MUSKOGEE COMMUNITY RECYCLING AND DISPOSAL FACILITY
MUSKOGEE COUNTY, OKLAHOMA
ODEQ PERMIT NO. 3551020

TIER III PERMIT MODIFICATION
LANDFILL EXPANSION

VOLUME 4 OF 4

Prepared for

Waste Management of Oklahoma, Inc.

October 2023

Prepared by

Weaver Consultants Group, LLC
CA 3804 PE 06/30/2025
6420 Southwest Boulevard, Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0086-364-11-19

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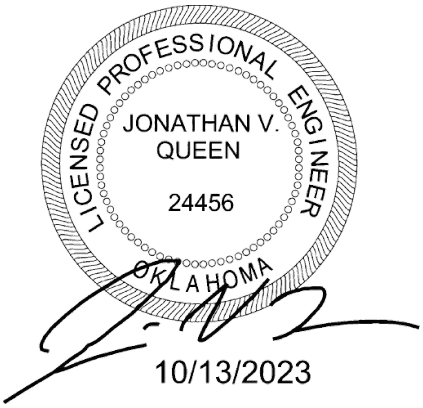

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APPENDIX L

LEACHATE COLLECTION SYSTEM DESIGN

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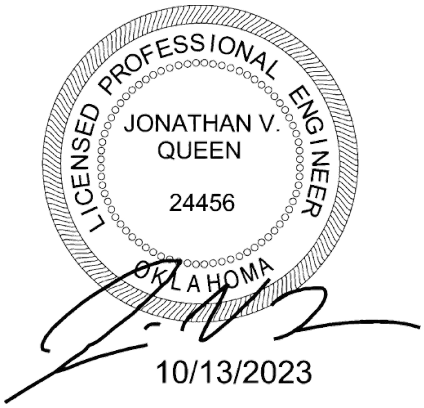


1 INTRODUCTION

This Leachate Collection System Design provides the design and operation details of the proposed leachate collection system for the Muskogee Community Recycling and Disposal Facility (RDF). In accordance with OAC 252:515-13-31 and OAC 352:515-11-3, the leachate collection system is designed to:

1. Maintain 1 foot or less of head above the top of the liner;
2. Drain leachate toward the perimeter of the disposal area; and
3. Provide at least a 5-foot separation above the highest groundwater elevation and the top of the liner.

Consistent with OAC 252:515-13, this appendix provides the design information for the leachate collection system. The layout for the liner, leachate collection system, and final cover system are presented in Appendix L-1. Compliance with OAC 252:515-11-3(a) is discussed in Section 7.

2 LEACHATE GENERATION

2.1 Generation Process

The capacity of solid waste to absorb moisture is known as field capacity. When the field capacity is exceeded, leachate is generated. However, leachate may also flow within the landfill through preferential pathways; therefore some downward flow of leachate will occur before the field capacity of waste is reached. The quantity of leachate produced depends upon the climate, site topography, type of cover, construction and landfilling procedures, and waste characteristics.

These factors, not including climate, will be controlled or modified to reduce the infiltration and the moisture content of solid waste, thereby reducing the quantity of leachate generated. The site will be graded with temporary and permanent drainage features to provide run-on/runoff controls for stormwater. Water that comes in contact with solid waste, leachate, or gas condensate will be considered contaminated water. Contaminated water will be kept to a minimum using temporary run-on and runoff control berms and will be treated as leachate. Surface water will be managed throughout the active life of the landfill to minimize infiltration into the filled areas and to minimize contact with solid waste. Also, intermediate cover will be graded and maintained to promote runoff and prevent ponding.

2.2 Leachate Generation Modeling

The Hydrologic Evaluation of Landfill Performance (HELP) model, Version 3.07, was used to estimate the amount of leachate that will be generated at the Muskogee RDF. The HELP model is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of landfills. The model uses climate, soil, and landfill design data to perform a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, soil-moisture storage, recirculation, evapotranspiration, and lateral drainage.

Leachate generation was evaluated for both active and closed landfill conditions. An explanation of the assumed conditions, methodologies, models, and printouts of the results are included in Appendix L-2. Consistent with OAC 252:515-13-31, the leachate collection system will maintain less than 12 inches of head on the top of liner in all cases.

2.3 Excavation Plan Design

As shown in Table 2-1 and on the Top of Liner Plan included in Appendix L-1, the top of liner grades are designed to maintain a 5-foot minimum separation between highest groundwater elevations beneath the site and the top of liner elevations.

Table 2-1
Difference Between Top of Liner Grades and Top of Uppermost Aquifer

Cell	Top of Liner Elevation in Sump (ft-msl)	Top of Uppermost Aquifer Elevation (ft-msl)[1]	Depth Above Groundwater (ft)
14	630.2	598.0	32.2
15	616.9	596.7	20.2
16	630.2	599.4	30.8
17	616.9	597.2	19.7
18	630.2	601.0	29.2
19	617.8	597.7	20.1
20	630.5	601.2	29.3
21	618.8	598.3	20.5
22	630.3	600.7	29.6
23	618.8	599.1	19.7
24	630.2	599.9	30.3
25	620.8	598.9	21.9
26	620.8	598.2	22.6
27	622.7	597.9	24.6

(1) See Attachment E-1-11 for top of uppermost aquifer contour map and Section 7 for compliance with OAC 252:515-11-3(a).

3 PROPOSED LEACHATE COLLECTION SYSTEM

3.1 System Layout

The leachate collection system layout and details are presented in Appendix L-1. The design includes a 24-inch-thick leachate collection layer. The 24-inch leachate collection layer will have a hydraulic conductivity of $k \geq 1x10^{-3}$ cm/s. The leachate collection layer will convey the leachate-to-leachate collection pipes, which will be bedded in granular media filled drains. Through the collection pipes, leachate will be conveyed to sumps and pumped out for disposal. The bottom elevation (top of the composite liner in sumps) of the sumps is designed to be the lowest point of the leachate collection system. Consistent with the requirements in OAC 252:515-11-3(a), the bottom elevation of the sumps will be at least 5 feet above the groundwater elevation (refer to Section 7 for additional information).

3.2 Leachate Collection Layer/Protective Cover Material

The leachate collection layer will be placed directly over the liner system to collect and transfer leachate to leachate collection system pipes and sumps. The leachate collection layer consists of a 24-inch soil layer with a permeability of $1x10^{-3}$ cm/sec or greater.

3.3 Drainage Aggregate Around Leachate Collection Pipes

The coarse aggregate selected for placement around the leachate collection pipes will consist of normal or lightweight materials that comply with the project specifications. The drainage aggregate shall meet the permeability specified in Section 5 of Appendix K – Quality Assurance/Quality Control (QA/QC) Plan for Liner and Leachate Collection System Installation and Testing. Refer to Appendix L-3 for pipe perforation calculations.

The drainage aggregate will be wrapped by a geotextile to maintain separation of the free-draining material from the adjacent fine-grained materials. The geotextile will be inert to commonly encountered chemicals, hydrocarbons, and mildew, and will be rot resistant. Geotextile calculations are presented in Appendix L-5.

3.4 Leachate Collection Piping

The liner and leachate collection system layer will slope to drain toward the leachate collection drains, which will contain a perforated pipe surrounded by drainage aggregate. The leachate collection pipes will direct the leachate to sumps at the perimeter of the disposal area. The leachate collection pipe will be HDPE SDR-17 or equivalent. A cleanout riser will be provided at the end of the leachate collection pipes to allow cleaning as necessary. Leachate collection pipe design calculations are provided in Appendix L-3.

3.5 Leachate Sumps

The leachate collection sumps and pumps for the undeveloped area have been sized to limit maximum head above the liner system to 12 inches and provide a reasonable pump cycle time. The leachate sumps will be 2-feet deep with minimum dimensions of 27 by 27 feet at the landfill floor and 15 by 15 feet at the sump base and will store over 900 gallons of leachate. The sumps will be backfilled with drainage stone meeting the permeability specified in Section 5 of Appendix K – QA/QC Plan for Liner and Leachate Collection System Installation and Testing.

Submersible pumps located in the 18-inch-diameter sidewall riser pipes will empty the sumps. The pumps will be operated either manually or automatically by pressure transducers. Control levels for automatic sump pumps will be set to maintain typical sump liquid levels at or below the floor of the landfill. The depth of leachate in the sumps will be monitored by the pressure transducers, which will be calibrated to provide direct read-out of the leachate level in the sumps. Sump volume calculations are presented in Appendix L-4.

3.6 Temporary Leachate Storage Sump

If needed, leachate may be conveyed to either a temporary sump or a leachate storage tank via a 3-inch-diameter, solid wall HDPE pipe. The 3-inch-diameter pipe will be contained within a 6-inch-diameter, solid wall HDPE pipe to provide for secondary containment. Temporary leachate sumps will be constructed as necessary as the site develops. Plans for these temporary facilities will be submitted and approved by the ODEQ prior to initiation of construction.

3.7 System Cleanouts

The leachate collection system has been designed such that the leachate collection piping can be cleaned out periodically in accordance with OAC 252:515-13-34. Cleanouts are provided on the sump ends of the leachate collection pipes. In

accordance with ODEQ regulations, the pipes will be cleaned out initially after protective cover has been placed over them, again after the placement of the first lift and once per year during final closure and postclosure maintenance.

3.8 Leachate Storage

The leachate collected in the leachate sumps may be pumped from the sumps and recirculated to the landfill working face, pumped directly into the City of Muskogee publicly owned treatment works (POTW), or pumped to the on-site leachate tanks or pond via a 3-inch-diameter solid walled SDR 17 HDPE pipe. The 3-inch diameter pipe will be contained within a 6-inch diameter, solid wall HDPE pipe to provide for secondary containment. Leachate will be discharged directly into the City of Muskogee POTW in accordance with Industrial Permit No. 078. A copy of Industrial Permit No. 078 is included in Appendix L-8. The site previously utilized leachate storage pond for storage prior to discharging to the City of Muskogee POTW; however the leachate storage pond was decommissioned in 2022. In the future the site may use leachate tanks or a leachate pond storage before pumping into the City of Muskogee POTW.

4 DOCUMENTATION REQUIREMENTS

4.1 Construction Quality Assurance/Quality Control Plan (QA/QC)

The construction QA/QC plan (Appendix K) was developed for the leachate collection system and the other components of the liner system in accordance with OAC 252:515-11-4.

4.2 Construction Report

Details of the leachate collection system as required by OAC 252:515-13-35 will be provided in the LIT report. Upon completion of each cell construction, a LIT Report will be submitted to the ODEQ.

4.3 Performance Evaluation

In accordance with OAC 252:515-13-34 the leachate collection system shall be inspected at least quarterly to ensure proper operation.

4.4 Corrective Action

In the event that the leachate collection system fails to perform as designed, a corrective action plan will be submitted to the ODEQ within 90 days in accordance with OAC 252:515-13-2. The corrective action plan will be implemented within 30 days of receiving approval of the plan from the ODEQ.

5 LEACHATE AND CONTAMINATED WATER DISPOSAL

Submersible pumps will pump leachate from the leachate collection sumps. Leachate will be conveyed from the sumps directly into the City of Muskogee POTW to a leachate storage pond, or pumped to a leachate storage tank via a forcemain. The proposed piping will consist of a minimum 3-inch to 6-inch-diameter pipe. The forcemain, if located within the waste fill area, will not need secondary containment. When the forcemain is not located within the waste fill area the forcemain will be encased in a larger-diameter carrier pipe. The carrier pipe will provide leak detection and containment. If the leachate forcemain is placed within the waste fill area and in the final cover, the forcemain pipe will be placed a minimum of 18 inches below the top of the erosion layer. After placement, any disturbed soil in the vegetation layer and vegetation support layer that occurs will be repaired in accordance with the Alternative Final Cover QA/QC Plan found in Appendix E of Appendix J. Forcemain placement above and in the final cover will require dual containment.

Leachate and contaminated water will be disposed of by one of the following methods.

1. Pumped into a leachate storage pond, temporary leachate storage pond, or a leachate storage tank.
2. Direct discharge to the City of Muskogee POTW consistent with OAC 252:515-13-55.
3. Recirculated at the working face, as needed, to stabilize waste and facilitate compaction. The recirculation of leachate will be performed following the procedures set for in the Leachate Recirculation System Operating Plan (Section 6).

Consistent with OAC 252:515-13-55, the site obtained approval from the City of Muskogee POTW prior to discharge of leachate and contaminated water to the POTW. A copy of the POTW authorization is maintained in the Site Operating Record and also included in Appendix L-8.

Contaminated water will be pumped directly to the City of Muskogee POTW via the onsite connection for treatment. Contaminated water may also be transported to a on-site leachate storage tank or a leachate storage pond for storage prior to disposal.

6 LEACHATE RECIRCULATION SYSTEM OPERATING PLAN

6.1 Introduction

The main purpose of recirculating leachate at the Muskogee RDF is to facilitate waste compaction by providing for the opportunity to create a uniform moisture content throughout the waste at the working face. The additional moisture will help stabilize the waste mass by providing for increased compaction of the waste.

This Leachate Recirculation System Operating Plan will establish the procedures and requirements for recirculating leachate in accordance with Oklahoma Department of Environmental Quality (ODEQ) guidelines (i.e., ODEQ 252:515-13-53 and the Guidance Document on Leachate Recirculation as shown in Appendix L-6) and previous discussions with the ODEQ concerning leachate recirculation. This plan will serve as a guide for the Muskogee RDF for managing the recirculation of leachate over the composite lined cells at the Muskogee RDF.

6.2 System Description and Operating Procedures

In accordance with ODEQ guidelines, recirculation of leachate will only occur over areas of the landfill that have been lined with ODEQ approved Subtitle D composite liner systems. Leachate recirculation will not occur in the eastern unit. The western unit is designed with Subtitle D composite liner system. Leachate may be recirculated in the western unit.

The leachate generated from the landfill will be recirculated to the landfill working face, and excess quantities of leachate will be directed to the leachate storage facilities. As discussed in Appendix L-2, the HELP Model was used to evaluate the ability of the leachate collection system to maintain less than 12 inches of head on the liner during leachate recirculation. As shown in Appendix L-2, even at 100 percent recirculation, the leachate collection system produces less than 12 inches of head on the liner.

The leachate collection system layout and details are presented in Appendix L-1. The leachate collection layer consists of a 24-inch sand layer with a permeability of $1x10^{-3}$ cm/sec or greater.

The leachate collected in the leachate collection sump will be pumped directly into the POTW through the onsite connection or pumped into the leachate storage

facilities such as a pond or tank. The leachate storage area is discussed in Section 3.8. Leachate will be recirculated using the following typical methods:

- Surface Spraying – Distributing leachate from a water truck using a spray bar or hose to distribute leachate back to the working face. In addition, leachate may also be sprayed on the haul road over a composite lined area to control dust. Another option of surface spraying at the working face would be a water-reel. This option would consist of a water reel, pump, and accessories for distributing leachate to the working face.
- Horizontal Trenches – Trenches placed in the waste fill at regular vertical intervals and backfilled with permeable materials (sand, aggregate, shredded tires, crushed glass, etc.) provides a method for distributing leachate in a uniform manner. Perforated piping is generally included in the trench to facilitate the flow of leachate.
- Drip Irrigation Tubing – This would consist of small diameter (typically 0.5") plastic tubing originally developed for irrigating food crops in arid environments. It allows a highly controlled application of moisture. The tubing can either be laid on the surface or be buried at shallow depths.

6.3 Application Rate

The following performance standards will govern the application rate of leachate recirculation.

- The rate of application will not exceed the moisture holding capacity of the landfill. For example, the application rate will be applied so that no seeps or ponding is observed in the vicinity of the recirculation area.
- Leachate recirculation will not occur immediately before, during, or immediately after rainfall events, or during freezing temperatures that could affect the holding capacity of the waste.
- The application rate shall not result in a release of pollutants in surface runoff.
- The recirculation of leachate will be accomplished in a manner that does not create a health risk to employees, the public, adjacent property owners or their property (e.g., application should not occur during high winds, or if an additional odor occurs due to the recirculation event).
- Typically, leachate will not be recirculated in a cell until after a 50-foot-thick waste column is in place. This is consistent with the HELP analysis included in Appendix L-2. However, the HELP analysis (which is used for design purposes) overestimates the amount of leachate generated at the site. If the actual leachate generated is shown to be less than the design values, then

recirculation can occur with less than a 50-foot waste column in the cell, provided that all the conditions above are met.

6.4 Leachate Sampling Requirements and Procedures

In accordance with the site's industrial permit, Muskogee Community RDF currently samples leachate semi-annually. Analytical results are submitted to Muskogee Community RDF and are available to ODEQ upon request. The site currently reports leachate quantities to ODEQ on a quarterly basis. Logs and analytical results will be maintained in the Site Operating Record.

If methane is detected at levels above regulatory limits or a statistically significant change is noted during a groundwater sampling event, the leachate recirculation will cease until the source is determined to be not associated with the landfill, unless otherwise approved by the ODEQ.

6.5 System Assessment

The site will be periodically inspected to verify that no known leachate springs or seeps have occurred and that leachate has not commingled with stormwater runoff that has been discharged from the site as a direct result of the operation of the leachate recirculation system. This inspection will also include an evaluation of the operating procedures to verify compliance with ODEQ guidelines.

In addition to the periodic inspections discussed above, an annual assessment will be submitted to ODEQ to document the performance of the recirculation system. The annual assessment will include an estimate of the volume of leachate recirculated and a summary of the analytical results. In addition, the overall performance of recirculation practices will be documented in the annual assessment.

7 COMPLIANCE WITH OAC 252:515-11-3(A)

7.1 Introduction

The purpose of this section is to set forth how the Western Landfill Unit liner system is in compliance with OAC 252:515-11-3(a), which requires the following:

> *"Liner system shall be designed and constructed to maintain a minimum five-foot vertical separation between the highest groundwater elevation and the lowermost surface on which waste, including leachate, will be placed."*

The lowermost surface on which waste, including leachate, will be placed is defined by the elevation of the top of the geomembrane liner given that this surface forms the bottom of the leachate collection system.

The "highest groundwater elevation" is not defined in OAC 252:515-1-2. However, according to OAC 252:515-1-2 (Definitions), "groundwater" is defined as "water below the land surface in a zone of saturation" and "Zone of Saturation" is defined as "a subsurface zone in which essentially all the interstices are filled with water under pressure greater than that of the atmosphere".

As discussed in Appendix E, a subsurface investigation has been completed for the expansion area at the Muskogee RDF. This subsurface investigation indicates the site stratigraphy consists of surficial sediments that overlay a Weathered Shale Zone that overlays an Unweathered Shale Zone. As indicated in Section 3.3.2 the Weathered Shale Zone sediments are mostly dry with some moist intervals and with less frequent extents of saturated fractured shale present in limited intervals near the base of the Weathered Shale Zone. This uppermost zone of saturation is contained exclusively within these limited intervals of Weathered Shale Zone which exhibit confined fracture-porosity conditions.

Groundwater within this uppermost zone of saturation is isolated by a unsaturated Weathered Shale Zone above and the Unweathered Shale Zone below. The sediments in the unsaturated portion of the Weathered Shale Zone consist of dense, hard, indurated, plastic, mudstone and claystone shale exhibiting varying degrees of moisture content and fracturing, and occasional thin seams of interbedded clay. As indicated in Table 3-5 of Appendix E, the mean vertical hydraulic conductivity of the unsaturated portion of the Weathered Shale Zone is 4.23×10^{-8} cm/sec. This unsaturated portion of the Weathered Shale Zone forms an aquitard that confines

groundwater in the saturated portion of the Weathered Shale Zone. This saturated portion of the Weathered Shale Zone exhibits horizontal hydraulic conductivity mean of 5.18 x 10^{-4} cm/sec as indicated on Table 3-4 of Appendix E.

The sediments in the Unweathered Shale Zone consist of dense, hard, indurated, mudstone and claystone shale exhibiting varying degrees of plasticity and fracturing, and occasional minor discontinues thin seams of interbedded coal and limestone. These seams have no significant hydrogeologic significance due to their dry and discontinuous nature. The Unweathered Shale Zone forms an aquitard that confines groundwater in the saturated portion of the Weathered Shale Zone.

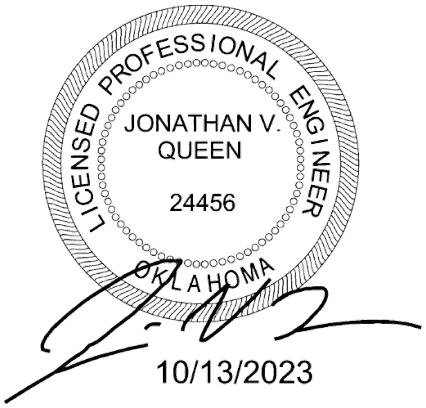
Therefore, given unsaturated portion of the Weathered Shale Zone aquitard above and the Unweathered Shale Zone aquitard below the saturated Weathered Shale Zone meets the definition of a subsurface zone in which essentially all interstices are filled with water under pressure greater than that of the atmosphere.

This conclusion is further confirmed by review of the potentiometric head differential shown on Table 3-2 in Appendix E. The table indicates that confined groundwater exhibits a potentiometric head ranging from about 11 to 36 feet higher than the top of the uppermost saturated zone. If this was a potentiometric surface representing a zone of saturation, the upper portions of the Weathered Shale Zone would have been saturated, which was not observed during the subsurface field investigation.

Therefore, the top of the uppermost saturated zone observed at time of drilling constitutes the highest groundwater elevation for evaluating groundwater/waste separation pursuant to OAC 252:515-7-54(a) and 252:515-11-3(a).

APPENDIX L-1

FIGURES



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Top of Protective Cover Plan

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FIGURE L-1-5
Liner System Details

FIGURE L-1-6
Leachate Collection System Details

FIGURE L-1-7
Leachate Collection System Details

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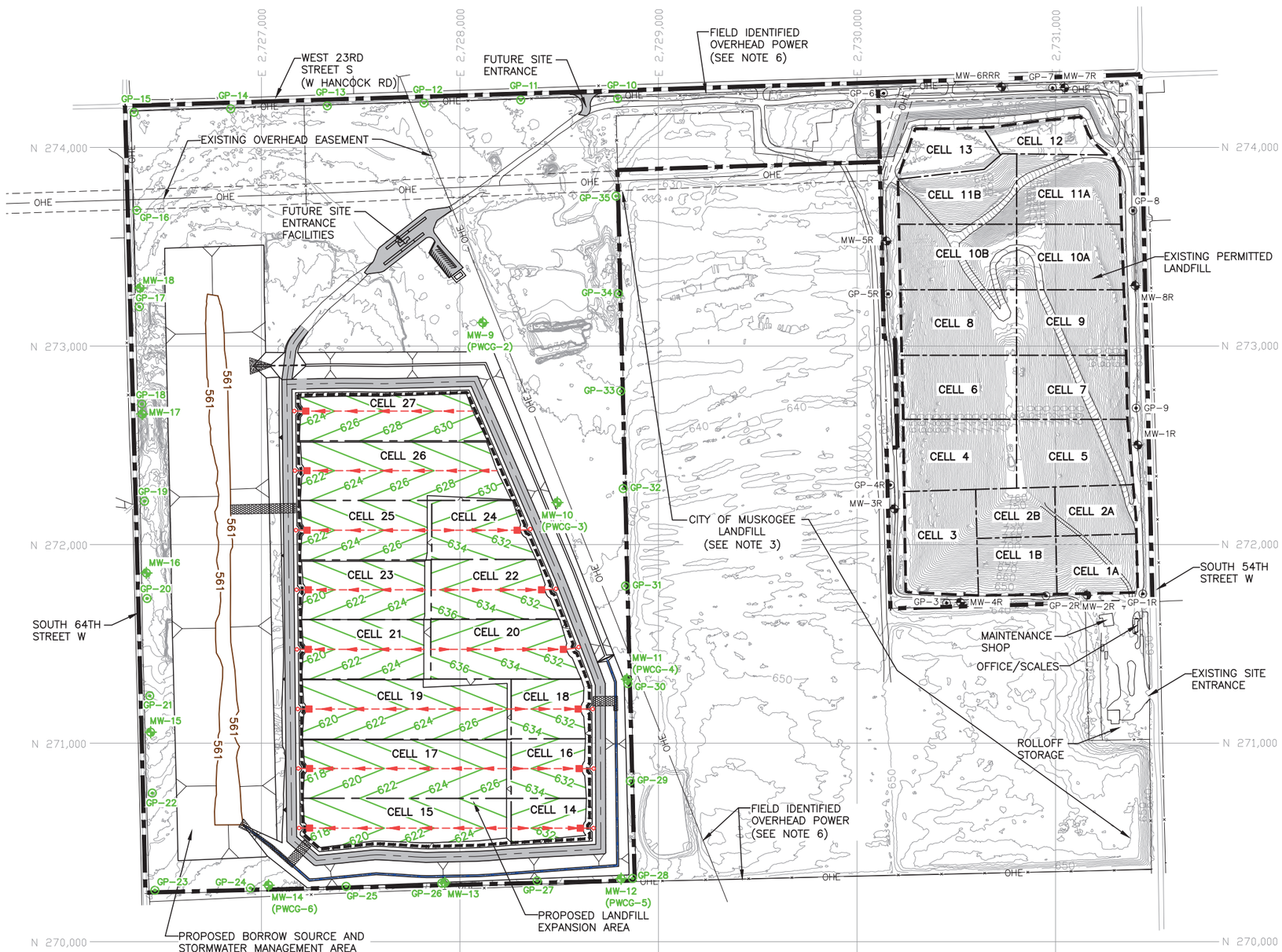

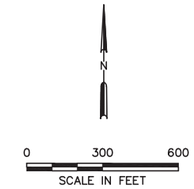

LEGEND

- EXISTING PERMIT BOUNDARY
- PROPOSED PERMIT BOUNDARY
- PERMITTED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- N 273,000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- 636 — EXCAVATION CONTOUR
- 561 — SOIL BORROW CONTOUR
- CELL BOUNDARY
- PROPOSED LEACHATE LINE
- PROPOSED LEACHATE SUMP
- PROPOSED LEACHATE CLEANOUT RISER
- PROPOSED DRAINAGE CHANNEL
- OHE — EXISTING OVERHEAD EASEMENT
- MW-5R — EXISTING GROUNDWATER MONITORING WELL
- MW-9 (PWCG-1) — PROPOSED GROUNDWATER MONITORING WELL
- GP-5 — EXISTING LANDFILL GAS MONITORING PROBE
- GP-10 — PROPOSED LANDFILL GAS MONITORING PROBE

NOTES:

1. EXISTING CONTOURS AND ELEVATIONS PROVIDED BY HYDREX ENVIRONMENTAL COMPILED FROM AERIAL PHOTOGRAPHY FLOWN 01-25-2023.
2. THE EXPANSION WILL ADD A SEPARATE UNIT TO THE WEST OF THE EXISTING LANDFILL. NO CHANGES ARE PROPOSED TO THE EASTERN UNIT.
3. THE CITY OF MUSKOGEE LANDFILL IS NOT PART OF THE PROPOSED EXPANSION AND IS SHOWN FOR REFERENCE PURPOSES.
4. PERMIT BOUNDARY AND EXISTING OVERHEAD EASEMENTS WERE REPRODUCED FROM LEGAL DESCRIPTION PREPARED BY WEAVER CONSULTANTS GROUP, SIGNED BY MICHAEL D BYTNER, LLS# 1986.
5. AN EASEMENT RECORD WAS NOT FOUND OR PROVIDED TO THE SURVEYOR. THE OVERHEAD POWER RUNNING ALONG THE NORTHERN AND SOUTHERN PROPERTY LINE AND NORTHWEST/SOUTHEAST ACROSS THE PROPERTY WAS FIELD IDENTIFIED AND SURVEYED.
6. ALL PROPOSED EXCAVATION SIDESLOPES ARE 3(HORIZONTAL):1(VERTICAL).
7. FOR LEACHATE COLLECTION/STORAGE INFORMATION SEE APPENDIX L-3 AND L-4.

