 587.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		
Reinforcement Line 132	GeoTube	587.5 V	No	(847.8904, 595)	(847.8904, 587.5)	7.5 ft	0 °	90 °	ft	2,400 lbf	0 ft		

Geometry

Name: East West Profile

Settings

View: 2D

Element Thickness: 1 ft

Points

	X	Y
Point 1	1,504.3671 ft	537.484 ft
Point 2	1,504.3671 ft	400 ft
Point 3	-1.6325 ft	400 ft
Point 4	-1.6325 ft	521.52159 ft
Point 5	5.1706 ft	521.52159 ft
Point 6	14.5155 ft	524.93605 ft
Point 7	17.1605 ft	530.4417 ft
Point 8	20.0809 ft	531.68945 ft
Point 9	38.7423 ft	532.79969 ft
Point 10	45.7344 ft	534.50992 ft
Point 11	56.2699 ft	534.50992 ft
Point 12	80.9491 ft	533.99787 ft
Point 13	97.8525 ft	536.0115 ft
Point 14	106.3958 ft	534.53512 ft
Point 15	127.1842 ft	534.43894 ft
Point 16	140.3356 ft	537.04947 ft
Point 17	175.5431 ft	550.59788 ft
Point 18	181.3269 ft	553.68731 ft
Point 19	214.5848 ft	551.85323 ft
Point 20	225.5655 ft	547.73585 ft
Point 21	230.0828 ft	546.22419 ft
Point 22	270.06 ft	529.5079 ft
Point 23	277.7048 ft	527.72643 ft
Point 24	298.4544 ft	524.93033 ft
Point 25	499.8713 ft	525.48135 ft
Point 26	700.9628 ft	525.48135 ft
Point 27	1,102.027 ft	524.8529 ft
Point 28	1,240.1486 ft	524.55129 ft
Point 29	1,248.2762 ft	526.86016 ft
Point 30	1,264.3203 ft	528.83307 ft
Point 31	1,295.2655 ft	540.91093 ft
Point 32	1,306.0689 ft	546.38067 ft
Point 33	1,311.0258 ft	547.85638 ft
Point 34	1,321.4712 ft	551.26914 ft
Point 35	1,343.9155 ft	552.25166 ft
Point 36	1,366.514 ft	551.12961 ft
Point 37	1,401.6504 ft	550.73319 ft
Point 38	1,418.2559 ft	550.24258 ft
Point 39	1,431.2469 ft	547.46237 ft
Point 40	1,440.227 ft	543.2104 ft
Point 41	1,458.758 ft	539.11622 ft

Point 42	1,473.7817 ft	538.02961 ft
Point 43	1,492.5848 ft	538.02961 ft
Point 44	1,288.6321 ft	552.32095 ft
Point 45	1,279.073 ft	552.79496 ft
Point 46	1,260.7327 ft	550.80543 ft
Point 47	970.8769 ft	550.29043 ft
Point 48	628.7548 ft	550.40632 ft
Point 49	486.748 ft	550.40632 ft
Point 50	484.1507 ft	552.60068 ft
Point 51	473.7974 ft	554.48394 ft
Point 52	467.0651 ft	557.03906 ft
Point 53	451.6321 ft	557.88158 ft
Point 54	438.8762 ft	557.06268 ft
Point 55	431.3171 ft	554.61386 ft
Point 56	408.7187 ft	554.61386 ft
Point 57	396.9623 ft	555.19391 ft
Point 58	355.3288 ft	552.63276 ft
Point 59	338.3209 ft	555.0955 ft
Point 60	290.0336 ft	553.96032 ft
Point 61	274.7817 ft	552.68079 ft
Point 62	257.1111 ft	552.68079 ft
Point 63	248.1216 ft	552.58565 ft
Point 64	1,145.5297 ft	586.01071 ft
Point 65	847.8904 ft	595.06945 ft
Point 66	687.7869 ft	595.06945 ft
Point 67	390.9695 ft	586.00601 ft
Point 68	1,145.6044 ft	587.96996 ft
Point 69	847.6404 ft	597.06563 ft
Point 70	689.8867 ft	597.06563 ft
Point 71	391.8543 ft	588.04515 ft
Point 72	1,600.183 ft	536.79114 ft
Point 73	1,600 ft	400 ft
Point 74	-100 ft	521.52159 ft
Point 75	-100 ft	400 ft
Point 76	-100 ft	500 ft
Point 77	1,600.1338 ft	500 ft
Point 78	15.9875 ft	528 ft
Point 79	276.5308 ft	528 ft
Point 80	1,600.1712 ft	528 ft
Point 81	1,257.5456 ft	528 ft
Point 82	245.8889 ft	550 ft
Point 83	1,290.8362 ft	550 ft
Point 84	276.4686 ft	557.5 ft
Point 85	445.6883 ft	557.5 ft
Point 86	458.6218 ft	557.5 ft
Point 87	1,260.1565 ft	557.5 ft
Point 88	1,229.9753 ft	565.00686 ft
Point 89	336.7195 ft	572.5 ft
Point 90	1,199.8493 ft	572.5 ft
Point 91	366.845 ft	580 ft
Point 92	1,169.6957 ft	580 ft
Point 93	389.6446 ft	587.5 ft
Point 94	439.896 ft	587.5 ft
Point 95	1,096.5967 ft	587.5 ft
Point 96	1,147.4899 ft	587.5 ft
Point 97	687.7869 ft	587.5 ft
Point 98	847.8904 ft	587.5 ft
Point 99	276.4686 ft	552.82231 ft
Point 100	276.4686 ft	550 ft
Point 101	1,260.1565 ft	550.80441 ft
Point 102	1,260.1565 ft	550 ft
Point 103	1,210.1565 ft	557.5 ft
Point 104	1,160.1565 ft	565 ft
Point 105	1,110.1565 ft	572.5 ft
Point 106	1,060.1565 ft	580 ft
Point 107	326.4686 ft	557.5 ft
Point 108	376.4686 ft	565 ft
Point 109	306.594 ft	565 ft
Point 110	1,230.0029 ft	565 ft
Point 111	326.4686 ft	565 ft
Point 112	1,210.1565 ft	565 ft
Point 113	1,160.1565 ft	572.5 ft
Point 114	1,110.1565 ft	580 ft
Point 115	1,060.0098 ft	587.5 ft

Point 116	426.4686 ft	572.5 ft
Point 117	476.4686 ft	580 ft
Point 118	476.4686 ft	572.5 ft
Point 119	426.4686 ft	565 ft
Point 120	376.4686 ft	572.5 ft
Point 121	426.4686 ft	580 ft
Point 122	476.4686 ft	587.5 ft

Regions

	Points	Area	Material
Region 1	34,44,33	61.529 ft²	
Region 2	32,83,102,100,82,21,22,79,23,24,25,26,27,28,29,81,30,31	25,550 ft²	2_CCR Ash Wet Dallman
Region 3	20,19,63	73.063 ft²	
Region 4	62,61,99,84	46.525 ft²	1_CCR Ash Wet Lakeside (D)
Region 5	45,44,33,32,83	51.848 ft²	0_CCR Cover (D)
Region 6	63,62,82,21,20	55.738 ft²	0_CCR Cover (D)
Region 7	63,62,84,109,89,91,67,94,93	309.8 ft²	0_CCR Cover (D)
Region 8	74,76,77,80,81,29,28,27,26,25,24,23,79,78,6,5,4	44,156 ft²	4_Alluvial (D)
Region 9	75,3,2,73,77,76	1.7001e+05 ft²	5_Shale
Region 10	22,21,20,19,18,17,16,15,14,13,12,11,10,9,8,7,78,79	3,014.2 ft²	3_Fill (D)
Region 11	72,1,43,42,41,40,39,38,37,36,35,34,33,32,31,30,81,80	4,960.7 ft²	3_Fill (D)
Region 12	45,46,101,102,83	49.919 ft²	1_CCR Ash Wet Lakeside (D)
Region 13	84,107,111,109	262.03 ft²	1_CCR Ash Wet Lakeside (D)
Region 14	53,85,86	2.4676 ft²	1_CCR Ash Wet Lakeside (D)
Region 15	52,51,50,49,48,47,101,87,103,86	5,535.5 ft²	1_CCR Ash Wet Lakeside (D)
Region 16	64,95,115,106,114,92	677.04 ft²	1_CCR Ash Wet Lakeside (D)
Region 17	89,120,116,121,91	560.15 ft²	1_CCR Ash Wet Lakeside (D)
Region 18	66,65,95,96,68,69,70,71,93,94	1,420.5 ft²	0_CCR Cover (D)
Region 19	65,98,115,95	941.28 ft²	1_CCR Ash Wet Lakeside (D)
Region 20	64,92,90,88,110,87,45,44,96,95	304.58 ft²	0_CCR Cover (D)
Region 21	94,122,97,66	938.2 ft²	1_CCR Ash Wet Lakeside (D)
Region 22	66,97,98,65	1,211.9 ft²	1_CCR Ash Wet Lakeside (D)
Region 23	60,59,58,57,56,55,54,85,107,84,99	520.21 ft²	1_CCR Ash Wet Lakeside (D)
Region 24	61,62,82,100,99	67.055 ft²	1_CCR Ash Wet Lakeside (D)
Region 25	46,45,87,101	63.892 ft²	1_CCR Ash Wet Lakeside (D)
Region 26	47,48,49,50,51,52,86,85,54,55,56,57,58,59,60,99,100,102,101	1,321.9 ft²	1_CCR Ash Wet Lakeside (D)
Region 27	88,90,113,104,112,110	410.77 ft²	1_CCR Ash Wet Lakeside (D)
Region 28	85,53,86,103,112,104,119,108,111,107	6,625.2 ft²	1_CCR Ash Wet Lakeside (D)
Region 29	87,110,112,103	261.92 ft²	1_CCR Ash Wet Lakeside (D)
Region 30	113,90,92,114,105	559.62 ft²	1_CCR Ash Wet Lakeside (D)
Region 31	94,67,91,121,117,122	677.14 ft²	1_CCR Ash Wet Lakeside (D)
Region 32	89,109,111,108,120	411.09 ft²	1_CCR Ash Wet Lakeside (D)
Region 33	120,108,119,104,113,105,118,116	5,877.7 ft²	1_CCR Ash Wet Lakeside (D)
Region 34	121,116,118,105,114,106,117	5,127.7 ft²	1_CCR Ash Wet Lakeside (D)
Region 35	106,115,98,97,122,117	4,377.1 ft²	1_CCR Ash Wet Lakeside (D)

Slip Results

Slip Surfaces Analysed: 2909 of 3381 converged

Current Slip Surface

Slip Surface: 3,381
Factor of Safety: 2.69
Volume: 3,793.4648 ft³
Weight: 445,743.57 lbf
Resisting Moment: 25,407,449 lbf·ft
Activating Moment: 9,447,166.5 lbf·ft
Resisting Force: 189,664.29 lbf
Activating Force: 70,520.113 lbf
Slip Rank: 1 of 3,381 slip surfaces
Exit: (389.71499, 587.51737) ft
Entry: (226.55814, 547.94928) ft
Radius: 81.024218 ft
Center: (285.95947, 651.18208) ft

Slip Columns

	X	Y	PWP	Base Normal Stress	Frictional Strength	Cohesive Strength	Suction Strength	Column Base Material
Column 1	389.7072 ft	587.50868 ft	-2,341.6742 psf	-51.328201 psf	-26.153025 psf	200 psf	0 psf	0_CCR Cover (D)
Column 2	389.6720 ft	587.46931 ft	-2,339.2163 psf	-48.631034 psf	-24.77875 psf	200 psf	0 psf	0_CCR Cover (D)
Column 3	388.6313 ft	586.30512 ft	-2,266.5356 psf	31.125935 psf	15.859456 psf	200 psf	0 psf	0_CCR Cover (D)
Column 4	386.4004 ft	583.80967 ft	-2,110.744 psf	230.41083 psf	193.33764 psf	0 psf	0 psf	1_CCR Ash Wet Lakeside (D)
Column 5	384.0758 ft	581.22386 ft	-1,949.3115 psf	388.20207 psf	325.74021 psf	0 psf	0 psf	1_CCR Ash Wet Lakeside (D)
Column 6	381.8097 ft	578.71869 ft	-1,792.9129 psf	539.85831 psf	452.99491 psf	0 psf	0 psf	1_CCR Ash Wet Lakeside (D)
Column 7	378.3846 ft	574.97665 ft	-1,559.297 psf	770.49779 psf	646.52441 psf	0 psf	0 psf	1_CCR Ash Wet Lakeside (D)

Column 8	373.8526 ft	570.13358 ft	-1,256.9429 psf	1,074.7227 psf	901.79945 psf	0 psf	0 psf	1_CCR Ash Wet Lakeside (D)
Column 9	370.1585 ft	566.37561 ft	-1,022.3324 psf	1,339.2872 psf	1,123.7954 psf	0 psf	0 psf	1_CCR Ash Wet Lakeside (D)
Column 10	367.8924 ft	564.19269 ft	-886.05263 psf	1,483.924 psf	1,245.1601 psf	0 psf	0 psf	1_CCR Ash Wet Lakeside (D)
Column 11	364.7883 ft	561.29730 ft	-705.29226 psf	1,674.1327 psf	1,404.7642 psf	0 psf	0 psf	1_CCR Ash Wet Lakeside (D)
Column 12	361.6256 ft	558.35460 ft	-521.57925 psf	1,853.2069 psf	1,555.0252 psf	0 psf	0 psf	1_CCR Ash Wet Lakeside (D)
Column 13	359.3595 ft	556.19477 ft	-386.74066 psf	1,980.4852 psf	1,661.8244 psf	0 psf	0 psf	1_CCR Ash Wet Lakeside (D)
Column 14	356.6474 ft	553.76289 ft	-234.91763 psf	2,211.0288 psf	1,855.2735 psf	0 psf	0 psf	1_CCR Ash Wet Lakeside (D)
Column 15	354.3814 ft	551.86129 ft	-116.20038 psf	2,335.3556 psf	1,959.596 psf	0 psf	0 psf	1_CCR Ash Wet Lakeside (D)
Column 16	352.6230 ft	550.54317 ft	-33.910206 psf	2,596.0584 psf	2,178.3516 psf	0 psf	0 psf	1_CCR Ash Wet Lakeside (D)
Column 17	350.3570 ft	549.06890 ft	58.128749 psf	2,791.3455 psf	1,453.2771 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 18	346.6597 ft	546.87087 ft	195.35218 psf	3,003.7474 psf	1,493.2502 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 19	342.1275 ft	544.46544 ft	345.52362 psf	3,203.5453 psf	1,519.6371 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 20	339.0912 ft	542.97862 ft	438.3462 psf	3,375.6062 psf	1,561.7688 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 21	337.5202 ft	542.26823 ft	482.696 psf	3,411.6547 psf	1,557.355 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 22	336.0245 ft	541.59186 ft	524.92148 psf	3,456.2704 psf	1,558.6258 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 23	333.0633 ft	540.36991 ft	601.20865 psf	3,525.0681 psf	1,554.6437 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 24	328.5312 ft	538.66653 ft	707.55036 psf	3,637.8165 psf	1,558.0502 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 25	323.9991 ft	537.18237 ft	800.20675 psf	3,738.1194 psf	1,562.1159 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 26	319.4669 ft	535.90834 ft	879.7453 psf	3,813.7153 psf	1,560.0195 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 27	314.9348 ft	534.82006 ft	947.68683 psf	3,858.637 psf	1,547.7797 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 28	310.4026 ft	533.85343 ft	1,008.0331 psf	3,866.9752 psf	1,520.1265 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 29	307.3653 ft	533.24846 ft	1,045.8017 psf	3,894.7809 psf	1,514.8291 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 30	305.0992 ft	532.83406 ft	1,071.6731 psf	3,869.5606 psf	1,487.6632 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 31	301.3383 ft	532.22249 ft	1,109.8533 psf	3,871.9821 psf	1,468.6499 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 32	296.8062 ft	531.66973 ft	1,144.3622 psf	3,873.9912 psf	1,451.3695 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 33	292.2741 ft	531.30235 ft	1,167.2978 psf	3,820.7762 psf	1,410.8795 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 34	287.7419 ft	531.03392 ft	1,184.056 psf	3,741.9645 psf	1,360.0641 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 35	283.2099 ft	530.85705 ft	1,195.0977 psf	3,659.4149 psf	1,310.3007 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 36	278.6777 ft	530.88996 ft	1,193.0434 psf	3,590.3828 psf	1,274.688 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 37	275.5967 ft	531.08084 ft	1,181.1268 psf	3,560.8349 psf	1,265.3132 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 38	273.3306 ft	531.34975 ft	1,164.3387 psf	3,457.4141 psf	1,219.2498 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 39	269.6135 ft	531.95804 ft	1,126.3627 psf	3,345.8206 psf	1,180.1067 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 40	265.0813 ft	532.95836 ft	1,063.9128 psf	3,132.1283 psf	1,099.6897 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 41	260.5491 ft	534.21108 ft	985.70525 psf	2,874.5092 psf	1,004.2949 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 42	257.6971 ft	535.10549 ft	929.8669 psf	2,705.2181 psf	943.97096 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 43	255.4311 ft	535.90175 ft	880.15624 psf	2,520.8733 psf	872.38474 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 44	251.4849 ft	537.36083 ft	789.06577 psf	2,214.6382 psf	757.99031 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 45	248.6702 ft	538.45834 ft	720.54831 psf	1,991.6282 psf	675.84515 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 46	247.0052 ft	539.15265 ft	677.20232 psf	1,842.8821 psf	619.80293 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 47	245.2878 ft	539.86885 ft	623.525 psf	1,692.4675 psf	568.36682 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 48	242.4206 ft	541.10163 ft	503.80206 psf	1,445.9485 psf	500.94817 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 49	237.8885 ft	543.06286 ft	313.77243 psf	1,038.3352 psf	385.25685 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 50	233.3564 ft	545.01936 ft	124.03791 psf	631.87986 psf	270.02436 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 51	230.7408 ft	546.14733 ft	14.611933 psf	397.54988 psf	203.61172 psf	0 psf	0 psf	2_CCR Ash Wet Dallman
Column 52	230.2371 ft	546.36435 ft	-6.4495207 psf	403.73097 psf	205.7112 psf	200 psf	0 psf	0_CCR Cover (D)
Column 53	228.3205 ft	547.19004 ft	-75.478736 psf	221.69562 psf	112.95956 psf	200 psf	0 psf	0_CCR Cover (D)

SECTION 4

RocScience Settle3 Settlement Analysis

ROCSCIENCE



CWLP Dallman Ash Pond Closure
Hanson Professional Services
Report Creation Date: 2025/09/14, 18:44:08

Table of Contents

Project Settings 3
Advanced Settings 3
Soil Profile 3
Stage Settings 4
Results 5
Stage: Stage 1 = 0 d 5
Stage: Stage 2 = 2 d 5
Stage: Stage 3 = 4 d 6
Stage: Stage 4 = 6 d 7
Stage: Stage 5 = 8 d 8
Stage: Stage 6 = 10 d 9
Stage: Stage 7 = 12 d 10
Stage: Stage 8 = 30 d 11
Stage: Stage 9 = 90 d 12
Stage: Stage 10 = 180 d 13
Stage: Stage 11 = 365 d 14
Stage: Stage 12 = 730 d 15
Stage: Stage 13 = 1825 d 16
Stage: Stage 14 = 3650 d 17
Embankments 19
1. Embankment: "Embankment Load 1" 19
Soil Layers 20
DB-01 20
DB-02 20
DB-03 20
DB-04 21
DB-05 21
Soil Properties 23
Groundwater 24
Piezometric Line Entities 24

Settle3 Analysis Information

CWLP Dallman Ash Pond Closure

Project Settings

Document Name	20250804_LoadSettlement_Embankment.s3z
Project Title	CWLP Dallman Ash Pond Closure
Analysis	Settlement
Author	OKO
Company	Hanson Professional Services
Date Created	7/17/2025, 2:11:53 PM
Last saved with Settle3 version	5.026
Stress Computation Method	Boussinesq
Stress Units	Imperial, stress as ksf
Settlement Units	inches
Time-dependent Consolidation Analysis	
Time Units	days
Permeability Units	inches/second

Advanced Settings

Start of secondary consolidation (% of primary)	95
Min. stress for secondary consolidation (% of initial)	1
Reset time when load changes for secondary consolidation	No
Minimum settlement ratio for subgrade modulus	0.9
Use average poisson's ratio to calculate layered stresses	
Update Cv in each time step (improves consolidation accuracy)	
Ignore negative effective stresses in settlement calculations	
Add field points to load edges	

Soil Profile

Layer Option	Non-Horizontal Layers
Interpolation Method	TIN Triangulation
Use Non-Horizontal Ground Surface	No
Vertical Axis	Elevation
Ground Elevation (ft)	550

Stage Settings

Stage #	Name	Time [days]
1	Stage 1	0
2	Stage 2	2
3	Stage 3	4
4	Stage 4	6
5	Stage 5	8
6	Stage 6	10
7	Stage 7	12
8	Stage 8	30
9	Stage 9	90
10	Stage 10	180
11	Stage 11	365
12	Stage 12	730
13	Stage 13	1825
14	Stage 14	3650

Results

Time taken to compute: 0 seconds

Stage: Stage 1 = 0 d

Data Type	Minimum	Maximum
Total Settlement [in]	0	0
Total Consolidation Settlement [in]	0	0
Virgin Consolidation Settlement [in]	0	0
Recompression Consolidation Settlement [in]	0	0
Immediate Settlement [in]	0	0
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	0	0
Loading Stress XX [ksf]	0	0
Loading Stress YY [ksf]	0	0
Effective Stress ZZ [ksf]	0	3.8158
Effective Stress XX [ksf]	0	3.8158
Effective Stress YY [ksf]	0	3.8158
Total Stress ZZ [ksf]	0	7.435
Total Stress XX [ksf]	0	7.435
Total Stress YY [ksf]	0	7.435
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	0	0
Pore Water Pressure [ksf]	0	3.6192
Excess Pore Water Pressure [ksf]	0	0
Degree of Consolidation [%]	0	0
Pre-consolidation Stress [ksf]	0.03	3.81449
Over-consolidation Ratio	1	1
Void Ratio	0	1
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	0	0

Stage: Stage 2 = 2 d

Data Type	Minimum	Maximum
Total Settlement [in]	0	3.10333
Total Consolidation Settlement [in]	0	0
Virgin Consolidation Settlement [in]	0	0
Recompression Consolidation Settlement [in]	0	0
Immediate Settlement [in]	0	3.10333
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	-1.2586e-11	0.862967
Loading Stress XX [ksf]	-0.249633	0.971572
Loading Stress YY [ksf]	-0.273712	0.986409
Effective Stress ZZ [ksf]	0	3.8158
Effective Stress XX [ksf]	-0.135639	4.69199
Effective Stress YY [ksf]	-0.152301	4.70423
Total Stress ZZ [ksf]	-1.2586e-11	8.28992
Total Stress XX [ksf]	-0.135639	9.08598
Total Stress YY [ksf]	-0.152301	9.03716
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	0	0.00729077
Pore Water Pressure [ksf]	-1.2586e-11	4.47705
Excess Pore Water Pressure [ksf]	-1.2586e-11	0.862967
Degree of Consolidation [%]	0	0
Pre-consolidation Stress [ksf]	0.03	3.81449
Over-consolidation Ratio	1	1
Void Ratio	0	1
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	-1.11022e-16	1.73472e-18

Stage: Stage 3 = 4 d

Data Type	Minimum	Maximum
Total Settlement [in]	-8.84459e-05	6.44978
Total Consolidation Settlement [in]	-8.84459e-05	0.326572
Virgin Consolidation Settlement [in]	0	0.326572
Recompression Consolidation Settlement [in]	-8.84459e-05	0
Immediate Settlement [in]	0	6.20609
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	2.94928e-10	1.725
Loading Stress XX [ksf]	-0.467837	1.88967
Loading Stress YY [ksf]	-0.529438	1.99942
Effective Stress ZZ [ksf]	0	3.8158
Effective Stress XX [ksf]	-0.273077	5.60015
Effective Stress YY [ksf]	-0.309348	5.71572
Total Stress ZZ [ksf]	2.98071e-10	9.14966
Total Stress XX [ksf]	-0.273075	10.7776
Total Stress YY [ksf]	-0.309343	10.7744
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	-4.08957e-06	0.0206453
Pore Water Pressure [ksf]	2.94305e-10	5.33687
Excess Pore Water Pressure [ksf]	2.94305e-10	1.72473
Degree of Consolidation [%]	0	4.91202
Pre-consolidation Stress [ksf]	0.03	3.81449
Over-consolidation Ratio	1	1.00063
Void Ratio	0	1.00001
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	-1.54451e-05	0.0305222

Stage: Stage 4 = 6 d

Data Type	Minimum	Maximum
Total Settlement [in]	-0.000147535	9.85133
Total Consolidation Settlement [in]	-0.000147535	0.714428
Virgin Consolidation Settlement [in]	0	0.714429
Recompression Consolidation Settlement [in]	-0.000155187	0
Immediate Settlement [in]	0	9.30746
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	2.03038e-09	2.58749
Loading Stress XX [ksf]	-0.80724	2.86377
Loading Stress YY [ksf]	-0.767803	2.89344
Effective Stress ZZ [ksf]	2.98071e-10	4.22177
Effective Stress XX [ksf]	-0.409391	6.66464
Effective Stress YY [ksf]	-0.466402	6.79337
Total Stress ZZ [ksf]	2.03353e-09	10.007
Total Stress XX [ksf]	-0.409378	12.5079
Total Stress YY [ksf]	-0.466376	12.2887
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	-1.04913e-05	0.0356931
Pore Water Pressure [ksf]	1.72819e-09	6.19439
Excess Pore Water Pressure [ksf]	1.72819e-09	2.58686
Degree of Consolidation [%]	0	7.30143
Pre-consolidation Stress [ksf]	0.03	4.21867
Over-consolidation Ratio	1	1.00161
Void Ratio	0	1.00002
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	-1.54451e-05	0.0552877

Stage: Stage 5 = 8 d

Data Type	Minimum	Maximum
Total Settlement [in]	-0.000323496	13.2802
Total Consolidation Settlement [in]	-0.000323496	1.13275
Virgin Consolidation Settlement [in]	0	1.13276
Recompression Consolidation Settlement [in]	-0.000339073	0
Immediate Settlement [in]	0	12.4055
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	3.27979e-08	3.44996
Loading Stress XX [ksf]	-1.15599	3.43426
Loading Stress YY [ksf]	-0.989159	3.2461
Effective Stress ZZ [ksf]	2.03353e-09	5.08257
Effective Stress XX [ksf]	-0.542379	8.23715
Effective Stress YY [ksf]	-0.620149	8.00066
Total Stress ZZ [ksf]	3.27979e-08	10.8599
Total Stress XX [ksf]	-0.542347	14.2804
Total Stress YY [ksf]	-0.620089	14.0096
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	-1.83011e-05	0.0475048
Pore Water Pressure [ksf]	2.45266e-08	7.04754
Excess Pore Water Pressure [ksf]	2.45266e-08	3.44861
Degree of Consolidation [%]	0	9.05085
Pre-consolidation Stress [ksf]	0.03	5.07948
Over-consolidation Ratio	1	1.00281
Void Ratio	0	1.00004
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	-1.54451e-05	0.076267

Stage: Stage 6 = 10 d

Data Type	Minimum	Maximum
Total Settlement [in]	-0.000455709	16.7213
Total Consolidation Settlement [in]	-0.000455709	1.57067
Virgin Consolidation Settlement [in]	0	1.57067
Recompression Consolidation Settlement [in]	-0.000458899	0
Immediate Settlement [in]	0	15.4957
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	9.61076e-08	4.31238
Loading Stress XX [ksf]	-1.46602	4.42047
Loading Stress YY [ksf]	-1.19368	4.16967
Effective Stress ZZ [ksf]	3.27979e-08	5.94139
Effective Stress XX [ksf]	-0.670337	9.99836
Effective Stress YY [ksf]	-0.768163	9.70432
Total Stress ZZ [ksf]	9.61115e-08	11.7041
Total Stress XX [ksf]	-0.67028	16.0959
Total Stress YY [ksf]	-0.768061	15.7695
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	-2.05189e-05	0.0572192
Pore Water Pressure [ksf]	4.90192e-08	7.89224
Excess Pore Water Pressure [ksf]	4.90192e-08	4.30974
Degree of Consolidation [%]	0	11.0522
Pre-consolidation Stress [ksf]	0.03	5.93831
Over-consolidation Ratio	1	1.00315
Void Ratio	0	1.00004
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	-1.54451e-05	0.0945314