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10/13/2023

Cell	Area (AC)	Cell	Area (AC)
14	1.9	21	4.5
15	5.7	22	4.2
16	2.7	23	4.5
17	7.2	24	3.3
18	2.7	25	4.6
19	7.3	26	7.0
20	5.0	27	4.9

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TIER III PERMIT MODIFICATION EXCAVATION PLAN

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FIGURE L-1-1

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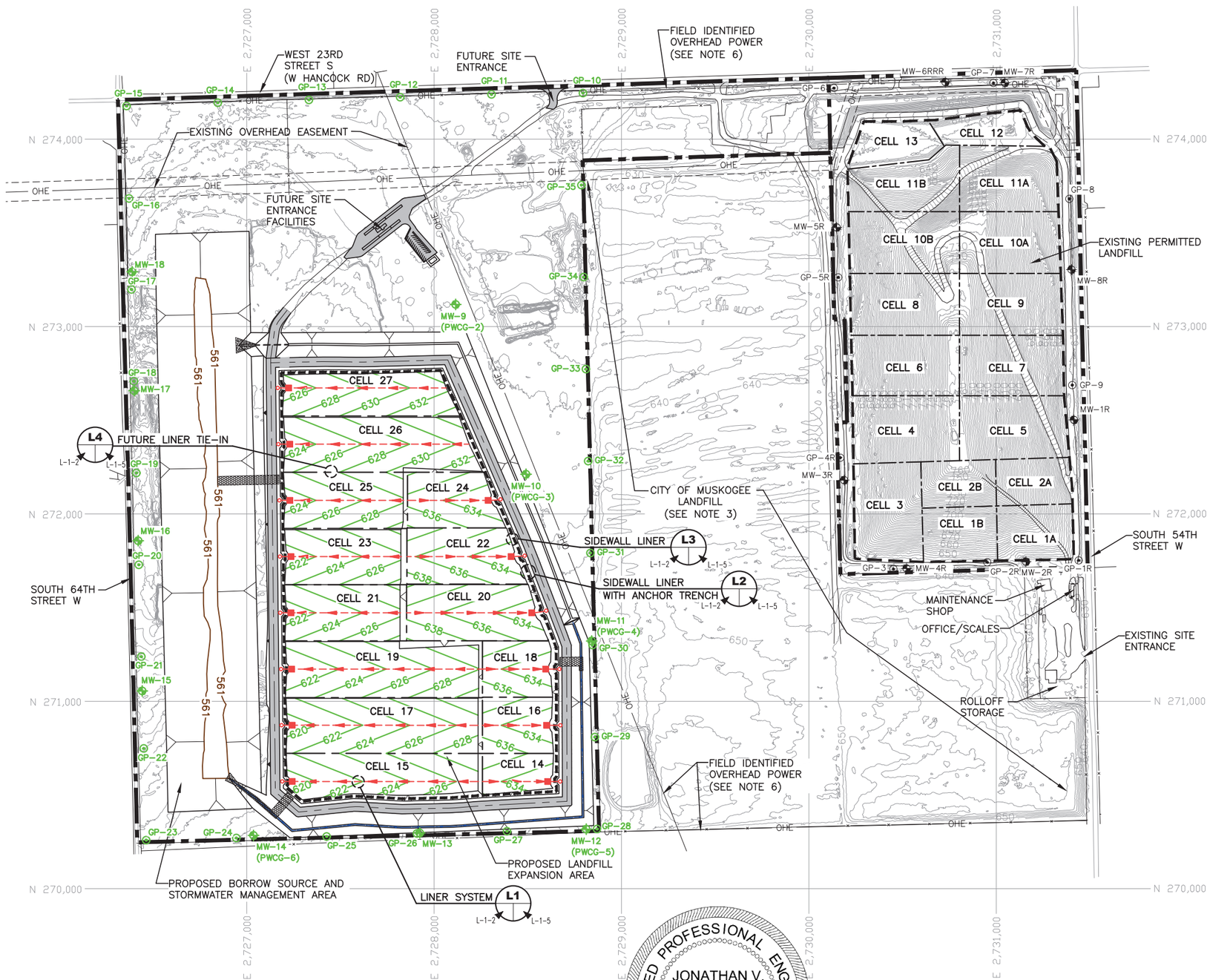

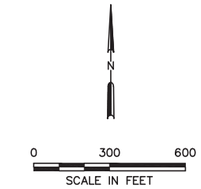

LEGEND

- EXISTING PERMIT BOUNDARY
- PROPOSED PERMIT BOUNDARY
- PERMITTED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- N 273,000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- 638 — TOP OF LINER CONTOUR
- 561 — SOIL BORROW CONTOUR
- CELL BOUNDARY
- PROPOSED LEACHATE LINE
- PROPOSED LEACHATE SUMP
- PROPOSED LEACHATE CLEANOUT RISER
- PROPOSED DRAINAGE CHANNEL
- OHE — EXISTING OVERHEAD EASEMENT
- MW-5R — EXISTING GROUNDWATER MONITORING WELL
- MW-9 (PWCG-1) — PROPOSED GROUNDWATER MONITORING WELL
- GP-5 — EXISTING LANDFILL GAS MONITORING PROBE
- GP-10 — PROPOSED LANDFILL GAS MONITORING PROBE

NOTES:

1. EXISTING CONTOURS AND ELEVATIONS PROVIDED BY HYDREX ENVIRONMENTAL COMPILED FROM AERIAL PHOTOGRAPHY FLOWN 01-25-2023.
2. THE EXPANSION WILL ADD A SEPARATE UNIT TO THE WEST OF THE EXISTING LANDFILL. NO CHANGES ARE PROPOSED TO THE EASTERN UNIT.
3. THE CITY OF MUSKOGEE LANDFILL IS NOT PART OF THE PROPOSED EXPANSION AND IS SHOWN FOR REFERENCE PURPOSES.
4. PERMIT BOUNDARY AND EXISTING OVERHEAD EASEMENTS WERE REPRODUCED FROM LEGAL DESCRIPTION PREPARED BY WEAVER CONSULTANTS GROUP, SIGNED BY MICHAEL D BYTNER, LLS# 1986.
5. A WASTE-FREE BUFFER ZONE AT LEAST 100-FEET OFFSET FROM THE PERMIT BOUNDARY FOR THE LANDFILL EXPANSION AREA INCLUDED IN THIS MODIFICATION WILL BE MAINTAINED.
6. AN EASEMENT RECORD WAS NOT FOUND OR PROVIDED TO THE SURVEYOR. THE OVERHEAD POWER RUNNING ALONG THE NORTHERN AND SOUTHERN PROPERTY LINE AND NORTHWEST/SOUTHEAST ACROSS THE PROPERTY WAS FIELD IDENTIFIED AND SURVEYED.
7. ALL PROPOSED EXCAVATION SIDESLOPES ARE 3(HORIZONTAL):1(VERTICAL).
8. THE SITE HAS AN OPTION TO REPLACE THE TOP 1-FOOT OF CLAY LINER WITH GCL.
9. FOR LEACHATE COLLECTION STORAGE INFORMATION SEE APPENDIX L-3 AND L-4.

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TIER III PERMIT MODIFICATION TOP OF LINER PLAN

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FIGURE L-1-2

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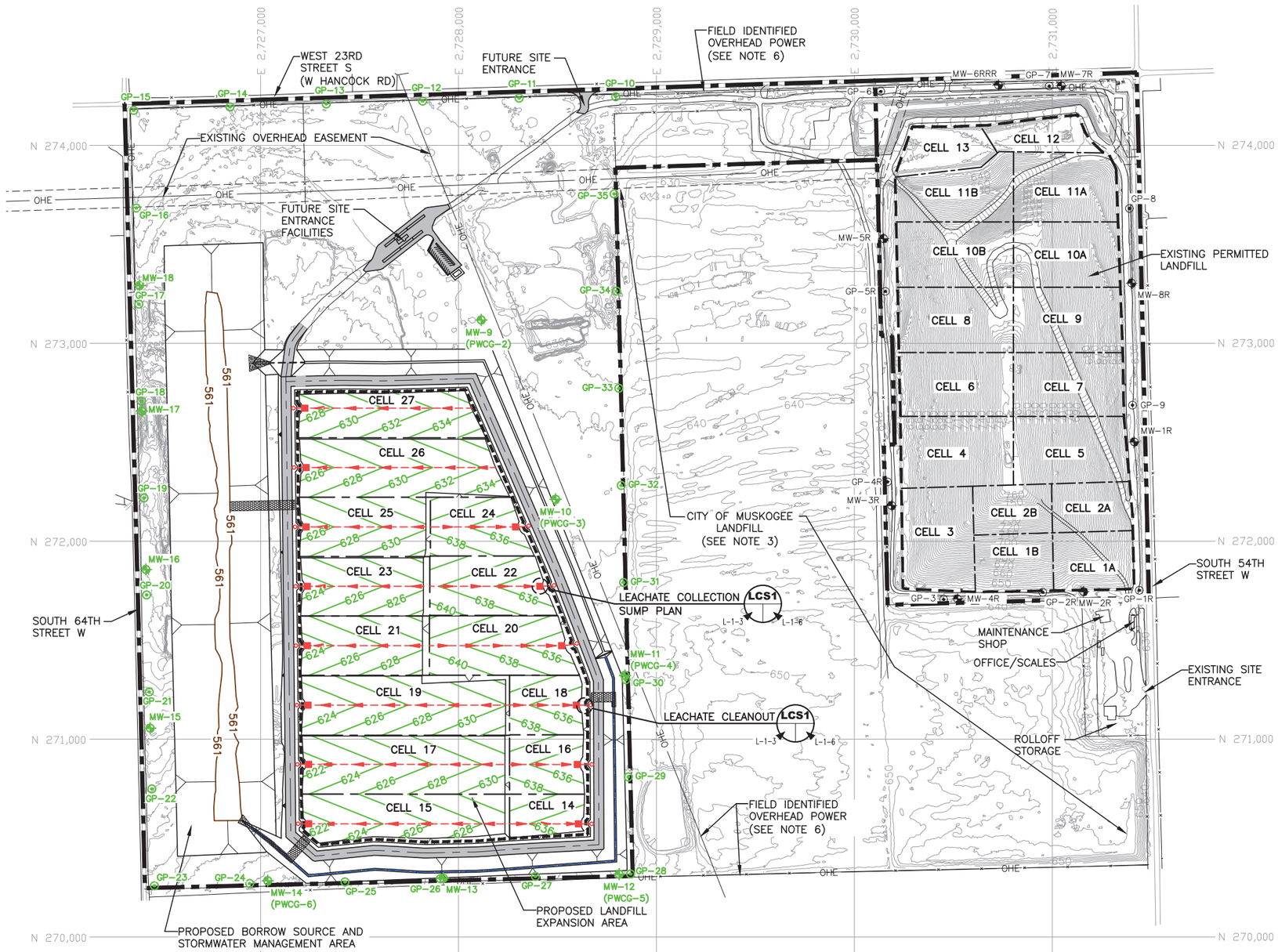

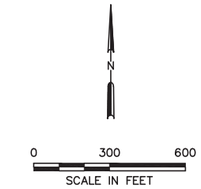

LEGEND

- EXISTING PERMIT BOUNDARY
- PROPOSED PERMIT BOUNDARY
- PERMITTED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- N 273,000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- 640 — TOP OF PROTECTIVE COVER CONTOUR
- 561 — SOIL BORROW CONTOUR
- CELL BOUNDARY
- PROPOSED LEACHATE LINE
- PROPOSED LEACHATE SUMP
- PROPOSED LEACHATE CLEANOUT RISER
- PROPOSED DRAINAGE CHANNEL
- OHE — EXISTING OVERHEAD EASEMENT
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NOTES:

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7. ALL PROPOSED EXCAVATION SIDESLOPES ARE 3(HORIZONTAL):1(VERTICAL).
8. THE SITE HAS AN OPTION TO REPLACE THE TOP 1-FOOT OF CLAY LINER WITH GCL.
9. FOR LEACHATE COLLECTION STORAGE INFORMATION SEE APPENDIX L-3 AND L-4.
10. THE TOP OF PROTECTIVE COVER CONTOURS REPRESENT THE TOP OF THE 24-INCH THICK $K \geq 1X10^{-3}$ CM/S LAYER

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FIGURE L-1-3

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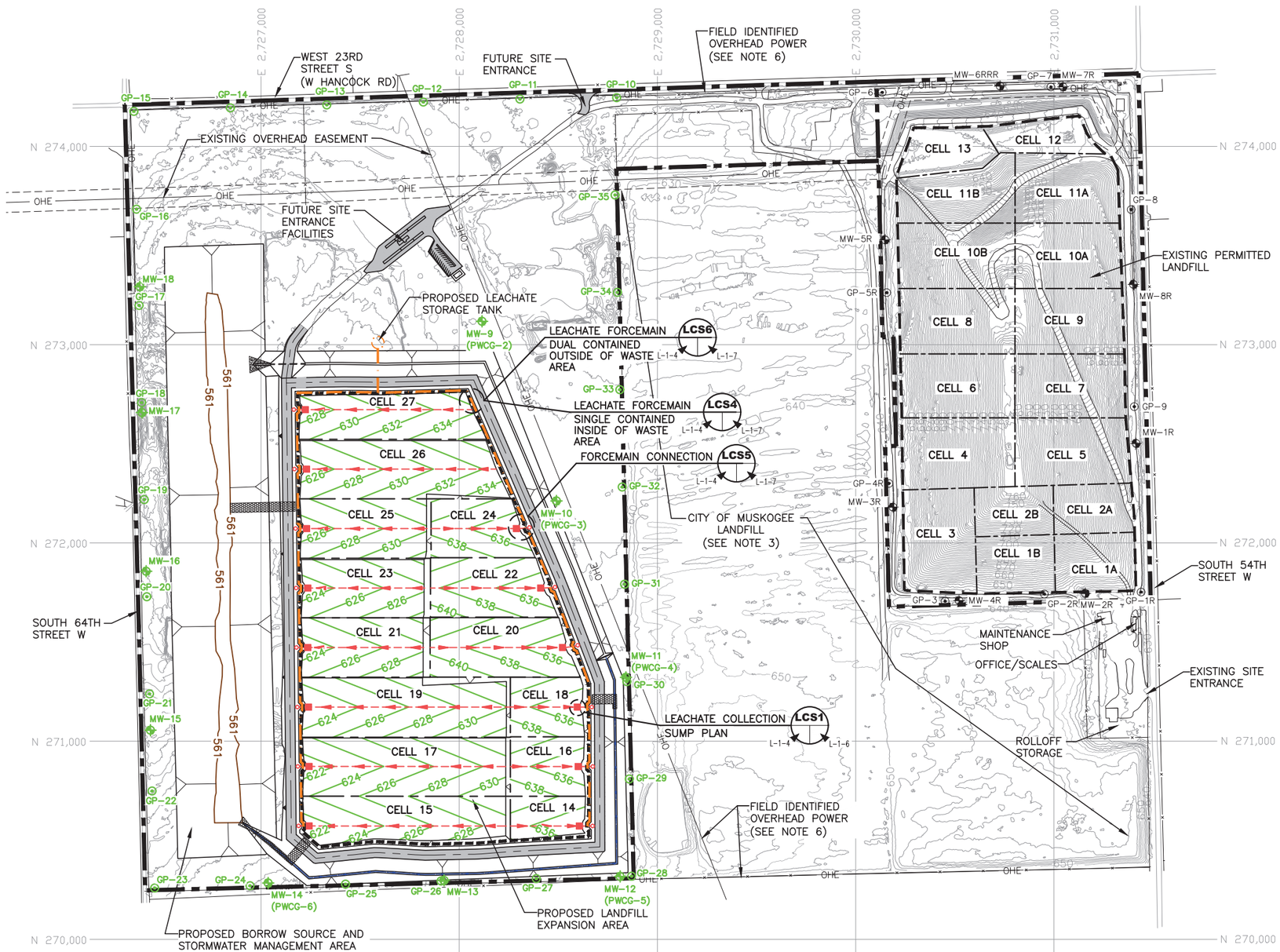

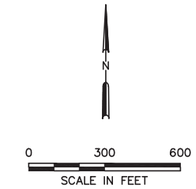

LEGEND

- EXISTING PERMIT BOUNDARY
- PROPOSED PERMIT BOUNDARY
- PERMITTED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- N 273,000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- 640 — TOP OF PROTECTIVE COVER CONTOUR
- 561 — SOIL BORROW CONTOUR
- CELL BOUNDARY
- PROPOSED LEACHATE LINE
- PROPOSED LEACHATE SUMP
- PROPOSED LEACHATE CLEANOUT RISER
- PROPOSED DRAINAGE CHANNEL
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8. THE SITE HAS AN OPTION TO REPLACE THE TOP 1-FOOT OF CLAY LINER WITH GCL.
9. FOR LEACHATE COLLECTION STORAGE INFORMATION SEE APPENDIX L-3 AND L-4.
10. THE TOP OF PROTECTIVE COVER CONTOURS REPRESENT THE TOP OF THE 24-INCH THICK $K \geq 1X10^{-3}$ CM/S LAYER.
11. THE LOCATION OF THE PROPOSED LEACHATE FORCEMAIN SHOWN IS APPROXIMATE AND MAY CHANGE BASED ON FIELD CONDITIONS AT THE TIME OF CONSTRUCTION. IF THE PROPOSED LEACHATE FORCEMAIN IS PLACED WITHIN THE WASTE FILL AREA SECONDARY CONTAINMENT WILL NOT BE NEEDED. SEE DETAIL LCS7 ON FIGURE L-1-7 FOR FORCEMAIN LOCATED WITHIN WASTE FILL AREA.

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TIER III PERMIT MODIFICATION LEACHATE FORCEMAIN PLAN

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FIGURE L-1-4

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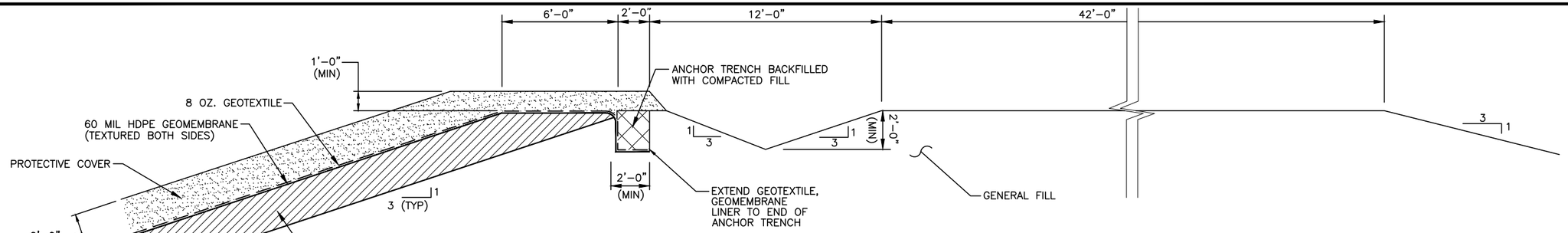
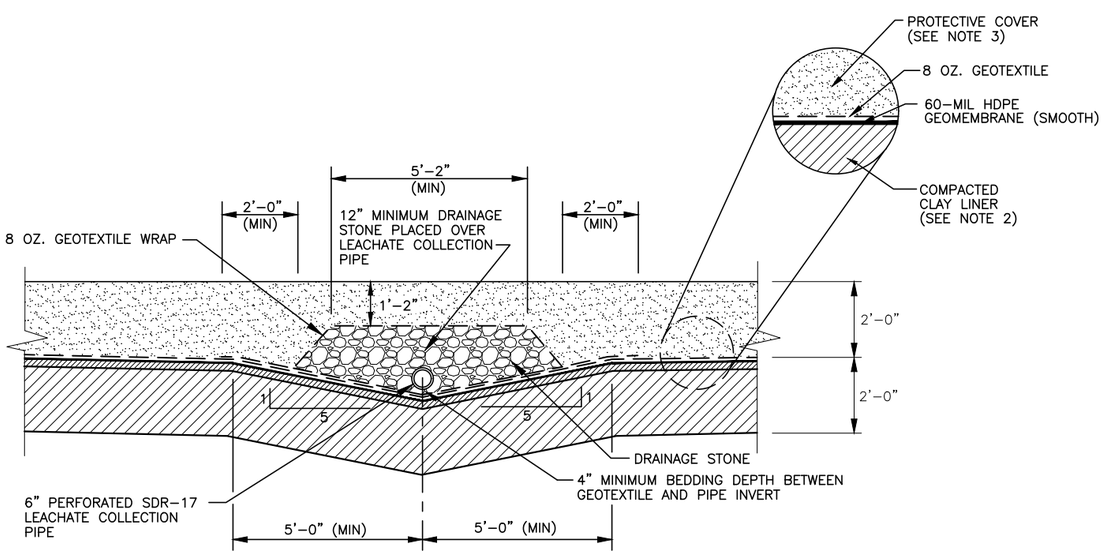


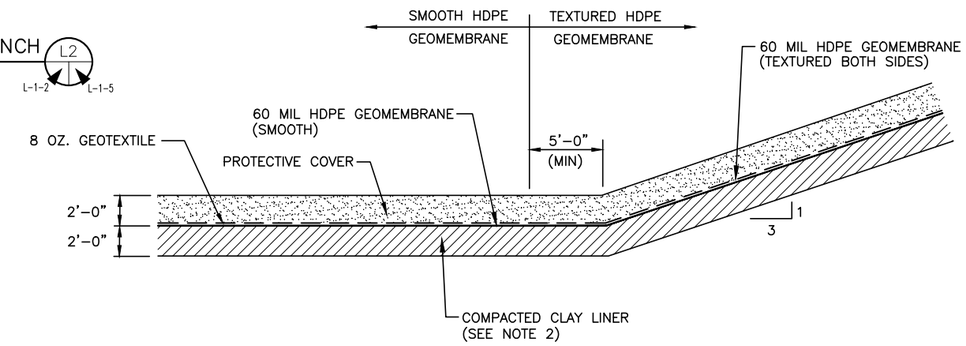
SIDEWALL LINER WITH ANCHOR TRENCH (L2)

0 3 6
SCALE IN FEET



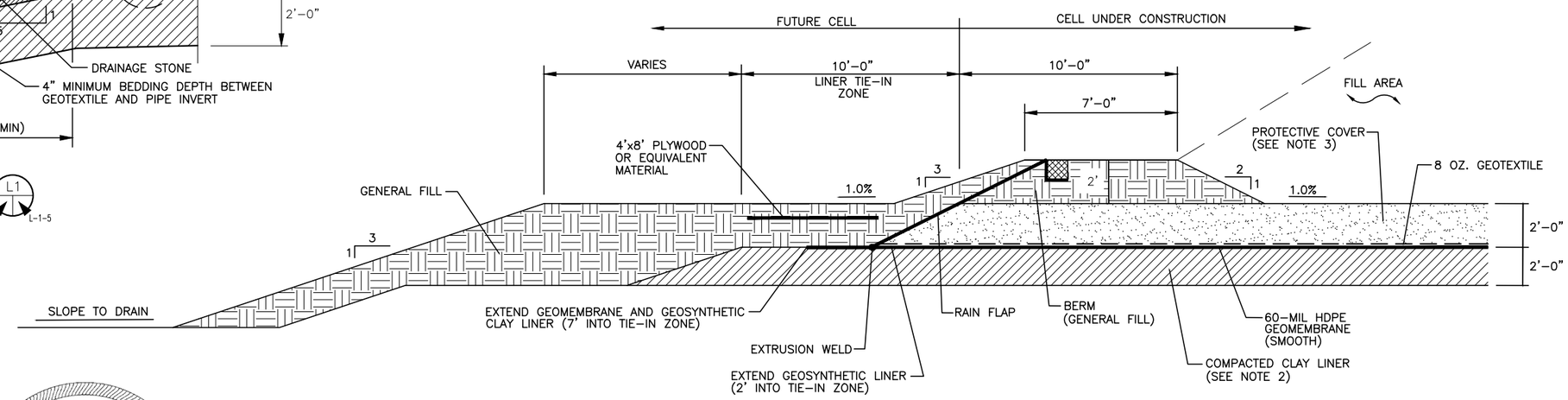
LINER SYSTEM (L1)

0 2 4
SCALE IN FEET



SIDEWALL LINER (L3)

0 5 10
SCALE IN FEET



FUTURE LINER TIE-IN (L4)

0 3 6
SCALE IN FEET

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24456
OKLAHOMA

10/13/2023

NOTE:

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2. AN ALTERNATE TO THE 2 FEET OF CLAY IS 1 FOOT OF CLAY OVERLAIN BY A GCL.
3. THE TOP OF PROTECTIVE COVER CONTOURS REPRESENT THE TOP OF THE 24-INCH THICK $K \geq 1 \times 10^{-3}$ CM/S LAYER

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LINER SYSTEM DETAILS

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MUSKOGEE COUNTY, OKLAHOMA

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FIGURE L-1-5

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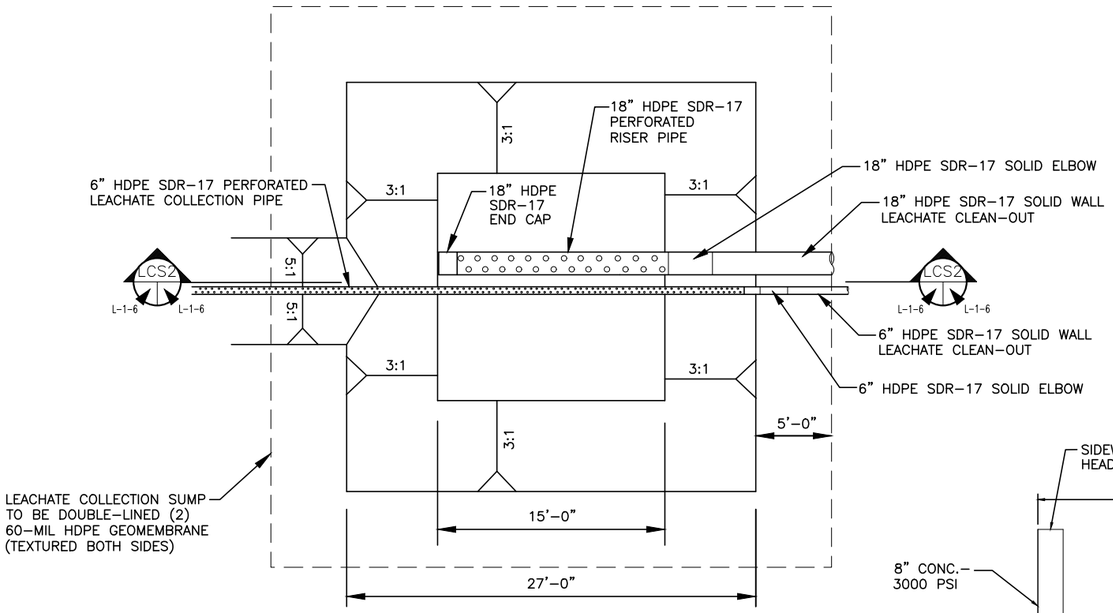
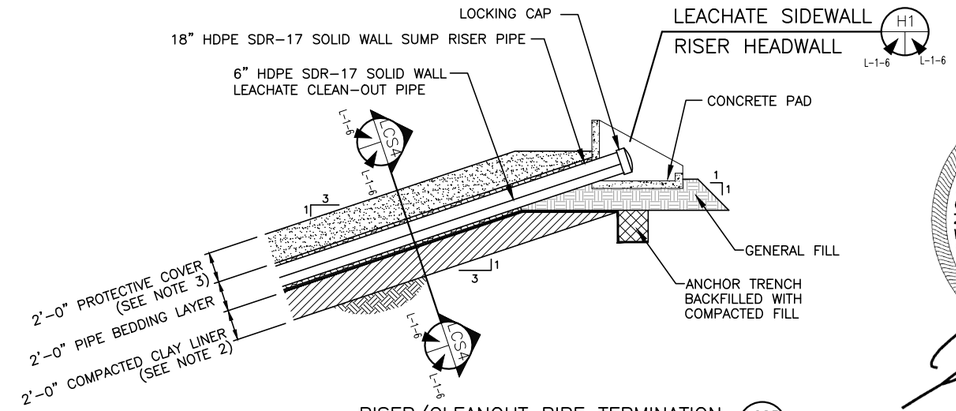


LEACHATE COLLECTION SUMP PLAN (LCS1, L-1-3, L-1-6)

0 5 10
SCALE IN FEET



RISER/CLEANOUT PIPE TERMINATION (LCS3, L-1-3, L-1-6)

0 5 10
SCALE IN FEET

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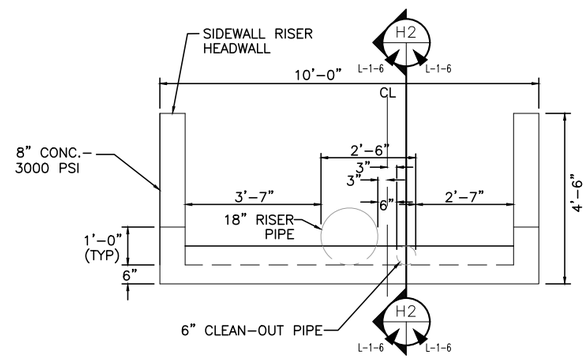
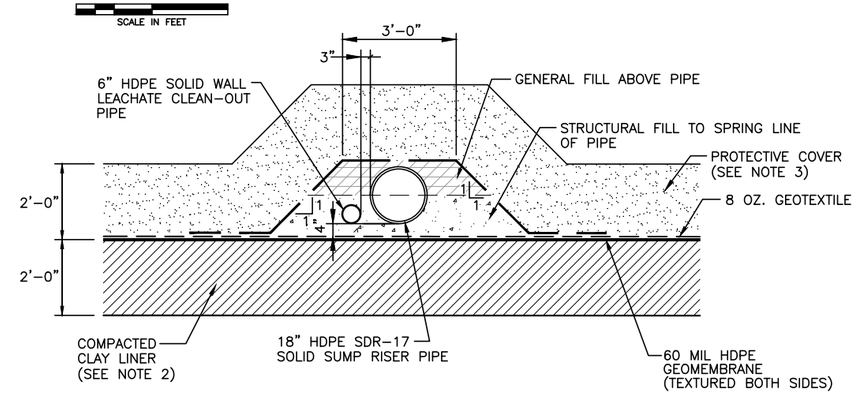


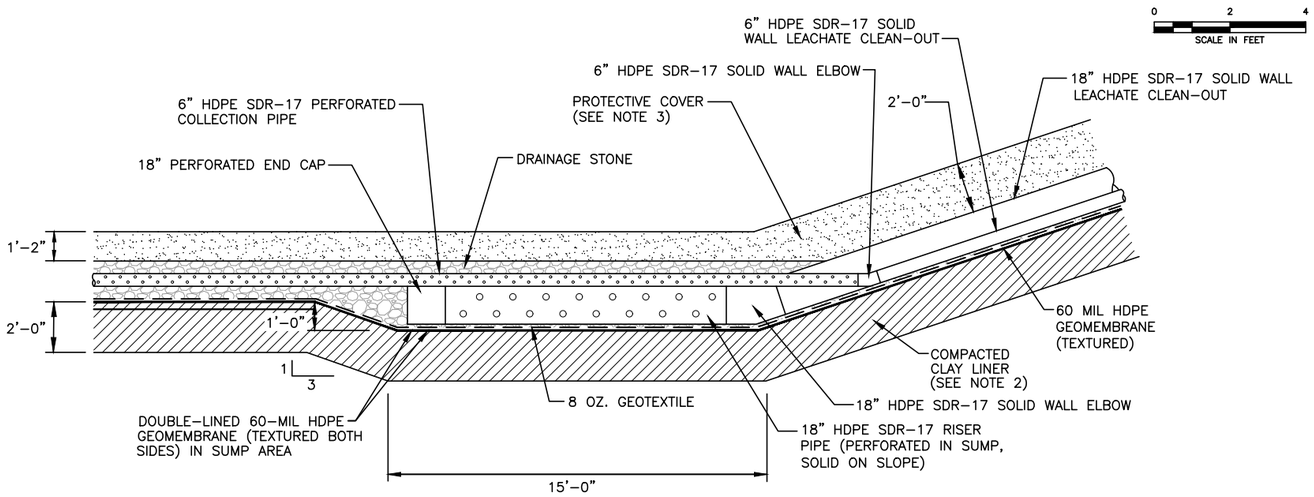
LEACHATE SIDEWALL RISER HEADWALL (H1, L-1-6)

0 2 4
SCALE IN FEET



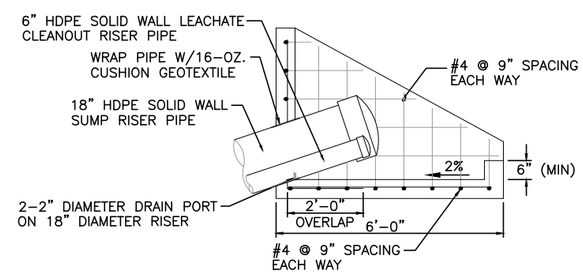
RISER/CLEANOUT PIPE SIDEWALL SECTION (LCS4, L-1-6)

0 2 4
SCALE IN FEET



TYPICAL LEACHATE SUMP SECTION (LCS2, L-1-6)

0 3 6
SCALE IN FEET



SIDEWALL RISER HEADWALL SECTION (H2, L-1-6)

0 2 4
SCALE IN FEET

NOTE:

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2. AN ALTERNATE TO THE 2 FEET OF CLAY IS 1 FOOT OF CLAY OVERLAIN BY A GCL.
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TIER III PERMIT MODIFICATION
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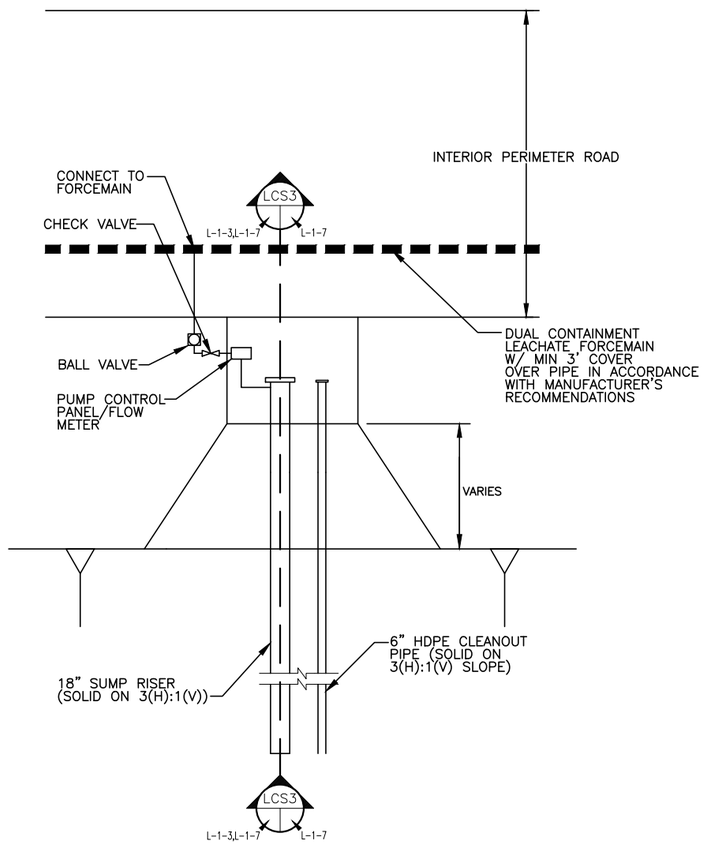
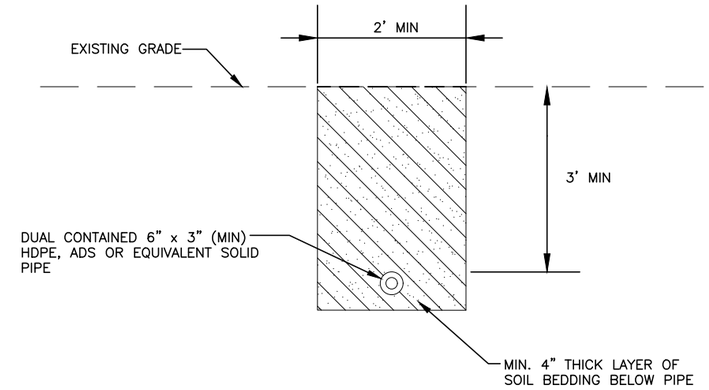
FIGURE L-1-6

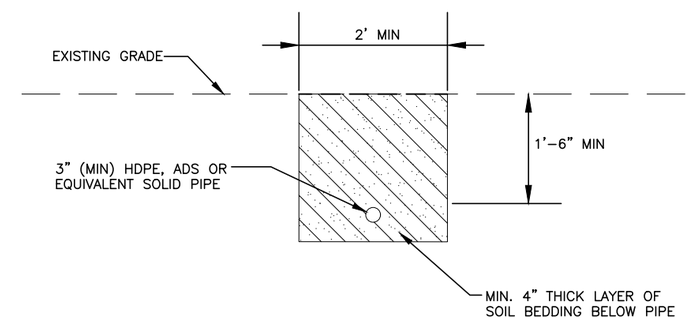
G:\0086\36\EXPANSION 2022\APPENDIX L\L-1-6-SUMP DETAILS.dwg, jpohr, 1:2



FORCEMAIN CONNECTION (LCS5)
NTS
L-1-4 L-1-7



LEACHATE FORCEMAIN (DUAL CONTAINED; OUTSIDE OF WASTE FILL AREA) (LCS6)
NTS
L-1-4 L-1-7



LEACHATE FORCEMAIN (SINGLE CONTAINED; INSIDE OF WASTE FILL AREA) (LCS7)
NTS
L-1-4 L-1-7

LICENSED PROFESSIONAL ENGINEER
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OKLAHOMA
10/13/2023

NOTES:

1. MATERIAL PROPERTIES AND QA/QC REQUIREMENTS FOR EACH OF THE LINER COMPONENTS ARE SPECIFIED IN APPENDIX K.
2. SEE APPENDIX K FOR LEACHATE COLLECTION SYSTEM MATERIAL REQUIRMENTS.

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REVIEWED BY: JVQ

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FIGURE L-1-7

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APPENDIX L-2

LEACHATE GENERATION MODEL

Includes pages L-2-1 through L-2-48

CONTENTS

1 LEACHATE GENERATION MODEL **L-2-1**

1.1 HELP Model L-2-1

1.2 Model Setup L-2-1

1.3 Climate Data Input L-2-2

1.4 Landfill Profile L-2-2

1.4.1 Composite Liner System L-2-2

1.4.2 Leachate Collection Layer/Protective Cover Material System L-2-2

1.4.3 Waste Layers L-2-2

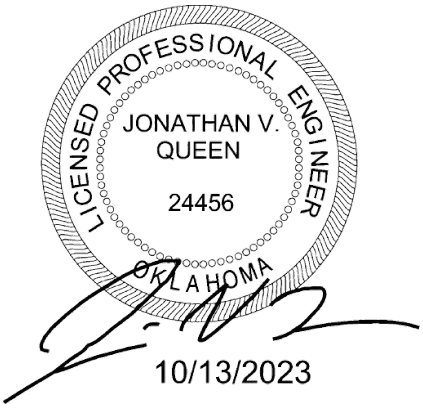
1.4.4 Cover Soils L-2-2

1.4.5 Final Cover L-2-3

1.5 HELP Model Output L-2-3

HELP SUMMARY TABLE **L-2-4**

HELP OUTPUT **L-2-5**



LEACHATE GENERATION MODEL

1.1 HELP Model

The Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3.07, was used to estimate the quantity of leachate that will be generated during the active life and postclosure period of the Muskogee Community RDF. The HELP Model is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of the landfill. The model uses climate, soil, and landfill design data to perform a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, soil moisture storage, evapotranspiration, and lateral drainage.

1.2 Model Setup

The site was modeled using 1-acre unit areas for the following stages of landfill development for the liner system and leachate collection layer/protective cover material system:

- Working face with 10 feet of waste (pages L-2-5 through L-2-12)
- 50 feet of waste with cover soils (pages L-2-13 through L-2-21)
- 100 feet of waste with cover soils (pages L-2-22 through L-2-30)
- 150 feet of waste with cover soils (pages L-2-31 through L-2-39)
- 150 feet of waste with final cover (pages L-2-40 through L-2-48)

To provide for a conservative demonstration, the active stage was modeled for 1 year with initial moisture contents initialized by the HELP program to steady-state moisture conditions. The interim stages with 50, 100, and 150 feet of waste were modeled for various timeframes depending on expected conditions. The closed landfill condition was modeled for 30 years. The HELP Model suggested the evaporative zone depth and leaf area index for Tulsa, Oklahoma. In addition, the HELP Model calculated the Soil Conservation Service (SCS) runoff curve numbers based on soil data and expected ground cover, surface slope, and slope length.

1.3 Climate Data Input

Mean monthly precipitation values for Muskogee City obtained from the National Oceanic and Atmospheric Administration (NOAA) 1991-2020 U.S. Climate Normals were entered into HELP. The HELP model synthetically generated precipitation data using program default coefficients for Tulsa, Oklahoma. The average annual precipitation over the modeled 30-year period was 42.46 inches. The HELP model also synthetically generated temperature and solar radiation data using program defaults for Tulsa, Oklahoma.

1.4 Landfill Profile

The landfill profiles for the active and closed stages of the landfill development are presented in the attached HELP Model summary sheet (page L-2-4). The profiles presented below represent the composite liner system and the alternative final cover system. The liner system and final cover drawings are presented in Volume 1.

1.4.1 Composite Liner System

The composite liner consists of a 24-inch compacted clay layer overlain by a 60-mil high-density polyethylene (HDPE) geomembrane. The 24-inch-thick clay layer will have a hydraulic conductivity of $1x10^{-7}$ cm/sec. Default soil characteristics from the HELP model were selected for the 24-inch-thick compacted clay liner. The geomembrane liner was modeled for good installation quality, 1 defect per acre, and a pinhole density of 0.5 holes/acre.

1.4.2 Leachate Collection Layer/Protective Cover Material System

The leachate collection/protective cover system consists of a 24-inch leachate collection layer with a permeability of $1x10^{-3}$ cm/sec or greater. An 8-oz/sy geotextile will underlie the 24-inch leachate collection layer.

The HELP model demonstration utilized recirculation. One hundred percent of leachate generated at the site may be recirculated as demonstrated in the HELP modeling. Actual leachate application rates will be limited to prevent surface runoff or erosion, or ponding of dispersed leachate.

1.4.3 Waste Layers

Waste layers of 10, 50, 100, and 150 feet were used to represent the active and closed stages of landfill development. The default characteristics were selected from HELP to represent municipal solid waste. The first 5 feet of waste will not include large appliances or other large, bulky items, and will serve as the upper component of the leachate collection layer/protective cover material system.

1.4.4 Cover Soils

The cover soils consist of a 6-inch-thick layer for the active and interim case and 12-inch-thick layer for the closed case of soil placed over the waste. Default soil characteristics from the HELP Version 3.07 table were selected to represent the available onsite soils.

1.4.5 Final Cover

The alternative final cover system consists of a 12-inch-thick vegetative topsoil layer capable of sustaining growth of vegetation, and a 24-inch-thick vegetative support layer.

1.5 HELP Model Output

The HELP summary table and output files for the active and closed stages of landfill development for the alternative composite liner design and final cover system are presented on pages L-2-4 through L-2-48.

Prep By: JBP
Date: 10/11/2023

MUSKOGEE COMMUNITY RDF
WESTERN LANDFILL UNIT
0086-364-11-18
HELP VERSION 3.07 SUMMARY SHEET

Chkd By: JVQ
Date: 10/11/2023

		ACTIVE (10 FT WASTE)	INTERIM (50 FT WASTE)	INTERIM (100 FT WASTE)	INTERIM (150 FT WASTE)	CLOSED (150 FT WASTE)
GENERAL INFORMATION	Case No.	1	2	3	4	5
	No. of Years	1	10	10	10	30
	Ground Cover	BARE	FAIR	FAIR	FAIR	GOOD
	SCS Runoff Curve No.	97.1	91.2	91.2	91.2	89.5
	Model Area (acre)	1	1	1	1	1
	Runoff Area (%)	70	85	85	85	100
	Maximum Leaf Area Index	0.0	2.0	2.0	2.0	3.5
	Evaporative Zone Depth (inch)	6	6	6	6	12
VEGETATIVE TOPSOIL LAYER (Texture = 26)	Thickness (in)	---	---	---	---	12
	Porosity (vol/vol)	---	---	---	---	0.4450
	Field Capacity (vol/vol)	---	---	---	---	0.3930
	Wilting Point (vol/vol)	---	---	---	---	0.2770
	Init. Moisture Content (vol/vol)	---	---	---	---	0.3000
	Hyd. Conductivity (cm/s)	---	---	---	---	1.9E-06
VEGETATIVE SUPPORT LAYER (Texture = 25)	Thickness (in)	---	---	---	---	24
	Porosity (vol/vol)	---	---	---	---	0.4370
	Field Capacity (vol/vol)	---	---	---	---	0.3730
	Wilting Point (vol/vol)	---	---	---	---	0.2660
	Init. Moisture Content (vol/vol)	---	---	---	---	0.3730
	Hyd. Conductivity (cm/s)	---	---	---	---	3.6E-06
Cover Soils (Texture = 26)	Thickness (in)	6	6	6	6	12
	Porosity (vol/vol)	0.4450	0.4450	0.4450	0.4450	0.4450
	Field Capacity (vol/vol)	0.3930	0.3930	0.3930	0.3930	0.3930
	Wilting Point (vol/vol)	0.2770	0.2770	0.2770	0.2770	0.2770
	Init. Moisture Content (vol/vol)	0.2770	0.2770	0.2770	0.2770	0.3930
	Hyd. Conductivity (cm/s)	1.9E-06	1.9E-06	1.9E-06	1.9E-06	1.9E-06
WASTE (Texture = 18)	Thickness (in)	120	600	1200	1800	1800
	Porosity (vol/vol)	0.6710	0.6710	0.6710	0.6710	0.6710
	Field Capacity (vol/vol)	0.2920	0.2920	0.2920	0.2920	0.2920
	Wilting Point (vol/vol)	0.0770	0.0770	0.0770	0.0770	0.0770
	Init. Moisture Content (vol/vol)	0.2920	0.2920	0.2920	0.2920	0.2920
	Hyd. Conductivity (cm/s)	1.0E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03
PROTECTIVE COVER/LEACHATE COLLECTION LAYER (Texture = 0)	Thickness (in)	24	24	24	24	24
	Porosity (vol/vol)	0.4370	0.4370	0.4370	0.4370	0.4370
	Field Capacity (vol/vol)	0.0620	0.0620	0.0620	0.0620	0.0620
	Wilting Point (vol/vol)	0.0240	0.0240	0.0240	0.0240	0.0240
	Init. Moisture Content (vol/vol)	0.0620	0.0622	0.0622	0.0622	0.0622
	Hyd. Conductivity (cm/s)	1.0E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03
	Slope (%)	2.0	2.0	2.0	2.0	2.0
	Slope Length (ft)	162	162	162	162	162
FLEXIBLE MEMBRANE LINER (Texture = 35)	Thickness (in)	0.06	0.06	0.06	0.06	0.06
	Hyd. Conductivity (cm/s)	2.0E-13	2.0E-13	2.0E-13	2.0E-13	2.0E-13
	Pinhole Density (holes/acre)	0.5	0.5	0.5	0.5	0.5
	Install. Defects (holes/acre)	1	1	1	1	1
	Placement Quality	GOOD	GOOD	GOOD	GOOD	GOOD
COMPACTED CLAY LINER (Texture = 16)	Thickness (in)	24	24	24	24	24
	Porosity (vol/vol)	0.4270	0.4270	0.4270	0.4270	0.4270
	Field Capacity (vol/vol)	0.4180	0.4180	0.4180	0.4180	0.4180
	Wilting Point (vol/vol)	0.3670	0.3670	0.3670	0.3670	0.3670
	Init. Moisture Content (vol/vol)	0.4270	0.4270	0.4270	0.4270	0.4270
	Hyd. Conductivity (cm/s)	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07
PRECIPITATION	Average Annual (in)	55.18	42.46	42.46	42.46	41.05
RUNOFF	Average Annual (in)	38.04	23.18	23.10	23.10	20.28
EVAPOTRANSPIRATION	Average Annual (in)	17.14	17.03	19.11	19.11	20.22
LATERAL DRAINAGE COLLECTED (1)	Average Annual (cf/acre/year)	1.698	893.475	893.469	893.469	0.502
	Peak Daily (cf/acre/day)	0.007	8.250	8.250	8.250	0.003
LATERAL DRAINAGE RECIRCULATED	Average Annual (cf/acre/year)		893.475	893.469	893.469	
	Peak Daily (cf/acre/day)		8.250	8.250	8.250	
HEAD ON LINER	Average Annual (in)	0.002	0.962	0.962	0.962	1.965
	Peak Daily (in)	0.002	5.086	5.086	5.086	6.694

(1) Drainage collected includes actual leachate pumped by the leachate pumps (i.e. the total of the collected and recirculated leachate).

ACTIVE CASE (10 FEET OF WASTE)

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



PRECIPITATION DATA FILE:    C:\MUSK\A10\DATA4.D4
TEMPERATURE DATA FILE:      C:\MUSK\A10\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MUSK\A10\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MUSK\A10\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MUSK\A10\DATA10.D10
OUTPUT DATA FILE:           C:\MUSK\A10\OUTPUT1.OUT



TIME:  13: 9     DATE:   2/28/2023


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

     TITLE:  MUSKOGEE LANDFILL - ACTIVE 10' WASTE

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

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


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  26
          THICKNESS                  =      6.00   INCHES
          POROSITY                   =      0.4450 VOL/VOL
          FIELD CAPACITY             =      0.3930 VOL/VOL
          WILTING POINT              =      0.2770 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.2770 VOL/VOL
```

```
EFFECTIVE SAT. HYD. COND.   =  0.190000003000E-05 CM/SEC


                        LAYER  2
                        --------

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


                        LAYER  3
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4370 VOL/VOL
FIELD CAPACITY              =      0.0620 VOL/VOL
WILTING POINT               =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0620 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    162.0    FEET


                        LAYER  4
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      0.50   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
```

```
FML PLACEMENT QUALITY       =  3 - GOOD


                         LAYER  5
                         --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #26 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF 25.% AND
          A SLOPE LENGTH OF  120. FEET.

SCS RUNOFF CURVE NUMBER             =     97.10
FRACTION OF AREA ALLOWING RUNOFF    =     70.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =      6.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      1.662  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      2.670  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.662  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     48.439  INCHES
TOTAL INITIAL WATER                 =     48.439  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


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

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          TULSA                 OKLAHOMA
```

```
STATION LATITUDE                        =  36.12 DEGREES
MAXIMUM LEAF AREA INDEX                 =   0.00
START OF GROWING SEASON (JULIAN DATE)   =     85
END OF GROWING SEASON (JULIAN DATE)     =    311
EVAPORATIVE ZONE DEPTH                  =   6.0  INCHES
AVERAGE ANNUAL WIND SPEED               =  10.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  66.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  68.00 %
```

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.94	2.36	3.09	4.88	5.25	5.00
3.32	3.14	4.31	4.07	3.23	2.56

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	41.90	51.20	59.90	69.00	77.50
82.30	81.20	73.20	61.50	49.80	40.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA
AND STATION LATITUDE = 36.12 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 30 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						

```
  TOTALS                 1.50     1.02     3.02     6.57     5.05     6.95
                         1.63     3.07     7.29     6.89    10.39     1.80

  STD. DEVIATIONS        0.00     0.00     0.00     0.00     0.00     0.00
                         0.00     0.00     0.00     0.00     0.00     0.00

RUNOFF
------
  TOTALS                 0.521    0.242    1.852    3.979    3.391    5.261
                         0.904    1.954    4.880    5.453    8.383    1.222

  STD. DEVIATIONS        0.000    0.000    0.000    0.000    0.000    0.000
                         0.000    0.000    0.000    0.000    0.000    0.000

EVAPOTRANSPIRATION
------------------
  TOTALS                 0.608    1.091    1.047    2.437    1.924    1.754
                         0.728    1.097    2.134    1.487    1.666    1.163

  STD. DEVIATIONS        0.000    0.000    0.000    0.000    0.000    0.000
                         0.000    0.000    0.000    0.000    0.000    0.000

LATERAL DRAINAGE COLLECTED FROM LAYER  3
----------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0001   0.0001   0.0001

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

PERCOLATION/LEAKAGE THROUGH LAYER  5
-------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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


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


DAILY AVERAGE HEAD ON TOP OF LAYER  4
-------------------------------------
  AVERAGES               0.0010   0.0012   0.0013   0.0015   0.0017   0.0018
                         0.0019   0.0021   0.0022   0.0023   0.0024   0.0025

  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
```

```
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS   30 THROUGH   30
-------------------------------------------------------------------------------
                                      INCHES            CU. FEET       PERCENT
                                 -------------------   -------------   ---------
 PRECIPITATION                    55.18    (   0.000)     200303.4     100.00

 RUNOFF                           38.041   (  0.0000)     138088.36     68.940

 EVAPOTRANSPIRATION               17.136   (  0.0000)      62204.68     31.055

 LATERAL DRAINAGE COLLECTED        0.00047 (  0.00000)         1.698    0.00085
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH       0.00000 (  0.00000)         0.012     0.00001
   LAYER  5

 AVERAGE HEAD ON TOP               0.002 (    0.000)
   OF LAYER  4

 CHANGE IN WATER STORAGE           0.002   (  0.0000)          8.61      0.004

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

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

                PEAK DAILY VALUES FOR YEARS   30 THROUGH   30
   ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------   -------------
      PRECIPITATION                              4.58         16625.400

      RUNOFF                                     4.012        14563.5879

      DRAINAGE COLLECTED FROM LAYER  3           0.00000          0.00653

      PERCOLATION/LEAKAGE THROUGH LAYER  5       0.000000         0.00004

      AVERAGE HEAD ON TOP OF LAYER  4            0.003

      MAXIMUM HEAD ON TOP OF LAYER  4            0.002

      LOCATION OF MAXIMUM HEAD IN LAYER  3
            (DISTANCE FROM DRAIN)               88.3 FEET

      SNOW WATER                                 0.83          3030.9639
```

```
      MAXIMUM VEG. SOIL WATER (VOL/VOL)                 0.3584

      MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.2770


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

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

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

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

                  FINAL WATER STORAGE AT END OF YEAR   30
    ---------------------------------------------------------------------
                   LAYER        (INCHES)       (VOL/VOL)
                   -----        --------       ---------
                     1            1.6620         0.2770

                     2           35.0399         0.2920

                     3            1.4911         0.0621

                     4            0.0000         0.0000

                     5           10.2480         0.4270

                 SNOW WATER       0.000

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

INTERIM CASE (50 FEET OF WASTE)

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

PRECIPITATION DATA FILE:    C:\MUSK\I50\DATA4.D4
TEMPERATURE DATA FILE:      C:\MUSK\I50\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MUSK\I50\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MUSK\I50\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MUSK\I50\DATA10.D10
OUTPUT DATA FILE:           C:\MUSK\I50\OUTPUT1.OUT

TIME:  12: 8     DATE:   1/ 4/2023

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

     TITLE:  MUSKOGEE LANDFILL - INTERIM 50

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

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


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  26
          THICKNESS                  =      6.00   INCHES
          POROSITY                   =      0.4450 VOL/VOL
          FIELD CAPACITY             =      0.3930 VOL/VOL
          WILTING POINT              =      0.2770 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.2770 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.190000003000E-05 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

```
                         LAYER  2
                         --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  18
  THICKNESS                   =    600.00   INCHES
  POROSITY                    =      0.6710 VOL/VOL
  FIELD CAPACITY              =      0.2920 VOL/VOL
  WILTING POINT               =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2920 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
NOTE:  100.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 3
         IS RECIRCULATED INTO THIS LAYER.


                         LAYER  3
                         --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   0
  THICKNESS                   =     24.00   INCHES
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.0622 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
  SLOPE                       =      2.00   PERCENT
  DRAINAGE LENGTH             =    162.0    FEET
NOTE:  100.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
         LAYER IS RECIRCULATED INTO LAYER #  2.


                         LAYER  4
                         --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
  THICKNESS                   =      0.06   INCHES
  POROSITY                    =      0.0000 VOL/VOL
  FIELD CAPACITY              =      0.0000 VOL/VOL
  WILTING POINT               =      0.0000 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
  FML PINHOLE DENSITY         =      0.50   HOLES/ACRE
```

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


                        LAYER  5
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #26 WITH A
          FAIR STAND OF GRASS, A SURFACE SLOPE OF 25.%
          AND A SLOPE LENGTH OF  120. FEET.

SCS RUNOFF CURVE NUMBER             =     91.20
FRACTION OF AREA ALLOWING RUNOFF    =     85.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =      6.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      1.662  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      2.670  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.662  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    188.603  INCHES
TOTAL INITIAL WATER                 =    188.603  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


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

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          TULSA                 OKLAHOMA
```

```
STATION LATITUDE                        =  36.12 DEGREES
MAXIMUM LEAF AREA INDEX                 =   2.00
START OF GROWING SEASON (JULIAN DATE)   =     85
END OF GROWING SEASON (JULIAN DATE)     =    311
EVAPORATIVE ZONE DEPTH                  =   6.0  INCHES
AVERAGE ANNUAL WIND SPEED               =  10.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  66.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  68.00 %
```

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.94	2.36	3.09	4.88	5.25	5.00
3.32	3.14	4.31	4.07	3.23	2.56

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	41.90	51.20	59.90	69.00	77.50
82.30	81.20	73.20	61.50	49.80	40.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA
AND STATION LATITUDE = 36.12 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 17 THROUGH 26

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						

```
-------------
  TOTALS                 2.04     2.63     3.77     5.42     6.61     5.15
                         3.00     3.29     2.68     4.41     1.82     1.63

  STD. DEVIATIONS        0.82     2.07     2.13     2.57     3.31     2.57
                         1.46     2.15     1.47     3.65     1.13     0.99

RUNOFF
------
  TOTALS                 0.821    1.235    2.069    3.070    3.838    3.041
                         1.472    1.547    1.330    3.053    0.851    0.768

  STD. DEVIATIONS        0.525    1.311    1.285    1.742    2.378    1.778
                         0.887    1.351    0.990    2.973    0.696    0.778

EVAPOTRANSPIRATION
------------------
  TOTALS                 0.965    1.411    1.795    2.351    2.698    2.145
                         1.573    1.624    1.372    1.392    0.898    0.886

  STD. DEVIATIONS        0.396    0.757    0.763    0.821    1.039    0.993
                         0.535    1.034    0.494    0.640    0.406    0.391

LATERAL DRAINAGE RECIRCULATED INTO LAYER  2
-------------------------------------------
  TOTALS                 0.0156   0.0149   0.0192   0.0203   0.0217   0.0213
                         0.0222   0.0223   0.0217   0.0225   0.0218   0.0225

  STD. DEVIATIONS        0.0234   0.0214   0.0254   0.0262   0.0278   0.0272
                         0.0283   0.0283   0.0274   0.0283   0.0274   0.0283

LATERAL DRAINAGE COLLECTED FROM LAYER  3
----------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

LATERAL DRAINAGE RECIRCULATED FROM LAYER  3
-------------------------------------------
  TOTALS                 0.0156   0.0149   0.0192   0.0203   0.0217   0.0213
                         0.0222   0.0223   0.0217   0.0225   0.0218   0.0225

  STD. DEVIATIONS        0.0234   0.0214   0.0254   0.0262   0.0278   0.0272
                         0.0283   0.0283   0.0274   0.0283   0.0274   0.0283

PERCOLATION/LEAKAGE THROUGH LAYER  5
--------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
```

```
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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


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


  DAILY AVERAGE HEAD ON TOP OF LAYER  4
  -------------------------------------
   AVERAGES               0.7202   0.7534   0.8869   0.9685   1.0012   1.0168
                          1.0249   1.0297   1.0329   1.0354   1.0372   1.0386

   STD. DEVIATIONS        1.0767   1.0804   1.1694   1.2482   1.2830   1.2971
                          1.3028   1.3052   1.3063   1.3069   1.3068   1.3064

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

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

    AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS   17 THROUGH   26
-------------------------------------------------------------------------------
                                      INCHES            CU. FEET       PERCENT
                                 -------------------   -------------   ---------
 PRECIPITATION                    42.46    (   8.916)     154126.2     100.00

 RUNOFF                           23.097   (  6.6218)      83840.30     54.397

 EVAPOTRANSPIRATION               19.109   (  3.0783)      69366.81     45.007

 DRAINAGE RECIRCULATED             0.24614 (  0.31576)       893.475    0.57970
   INTO LAYER  2

 LATERAL DRAINAGE COLLECTED        0.00000 (  0.00000)         0.000    0.00000
   FROM LAYER  3

 DRAINAGE RECIRCULATED             0.24614 (  0.31576)       893.475    0.57970
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH       0.00029 (  0.00036)         1.038     0.00067
   LAYER  5

 AVERAGE HEAD ON TOP               0.962 (    1.235)
   OF LAYER  4

 CHANGE IN WATER STORAGE           0.253   (  0.2753)        917.20      0.595
```

****

****

PEAK DAILY VALUES FOR YEARS 17 THROUGH 26

	(INCHES)	(CU. FT.)
PRECIPITATION	5.50	19965.000
RUNOFF	4.887	17738.2227
DRAINAGE RECIRCULATED INTO LAYER 2	0.00227	8.25029
DRAINAGE COLLECTED FROM LAYER 3	0.00000	0.00000
DRAINAGE RECIRCULATED FROM LAYER 3	0.00227	8.25029
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000003	0.00926
AVERAGE HEAD ON TOP OF LAYER 4	3.249	
MAXIMUM HEAD ON TOP OF LAYER 4	5.086	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	35.1 FEET	
SNOW WATER	1.18	4284.5435

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4426
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.2770

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

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

****

****

FINAL WATER STORAGE AT END OF YEAR 26

LAYER	(INCHES)	(VOL/VOL)
1	2.0789	0.3465
2	175.1999	0.2920
3	3.6031	0.1501
4	0.0000	0.0000
5	10.2480	0.4270
SNOW WATER	0.000	

****
****

INTERIM CASE (100 FEET OF WASTE)

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



PRECIPITATION DATA FILE:    C:\MUSK\I100\DATA4.D4
TEMPERATURE DATA FILE:      C:\MUSK\I100\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MUSK\I100\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MUSK\I100\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MUSK\I100\DATA10.D10
OUTPUT DATA FILE:           C:\MUSK\I100\OUTPUT1.OUT



TIME:  12:13     DATE:   1/ 4/2023



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

     TITLE:  MUSKOGEE LANDFILL - INTERIM 100 FT WASTE

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



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



                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  26
          THICKNESS                   =      6.00   INCHES
```

```
  POROSITY                    =      0.4450 VOL/VOL
  FIELD CAPACITY              =      0.3930 VOL/VOL
  WILTING POINT               =      0.2770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2770 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.190000003000E-05 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  18
  THICKNESS                   =   1200.00   INCHES
  POROSITY                    =      0.6710 VOL/VOL
  FIELD CAPACITY              =      0.2920 VOL/VOL
  WILTING POINT               =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2920 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
NOTE:  100.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 3
         IS RECIRCULATED INTO THIS LAYER.


                          LAYER  3
                          --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   0
  THICKNESS                   =     24.00   INCHES
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.0622 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
  SLOPE                       =      2.00   PERCENT
  DRAINAGE LENGTH             =    162.0    FEET
NOTE:  100.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
         LAYER IS RECIRCULATED INTO LAYER #  2.


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

```
            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      0.50   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                         LAYER  5
                         --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #26 WITH A
          FAIR STAND OF GRASS, A SURFACE SLOPE OF 25.%
          AND A SLOPE LENGTH OF  120. FEET.

SCS RUNOFF CURVE NUMBER             =     91.20
FRACTION OF AREA ALLOWING RUNOFF    =     85.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =      6.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      1.662  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      2.670  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.662  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    363.803  INCHES
TOTAL INITIAL WATER                 =    363.803  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
TULSA OKLAHOMA

STATION LATITUDE	=	36.12 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	85
END OF GROWING SEASON (JULIAN DATE)	=	311
EVAPORATIVE ZONE DEPTH	=	6.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	10.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	68.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.94	2.36	3.09	4.88	5.25	5.00
3.32	3.14	4.31	4.07	3.23	2.56

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	41.90	51.20	59.90	69.00	77.50
82.30	81.20	73.20	61.50	49.80	40.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA
AND STATION LATITUDE = 36.12 DEGREES

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

         AVERAGE MONTHLY VALUES IN INCHES FOR YEARS   17 THROUGH   26
-------------------------------------------------------------------------------

                        JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                        -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                 2.04     2.63     3.77     5.42     6.61     5.15
                           3.00     3.29     2.68     4.41     1.82     1.63

    STD. DEVIATIONS        0.82     2.07     2.13     2.57     3.31     2.57
                           1.46     2.15     1.47     3.65     1.13     0.99

  RUNOFF
  ------
    TOTALS                 0.821    1.235    2.069    3.070    3.838    3.041
                           1.472    1.547    1.330    3.053    0.851    0.768

    STD. DEVIATIONS        0.525    1.311    1.285    1.742    2.378    1.778
                           0.887    1.351    0.990    2.973    0.696    0.778

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                 0.965    1.411    1.795    2.351    2.698    2.145
                           1.573    1.624    1.372    1.392    0.898    0.886

    STD. DEVIATIONS        0.396    0.757    0.763    0.821    1.039    0.993
                           0.535    1.034    0.494    0.640    0.406    0.391

  LATERAL DRAINAGE RECIRCULATED INTO LAYER  2
  -------------------------------------------
    TOTALS                 0.0156   0.0149   0.0192   0.0203   0.0217   0.0213
                           0.0222   0.0223   0.0217   0.0225   0.0218   0.0225

    STD. DEVIATIONS        0.0234   0.0214   0.0254   0.0262   0.0278   0.0272
                           0.0283   0.0283   0.0274   0.0283   0.0274   0.0283

  LATERAL DRAINAGE COLLECTED FROM LAYER  3
  -----------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
```

```
  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

 LATERAL DRAINAGE RECIRCULATED FROM LAYER  3
 -------------------------------------------
  TOTALS                 0.0156   0.0149   0.0192   0.0203   0.0217   0.0213
                         0.0222   0.0223   0.0217   0.0225   0.0218   0.0225

  STD. DEVIATIONS        0.0234   0.0214   0.0254   0.0262   0.0278   0.0272
                         0.0283   0.0283   0.0274   0.0283   0.0274   0.0283

 PERCOLATION/LEAKAGE THROUGH LAYER  5
 -------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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


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


 DAILY AVERAGE HEAD ON TOP OF LAYER  4
 -------------------------------------
  AVERAGES               0.7202   0.7534   0.8869   0.9685   1.0012   1.0168
                         1.0249   1.0297   1.0329   1.0354   1.0372   1.0386

  STD. DEVIATIONS        1.0767   1.0804   1.1694   1.2482   1.2830   1.2971
                         1.3028   1.3052   1.3063   1.3069   1.3068   1.3064

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



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

    AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS   17 THROUGH   26
-------------------------------------------------------------------------------
                                     INCHES            CU. FEET       PERCENT
                                 -------------------   -------------   ---------
 PRECIPITATION                    42.46    (   8.916)     154126.2     100.00

 RUNOFF                           23.097   (  6.6218)      83840.30     54.397

 EVAPOTRANSPIRATION               19.109   (  3.0783)      69366.81     45.007

 DRAINAGE RECIRCULATED             0.24613 (  0.31576)       893.469    0.57970
```

```
  INTO LAYER  2

LATERAL DRAINAGE COLLECTED      0.00000 (  0.00000)         0.000    0.00000
  FROM LAYER  3

DRAINAGE RECIRCULATED           0.24613 (  0.31576)       893.469    0.57970
  FROM LAYER  3

PERCOLATION/LEAKAGE THROUGH     0.00029 (  0.00036)         1.038     0.00067
  LAYER  5

AVERAGE HEAD ON TOP             0.962 (    1.235)
  OF LAYER  4

CHANGE IN WATER STORAGE         0.253   (  0.2753)        917.22      0.595

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


↑
*****************************************************************************

              PEAK DAILY VALUES FOR YEARS   17 THROUGH   26
  ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------   -------------
     PRECIPITATION                               5.50         19965.000

     RUNOFF                                      4.887        17738.2227

     DRAINAGE RECIRCULATED INTO LAYER  2         0.00227          8.25029

     DRAINAGE COLLECTED FROM LAYER  3            0.00000          0.00000

     DRAINAGE RECIRCULATED FROM LAYER  3         0.00227          8.25029

     PERCOLATION/LEAKAGE THROUGH LAYER  5        0.000003         0.00926

     AVERAGE HEAD ON TOP OF LAYER  4             3.249

     MAXIMUM HEAD ON TOP OF LAYER  4             5.086

     LOCATION OF MAXIMUM HEAD IN LAYER  3
           (DISTANCE FROM DRAIN)                35.1 FEET

     SNOW WATER                                  1.18          4284.5435


     MAXIMUM VEG. SOIL WATER (VOL/VOL)                   0.4426
```

```
      MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.2770


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

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

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

                  FINAL WATER STORAGE AT END OF YEAR   26
    ------------------------------------------------------------------
                   LAYER        (INCHES)       (VOL/VOL)
                   -----        --------       ---------
                     1            2.0789         0.3465

                     2          350.3999         0.2920

                     3            3.6031         0.1501

                     4            0.0000         0.0000

                     5           10.2480         0.4270

                  SNOW WATER       0.000

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

INTERIM CASE (150 FEET OF WASTE)

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



PRECIPITATION DATA FILE:    C:\MUSK\I150\DATA4.D4
TEMPERATURE DATA FILE:      C:\MUSK\I150\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MUSK\I150\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MUSK\I150\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MUSK\I150\DATA10.D10
OUTPUT DATA FILE:           C:\MUSK\I150\OUTPUT1.OUT



TIME:  12:16     DATE:   1/ 4/2023



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

     TITLE:  MUSKOGEE LANDFILL - INTERIM 150 FT WASTE

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



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



                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  26
          THICKNESS                   =      6.00   INCHES
```

```
  POROSITY                    =      0.4450 VOL/VOL
  FIELD CAPACITY              =      0.3930 VOL/VOL
  WILTING POINT               =      0.2770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2770 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.190000003000E-05 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  18
  THICKNESS                   =   1800.00   INCHES
  POROSITY                    =      0.6710 VOL/VOL
  FIELD CAPACITY              =      0.2920 VOL/VOL
  WILTING POINT               =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2920 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
NOTE:  100.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 3
         IS RECIRCULATED INTO THIS LAYER.


                          LAYER  3
                          --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   0
  THICKNESS                   =     24.00   INCHES
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.0622 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
  SLOPE                       =      2.00   PERCENT
  DRAINAGE LENGTH             =    162.0    FEET
NOTE:  100.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
         LAYER IS RECIRCULATED INTO LAYER #  2.


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

```
            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
   THICKNESS                   =      0.06   INCHES
   POROSITY                    =      0.0000 VOL/VOL
   FIELD CAPACITY              =      0.0000 VOL/VOL
   WILTING POINT               =      0.0000 VOL/VOL
   INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
   FML PINHOLE DENSITY         =      0.50   HOLES/ACRE
   FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
   FML PLACEMENT QUALITY       =  3 - GOOD


                          LAYER  5
                          --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
   THICKNESS                   =     24.00   INCHES
   POROSITY                    =      0.4270 VOL/VOL
   FIELD CAPACITY              =      0.4180 VOL/VOL
   WILTING POINT               =      0.3670 VOL/VOL
   INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #26 WITH A
          FAIR STAND OF GRASS, A SURFACE SLOPE OF 25.%
          AND A SLOPE LENGTH OF  120. FEET.

SCS RUNOFF CURVE NUMBER             =     91.20
FRACTION OF AREA ALLOWING RUNOFF    =     85.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =      6.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      1.662  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      2.670  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.662  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    539.003  INCHES
TOTAL INITIAL WATER                 =    539.003  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
TULSA OKLAHOMA

STATION LATITUDE	=	36.12 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	85
END OF GROWING SEASON (JULIAN DATE)	=	311
EVAPORATIVE ZONE DEPTH	=	6.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	10.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	68.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.94	2.36	3.09	4.88	5.25	5.00
3.32	3.14	4.31	4.07	3.23	2.56

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	41.90	51.20	59.90	69.00	77.50
82.30	81.20	73.20	61.50	49.80	40.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA
AND STATION LATITUDE = 36.12 DEGREES

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

         AVERAGE MONTHLY VALUES IN INCHES FOR YEARS   17 THROUGH   26
-------------------------------------------------------------------------------

                        JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                        -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                 2.04     2.63     3.77     5.42     6.61     5.15
                           3.00     3.29     2.68     4.41     1.82     1.63

    STD. DEVIATIONS        0.82     2.07     2.13     2.57     3.31     2.57
                           1.46     2.15     1.47     3.65     1.13     0.99

  RUNOFF
  ------
    TOTALS                 0.821    1.235    2.069    3.070    3.838    3.041
                           1.472    1.547    1.330    3.053    0.851    0.768

    STD. DEVIATIONS        0.525    1.311    1.285    1.742    2.378    1.778
                           0.887    1.351    0.990    2.973    0.696    0.778

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                 0.965    1.411    1.795    2.351    2.698    2.145
                           1.573    1.624    1.372    1.392    0.898    0.886

    STD. DEVIATIONS        0.396    0.757    0.763    0.821    1.039    0.993
                           0.535    1.034    0.494    0.640    0.406    0.391

  LATERAL DRAINAGE RECIRCULATED INTO LAYER  2
  -------------------------------------------
    TOTALS                 0.0156   0.0149   0.0192   0.0203   0.0217   0.0213
                           0.0222   0.0223   0.0217   0.0225   0.0218   0.0225

    STD. DEVIATIONS        0.0234   0.0214   0.0254   0.0262   0.0278   0.0272
                           0.0283   0.0283   0.0274   0.0283   0.0274   0.0283

  LATERAL DRAINAGE COLLECTED FROM LAYER  3
  -----------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
```

```
  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

 LATERAL DRAINAGE RECIRCULATED FROM LAYER  3
 -------------------------------------------
  TOTALS                 0.0156   0.0149   0.0192   0.0203   0.0217   0.0213
                         0.0222   0.0223   0.0217   0.0225   0.0218   0.0225

  STD. DEVIATIONS        0.0234   0.0214   0.0254   0.0262   0.0278   0.0272
                         0.0283   0.0283   0.0274   0.0283   0.0274   0.0283

 PERCOLATION/LEAKAGE THROUGH LAYER  5
 -------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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


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


 DAILY AVERAGE HEAD ON TOP OF LAYER  4
 -------------------------------------
  AVERAGES               0.7202   0.7534   0.8869   0.9685   1.0012   1.0168
                         1.0249   1.0297   1.0329   1.0354   1.0372   1.0386

  STD. DEVIATIONS        1.0767   1.0804   1.1694   1.2482   1.2830   1.2971
                         1.3028   1.3052   1.3063   1.3069   1.3068   1.3064

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



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

    AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS   17 THROUGH   26
-------------------------------------------------------------------------------
                                    INCHES            CU. FEET       PERCENT
                               -------------------   -------------   ---------
 PRECIPITATION                  42.46    (   8.916)     154126.2     100.00

 RUNOFF                         23.097   (  6.6218)      83840.30     54.397

 EVAPOTRANSPIRATION             19.109   (  3.0783)      69366.81     45.007

 DRAINAGE RECIRCULATED           0.24613 (  0.31576)       893.469    0.57970
```

```
  INTO LAYER  2

LATERAL DRAINAGE COLLECTED      0.00000 (  0.00000)         0.000    0.00000
  FROM LAYER  3

DRAINAGE RECIRCULATED           0.24613 (  0.31576)       893.469    0.57970
  FROM LAYER  3

PERCOLATION/LEAKAGE THROUGH     0.00029 (  0.00036)         1.038     0.00067
  LAYER  5

AVERAGE HEAD ON TOP             0.962 (    1.235)
  OF LAYER  4

CHANGE IN WATER STORAGE         0.253   (  0.2753)        917.18      0.595
```

****

****

```
              PEAK DAILY VALUES FOR YEARS   17 THROUGH   26
  ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------   -------------
     PRECIPITATION                               5.50         19965.000

     RUNOFF                                      4.887        17738.2227

     DRAINAGE RECIRCULATED INTO LAYER  2         0.00227          8.25029

     DRAINAGE COLLECTED FROM LAYER  3            0.00000          0.00000

     DRAINAGE RECIRCULATED FROM LAYER  3         0.00227          8.25029

     PERCOLATION/LEAKAGE THROUGH LAYER  5        0.000003         0.00926

     AVERAGE HEAD ON TOP OF LAYER  4             3.249

     MAXIMUM HEAD ON TOP OF LAYER  4             5.086

     LOCATION OF MAXIMUM HEAD IN LAYER  3
           (DISTANCE FROM DRAIN)                35.1 FEET

     SNOW WATER                                  1.18          4284.5435


     MAXIMUM VEG. SOIL WATER (VOL/VOL)                   0.4426
```

```
      MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.2770


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

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

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



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

                  FINAL WATER STORAGE AT END OF YEAR   26
    ------------------------------------------------------------------
                   LAYER        (INCHES)       (VOL/VOL)
                   -----        --------       ---------
                     1            2.0789         0.3465

                     2          525.6000         0.2920

                     3            3.6031         0.1501

                     4            0.0000         0.0000

                     5           10.2480         0.4270

                  SNOW WATER       0.000

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

CLOSED CASE (150 FEET OF WASTE)

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



PRECIPITATION DATA FILE:    C:\MUSK\CL\DATA4.D4
TEMPERATURE DATA FILE:      C:\MUSK\CL\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MUSK\CL\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MUSK\CL\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MUSK\CL\DATA10.D10
OUTPUT DATA FILE:           C:\MUSK\CL\OUTPUT1.OUT



TIME:  11:47     DATE:   3/ 7/2023



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

     TITLE:  MUSKOGEE LANDFILL - CLOSED 150 FT WASTE

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



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



                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  26
          THICKNESS                   =     12.00   INCHES
```

```
  POROSITY                    =      0.4450 VOL/VOL
  FIELD CAPACITY              =      0.3930 VOL/VOL
  WILTING POINT               =      0.2770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.3000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.190000003000E-05 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
        FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                        LAYER  2
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  25
  THICKNESS                   =     24.00   INCHES
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.3730 VOL/VOL
  WILTING POINT               =      0.2660 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.3730 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.359999990000E-05 CM/SEC


                        LAYER  3
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  26
  THICKNESS                   =     12.00   INCHES
  POROSITY                    =      0.4450 VOL/VOL
  FIELD CAPACITY              =      0.3930 VOL/VOL
  WILTING POINT               =      0.2770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.3930 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.190000003000E-05 CM/SEC


                        LAYER  4
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  18
  THICKNESS                   =   1800.00   INCHES
  POROSITY                    =      0.6710 VOL/VOL
  FIELD CAPACITY              =      0.2920 VOL/VOL
  WILTING POINT               =      0.0770 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =      0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC


                        LAYER  5
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4370 VOL/VOL
FIELD CAPACITY              =      0.0620 VOL/VOL
WILTING POINT               =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0665 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    162.0    FEET


                        LAYER  6
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      0.50   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  7
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
```

```
  INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

```
NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE #26 WITH A
         GOOD STAND OF GRASS, A SURFACE SLOPE OF 25.%
         AND A SLOPE LENGTH OF   12. FEET.

SCS RUNOFF CURVE NUMBER             =     89.50
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     12.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      3.600  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      5.340  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      3.324  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    553.913  INCHES
TOTAL INITIAL WATER                 =    553.913  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

```
NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         TULSA                 OKLAHOMA

    STATION LATITUDE                       =  36.12 DEGREES
    MAXIMUM LEAF AREA INDEX                =   3.50
    START OF GROWING SEASON (JULIAN DATE)  =     85
    END OF GROWING SEASON (JULIAN DATE)    =    311
    EVAPORATIVE ZONE DEPTH                 =  12.0  INCHES
    AVERAGE ANNUAL WIND SPEED              =  10.50 MPH
    AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  64.00 %
    AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  67.00 %
    AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  66.00 %
    AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  68.00 %

NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
```

COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.94	2.36	3.09	4.88	5.25	5.00
3.32	3.14	4.31	4.07	3.23	2.56

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	41.90	51.20	59.90	69.00	77.50
82.30	81.20	73.20	61.50	49.80	40.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA
AND STATION LATITUDE = 36.12 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.05	2.33	3.11	4.71	5.48	4.62
	2.60	2.65	4.10	4.32	2.97	2.13
STD. DEVIATIONS	1.19	1.53	2.00	2.45	2.85	2.75
	1.27	1.51	2.45	3.07	2.71	1.45
RUNOFF						
TOTALS	0.730	0.943	1.407	2.258	2.791	2.465

```
                          1.079    1.077    2.180    2.705    1.604    1.038

    STD. DEVIATIONS       0.705    0.980    1.236    1.571    2.217    1.906
                          0.787    0.956    1.772    2.512    2.038    0.958

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                1.069    1.416    1.879    2.628    2.810    2.272
                          1.501    1.547    1.806    1.337    1.058    0.893

    STD. DEVIATIONS       0.290    0.478    0.722    0.965    0.903    1.066
                          0.634    0.721    0.860    0.578    0.372    0.291

  LATERAL DRAINAGE COLLECTED FROM LAYER  5
  ----------------------------------------
    TOTALS                0.0346   0.0342   0.0418   0.0461   0.0507   0.0482
                          0.0477   0.0450   0.0412   0.0402   0.0367   0.0361

    STD. DEVIATIONS       0.0175   0.0166   0.0197   0.0212   0.0248   0.0239
                          0.0238   0.0225   0.0205   0.0200   0.0183   0.0177

  PERCOLATION/LEAKAGE THROUGH LAYER  7
  -------------------------------------
    TOTALS                0.0000   0.0000   0.0000   0.0001   0.0001   0.0001
                          0.0001   0.0001   0.0000   0.0000   0.0000   0.0000

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


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


  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES              1.5931   1.7311   1.9284   2.1964   2.3370   2.2949
                          2.1994   2.0758   1.9610   1.8527   1.7505   1.6654

    STD. DEVIATIONS       0.8051   0.8371   0.9079   1.0077   1.1447   1.1388
                          1.0969   1.0354   0.9780   0.9241   0.8730   0.8168

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


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

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   30
```

```
-------------------------------------------------------------------------------
                                     INCHES            CU. FEET       PERCENT
                                 -------------------   -------------   ---------
 PRECIPITATION                    41.05    (   7.375)     149028.5     100.00

 RUNOFF                           20.276   (  5.5350)      73602.29     49.388

 EVAPOTRANSPIRATION               20.218   (  2.6577)      73390.15     49.246

 LATERAL DRAINAGE COLLECTED        0.50244 (  0.22231)      1823.856    1.22383
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH       0.00058 (  0.00024)         2.109     0.00142
   LAYER  7

 AVERAGE HEAD ON TOP               1.965 (    0.868)
   OF LAYER  6

 CHANGE IN WATER STORAGE           0.058   (  0.8709)        210.06      0.141
*******************************************************************************



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

                PEAK DAILY VALUES FOR YEARS    1 THROUGH   30
   ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------   -------------
      PRECIPITATION                              5.50         19965.000

      RUNOFF                                     5.104        18529.0293

      DRAINAGE COLLECTED FROM LAYER  5           0.00314         11.40235

      PERCOLATION/LEAKAGE THROUGH LAYER  7       0.000003         0.01250

      AVERAGE HEAD ON TOP OF LAYER  6            4.490

      MAXIMUM HEAD ON TOP OF LAYER  6            6.694

      LOCATION OF MAXIMUM HEAD IN LAYER  5
            (DISTANCE FROM DRAIN)               41.2 FEET

      SNOW WATER                                 3.24         11773.0791


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.4433
```

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.2770

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

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

****

****

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	3.9590	0.3299
2	9.6503	0.4021
3	5.0197	0.4183
4	525.6000	0.2920
5	1.1723	0.0977
6	0.0000	0.0000
7	10.2480	0.4270
SNOW WATER	0.000	

****
****

APPENDIX L-3

LEACHATE COLLECTION PIPE DESIGN

Includes pages L-3-1 through L-3-29

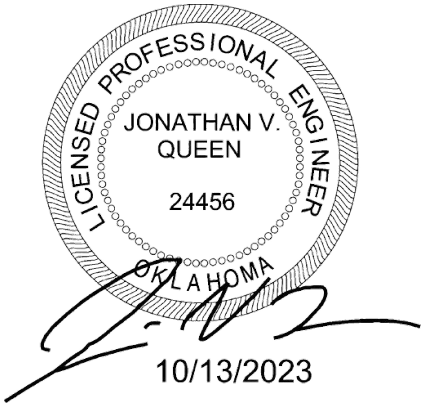
LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA

10/13/2023

CONTENTS

PIPE CAPACITY **L-3-1**

PIPE STRUCTURAL STABILITY **L-3-5**



REQUIRED: Size the leachate collection system pipe.

METHOD:

A. Use leachate production rates determined from the HELP model analysis to size the leachate collection pipes.

B. Determine required hole size (perforations) based on characteristics of the surrounding drainage media.

REFERENCES:

1. Bass, J., *Avoiding Failure of Leachate Collection and Cap Drainage Systems* , Pollution Technology Review No. 138, Noyles Data Corporation, 1986.

2. Texas Natural Resource Conservation Commission, *Leachate Collection System Handbook* , 30 TAC 330.201, 1993.

SOLUTION:

A. Estimate the average daily flow rate:

The following table summarizes the fill conditions that are likely to be present and have the greatest contribution of leachate into the LCS. The average flow rate (lateral drainage in the LCS layer) is shown for each condition. All flow rates are cubic feet per year per acre (cfy/ac) and gallons per day per acre (gpd/ac).

From the HELP models (Appendix L-2):

CONDITION	AVERAGE cfy/ac	AVERAGE gpd/ac
Active, 10' Waste	1.70	0
Interim, 50' Waste	893.48	18
Interim, 100' Waste	893.47	18
Interim, 150' Waste	893.47	18
Closed, 150' Waste	0.502	0

The largest area draining to one pipe is 7.3. acres (pipe located in Cell 19).

The maximum leachate production is predicted to occur assuming the following scenario:

Active, 10' Waste	1.0	ac
Interim, 50' Waste	1.6	ac
Interim, 100' Waste	2.0	ac
Interim, 150' Waste	1.7	ac
Closed, 150' Waste	1.0	ac

CONDITION	AREA ac	AVERAGE gpd/ac	AVERAGE gpd	AVERAGE cfs
Active, 10' Waste	1.0	0	0	0.00000
Interim, 50' Waste	1.6	18	29	0.00005
Interim, 100' Waste	2.0	18	37	0.00006
Interim, 150' Waste	1.7	18	31	0.00005
Closed, 150' Waste	1.0	0	0	0.00000
Total	7.3		97	0.00015

Apply Factor of Safety of 1.5:			
Total		146	0.00023

Determination of flow capacity (Q_{full}) for a 6 inch perforated pipe:

$$Q_{full} = \frac{1.486}{n} AR^{2/3}S^{1/2}$$

Where: A = Cross-sectional area of pipe, with d representing the inside diameter in feet
R = Hydraulic radius of pipe in feet under full flow conditions

From Pipe Structural Stability Calculations (presented latter in this appendix):

Standard dimension ratio (SDR) = 17

ID = 5.845 in
= 0.487 ft

$$A = \frac{\Pi \times d^2}{4}$$ A = 0.186 sq ft

$$R = \frac{d}{4}$$ R = 0.122 ft

S = Design slope of pipe S = 0.007 ft/ft

n = Manning's number n = 0.015

Q_{full} =	0.37943	cfs

Compare Q_{max} and Q_{full}:

Q_{full} =	0.37943	cfs	>>	Q_{max} =	0.00023	cfs

Conclusion:

An SDR 17 pipe with an outer diameter of 6 inches exceeds flow capacity requirements. Because the minimum recommended size of pipe for use is 6 inches, a perforated SDR 17 HDPE pipe will be used in the leachate collection trenches.

B. Perforation configuration

Pipe perforations must allow free passage of leachate and also prevent migration of drainage media into collection pipes. Therefore, size of perforations depends on media particle size. Two perforations alternatives are tested below:

For leachate collection pipes with slotted perforations:

$$\frac{D_{85} \text{ of Filter}}{\text{Slot Width}} > 2.0$$

Where: D_{85} = Particle size for which 85% of all particles are smaller than

Assume: Drainage media is an ASTM 448 size number 467 aggregate

D_{85} = 25 mm
= 0.984 in

Standard slot width: d = 0.125 in

Compare the sizes of D_{85} and slot width:

$$\frac{D_{85} \text{ of Filter}}{\text{Slot Width}} = 7.9 > 2.0 \quad \text{(acceptable)}$$

For leachate collection pipes with circular holes:

$$\frac{D_{85} \text{ of Filter}}{\text{Hole Diameter}} > 1.7$$

Where: D_{85} = Particle size for which 85% of all particles are smaller than

Assume: Drainage media is an ASTM 448 size number 467 aggregate

D_{85} = 25 mm
= 0.984 in

Standard hole diameter d = 0.5 in

Compare the sizes of D_{85} and hole diameter:

$$\frac{D_{85} \text{ of Filter}}{\text{Hole Diameter}} = 2.0 > 1.7 \quad \text{(acceptable)}$$

In Addition:

A minimum open area of 1 square inch per foot of drainage pipe is recommended by the U.S. Soil Conservation Service and the U.S. Bureau of Reclamation.

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PIPE STRUCTURAL STABILITY
6-INCH LEACHATE COLLECTION PIPE

REQUIRED: Analyze structural stability of the leachate collection system pipes.

A. 6-inch-diameter HDPE perforated leachate collection pipe

METHOD:

1. Determine the critical load under the following two conditions:

   a. Construction loading
   b. Overburden loading

2. Use the critical loading pressure to analyze pipe stability under the following three possible failure conditions:

   a. Wall crushing
   b. Wall buckling
   c. Ring deflection

REFERENCES:

1. Bass, J., *Avoiding Failure of Leachate Collection and Cap Drainage Systems* , Pollution Technology Review No. 138, Noyles Data Corporation, 1986.

2. Texas Natural Resource Conservation Commission, *Leachate Collection* System Handbook, 30 TAC 330.201, 1993.

3. Phillips 66 Driscopipe, *System Design* , 1991.

4. Landfill Design Series, *Leachate Gas Management Systems Design, Volume 5, Leachate Management and Storage* , Appendix A, 1993.

5. Caterpillar Tractor Company, *Caterpillar Performance Handbook,* Edition 27, October 1996.

6 Qian, Koerner, and Gray, Geotechnical Aspects of Landfill Design and Construction. Prentice-Hall, 2002.

SOLUTION: **A. Structural stability of 6-inch-diameter SDR 17 perforated leachate collection pipe:**

A.1.a. Maximum Construction Loading

Assume: CAT 637E Series II scraper with an even load distribution

Loaded weight =	190,500	lb	(From Ref. 5, Page 9-3)
Tire pressure =	80	psi	(From Ref. 5, Section 12)
Number of tires =	4		

For a circular tire imprint:

$$F = \frac{\text{Loaded Weight}}{\text{Number of Tires}}$$

Where: F = Force exerted by one tire (lb)

F = 47,625 lb

Determine area of contact for circular tire imprint:

$$r = (F/\pi p)^{1/2}$$

Where:
r = Radius of contact (in)
F = Force exerted by one tire (lb)
p = Tire pressure (psi)

r = 13.8 in

Use Boussinesq's solution to find the stress at a point below a uniformly loaded circular area:

$$y = p\,(1 - ((r/z)^2+1)^{-3/2})$$

Where:
y = Change in vertical stress (psi)
p = Tire pressure (psi)
r = Radius of contact (in)
z = Protective cover thickness (in)

z = 24 in

y = 27.8 psi

Assume only one wheel load on pipe and add 50% for impact loading:

$P_L = 1.5y$

Where: P_L = Maximum live load (psi)

P_L =	41.7	psi

$P_D = (zw)/1728$

Where: P_D = Maximum dead load (psi)
z = Protective cover thickness (in)
w = Unit weight of protective cover (pcf)

z =	24	in
w =	120	pcf

P_D =	1.67	psi

$P_T = P_L + P_D$

Where: P_T = Maximum construction load (psi)

P_T =	43.3	psi

A.1.b. Overburden loading (postclosure load)

For maximum fill load on pipe:

2	ft protective cover @	120	pcf =	240	psf
4	ft final & intermediate cover @	120	pcf =	480	psf
150	ft solid waste @	80.0	pcf =	12,000	psf
			S =	12,720	psf

P_T =	88.3	psi

Determine critical loading condition:

Construction loading:	P_T =	43.3	psi
Overburden loading:	P_T =	88.3	psi

Overburden loading is most critical to the structural stability of the pipe and will be used to determine the design pipe stress.

A.1.b.1. Determine Design Stress:

A.1.b.1.a. Adjust critical stress to account for loss of strength in the pipe due to perforations:

$$P_{DES1} = 12P_T / (12 - l_p)$$

Where:

l_p	= Cumulative length of perforations per foot of pipe	
P_T	= Critical pipe stress (psi)	
P_{DES1}	= Pipe stress adjusted for loss of strength (psi)	

6	holes / foot
0.5	in / hole

l_p =	3.0	in/ft

From determination of critical loading:

P_T =	88.3	psi

P_{DES1} =	117.8	psi

A.1.b.1.b. Adjust pipe stress determined above to account for effects of soil arching:

The design pipe stress is estimated by accounting for the soil structure interaction between the buried leachate collection pipe and its' backfill to obtain a realistic loading condition on the pipe.

A.1.b.1.b.1. For the burial conditions shown on Figure 1 (page L-3-27), the pipe may be classified as a positive projecting conduit.

A.1.b.1.b.2. Because the pipe is flexible and will deflect in the vertical plane as shown on Figure 2 (page L-3-28), the pipe will experience a reduction in loading due to soil arching. Soil arching is present when the soil column over the pipe settles and creates shear stresses in the surrounding soil. Those shear stresses will support the soil column, thereby reducing the load experienced by the pipe (see Figure 3, page L-3-28).