Stage: Stage 7 = 12 d

Data Type	Minimum	Maximum
Total Settlement [in]	-0.000526598	20.1552
Total Consolidation Settlement [in]	-0.000526598	2.02226
Virgin Consolidation Settlement [in]	0	2.02227
Recompression Consolidation Settlement [in]	-0.000529788	0
Immediate Settlement [in]	0	18.5644
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	1.00146e-07	5.17453
Loading Stress XX [ksf]	-1.67977	5.40688
Loading Stress YY [ksf]	-1.32859	4.94833
Effective Stress ZZ [ksf]	9.61115e-08	6.79588
Effective Stress XX [ksf]	-0.7846	11.8033
Effective Stress YY [ksf]	-0.871234	11.2875
Total Stress ZZ [ksf]	1.0015e-07	12.5293
Total Stress XX [ksf]	-0.783325	17.9362
Total Stress YY [ksf]	-0.871166	17.2868
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	-1.92202e-05	0.065466
Pore Water Pressure [ksf]	1.92354e-09	8.71824
Excess Pore Water Pressure [ksf]	1.92354e-09	5.16863
Degree of Consolidation [%]	0	12.9758
Pre-consolidation Stress [ksf]	0.0300001	6.79282
Over-consolidation Ratio	1	1.00295
Void Ratio	0	1.00004
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	-1.54451e-05	0.110714

Stage: Stage 8 = 30 d

Data Type	Minimum	Maximum
Total Settlement [in]	-0.000663159	22.141
Total Consolidation Settlement [in]	-0.000663159	4.48808
Virgin Consolidation Settlement [in]	0	4.4881
Recompression Consolidation Settlement [in]	-0.000663293	0
Immediate Settlement [in]	0	18.5644
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	1.00146e-07	5.17453
Loading Stress XX [ksf]	-1.67977	5.40688
Loading Stress YY [ksf]	-1.32859	4.94833
Effective Stress ZZ [ksf]	1.0015e-07	7.63975
Effective Stress XX [ksf]	-0.783325	12.6472
Effective Stress YY [ksf]	-0.871166	12.0271
Total Stress ZZ [ksf]	1.0015e-07	12.5293
Total Stress XX [ksf]	-0.783325	17.9362
Total Stress YY [ksf]	-0.871166	17.2868
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	-2.32333e-05	0.0730111
Pore Water Pressure [ksf]	0	8.72312
Excess Pore Water Pressure [ksf]	0	5.16725
Degree of Consolidation [%]	0	24.1261
Pre-consolidation Stress [ksf]	0.0300001	7.63671
Over-consolidation Ratio	1	1.00357
Void Ratio	0	1.00005
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	-0.000124721	0.125169

Stage: Stage 9 = 90 d

Data Type	Minimum	Maximum
Total Settlement [in]	0	25.0728
Total Consolidation Settlement [in]	0	8.09328
Virgin Consolidation Settlement [in]	0	8.09328
Recompression Consolidation Settlement [in]	0	0
Immediate Settlement [in]	0	18.5644
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	1.00146e-07	5.17453
Loading Stress XX [ksf]	-1.67977	5.40688
Loading Stress YY [ksf]	-1.32859	4.94833
Effective Stress ZZ [ksf]	1.0015e-07	7.63975
Effective Stress XX [ksf]	-0.783325	12.6472
Effective Stress YY [ksf]	-0.871166	12.0271
Total Stress ZZ [ksf]	1.0015e-07	12.5293
Total Stress XX [ksf]	-0.783325	17.9362
Total Stress YY [ksf]	-0.871166	17.2868
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	0	0.0731986
Pore Water Pressure [ksf]	0	8.61376
Excess Pore Water Pressure [ksf]	0	5.04811
Degree of Consolidation [%]	0	43.5062
Pre-consolidation Stress [ksf]	0.0300001	7.63671
Over-consolidation Ratio	1	1
Void Ratio	0	1
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	0	0.125169

Stage: Stage 10 = 180 d

Data Type	Minimum	Maximum
Total Settlement [in]	0	27.5798
Total Consolidation Settlement [in]	0	11.1139
Virgin Consolidation Settlement [in]	0	11.1139
Recompression Consolidation Settlement [in]	0	0
Immediate Settlement [in]	0	18.5644
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	1.00146e-07	5.17453
Loading Stress XX [ksf]	-1.67977	5.40688
Loading Stress YY [ksf]	-1.32859	4.94833
Effective Stress ZZ [ksf]	1.0015e-07	7.63975
Effective Stress XX [ksf]	-0.783325	12.6472
Effective Stress YY [ksf]	-0.871166	12.0271
Total Stress ZZ [ksf]	1.0015e-07	12.5293
Total Stress XX [ksf]	-0.783325	17.9362
Total Stress YY [ksf]	-0.871166	17.2868
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	0	0.0732577
Pore Water Pressure [ksf]	0	7.95973
Excess Pore Water Pressure [ksf]	0	4.38024
Degree of Consolidation [%]	0	59.7441
Pre-consolidation Stress [ksf]	0.0300001	7.63671
Over-consolidation Ratio	1	1
Void Ratio	0	1
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	0	0.125169

Stage: Stage 11 = 365 d

Data Type	Minimum	Maximum
Total Settlement [in]	0	30.4651
Total Consolidation Settlement [in]	0	14.4484
Virgin Consolidation Settlement [in]	0	14.4484
Recompression Consolidation Settlement [in]	0	0
Immediate Settlement [in]	0	18.5644
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	1.00146e-07	5.17453
Loading Stress XX [ksf]	-1.67977	5.40688
Loading Stress YY [ksf]	-1.32859	4.94833
Effective Stress ZZ [ksf]	1.0015e-07	7.63975
Effective Stress XX [ksf]	-0.783325	12.6472
Effective Stress YY [ksf]	-0.871166	12.0271
Total Stress ZZ [ksf]	1.0015e-07	12.5293
Total Stress XX [ksf]	-0.783325	17.9362
Total Stress YY [ksf]	-0.871166	17.2868
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	0	0.0733015
Pore Water Pressure [ksf]	0	6.46973
Excess Pore Water Pressure [ksf]	0	2.86736
Degree of Consolidation [%]	0	77.6688
Pre-consolidation Stress [ksf]	0.0300001	7.6378
Over-consolidation Ratio	1	1
Void Ratio	0	1
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	0	0.125169

Stage: Stage 12 = 730 d

Data Type	Minimum	Maximum
Total Settlement [in]	0	32.885
Total Consolidation Settlement [in]	0	17.0963
Virgin Consolidation Settlement [in]	0	17.0963
Recompression Consolidation Settlement [in]	0	0
Immediate Settlement [in]	0	18.5644
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	1.00146e-07	5.17453
Loading Stress XX [ksf]	-1.67977	5.40688
Loading Stress YY [ksf]	-1.32859	4.94833
Effective Stress ZZ [ksf]	1.0015e-07	7.72226
Effective Stress XX [ksf]	-0.783325	13.1291
Effective Stress YY [ksf]	-0.871166	12.4797
Total Stress ZZ [ksf]	1.0015e-07	12.5293
Total Stress XX [ksf]	-0.783325	17.9362
Total Stress YY [ksf]	-0.871166	17.2868
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	0	0.0733391
Pore Water Pressure [ksf]	0	4.80708
Excess Pore Water Pressure [ksf]	0	1.19105
Degree of Consolidation [%]	0	91.9028
Pre-consolidation Stress [ksf]	0.0300001	7.721
Over-consolidation Ratio	1	1
Void Ratio	0	1
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	0	0.125169

Stage: Stage 13 = 1825 d

Data Type	Minimum	Maximum
Total Settlement [in]	0	34.2709
Total Consolidation Settlement [in]	0	18.511
Virgin Consolidation Settlement [in]	0	18.511
Recompression Consolidation Settlement [in]	0	0
Immediate Settlement [in]	0	18.5644
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	1.00146e-07	5.17453
Loading Stress XX [ksf]	-1.67977	5.40688
Loading Stress YY [ksf]	-1.32859	4.94833
Effective Stress ZZ [ksf]	1.0015e-07	8.82714
Effective Stress XX [ksf]	-0.783325	14.234
Effective Stress YY [ksf]	-0.871166	13.5846
Total Stress ZZ [ksf]	1.0015e-07	12.5293
Total Stress XX [ksf]	-0.783325	17.9362
Total Stress YY [ksf]	-0.871166	17.2868
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	0	0.0733624
Pore Water Pressure [ksf]	0	3.7022
Excess Pore Water Pressure [ksf]	0	0.0861679
Degree of Consolidation [%]	0	99.5077
Pre-consolidation Stress [ksf]	0.0300001	8.82587
Over-consolidation Ratio	1	1
Void Ratio	0	1
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	0	0.139403

Stage: Stage 14 = 3650 d

Data Type	Minimum	Maximum
Total Settlement [in]	0	34.3719
Total Consolidation Settlement [in]	0	18.6016
Virgin Consolidation Settlement [in]	0	18.6016
Recompression Consolidation Settlement [in]	0	0
Immediate Settlement [in]	0	18.5644
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	1.00146e-07	5.17453
Loading Stress XX [ksf]	-1.67977	5.40688
Loading Stress YY [ksf]	-1.32859	4.94833
Effective Stress ZZ [ksf]	1.0015e-07	8.91223
Effective Stress XX [ksf]	-0.783325	14.3191
Effective Stress YY [ksf]	-0.871166	13.6697
Total Stress ZZ [ksf]	1.0015e-07	12.5293
Total Stress XX [ksf]	-0.783325	17.9362
Total Stress YY [ksf]	-0.871166	17.2868
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	0	0.073364
Pore Water Pressure [ksf]	0	3.6192
Excess Pore Water Pressure [ksf]	-8.06607e-10	0.00107683
Degree of Consolidation [%]	0	99.995
Pre-consolidation Stress [ksf]	0.0300001	8.91096
Over-consolidation Ratio	1	1
Void Ratio	0	1
Permeability [in/s]	0	1.35467e-07
Coefficient of Consolidation [in^2/s]	0	0.000866
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	0	0.141135

Embankments

1. Embankment: "Embankment Load 1"

Label	Embankment Load 1
Center Line	(2.45643e+06, 1.12975e+06) to (2.45526e+06, 1.12975e+06)
Near End Angle	12.4 degrees
Far End Angle	12.4 degrees
Number of Layers	6
Base Width	1705

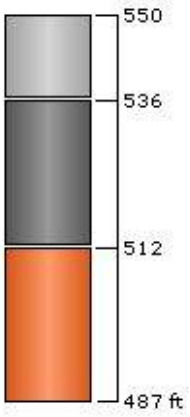
Layer	Stage	Left Bench Width (ft)	Left Angle (deg)	Height (ft)	Unit Weight (kips/ft3)	Right Angle (deg)	Right Bench Width (ft)
1	Stage 2 = 2 d	0	12.4	7.5	0.115	12.4	0
2	Stage 3 = 4 d	0	12.4	7.5	0.115	12.4	0
3	Stage 4 = 6 d	0	12.4	7.5	0.115	12.4	0
4	Stage 5 = 8 d	0	12.4	7.5	0.115	12.4	0
5	Stage 6 = 10 d	0	12.4	7.5	0.115	12.4	0
6	Stage 7 = 12 d	0	1.48	7.5	0.115	1.48	0

Soil Layers

Ground Surface Drained: Yes

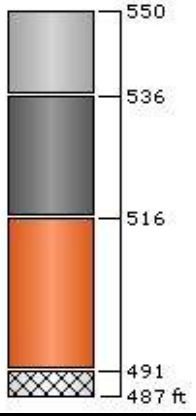
DB-01

XY Location:		DB-01: (2.45547e+06, 1.12983e+06)		
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**	**Drained at Bottom**
1	Ash1	14	550	Yes
2	Ash2	24	536	Yes
3	Fill	0	512	No
4	Alluvial	25	512	No



DB-02

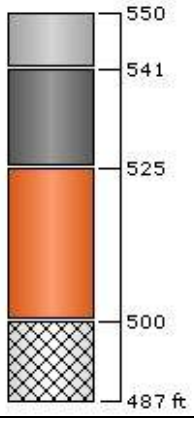
XY Location:		DB-02: (2.45618e+06, 1.13034e+06)		
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**	**Drained at Bottom**
1	Ash1	14	550	Yes
2	Ash2	20	536	Yes
3	Fill	0	516	No
4	Alluvial	25	516	No



DB-03

XY Location: DB-03: (2.45596e+06, 1.12952e+06)

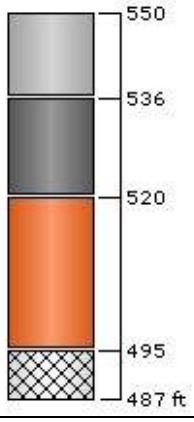
Layer #	Type	Thickness [ft]	Elevation [ft]	Drained at Bottom
1	Ash1	9	550	Yes
2	Ash2	16	541	Yes
3	Fill	0	525	No
4	Alluvial	25	525	No



DB-04

XY Location: DB-04: (2.45538e+06, 1.12916e+06)

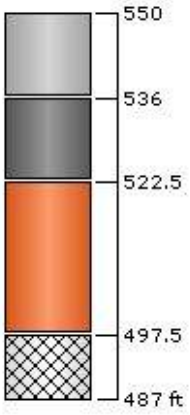
Layer #	Type	Thickness [ft]	Elevation [ft]	Drained at Bottom
1	Ash1	14	550	Yes
2	Ash2	16	536	Yes
3	Fill	0	520	No
4	Alluvial	25	520	No



DB-05

XY Location: DB-05: (2.45624e+06, 1.12918e+06)

Layer #	Type	Thickness [ft]	Elevation [ft]	Drained at Bottom
1	Ash1	14	550	Yes
2	Ash2	13.5	536	Yes
3	Fill	0	522.5	No
4	Alluvial	25	522.5	No



Soil Properties

Property	Ash1	Alluvial	Fill	Ash2
Color				
Unit Weight [kips/ft3]	0.12	0.115	0.115	0.12
Saturated Unit Weight [kips/ft3]	0.12	0.115	0.115	0.12
K0	1	1	1	1
Immediate Settlement	Enabled	Disabled	Disabled	Enabled
Es [ksf]	143.7	-	-	118.3
Esur [ksf]	143.7	-	-	118.3
Primary Consolidation	Disabled	Enabled	Enabled	Disabled
Material Type		Non-Linear	Non-Linear	
Cc	-	0.25	0.3	-
Cr	-	0.03	0.03	-
e0	-	1	1.1	-
OCR	-	1	1	-
Cv [in2/s]	-	0.000866	0.000866	-
Cvr [in2/s]	-	1e-05	0.0001	-
B-bar	-	1	1	-
Undrained Su A [kips/ft2]	0	0	0	0
Undrained Su S	0.2	0.2	0.2	0.2
Undrained Su m	0.8	0.8	0.8	0.8
Piezo Line ID	Staged	Staged	Staged	Staged

Groundwater

Groundwater method	Piezometric Lines
Water Unit Weight	0.0624 kips/ft3
Generating excess pore pressure above water table	

Piezometric Line Entities

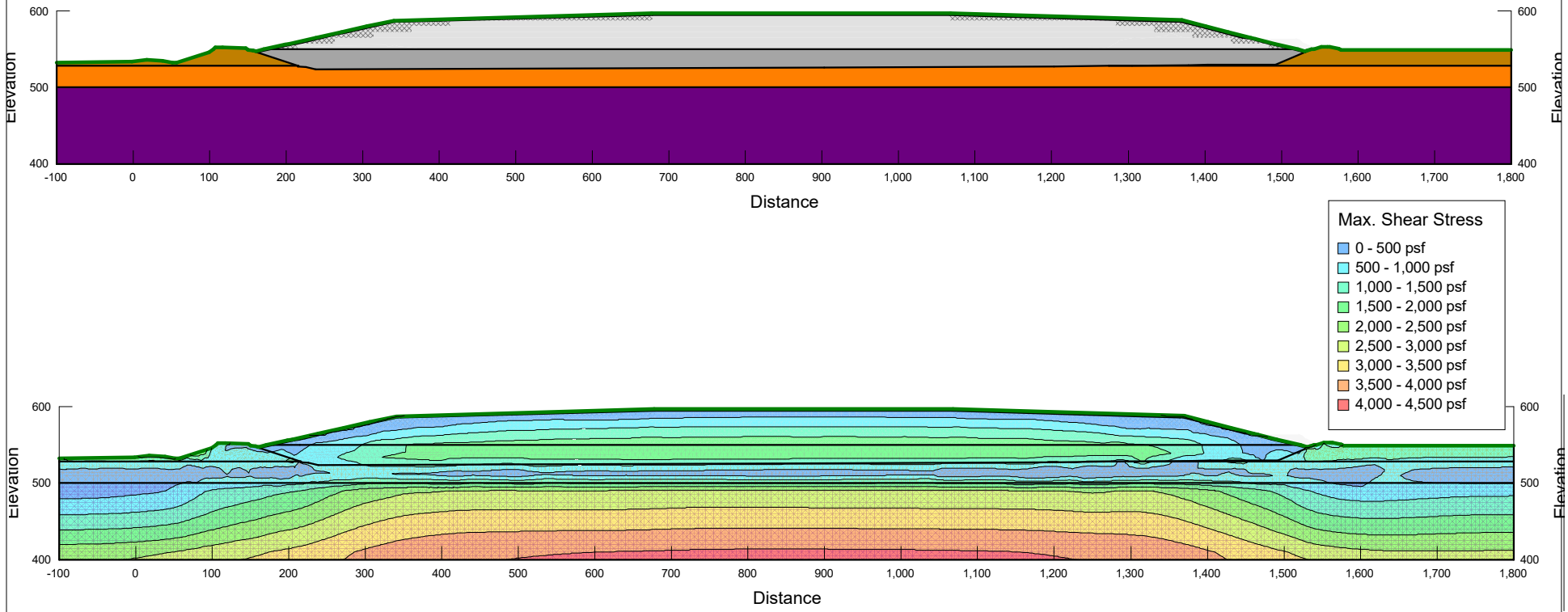
ID	Elevation (ft)
1	545 ft

SECTION 4

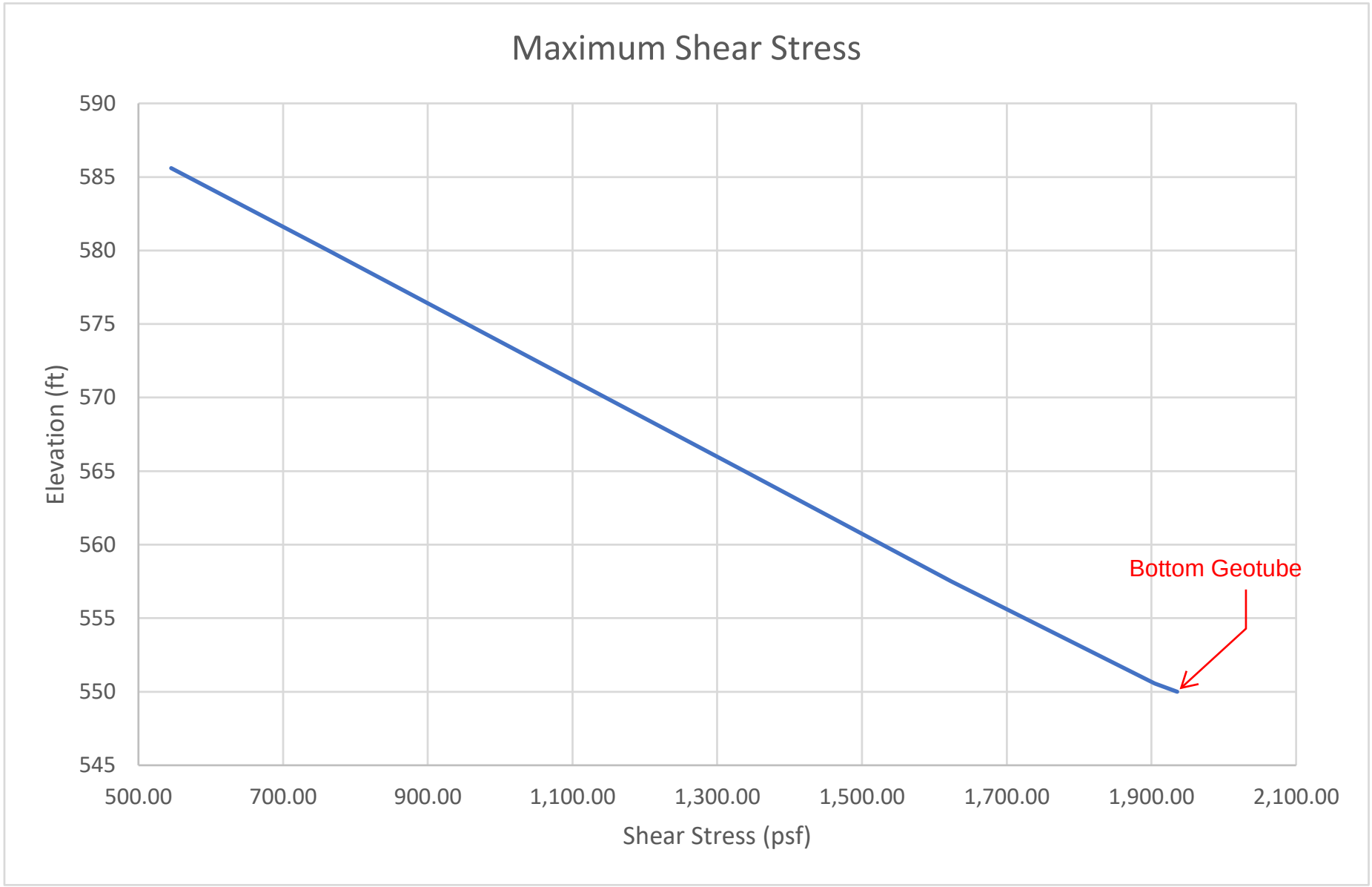
GeoStudio Sigma Stress Analysis



Color	Name	Stress Material Model	Initial Void Ratio	Unit Weight (pcf)	Response Type	Effective Elastic Modulus (psf)	Effective Poisson's Ratio	Effective Cohesion (psf)	Effective Friction Angle (°)	Dilation Angle (°)	Tensile Strength (psf)	K0 Type	K0	Hydraulic Material Model
	0_CCR Cover	Mohr-Coulomb	1	120	Drained	750,000	0.35	1,000	0	0	0	Calculated	1	(none)
	1_CCR Ash Wet Lakeside	Mohr-Coulomb	1.2	115	Drained	500,000	0.25	200	30	0	0	Calculated	0.5	(none)
	2_CCR Ash Wet Dallman	Mohr-Coulomb	1.1	120	Drained	500,000	0.25	0	28	0	0	Calculated	0.5305	(none)
	3_Fill	Mohr-Coulomb	1.1	115	Undrained	1,000,000	0.45	1,800	0	0	0	Calculated	1	(none)
	4_Alluvial	Mohr-Coulomb	1	115	Undrained	575,000	0.4	750	0	0	0	Calculated	1	(none)
	5_Shale	Mohr-Coulomb	0.4	130	Drained	100,000	0.3	3,500	10	0	0	Calculated	0.8264	(none)



CWLP ASH POND CLOSURE	HANSON™	Name: Complete Construction
CITY WATER, LIGHT, AND POWER		Analysis Location: DALLMAN
SPRINGFIELD, SANGAMON COUNTY, ILLINOIS		Kind: SIGMA/W
HANSON PROJECT NUMBER: 25E0006	Last Edited By: Beya Kazadi Date: 09/14/2025	Analysis Type: Load/Deformation
		Additional Note:


Maximum Shear Stress
590
585
580
575
570
565
560
555
550
545
Elevation (ft)
500.00
700.00
900.00
1,100.00
1,300.00
1,500.00
1,700.00
1,900.00
2,100.00
Shear Stress (psf)
Bottom Geotube

Complete Construction

Report generated using GeoStudio 2025.1.1. Copyright © 2025 Bentley Systems, Incorporated.