A.1.b.1.b.3. The load on the pipe will be estimated using Marston's Formula:

$$W_c = \gamma C_c B_c^{\ 2} \tag{1}$$

$$C_c = \frac{e^{\pm 2k\mu(H_e/B_c)} - 1}{\pm 2k\mu} + \left(\frac{H}{B_c} - \frac{H_e}{B_c}\right) e^{\pm 2k\mu(H_e/B_c)} \tag{2}$$

Where:
- W_c = Load per unit length of conduit (lb/ft)
- g = Unit weight of soil above conduit (pcf)
- B_c = Outer diameter of conduit (ft)
- H = Height of fill above conduit (ft)
- H_e = Height of plane of equal settlement above critical plane (ft)
- k = Lateral pressure ratio (earth pressure coefficient)
- m = tan f
- f = Angle of internal friction of pipe-zone backfill (PZB) (degrees)

$$H_e = \pm r_{sd}\, p\left(\frac{H}{B_c}\right) \tag{3}$$

Where:
- r_{sd} = Settlement ratio
- p = Ratio of the conduit projection above the compacted soil liner to its diameter

$$r_{sd} = \frac{\left(S_m + S_g\right) - \left(S_f + dc\right)}{S_m} \tag{4}$$

Where:
- S_m = Compression deformation of soil column adjacent to conduit
- S_g = Settlement of natural ground adjacent to conduit
- S_f = Settlement of conduit into foundation material
- dc = Vertical deflection of the conduit

It is assumed that for a leachate collection pipe S_g and S_f are equivalent. The equation settlement ratio, therefore, reduces to the following:

$$r_{sd} = \frac{S_m - dc}{S_m} \tag{5}$$

Since the PZB is much stiffer than the pipe, dc is larger than S_m implying that r_{sd} will be negative. Because r_{sd} is negative, the pipe is categorized as an incomplete ditch as specified by Marston. Note that in the above equations, where a "+" and a "-" signs are used together, the upper sign corresponds to a positive r_{sd} and a the lower sign to a negative r_{sd}.

A.1.b.1.b.4. Load analysis solution by trial and error

Step 1: Assume a value for the settlement ratio, r_{sd}.

r_{sd} = -0.33

Step 2: Calculate S_m based on the estimated vertical stress at the level of the pipe and the deformation modulus E of the PZB.

$$S_m = P_{DES1} D / E_s$$

Where:
P_{DES1} = Pipe stress adjusted for loss of strength (psi)
D = Outside Pipe diameter (in)
E_s = PZB soil modulus (psi)

P_{DES1} =	117.8	psi
D =	6.0	in
E_s =	3,000	psi
S_m =	0.236	in

Step 3: Calculate dc using Equation (5):

$$dc = S_m (1 - r_{sd})$$

dc =	0.313	in

Step 4: Use the Iowa Formula (provided below) to calculate W_c.

$$W_c = \frac{dc}{(DL)k}\left(\frac{EI}{r^3} + 0.061E'\right)$$

Where:
DL = Deflection lag factor
k = Bedding factor
E = Young's modulus for pipe material (psi)
I = Moment of inertia for pipe wall = $t^3/12$ (in^4/in)
r = Pipe radius (in)
E' = Modulus of soil reaction (psi)

DL =	1.5	(refer to page 306 of Ref. 6)
k =	0.1	(refer to page 307 of Ref. 6)
E =	32,000	psi (refer to Chart 25 on page L-3-29 using P_{DES1} above)
t =	0.390	in (SDR 17 Pipe)
I =	0.005	in^4/in
r =	2.61	in
E' =	3,000	psi
W_c =	360	lb/in

Step 5: Calculate C_c using Equation 1:

$$C_c = \frac{W_c}{\gamma B_c^{\,2}}$$

Composite unit weight for waste and soil:

2	ft protective cover @	120	pcf =	240	psf
	ft final & intermediate				
4	cover @	120	pcf =	480	psf
150	ft solid waste @	80.0	pcf =	12,000	psf
			Σ =	12,720	psf

γ = 81.5 pcf (weighted average based on above table)
B_c = 6.0 in

C_c = 212.1 (unitless)

Step 6: Solve for He/Bc using Equation 2 (page L-3-9) in an iterative manner:

H = 156 ft
H/B_c = 312.0

Assume: H_e/B_c = 1.49

$k\mu$ = 0.13
$e^{-2km(He/Bc)}-1$ = -0.32
-2km = -0.26
$(H/B_c - H_e/B_c)$ = 310.5
$e^{-2km(He/Bc)}$ = 0.68

Left-hand-side of equation (LHS) = 212
Right-hand-side of equation (RHS) = 212

Step 7: Substitute H_e/B_c into equation given below to determine if proper value for r_{sd} was used.

$$\left[\frac{1}{2k\mu} \pm \left(\frac{H}{B_c} - \frac{H_e}{B_c}\right) \pm \frac{r_{sd}\,p}{3}\right] \frac{e^{\pm 2k\mu\left(H_e/B_c\right)} - 1}{\pm 2k\mu} \pm \frac{1}{2}\left(\frac{H_e}{B_c}\right)^2$$
$$\pm \frac{r_{sd}\,p}{3}\left(\frac{H}{B_c} - \frac{H_e}{B_c}\right) e^{\pm 2k\mu\left(H_e/B_c\right)} - \frac{1}{2k\mu}\left(\frac{H_e}{B_c}\right) \mp \left(\frac{H}{B_c}\right)\left(\frac{H_e}{B_c}\right) = \pm r_{sd}\,p\left(\frac{H}{B_c}\right)$$

Because r_{sd} is negative for the incomplete ditch condition, the lower signs in the above equation are used.

p =	1
km =	0.13
H/B_c =	312.0
H_e/B_c =	1.4877805
r_{sd} =	-0.33
LHS =	102
RHS =	102

If LHS is not approximately equal to RHS, adjust value for r_{sd} in Step 1 and repeat solution procedure.

A.1.b.1.b.5. Once the solutions to the above equations are determined, the design pipe stress may be calculated and the deflection of the pipe determined.

P_{DES2} = W_c / D

Where: P_{DES2} = Load on pipe adjusted to account for effects of soil arching (psi)

W_c =	360	lb/in
D =	6.000	in

P_{DES2} =	60	psi

A summary table for the structural stability analyses presented below is provided on page L-3-15 for the 6-inch-diameter leachate collection pipe. A pipe will be selected from this table for use in the collection system based on the calculated factors of safety for each possible failure condition. An example calculation is provided below that outlines the procedures used to determine the factors of safety for all pipe SDR sizes shown in the summary table.

A.2. Example pipe structural stability calculations:

SDR	= Standard dimension ratio	=	17	
S_Y	= compressive yield strength	=	1,500	psi (Ref. 3, page 37)
RD_{all}	= allowable ring deflection	=	4.2	% (Ref. 3, page 38)

A.2.a. Wall crushing (Ref 3)

$S_A = P_{DES2} (SDR - 1) / 2$ FS $= S_Y / S_A$

Where:
- S_A = Actual compressive stress (psi)
- SDR = Standard dimension ratio
- P_{DES2} = Load pipe adjusted to account for effects of soil arching (psi)
- S_Y = Compressive yield strength (psi)
- FS = Factor of safety against wall crushing

P_{DES2} = 60 psi

S_A =	480.5	psi
FS =	3.1	

Compare calculated and suggested factor of safety:	3.1	> 1.0

A.2.b. Wall buckling (Ref 3)

$P_{cb} = 0.8 (E' (2.32E / SDR^3))^{1/2}$ FS $= P_{cb} / P_{DES2}$

Where:
- P_{cb} = Critical buckling pressure at top of pipe (psi)
- E' = Soil modulus (psi)
- E = Stress/time dependent tensile modulus for design loading conditions (psi)
- P_{DES2} = Load pipe adjusted to account for effects of soil arching (psi)
- FS = Factor of safety against wall buckling

E' = 3,000 psi

E = 20,000 psi (refer to Chart 25 on page L-3-29 using S_A above)

P_{DES2} = 60 psi

P_{cb} =	134.7	psi
FS =	2.2	

Compare calculated and suggested factor of safety:	2.2	> 1.0

A.2.c. Ring deflection (Ref 3)

$E_S = P_{DES2} / E'$

Where: E_S = Soil strain (%)
P_{DES2} = Load pipe adjusted to account for effects of soil arching (psi)
E' = Soil modulus (psi)

P_{DES2} =	60	psi
E' =	3,000	psi

E_S =	2.0	%

Ring deflection for buried HDPE pipe is conservatively the same (no more than) the vertical compression of the soil envelope around the pipe. Therefore, assumed actual ring deflection (RD_{act}) is equal to soil strain.

RD_{act} = 2.0 %

Allowable ring deflection, RD_{all} = 4.2 %

$RD_{act} < RD_{all}$, design is acceptable

Note: An additional factor of safety is inherent to the design of the leachate collection system due to the presence of a gravel envelope surrounding the leachate collection pipe. The gravel layer will transmit leachate in the event that the leachate collection pipe becomes plugged or crushed.

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PIPE STRUCTURAL STABILITY
6-INCH LEACHATE COLLECTION PIPE

Adjusted load to account for soil arching = 60 psi

	Wall Crushing			Wall Buckling				Ring Deflection			
SDR	S_Y	S_A	FS_{WC}	E^2	E'	P_{cb}	FS_{WB}	RD_{all}	E'	RD_{act}	FS_{RD}
32.5	1,500	946.0	1.6	12,000	3,000	39.5	0.7	8.1	3,000	2.0	4.0
26.0	1,500	750.8	2.0	14,000	3,000	59.6	1.0	6.5	3,000	2.0	3.2
21.0	1,500	600.6	2.5	17,000	3,000	90.4	1.5	5.2	3,000	2.0	2.6
19.0	1,500	540.5	2.8	18,000	3,000	108.1	1.8	4.7	3,000	2.0	2.3
17.0 [1]	1,500	480.5	3.1	20,000	3,000	134.7	2.2	4.2	3,000	2.0	2.1
15.5	1,500	435.4	3.4	21,000	3,000	158.5	2.6	3.9	3,000	2.0	1.9
13.5	1,500	375.7	4.0	22,500	3,000	201.6	3.4	3.4	3,000	2.0	1.7
11.0	1,500	300.3	5.0	25,500	3,000	292.1	4.9	2.7	3,000	2.0	1.3

denotes standard size

[1] Select 6-inch-diameter HDPE SDR 17 pipe for use in the leachate collection system based on the calculated factors of safety.

[2] Values for the modulus of elasticity were selected from the attached chart (page L-3-29), Reference 3, using the calculated stress in the pipe wall (S_A under the wall crushing heading in the above table) for a 50 year duration (maximum loading is the overburden load on the pipe).

REQUIRED: Analyze structural stability of the leachate collection system pipes.

B. 18-inch-diameter HDPE solid-wall sidewall riser

METHOD:

1. Determine the critical load under the following two conditions:

   a. Construction loading
   b. Overburden loading

2. Use the critical loading pressure to analyze pipe stability under the following three possible failure conditions:

   a. Wall crushing
   b. Wall buckling
   c. Ring deflection

REFERENCES:

1. Bass, J., *Avoiding Failure of Leachate Collection and Cap Drainage Systems* , Pollution Technology Review No. 138, Noyles Data Corporation, 1986.

2. Texas Natural Resource Conservation Commission, *Leachate Collection* System Handbook, 30 TAC 330.201, 1993.

3. Phillips 66 Driscopipe, *System Design* , 1991.

4. Landfill Design Series, *Leachate Gas Management Systems Design, Volume 5, Leachate Management and Storage* , Appendix A, 1993.

5. Caterpillar Tractor Company, *Caterpillar Performance Handbook,* Edition 27, October 1996.

6 Qian, Koerner, and Gray, Geotechnical Aspects of Landfill Design and Construction. Prentice-Hall, 2002.

SOLUTION: **B. Structural stability of 18-inch-diameter HDPE SDR 17 perforated leachate collection pipe:**

B.1.a. Maximum construction loading

Assume: CAT 637E Series II scraper with an even load distribution

Loaded weight =	190,500	lb	(From Ref. 5, Page 9-3)
Tire pressure =	80	psi	(From Ref. 5, Section 12)
Number of tires =	4		

For a circular tire imprint:

$$F = \frac{\text{Loaded Weight}}{\text{Number of Tires}}$$

Where: F = Force exerted by one tire (lb)

F =	47,625	lb

Determine area of contact for circular tire imprint:

$$r = (F/\pi p)^{1/2}$$

Where:
- r = Radius of contact (in)
- F = Force exerted by one tire (lb)
- p = Tire pressure (psi)

r =	13.8	in

Use Boussinesq's solution to find the stress at a point below a uniformly loaded circular area:

$$y = p\,(1 - ((r/z)^2+1)^{-3/2})$$

Where:
- y = Change in vertical stress (psi)
- p = Tire pressure (psi)
- r = Radius of contact (in)
- z = Gravel and protective cover thickness (in)

z = 24 in

y =	27.8	psi

Assume only one wheel load on pipe and add 50% for impact loading:

$P_L = 1.5y$

Where: P_L = Maximum live load (psi)

P_L =	41.7	psi

$P_D = (zw)/1728$

Where: P_D = Maximum dead load (psi)
z = Gravel and protective cover thickness (in)
w = Unit weight of gravel and protective cover (pcf)

z =	24	in
w =	120	pcf

P_D =	1.67	psi

$P_T = P_L + P_D$

Where: P_T = Maximum construction load (psi)

P_T =	43.3	psi

B.1.b. Overburden loading (postclosure load)

For maximum fill load on pipe:

2	ft gravel & protective cover	120	pcf =	240	psf
	ft final & intermediate cover				
4	@	120	pcf =	480	psf
150	ft solid waste @	80.0	pcf =	12,000	psf
			Σ =	12,720	psf

P_T =	88.3	psi

Determine critical loading condition:

Construction loading:	P_T =	43.3	psi
Overburden loading:	P_T =	88.3	psi

Overburden loading is most critical to the structural stability of the pipe and will be used to determine the design pipe stress.

B.1.b.1. Determine Design Stress:

B.1.b.1.a. Adjust critical stress to account for loss of strength in the pipe due to perforations:

$P_{DES1} = 12P_T / (12 - l_p)$

Where:

l_p	= Cumulative length of perforations per foot of pipe
P_T	= Critical pipe stress (psi)
P_{DES1}	= Pipe stress adjusted for loss of strength (psi)

6	holes / foot
0.5	in / hole

l_p =	3.0	in/ft

From determination of critical loading:

P_T =	88.3	psi

P_{DES1} =	117.8	psi

B.1.b.1.b. Adjust pipe stress determined above to account for effects of soil arching:

The design pipe stress is estimated by accounting for the soil structure interaction between the buried leachate collection pipe and its backfill to obtain a realistic loading condition on the pipe.

B.1.b.1.b.1. For the burial conditions shown on Figure 1 (page L-3-27), the pipe may be classified as a positive projecting conduit.

B.1.b.1.b.2. Because the pipe is flexible and will deflect in the vertical plane as shown on Figure 2 (page L-3-28), the pipe will experience a reduction in loading due to soil arching. Soil arching is present when the soil column over the pipe settles and creates shear stresses in the surrounding soil. Those shear stresses will support the soil column, thereby reducing the load experienced by the pipe (see Figure 3, page L-3-28).

B.1.b.1.b.3. The load on the pipe will be estimated using Marston's Formula:

$$W_c = \gamma C_c B_c^{\,2} \tag{1}$$

$$C_c = \frac{e^{\pm 2k\mu\left(H_e/B_c\right)} - 1}{\pm 2k\mu} + \left(\frac{H}{B_c} - \frac{H_e}{B_c}\right) e^{\pm 2k\mu\left(H_e/B_c\right)} \tag{2}$$

Where:

W_c	=	Load per unit length of conduit (lb/ft)
γ	=	Unit weight of soil above conduit (pcf)
B_c	=	Outer diameter of conduit (ft)
H	=	Height of fill above conduit (ft)
H_e	=	Height of plane of equal settlement above critical plane (ft)
k	=	Lateral pressure ratio (earth pressure coefficient)
μ	=	tan ϕ
ϕ	=	Angle of internal friction of pipe-zone backfill (PZB) (degrees)

$$H_e = \pm r_{sd}\, p\left(\frac{H}{B_c}\right) \tag{3}$$

Where:

r_{sd}	=	Settlement ratio
p	=	Ratio of the conduit projection above the compacted soil liner to its diameter

$$r_{sd} = \frac{\left(S_m + S_g\right) - \left(S_f + dc\right)}{S_m} \tag{4}$$

Where:

S_m	=	Compression deformation of soil column adjacent to conduit
S_g	=	Settlement of natural ground adjacent to conduit
S_f	=	Settlement of conduit into foundation material
dc	=	Vertical deflection of the conduit

It is assumed that for a leachate collection pipe S_g and S_f are equivalent. The equation settlement ratio, therefore, reduces to the following:

$$r_{sd} = \frac{S_m - dc}{S_m} \tag{5}$$

Since the PZB is much stiffer than the pipe, dc is larger than S_m implying that r_{sd} will be negative. Because r_{sd} is negative, the pipe is categorized as an incomplete ditch as specified by Marston. Note that in the above equations, where a "+" and a "-" signs are used together, the upper sign corresponds to a positive r_{sd} and a the lower sign to a negative r_{sd}.

B.1.b.1.b.4. Load analysis solution by trial and error

Step 1: Assume a value for the settlement ratio, r_{sd}.

r_{sd} = -0.27

Step 2: Calculate S_m based on the estimated vertical stress at the level of the pipe and the deformation modulus E of the PZB.

$S_m = P_{DES1} D / E_s$

Where:
P_{DES1} = Pipe stress adjusted for loss of strength (psi)
D = Outside Pipe diameter (in)
E_s = PZB soil modulus (psi)

P_{DES1} =	117.8	psi
D =	18	in
E_s =	3,000	psi
S_m =	0.707	in

Step 3: Calculate dc using Equation (5):

$dc = S_m (1 - r_{sd})$

dc =	0.894	in

Step 4: Use the Iowa Formula (provided below) to calculate W_c.

$$W_c = \frac{dc}{(DL)k}\left(\frac{EI}{r^3} + 0.061E'\right)$$

Where:
DL = Deflection lag factor
k = Bedding factor
E = Young's modulus for pipe material (psi)
I = Moment of inertia for pipe wall = $t^3/12$ (in^4/in)
r = Pipe radius (in)
E' = Modulus of soil reaction (psi)

DL =	1.5	(refer to page 306 of reference 6)
k =	0.1	(refer to page 307 of reference 6)
E =	32,000	psi (refer to Chart 25 on page L-3-29 using P_{DES1} above)
t =	1.059	in (SDR-17 Pipe)
I =	0.099	in^4/in
r =	7.9	
E' =	3,000	
W_c =	1,129	lb/in

Step 5: Calculate C_c using Equation 1:

$$C_c = \frac{W_c}{\gamma B_c^{\,2}}$$

Composite unit weight for waste and soil:

2	ft gravel & protective cover	120	pcf =	240	psf
4	ft final & intermediate cover	120	pcf =	480	psf
150	ft solid waste @	80.0	pcf =	12,000	psf
			Total =	12,720	psf

γ =	81.5	pcf (weighted average based on above table)
B_c =	18	in

C_c =	73.8	(unitless)

Step 6: Solve for He/Bc using Equation 2 (page L-3-20) in an iterative manner:

	H =	156	ft
	H/B_c =	104.0	
Assume:	H_e/B_c =	1.33	
	$k\mu$ =	0.13	(Ref 4)
	$e^{-2k\mu(He/Bc)}-1$ =	-0.29	
	$-2k\mu$ =	-0.26	
	$(H/B_c - H_e/B_c)$ =	102.7	
	$e^{-2k\mu(He/Bc)}$ =	0.71	

Left-hand-side of equation (LHS) =	74
Right-hand-side of equation (RHS) =	74

Step 7: Substitute H_e/B_c into equation given below to determine if proper valuefor r_{sd} was used.

$$\left[\frac{1}{2k\mu} \pm \left(\frac{H}{B_c} - \frac{H_e}{B_c}\right) \pm \frac{r_{sd}\,p}{3}\right] \frac{e^{\pm 2k\mu\left(H_e/B_c\right)} - 1}{\pm 2k\mu} \pm \frac{1}{2}\left(\frac{H_e}{B_c}\right)^2$$
$$\pm \frac{r_{sd}\,p}{3}\left(\frac{H}{B_c} - \frac{H_e}{B_c}\right) e^{\pm 2k\mu\left(H_e/B_c\right)} - \frac{1}{2k\mu}\left(\frac{H_e}{B_c}\right) \mp \left(\frac{H}{B_c}\right)\left(\frac{H_e}{B_c}\right) = \pm r_{sd}\,p\left(\frac{H}{B_c}\right)$$

Because r_{sd} is negative for the incomplete ditch condition, the lower signs in the above equation are used.

p =	1
kμ =	0.13
H/B_c =	104.0
H_e/B_c =	1.326579727
r_{sd} =	-0.27
LHS =	28
RHS =	28

If LHS is not approximately equal to RHS, adjust value for r_{sd} in Step 1 and repeat solution procedure.

B.1.b.1.b.i Once the solutions to the above equations are determined, the design pipe stress may be calculated and the deflection of the pipe determined.

P_{DES2} = W_c / D

Where: P_{DES2} = Load on pipe adjusted to account for effects of soil arching (psi)

W_c=	1129	lb/in
D =	18.0	in

P_{DES2} =	63	psi

A summary table for the structural stability analyses presented below is provided on page L-3-26 for the 18-inch-diameter leachate riser pipe.
A pipe will be selected from this table for use in the collection system based on the calculated factors of safety for each possible failure condition. An example calculation is provided below that outlines the procedures used to determine the factors of safety for all pipe SDR sizes shown in the summary table.

B.2. Example pipe structural stability calculations:

SDR	= Standard dimension ratio	=	17	
S_Y	= compressive yield strength	=	1,500	psi (Ref. 3, page 37)
RD_{all}	= allowable ring deflection	=	4.2	% (see Ref. 3, page 38)

B.2.a. Wall crushing (Ref 3)

$S_A = P_{DES2} (SDR - 1) / 2$ FS $= S_Y / S_A$

Where:
- S_A = Actual compressive stress (psi)
- SDR = Standard dimension ratio
- P_{DES2} = Load pipe adjusted to account for effects of soil arching (psi)
- S_Y = Compressive yield strength (psi)
- FS = Factor of safety against wall crushing

P_{DES2} = 63 psi

S_A =	501.8	psi
FS =	3.0	

Compare calculated and suggested	3.0	> 1.0

B.2.b. Wall buckling (Ref 3)

$P_{cb} = 0.8 (E' (2.32E / SDR^3))^{1/2}$ FS $= P_{cb} / P_{DES2}$

Where:
- P_{cb} = Critical buckling pressure at top of pipe (psi)
- E' = Soil modulus (psi)
- E = Stress/time dependent tensile modulus for design loading conditions (psi)
- P_{DES2} = Pipe stress adjusted to account for effects of soil arching (psi)
- FS = Factor of safety against wall buckling

E'=	3,000	psi
E=	19,000	psi (see Chart 25 on page L-3-29 using SA above)
P_{DES2} =	63	psi

P_{cb} =	131.2	psi
FS =	2.1	

Compare calculated and suggested factor of safety:	2.1	> 1.0

B.2.c. Ring deflection (Ref 3)

$E_S = P_{DES2} / E'$

Where: E_S = Soil strain (%)
P_{DES2} = Pipe stress adjusted to account for effects of soil arching (psi)
E' = Soil modulus (psi)

P_{DES2} =	63	psi
E' =	3,000	psi

E_S =	2.1	%

Ring deflection for buried HDPE pipe is conservatively the same (no more than) the vertical compression of the soil envelope around the pipe. Therefore, assumed actual ring deflection (RD_{act}) is equal to soil strain.

RD_{act} = 2.1 %

Allowable ring deflection, RD_{all} = 4.20 %

$RD_{act} < RD_{all}$, design is acceptable

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WESTERN LANDFILL UNIT
0086-364-11-18
PIPE STRUCTURAL STABILITY
18-INCH RISER PIPE

Adjusted load to account for soil arching = 63 psi

	Wall Crushing			Wall Buckling				Ring Deflection			
SDR	S_Y	S_A	FS_{WC}	E[2]	E'	P_{cb}	FS_{WB}	RD_{all}	E'	RD_{act}	FS_{RD}
32.5	1,500	987.9	1.5	13,000	3,000	41.1	0.7	8.1	3,000	2.1	3.9
26.0	1,500	784.0	1.9	13,750	3,000	59.0	0.9	6.5	3,000	2.1	3.1
21.0	1,500	627.2	2.4	16,000	3,000	87.7	1.4	5.2	3,000	2.1	2.5
19.0	1,500	564.5	2.7	18,000	3,000	108.1	1.7	4.7	3,000	2.1	2.2
17.0 [1]	1,500	501.8	3.0	19,000	3,000	131.2	2.1	4.2	3,000	2.1	2.0
15.5	1,500	454.7	3.3	20,000	3,000	154.7	2.5	3.9	3,000	2.1	1.9
13.5	1,500	392.3	3.8	22,500	3,000	201.6	3.2	3.4	3,000	2.1	1.6
11.0	1,500	313.6	4.8	24,000	3,000	283.4	4.5	2.7	3,000	2.1	1.3

denotes standard size

[1] Select 18-inch-diameter HDPE SDR 17.0 pipe for use in the leachate collection system based on the calculated factors of safety.

[2] Values for the modulus of elasticity were selected from the attached chart (page L-3-29), Reference 3, using the calculated stress in the pipe wall (S_A under the wall crushing heading in the above table) for a 50 year duration (maximum loading is the overburden load on the pipe).

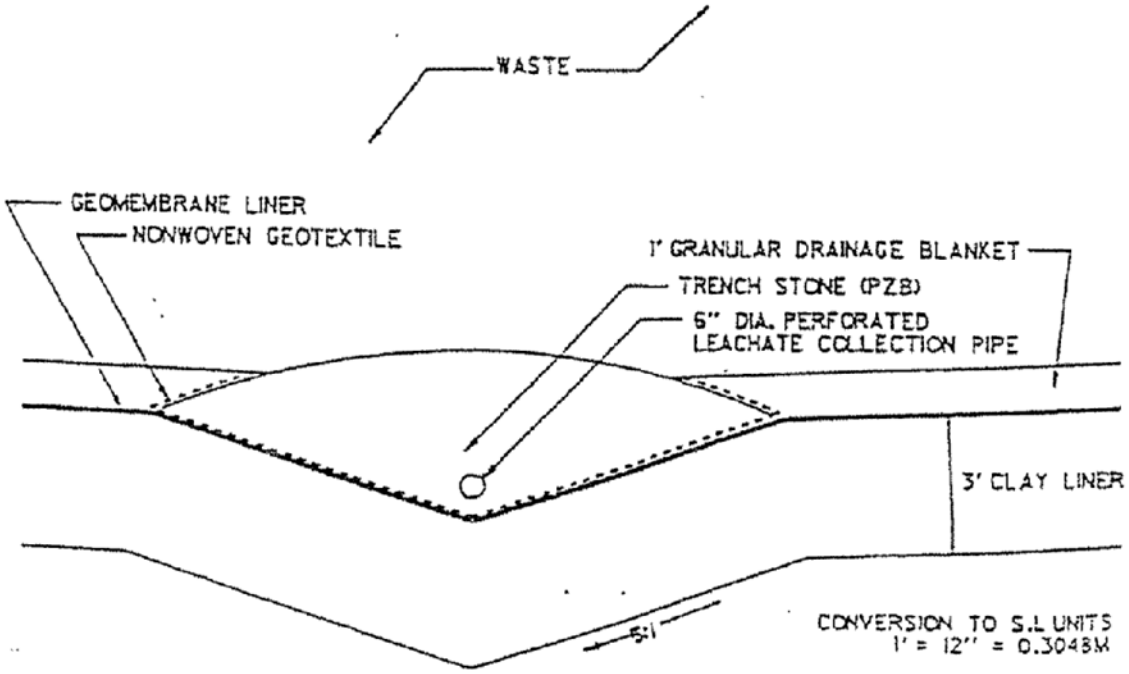


FIGURE 1: TYPICAL V-SHAPED TRENCH
FOR LANDFILLS WITH COMPOSITE LINERS

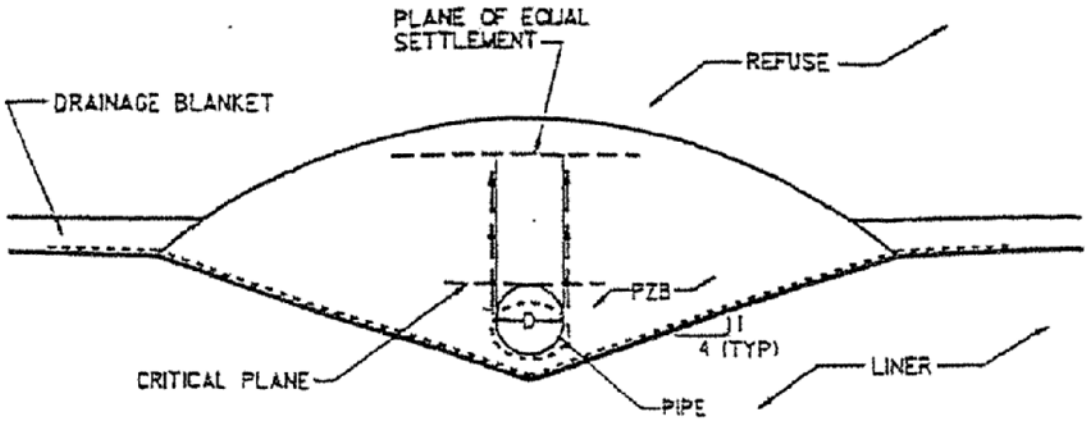


FIGURE 2: SETTLEMENT OF LEACHATE PIPE INDUCING SHEAR STRESSES IN PZB

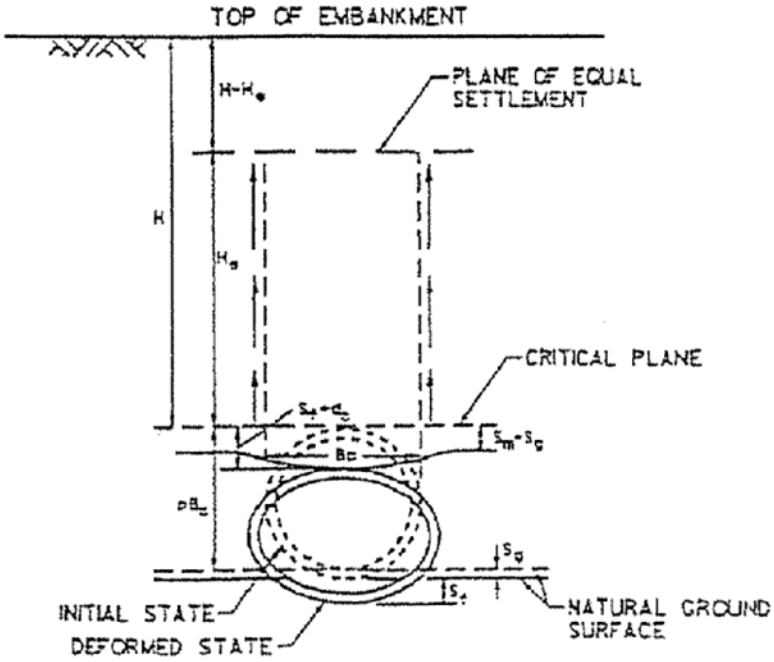
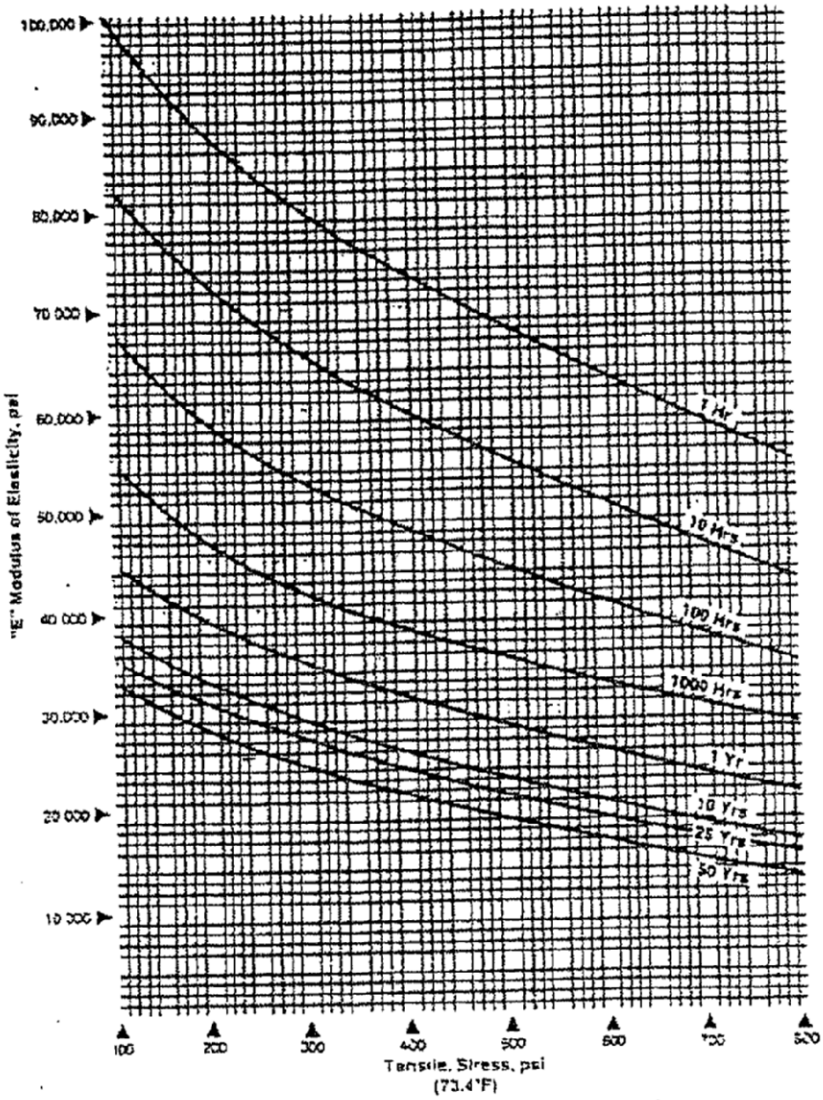