File Information

File Version: 11.08
Product Version: 25.1.1.182
Created By: Beya Kazadi
Last Edited By: Beya Kazadi
Revision Number: 376
Date: 09/14/2025
Time: 06:55:56 PM
File Name: CWLP Ash Pond Closure Slope Stabilty.gsz
Directory: I:\25jobs\25E0006_00\Admin\13-Calculations\GEOTECH\Geostudio Model\
Last Solved Date: 09/14/2025
Last Solved Time: 06:56:34 PM

Project Settings

Unit System: U.S. Customary Units

Analysis Settings

Complete Construction

Kind: SIGMA/W
Parent: Geotube Row 6
Analysis Type: Load/Deformation
Settings
- Initial Stress and PWP Conditions from Parent Analysis: Geotube Row 6 [(last)]
- Final PWP Conditions from: (none)
- Bulk Modulus of Pore-Fluid: 43,511,321 psf
- Reset displacements and strains: No
- Reset state variables: No

Convergence
- Maximum Number of Iterations: 300
- Convergence Scheme: Unbalanced Energy
- Tolerable Error: 1e-05
- Tolerable Error for Stress Update: 0.005

Steps
- Starting Time: 6 d
- Duration: 1 d
- # of Steps: 1
- Time Increment: 1 d
- Save Steps Every: 1

Materials

3_Fill

Stress

- Stress Material Model: Mohr-Coulomb
- Initial Void Ratio: 1.1
- Unit Weight: 115 pcf
- Response Type: Undrained
- Effective Elastic Modulus: 1,000,000 psf
- Effective Poisson's Ratio: 0.45
- Effective Cohesion: 1,800 psf
- Effective Friction Angle: 0 °
- Dilation Angle: 0 °
- Tensile Strength: 0 psf
- K0 Type: Calculated
- K0: 1

Hydraulic

- Hydraulic Material Model: (none)

4_Alluvial

Stress

- Stress Material Model: Mohr-Coulomb
- Initial Void Ratio: 1
- Unit Weight: 115 pcf
- Response Type: Undrained
- Effective Elastic Modulus: 575,000 psf
- Effective Poisson's Ratio: 0.4
- Effective Cohesion: 750 psf
- Effective Friction Angle: 0 °
- Dilation Angle: 0 °
- Tensile Strength: 0 psf
- K0 Type: Calculated
- K0: 1

Hydraulic

- Hydraulic Material Model: (none)

2_CCR Ash Wet Dallman

Stress

- Stress Material Model: Mohr-Coulomb
- Initial Void Ratio: 1.1
- Unit Weight: 120 pcf
- Response Type: Drained
- Effective Elastic Modulus: 500,000 psf
- Effective Poisson's Ratio: 0.25
- Effective Cohesion: 0 psf
- Effective Friction Angle: 28 °
- Dilation Angle: 0 °
- Tensile Strength: 0 psf
- K0 Type: Calculated
- K0: 0.5305

Hydraulic

- Hydraulic Material Model: (none)

1_CCR Ash Wet Lakeside

Stress

Stress Material Model: Mohr-Coulomb
Initial Void Ratio: 1.2
Unit Weight: 115 pcf
Response Type: Drained
Effective Elastic Modulus: 500,000 psf
Effective Poisson's Ratio: 0.25
Effective Cohesion: 200 psf
Effective Friction Angle: 30 °
Dilation Angle: 0 °
Tensile Strength: 0 psf
K0 Type: Calculated
K0: 0.5

Hydraulic

Hydraulic Material Model: (none)

5_Shale

Stress

Stress Material Model: Mohr-Coulomb
Initial Void Ratio: 0.4
Unit Weight: 130 pcf
Response Type: Drained
Effective Elastic Modulus: 100,000 psf
Effective Poisson's Ratio: 0.3
Effective Cohesion: 3,500 psf
Effective Friction Angle: 10 °
Dilation Angle: 0 °
Tensile Strength: 0 psf
K0 Type: Calculated
K0: 0.8264

Hydraulic

Hydraulic Material Model: (none)

0_CCR Cover

Stress

Stress Material Model: Mohr-Coulomb
Initial Void Ratio: 1
Unit Weight: 120 pcf
Response Type: Drained
Effective Elastic Modulus: 750,000 psf
Effective Poisson's Ratio: 0.35
Effective Cohesion: 1,000 psf
Effective Friction Angle: 0 °
Dilation Angle: 0 °
Tensile Strength: 0 psf
K0 Type: Calculated
K0: 1

Hydraulic

Hydraulic Material Model: (none)

Boundary Conditions

Fixed X

Category: Stress/Strain
X-Type: X-Displacement 0 ft

Fixed X/Y

Category: Stress/Strain
X-Type: X-Displacement 0 ft
Y-Type: Y-Displacement 0 ft

Geometry

Name: Default Geometry (2)

Settings

View: 2D
Element Thickness: 1 ft

Points

	X	Y
Point 1	-100 ft	532.52639 ft
Point 2	-1.3284 ft	533.77631 ft
Point 3	17.9944 ft	536.23773 ft
Point 4	38.8763 ft	534.5275 ft
Point 5	51.3487 ft	532.17002 ft
Point 6	56.7613 ft	532.17002 ft
Point 7	99.5926 ft	545.80069 ft
Point 8	107.7237 ft	551.98231 ft
Point 9	117.0143 ft	552.22296 ft
Point 10	147.6952 ft	551.2307 ft
Point 11	161.9987 ft	546.02071 ft
Point 12	215.5858 ft	527.93508 ft
Point 13	226.0745 ft	527.17684 ft
Point 14	238.4378 ft	523.80851 ft
Point 15	903.1371 ft	525.95454 ft
Point 16	1,203.088 ft	527.39817 ft
Point 17	1,304.9787 ft	528.24967 ft
Point 18	1,378.955 ft	529.2834 ft
Point 19	1,403.3082 ft	529.63559 ft
Point 20	1,492.6242 ft	529.63559 ft
Point 21	1,530.5363 ft	546.11057 ft
Point 22	1,536.3762 ft	548.0397 ft
Point 23	1,551.8672 ft	553.12281 ft
Point 24	1,560.4904 ft	553.12281 ft
Point 25	1,563.5248 ft	553.50664 ft
Point 26	1,574.64 ft	551.0582 ft
Point 27	1,578.0494 ft	549.06529 ft
Point 28	1,800 ft	549.06529 ft
Point 29	1,800 ft	400 ft

Point 30	-100 ft	400 ft
Point 31	150.291 ft	548.93321 ft
Point 32	150.698 ft	551.88293 ft
Point 33	156.094 ft	552.75427 ft
Point 34	168.1675 ft	554.09285 ft
Point 35	174.4613 ft	553.48918 ft
Point 36	177.6054 ft	553.48918 ft
Point 37	184.5848 ft	555.08891 ft
Point 38	198.64 ft	556.15978 ft
Point 39	204.727 ft	555.39206 ft
Point 40	210.9606 ft	554.60466 ft
Point 41	210.9606 ft	554.15091 ft
Point 42	216.1279 ft	554.15091 ft
Point 43	223.0888 ft	557.27789 ft
Point 44	229.388 ft	556.38419 ft
Point 45	234.6636 ft	553.45899 ft
Point 46	275.5124 ft	554.47584 ft
Point 47	330.2738 ft	555.51345 ft
Point 48	333.8827 ft	553.04954 ft
Point 49	341.724 ft	555.36253 ft
Point 50	347.5967 ft	553.96162 ft
Point 51	362.5573 ft	552.72146 ft
Point 52	373.4497 ft	550.79232 ft
Point 53	989.441 ft	550.51881 ft
Point 54	1,201.8289 ft	551.45505 ft
Point 55	1,236.8934 ft	551.16084 ft
Point 56	1,261.2401 ft	551.49757 ft
Point 57	1,264.5495 ft	551.1007 ft
Point 58	1,274.344 ft	552.7644 ft
Point 59	1,287.9775 ft	560.82205 ft
Point 60	1,293.7738 ft	562.87932 ft
Point 61	1,309.6932 ft	565.3856 ft
Point 62	1,318.4263 ft	564.27949 ft
Point 63	1,350.2305 ft	567.18734 ft
Point 64	1,352.9707 ft	569.88025 ft
Point 65	1,357.4064 ft	570.72671 ft
Point 66	1,363.4494 ft	568.71143 ft
Point 67	1,363.4494 ft	567.39994 ft
Point 68	1,375.8447 ft	565.12303 ft
Point 69	1,384.4405 ft	566.16962 ft
Point 70	1,389.4656 ft	566.97707 ft
Point 71	1,397.4671 ft	567.35249 ft
Point 72	1,410.1123 ft	567.18774 ft
Point 73	1,418.0691 ft	566.23196 ft
Point 74	1,420.554 ft	565.94169 ft
Point 75	1,425.8016 ft	566.32274 ft
Point 76	1,427.3794 ft	566.04611 ft
Point 77	1,437.6302 ft	566.7424 ft
Point 78	1,449.3014 ft	565.45348 ft

Point 79	1,459.5025 ft	563.48662 ft
Point 80	1,485.8698 ft	563.4284 ft
Point 81	1,495.1677 ft	563.82023 ft
Point 82	1,503.606 ft	563.5539 ft
Point 83	1,518.0794 ft	563.79841 ft
Point 84	1,519.0905 ft	564.14722 ft
Point 85	1,524.2305 ft	563.15269 ft
Point 86	1,528.7274 ft	558.69946 ft
Point 87	1,537.3124 ft	554.42556 ft
Point 88	1,542.6535 ft	553.62041 ft
Point 89	1,368.64 ft	585.87631 ft
Point 90	1,067.0022 ft	595 ft
Point 91	678.6006 ft	595 ft
Point 92	342.7615 ft	585.89846 ft
Point 93	341.0967 ft	587.77159 ft
Point 94	677.846 ft	596.80939 ft
Point 95	1,067.8526 ft	596.80939 ft
Point 96	1,369.7423 ft	587.98135 ft
Point 97	1,466.2031 ft	563.47182 ft
Point 98	161.2923 ft	547.92314 ft
Point 99	156.8735 ft	548.00979 ft
Point 100	1,530.9628 ft	547.8855 ft
Point 101	1,534.0799 ft	548.0314 ft
Point 102	1,548.5695 ft	553.30091 ft
Point 103	1,530.3985 ft	546.05069 ft
Point 104	-100 ft	528 ft
Point 105	215.3734 ft	528 ft
Point 106	215.3934 ft	528 ft
Point 107	212 ft	529 ft
Point 108	1,800 ft	528 ft
Point 109	1,275.1031 ft	528 ft
Point 110	105.1162 ft	550 ft
Point 111	149.0857 ft	550 ft
Point 112	170.7095 ft	550 ft
Point 113	180.1421 ft	550 ft
Point 114	1,514.3403 ft	550 ft
Point 115	1,522.1773 ft	550 ft
Point 116	1,539.493 ft	550 ft
Point 117	1,542.3503 ft	550 ft
Point 118	1,576.4503 ft	550 ft
Point 119	1,528.4239 ft	559 ft
Point 120	1,284.8946 ft	559 ft
Point 121	221.0521 ft	559 ft
Point 122	261.775 ft	568 ft
Point 123	1,351.0574 ft	568 ft
Point 124	1,363.4494 ft	568 ft
Point 125	1,364.5018 ft	586 ft
Point 126	346.5531 ft	586 ft
Point 127	1,491.0155 ft	557.5 ft

Point 128	1,483.8446 ft	557.5 ft
Point 129	1,282.3566 ft	557.5 ft
Point 130	214.2649 ft	557.5 ft
Point 131	204.6796 ft	557.5 ft
Point 132	214.2649 ft	554.15091 ft
Point 133	214.2649 ft	550 ft
Point 134	1,483.8446 ft	550 ft
Point 135	238.4779 ft	565 ft
Point 136	248.2007 ft	565 ft
Point 137	1,307.2439 ft	565 ft
Point 138	1,312.7376 ft	565 ft
Point 139	1,326.3068 ft	565 ft
Point 140	1,451.6534 ft	565 ft
Point 141	1,460.1887 ft	565 ft
Point 142	264.2649 ft	557.5 ft
Point 143	1,433.8446 ft	557.5 ft
Point 144	272.2762 ft	572.5 ft
Point 145	282.1365 ft	572.5 ft
Point 146	1,421.4706 ft	572.5 ft
Point 147	1,430.6714 ft	572.5 ft
Point 148	306.0745 ft	580 ft
Point 149	316.0723 ft	580 ft
Point 150	1,391.8489 ft	580 ft
Point 151	1,401.1541 ft	580 ft
Point 152	1,383.8446 ft	572.5 ft
Point 153	314.2649 ft	572.5 ft
Point 154	401.8943 ft	587.5 ft
Point 155	1,314.9185 ft	587.5 ft
Point 156	1,333.8446 ft	580 ft
Point 157	364.2649 ft	580 ft
Point 158	678.6006 ft	587.5 ft
Point 159	1,067.0022 ft	587.5 ft
Point 160	-100 ft	500 ft
Point 161	1,800 ft	500 ft
Point 162	1,433.8446 ft	565 ft
Point 163	264.2649 ft	565 ft
Point 164	314.2649 ft	565 ft
Point 165	1,383.8446 ft	566.09707 ft
Point 166	1,383.8446 ft	565 ft
Point 167	364.2649 ft	572.5 ft
Point 168	414.2649 ft	580 ft
Point 169	414.2649 ft	587.5 ft
Point 170	1,333.8446 ft	572.5 ft
Point 171	1,283.8446 ft	580 ft
Point 172	1,283.8446 ft	587.5 ft

Lines

	Start Point	End Point	Length	Angle	Stress/Strain Boundary
Line 1	1	2	98.68 ft	0.726 °	

Line 2	2	3	19.479 ft	7.26 °	
Line 3	3	4	20.952 ft	-4.68 °	
Line 4	4	5	12.693 ft	-10.7 °	
Line 5	5	6	5.4126 ft	0 °	
Line 6	6	7	44.948 ft	17.7 °	
Line 7	8	9	9.2937 ft	1.48 °	
Line 8	9	10	30.697 ft	-1.85 °	
Line 9	12	13	10.516 ft	-4.13 °	
Line 10	13	14	12.814 ft	-15.2 °	
Line 11	14	15	664.7 ft	0.185 °	
Line 12	15	16	299.95 ft	0.276 °	
Line 13	17	18	73.984 ft	0.801 °	
Line 14	18	19	24.356 ft	0.829 °	
Line 15	19	20	89.316 ft	0 °	
Line 16	21	22	6.1503 ft	18.3 °	
Line 17	23	24	8.6232 ft	0 °	
Line 18	24	25	3.0586 ft	7.21 °	
Line 19	25	26	11.382 ft	-12.4 °	
Line 20	27	28	221.95 ft	0 °	
Line 21	29	30	1,900 ft	0 °	Fixed X/Y
Line 22	31	11	12.065 ft	-14 °	
Line 23	10	32	3.0728 ft	12.3 °	
Line 24	32	33	5.4659 ft	9.17 °	
Line 25	33	34	12.147 ft	6.33 °	
Line 26	34	35	6.3227 ft	-5.48 °	
Line 27	35	36	3.1441 ft	0 °	
Line 28	36	37	7.1604 ft	12.9 °	
Line 29	37	38	14.096 ft	4.36 °	
Line 30	38	39	6.1352 ft	-7.19 °	
Line 31	39	40	6.2831 ft	-7.2 °	
Line 32	40	41	0.45375 ft	90 °	
Line 33	42	43	7.631 ft	24.2 °	
Line 34	43	44	6.3623 ft	-8.07 °	
Line 35	44	45	6.0323 ft	-29 °	
Line 36	46	47	54.771 ft	1.09 °	
Line 37	47	48	4.3698 ft	-34.3 °	
Line 38	48	49	8.1753 ft	16.4 °	
Line 39	49	50	6.0375 ft	-13.4 °	
Line 40	50	51	15.012 ft	-4.74 °	
Line 41	51	52	11.062 ft	-10 °	
Line 42	52	53	615.99 ft	-0.0254 °	
Line 43	53	54	212.39 ft	0.253 °	
Line 44	54	55	35.066 ft	-0.481 °	
Line 45	55	56	24.349 ft	0.792 °	
Line 46	56	57	3.3331 ft	-6.84 °	
Line 47	57	58	9.9348 ft	9.64 °	
Line 48	59	60	6.1506 ft	19.5 °	
Line 49	64	65	4.5157 ft	10.8 °	
Line 50	65	66	6.3702 ft	-18.4 °	

Line 51	67	68	12.603 ft	-10.4 °	
Line 52	69	70	5.0896 ft	9.13 °	
Line 53	70	71	8.0103 ft	2.69 °	
Line 54	71	72	12.646 ft	-0.746 °	
Line 55	72	73	8.014 ft	-6.85 °	
Line 56	73	74	2.5018 ft	-6.66 °	
Line 57	75	76	1.6019 ft	-9.94 °	
Line 58	76	77	10.274 ft	3.89 °	
Line 59	77	78	11.742 ft	-6.3 °	
Line 60	80	81	9.3062 ft	2.41 °	
Line 61	81	82	8.4425 ft	-1.81 °	
Line 62	82	83	14.475 ft	0.968 °	
Line 63	83	84	1.0696 ft	19 °	
Line 64	84	85	5.2353 ft	-11 °	
Line 65	86	87	9.59 ft	-26.5 °	
Line 66	87	88	5.4014 ft	-8.57 °	
Line 67	90	91	388.4 ft	0 °	
Line 68	79	97	6.7006 ft	-0.127 °	
Line 69	97	80	19.667 ft	-0.126 °	
Line 70	93	94	336.87 ft	1.54 °	
Line 71	94	95	390.01 ft	0 °	
Line 72	95	96	302.02 ft	-1.68 °	
Line 73	98	99	4.4196 ft	-1.12 °	
Line 74	99	31	6.647 ft	-7.99 °	
Line 75	100	101	3.1205 ft	2.68 °	
Line 76	88	102	5.9246 ft	-3.09 °	
Line 77	102	23	3.3025 ft	-3.09 °	
Line 78	20	103	41.187 ft	23.5 °	
Line 79	103	21	0.15025 ft	23.5 °	
Line 80	104	1	4.5264 ft	90 °	Fixed X
Line 81	104	105	315.37 ft	0 °	
Line 82	12	106	0.20306 ft	-18.6 °	
Line 83	106	11	56.354 ft	-18.6 °	
Line 84	105	106	0.02 ft	0 °	
Line 85	28	108	21.065 ft	90 °	Fixed X
Line 86	16	109	72.018 ft	0.479 °	
Line 87	109	17	29.877 ft	0.479 °	
Line 88	108	109	524.9 ft	0 °	
Line 89	7	110	6.9386 ft	37.2 °	
Line 90	110	8	3.2755 ft	37.2 °	
Line 91	10	111	1.8569 ft	-41.5 °	
Line 92	111	31	1.6096 ft	-41.5 °	
Line 93	38	112	28.602 ft	12.4 °	
Line 94	112	98	9.6435 ft	12.4 °	
Line 95	11	113	18.575 ft	12.4 °	
Line 96	113	39	25.169 ft	12.4 °	
Line 97	112	113	9.4326 ft	0 °	
Line 98	114	103	16.537 ft	-13.8 °	
Line 99	115	100	9.0364 ft	-13.5 °	

Line 100	114	115	7.837 ft	0 °	
Line 101	101	116	5.76 ft	20 °	
Line 102	116	102	9.6581 ft	20 °	
Line 103	115	116	17.316 ft	0 °	
Line 104	22	117	6.2875 ft	18.2 °	
Line 105	117	23	10.016 ft	18.2 °	
Line 106	116	117	2.8573 ft	0 °	
Line 107	26	118	2.0969 ft	-30.3 °	
Line 108	118	27	1.8522 ft	-30.3 °	
Line 109	85	119	5.9016 ft	-44.7 °	
Line 110	119	86	0.42713 ft	-44.7 °	
Line 111	120	59	3.5811 ft	30.6 °	
Line 112	63	123	1.1594 ft	44.5 °	
Line 113	123	64	2.6825 ft	44.5 °	
Line 114	66	124	0.71143 ft	90 °	
Line 115	124	67	0.60006 ft	90 °	
Line 116	89	125	4.14 ft	-1.71 °	
Line 117	126	92	3.793 ft	1.53 °	
Line 118	127	115	32.052 ft	-13.5 °	
Line 119	128	114	31.404 ft	-13.8 °	
Line 120	127	128	7.1709 ft	0 °	
Line 121	58	129	9.3074 ft	30.6 °	
Line 122	129	120	2.9481 ft	30.6 °	
Line 123	121	130	6.951 ft	12.5 °	
Line 124	130	39	9.7681 ft	12.5 °	
Line 125	38	131	6.1865 ft	12.5 °	
Line 126	130	131	9.5853 ft	0 °	
Line 127	41	132	3.3043 ft	0 °	
Line 128	132	42	1.863 ft	0 °	
Line 129	130	132	3.3491 ft	90 °	
Line 130	113	133	34.123 ft	0 °	
Line 131	132	133	4.1509 ft	90 °	
Line 132	133	134	1,269.6 ft	0 °	
Line 133	134	114	30.496 ft	0 °	
Line 134	122	136	13.902 ft	12.5 °	
Line 135	136	121	27.804 ft	12.5 °	
Line 136	135	136	9.7228 ft	0 °	
Line 137	60	137	13.636 ft	8.95 °	
Line 138	137	61	2.4795 ft	8.95 °	
Line 139	61	138	3.0687 ft	-7.22 °	
Line 140	138	62	5.7341 ft	-7.22 °	
Line 141	137	138	5.4937 ft	0 °	
Line 142	62	139	7.9134 ft	5.22 °	
Line 143	139	63	24.023 ft	5.22 °	
Line 144	138	139	13.569 ft	0 °	
Line 145	78	140	2.3953 ft	-10.9 °	
Line 146	140	79	7.9937 ft	-10.9 °	
Line 147	141	97	6.2055 ft	-14.3 °	
Line 148	140	141	8.5353 ft	0 °	

Line 149	129	142	1,018.1 ft	0 °	
Line 150	142	130	50 ft	0 °	
Line 151	128	143	50 ft	0 °	
Line 152	143	129	151.49 ft	0 °	
Line 153	145	122	20.853 ft	12.5 °	
Line 154	144	145	9.8603 ft	0 °	
Line 155	146	147	9.2008 ft	0 °	
Line 156	92	149	27.333 ft	12.5 °	
Line 157	148	149	9.9978 ft	0 °	
Line 158	150	89	23.941 ft	-14.2 °	
Line 159	150	151	9.3052 ft	0 °	
Line 160	152	146	37.626 ft	0 °	
Line 161	145	153	32.128 ft	0 °	
Line 162	154	126	55.362 ft	1.55 °	
Line 163	125	155	49.606 ft	-1.73 °	
Line 164	156	150	58.004 ft	0 °	
Line 165	149	157	48.193 ft	0 °	
Line 166	91	158	7.5 ft	90 °	
Line 167	158	159	388.4 ft	0 °	
Line 168	90	159	7.5 ft	90 °	
Line 169	30	160	100 ft	90 °	Fixed X
Line 170	160	104	28 ft	90 °	Fixed X
Line 171	108	161	28 ft	90 °	Fixed X
Line 172	161	29	100 ft	90 °	Fixed X
Line 173	160	161	1,900 ft	0 °	
Line 174	151	96	32.41 ft	-14.3 °	
Line 175	146	78	28.709 ft	-14.2 °	
Line 176	141	147	30.455 ft	-14.3 °	
Line 177	128	79	25.067 ft	-13.8 °	
Line 178	97	127	25.521 ft	-13.5 °	
Line 179	147	151	30.455 ft	-14.3 °	
Line 180	150	146	30.556 ft	-14.2 °	
Line 181	148	144	34.62 ft	12.5 °	
Line 182	145	149	34.755 ft	12.5 °	
Line 183	93	148	35.874 ft	12.5 °	
Line 184	144	135	34.62 ft	12.5 °	
Line 185	135	131	34.62 ft	12.5 °	
Line 186	128	134	7.5 ft	90 °	
Line 187	162	140	17.809 ft	0 °	
Line 188	143	162	7.5 ft	90 °	
Line 189	45	46	40.861 ft	1.43 °	
Line 190	136	163	16.064 ft	0 °	
Line 191	142	163	7.5 ft	90 °	
Line 192	75	74	5.2614 ft	4.15 °	
Line 193	163	164	50 ft	0 °	
Line 194	164	137	992.98 ft	0 °	
Line 195	153	164	7.5 ft	90 °	
Line 196	68	165	8.059 ft	6.94 °	
Line 197	165	69	0.6003 ft	6.94 °	

Line 198	152	165	6.4029 ft	90 °	
Line 199	139	166	57.538 ft	0 °	
Line 200	166	162	50 ft	0 °	
Line 201	165	166	1.0971 ft	90 °	
Line 202	153	167	50 ft	0 °	
Line 203	157	167	7.5 ft	90 °	
Line 204	157	168	50 ft	0 °	
Line 205	154	169	12.371 ft	0 °	
Line 206	169	158	264.34 ft	0 °	
Line 207	168	169	7.5 ft	90 °	
Line 208	154	91	276.81 ft	1.55 °	
Line 209	167	170	969.58 ft	0 °	
Line 210	170	152	50 ft	0 °	
Line 211	156	170	7.5 ft	90 °	
Line 212	168	171	869.58 ft	0 °	
Line 213	171	156	50 ft	0 °	
Line 214	159	172	216.84 ft	0 °	
Line 215	172	155	31.074 ft	0 °	
Line 216	171	172	7.5 ft	90 °	
Line 217	90	155	248.03 ft	-1.73 °	

Regions

	Material	Points	Area
Region 1	3_Fill	7,6,5,4,3,2,1,104,105,106,11,31,111,10,9,8,110	3,245.9 ft²
Region 2	0_CCR Cover	151,150,146,147	69.398 ft²
Region 3	0_CCR Cover	39,113,112,38	54.899 ft²
Region 4		85,84,83,82,81,80,97,127,115,116,102,88,87,86,119	544.34 ft²
Region 5	4_Alluvial	104,160,161,108,109,16,15,14,13,12,106,105	50,673 ft²
Region 6	3_Fill	22,21,103,20,19,18,17,109,108,28,27,118,26,25,24,23,117	6,391.6 ft²
Region 7		31,99,98,112,38,37,36,35,34,33,32,10,111	144.93 ft²
Region 8	0_CCR Cover	11,31,99,98,112,113	36.812 ft²
Region 9	2_CCR Ash Wet Dallman	11,106,12,13,14,15,16,109,17,18,19,20,103,114,134,133,113	31,469 ft²
Region 10	0_CCR Cover	100,101,116,117,22,21,103,114,115	34.206 ft²
Region 11		101,100,115,116	20.98 ft²
Region 12		102,23,117,116	10.712 ft²
Region 13	0_CCR Cover	114,115,127,128	56.28 ft²

Region 14	1_CCR Ash Wet Lakeside	128,79,140,162,143	259.36 ft²
Region 15	0_CCR Cover	97,79,128,127	41.289 ft²
Region 16	1_CCR Ash Wet Lakeside	39,40,41,132,130	16.608 ft²
Region 17	0_CCR Cover	38,39,130,131	16.5 ft²
Region 18	1_CCR Ash Wet Lakeside	42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,129,142,130,132	6,557.7 ft²
Region 19	1_CCR Ash Wet Lakeside	41,40,39,113,133,132	111.16 ft²
Region 20	1_CCR Ash Wet Lakeside	114,128,134	114.36 ft²
Region 21	0_CCR Cover	131,130,121,136,135	72.406 ft²
Region 22	1_CCR Ash Wet Lakeside	121,130,142,163,136	247.74 ft²
Region 23	1_CCR Ash Wet Lakeside	61,137,138	1.0592 ft²
Region 24	1_CCR Ash Wet Lakeside	62,139,138	4.8884 ft²
Region 25	1_CCR Ash Wet Lakeside	140,78,77,76,75,74,73,72,71,70,69,165,166,162	106.36 ft²
Region 26	0_CCR Cover	79,97,141,140	11.534 ft²
Region 27	0_CCR Cover	135,136,122,145,144	73.437 ft²
Region 28	0_CCR Cover	78,140,141,147,146	68.487 ft²
Region 29	1_CCR Ash Wet Lakeside	75,76,77,78,146,152,165,69,70,71,72,73,74	287.04 ft²
Region 30	0_CCR Cover	144,145,149,148	74.468 ft²
Region 31	1_CCR Ash Wet Lakeside	156,150,89,125,155,172,171	660.51 ft²
Region 32	0_CCR Cover	91,90,155,125,89,150,151,96,95,94,93,148,149,92,126,154	2,067.8 ft²
Region 33	1_CCR Ash Wet Lakeside	145,153,167,157,149	488.7 ft²
Region 34	1_CCR Ash Wet	90,159,172,155	929.69 ft²

	Lakeside		
Region 35	1_CCR Ash Wet Lakeside	154,169,158,91	1,037.6 ft²
Region 36	1_CCR Ash Wet Lakeside	91,158,159,90	2,913 ft²
Region 37	5_Shale	30,29,161,160	1.9e+05 ft²
Region 38	1_CCR Ash Wet Lakeside	143,129,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,43,42,132,133,134,128	2,964.2 ft²
Region 39	1_CCR Ash Wet Lakeside	139,62,138,137,60,59,120,129,143,162,166	1,065.9 ft²
Region 40	1_CCR Ash Wet Lakeside	129,120,59,60,137,164,163,142	7,701 ft²
Region 41	1_CCR Ash Wet Lakeside	145,122,136,163,164,153	368.22 ft²
Region 42	1_CCR Ash Wet Lakeside	153,164,137,61,138,139,63,123,64,65,66,124,67,68,165,152,170,167	7,912.4 ft²
Region 43	1_CCR Ash Wet Lakeside	68,67,124,66,65,64,123,63,139,166,165	108.41 ft²
Region 44	1_CCR Ash Wet Lakeside	152,146,150,156,170	546.11 ft²
Region 45	1_CCR Ash Wet Lakeside	154,126,92,149,157,168,169	567.6 ft²
Region 46	1_CCR Ash Wet Lakeside	168,157,167,170,156,171	7,271.8 ft²
Region 47	1_CCR Ash Wet Lakeside	159,158,169,168,171,172	6,521.8 ft²

Mesh Properties

Global Element Size: 10 ft

SECTION 5

Geotech Data from Andrew Engineering

HANSON™

City Water, Light & Power
Ash Ponds
Springfield, Sangamon County, Illinois

Geotechnical Investigation Report for Unstable Areas Demonstration, Safety Factor and Liquefaction Analysis for Coal Combustion Residuals Surface Impoundments

June 2024

Prepared for:
City Water, Light & Power
3100 Stevenson Drive
Springfield, Illinois 62703

ANDREWS ENGINEERING

3300 Ginger Creek Drive, Springfield, IL 62711 | 217.787.2334

ILLINOIS | MISSOURI | INDIANA

vertical expansion consists of berms built on top and inside of the existing embankments in such a way that the toe of the outer slope of the expansion berms match up with the top of the inner slope of the existing embankments, typically identified as upstream construction. The vertical expansion berms are approximately ten feet in height.

A site map drawing containing an aerial photograph and approximate boundaries for the CWLP CCR ash ponds, including the clarification pond and landfill units, is provided in Appendix A.

No changes to the geometry of the structures are applicable for this report. No changes are apparent due to structure movement or deformation.

6. MATERIAL PROPERTIES

A geotechnical investigation was conducted in October 2023 to obtain site specific information for the soils surrounding and within the embankments for the Lakeside Ash Pond and Dallman Ash Pond. As part of the geotechnical investigation, split-spoons were driven recording blow counts, with visual identification of the samples and pocket penetrometers recorded for unconfined compressive strengths and jar samples collected for laboratory moisture content and additional Atterberg limits as needed for the liquefaction screening analysis. Shelby tubes were pushed with the samples analyzed in the laboratory for hydraulic conductivity, Atterberg limits, wet and dry densities, torvane, grain size distribution, and moisture content. Insitu field vane shear was used within the boreholes to determine the insitu shear strength of the soils and is recorded on the boring logs. A cone penetration test (CPT) sounding investigation was conducted in February 2024 as the split spoon test (SPT) results from the geotechnical investigation for the liquefaction screening analysis were inconclusive. The CPT soundings provided additional information about the soils surrounding the CCR ash ponds. An additional limited geotechnical investigation was conducted in April and May of 2024 to obtain samples of the clay directly below the CCR in Lakeside Ash Pond and Dallman Ash Pond as requested by the Illinois EPA. Laboratory analyses for hydraulic conductivity, Atterberg limits and grain size distribution were conducted on the clay liner samples collected from directly below the CCR in each ash pond. Included in Appendix C are copies of the boring logs, laboratory analysis, CPT soundings with shear strength calculations and cross sections that support the geotechnical parameters provided in Table 1 through Table 4.