FIGURE 3: CASE OF AN INCOMPLETE DITCH CONDITION FOR A POSITIVE PROJECTING CONDUIT

/cl/users/jcw/proetrsn.com

Chart 25

Time Dependent Modulus of Elasticity for Polyethylene Pipe vs. Stress Intensity (73.4°F)



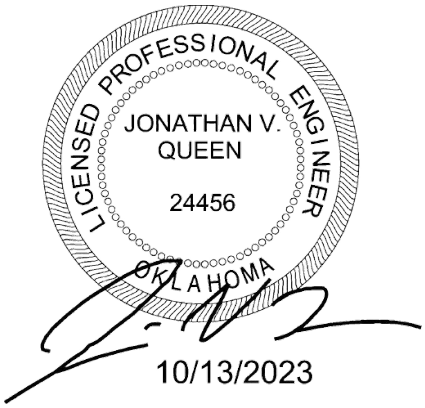
NOTE: The short term modulus of elasticity of Driscopipe per ASTM D 638 is approximately 100,000 psi. Due to the cold flow (creep) characteristic of the pipe material, this modulus is dependent upon the stress intensity and the time duration of the applied stress.

3. Phillips'66 Driscopipe, "System Design", 1991

APPENDIX L-4

LEACHATE SUMP DESIGN

Includes pages L-4-1 through L-4-4



REQUIRED: Evaluate the size of the leachate collection sumps and storage tanks.

METHOD:

A. Determine the flow rate into the sump using the leachate production rates from HELP model and the sump drainage area shown in Appendix L-1.
B. Determine the geometry of the sump and its storage capacity.
C. Assume pump size and determine the average pump cycle time.

REFERENCES:

1. Texas Natural Resource Conservation Commission, *Leachate Collection System Handbook* , 30 TAC 330.201, 1993.
2. Phillips 66 Driscopipe, *System Design* , 1991.
3. Heisler, Sanford I., P.E., Wiley Engineer's Desk Reference, John Wiley & Sons, Inc., New York, 1998.

SOLUTION: **A. Determine the flow rate into the sump using the leachate production rates from HELP model and the sump drainage area shown in Appendix L-1.**

The following table summarizes the fill conditions that are likely to be present and have the greatest contribution of leachate into the LCS and sump. The average flow rates (lateral drainage in the LCS layer) are shown for each condition. Flow rates are cubic feet per year per acre (cfy/ac) and gallons per day per acre (gpd/ac).

From the HELP model (Appendix L-2):

CONDITION	AVERAGE[1] cfy/ac	AVERAGE gpd/ac
Active, 10' Waste	1.70	0.0
Interim, 50' Waste	893.48	18.3
Interim, 100' Waste	893.47	18.3
Interim 150' Waste	893.47	18.3
Closed, 150' Waste	0.502	0.0

The largest area draining to one sump is 7.3 acres (sump receives leachate from the sidewall and Cell 19).

Condition	Rate	Active		Inactive		Closed	
	(gpd/ac)	area (ac)	rate (gpd)	area (ac)	rate (gpd)	area (ac)	rate (gpd)
Active, 10' Waste	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Interim, 50' Waste	18.3	1.6	29.3	0.0	0.0	0.0	0.0
Interim, 100' Waste	18.3	2.0	36.6	0.0	0.0	0.0	0.0
Interim 150' Waste	18.3	1.7	31.1	7.3	133.7	0.0	0.0
Closed, 150' Waste	0.0	1.0	0.0	0.0	0.0	7.3	0.1
Total Area		7.3	97.1	7.3	133.7	7.3	0.1
with 1.5 F.S.			145.6		200.5		0.1

B. Determine the geometry of the sump and its storage capacity.

Assumed porosity of drainage stone: P = 0.35

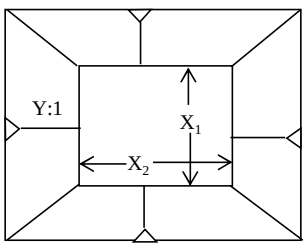
$V_{REQ} = V_C / P$

Condition	V_C (gpd)	V_C (cf/d)	V_{REQ} (cf/d)
Active	145.6	19.5	55.6
Inactive with Intermediate Cover	200.5	26.8	76.6
Closed	0.1	0.0	0.0

Total sump volume:

$$V_{TOT} = 1/3\left(A_1 + A_2 + \sqrt{(A_1 \cdot A_2)}\right)h$$ (Ref. 3, page 17)

Where:
A_1 = Area of bottom of sump
A_2 = Area of top of sump
h = Depth of sump



Y = Slope of sump side walls
$A_1 = X_1 * X_2$
$A_2 = (X_1 + 2(h*Y))*(X_2 + 2(h*Y))$

X_1 =	15	ft	A_1=	225	sf
X_2 =	15	ft	A_2=	729	sf
Y =	3				
h =	2	ft			

V_{TOT} =	906.0	cu ft

Compute the number of days storage provided for the following:

$$\text{STORAGE (Detention Time)} = \frac{V_{TOT}}{V_{REQ}}$$

Condition	V_{REQ} (cf/d)	V_{TOT} (cf)	Storage (d)
Active	55.6	906.0	16.3
Inactive with Intermediate Cover	76.6	906.0	11.8
Closed	0.0	906.0	21,055.8

C. Assume pump size and determine the average pump cycle time.

Submersible pump capacity = 10 gpm

Phase	Production (gpd)	Average Pump Time	
		(min/day)	(hr/day)
Active	146	15	0.2
Inactive with Intermediate Cover	200	20	0.3
Closed	0	0	0.0

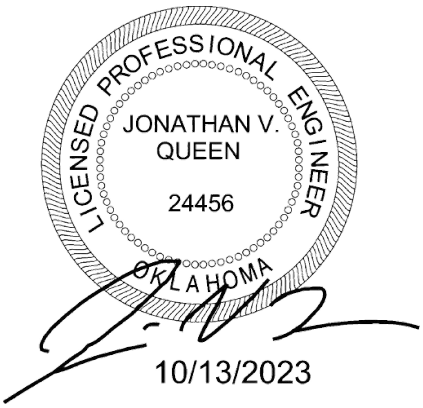
Production rate includes a factor of safety of 1.5.

Note: The size of the sump will be the same for all cells. The sump calculations are based on the largest cell size as well as the constructability of the sump. Should a different size of sump be used due to a smaller cell size, calculations should be revised.

APPENDIX L-5

GEOTEXTILE DESIGN

Includes pages L-5-1 through L-5-11



REQUIRED: Determine geotextile properties for the following:

A. Geotextile around granular drainage material.
B. Geotextile underlying as the top component of the drainage geocomposite.

METHOD: Design geotextiles and determine material property requirements.

REFERENCES:

1. Standard Speficitiaon for *Geotextile Specification for Highway Applications.* AASHTO Designation: M 288-06. FHWA NHI-07-092, Appendix D, September 2007.
2. Koerner, R.M., *Designing With Geosynthetics* , Fifth Edition, 2005.
3. AASHTO Designation: M288-06.
4. GRI White Paper #4, *Reduction Factors (RFs) Used in Geosynthetic Design*, Feb. 3, 2005, revised Mar. 1, 2007.

A. Geotextile Around Granular Drainage Material

SOLUTION:

The design calculations assume the leachate collection layer will consist of one of the following:

Hydraulic conductivity greater than or equal to $1x10^{-3}$ cm/s and percent fines (passing #200 sieve) less than 20 percent.

If the leachate collection layer material contains greater than 20 percent fines, these geotextile calculations will be revised.

Retention:

Based on Chart 1 - "Soil Retention Criteria" (shown on page L-5-8) the apparent opening size (O_{95}) may be determined.

O_{95} < 0.4755 mm For leachate collection layer materials

Permeability:

The required permeability is determined by comparing the permeability of the overlying waste material ($1.0x10^{-3}$ cm/s) and the leachate collection/ protective cover layer material (1.0x10-3 cm/s) with the permeability of the geotextile after the appropriate reduction factors are applied to the laboratory permeability of the geotextile.

Minimum Laboratory Permeability Specified (k_{ult}) = 0.2 cm/s

To determine the allowable permeability (k_{allow}) of the geotextile, the following reduction factors are used:

Table 2 - Reduction Factors[1]

RF_{SCB} = Reduction factor for soil clogging and blinding	2.0
RF_{CR} = Reduction factor for creep reduction of void space	2.0
RF_{IN} = Reduction factor for adjacent materials intruding into void spaces	1.2
RF_{CC} = Reduction factor for chemical clogging	1.5
RF_{BC} = Reduction factor for biological clogging	2.0
Overall Reduction Factor (ORF) =	14.4

[1] Reduction factors obtained from Ref. 4.

$$k_{allow} = k_{ult} / ORF = (0.2 \text{ cm/s}) / 14.4$$

$$\boxed{k_{allow} = 1.4E\text{-}02 \text{ cm/s}}$$

$k_{allow} >> k_{\text{leachate collection/protective cover}}$ (1.0×10^{-3} cm/s).

The predicted permeability of the geotextile is greater than the surrounding materials (i.e., waste and leachate collection/protective cover). The drainage stone geotextile will not impede the flow of leachate into the LCS pipe. Therefore, no head will develop on the leachate line geotextile.

Specification: Leachate line geotextile permeability shall be equal to or greater than 0.2 cm/s as determined by ASTM D 4491.

Clogging:

For geotextile filters where retention is important, use smallest O_{95} that meets the geotextile permeability requirement.

Survivability:

Based on Table 4, provided on page L-5-10, Class 2 geotextile was selected based on the subgrade condition and type of equipment that would be used to at the site. Assuming Class 2 geotextile, Table 1, "Geotextile Strength Property Requirements", provided on page L-5-11, was used to obtain the physical properites required.

Durability:

Chemical compatibility with leachate was considered during the selection process for the specific leachate.

Summary of required properties for geotextile (around granular drainage material):

Apparent opening size	<	0.4755	mm
Grab tensile strength	>	157	lb
Sewn seam strength	>	142	lb
Puncture strength	>	309	lb
Tear strenght	>	56	lb
Permeability	>=	0.20	cm/s

B. Geotextile Used as Top Component of Drainage Geocomposite.

The design calculations assume the leachate collection layer soil will consist of soils with a hydraulic conductivity greater than $1.0x10^{-3}$ cm/s and percent fines (passing #200 sieve) less than 20 percent.

If the leachate collection layer material contains greater than 20 percent fines, these geotextile calculations will be revised and included in the LIT for a specific cell to demonstrate adequacy of the material used.

Retention:

Based on Chart 1 - "Soil Retention Criteria," given on page L-5-8, the apparent opening size (O_{95}) may be determined.

O_{95} < 0.4755 mm

Permeability:

The required permeability is determined by comparing the permeability of the leachate collection layer ($1.0x10^{-3}$cm/s) with the permeability of the geotextile after the appropriate reduction factors are applied to the laboratory permeability of the geotextile.

Minimum Laboratory Permeability Specified (k_{ult}) = 0.2 cm/s

To determine the allowable permeability (k_{allow}) of the geotextile, the following reduction factors are used:

Table 2 - Reduction Factors[1]

RF_{SCB} = Reduction factor for soil clogging and blinding	2.0
RF_{CR} = Reduction factor for creep reduction of void space	2.0
RF_{IN} = Reduction factor for adjacent materials intruding into void spaces	1.2
RF_{CC} = Reduction factor for chemical clogging	1.5
RF_{BC} = Reduction factor for biological clogging	2.0
Overall Reduction Factor (ORF) =	14.4

[1] Reduction factors obtained from Ref. 4.

$k_{allow} = k_{ult} / ORF = (0.2 \text{ cm/s}) / 14.4$

k_{allow} = 1.4E-02 cm/s

$k_{allow} >> k_{leachate\ collection\ layer}$ (1.0×10^{-3} cm/s).

Specification: Geotextile component of geocomposite permeability shall be equal to or greater than 0.2 cm/s as determined by ASTM D 4491.

Survivability:

Based on Table 2, "Survivability Strength Requirements," provided on page L-5-9, geotextile properties should be selected considering high contact stresses (i.e., heavy confining stress).

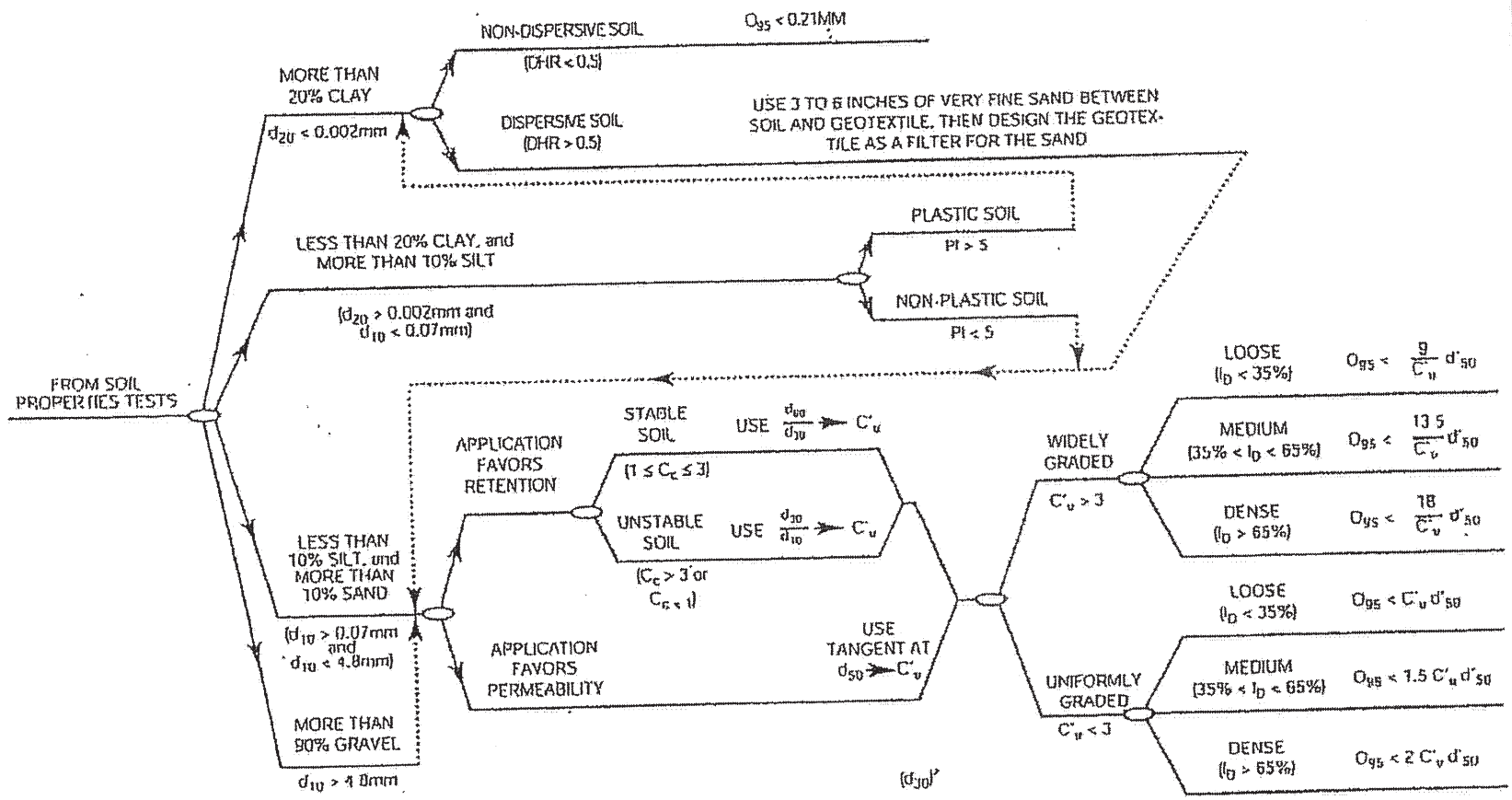
Durability:

Chemical compatibility with leachate will be considered during the selection process for the specific geotextile.

Summary of required properties for geotextile component of drainage geocomposite:

Apparent opening size	<	0.4755	mm
Grab tensile strength	>	157	lbs
Elongation	>=	50	%
Puncture strength	>	56	lbs
Trapezoid tear	>	56	lbs
Permeability	>=	0.2	cm/s

Chart 1. Soil Retention Criteria of Steady-State Flow Conditions



NOTES:

d_x = particle diameter of which size x percent is smaller

$C'_u = \sqrt{\frac{d'_{90}}{d'_{10}}}$ where: d'_{90} and d'_{10} are the extremeties of a straight line drawn through the particle-size distribution, as directed above and d'_{50} is the midpoint of this line

$C_c = \frac{(d_{30})^2}{d_{60} \times d_{10}}$

I_D = relative density of the soil
PI = plasticity index of the soil
DHR = double-hydrometer ratio of the soil
O_{95} = geotextile opening size

Table 2. Survivability Strength Requirements (after AASHTO, 1996)

		GRAB STRENGTH (LBS)	ELONGATION (%)	SEWN SEAM STRENGTH (LBS)	PUNCTURE STRENTH (LBS)	BURST STRENTH (LBS)	TRAPEZOID TEAR (LBS)
SUBSURFACE DRAINAGE	HIGH CONTACT STRESSES	247	< 50% *	222	90	392	56
	(ANGULAR DRAINAGE MEDIA) (HEAVY COMPACTION) or (HEAVY CONFINING STRESSES)	✳ 157	≥ 50%	142	✳ 56	189	✳ 56
	LOW CONTACT STRESSES	180	< 50% *	162	67	305	56
	(ROUNDED DRAINAGE MEDIA) (LIGHT COMPACTION) or (LIGHT CONFINING STRESSES)	112	≥ 50%	101	40	138	40
ARMORED EROSION CONTROL	HIGH CONTACT STRESSES	247	< 50% *	222	90	392	56
	(DIRECT STONE PLACEMENT) (DROP HEIGHT > 3 FT)	202	≥ 50%	182	79	247	79
	LOW CONTACT STRESSES	247	< 50% *	222	90	292	56
	(SAND OR GEOTEXTILE CUSHION) and (DROP HEIGHT < 3 FT)	157	≥ 50%	142	56	189	56

* Only woven monofilament geotextiles are acceptable as < 50% elongation filtration geotextiles. No woven slit film geotextiles are permitted.

Table 4 – Required Degree of Survivability as a Function of Subgrade Conditions, Construction Equipment, and Lift Thickness (Class 1, 2, and 3 properties are given in Table 1; Class 1 + properties are higher than Class 1, but not defined at this time and if used must be specified by the purchaser)[a]

	Low-ground pressure equipment ≤ 25 kPa (3.6 psi)	Medium ground-pressure equipment > 25 to ≤ 50 kPa (>3.6 to ≤ 7.3 psi)	High ground-pressure equipment > 50 kPa (> 7.3 psi)
Subgrade has been cleared of all obstacles except grass, weeds, leaves, and fine wood debris. Surface is smooth and level so that any shallow depressions and humps do not exceed 450 mm (18 in.) in depth or height. All larger depressions are filled. Alternatively, a smooth working table may be placed.	Low (Class 3)	Moderate (Class 2)	High (Class 1)
Subgrade has been cleared of obstacles larger than small to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 450 mm (18 in.) in depth or height. Larger depressions should be filled.	Moderate (Class 2)	High (Class 1)	Very high (Class 1+)
Minimal site preparation is required. Trees may be felled, delimbed, and left in place. Stumps should be cut to project not more than ± 150 mm (± 6 in.) above subgrade. Geotextile may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders. Items should be removed only I f placing the geotextile and cover material over them will distort the finished road surface.	High (Class 1)	Very high (Class 1+)	Not recommended

[a] Recommendations are for 150 to 300 mm (6 to 12 in.) initial lift thickness. For other initial lift thicknesses:

300 to 450 (12 to 18 in.): reduce survivability requirement by one level;
450 to 600 mm (18 to 24 in.): reduce survivability requirement two levels;
> 600 mm ((24 in.): reduce survivability requirement three levels

For special construction techniques such as prerutting, increase the geotextile survivability requirement one level. Placement of excessive initial cover material thickness may cause bearing failure of the soft subgrade.

Stabilization Requirements:

8.3.5 *Description* – This specification is applicable to the use of a geotextile in wet, saturated conditions to provide the coincident functions of separation and filtration. In some installations, the geotextile can also provide the function of reinforcement. Stabilization is applicable to pavement structures constructed over soils with a California Bearing Ratio between one and three (1<CBR<3) (shear strength between approximately 30 kPa and 90 kPa).

Table 1 – Geotextile Strength Property Requirements

			Geotextile Class[a,b]					
			Class 1		Class 2		Class 3	
	Test Methods	Units	Elongation < 50%[c]	Elongation ≥ 50%[c]	Elongation < 50%[c]	Elongation ≥ 50%[c]	Elongation < 50%[c]	Elongation ≥ 50%[c]
Grab strength	ASTM D 4632	N	1400	900	1100	700	800	500
Sewn seam strength[d]	ASTM D 4632	N	1260	810	990	630	720	450
Tear strength	ASTM D 4533	N	500	350	400[e]	250	300	180
Puncture strength	ASTM D 6241	N	2750	1925	2200	1375	1650	990
Permittivity	ASTM D 4491	sec^{-1}	Minimum property values for permittivity, AOS, and UV stability are based on geotextile application. Refer to Table 2 subsurface drainage, Table 3 and Table 4 for separation, Table 5 for stabilization, and Table 6 for permanent erosion control.					
Apparent opening size	ASTM D 4751	mm						
Ultraviolet stability (retained strength)	ASTM D 4355	%						

[a] Required geotextile class is designated in Tables 2, 3, 4, 5, or 6 for the indicated application. The severity of installation conditions for the application generally dictate the required geotextile class. Class 1 is specified for more severe or harsh installation conditions where there is a greater potential for geotextile damage, and Classes 2 and 3 are specified for less severe conditions.

[b] All numeric values represent MARV in the weaker principal direction. (See Section 8.1.2)

[c] As measured in accordance with ASTM D 4632.

[d] When sewn seams are required. Refer to Appendix for overlap seam requirements.

[e] The required MARV tear strength for woven monofilament geotextiles is 250 N.

8.2 *Subsurface Drainage Requirements:*

8.2.1 *Description* – This specification is applicable to placing a geotextile against a soil to allow for long-term passage of water into a subsurface drain system retaining the *in situ* soil. The primary function of the geotextile in subsurface drainage applications is filtration. Geotextile filtration properties are a function of the *in situ* soil gradation, plasticity, and hydraulic conditions.

APPENDIX L-6

ODEQ LEACHATE RECIRCULATION GUIDANCE

DEQ Guidance on Leachate Recirculation

Regulatory Reference: OAC 252:515-13-53

Applicability. MSWLFs where leachate is intended to be recirculated.

Purpose. To identify the minimum requirements for plans to recirculate landfill leachate over areas with a composite liner and leachate collection system.

Technical Discussion. As a minimum, a leachate recirculation plans must include the following components.

Location where leachate will be recirculated
Leachate may be recirculated only over areas of the landfill with a composite liner and leachate collection system. If recirculation will take place near the interface between a composite-lined cell and a clay-lined cell, a barrier must be constructed at the interface to prevent leachate from filtering into the clay-lined area.

The plan must include a map of the landfill showing locations where recirculation is proposed and design criteria for the interface, if one is required.

Leachate collection system design
The plan must include supporting assumptions, drawings, and calculations to demonstrate the leachate collection system will be able to handle the additional volume of liquid and still maintain no more than one-foot of head above the liner.[1]

In developing recirculation plans, DEQ believes the following, at a minimum, should be thoroughly considered and discussed:

- specific design of the drainage layer;[2]
- the potential for plugging of the drainage layer;
- the potential for chemical reaction of the leachate with the drainage layer material;
- long-term permeability of the drainage layer; and
- a method to verify excessive head is not collecting above the liner.

Routine testing program
The recirculation plan must include a routine testing program to monitor changes to leachate composition. A testing program must be established prior to beginning recirculation and submitted as part of the recirculation plan. As a minimum, leachate must be tested for the constituents identified in OAC 252:515-9-31(d)(1)(A) and (B). The plan must also include a sampling protocol that addresses the method and number of samples necessary to ensure a representative sample of the leachate volume is collected.

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[1] Considerations may include HELP model output, pipe slopes and diameter, drainage layer permeability, etc.
[2] For instance, some materials, such as geotextile, may be incompatible with recirculation due to plugging problems.

Sampling must initially be performed quarterly and sample results submitted to the DEQ. After four quarterly samples have been collected, the DEQ may consider requests to reduce sampling frequency.

Standards for leachate recirculation

Application rates must take into consideration the hydraulic conductivity of the waste and any cover present, waste compaction, surface grade, time of year, and weather conditions. Using these considerations, the recirculation plan must include a comprehensive discussion of how the following will be met.

- During leachate application, exposure to landfill employees and customers must be minimized.
- Leachate must be prevented from discharging from the landfill.
- Leachate application must be at a low flow rate with uniform distribution over the proposed recirculation area.[3]
- Leachate application must not exceed holding capacity of the soils so as to cause ponding or runoff.[4]
- Leachate application must not occur during periods of high winds, freezing temperatures, or during or immediately after rainfall events.
- Adequate leachate storage must be available to store leachate when it is not being applied.[5]
- Procedures must be implemented to annually assess the performance of the leachate collection system to determine if any adverse effects from the added volume of leachate have occurred.

Recordkeeping

Owner/operators must keep records of the amount of leachate recirculated, locations of recirculation, and leachate testing results.

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[3] Acceptable application methods may include surface spraying, drip irrigation tubing, pipes within the waste mass, etc.

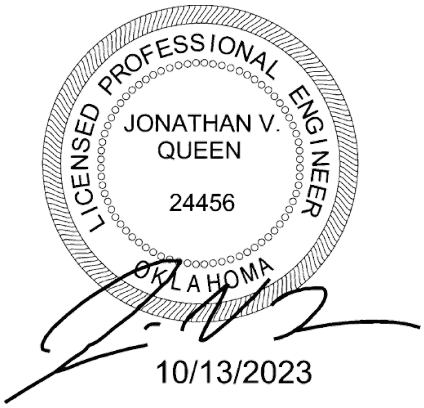
[4] DEQ recommends owner/operators consult with their local extension agent to assist with determining appropriate application rates.

[5] Leachate storage is subject to the requirements of OAC 252:515-13-52.