The soil shear strengths were computed from the CPT soundings using the below equations:

$$S_u = (q_t - \sigma_{v)} / N_{kt}$$

where

$$N_{kt} = 10.5 – 4.6 \ln (B_q + 0.1)$$

These values were then graphed to approximate conservative values of shear strength for the soil profiles. These graphs are provided with the CPT sounds.

The silty clay fill soil strengths provided in the tables below for the embankments is conservative using a reduced strength with the strength parameters taken from the U.S. Department of Labor, Mine Safety and Health Administration's Engineering and Design Manual Coal Refuse Disposal Facilities, Second Edition. Water levels are based upon the maximum storage pool at full crest within the CCR. The water levels used for the rapid drawdown of the clarification pond is discussed in Section 7.3 Rapid Drawdown Analysis.

Conservative values for the impounded ash was taken from the fly ash technical paper included in Appendix D. These values were compared to those obtained during the multiple investigations.

TABLE 1

Lakeside Ash Pond Soil Strength Parameters

Profile D-D'

Soil Description	Density (pcf)	Total Strengths (Short Term)		Effective Strengths (Long Term)	
		ϕ (degrees)	c (psf)	ϕ' (degrees)	c (psf)
CCR Wet Ash	100	15	0	25	0
CCR Moist Ash	95	30	0	30	0
Silty Clay Fill	124	0	1,800	28	270
Scrubber Sludge	125	0	750	30	0
Bottom Ash	100	35	0	35	0
Sandy Lean Clay	115	0	550	24	0
Brown Silty Clay	120	0	1,040	28	0
Gray Silty Clay	119	0	1,100	28	0
Silty Clay	124	0	450	28	0
Light Gray Silty Clay	124	0	840	28	0
Gray Clayey Silt	126.5	0	500	32	0
Clayey Silt	125	0	1,400	32	0
Sand	125	34	0	34	0
Shale	Bedrock (Impenetrable)				

TABLE 2

Dallman Ash Pond Soil Strength Parameters

Profile F-F'

Soil Description	Density (pcf)	Total Strengths (Short Term)		Effective Strengths (Long Term)	
		ϕ (degrees)	c (psf)	ϕ' (degrees)	c (psf)
CCR Ash Moist	95	30	0	30	0
CCR Ash Wet	100	15	0	25	0
Lean Clay Fill	124	0	1,800	28	270
Clayey Silt	120	0	900	32	0
Silty Clay	124	0	700	28	0
Soft Clay	120	0	300	19	0
Sand	125	34	0	34	0
Shale	Bedrock (Impenetrable)				

TABLE 3

Dallman Ash Pond Soil Strength Parameters

Profile G-G'

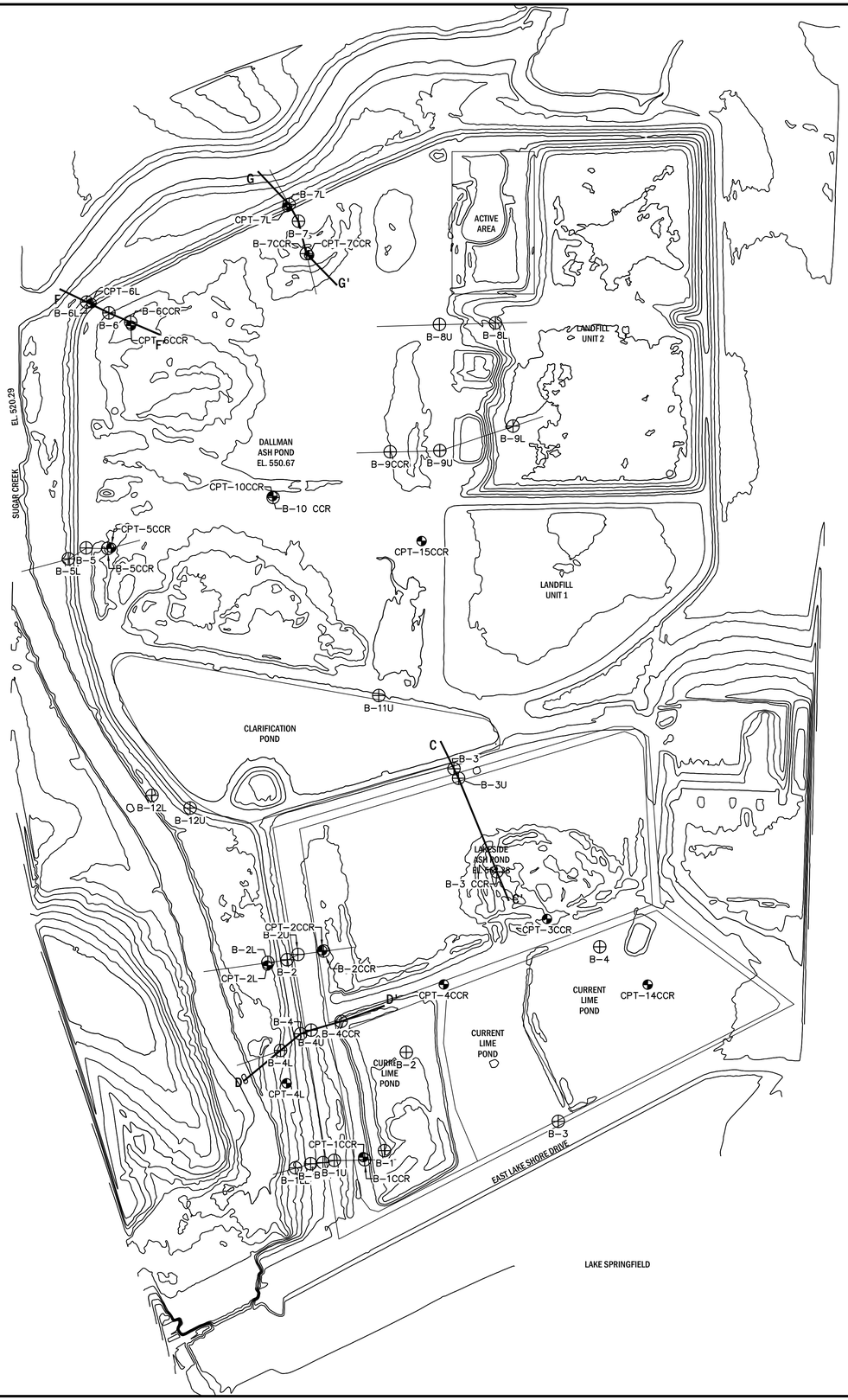
Soil Description	Density (pcf)	Total Strengths (Short Term)		Effective Strengths (Long Term)	
		ϕ (degrees)	c (psf)	ϕ' (degrees)	c (psf)
CCR Ash Layer	100	0	900	25	0
CCR Ash Moist	95	30	0	30	0
CCR Ash Wet	100	15	0	25	0
Lean Clay Fill	124	0	1,800	28	270
Clayey Silt	120	0	800	32	0
Silty Clay	124	0	1,200	28	0
Sand	125	34	0	34	0
Shale	Bedrock (Impenetrable)				

TABLE 4

Clarification Pond Soil Strength Parameters

Profile C-C'

Soil Description	Density (pcf)	Total Strengths (Short Term)		Effective Strengths (Long Term)	
		ϕ (degrees)	c (psf)	ϕ' (degrees)	c (psf)
CCR Wet Ash	100	15	0	25	0
CCR Moist Ash	95	30	0	30	0
Silty Clay Fill	124	0	1,800	28	270
Scrubber Sludge	125	0	750	30	0
Bottom Ash	100	35	0	35	0
Clarification Pond Sediment	105	0	250	28	0
Brown Silty Clay	120	0	1,040	28	0
Gray Clayey Silt	126.5	0	500	32	0



LEGEND

- ⊕ AS-BUILT BORING (2023-2024)
- ◒ AS-BUILT CPT

NOTES

1. LIDAR DATA DERIVED FROM USGS WEBSITE (FLIGHT DATE: OCTOBER 15, 2018).
2. SUGAR CREEK SURFACE WATER ELEVATION IS BASED ON USGS GAGE 05576250 FOR 12/20/2022.

N

0 200 400 800

SCALE: IN FEET

NO.	DATE	REVISION DESCRIPTION	BY

ANDREWS ENGINEERING
3300 GINGER CREEK DRIVE
SPRINGFIELD, ILLINOIS 62711-7233
PH (217) 787-2334 WWW.ANDREWS-ENG.COM
PONTIAC, IL • LOMBARD, IL • INDIANAPOLIS, IN • WARRENTON, MO

DESIGNED BY: KWF | DRAWN BY: BCK | APPROVED BY: KWF

AS-BUILT BORING LOCATIONS

PREPARED FOR
CITY WATER, LIGHT, AND POWER
SPRINGFIELD, SANGAMON COUNTY, ILLINOIS

DATE: JUNE 2024

PROJECT ID: 240227/0006

SHEET NUMBER:

FIG. 3

© 2024 Andrews Engineering, Inc.

Tab: FIGURE 3 Last Saved: June 28, 2024, by Ben Korpus Plotted: Friday, June 28, 2024 10:48:03 AM
J:\S\Springfield CWLP\CWLP Ash Pond\DWG\2024\As-Built Borings 2024 Site.dwg

8. LIQUEFACTION

8.1 Liquefaction Screening

A liquefaction screening was conducted on the embankments of the ash ponds. A review of the borings and laboratory testing from the Lakeside and Dallman Geotechnical Investigation conducted in October 2023 were undertaken. The liquefaction screening process followed the guidelines provided by Bray et al. (2004a) in "Evaluating The Potential For Liquefaction Or Cyclic Failure of Silts and Clays" by R. W. Boulanger and I. M. Idriss. Within the technical paper it states that "Bray et al. (2004a) concluded that soils with PI<=12 and water contents greater than 85% of the LL were susceptible to liquefaction". Additionally, Bray further concludes that "soils with 12<PI<20 and water contents greater than 80% of the LL were 'systematically more resistant to liquefaction but still susceptible to cyclic mobility".

Analysis of samples collected during the October 2023 geotechnical investigation were evaluated against the liquefaction screening guidelines. The liquefaction screening of the borings between the ash ponds and Sugar Creek were inconclusive, thus leading to another geotechnical investigation conducted with a CPT rig. The CPT investigation was conducted near geotechnical borings B-2, B-4, B-6 and B-7 surrounding the ash ponds with additional CPTs being pushed within the ash ponds. The CPT logs are included in Appendix C.

8.2 Liquefaction Analysis

A liquefaction analysis was conducted on the CPT soundings CPT-2L, CPT-4L, CPT-6L and CPT-7L for the perimeter of the ash ponds and on CPT-1CCR, CPT-2CCR, CPT-3CCR, CPT-4CCR, CPT-5CCR, CPT-6CCR, CPT-7CCR, CPT-10CCR, CPT-14CCR, and CPT-15CCR within the ash ponds for estimated liquefaction settlement. The liquefaction analysis was conducted using the CLiq software version 3.5.3.8, copyright by GeoLogismiki.

The liquefaction assessment calculation method employed within the CLiq software was Robertson 2009. The Robertson 2009 method for soil liquefaction is a deterministic model and provides liquefaction potential. The seismic parameters for the liquefaction analysis were obtained from the USGS Earthquake Hazards Program Unified Hazard Tool, Edition Dynamic: Conterminous U.S. 2014 as recommended by Dr. Robertson in his October 2021 short course. This tool provides the site specific peak ground acceleration of 0.0955g with a mean moment magnitude (Mw) of 6.62. The parameters entered into the CLiq software for the maximum acceleration was 0.10g and an earthquake moment magnitude (Mw) of 6.62. As recommended by Robertson, removing transition zones and weighting strains with depth generally obtains results that are less conservative while still being conservative based upon case histories. A factor of safety of 1.2 was entered into the CLiq software as required by 40 CFR 257.73(e)(1)(iv). The lateral displacement analysis utilized the level ground with free face as the insitu alluvial soils are approximately level with Sugar Creek being the free face. The liquefaction analysis reports are

provided in Attachment J. Provided below in Figure 4 is the calculated lateral displacement at each of the CPT soundings surrounding the Lakeside Ash Pond and Dallman Ash Pond. Figure 5 is the overall liquefaction potential index (LPI).

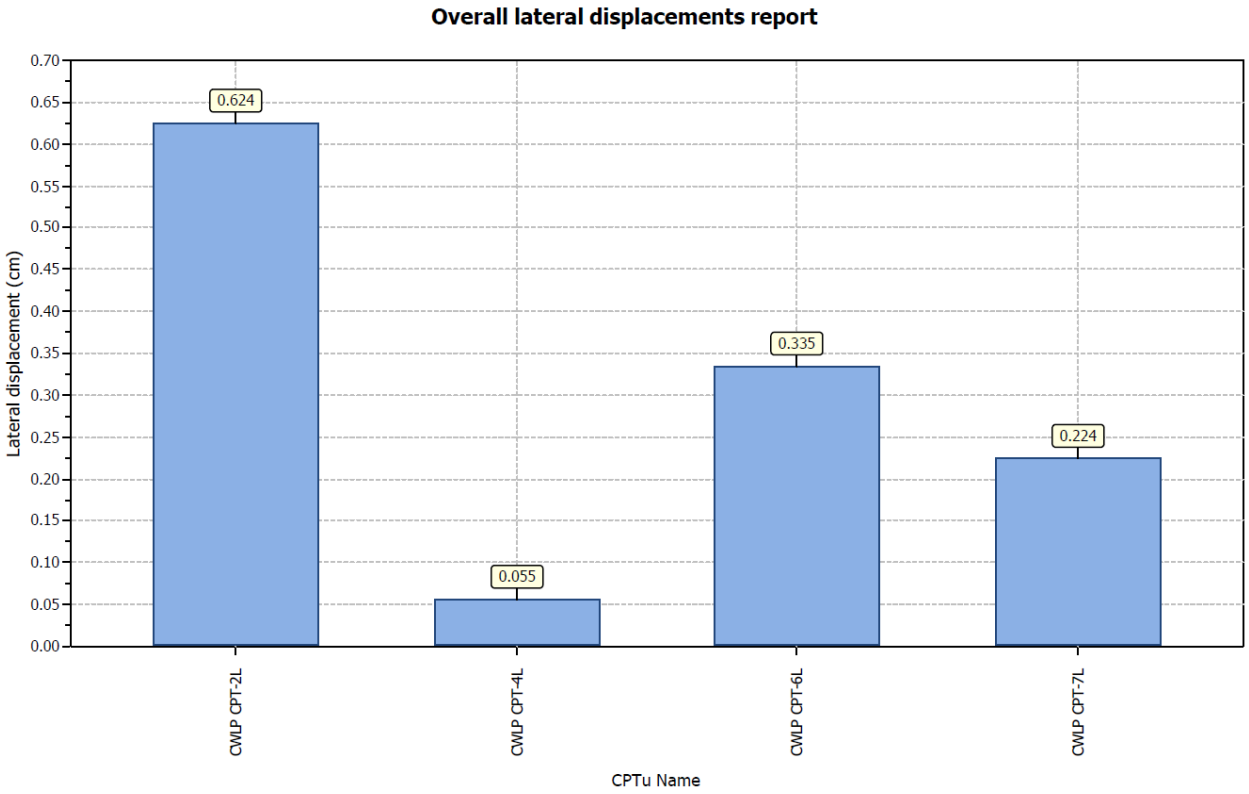


Figure 4

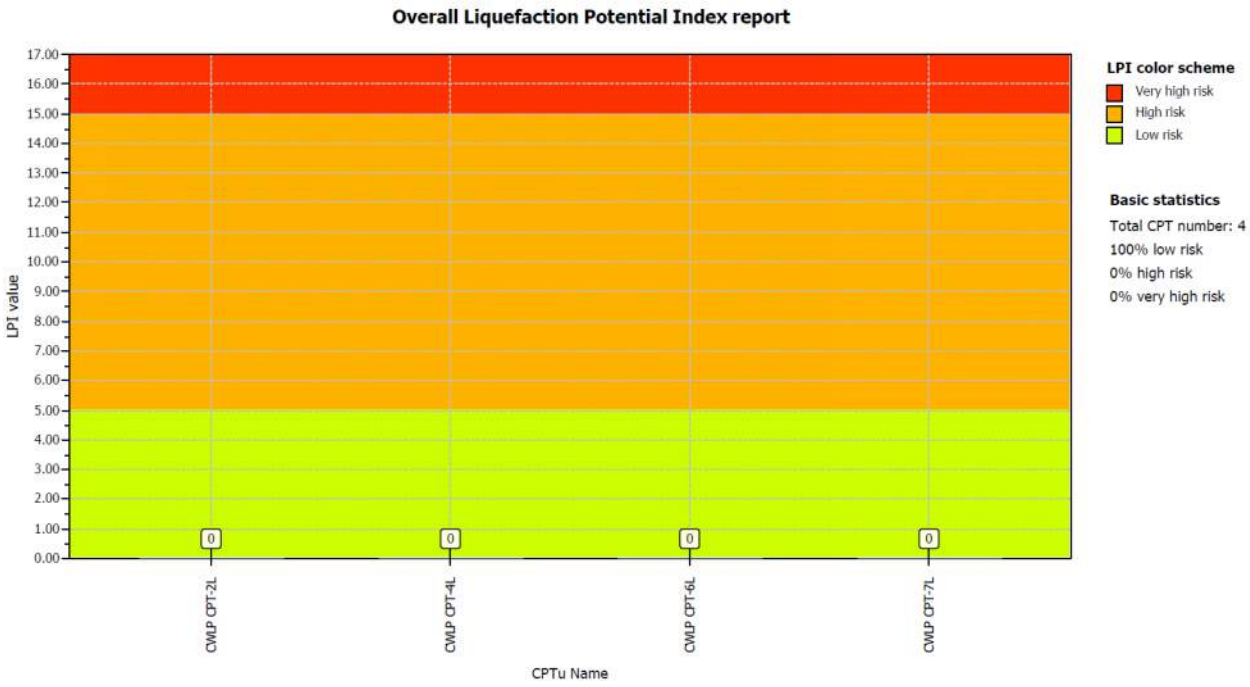


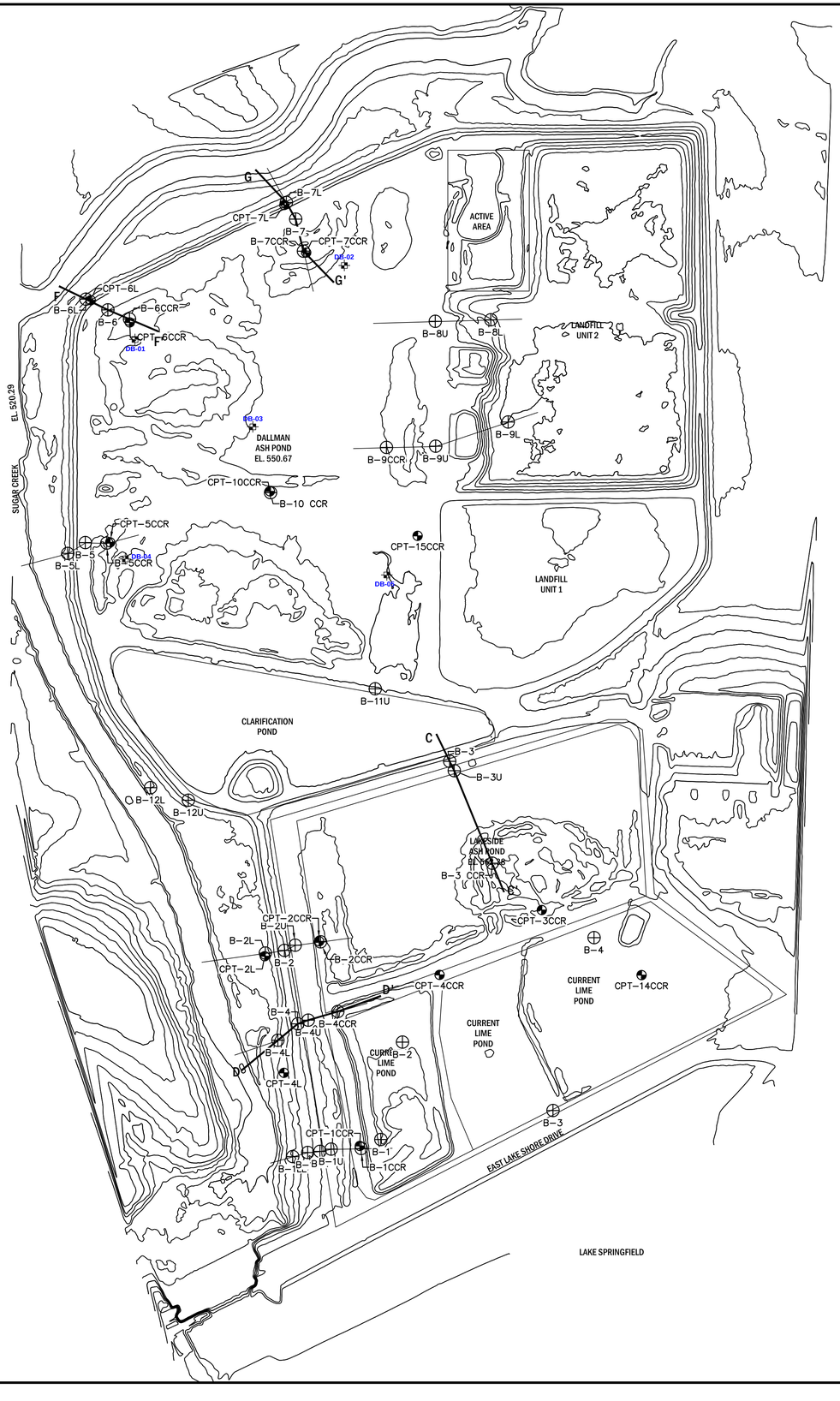
Figure 5

The lateral displacement calculated at CPT-2L is approximately 6 millimeters with the remaining CPTs surrounding the ash ponds being significantly less. This amount of displacement would have no impact on the embankment integrity. With insignificant transitional displacement along the embankment and with no rigid structures within the earthen embankment, displacement would not result in a catastrophic release because of the self-healing nature of clay soils of which the embankment is constructed.

The liquefaction risk as interpreted by Iwasaki is very low if the LPI is zero, low if the LPI is equal to or below five but greater than zero, high if the LPI is equal to or below 15 but greater than 5, and very high if the LPI exceeds 15. Using the Iwasaki criterion for liquefaction potential index, there is a very low risk of liquefaction within the soils investigated. Based upon this information, post-liquefaction slope stability analysis is deemed unnecessary.

9. SUMMARY

The Unstable Areas Demonstration provides the breakthrough, pillar and floor failure analysis. These analyses resulted in factor of safeties exceeding 1.5. The geotechnical analysis indicates that Lakeside Ash Pond and Dallman Ash Pond result in factors of safety equal to or greater than minimum values as required by 40 CFR 257.73(e)(1). This is predicated upon the assumption that cohesive and frictional shear strengths of materials meet or exceed those used in the analyses.



LEGEND

- AS-BUILT BORING (2023-2024)
- AS-BUILT CPT
- Hanson Borings

NOTES

1. LIDAR DATA DERIVED FROM USGS WEBSITE (FLIGHT DATE: OCTOBER 15, 2018).
2. SUGAR CREEK SURFACE WATER ELEVATION IS BASED ON USGS GAGE 05576250 FOR 12/20/2022.

N

0 200 400 800

SCALE: IN FEET

NO.	DATE	REVISION DESCRIPTION	BY

ANDREWS ENGINEERING
3300 GINGER CREEK DRIVE
SPRINGFIELD, ILLINOIS 62711-7233
PH (217) 787-2334 WWW.ANDREWS-ENG.COM
PONTIAC, IL • LOMBARD, IL • INDIANAPOLIS, IN • WARRENTON, MO

DESIGNED BY: KWF | DRAWN BY: BCK | APPROVED BY: KWF

AS-BUILT BORING LOCATIONS

PREPARED FOR
CITY WATER, LIGHT, AND POWER
SPRINGFIELD, SANGAMON COUNTY, ILLINOIS

DATE: JUNE 2024

PROJECT ID: 240227/0006

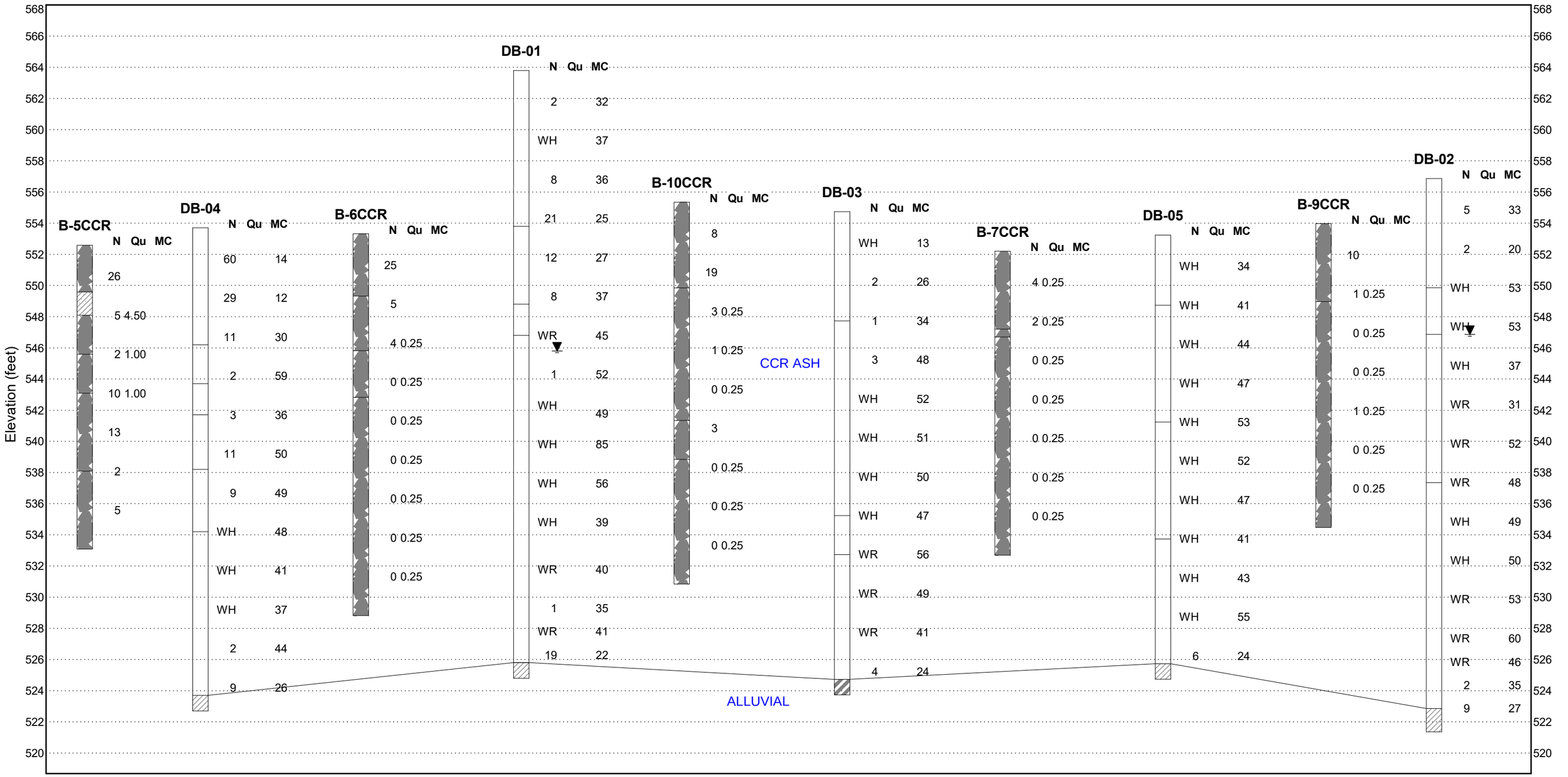
SHEET NUMBER:

FIG. 3

© 2024 Andrews Engineering, Inc.

Tab: FIGURE 3 Last Saved: June 28, 2024, by Ben Korpus Plotted: Friday, June 28, 2024 10:48:03 AM
J:\S\Springfield CWLP\CWLP Ash Pond\DWG\2024\As-Built Borings 2024 Site.dwg

ATTACHMENT 2A (Pond Center)



STRATIGRAPHY - B SIZE 24E0022 - CWLP BORING LOGS.GPJ 2010 HANSON.GDT 3/13/25

HANSON

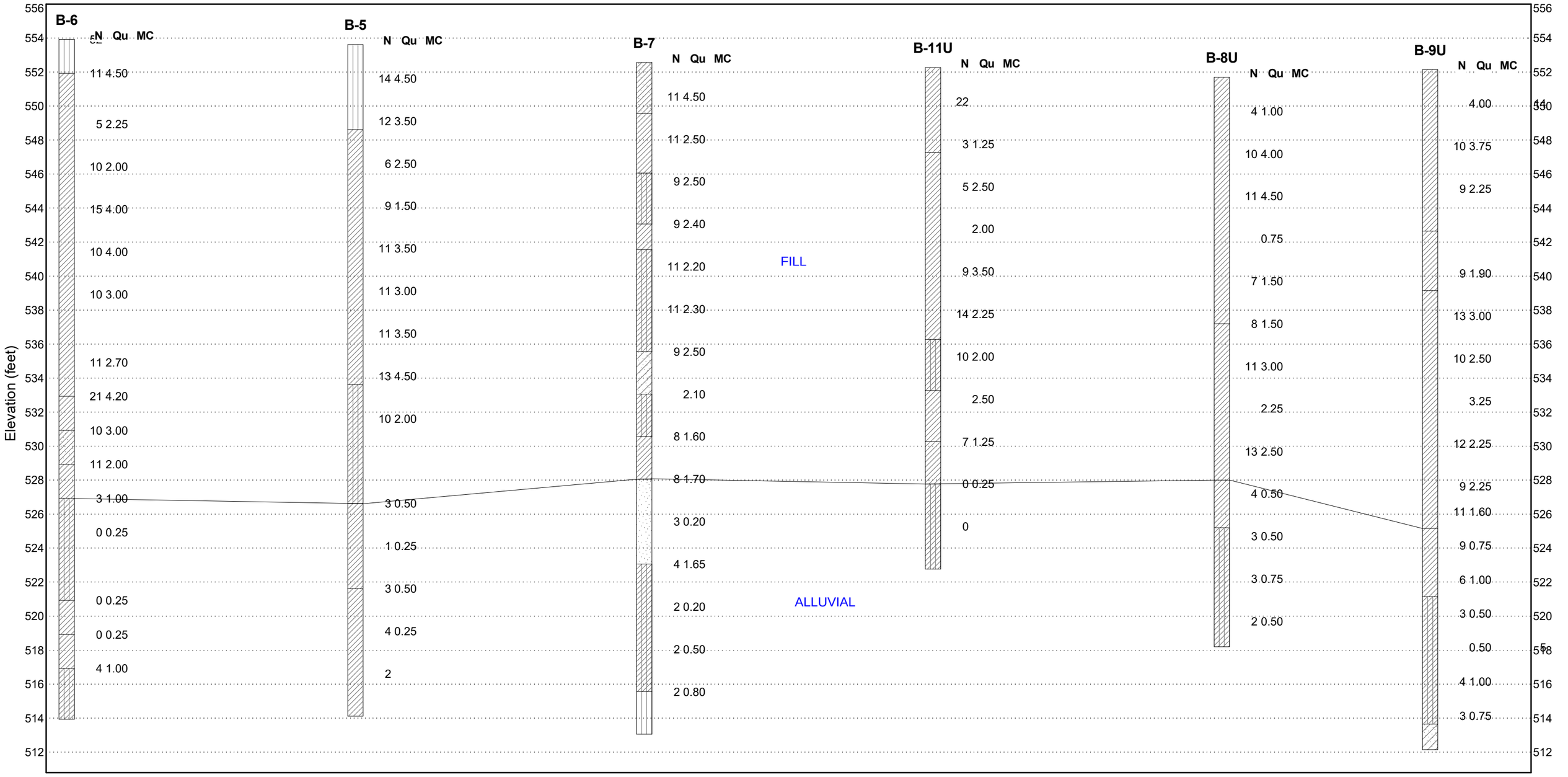
LITHOLOGY GRAPHICS

- Coal
- USCS Low Plasticity Sandy Clay
- USCS Low Plasticity Clay
- USCS High Plasticity Clay

CWLP Ash Pond Dewatering
CWLP

Project Number: 24E0022

ATTACHMENT 2B (Pond Crest)



Distance Along Baseline (feet)

STRATIGRAPHY - B SIZE 24E0022 - CWLP BORING LOGS.GPJ 2010 HANSON.GDT 3/13/25

HANSON

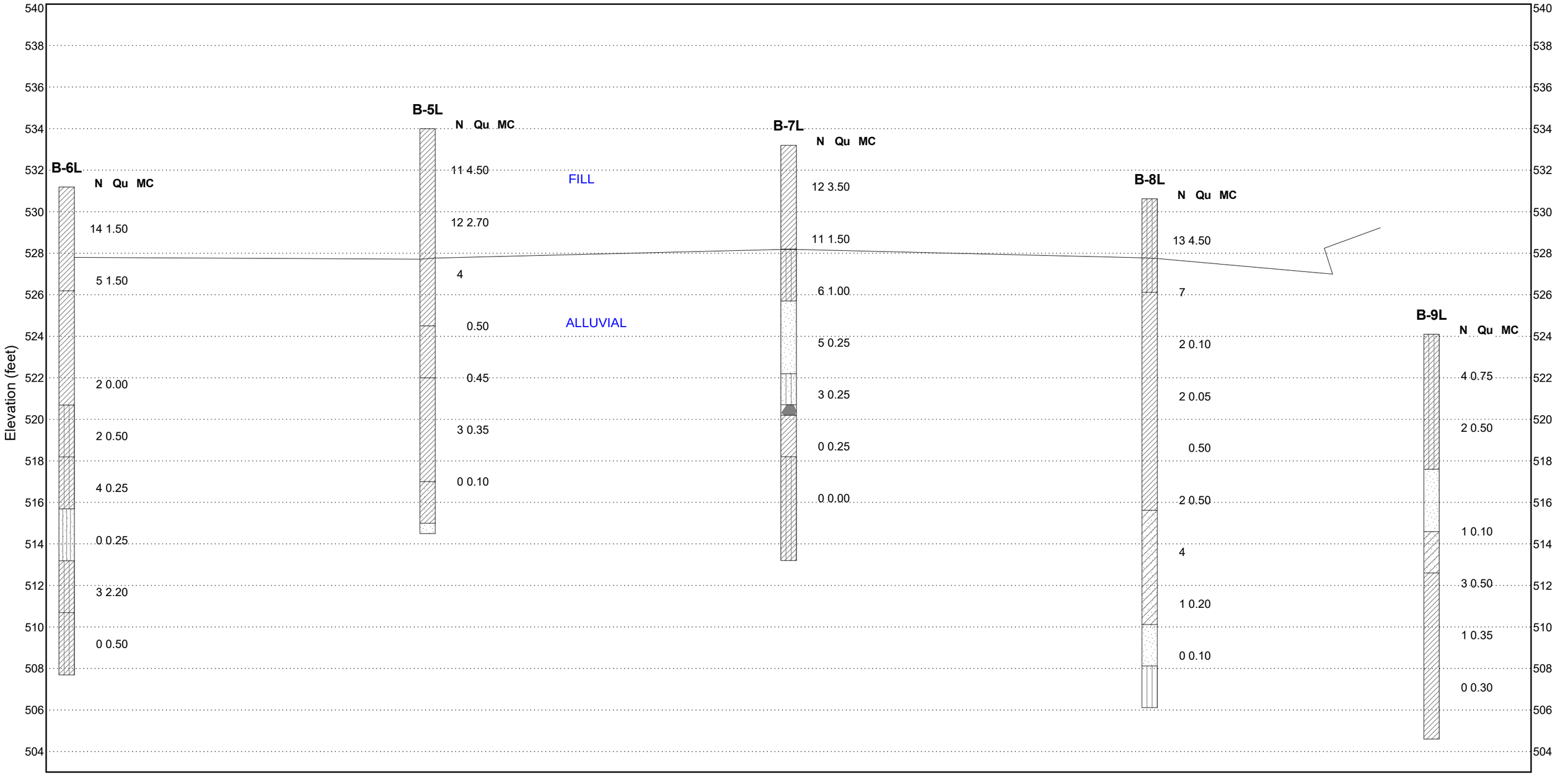
LITHOLOGY GRAPHICS

- USCS Low Plasticity Clay
- USCS Low Plasticity Silty Clay
- USCS Silt
- USCS Low Plasticity Sandy Clay
- USCS Clayey Sand
- USCS Poorly-graded Sand

CWLP Ash Pond Dewatering
CWLP

Project Number: 24E0022

ATTACHMENT 2C (Pond Outer Toe)



Distance Along Baseline (feet)

HANSON

LITHOLOGY GRAPHICS

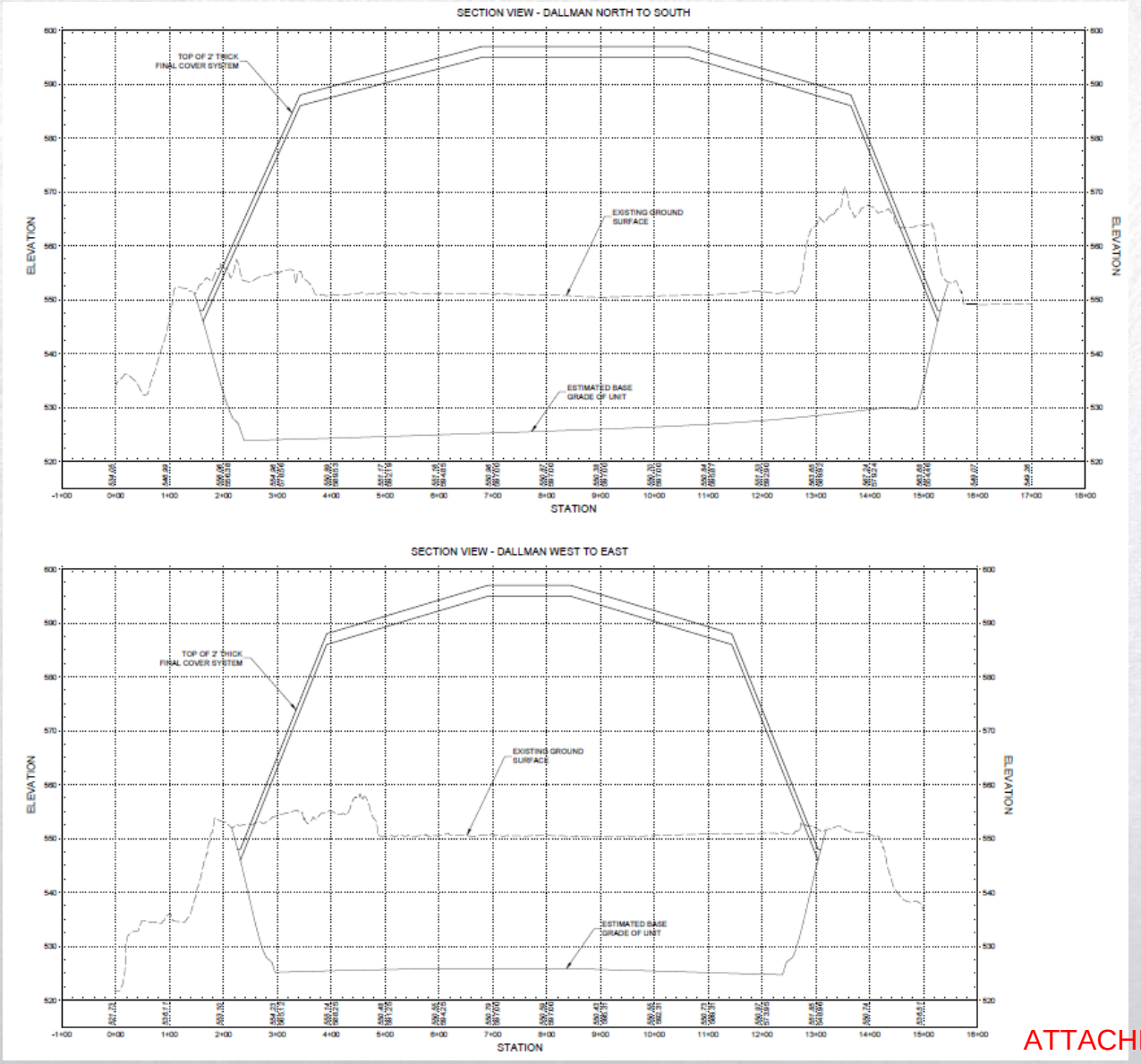
- USCS Low Plasticity Clay
- USCS Low Plasticity Sandy Clay
- USCS Poorly-graded Sand
- USCS Low Plasticity Silty Clay
- USCS Sandy Silt
- USCS Silty Sand
- Coal
- USCS Clayey Sand
- USCS Silt

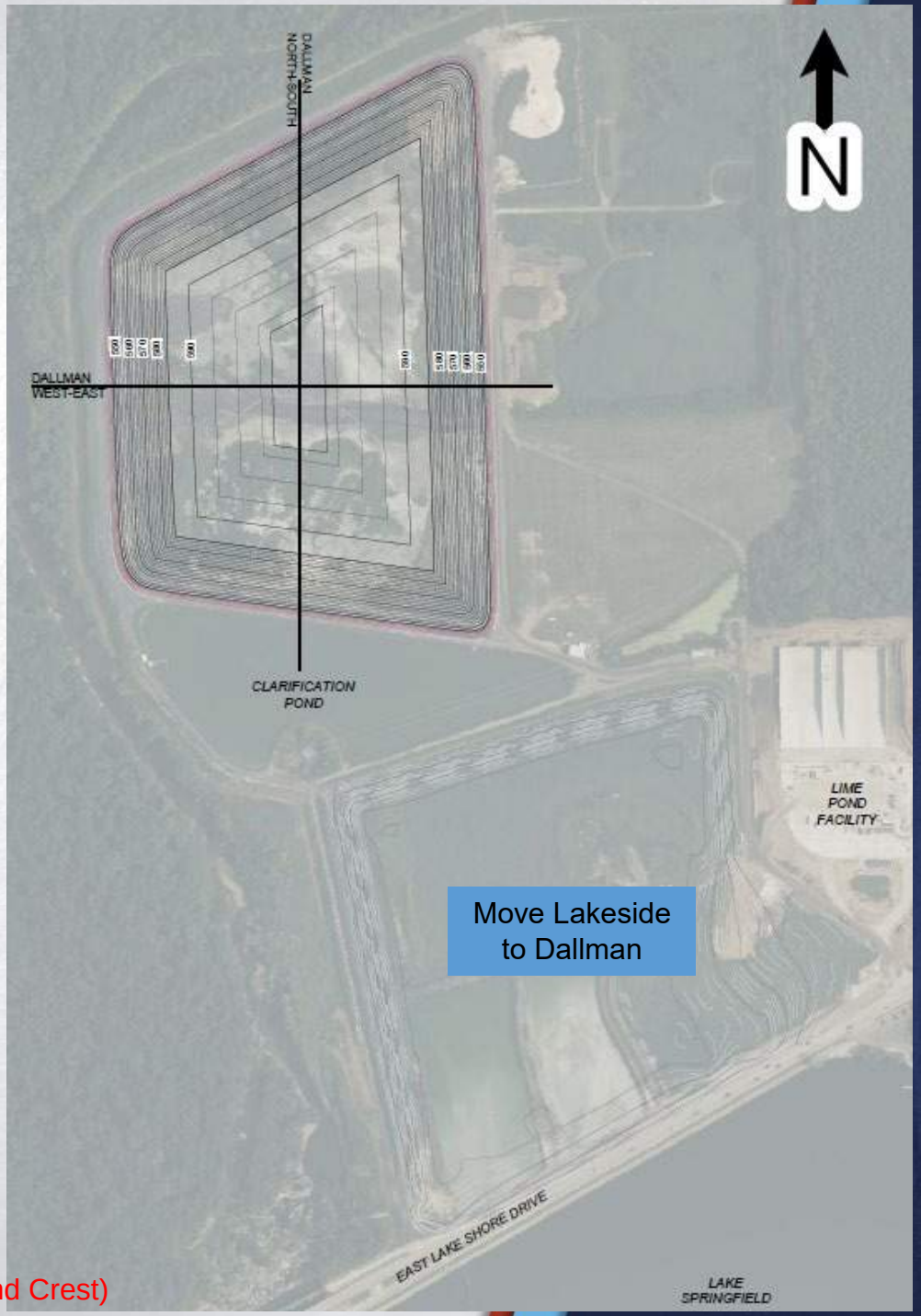
CWLP Ash Pond Dewatering
CWLP

Project Number: 24E0022

STRATIGRAPHY - B SIZE 24E0022 - CWLP BORING LOGS.GPJ 2010 HANSON.GDT 3/13/25

Move Lakeside to Dallman





ATTACHMENT 3 (Pond Crest)

Appendix F

Closure Plan Drawings and Sections

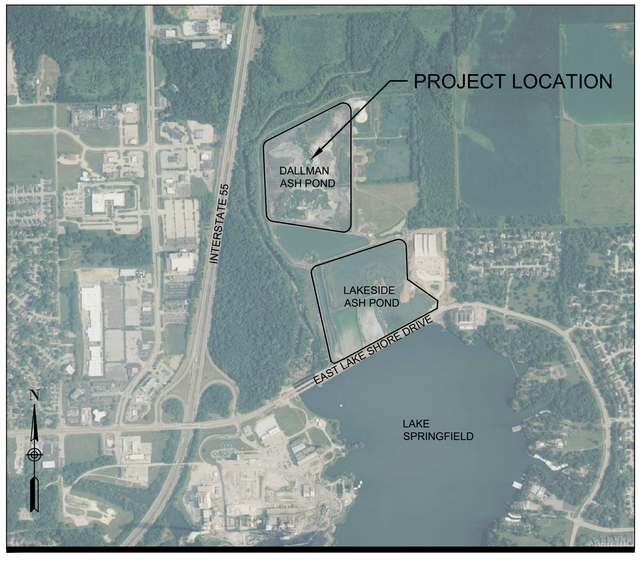
PRELIMINARY PLANS - ISSUED 09-20-2025

ASH POND CLOSURE

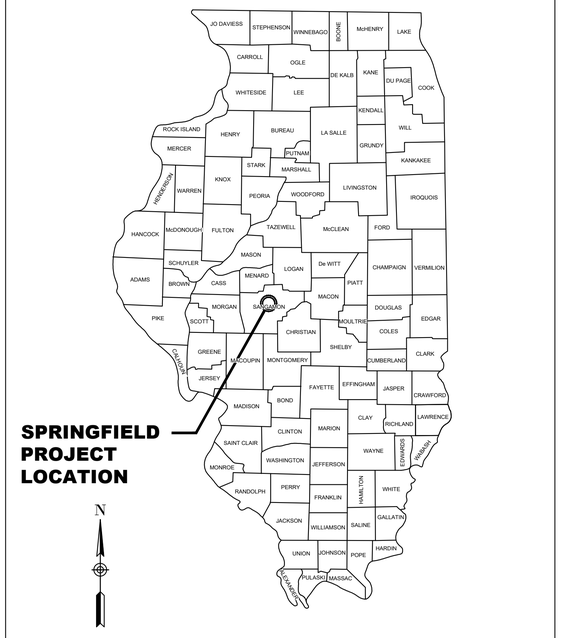
CWLP
CITY WATER LIGHT AND POWER
SPRINGFIELD, SANGAMON COUNTY, ILLINOIS

SHEET INDEX	
Sheet	Sheet Title
G001	COVER SHEET
G002	GENERAL NOTES AND SURVEY DATA
C101	CONSOLIDATION PLAN
C102	DALLMAN ASH POND ALIGNMENT PLAN
C103	DALLMAN ASH POND INTERIM GRADING PLAN
C104	DALLMAN ASH POND CLOSURE PLAN
C105	LAKESIDE CLOSURE PLAN
C106	DALLMAN PUMP WELL LAYOUT
C201	DALLMAN ASH POND VERTICAL ALIGNMENTS
C202	TYPICAL SECTIONS
C501	DEWATERING WELL DETAILS
C502	PUMP DETAILS
E101	ELECTRICAL ONE-LINE DIAGRAM

VICINITY MAP



LOCATION MAP



G001

No.	Issue/Description	Sheets Changed	Date	By

HANSON™
HANSON PROFESSIONAL SERVICES INC.
1525 South Sixth Street
Springfield, Illinois 62703-2886
Telephone: 217.788.2450
Fax: 217.788.2503

EXP. MM/DD/YY

MM/DD/YYYY
Date

BARRY ROWE, P.E.
Electrical Engineer

HANSON™
HANSON PROFESSIONAL SERVICES INC.
1525 South Sixth Street
Springfield, Illinois 62703-2886
Telephone: 217.788.2450
Fax: 217.788.2503

EXP. MM/DD/YY

INTERIM REVIEW xx%
FOR REVIEW PURPOSES ONLY.
NOT FOR CONSTRUCTION,
PERMIT OR BIDDING

MM/DD/YYYY
Date

BRAD HOOTS, P.E.
Civil Engineer

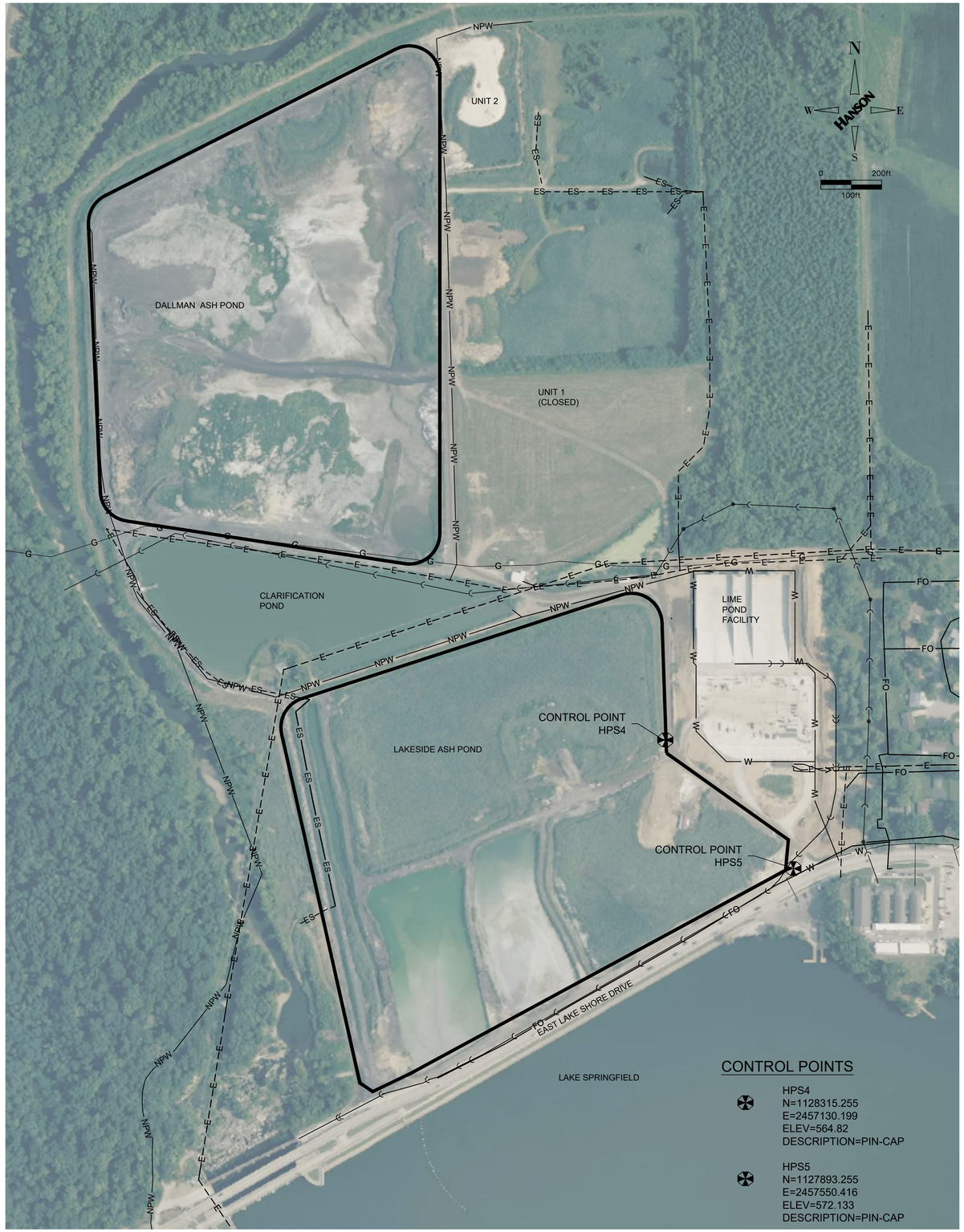
BRANS00939 9/19/2025 9:18 AM
i:\25jobs\25e0006_00\CADSite\Sheet\G001.dwg

GENERAL NOTES

1. "IDOT STANDARD SPECIFICATIONS", WHERE REFERENCED IN THE PLANS OR TECHNICAL SPECIFICATIONS, REFERS TO THE "STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION" ADOPTED JANUARY 1, 2022, PUBLISHED BY THE ILLINOIS DEPARTMENT OF TRANSPORTATION (IDOT).
2. ALL SECTIONS, DETAILS, AND NOTES SHOWN ON THE DRAWINGS ARE INTENDED TO BE TYPICAL AND SHALL APPLY TO SIMILAR SITUATIONS ELSEWHERE, UNLESS OTHERWISE SHOWN.
3. CONTRACTOR SHALL VERIFY ALL DIMENSIONS AND EXISTING CONDITIONS BEFORE STARTING WORK. IF CONDITIONS VARY FROM THOSE INDICATED ON THE DRAWINGS, OWNER SHALL BE NOTIFIED AND NO WORK SHALL BE DONE IN THE AREA WITHOUT APPROVAL.
4. SCALE FOR THE DRAWINGS IS FOR GENERAL INFORMATION ONLY. LOCATIONS AND DIMENSIONS SHALL BE TAKEN AS SHOWN AND NOT SCALED.
5. IT IS CONTRACTOR'S RESPONSIBILITY TO ASCERTAIN EXISTING FIELD CONDITIONS BEFORE BIDDING ON THIS PROJECT, ORDERING MATERIALS, OR BEGINNING CONSTRUCTION.
6. CONTRACTOR'S WORK ACTIVITIES SHALL BE RESTRICTED TO AREAS WITHIN THE LIMITS OF CONSTRUCTION. CONTRACTOR'S ACTIVITIES AND VEHICLES SHALL NOT BE ALLOWED OUTSIDE OF THESE LIMITS UNLESS APPROVED BY OWNER.
7. DISTURBED EARTH SURFACES SHALL BE SEEDED PER THE PROJECT SPECIFICATIONS.
8. CONTRACTOR IS RESPONSIBLE FOR THE SITE RESTORATION.
9. TEMPORARY EROSION CONTROL SYSTEMS SHALL BE INSTALLED IN ACCORDANCE WITH IDOT STANDARD DRAWING 280001-07 TEMPORARY EROSION CONTROL SYSTEMS. AND ARTICLE 280 OF THE IDOT STANDARD SPECIFICATIONS.
10. ALL OPEN EXCAVATION WORK SHALL BE PERFORMED IN ACCORDANCE WITH OSHA 29 CFR 1926, SUBPART P- "EXCAVATIONS". THE SUBCONTRACTOR SHALL DESIGNATE A QUALIFIED "COMPETENT PERSON" AS DEFINED IN OSHA SECTION 1926.650(b) PRIOR TO THE COMMENCEMENT OF ANY EXCAVATION ACTIVITIES.