APPENDIX L-7

CONTAINMENT AND DIVERSION BERM CALCULATIONS

Includes pages L-7-1 through L-7-9

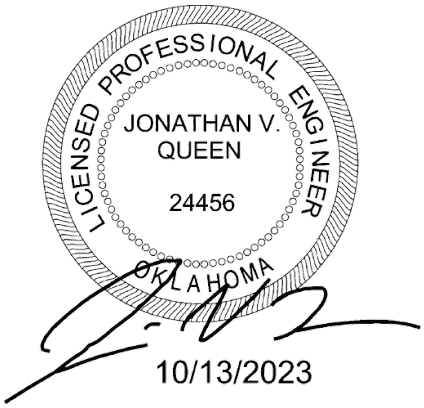


CONTENTS

CONTAINMENT AND DIVERSION BERM CALCULATIONS **L-7-1**

CONTAINMENT BERM CALCULATIONS **L-7-3**

DIVERSION BERM CALCULATIONS **L-7-6**



CONTAINMENT AND DIVERSION BERM CALCULATIONS

A contaminated water run-off containment berm will typically be maintained down-slope from the active disposal area to contain any water running off or seeping out of the working face. Additional methods of containment include detention areas or operational methods (grading). Water contained by this berm is considered contaminated and will largely be absorbed into the landfill and collected by the leachate containment system. If excessive quantities of such water interfere with disposal operations, the leachate or contaminated water will be removed and handled in accordance with Section 5.

Stormwater run-on from drainage areas onto active landfill areas will be prevented by constructing a diversion berm along the edge of the intermediate cover. Run-off will be routed to bypass the active areas of the landfill. Containment berm calculations for run-off volumes of various working face areas are presented on pages L-7-2 through L-7-5 and L-7-7. In addition, diversion berm calculations for run-on volumes of various drainage areas are presented on pages L-7-6 and L-7-8.

A typical berm configuration at the working face is shown in Sheet L-7-9. A containment and diversion berm will be maintained and relocated as necessary to ensure that the berms are always ahead of the disposal operations and the diversion berm is advanced along the intermediate cover as it is applied. These berms will be compacted and of adequate crest width so that they are not destroyed by equipment driving over them.

REQUIRED:

1. Determine the height of the contaminated water berm required at the working face.
2. Determine the height of the diversion berm required for run-on control of the working face.

PROCEDURE: **Containment Berm Calculations**

1. Determine the 25-year, 24-hour rainfall.
2. Calculate the volume of water captured behind the containment berm for 25-year, 24-hour rainfall event.
3. Determine the height of the containment berm for a non-sloping water storage area.
4. Determine the height of the berm for a sloping water storage area.

Diversion Berm Calculations

1. Determine the 25-year frequency runoff flow rates for the diversion berm run-on drainage areas by the Rational Method.
2. Calculate the capacity of the diversion berm at various slopes and determine the required height of the diversion berm.

REFERENCES:

1. U.S. Weather Bureau, "Technical Paper No. 40," 1963.
2. State of Oklahoma Department of Transportation, Drainage Design Manual, Revised: Feb. 1988.
3. NOAA Atlas 14 - Precipitation-Frequency Atlas of the United States, Volume 11, Version 2.0: Texas (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, and National Weather Service, 2018)
4. State of Oklahoma, Department of Transportation, *Drainage Design Manual* , February 1988.

SOLUTION: **Containment Berm Calculations**

1. Based on Reference 3, the 25-year, 24-hour rainfall depth for Muskogee County is:

$R \approx$ 6.98 in

2. Determine the volume of storage required, V_R.

$V_R = CAR$

Where:	C = Runoff coefficient	=	0.5	
	A = Drainage area	=	varies	ac
	R = 25-year, 24-hour rainfall depth	=	6.98	in

The storage volume required for varying drainage areas are shown on the attached table.

3. Determine the height of the containment berm for a non-sloping water storage area.

$$H = \frac{V_R}{A_{stor}}$$

Where: A_{stor} = Storage area (sf)

Example Calculation:

Variables:	S_o =	0.00	%	R =	6.98	in
	A_{stor} =	0.25	ac	C =	0.5	
	A =	0.50	ac	W =	100	ft

Volume:	V_R =	6,334	cf
Height:	H =	0.582	ft

Values for height of the containment berm (H) are listed on Sheet L-7-9 for several storage areas.

4. Determine the height of the berm for a sloping water storage area.

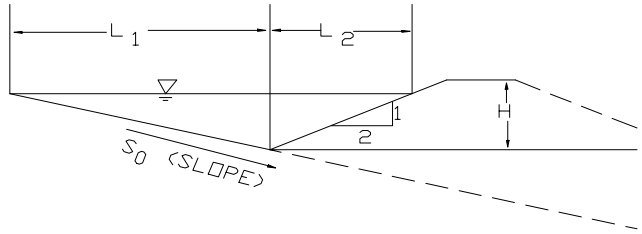
The volume contained by the berm is equal to the cross-sectional storage area multiplied by the width of the berm. The computed volume must be greater than the volume found in step 2.

$V_C = A_s W$

Where: A_s = Cross-sectional storage area (sf)
W = Width (ft)

The minimum width of the downstream berm is 100 feet.

Figure 1. Cross Section of Berm and Storage Area



$$A_s = \frac{(L_1 + L_2)H}{2}$$

Where:

$$L_1 = \frac{H}{S_o} \text{ (ft)}$$

$L_2 =$ 2H (ft)

$S_o =$ Slope of active cell (ft/ft)

Example calculations:

1. Non-sloping water storage area:

Variables:	S_o =	0.00	%	R =	6.98	in
	A_{stor} =	0.25	ac	C =	0.5	
	A =	0.50	ac			
Volume:	V_R =	6,334	cf			
Height:	H =	0.582	ft			

2. Sloping water storage area:

Variables:						
	S_o =	1.00	%	R =	6.98	in
	A_{stor} =	0.25	ac	C =	0.5	
	A =	0.50	ac	W =	100	ft

Height: An iterative process is used to determine the height of the berm required to meet the storage volume requirement for a non-sloping storage area.

H = 1.2 ft

Check to ensure that the above berm height is adequate:

L_1 =	120.00	ft
L_2 =	2.40	ft
A_s =	73.44	sf
V_C =	7,344	cf

V_C is larger than V_R; berm has adequate height. See Sheet L-7-7 and page L-7-9 for summary.

3. Sloping water storage area:

Variables:						
	S_o =	2.00	%	R =	6.98	in
	A_{stor} =	0.25	ac	C =	0.5	
	A =	0.50	ac	W =	100	ft

Height: An iterative process is used to determine the height of the berm required to meet the storage volume requirement for a non-sloping storage area.

H = 1.6 ft

Check to ensure that the above berm height is adequate:

L_1 =	80.00	ft
L_2 =	3.20	ft
A_s =	66.56	sf
V_C =	6,656	cf

V_C is larger than V_R; berm has adequate height. See Sheet L-7-7 and page L-7-9 for summary.

Diversion Berm Calculations

- As shown on Sheet L-7-9, several swales were analyzed to determine the adequacy of the swale configuration.
- Hydraulic calculations are summarized on page L-7-8.

The swales were analyzed by the Rational Method.

From Reference 2 for Muskogee County:

$Q = C\ C_f\ I\ A$

C =	0.5	(intermediate cover)
C_f=	1.1	(runoff correction factor, from Ref 4 for 25-yr design storm frequen
I =	7.08	intensity, in/hr (see calculation below)
A =	varies	drainage area, ac

$$I = \frac{b}{(t_c + d)^e}$$

b =	67
d =	10
e =	0.75

t_c is assumed to be 10 min. for all cases

I = 7.08 in/hr

Diversion Berm Flow Rate Summary

Area (ac)	Flow Rate (cfs)
0.5	1.9
1	3.9
1.5	5.8
2	7.8
2.5	9.7
3	11.7

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0086-364-11-18
CONTAINMENT BERM
CALCULATIONS SUMMARY

Drainage Area	Storage Area	Volume Required	Slope	Berm Height	Cross Sectional Area	Width	Water Surface Area	Volume Provided	L_1[1]	L_2[1]
(ac)	(ac)	(cf)	(%)	(ft)	(sf)	(ft)	(ac)	(cf)	(ft)	(ft)
			0	0.582						
0.5	0.25	6,334	1	1.2	73.44	100	0.281	7,344	120.0	2.4
			2	1.6	66.56	100	0.191	6,656	80.0	3.2
			0	0.582						
1.0	0.50	12,669	1	1.6	130.56	100	0.375	13,056	160.0	3.2
			2	2.3	137.54	100	0.275	13,754	115.0	4.6
			0	0.582						
2.0	1.00	25,337	1	2.3	269.79	100	0.539	26,979	230.0	4.6
			2	3.2	266.24	100	0.382	26,624	160.0	6.4
			0	0.582						
4.0	2.00	50,675	1	3.2	522.24	100	0.749	52,224	320.0	6.4
			2	4.5	526.50	100	0.537	52,650	225.0	9.0

[1] L1 and L2 are shown on Sheet L-7-4.

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DIVERSION BERM
CALCULATION SUMMARY

For 16H:1V Diversion Berm Area Slope

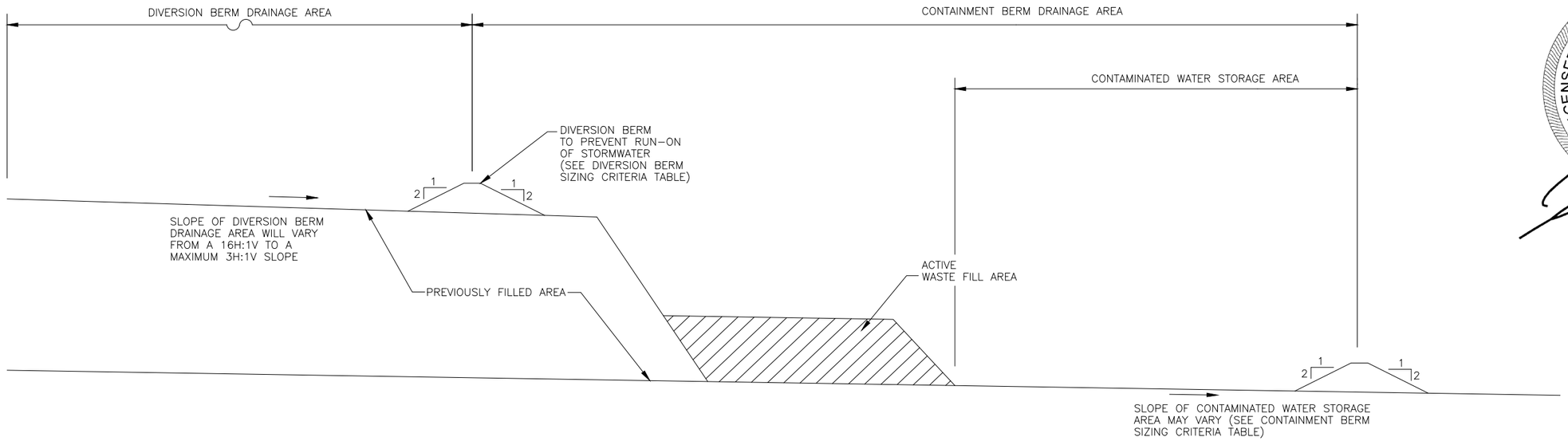
Drainage Area	Flow Rate (cfs)	Bottom Slope (ft/ft)	Manning's n	Side Slope (left)	Side Slope (right)	Bottom Width (ft)	Normal Depth (ft)	Flow Vel. (fps)	Froude Number	Velocity Head (ft)	Energy Head (ft)	Flow Area (sf)	Flow Top Width (ft)
0.5	1.9	0.01	0.03	2	16	0	0.36	1.59	0.655	0.04	0.40	1.20	6.57
1	3.9	0.01	0.03	2	16	0	0.48	1.90	0.684	0.06	0.53	2.06	8.60
1.5	5.8	0.01	0.03	2	16	0	0.55	2.09	0.701	0.07	0.62	2.77	9.99
2	7.8	0.01	0.03	2	16	0	0.62	2.25	0.713	0.08	0.70	3.46	11.16
2.5	9.7	0.01	0.03	2	16	0	0.67	2.38	0.723	0.09	0.76	4.08	12.12
3	11.7	0.01	0.03	2	16	0	0.72	2.49	0.731	0.10	0.82	4.69	13.00

Note: Calculations were performed using the HYDROCALC Hydraulics for Windows developed by Dodson and Associates (Version 1.2a, 1996).

For 3H:1V Diversion Berm Area Slope

Drainage Area	Flow Rate (cfs)	Bottom Slope (ft/ft)	Manning's n	Side Slope (left)	Side Slope (right)	Bottom Width (ft)	Normal Depth (ft)	Flow Vel. (fps)	Froude Number	Velocity Head (ft)	Energy Head (ft)	Flow Area (sf)	Flow Top Width (ft)
0.5	1.9	0.01	0.03	2	3	0	0.60	2.11	0.681	0.07	0.67	0.90	3.00
1	3.9	0.01	0.03	2	3	0	0.79	2.52	0.707	0.10	0.88	1.55	3.94
1.5	5.8	0.01	0.03	2	3	0	0.91	2.79	0.727	0.12	1.03	2.08	4.56
2	7.8	0.01	0.03	2	3	0	1.02	3.01	0.744	0.14	1.16	2.59	5.09
2.5	9.7	0.01	0.03	2	3	0	1.10	3.18	0.753	0.16	1.26	3.05	5.53
3	11.7	0.01	0.03	2	3	0	1.19	3.32	0.760	0.17	1.36	3.52	5.94

Note: Calculations were performed using the HYDROCALC Hydraulics for Windows developed by Dodson and Associates (Version 1.2a, 1996).



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10/13/2023

DIVERSION BERM SIZING CRITERIA *

DIVERSION BERM DRAINAGE AREA (ACRES)	MINIMUM 6%			MAXIMUM 33%		
	FLOW RATE (CFS)	FLOW DEPTH (FT)	REQUIRED MINIMUM DIVERSION BERM HEIGHT (FT)	FLOW RATE (CFS)	FLOW DEPTH (FT)	REQUIRED MINIMUM DIVERSION BERM HEIGHT (FT)
0.5	1.9	0.36	1.36	1.9	0.60	1.60
1	3.9	0.48	1.48	3.9	0.79	1.79
1.5	5.8	0.55	1.55	5.8	0.91	1.91
2	7.8	0.62	1.62	7.8	1.02	2.02
2.5	9.7	0.67	1.67	9.7	1.10	2.10
3	11.7	0.72	1.72	11.7	1.19	2.19

* DIVERSION BERM WILL BE SIZED USING THE ABOVE TABLE AS A GUIDELINE TO CONTAIN STORMWATER FROM THE 25 YEAR. SUPPORTING CALCULATIONS ARE INCLUDED ON PAGE M-7-8.

CONTAINMENT BERM SIZING CRITERIA *

CONTAINMENT BERM DRAINAGE AREA (ACRES)	CONTAMINATED WATER STORAGE AREA (ACRES)	FLOOR SLOPE OF CONTAMINATED WATER STORAGE AREA	REQUIRED MINIMUM HEIGHT OF CONTAINMENT BERM (FT)
0.5	0.25	0 % 1 % 2 %	0.582 1.2 1.6
1.0	0.50	0 % 1 % 2 %	0.582 1.6 2.3
2.0	1.00	0 % 1 % 2 %	0.582 2.3 3.2
4.0	2.00	0 % 1 % 2 %	0.582 3.2 4.5

* CONTAINMENT BERM WILL BE SIZED USING THE ABOVE TABLE AS A GUIDLINE TO CONTAIN STORMWATER FROM THE 25 YEAR, 24 HOUR STORM EVENT. SUPPORTING CALCULATIONS ARE INCLUDED ON PAGES L-7-2 THROUGH L-7-5. NOTE THAT THE CRITERIA SET FORTH IN THE ABOVE TABLE IS BASED ON A MINIMUM DOWNSLOPE CONTAINMENT BERM WIDTH OF 100 FEET.

☐ DRAFT
☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 10/2023
FILE: 0086-364-11
CAD: L-7-9- BERM CALCS.DWG

DRAWN BY: JDW
DESIGN BY: JBP
REVIEWED BY: JVQ

Weaver Consultants Group
CA 3804 PE - 06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION
DIVERSION AND CONTAINMENT BERM CALCULATION

MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

WWW.WCGRP.COM

FIGURE L-7-9

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O:\0086\364\EXPANSION 2022\APPENDIX LVL-7-9-DIVERSION BERM.dwg, jpuhr, 1:2

APPENDIX L-8

INDUSTRIAL PERMIT 078

MUSKOGEE
PUBLIC WORKS

301 South Cherokee
PO Box 1927
Muskogee, OK 74402-1927

CITY OF MUSKOGEE

INDUSTRIAL USER PERMIT

PERMIT NO. 078

In accordance with the provisions of Section 82, City of Muskogee's Industrial Pretreatment Ordinance,

Waste Management of Oklahoma, Inc.
2801 South 54th Street West
Muskogee, Oklahoma 74401

is hereby authorized to discharge industrial wastewater from the above identified facility and through the outfalls identified herein into the City of Muskogee's sewer system in accordance with the conditions set forth in this permit. Compliance with this permit does not relieve the permittee of its obligation to comply with any or all applicable pretreatment regulations, standards or requirements under local, State, and Federal laws, including any such regulations, standards, requirements, or laws that may become effective during the term of this permit.

Noncompliance with any term or condition of this permit shall constitute a violation of the City of Muskogee's sewer use ordinance.

This permit shall become effective on December 1, 2022 and shall expire at midnight on November 30, 2027.

If the permittee wishes to continue to discharge after the expiration date of this permit, an application must be filed for a renewal permit in accordance with the requirements of Section 82, a minimum of 90 days prior to the expiration date.

BY: _____

Mike Stewart
Director of Public Works

Issued this 22nd day of November, 2022.

(918) 684-6333
www.muskogeeonline.org

MUSKOGEE
PUBLIC WORKS

301 South Cherokee
PO Box 1927
Muskogee, OK 74402-1927

November 22, 2022

Peter Schultze
Waste Management of Oklahoma, Inc.
2801 South 54th Street West
Muskogee, Oklahoma 74401

RE: Issuance of Industrial User Permit to Waste Management of Oklahoma, Inc. by the City of Muskogee, Oklahoma Permit No. 078

Dear Mr. Schultze:

Your application for an industrial user pretreatment permit has been reviewed and processed in accordance with Section 82 of the City of Muskogee's Industrial Pretreatment Ordinance.

The enclosed Permit No. 078 covers the wastewater discharged from the facility located at 2801 South 54th Street West into the City of Muskogee's sewer system. All discharges from this facility and actions and reports relating thereto shall be in accordance with the terms and conditions of this permit.

If you wish to appeal or challenge any conditions imposed in this permit, a petition shall be filed for modification or reissuance of this permit in accordance with the requirements of Section 82 of the City of Muskogee's Industrial Pretreatment Ordinance, within 30 days of your receipt of this correspondence. Pursuant to Section 82 of the Industrial Pretreatment Ordinance, failure to petition for reconsideration of the permit within the allotted time is deemed a waiver by the permittee of his right to challenge the terms of this permit.

BY: _____
Signature
Mike Stewart
Director of Public Works

Issued this 22nd day of November, 2022.

(918) 684-6333
www.muskogeeonline.org

MUSKOGEE PUBLIC WORKS
301 South Cherokee
PO Box 1927
Muskogee, OK 74402-1927

PART 1 - EFFLUENT LIMITATIONS

A. During the period from December 1, 2022 to November 30, 2027_ the permittee is authorized to discharge process wastewater to the City of Muskogee's sewer system from the outfalls listed below.

Description of outfalls:

Outfall	Description
001	Manhole at the North West corner of S 54th St. West and West Hancock St.

B. The discharge from outfall 001 shall not exceed the following effluent limitations.

EFFLUENT LIMITATIONS

Parameter		Daily Maximum (mg/l)
Flow		(gallons per day)
pH		Lower Limit 5; Upper Limit 12
Temp		140 F
BOD 5		**
COD		**
TSS		**
Oil & Grease		200 mg/l
Molybdenum	(T)	0.44 mg/l
Selenium	(T)	2.14 mg/l
Arsenic	(T)	0.184 mg/l
Cadmium	(T)	0.082 mg/l
Chromium	(T)	2.342 mg/l
Copper	(T)	0.737 mg/l
Lead	(T)	0.813 mg/l
Nickel	(T)	0.960 mg/l
Zinc	(T)	5.010 mg/l
Cyanide	(T)	1.730 mg/l
Silver	(T)	0.591 mg/l
Mercury	(T)	0.019 mg/l

(T) – Total
** -- No discharge limit, but reporting is required.

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PO Box 1927
Muskogee, OK 74402-1927

C. All discharges shall comply with all other applicable laws, regulations, standards, and requirements contained in Section 82 of the Industrial Pretreatment Ordinance and any applicable State and Federal pretreatment laws, regulations, standards, and requirements including any such laws, regulations, standards, or requirements that may become effective during the term of this permit.

PART 2 - MONITORING REQUIREMENTS

A. From the period beginning on the effective date of the permit the permittee shall monitor outfall 001 for the following parameters, at the frequency of once every 6 months:

Sample Parameter (units)	Measurement Location	Sample Type
Flow (GPD)	Meter	
pH		Grab
Temp.		Grab
BOD 5		Composite
COD		Composite
TSS		Composite
Oil & Grease		Grab
Molybdenum		Composite
Selenium		Composite
Arsenic		Composite
Cadmium		Composite
Chromium		Composite
Copper		Composite
Lead		Composite
Nickel		Composite
Zinc		Composite
Cyanide		Grab
Silver		Composite
Mercury		Composite

Reports are due in June and December of each year.

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PART 3 - REPORTING REQUIREMENTS

A. Monitoring Reports

Monitoring results obtained shall be summarized and reported on Industrial User Monitoring Report Form. The first report is due on December 31, 2022. The report shall indicate the nature and concentration of all pollutants in the effluent for which sampling and analyses were performed. These reports will be due by June 30 and December 31 respectively.

B. If the permittee monitors any pollutant more frequently than required by this permit, using test procedures prescribed in 40 CFR Part 136 or amendments thereto, or otherwise approved by EPA or as specified in this permit, the results of such monitoring shall be submitted to the City of Muskogee.

C. Automatic Resampling

If the results of the permittee's wastewater analysis indicates that a violation of this permit has occurred, the permittee must:

1. Inform the City of Muskogee of the violation within 24 hours; and

2. Repeat the sampling and pollutant analysis and submit, in writing, the results of this analysis within 30 days of the first violation.

D. All reports required by this permit shall be submitted to the City of Muskogee at the following address:

City of Muskogee
5000 East Hancock
Muskogee, Oklahoma 74403
Attn: Abigail Wright

301 South Cherokee
PO Box 1927
Muskogee, OK 74402-1927

PART 4 - SPECIAL CONDITIONS

SECTION 1 - ADDITIONAL/SPECIAL MONITORING REQUIREMENTS

A. All laboratory fees associated with compliance monitoring by the POTW will be paid by the Permittee. The POTW will forward the laboratory bills directly to the Permittee.

B. The POTW will conduct a minimum of one plant inspection each year. The Permittee will be billed for inspection services.

C. The Permittee shall install and maintain a flow meter at the point where leachate water discharges into the City's sanitary sewer. The flow meter must be calibrated at least once per year and proof of calibration submitted to the City. The permittee shall submit monthly flow measurements to the City.

SECTION 2 - COMPLIANCE SCHEDULE

A. The permittee shall accomplish the following tasks in the designated time period:

Event	No Later Than
N/A	N/A

B. Compliance Schedule Reporting

No later than 14 days following each date in the above schedule, the permittee shall submit to the City of Muskogee a report including, at a minimum, whether or not it complied with the increment of progress to be met on such date and, if not, the date on which it expects to comply with the increment of progress, the reasons for delay, and the steps being taken to return the project to the schedule established.

PART 5 - STANDARD CONDITIONS

Refer to Industrial Pretreatment Ordinance pages 1 to 31, attached.

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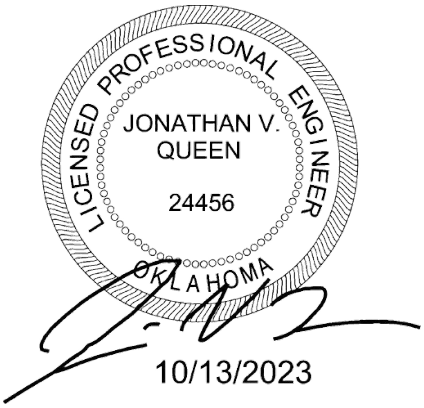
MUSKOGEE COMMUNITY RECYCLING AND DISPOSAL FACILITY
MUSKOGEE COUNTY, OKLAHOMA
ODEQ PERMIT NO. 3551020

APPENDIX M
GEOTECHNICAL ASSESSMENT

Prepared for

Waste Management of Oklahoma, Inc.

October 2023



Prepared by

Weaver Consultants Group, LLC
CA 3804 PE – 06/30/2025
6420 Southwest Boulevard, Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0086-364-11-19

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LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA
10/13/2023

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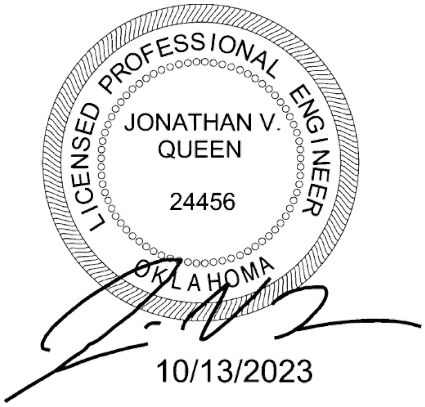

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1 INTRODUCTION

The purpose of this report is to present the geotechnical analysis and design for the lateral expansion of the Muskogee Community Recycling and Disposal Facility (Landfill) located in Muskogee County, Oklahoma. This report addresses the geotechnical testing information that has been compiled for the site, a stability analysis, and settlement, heave and strain analyses for the Landfill. Recommendations for construction of the various landfill components including the composite liner and final cover systems are also provided in this appendix.

2 SUMMARY OF LABORATORY TESTING

2.1 General

Subsurface characterization for this geotechnical assessment of the Landfill expansion was based primarily on field exploration performed by Weaver Consultants Group in 2022.

Laboratory tests were performed in general accordance with ASTM and U.S. Army Corps of Engineers procedures. The following laboratory tests were performed on selected soil samples recovered during geotechnical investigations.

Table 2-1
Geotechnical Test Methods Performed

Test	Test Method
Hydraulic Conductivity	ASTM D5084 and EM 1110-2-1906, Appendix VII
Soil Classification	ASTM D2487
Particle Size	ASTM D422
Percent Passing 200 Sieve	ASTM D1140
Atterberg Limits	ASTM D4318
Moisture Content	ASTM D2216 (Oven Drying) or ASTM D4643 (Microwave Drying)
Moisture/Density (from previous construction events at the existing landfill)	ASTM D698 (Standard Proctor) or ASTM D1557 (Modified Proctor)
Consolidated-Undrained (CU) Triaxial Testing	ASTM D4767
Consolidation Testing	ASTM D2435

Copies of the boring logs from previous site investigations are included in Appendix E of this application. Results from geotechnical tests, including material classification, strength tests, consolidation tests, and laboratory hydraulic conductivity tests are included in Appendix M-1, and summarized in Table M-1-1 also included in Appendix M-1.

2.2 Material Properties

The subsurface materials encountered at the site are discussed in detail in Appendix E - Subsurface Investigation and Groundwater Study. In general, the subsurface at the site is characterized by the units listed below.

- Surfacial Soils (silts, clays, clayey silts and silty clays with various levels of sand)
- Weathered Shale
- Unweathered Shale

The results of laboratory tests performed on soil samples recovered from the site are summarized in Table 2-2 and Table M-1-1 (Appendix M-1). These test results were reviewed with the boring log information and compared to literature values to develop generalized soil properties used in the geotechnical design and analyses included in this appendix.

2.3 Conclusion of Lab Testing

Classification testing along with unit weight, moisture content, sieve analysis, shear strength, triaxial compression strength, and consolidation test results were used to support field observations during subsurface explorations. Testing results were also used to support the subsurface characterization utilized in both the stability and settlement studies.

Table 2-2
Typical Properties of On-Site Materials

Laboratory Test[1]	Test Method	Typical Values[2,3]			Number of Tests		
		Overburden Soil	Weathered Shale	Unweathered Shale	Overburden Soil	Weathered Shale	Unweathered Shale
Liquid Limit (LL)	ASTM D4318	40.3	35.3	36.8	19	24	4
Plastic Limit (PL)	ASTM D4318	17.4	19.8	18.8	19	24	4
Plasticity Index (PI)	ASTM D4318	23.4	17.0	18	19	24	4
% Passing No. 200 Sieve	ASTM D1140	66.1	49.3	21.0	18	26	6
Natural Moisture Content, %	ASTM D2216	13	5.5	4.5	19	26	6
Unit Dry Weight, pcf		117.5	138.7	142.5	2	12	2
Vertical Hydraulic Conductivity[4] (cm/s)	ASTM D5084	1.1E-07	3.3E-08	---	0	10	0

1 Laboratory test results were obtained from site subsurface investigations. Laboratory test data from site subsurface investigations are presented in Appendix M-1.
2 Values listed are averages of the data for each soil layer.
3 Refer to Appendix E for information regarding geologic unit and primary lithology.
4 Refer to Appendices E and M-1 for in-situ hydraulic conductivity information.

3 PERMIT REQUIREMENTS AND CONSTRUCTION RECOMMENDATIONS

3.1 General

This section contains permit requirements and construction recommendations for landfill excavation, soil liner construction, leachate collection layer placement, cover soils, final cover construction, and perimeter berm construction.

3.2 Material Requirements

Construction of the landfill will require clay or clayey soils which can be compacted to have an in-place hydraulic conductivity of $1x10^{-7}$ cm/s or less for the soil liner portion of the composite liner system. Soil will also be required for the leachate collection layer and protective cover material on the soil liner, operational cover (daily and intermediate), the erosion layer component of the final cover, berm construction, and other miscellaneous general fill. Commercially available granular material (i.e., gravel) will be used for the leachate collection trenches and sumps. Typical material requirements are summarized in Table 3-1. Testing requirements and construction quality control and quality assurance for soil liner material is detailed in Appendix K – Quality Assurance/Quality Control Plan for Liner and Leachate Collection System Installation and Testing. Testing requirements and construction quality control and quality assurance for final cover system soils are detailed in Appendix J – Alternative Final Cover System Design. Liner system details, leachate collection system details, and final cover system details are included in Volume 1.

3.3 Landfill Excavation

The landfill will be founded primarily in the Overburden Surficial Soil and Weathered Shale. Landfill base grades will be excavated in a manner that will achieve reasonable segregation of soil liner quality material from the topsoil. Materials will be stockpiled separately, according to construction material properties outlined in Table 3-1 and visual observation during excavation.