SURVEY AND LAYOUT

1. THE DESIGN PLANS INCLUDED WERE BASED UPON A HORIZONTAL COORDINATE SYSTEM BASED ON THE NORTH AMERICAN DATUM OF 1983 (NAD83), ILLINOIS STATE PLANE WEST ZONE AND VERTICAL ELEVATIONS BASED ON NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88).
2. CONTRACTOR SHALL BE RESPONSIBLE FOR RE-ESTABLISHING ANY PROPERTY MONUMENTS THAT BECOME DAMAGED OR DESTROYED DURING CONSTRUCTION ACTIVITIES.
3. CONTRACTOR SHALL BE RESPONSIBLE FOR PROPER ALIGNMENT (VERTICAL AND HORIZONTAL) AT ALL INTERFACES BETWEEN NEW AND EXISTING WORK TO ASSURE PROPER INSTALLATION AND USAGE.
4. MONITORING WELLS IDENTIFIED ON THE PLAN SHEETS SHALL BE PROTECTED FROM DAMAGE DURING THE SITE WORK, EXCEPT THOSE IDENTIFIED FOR REMOVAL.



CONTROL POINTS

HPS4
N=1128315.255
E=2457130.199
ELEV=564.82
DESCRIPTION=PIN-CAP

HPS5
N=1127893.255
E=2457550.416
ELEV=572.133
DESCRIPTION=PIN-CAP

HANSON

© Copyright Hanson Professional Services 2025

Hanson Professional Services Inc.
1525 S. 6th Street
Springfield, IL 62568
phone: 217-788-2450
fax: 217-788-2503
Offices Nationwide
www.hanson-inc.com

INTERIM REVIEW xx%
FOR REVIEW PURPOSES ONLY. NOT FOR CONSTRUCTION, PERMIT OR BIDDING

BRAD HOOTS, P.E
LIC: IL 062-055737
DATE: 08/27/2025

CITY WATER LIGHT AND POWER · SPRINGFIELD, IL

CWLP

DALLMAN ASH POND CLOSURE

SPRINGFIELD, ILLINOIS

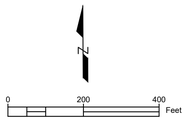
MARK	DATE	DESCRIPTION		
		DES	DRN	REV

ISSUE: 09-20-2025
PROJECT NO: 25E0006
CAD FILE:
DESIGN BY: BR
DRAWN BY: BR
REVIEWED BY: MH

SHEET TITLE
GENERAL NOTES AND SURVEY DATA

G002

SEP 19, 2025 9:18 AM BRANS00939
I:\25JOBS\25E0006_00\CAD\SITE\SHEET\G002.DWG



CONSTRUCTION SEQUENCE:

STEP 1
INSTALL TEMPORARY EROSION AND SEDIMENT CONTROL MEASURES.

STEP 2
GRADE THE EXISTING SURFACE OF DALLMAN ASH POND TO DRAIN TOWARD THE OUTSIDE EDGES PRIOR TO PLACING FILTER BAGS.

STEP 3
PUMP WATER FROM THE 10 NEW DEWATERING WELLS TO LOWER WATER CONTENT OF THE DALLMAN ASH POND.

STEP 4A
MOVE ENOUGH DRY LAKESIDE ASH POND CCR TO STOCK PILES ON DALLMAN ASH POND SO SLURRY OPERATIONS CAN BEGIN.

STEP 4B
SLURRY LAKESIDE ASH POND AND PUMP INTO FILTER BAGS INSTALLED ON THE SURFACE OF THE DALLMAN ASH POND.

STEP 4C
RAISE THE DEWATERING WELLS AS BAGS ARE BUILT UP AROUND THE WELLS.

STEP 5
USE DRY CCR MATERIAL OR LAKESIDE ASH POND BERM MATERIAL TO COVER THE FILTER BAGS AND GRADE TO THE ELEVATIONS SHOWN ON THE FINAL COMPLETION PLAN.

STEP 6A
COMMENCE ALTERNATE FINAL COVER INSTALLATION (CLOSURETURF) ONCE ALL MATERIAL IS TRANSFERRED FROM THE LAKESIDE ASH POND TO THE DALLMAN ASH POND. THE DEWATERING WELLS WILL BE RAISED TO THE FINAL SURFACE ELEVATION AND WILL REMAIN IN PLACE TO FACILITATE FUTURE DEWATERING OPERATIONS.

STEP 6B
CONSTRUCT LAKESIDE CHANNEL OUTFALL
GRADE THE LAKESIDE ASH POND TO DRAIN VISIBLY REMOVING ALL CCR.
APPLY FERTILIZER, SEED AND MULCH.

STEP 7
ONCE FINAL SEEDING IS ESTABLISHED, REMOVE TEMPORARY EROSION AND SEDIMENT CONTROLS.



© Copyright Hanson Professional Services 2025

Hanson Professional Services Inc.
1525 S. 6th Street
Springfield, IL 62568
phone: 217-788-2450
fax: 217-788-2503
Offices Nationwide
www.hanson-inc.com

INTERIM REVIEW xx%
FOR REVIEW PURPOSES ONLY. NOT FOR CONSTRUCTION, PERMIT OR BIDDING

BRAD HOOTS, P.E
LIC: IL 062-055737
DATE: 08/27/2025

CWLP

DALLMAN ASH POND CLOSURE

SPRINGFIELD, ILLINOIS

MARK	DATE	DESCRIPTION		
		DES	DRN	REV

ISSUE: 09-20-2025
PROJECT NO: 25E0006
CAD FILE:
DESIGN BY: DBH
DRAWN BY: DBH
REVIEWED BY: XX

SHEET TITLE

CONSOLIDATION PLAN

C101
SHEET 3 OF 14

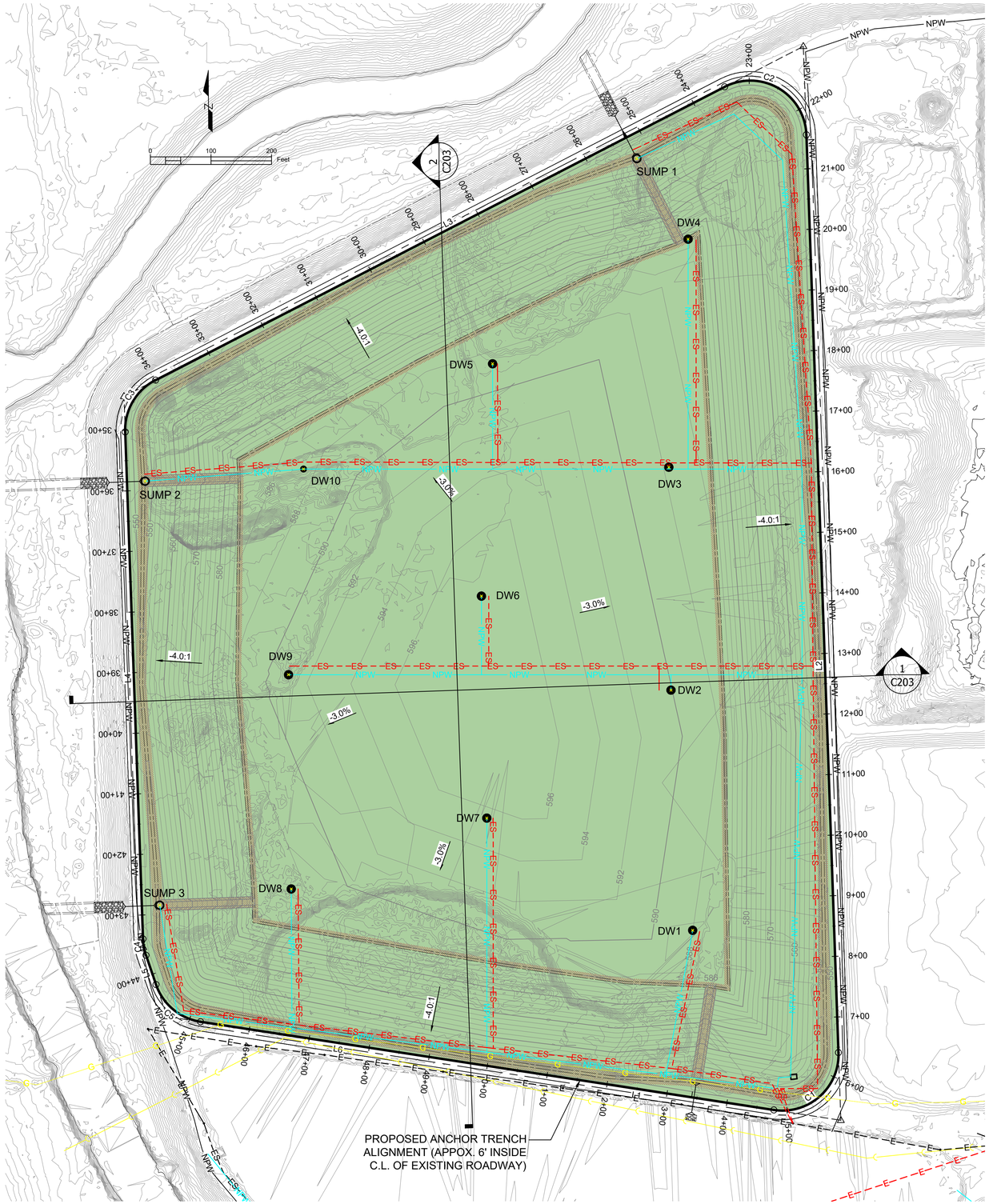
SEP 19, 2025 9:18 AM BRANSO0939
I:\25JOBS\25E0006_00\CAD\SITE\SHEET\C101-CBR PLAN.DWG

LINE TABLE: ALIGNMENTS								
LINE #	LENGTH	DIRECTION	START STA	START NORTHING	START EASTING	END STA	END NORTHING	END EASTING
L1	478.43'	S81° 15' 03.50"E	0+00.00	1128949.28	2455851.68	4+78.43	1128876.51	2456324.53
L2	1514.99'	N02° 00' 08.01"W	6+41.08	1128971.17	2456431.05	21+56.07	1130485.23	2456378.12
L3	1055.98'	S62° 44' 13.04"W	23+42.15	1130564.22	2456243.30	33+98.13	1130080.50	2455304.63
L4	836.98'	S02° 00' 08.01"E	35+02.64	1129995.04	2455254.56	43+39.62	1129158.58	2455283.80
L5	51.12'	S19° 00' 09.65"E	43+67.07	1129131.69	2455288.78	44+18.18	1129083.36	2455305.43
L6	478.43'	S81° 15' 03.50"E	45+18.68	1129022.05	2455378.82	49+97.10	1128949.28	2455851.68

CURVE TABLE: ALIGNMENTS					
CURVE #	LENGTH	RADIUS	DELTA	CHORD DIRECTION	CHORD LENGTH
C1	162.66'	92.50'	100°45'05"	N48° 22' 24.24"E	142.49'
C2	186.08'	92.50'	115°15'39"	N59° 37' 57.49"W	156.25'
C3	104.52'	92.50'	64°44'21"	S30° 22' 02.51"W	99.05'
C4	27.45'	92.50'	17°00'02"	S10° 30' 08.83"E	27.35'
C5	100.50'	92.50'	62°14'54"	S50° 07' 36.57"E	95.63'

NOTES:

1. SEE SHEET C201 FOR ANCHOR TRENCH AND PERIMETER DITCH PROFILES.



© Copyright Hanson Professional Services 2025

Hanson Professional Services Inc.
1525 S. 6th Street
Springfield, IL 62568
phone: 217-788-2450
fax: 217-788-2503
Offices Nationwide
www.hanson-inc.com

INTERIM REVIEW xx%
FOR REVIEW PURPOSES ONLY. NOT FOR CONSTRUCTION, PERMIT OR BIDDING

BRAD HOOTS, P.E
LIC: IL 062-055737
DATE: 08/27/2025

CWLP

DALLMAN ASH POND CLOSURE

SPRINGFIELD, ILLINOIS

MARK	DATE	DESCRIPTION		
		DES	DRN	REV

ISSUE: 09-20-2025
PROJECT NO: 25E0006
CAD FILE:
DESIGN BY: DBH
DRAWN BY: DBH
REVIEWED BY: JMH

SHEET TITLE

DALLMAN ASH POND ALIGNMENT PLAN

C102

SEP 19, 2025 9:18 AM BRANS00939
I:\25JOBS\25E0006_00\CAD\SITE\SHEET\C102-DALLMAN ALIGNMENT PLAN.DWG

LEGEND:

- EXISTING UNDERGROUND PRIMARY ELECTRICAL
- EXISTING UNDERGROUND SECONDARY ELECTRICAL
- PROPOSED UNDERGROUND SECONDARY ELECTRICAL
- EXISTING OVERHEAD PRIMARY ELECTRICAL
- EXISTING OVERHEAD SECONDARY ELECTRICAL
- EXISTING GAS LINE
- EXISTING WATER LINE
- EXISTING NON-POTABLE WATER LINE
- PROPOSED NON POTABLE WATER LINE
- EXISTING SEWER LINE
- EXISTING COMMUNICATION LINE
- EXISTING POWER POLE
- PROPOSED DEWATERING WELLS
- PROPOSED INTERIM DITCH SUMP
- EXISTING MONITORING WELLS



N

0 100 200 Feet

NOTES:

1. CONTOURS REPRESENT PERIMETER DRAINAGE DITCH CONSTRUCTION AND GRADING OF EXISTING CCR TO PROMOTE POSITIVE DRAINAGE DURING DEWATERING AND FILL PLACEMENT VIA GEOTUBE.
2. SEE SHEET C102 FOR ANCHOR TRENCH ALIGNMENT AND SHEET C201 FOR PERIMETER DITCH PROFILE.

HANSON

Hanson Professional Services Inc.
1525 S. 6th Street
Springfield, IL 62568
phone: 217-788-2450
fax: 217-788-2503
Offices Nationwide
www.hanson-inc.com

© Copyright Hanson Professional Services 2025

INTERIM REVIEW xx%
FOR REVIEW PURPOSES ONLY. NOT FOR CONSTRUCTION, PERMIT OR BIDDING

BRAD HOOTS, P.E
LIC: IL 062-055737
DATE: 08/27/2025

CITY WATER LIGHT AND POWER · SPRINGFIELD, IL ·

CWLP

DALLMAN ASH POND CLOSURE

SPRINGFIELD, ILLINOIS

MARK	DATE	DESCRIPTION		
		DES	DRN	REV

ISSUE: 09-20-2025
PROJECT NO: 25E0006
CAD FILE:
DESIGN BY: DBH
DRAWN BY: DBH
REVIEWED BY: XX

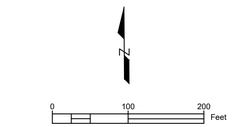
SHEET TITLE

DALLMAN ASH POND INTERIM GRADING PLAN

C103

SHEET 5 OF 14

SEP 19, 2025 9:18 AM BRANSO0939
I:\25JOBS\25E0006_00\CAD\SITE\SHEET\C104-INTERIM SITE PLAN.DWG



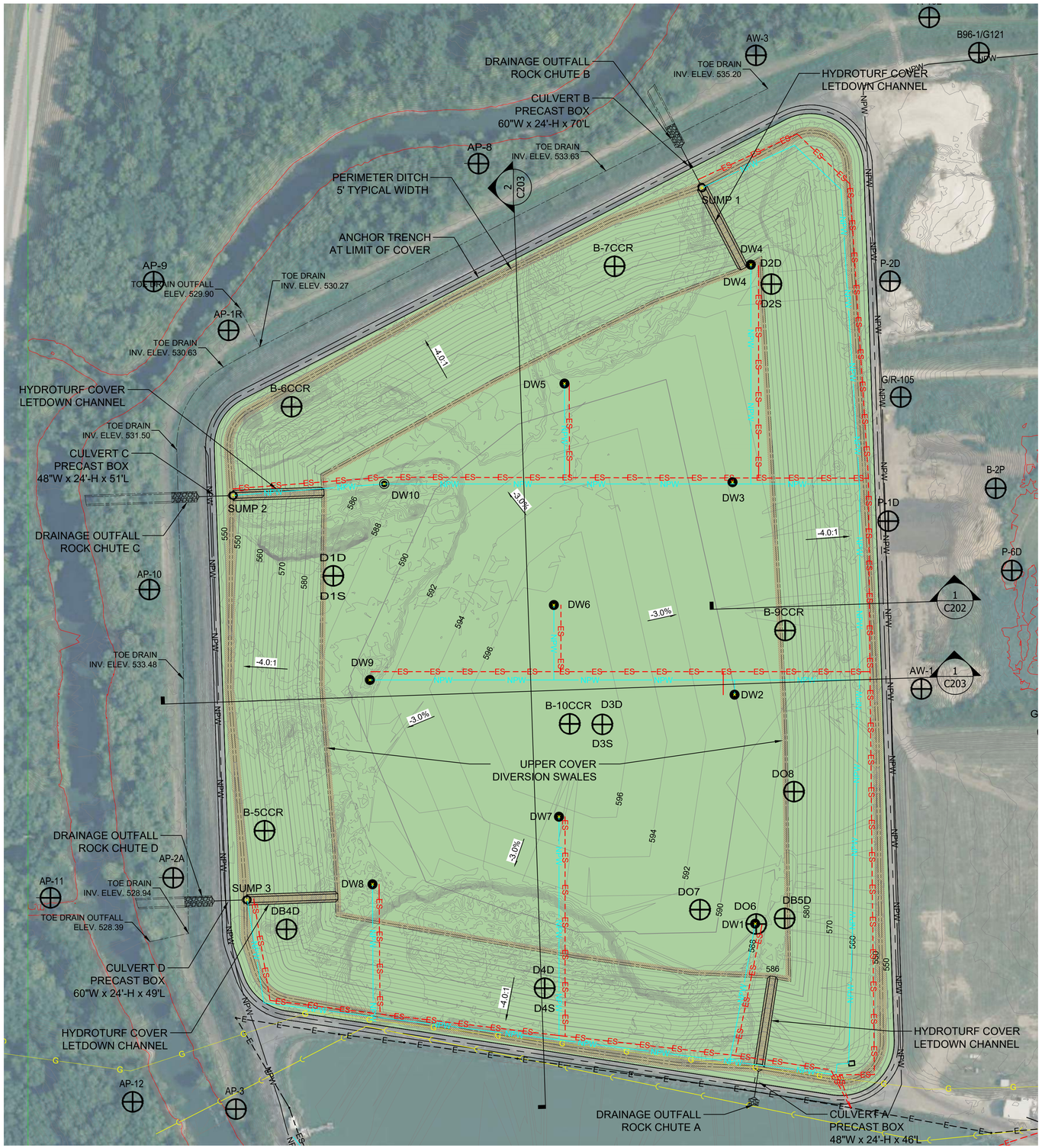
LEGEND

- CLOSURE TURF
- HYDROTURF
- PERMANENT SEEDING
- RIPRAP

NOTES:

1. SEE SHEET C102 FOR ANCHOR TRENCH ALIGNMENT AND SHEET C201 FOR PERIMETER DITCH PROFILE.

DALLMAN MONITORING WELLS		
Short ID	Northing	Easting
D1D	1,129,774.646	2,455,460.387
D2D	1,130,279.471	2,456,218.172
D3D	1,129,517.696	2,455,925.821
D4	1,129,061.184	2,455,862.181
DB4D	1,129,163.191	2,455,379.61
DB5D	1,129,181.966	2,456,241.368
DW1	1,129,174.103	2,456,191.27
DO6	1,129,172.348	2,456,192.204
DO7	1,129,197.213	2,456,094.954
DO8	1,129,401.38	2,456,257.44
B-5CCR	1,129,333.75	2,455,341.56
B-6CCR	1,130,067.17	2,455,388.17
B-7CCR	1,130,310.33	2,455,947.06
B-9CCR	1,129,680.19	2,456,242.16
B-10CCR	1,129,518.55	2,455,869.56
D1S	1,129,777.846	2,455,464.375
D2S	1,130,282.963	2,456,222.602
D3S	1,129,514.675	2,455,930.029
DB4S	1,129,157.327	2,455,380.777
DB5S	1,129,176.576	2,456,240.522



SEP 19, 2025 9:19 AM BRANSO0939
I:\25JOBS\25E0006_00\CAD\SITE\SHEET\C103-DALLMAN SITE PLAN.DWG

HANSON

© Copyright Hanson Professional Services 2025

Hanson Professional Services Inc.
1525 S. 6th Street
Springfield, IL 62568
phone: 217-788-2450
fax: 217-788-2503
Offices Nationwide
www.hanson-inc.com

INTERIM REVIEW xx%
FOR REVIEW PURPOSES ONLY. NOT FOR CONSTRUCTION, PERMIT OR BIDDING

BRAD HOOTS, P.E
LIC: IL 062-055737
DATE: 08/27/2025

CITY WATER LIGHT AND POWER · SPRINGFIELD, IL ·

CWLP

DALLMAN ASH POND CLOSURE

SPRINGFIELD, ILLINOIS

MARK	DATE	DESCRIPTION		
		DES	DRN	REV

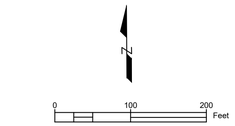
ISSUE: 09-20-2025
PROJECT NO: 25E0006
CAD FILE:
DESIGN BY: DBH
DRAWN BY: DBH
REVIEWED BY: JMH

SHEET TITLE

DALLMAN ASH POND CLOSURE PLAN

C104

SHEET 6 OF 14



LEGEND

- CLOSURE TURF
- HYDROTURF
- PERMANENT SEEDING
- RIPRAP

NOTES:

1. SEE SHEET C102 FOR ANCHOR TRENCH ALIGNMENT AND SHEET C201 FOR PERIMETER DITCH PROFILE.

LAKESIDE MONITORING WELLS		
Short ID	Northing	Easting
L1D	1,127,471.500	2,456,543.151
LB2D	1,127,826.170	2,456,727.264
L3D	1,128,216.985	2,456,765.964
L4	1,127,968.131	2,457,141.149
L5D	1,128,308.427	2,456,118.312
B-1CCR	1,127,387.376	2,456,173.675
B-2CCR	1,128,059.370	2,456,087.510
B-3CCR	1,128,336.730	2,456,638.090
B-4CCR	1,127,834.100	2,456,152.870
L1S	1,127,476.295	2,456,541.736
LB2S	1,127,821.347	2,456,728.788
L3S	1,128,212.801	2,456,770.611
L5S	1,128,304.992	2,456,121.932



HANSON

© Copyright Hanson Professional Services 2025

Hanson Professional Services Inc.
1525 S. 6th Street
Springfield, IL 62568
phone: 217-788-2450
fax: 217-788-2503
Offices Nationwide
www.hanson-inc.com

INTERIM REVIEW xx%
FOR REVIEW PURPOSES ONLY. NOT FOR CONSTRUCTION, PERMIT OR BIDDING

BRAD HOOTS, P.E
LIC: IL 062-055737
DATE: 08/27/2025

CITY WATER LIGHT AND POWER · SPRINGFIELD, IL

CWLP

DALLMAN ASH POND CLOSURE

SPRINGFIELD, ILLINOIS

MARK	DATE	DESCRIPTION		
		DES	DRN	REV

ISSUE: 09-20-2025
PROJECT NO: 25E0006
CAD FILE:
DESIGN BY: DBH
DRAWN BY: DBH
REVIEWED BY: JMH

SHEET TITLE

LAKESIDE ASH POND CLOSURE PLAN

C105

SHEET 7 OF 14

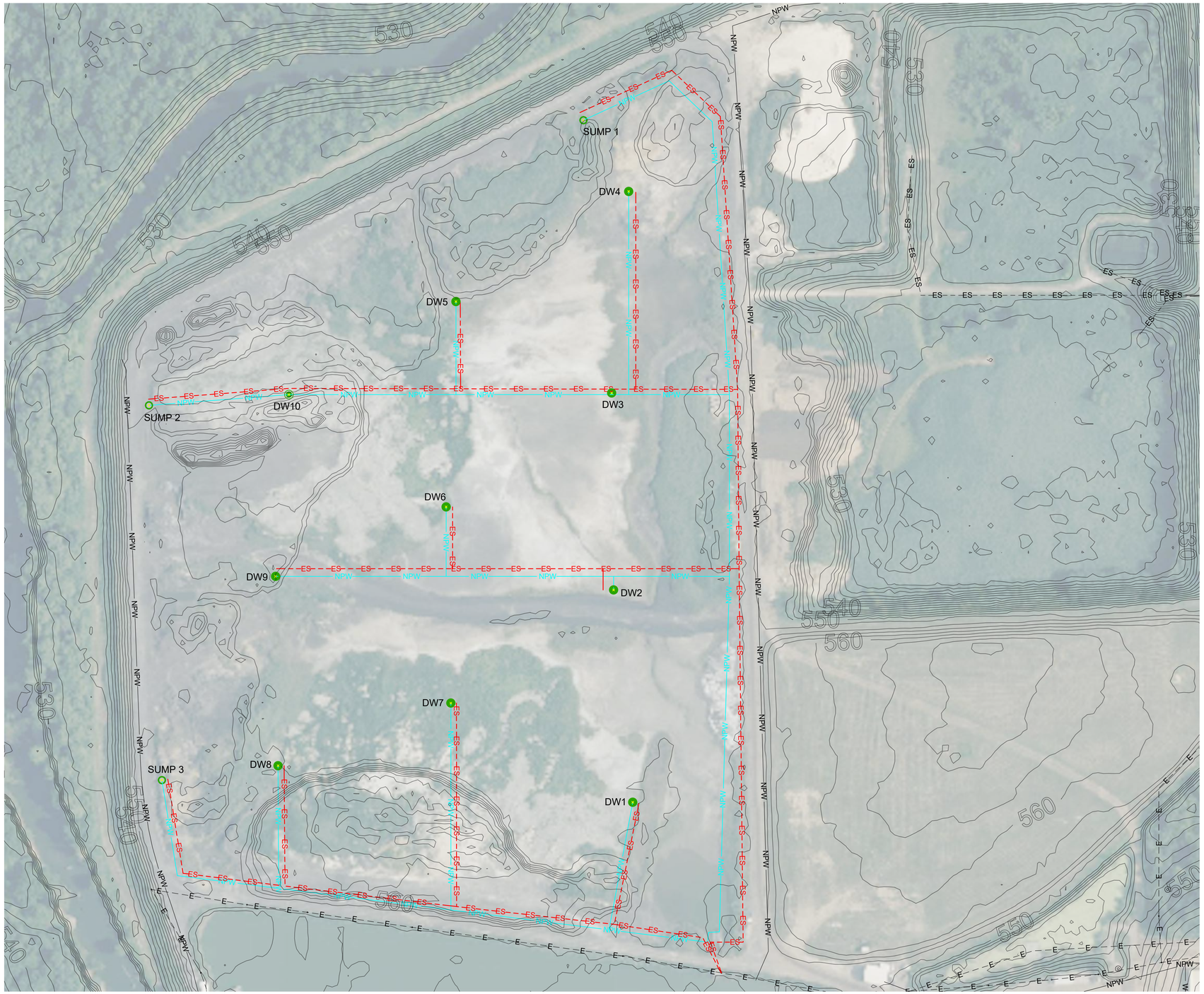
SEP 19, 2025 9:18 AM BRANS00939
I:\25JOBS\25E0006_00\CAD\SITE\SHEET\C103-DALLMAN SITE PLAN.DWG

LEGEND:

- EXISTING UNDERGROUND PRIMARY ELECTRICAL
- EXISTING UNDERGROUND SECONDARY ELECTRICAL
- PROPOSED UNDERGROUND SECONDARY ELECTRICAL
- EXISTING OVERHEAD PRIMARY ELECTRICAL
- EXISTING OVERHEAD SECONDARY ELECTRICAL
- EXISTING GAS LINE
- EXISTING WATER LINE
- EXISTING NON-POTABLE WATER LINE
- PROPOSED NON POTABLE WATER LINE
- EXISTING SEWER LINE
- EXISTING COMMUNICATION LINE
- EXISTING POWER POLE
- PROPOSED DEWATERING WELLS
- PROPOSED INTERIM DITCH SUMP
- EXISTING MONITORING WELLS

DEWATERING WELLS		
Well ID	Northing	Easting
DW1	1,129,172.894	2,456,190.498
DW2	1,129,569.144	2,456,154.745
DW3	1,129,936.797	2,456,151.227
DW4	1,130,313.072	2,456,182.954
DW5	1,130,107.459	2,455,860.460
DW6	1,129,724.222	2,455,842.104
DW7	1,129,357.981	2,455,850.937
DW8	1,129,241.101	2,455,528.397
DW9	1,129,594.511	2,455,523.840
DW10	1,129,933.797	2,455,548.635

SUMPS		
ID	Northing	Easting
SUMP 1	1,130,446.03	2,456,098.46
SUMP 2	1,129,913.78	2,455,287.42
SUMP 3	1,129,214.21	2,455,311.52



N

0 300 600

© Copyright Hanson Professional Services 2025

Hanson Professional Services Inc.
1525 S. 6th Street
Springfield, IL 62568
phone: 217-788-2450
fax: 217-788-2503
Offices Nationwide
www.hanson-inc.com

INTERIM REVIEW xx%
FOR REVIEW PURPOSES ONLY. NOT FOR CONSTRUCTION, PERMIT OR BIDDING

BRAD HOOTS, P.E
LIC: IL 062-055737
DATE: 08/27/2025

CWLP

DALLMAN ASH POND CLOSURE

SPRINGFIELD, ILLINOIS

MARK	DATE	DESCRIPTION		
		DES	DRN	REV

ISSUE: 09-20-2025
PROJECT NO: 25E0006
CAD FILE:
DESIGN BY: BR
DRAWN BY: BR
REVIEWED BY: JMH

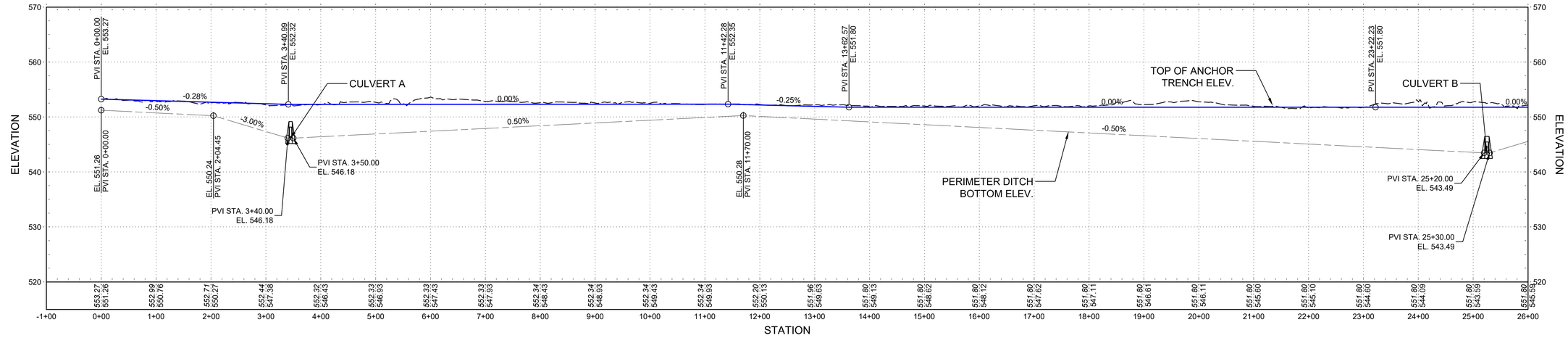
SHEET TITLE

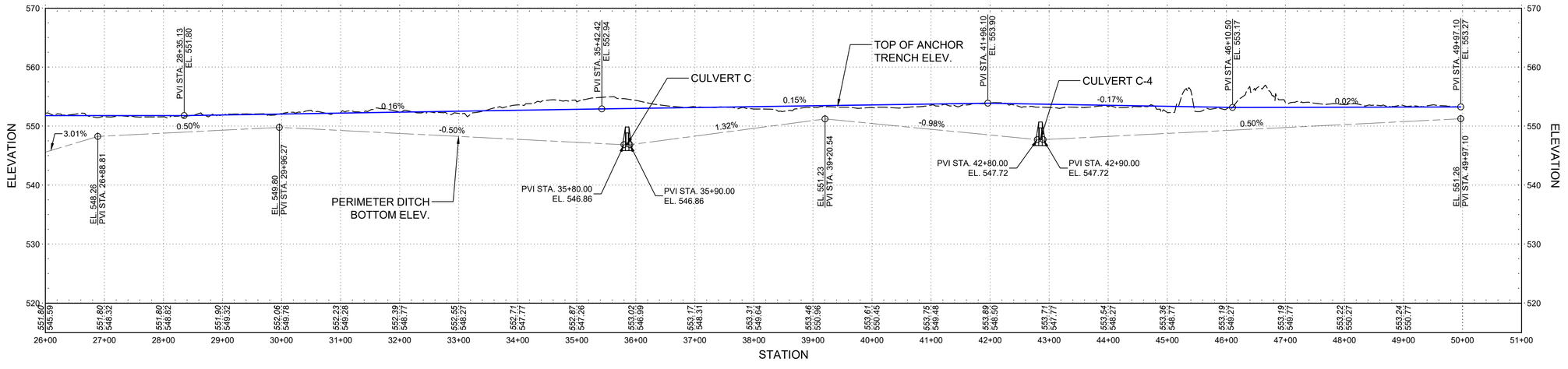
DALLMAN ASH POND DEWATERING WELLS

C106

SHEET 8 OF 14

SEP 19, 2025 9:18 AM BRANSO0939
I:\25JOBS\25E0006_00\CAD\SITE\SHEET\C105-DALLMAN ASH POND.DWG





SCALES

VERTICAL 0 10 20

HORIZONTAL 0 100 200

© Copyright Hanson Professional Services 2025

Hanson Professional Services Inc.
1525 S. 6th Street
Springfield, IL 62568
phone: 217-788-2450
fax: 217-788-2503
Offices Nationwide
www.hanson-inc.com

INTERIM REVIEW xx%
FOR REVIEW PURPOSES ONLY.
NOT FOR CONSTRUCTION,
PERMIT OR BIDDING

BRAD HOOTS, P.E
LIC: IL 062-055737
DATE: 08/27/2025

MARK	DATE	DESCRIPTION		
		DES	DRN	REV

ISSUE: 09-20-2025
PROJECT NO: 25E0006
CAD FILE:
DESIGN BY: DBH
DRAWN BY: DBH
REVIEWED BY: JMH

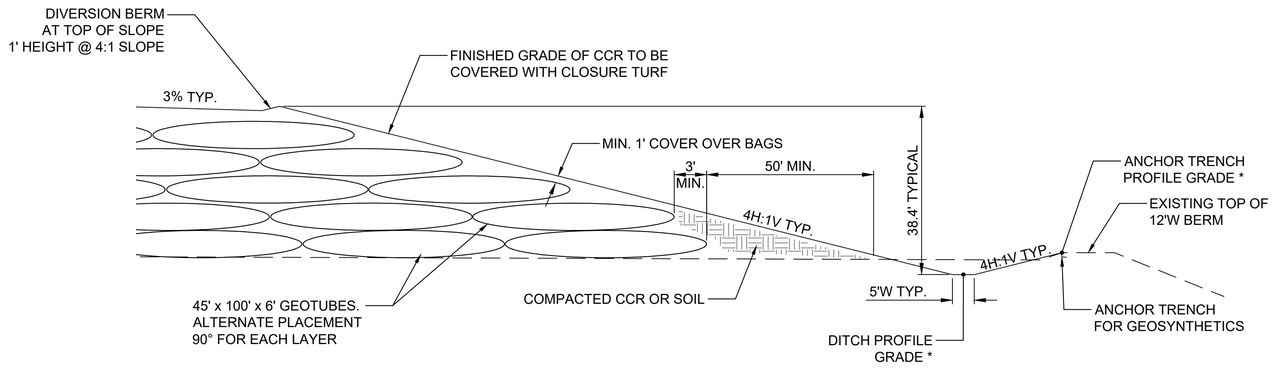
SHEET TITLE

DALLMAN ASH POND VERTICAL ALIGNMENTS

C201

SHEET 9 OF 100

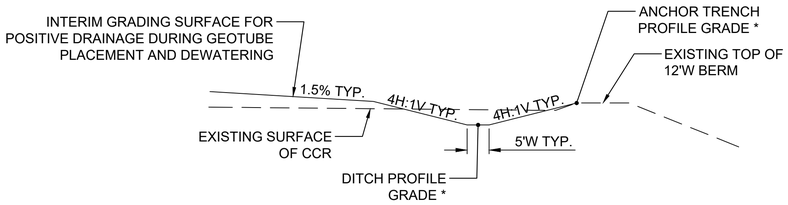
SEP 19, 2025 9:18 AM BRANS00939
I:\25JOBS\25E0006_00\CAD\SITE\SHEET\C201-DALLMAN PROFILES.DWG



1 DALLMAN FINAL COVER
SECTION - NOT TO SCALE

NOTES:

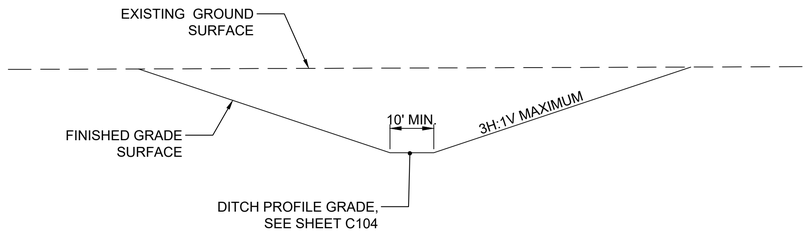
* SEE SHEET C102 FOR ANCHOR TRENCH ALIGNMENT AND SHEET C201 FOR VERTICAL ALIGNMENT AND DITCH PROFILE GRADES.



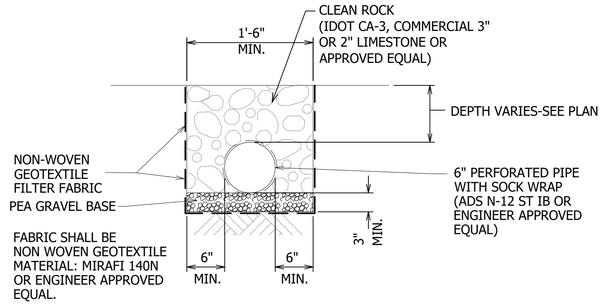
2 DALLMAN INTERIM GRADING
SECTION - NOT TO SCALE

NOTES:

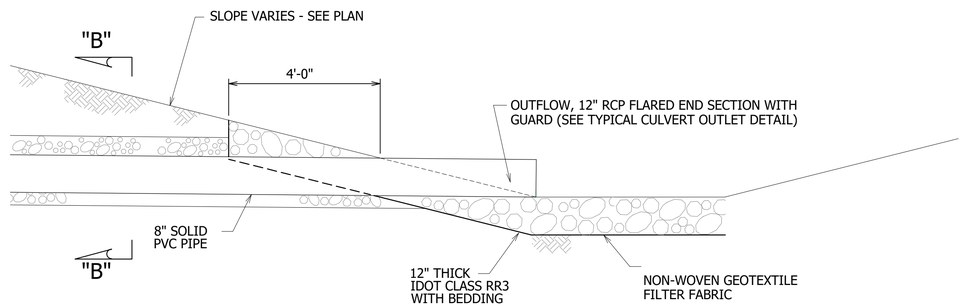
* SEE SHEET C102 FOR ANCHOR TRENCH ALIGNMENT AND SHEET C201 FOR VERTICAL ALIGNMENT AND DITCH PROFILE GRADES.



3 LAKESIDE OUTFALL CHANNEL
SECTION - NOT TO SCALE



4 TOE DRAIN
SECTION - NOT TO SCALE



6 TOE DRAIN OUTFALL
SECTION - NOT TO SCALE

SEP 19, 2025 9:18 AM BRANSO0939
I:\25JOBS\25E0006_00\CAD\SITE\SHEET\C201-DALLMAN PROFILES.DWG

HANSON

© Copyright Hanson Professional Services 2025

Hanson Professional Services Inc.
1525 S. 6th Street
Springfield, IL 62568
phone: 217-788-2450
fax: 217-788-2503
Offices Nationwide
www.hanson-inc.com

INTERIM REVIEW xx%
FOR REVIEW PURPOSES ONLY.
NOT FOR CONSTRUCTION,
PERMIT OR BIDDING

BRAD HOOTS, P.E
LIC: IL 062-055737
DATE: 08/27/2025

CITY WATER LIGHT AND POWER
SPRINGFIELD, IL

CWLP

DALLMAN ASH POND CLOSURE

SPRINGFIELD, ILLINOIS

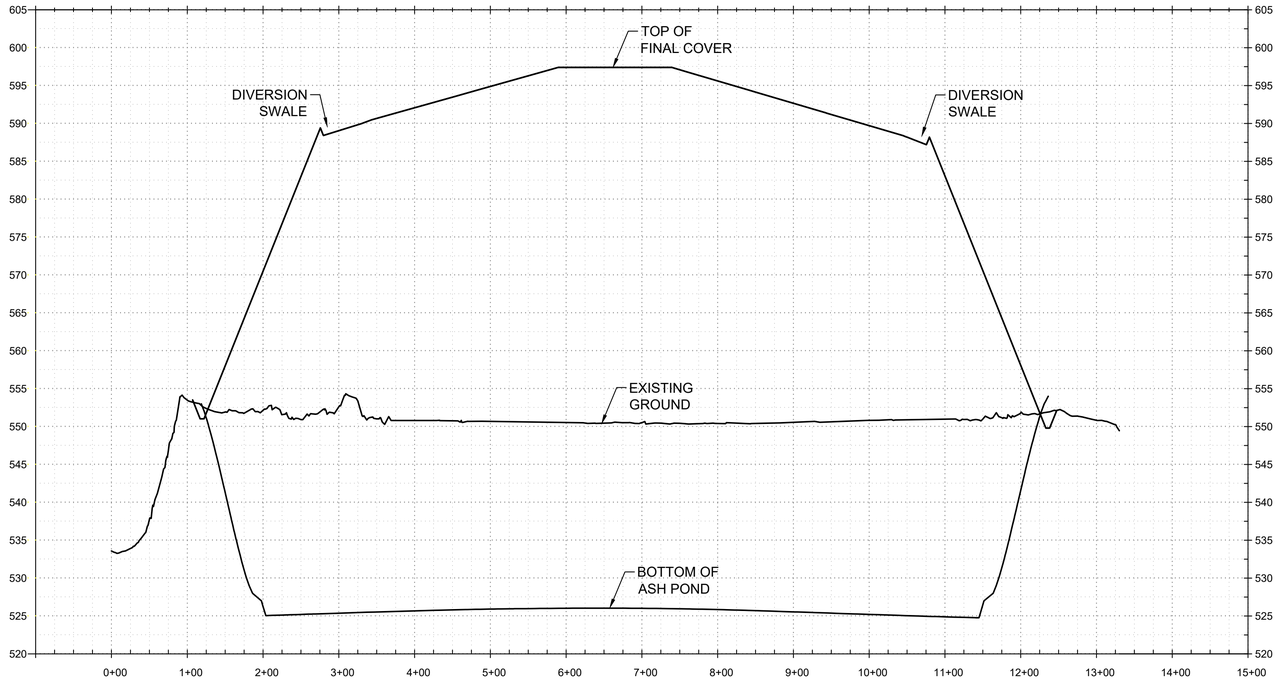
MARK	DATE	DESCRIPTION		
		DES	DRN	REV

ISSUE: 09-20-2025
PROJECT NO: 25E0006
CAD FILE:
DESIGN BY: DBH
DRAWN BY: DBH
REVIEWED BY: JMH

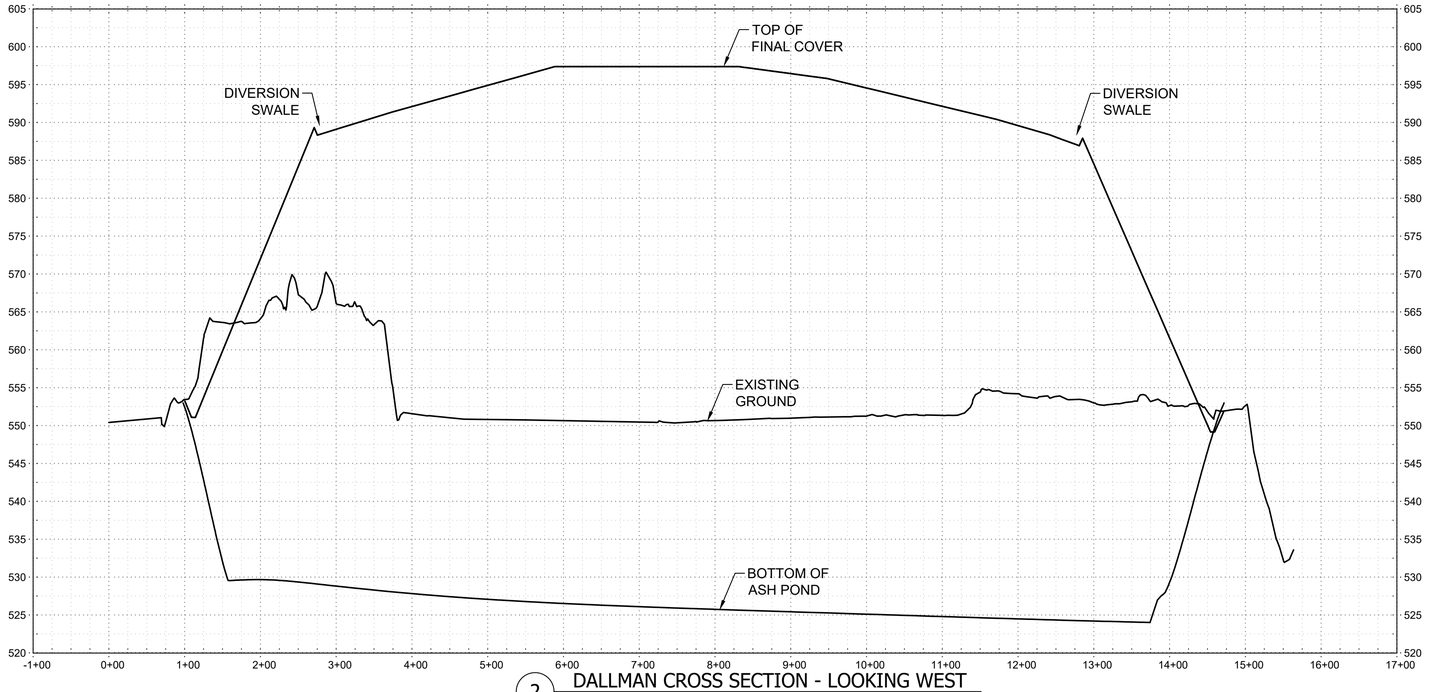
SHEET TITLE

TYPICAL SECTIONS

C202



1 DALLMAN CROSS SECTION - LOOKING NORTH



2 DALLMAN CROSS SECTION - LOOKING WEST

SCALES

VERTICAL 0 10 20

HORIZONTAL 0 100 200

© Copyright Hanson Professional Services 2025

Hanson Professional Services Inc.
1525 S. 6th Street
Springfield, IL 62568
phone: 217-788-2450
fax: 217-788-2503
Offices Nationwide
www.hanson-inc.com

INTERIM REVIEW xx%
FOR REVIEW PURPOSES ONLY.
NOT FOR CONSTRUCTION,
PERMIT OR BIDDING

BRAD HOOTS, P.E
LIC: IL 062-055737
DATE: 08/27/2025

MARK	DATE	DESCRIPTION		
		DES	DRN	REV

ISSUE: 09-20-2025
PROJECT NO: 25E0006
CAD FILE:
DESIGN BY: DBH
DRAWN BY: DBH
REVIEWED BY: JMH

SHEET TITLE

DALLMAN ASH POND
CROSS SECTIONS

C203

SHEET 11 OF 100

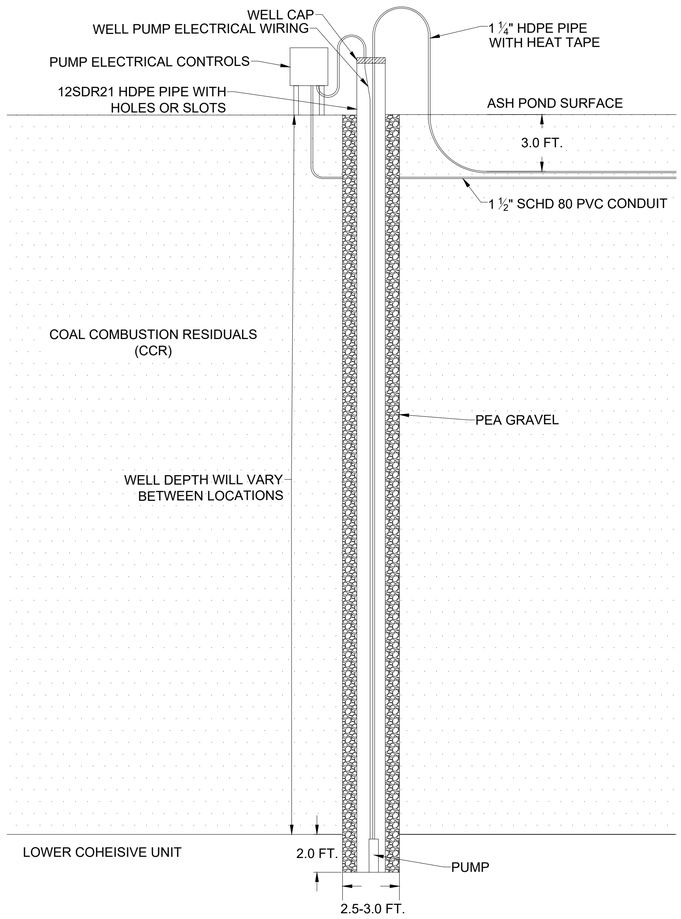
SEP 19, 2025 9:18 AM BRANS00939
I:\25JOBS\25E0006_00\CAD\SITE\SHEET\C201-DALLMAN PROFILES.DWG

LEGEND:

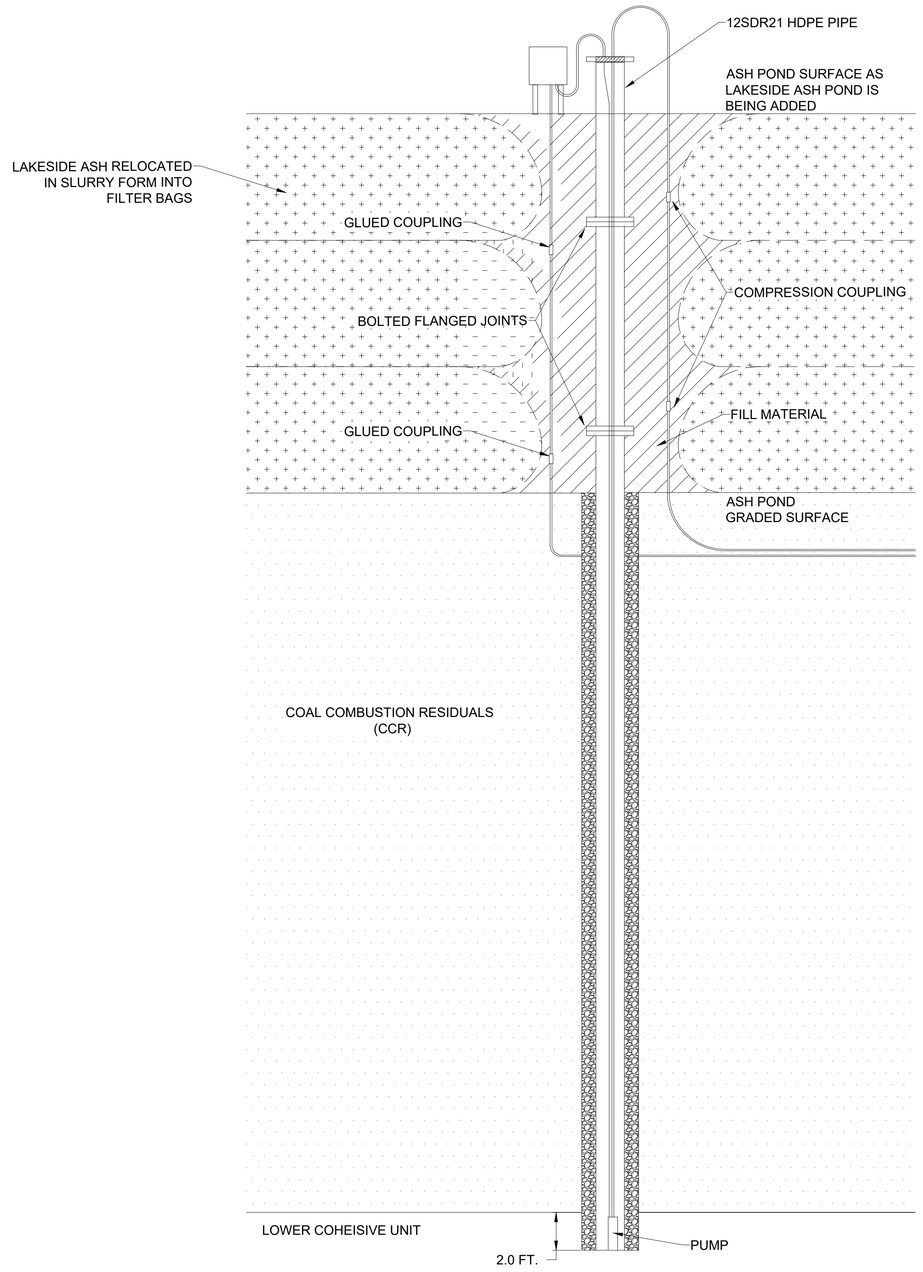
LAKESIDE ASH POND CCR

DALLMAN ASH POND CCR

FILL MATERIAL



INITIAL WELL INSTALLATION



WELL EXTENSION DETAIL

© Copyright Hanson Professional Services 2025

Hanson Professional Services Inc.
1525 S. 6th Street
Springfield, IL 62568
phone: 217-788-2450
fax: 217-788-2503
Offices Nationwide
www.hanson-inc.com

INTERIM REVIEW xx%
FOR REVIEW PURPOSES ONLY. NOT FOR CONSTRUCTION, PERMIT OR BIDDING

BRAD HOOTS, P.E
LIC: IL 062-055737
DATE: 08/27/2025

CWLP

DALLMAN ASH POND CLOSURE

SPRINGFIELD, ILLINOIS

MARK	DATE	DESCRIPTION		
		DES	DRN	REV

ISSUE: 09-20-2025
PROJECT NO: 25E0006
CAD FILE:
DESIGN BY: RH
DRAWN BY: BR
REVIEWED BY: JMH

SHEET TITLE

DEWATERING WELL DETAILS

C501
SHEET 12 OF 14

SEP 19, 2025 9:18 AM BRANSO0939
I:\25JOBS\25E0006_00\ADMIN\11-PLANS\DEWATERING WELL DETAIL.DWG

xylem
Let's Solve Water

GS

60 HZ STANDARD CAPACITY 4" SUBMERSIBLE PUMPS
VFD COMPATIBLE - UP TO 80 HZ

BUILT IN THE USA
ENGINEERED, ASSEMBLED & TESTED



FEATURES

Powered by Goulds Water Technology 4" motors for dependable operation and long service life.

Stainless steel construction provides strength and corrosion resistance.

Glass filled engineered composite impellers and diffusers deliver excellent abrasion resistance.

Floating impeller stack has proven itself for over 50 years as a superior sand handling and durable pump design.

The proprietary engineering polymer bearing is strong and resistant to abrasion and wear.

Cast stainless steel discharge head with built in stainless steel check valve. Two cast-in safety line loops for installer convenience.

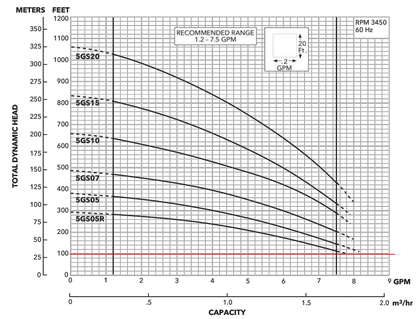
MATERIALS OF CONSTRUCTION

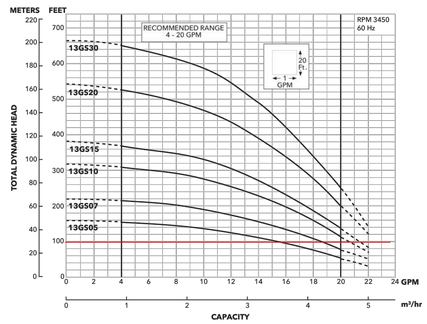
Part Name	Material
Discharge Head	AISI 303 SS
Check Valve Poppet	AISI 304 SS
Check Valve Seal	BUNA, FDA compliant
Check Valve Seat	AISI 304 SS
Check Valve Retaining Ring	AISI 302 SS
Bearing Spider – Upper	Glass Filled Engineered Composite GFN2
Bearing (s)	Proprietary Engineered Polymer
Klipring	AISI 301 SS
Diffuser	Glass Filled Engineered Composite
Impeller	Glass Filled Engineered Composite
Bowl	AISI 304 SS
Motor Adapter	AISI 303 SS
Casing	AISI 304 SS
Shaft	AISI 304 SS
Coupling	AISI 304 SS
Cable Guard / Screws	AISI 304 SS
Suction Screen	AISI 304 SS

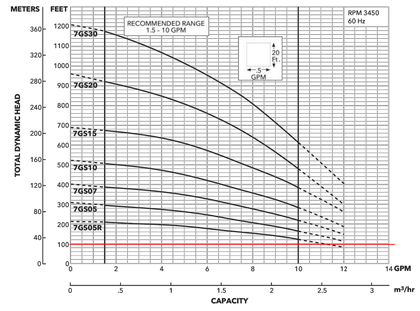
WATER END DATA

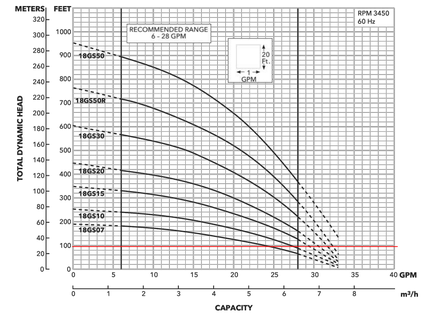
Series	Model	Req. HP	Stages	Length (in)	Weight (lbs)
5GS	5GS05R	0.5	9	12.9	8
	5GS05	0.5	12	15.0	9
	5GS07	0.75	15	17.0	11
	5GS10	1	20	21.7	13
	5GS15	1.5	26	25.8	15
	5GS20	2	33	31.6	19
7GS	7GS05R	0.5	7	11.7	6
	7GS05	0.5	10	13.8	7
	7GS07	0.75	13	16.0	8
	7GS10	1	17	18.8	9
	7GS15	1.5	22	23.6	12
	7GS20	2	27	27.2	13
	7GS30	3	34	33.2	18
10GS	10GS05R	0.5	5	10.1	6
	10GS05	0.5	7	11.5	7
	10GS07	0.75	10	13.6	8
	10GS10	1	12	15.0	9
	10GS15	1.5	17	18.4	12
	10GS20	2	20	21.7	13
	10GS30	3	27	27.5	18
	10GS50R	5	35	33.0	21
	10GS50	5	42	40.2	24
13GS	13GS05	0.5	5	10.1	6
	13GS07	0.75	7	11.5	7
	13GS10	1	10	13.6	8
	13GS15	1.5	12	15.0	9
	13GS20	2	17	18.4	12
	13GS30	3	21	22.3	15
18GS	18GS07	0.75	6	11.8	7
	18GS10	1	8	13.5	8
	18GS15	1.5	11	16.1	10
	18GS20	2	14	18.6	11
	18GS30	3	19	24.1	15
	18GS50R	5	24	28.3	17
	18GS50	5	30	34.4	21
25GS	25GS10	1	7	13.4	8
	25GS15	1.5	9	15.3	9
	25GS20	2	11	17.2	10
	25GS30	3	15	20.9	14
	25GS50R	5	22	28.7	17
	25GS50	5	26	33.4	21

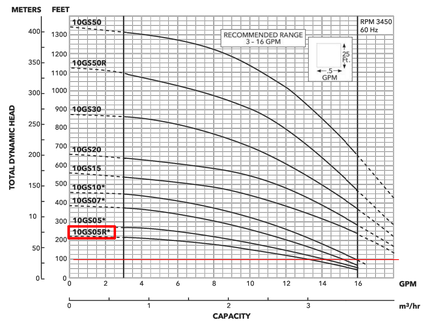
GOULDS WATER TECHNOLOGY
a xylem brand

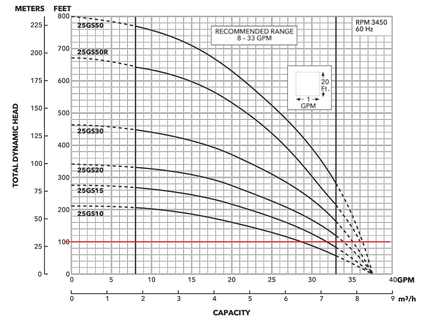












xylem
Let's Solve Water

Xylem Inc.
Phone: (866) 325-4210 • Fax: (888) 322-5877
www.xylem.com/goulds

Xylem is a registered trademark of Xylem Inc. or one of its subsidiaries. Goulds is a registered trademark of ITT Manufacturing Enterprises LLC and is used under license. All other trademarks or registered trademarks are property of their respective owners.
© 2023 Xylem Inc. GSSPEC R3 July 2023

© Copyright Hanson Professional Services 2025

Hanson Professional Services Inc.
1525 S. 6th Street
Springfield, IL 62568
phone: 217-788-2450
fax: 217-788-2503
Offices Nationwide
www.hanson-inc.com

INTERIM REVIEW xx%
FOR REVIEW PURPOSES ONLY. NOT FOR CONSTRUCTION, PERMIT OR BIDDING

BRAD HOOTS, P.E
LIC: IL 062-055737
DATE: 08/27/2025

CITY WATER LIGHT AND POWER · SPRINGFIELD, IL

CWLP

DALLMAN ASH POND CLOSURE

SPRINGFIELD, ILLINOIS

MARK	DATE	DESCRIPTION		
		DES	DRN	REV

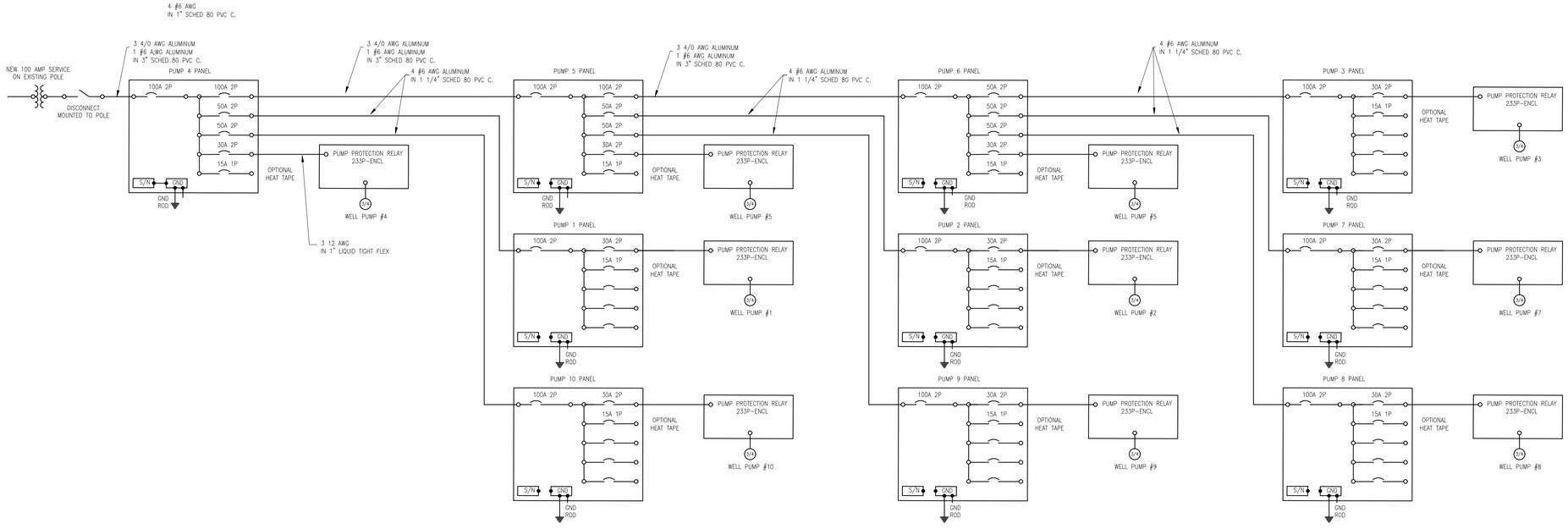
ISSUE: 09-20-2025
PROJECT NO: 25E0006
CAD FILE:
DESIGN BY: BR
DRAWN BY: BR
REVIEWED BY: MH

SHEET TITLE

PUMP DETAILS

C502

SEP 19, 2025 9:18 AM BRANSO0939
I:\25JOBS\25E0006_00\ADMIN\11-PLANS\DEWATERING WELL DETAIL.DWG



SEP 19, 2025 9:18 AM BRANSO0939
I:\25JOBS\25E0006_00\CAD\ELEC\MODEL\DWR_20250310_ONELINE.DWG

© Copyright Hanson Professional Services 2025

Hanson Professional Services Inc.
1525 S. 6th Street
Springfield, IL 62568
phone: 217-788-2450
fax: 217-788-2503
Offices Nationwide
www.hanson-inc.com

CWLP

DALLMAN ASH POND
CLOSURE
CWLP ASH PONDS
SPRINGFIELD,
ILLINOIS

MARK	DATE	DESCRIPTION		
		DES	DRN	REV

ISSUE: 09-20-2025
PROJECT NO: 25E0006
CAD FILE:
DESIGN BY: BR
DRAWN BY: BR
REVIEWED BY: MH

SHEET TITLE

ELECTRICAL
ONE-LINE DIAGRAM

E101
SHEET 14 OF 14

Dallman and Lakeside Ash Ponds

Post-Closure Plan

City Water, Light and Power
Springfield, Sangamon County, Illinois

September 23, 2025

Table of Contents

1. Responses to Attachment 3 Items 1

1.1 Post-Closure Plan 1
1.1.1 Include the wells identified as part of the Surface Impoundment GWMS from the CAFO. 1
1.1.2 The post-closure monitoring necessary to meet the federal groundwater monitoring requirements and the CAFO. 1
1.1.3 Extending the assessment and corrective measures monitoring period until such time as the GWPS are met or work towards meeting GWPS. 1
1.1.4 Restrictions or institutional controls necessary to maintain the final cover and use of the property (i.e., open space) and the integrity of the ground water monitoring system. 1
1.1.5 The post-closure maintenance of the leachate management system, including information on the components of the cover system that need to be inspected or maintained. 1

2. Introduction 2

2.1 Regulatory Requirements 2

3. Site Background 2

3.1 Lakeside Ash Ponds 2
3.2 Dallman Ash Ponds 2
3.3 Clarification Pond 4

4. Post-Closure Maintenance 4

4.1 Introduction 4
4.2 Final Cover Maintenance 4
4.3 Leachate Collection System Maintenance 4
4.4 Groundwater Monitoring System Maintenance 5

5. Post-Closure Care Period 5

6. Written Post-Closure Plan 5

6.1 Monitoring and Maintenance Activities 5
6.2 Contact Information 7
6.3 Planned Property Use 7

7. Professional Engineer Certification 8

8. References 8

Figures and Tables

Figures

Figure 1. Site Location Map 3
Figure 2. Monitoring Well Location Map 6

Tables

Table 1. Post-Closure Maintenance Activities and Frequency 5

Abbreviations

CAFO..... Consent Agreement and Final Order

CCR..... coal combustion residuals

CFR..... Code of Federal Regulations

cu. ft. ..... cubic feet

CWLP..... City Water, Light and Power

ft..... feet

GWMS ..... groundwater monitoring system

GWPS..... groundwater protection standard

IDOT ..... Illinois Department of Transportation

IEPA ..... Illinois Environmental Protection Agency

NPDES ..... National Pollutant Discharge Elimination System

sq. ft. ..... square feet

U.S. EPA ..... United States Environmental Protection Agency

Copyright © 2025 by Hanson Professional Services Inc. All rights reserved. This document is intended solely for the individual or the entity to which it is addressed. The information contained in this document shall not be duplicated, stored electronically, or distributed, in whole or in part, by anyone other than the recipient without the express written permission of Hanson Professional Services Inc., 1525 S. Sixth St., Springfield, IL 62703, (217) 788-2450, www.hanson-inc.com. Unauthorized reproduction or transmission of any part of this document is a violation of federal law. Any concepts, designs and project approaches contained herein are considered proprietary. Any use of these concepts and approaches by others is considered a violation of copyright law.

1. Responses to Attachment 3 Items

1.1 Post-Closure Plan

1.1.1 Include the wells identified as part of the Surface Impoundment GWMS from the CAFO.

See Section 4.4 for the monitoring well information and Figure 2 for a location map.

1.1.2 The post-closure monitoring necessary to meet the federal groundwater monitoring requirements and the CAFO.

CWLP believes that the impoundments will still be in assessment monitoring pursuant to 40 CFR §257.95 and will remain in assessment monitoring until groundwater meets the GWPS.

1.1.3 Extending the assessment and corrective measures monitoring period until such time as the GWPS are met or work towards meeting GWPS.

In accordance with 40 CFR §257.95 the Site cannot return to detection monitoring until the GWPS are met. The assessment of corrective measures report is being reviewed by U.S. EPA currently and the closure and post-closure plans are due to U.S. EPA on September 23, 2025.

1.1.4 Restrictions or institutional controls necessary to maintain the final cover and use of the property (i.e., open space) and the integrity of the ground water monitoring system.

See Section 4.4 Groundwater Monitoring System Maintenance for a discussion of access control and the groundwater monitoring system.

A deed restriction will be placed on the property noting the property was used for CCR disposal per 40 CFR 257.102(i).

1.1.5 The post-closure maintenance of the leachate management system, including information on the components of the cover system that need to be inspected or maintained.

The reference to the design criteria of 40 CFR §257.70 listed in §257.104(b)(2) is specifically for CCR landfills. The CWLP impoundments are exempt from this requirement.

2. Introduction

2.1 Regulatory Requirements

This document amends the CWLP's 2016 Post-Closure Plan (AEI, 2016b) to meet the requirements of 40 CFR 257.104 and the January 2025 Consent Agreement and Final Order.

§ 257.104

- *Applicability.* (1) Except as provided by paragraph (a)(2) of this section, § 257.104 applies to the owners or operators of CCR landfills, CCR surface impoundments, and all lateral expansions of CCR units that are subject to the closure criteria under § 257.102.

CAFO Count 9

- The 2016 Post-Closure Plan does not have sufficient information to demonstrate that it meets the requirements of 40 C.F.R. §§ 257.104(b)(1) and (3), (d)(1), and (2)(i) and, therefore, is in violation of these regulations.

CAFO Attachment 3

- Additional requirements to be considered in the Post-Closure Plan.

3. Site Background

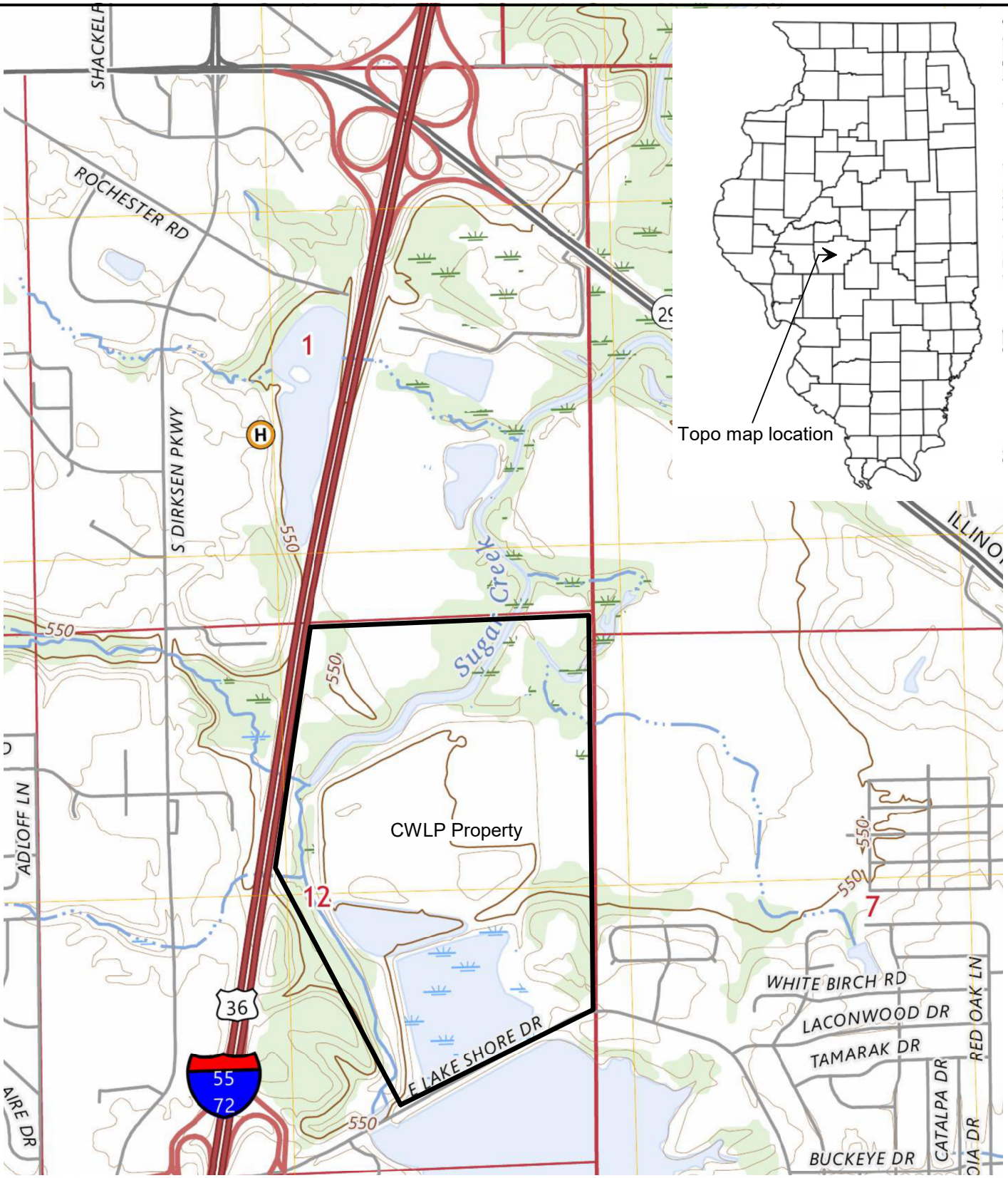
The CWLP ash ponds are in Section 12 R.5W, T.15N of the Third Principal Meridian in Springfield, Sangamon County, Illinois. The Site is in the Springfield Plain of the Central Lowland Province Physiographic Division of Illinois (Leighton et al., 1948).

3.1 Lakeside Ash Ponds

The older of the two (2) impoundments is Lakeside Ash Pond (LAP). LAP has a footprint of approximately 36 acres and contains approximately 1,565,000 cubic yards (cu. yd.) of CCR along with water treatment plant sludge. The current footprint is the maximum area that would require final cover if LAP was closed-in-place. The floor of LAP is approximately elevation 530 ft. and slopes upward in the southeast corner following the natural topography.

3.2 Dallman Ash Ponds

Dallman Ash Pond (DAP) has a footprint of approximately 36 acres and currently contains approximately 1,217,000 cu. yd. of CCR. In the past, there were two (2) IDOT construction projects that used approximately 875,000 cu. yd. of DAP CCR for a maximum volume of CCR of almost 2,100,000 cu. yd. The current footprint is the maximum area that would require final cover if DAP was closed-in-place. The floor of DAP slopes from the south to the northeast corner (from elevation 525 ft. to about 523 ft. Note that the bottom of DAP at boring D4 is over elevation 530 ft.



SCALE: 1 inch equals 400 feet

0 400 800 1200

CONTOUR INTERVAL = 10 feet

© Copyright Hanson Professional Services Inc. 2025

HANSON

Site Location Map

Dallman and Lakeside Ash Ponds
City Water, Light and Power
Springfield, Sangamon Co., Illinois

HANSON NO. 25E0006.00 FIGURE 1

3.3 Clarification Pond

The Clarification Pond footprint is approximately 7.8 acres and is a non-CCR unit. The Clarification Pond collects storm water runoff from DAP and LAP for treatment and discharge at NPDES Outfall 004. Unit 2 Landfill leachate and process water from the Lime Lagoons is also discharged to the Clarification Pond for treatment and discharge at Outfall 004. A modification of the CWLP NPDES permit is currently pending at IEPA Bureau of Water to allow treatment and discharge of pore water in contact with CCR (dewatering fluids).

4. Post-Closure Maintenance

4.1 Introduction

CWLP intends to consolidate LAP into DAP. CWLP intends to cover the consolidated LAP and DAP using WatershedGeo's® ClosureTurf® a three-component system comprised of an engineered synthetic turf for durability and functional longevity, a specified infill material for enhanced protection, and a structured geomembrane for environmental containment.

4.2 Final Cover Maintenance

Maintenance of ClosureTurf® requires considerably less effort than traditional soil cover systems. The manufacturer's literature notes that maintenance costs can be as much as 90% lower than maintenance of traditional soil cover systems. It is also expected to have a design life of more than 100 years.

The final cover system will be inspected quarterly, and any defects will be noted. Any issues with the synthetic turf will be watched for signs of additional wear/damage. At that point repairs will be scheduled to prevent further damage.

Signs of settlement will also be noted and a determination that the cover is holding water will be made. If water is determined to be ponding on the final cover, then mitigation of the settlement will be completed.

Run-on and run-off of storm water is controlled by the ClosureTurf® and perimeter ditches. Run-on is controlled by an outward slope on the perimeter roads. Run-off is controlled by the MicroDrain® geomembrane, which has small studs on the upper surface, which acts similarly to a geocomposite drainage layer. Stormwater is transferred downslope to the perimeter ditches where it is directed to drainage outfalls for discharge to Sugar Creek or the Clarification Pond.

4.3 Leachate Collection System Maintenance

DAP and LAP are not subject to 40 CFR §257.70. However, the dewatering system wells will be inspected at least quarterly or if a dewatering well is not working. Pump operating equipment (controllers, cycle counter, etc.) will be inspected and pump discharges will be noted. Pumps will be replaced as necessary.

4.4 Groundwater Monitoring System Maintenance

The groundwater monitoring system consists of the following monitoring wells AP-1, AP-2, AP-3, AP-4†, AP-5†, AP-6, AP-7‡, AP-8, AP-10, AP-14, AP-15D, AP-15S, AW-1, RW-3, and G120. Figure 2 shows the locations of the monitoring wells relative to the impoundments.

All the groundwater monitoring wells are constructed with lockable, protective, steel casings to restrict access to the well itself. The post-closure access to the Site is controlled by fencing (concrete wall on the south side, Interstate 55/72 fencing on the west side, and fencing along the farm field on the east side of the Unit 2 Landfill). Access from the north is controlled by Sugar Creek. The Site entrance is gated and CWLP Security frequently checks the area on a regular basis.

Wells are inspected each time they are sampled, and any defects are noted. Any defects that affect the integrity of the monitoring well or that affect the water quality will require the monitoring well to be replaced.

5. Post-Closure Care Period

Pursuant to 40 CFR §257.104(c) the post-closure care period must be conducted for 30 years unless the CCR Unit is operating under assessment monitoring in accordance with §257.95. Post closure care must continue until the monitoring system returns to detection monitoring in accordance with §257.95.

6. Written Post-Closure Plan

6.1 Monitoring and Maintenance Activities

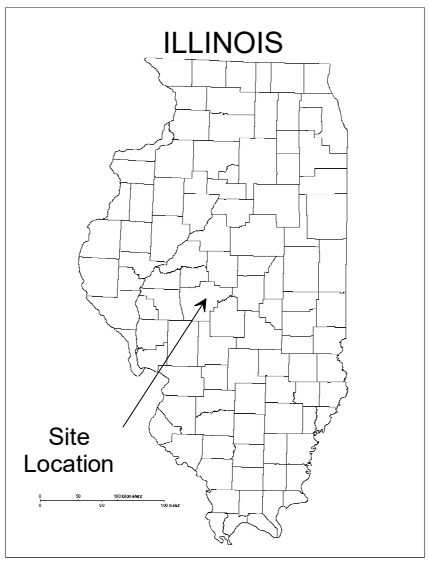
Table 1 lists the monitoring and maintenance activities required during the post-closure period.

Table 1. Post-Closure Maintenance Activities and Frequency

Activity	Frequency
Mowing berms	2x per year
Final cover inspections	quarterly
Berm inspections	quarterly
Drainage structures	quarterly
Dewatering wells	quarterly or when not functioning properly
Groundwater monitoring wells	each sampling event

† Upgradient well.

‡ Compliance boundary well.



Sugar Creek

AP-7
AP-6
RW3
AP-8
AP-1
AP-10
AP-2
AP-3
AP-14
AP-15D
AP-15S
AP-4
AP-5
G120
AW-1

Dallman Ash Pond

Unit 2 Landfill

Unit 1 Landfill

Clarification Pond

Lakeside Ash Pond

Lake Springfield

© Copyright Hanson Professional Services Inc. 2025

SCALE: 1 inch equals 400 feet

0 ft. 400 ft. 800 ft. 1,200 ft.

HANSON™

Monitoring Well Location Map

Dallman and Lakeside Ash Ponds
City Water, Light and Power
Springfield, Sangamon Co., Illinois

HANSON NO. 25E0006.00 FIGURE NO. 2

Other earthwork and maintenance include:

1. Rills, gullies, and crevices identified in the ash pond berm shall be filled.
2. Areas with missing vegetation (100 sq. ft. or more) will be revegetated.
3. Brush, trees, or vegetation with tap roots shall be removed.
4. Drainage channels with signs of erosion/scour will be repaired.
5. Any damage to the synthetic turf shall be repaired.

6.2 Contact Information

The name, address, telephone number, and email address of the person or office to contact about the facility during the post-closure care period is:

P.J. Becker
Environmental Health & Safety Manager
City Water Light and Power
3100 Stevenson Drive
Springfield Illinois 62703
(217) 757-8610 ext. 1110
pj.becker@cwlp.com

6.3 Planned Property Use

The post-closure property use for the CCR impoundments will be:

Lakeside Ash Pond – after consolidation with the Dallman Ash Pond, Lakeside will be returned to a natural area with native vegetation. The area will also be used for storage of water released from Lake Springfield.

Dallman Ash Pond – once Lakeside Ash Pond is consolidated into Dallman Ash Pond and the ClosureTurf® final cover system is installed the end use will be open space that will not disturb the final cover system, dewatering system, or other monitoring equipment.

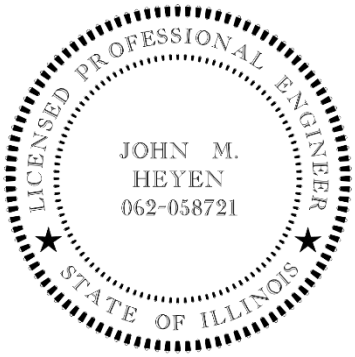
7. Professional Engineer Certification

This amendment to the CWLP Post-Closure Plan meets the requirements of 40 CFR §257.104.

John M. Heyen

September 23, 2025
Date

SEAL



Expires November 30, 2027

8. References

AEI, 2016b. "Post-Closure Plan for Coal Combustion Residuals Surface Impoundments", October 2016, Andrews Engineering, Inc., Springfield, IL. 4 pp. + 1 app.

Leighton, M.M., G.E. Ekblaw, and L. Horberg, 1948. "Physiographic Divisions of Illinois, Report of Investigations No. 129," Illinois State Geological Survey, Urbana, IL. 33 pp.

USGS, 1965. *Springfield East, Ill, USGS 7½-minute Series*, United States Geological Survey, US Department of Interior, Reston, VA, 1965.