Table 3-1
Typical Soil Requirements for Landfill Construction

Landfill Component	Soil Description	Classification	Test Parameters				Material Source[1]
			LL	PI	% - 200	Hydraulic Conductivity cm/s	
Vegetation Layer	clayey sand, sandy clay, or clay	SC, CL, SM	Suitable to support plant growth				On site
Vegetation Support Layer[3]	homogeneous clay, silty clay, sandy clay, or clayey sand	CL, CH, ML, SM, or SC				none	On site
Protective Cover Material	sand or sand with silt and clay	SP-SM, SP, SP-SC, SW, SM or SM-SC				$1x10^{-3}$ min	On site
Leachate Collection Layer	sand or sand with silt and clay	SP-SM, SP, SP-SC, SW, SM or SM-SC				$1x10^{-3}$ min	On site
Soil Liner	clayey sand, sandy clay, or clay	SC, CL, CH	24 min	10 min	30 min	$1x10^{-7}$ max	On site
Alternative Soil Liner[2]	clayey sand, sandy clay, or clay	SC, CL, CH	--	--	--	$1x10^{-7}$ max	On Site
Operational Cover (Daily Cover/Intermediate Cover)[3]	sand, clayey sand, sandy clay, or clay	SP, SC, CL, CH	--	--	--	--	On Site
Earth Fill: Perimeter Berm & Subgrade Preparation[3]	clayey sand, sandy clay, or clay	SC, CL, CH	--	--	--	--	On Site

1 Offsite material may also be used.

2 Alternative soil liner may be used when GCL is installed above soil liner.

3 Processed or decomposed weathered shale and shale may be used in this application.

Hard materials have been encountered in previous excavations. If no significantly hard materials are encountered, excavation will be achieved with standard excavation equipment. However, if encountered during excavation, hard materials will be broken up with an excavator equipped with a hydraulic hammer tool, ripper, or other appropriate equipment. The hydraulic hammer may be fitted with a pointed chisel or a blunt tool as needed. Based on the material properties determined in the field and laboratory studies, the above sequence for excavating the onsite materials is expected to be adequate. If blasting is required for excavation, the appropriate authorization will be received prior to the beginning of blasting operations.

Waste fill area excavation sideslopes (i.e., slopes that will be lined) will be graded no steeper than 3 horizontal to 1 vertical (3H:1V). Excavation cut slopes around the perimeter will require erosion protection if an extended period of time occurs between excavation and soil liner construction. Interim erosion protection can be accomplished by diverting most of the runoff water away from the slopes. "Track walking", with a bulldozer, up and down the slopes will create the effect of "mini dikes," which will reduce erosion.

Prior to beginning construction of the landfill components, the subgrade area will be stripped to a depth sufficient to remove all loose surface soils or soft zones within the exposed excavation. The soil liner subgrade area will be proof-rolled with heavy, rubber-tired construction equipment to detect soft areas. Soft areas will be undercut to firm material and backfilled with suitable compacted earth fill. Preparation of the subgrade will result in a surface that is stable and that does not exhibit significant rutting from construction traffic. The prepared subgrade will be approved by the POR and will be surveyed to verify grades, consistent with procedures included in Appendix K - Quality Assurance/Quality Control Plan for Liner and Leachate Collection System Installation and Testing.

3.4 Soil Liner Construction

The bottom and sides of the landfill excavation will consist of a 24-inch-thick compacted soil liner (an option is provided for an alternative 12-inch-thick compacted soil liner that is overlain by a GCL). Details for the proposed liner systems are provided on Drawing 14 in Volume 1. Adequate soil liner quality material will be available from proposed landfill excavations, on-site borrow sources or off-site borrow sources to provide material for the constructed soil liners. Laboratory tests indicate that these materials are adequate to meet the compacted clay liner requirements listed in OAC 252:515-11-33. Laboratory tests of clay liner samples included in the LITs for previous sector construction, indicate that soils will achieve a hydraulic conductivity of less than $1x10^{-7}$ cm/s.

The following soil liner properties are included in Appendix K – Quality Assurance/Quality Control Plan for Liner and Leachate Collection System Installation and Testing.

Table 3-2
Soil Liner Properties

Test	Specifications
In-place Dry Density	95% of Maximum Standard Proctor (ASTM D698) Dry Density or 90% of Maximum Modified Proctor (ASTM D1557) Dry Density
In-Place Moisture Content	Standard Proctor Optimum Moisture Content or Greater
Hydraulic Conductivity	1.0×10^{-7} cm/s or less
Plasticity Index	10 minimum
Liquid Limit, percent	24 minimum
Percent Passing No. 200 Mesh Sieve	30% minimum
Percent Retained No. 4 Mesh Sieve	20% maximum

Representative preliminary sampling and testing will be performed on stockpiled soils to be used as soil liner material. Prior to construction of each new phase, conformance tests that include liquid limit, plastic limit, percent passing the No. 4 and No. 200 sieves, standard Proctor (ASTM D698) compaction test and remolded hydraulic conductivity test will be performed for each material proposed for soil liner construction. Additional conformance tests will be conducted if there are visual changes in borrow material or the liquid limit or plasticity index vary by more than 10 points. The soil liner construction and testing procedures are outlined in Appendix K – Quality Assurance/Quality Control Plan for Liner and Leachate Collection System Installation and Testing.

3.5 Leachate Collection Layer

The leachate collection system (LCS) drainage material will consist of a 12-inch-thick soil material with a minimum hydraulic conductivity of 1×10^{-3} cm/s or greater over the entire bottom and side slopes of each phase of the landfill. Each phase will have a bottom slope toward an LCS trench (i.e., pipe enveloped in gravel and geotextile) that will collect drainage from the bottom and side slopes of the cell. The leachate collection system details are illustrated on Drawing 15 in Volume 1. The construction procedures for the LCS are outlined in Appendix K – Quality Assurance/Quality Control Plan for Liner and Leachate Collection System Installation and Testing. The material specifications for the LCS are provided in Appendix L – Leachate Collection System Design.

3.6 Protective Cover Material

The protective cover material will consist of a 12-inch-thick layer of leachate collection layer material (see Appendix K – Quality Assurance/Quality Control Plan for Liner and Leachate Collection System Installation and Testing). The 12-inch-thick layer of leachate collection layer material will allow percolation of leachate into the LCS (minimum hydraulic conductivity of $1x10^{-3}$ cm/s). The protective cover material will be placed with construction equipment in one lift such that it covers the leachate collection layer completely. The 24-inch-thick layer of leachate collection/protective cover material will be free of solid waste and will not require compaction under the density-controlled construction procedures.

3.7 Operational Cover Soils

Operational cover soils include daily cover (6-inch-thick minimum soil layer placed over the waste each day) and intermediate cover (6-inch-thick minimum soil layer placed over waste in areas that will not receive additional fill for at least 6 months). All soils excavated at the site may be used for operational cover soil.

3.8 Final Cover System Vegetation Support Layer Construction

The vegetation support layer will consist of a minimum 24-inch-thick soil layer that will extend along the top and sideslopes of the landfill. Material used for the vegetation support layer classifies as CL, CH, ML, SM, or SC according to the Unified Soil Classification System (USCS). The vegetation support layer will be placed as a single lift and compacted to a density that is between 75 and 85 percent of the maximum dry density determined by standard Proctor (ASTM D698) at a moisture content less than the optimum moisture content.

3.9 Final Cover System Vegetation Layer Construction

The vegetation layer will consist of a 12-inch-thick layer placed over the vegetation support layer. This vegetation layer consists of soil capable of supporting vegetation growth. The soil will be placed in one lift over the entire surface of the vegetation support layer and compacted in place with a dozer. The surface of the vegetation layer should be graded to achieve the desired final grades and disked parallel to the proposed contours, in preparation for seeding and to prevent excessive loss due to heavy rainfall.

3.10 Perimeter Embankment Construction

Permanent perimeter embankments (berms) may be constructed to prevent surface water flow entering the landfill excavation. The constructed berms will have side slopes, in general, no steeper than 3H:1V. A sufficient amount of soil is available from the landfill excavations to construct the perimeter berms and other features that require earth fill material. Temporary containment and diversion berms information is included in Appendix L – Leachate Collection System Design.

Prior to beginning embankment fill, the subgrade area will be stripped to a depth sufficient to remove all topsoil and vegetation. Topsoil will be stockpiled for later use. The subgrade area will be proof-rolled with heavy, rubber-tired construction equipment (e.g., dump truck, scraper) to detect soft areas. Soft areas will be undercut to firm material and backfilled with suitable compacted earth fill. The subgrade preparation will result in a subgrade surface that is stable and does not exhibit significant rutting from construction equipment traffic.

The embankments will be constructed of onsite soils free of organic or other objectionable materials. The earth fill will be spread in maximum 9-inch-thick, loose, horizontal lifts and compacted to a minimum of 95 percent of standard Proctor (ASTM D698) maximum dry density, at a moisture content equal to or greater than the optimum moisture content as determined by the Proctor test. A minimum of one Proctor test will be performed on each representative soil used as earth fill material. Each lift will receive a minimum of four passes with a heavy tamping roller unless adequate compaction can be demonstrated with fewer passes. Each lift will be scarified prior to placement of subsequent lifts. Qualified CQA personnel will provide moisture-density field-testing and monitoring during construction. As necessary, the outside face of all embankment construction will be vegetated to minimize erosion and desiccation.

4 SLOPE STABILITY ANALYSIS

4.1 General

This slope stability analysis has been developed to analyze excavation slopes, interim slopes, and landfill completion slopes using critical sections developed for each condition. The computer model SLIDE2 (RocScience, Inc., 2020) was used for the analyses. SLIDE2 is an industry standard computer program developed by RocScience, Inc.

SLIDE2 is a 2-dimensional slope stability program for evaluating the factors of safety or probability of failure of circular and non-circular failure surfaces in soil or rock slopes. SLIDE2 analyzes the stability of slip surfaces using vertical slice or non-vertical slice limit equilibrium methods like Bishop, Janbu, Spencer, and Sarma, among others. Individual slip surfaces can be analyzed, or search methods can be applied to locate the critical slip surface for a given slope. SLIDE2 incorporates a windows-based interface that allows input of analysis sections and geological conditions from AutoCAD design drawings.

Input parameters for the SLIDE2 program include:

- Slope surface geometry.
- Final cover geometry (typically a single layer is input for the final cover system).
- Subsurface information to identify and characterize the soil strata in horizontal and vertical planes, and correlating strength and unit weight parameters from the geotechnical laboratory test results to each stratum.
- Groundwater information. The program is capable of modeling multiple groundwater surfaces that may be applicable to various subsurface strata identified in the second bullet.
- Material strength information. Each soil section (horizontal or vertical) identified in the second bullet is assigned with strength parameters including cohesion and internal friction angles for both total and effective stress conditions.

- Model control and simulation user interface of the model that allows selection of the method of analysis (e.g., Simplified Bishop) and identifying simulation control parameters.

Automatic failure surface generation functions, that use either initiation/termination ranges of the failure surface or use search boxes to define failure surface location, are used to locate the critical failure surface. The methods employed for this slope stability analysis are described below.

1. Simplified Janbu Method – This method uses the method of slices to determine the stability of the mass above a failure surface.
2. Simplified Bishop Method – This method uses the method of slices to discretize the soil mass for determining the factor of safety.

In general, the stability of various critical sections were analyzed under static conditions for short-term (excavation and construction) and long-term (after construction) factors of safety. The slope stability analyses are provided in M-2. The stability of the various liner and final cover configurations with the geosynthetic components were also evaluated by using infinite slope stability analysis (refer to Appendix M-2D).

The stability analysis has been developed using demonstrations showing that, for each analyzed section, the forces resisting movement of the slopes are higher than the forces that potentially create movement. Therefore, the ratio of forces resisting movement to the forces potentially creating movement is defined as the factor of safety (FS). When the FS is equal to or greater than 1.0, it means that the slope is stable. For the slope stability analysis, a factor of safety greater than 1.0 is desired. The FS value is increased to address the uncertainty of the system analyzed (i.e., soil strength, groundwater conditions, equipment loading, etc.). A factor of safety of 1.5 has been used for slopes that will remain in place long-term, including final landfill and final cover configurations. A factor of safety of 1.3 is acceptable for total stress conditions that will be in place for a short period of time, including interim and excavation slopes.

4.2 Sections Selected for Analysis

Slope stability analyses were performed on critical sections to estimate the stability of the excavation, liner, interim fill, perimeter drainage structure, and final cover slopes. The geometry of the slope configurations analyzed was determined by reviewing the drawings included in Volume 1: the proposed excavation plan, top of liner plan, top of leachate collection layer plan, and the closure contour and stormwater management map. The evaluation locations were selected to analyze critical slopes that include the landfill configuration as well as natural soils at the toe and below the landfill excavation slopes. The critical section locations were selected

to represent the longest and steepest slopes for excavation and final landfill configurations. The interim fill slope was analyzed using an assumed geometry as discussed in Section 4.3. Figures showing the location of the cross sections are included in Appendix M-2B.

4.3 Configurations Analyzed

The excavation, liner, interim fill, and final landfill configurations were modeled to represent critical slope conditions, and the analysis was performed using circular and block failure surfaces. The maximum final fill slopes will be 4 horizontal to 1 vertical (4H:1V), while interim fill slopes, liner slopes, and excavation slopes could be as steep as 3H:1V. The excavation and liner slopes were analyzed with a slope angle of 3H:1V, and interim fill slopes were analyzed with slope angles of 3H:1V and 4H:1V, and a 4H:1V final side slope was used to evaluate final cover. Additionally, the highest measured groundwater potentiometric head surface contours were considered to provide a conservative demonstration. A copy of the excavation contour map, and closure contour map showing the location of the cross sections selected for analysis are included in Appendix M-2A, M-2B, and M-2C. Additionally, the configurations analyzed are graphically illustrated in each appendix. The interim conditions were analyzed considering a 3H:1V slope with a horizontal length of 415 feet. If actual interim 3H:1V slopes longer than 415 feet and are developed during site operations, an additional analysis will be completed at that time and maintained in the Site Operating Record.

4.4 Input Parameters

The cross sections for slope stability analysis were developed from the proposed excavation plan and the closure contour map (see Sheets M-2A-1, M-2B-1 and M-2C-3 in Appendix M-2). The soil parameters were selected based on a review of the boring logs and laboratory test results from the subsurface investigation studies at the site and upon engineering judgment and experience with similar materials. Laboratory testing should be performed again to confirm the design parameters if materials properties appear different at the time of construction.

Waste strength parameters were derived from several references. MSW shear strength parameters reported in technical literature references vary, with friction angles as low as 10 degrees and as high as 53 degrees and cohesion values varying from 0 psf to 7500 psf. To provide for a conservative analysis, a cohesion of 288 psf and a friction angle of 33 degrees were selected for the waste.

Total and effective stress soil parameters were determined for use in the short and long-term static conditions, respectively. Table 4-1 summarizes the strength parameters used for the stability analyses. Note in Table 4-1 that the worst case shear strength interface for the bottom liner system was assumed to be the smooth

geomembrane/geosynthetic clay liner (GCL) interface proposed in the alternative bottom liner system (for both cell bottom and sideslopes). For this interface, shear strength parameters of phi = 9.3 degrees and cohesion = 50 psf were used for both effective (drained) and total (undrained conditions). All other interfaces within both the prescribed and alternative bottom liner system exceed these values. Note that the stability analyses assumes that a reinforced GCL is used for the alternative bottom liner, which exhibits shear strength parameters exceeding the values used in the stability modeling.

Table 4-1
Summary of Material Weight and Strength Properties for Landfill Slope Stability Analysis

Material Type	Moist Unit Weight (pcf)	Effective Stress		Total Stress	
		Cohesion (psf)	Friction Angle (degrees)	Cohesion (psf)	Friction Angle (degrees)
Final Cover Material	116	80	25	80	25
Waste	60	288	33	288	33
Bottom Liner[1]	120	50	9.3	50	9.3
Silty Sand/Clay	128	864	269	763	14.9
Weathered Shale	124	936	35.8	1,958	18.3
Unweathered Shale	155	748	57.2	2,217	47.2

[1] For the bottom liner system a cohesion/adhesion value of 50 psf and a interface friction angle of 9.3 degrees was used to represent the interface strength on both the bottom liner and sideslopes. These strength values are representative of the interface strength parameters for the smooth geomembrane/ geosynthetic clay liner (GCL) interface under hydrated testing conditions. The permit requires that textured geomembrane be used on the sideslopes, making the assumptions incorporated into the stability analyses conservative.

4.5 Results of Stability Analysis

4.5.1 Stability Analysis Using SLIDE2

The results of the stability analyses using SLIDE2 computer program indicate that the proposed excavation, liner, interim fill and final configuration slopes are stable under the conditions analyzed. Table 4-2 summarizes the results of the stability analyses for the landfill slopes and compares the calculated factor of safety to the recommended minimum factor of safety. The recommended minimum factors of safety for the conditions analyzed were determined using recommendations from the USACE Slope Stability, Engineering and Design Manual (EM 1110-02-1902, October 31, 2003).

Loading Conditions	Recommended Minimum Factor of Safety
Permanent Long-Term	1.5
Short-Term (Excavation and Construction)	1.3

Computer-generated slope stability analysis output is included in Appendix M-2A, M-2B, and M-2C. As shown in Table 4-2, the calculated factor of safety for excavation, liner, interim and final cover slopes exceed the recommended factors of safety.

Table 4-2
Summary of Slope Stability Analyses

Analyzed Section-Run[1]	Method	Calculated Factor of Safety		
		Long-Term	Short-Term	Factor of Safety Acceptable
Recommended Minimum Factor of Safety		1.5[2]	1.3[2]	
Excavation Slope A-1-Exterior	Bishop-Circular	3.85	4.42	YES
Excavation Slope A-1 Interior	Bishop-Circular	7.09	6.20	YES
Interim Slope B-1 [3]	Bishop-Circular	NA	1.99	YES
Interim Slope B-2 [3]	Rankine-Block	NA	1.41	YES
Final Cover C-1	Bishop-Circular	2.67	2.67	YES
Final Cover C-2	Rankine-Block	1.69	1.69	YES
Final Cover D-1	Bishop-Circular	2.44	2.53	YES
Final Cover D-2	Rankine-Block	1.69	1.69	YES
Final Cover E-1	Bishop-Circular	2.60	2.61	YES
Final Cover E-2	Rankine-Block	1.60	1.60	YES

[1] For excavation and liner slopes, run 1 represents the circular failure analysis. For interim slopes, run 1 represents the circular failure analysis, while run 2 represents the block failure analysis. For final cover slopes, run 1 represents the circular failure analysis through the waste and 2 represents block failure analysis.
[2] Recommended minimum factor of safety provided in reference 3 on page IIIM-A-3.
[3] Recommended Minimum Factor of Safety of 1.3 for interim (temporary) slopes.

4.6 Infinite Slope Stability Analysis

Infinite slope stability analysis for the liner system and alternative liner system has been included in this design. The infinite liner stability analysis addresses anchor trench design, stability of cover and drainage material on anchored geosynthetics, and shear forces within the liner system. These calculations are presented in Appendix M-2D and indicate the liner system to be satisfactory using the assumed parameters.

5 SETTLEMENT, STRAIN, AND HEAVE ANALYSIS

5.1 General

The purpose of this settlement and heave analysis is to demonstrate that the bottom liner system will not be adversely impacted by foundation settlement induced by waste placed over the liner system. The settlement analysis also addresses the settlement of the final cover system to demonstrate that the proposed final cover is designed to withstand the potential strain induced by differential settlement within the waste.

Settlement of the liner system will occur due to consolidation of the foundation strata resulting from the weight of the landfill components (i.e., protective cover, solid waste and daily cover, and final cover systems). Laboratory consolidation tests indicate that the foundation soils have generally low to moderate compressibility. Settlement of the final cover system will occur primarily due to consolidation and settlement within the solid waste. The total consolidation of the final cover includes both primary and secondary consolidation of deposited waste within the respective cell. Appendix M-3 includes details for the foundation settlement and heave of the bottom liner, and the final cover settlement analyses.

5.2 Foundation Heave

Potential heave (rebound) due to excavation of overburden above the excavation base was estimated using the standard consolidation theory for soils and the recompression index obtained from the rebound portion of the consolidation tests. In order to estimate potential for heave, the load is decreased, instead of increasing the load on the soils, to correspond with the projected weight of excavated soil. Using a maximum excavation depth of approximately 10 feet (existing ground elevation minus bottom of excavation at a given location), a heave of approximately 0.8 inches was calculated. Where the excavation depth is less, heave will also be less and therefore negligible. These calculations are included in Appendix M-3C.

Heave will occur soon after excavation (before and during liner construction) and will not adversely affect the performance of the liner system. The pre-consolidation of the liner foundation strata resulting from removal of the overburden soils prior to liner construction has conservatively been disregarded for the settlement analyses presented in this application, and therefore the calculated heave exceeds actual field conditions.

5.3 Foundation/Bottom Liner Settlement and Strain

Foundation settlement potential has been assessed using estimates of consolidation properties for site-specific strata. Settlement calculations were performed using SETTLE3, a computer-based model developed by RocScience Incorporated. Input parameters include surfaces representing the subsurface strata, vertical loads representing the waste placed in the cell, and the settlement characteristics of the subsurface strata (from laboratory consolidation testing). The SETTLE3 model creates an isopach of the settlement of the bottom liner system, which then can be used to calculate strain within the bottom liner components.

The analysis is performed by creating a horizontal plane within the SETTLE3 program, with subsurface data input from available boring logs that has been normalized to the excavation grades (i.e., grades below the bottom liner system) designed for the landfill. Thus, the horizontal plane within the model represents the soil conditions beneath the excavation grade contours. Vertical fill loads are then calculated by subtracting the final landfill elevation from the excavation grades, and then multiplying the fill height by the unit weight assumed at each fill point. Unit weight values are adjusted based on the total waste thickness and assume that deeper waste fill heights result in higher waste densities.

For the analysis, a conservative approach of assuming pre-consolidation pressures equal to the overburden stress were used. This is a conservative approach in that it results in greater settlement at each analysis point when compared to analyses performed using an assumed or calculated higher pre-consolidation stress value, or accounting for pre-consolidation that has occurred prior to unloading (excavation) of the cells.

The results of the analyses are presented in Appendix M-3A. A settlement contour map presenting the settlement of the expanded landfill is included. As demonstrated in the calculations, even with this more conservative approach the settlement at the site is negligible and will not adversely affect the performance of the leachate collection system and will not result in detrimental strain on the liner system components.

5.4 Final Cover Settlement and Strain

Landfill final cover settlement occurs due to settlement of foundation soils and the settlement within the overlying waste materials. In general, foundation settlement is insignificant in comparison to the settlement of deposited waste and is assumed to occur over the period of waste placement, well before the final cover is installed. Therefore, foundation settlement is not evaluated for the final cover settlement analysis. Waste settlement includes both primary and secondary settlement.

Settlement of solid waste generally begins rapidly as the waste load is placed and continues to occur for long periods of time after the initial placement. Initially, municipal solid waste will undergo primary settlement due to its self-weight, and stresses imposed by the final cover, construction equipment, etc. Primary settlement occurs quickly, generally within the first several months after loading. Therefore, the weight of the final cover system is the only remaining factor that contributes to primary consolidation. By the time the construction of the final cover is complete, settlement of the waste due to the weight of the final cover will be complete.

Secondary settlement continues at substantial rates for periods of time well beyond primary settlement. It is a combination of mechanical secondary compression, physico-chemical reaction, and bio-chemical decay. Settlement analysis for the final cover system is presented in Appendix M-3B.

A strain analysis has been incorporated into the final cover settlement analysis presented in Appendix M-3B. The purpose of the settlement and strain analysis is to demonstrate that the final cover system will remain stable after installation and will maintain positive drainage.

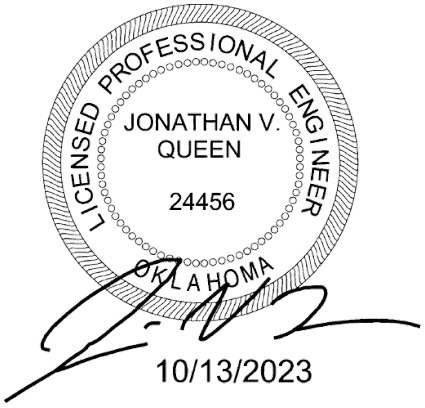
Based on the estimates of settlement for the maximum waste thickness (where maximum waste settlement is expected to occur on the top deck of the landfill) and minimum waste thickness (where minimum settlement is expected to occur on the of the landfill waste mass), the landfill final cover will be subject to a (compressive) strain within the limits of the components comprising the final cover, as demonstrated in the calculations included in Appendix M-3B. The results are less than the allowable strain for the final cover components. The strain demonstration also shows that the top deck areas of the final cover will be stable and maintain positive drainage after settlement.

7 CONCLUSIONS AND RECOMMENDATIONS

- Based upon field exploration, laboratory testing, and engineering analysis, the soil and strata at the site are geotechnically suitable for continued development of a municipal solid waste landfill.
- All geotechnical engineering tests were performed in general accordance with industry practice and recognized procedures (e.g., ASTM standards).
- Stability of the proposed landfill excavation slopes, constructed liner slopes, interim fill slopes, and the final cover sideslopes are acceptable as designed (see Appendix M-2).
- Stability of the liner system is acceptable as designed (see Appendix M-2D).
- Foundation heave during excavation is expected to be negligible and is within the strain limits of the liner system (refer to Appendix M-3C).
- Foundation settlement after filling is expected to be negligible and within the strain limits of the liner system (refer to Appendices M-3A and M-3C).
- Settlement of the final cover system will not adversely affect the final cover system components, and the final cover system will function as designed (refer to Appendix M-3B).

APPENDIX M-1

GEOTECHNICAL DATA SUMMARY



SUMMARY

The geotechnical and geological subsurface explorations that included geotechnical testing for the Muskogee Landfill conducted in 2022/2023. Additional information was derived for previous investigations associated with the fill area adjacent to the Muskogee Landfill, although that information has not been incorporated into this appendix.

The expansion area borings range in depth from 7 to 70 feet. A more detailed discussion of the previous site explorations are included in Appendix E – Subsurface Investigation and Groundwater Study. Logs of the borings are also contained in Appendix E. The geotechnical studies included geotechnical field and laboratory testing. The results are presented in this appendix.

TABLE M-1-1. GEOTECHNICAL LABORATORY TESTING SUMMARY TABLE

Boring	Depth (ft)	Classification ASTM D2487	Mc (%) ASTM D2216	Degree Sat. (%)	Dry Unit Wt. (pcf)	PL (%) ASTM D4318	LL (%) ASTM D4318	PI (%) ASTM D4318	<#200 (%) ASTM D6913	Permeability (cm/s) ASTM D5084	Consolidated-Undrained Shear Strength (ASTM D4767)		Consolidation (ASTM D2435)	
											Effective (C/ϕ)	Total (C/ϕ)	C_r	C_c
OVERBURDEN SOILS TEST RESULTS SUMMARY														
PWCG-2	5-7	CH	14			18	50	32	81					
PWCG-2	15-17	CL	8			15	44	29	76					
PWCG-2	15-17	CL	8			15	44	29						
PWCG-2	23-25	CL	9			15	45	30	84					
PWCG-3	10-12	CL Sandy Gravel	15			14	38	14	48					
PWCG-4	5-7	CL	18			18	46	31	81					
PWCG-5	8-10	CL	12			18	48	30	85					
PWCG-6	9-11	ML	16.6	95.4	116	25	28	3	89.4	1.10E-07				
WCG-11	11-13	CL	12	74	119	17	46	29	54		173/27.4	274/24.2		
WCG-11	13-15	CL	11			16	37	21	57					
WCG-12	3-5	CL Shaley	7			17	24	7	59					
WCG-13	5-7	CL/Gravel	13			15	31	16	39					
WCG-13	11-13	CL-ML	18.8			NP	24	--	61.1				0.003	0.019
WCG-15	8-10	CL	14			18	41	23	88					
WCG-16	6-8	CL Sandy	13			17	44	27	42					
WCG-17	15-17	CL Shaley	10			20	39	19	65					
WCG-17	20-22	CL	12			18	39	21	83					
WCG-18	3-5	Cl	17			21	62	41	75					
WCG-19	10-12	Shale	13			17	36	19	23					
No. of Tests			**19**	**2**	**2**	**19**	**19**	**19**	**18**	**1**	**1**	**1**	**1**	**1**
Max			**18.8**	**95.4**	**119**	**25**	**62**	**41**	**89.4**	**1.10E-07**	**173/27.4**	**274/24.2**	**0.003**	**0.019**
Min			**7**	**74**	**116**	**14**	**24**	**3**	**23**	**1.10E-07**	**173/27.4**	**274/24.2**	**0.003**	**0.019**
Ave			**14.3**	**84.7**	**117.5**	**17.4**	**40.3**	**23.4**	**66.1**	**1.10E-07**	**173/27.4**	**274/24.2**	**0.003**	**0.019**
WEATHERED SHALE TEST RESULTS SUMMARY														
PWCG-1	20-22.5	Shale	5			18	35	17	5	1.40E-10				
PWCG-2	35-37	Shale	6			17	48	31	32					
PWCG-3	27-29	CL	10.1	72.1	123.8	23	31	8	96.3	6.30E-09				
PWCG-3	38-40	ML	4.9	62.2	141	NP	18	--	62.3	1.50E-08				
PWCG-4	25-30	CL	9.8	80.7	128.5	21	39	18	90	6.70E-09				
PWCG-4	37.5-40	ML	5.5	73.8	142.3	NP	28	--	57.8	3.10E-08				
PWCG-5	25-30	ML	3.4	61.2	148.7	NP	29	--	60.7	3.40E-08				
PWCG-6	5-7	CH	13			19	51	32	74					
WCG-8	10-12	CL	6			18	30	12	56					
WCG-8	30-32	Shale	2			NP	NP	NP	13					
WCG-9	10-12	Shale	3			18	36	18	47					
WCG-10	12-14	Shale	6	98	147	15	30	15	10		936/55.2	29/53.5		
WCG-10	15-17.5	CL-ML	3.2	62.4	150.1	21	27	6	71.7	4.60E-08				
WCG-10	18-20	Shale	3			16	34	18	16					
WCG-10	17-20	Shale	3.7						55.3				0.008	0.027
WCG-11	25-27	Shale	7			20	44	24	31					
WCG-12	15-17	Shale	4			20	39	19	20					
WCG-13	17-19	CL	12	83	121	18	37	19	88		864/21.9	763/14.9		

TABLE M-1-1. GEOTECHNICAL LABORATORY TESTING SUMMARY TABLE

Boring	Depth (ft)	Classification ASTM D2487	Mc (%) ASTM D2216	Degree Sat. (%)	Dry Unit Wt. (pcf)	PL (%) ASTM D4318	LL (%) ASTM D4318	PI (%) ASTM D4318	<#200 (%) ASTM D6913	Permeability (cm/s) ASTM D5084	Consolidated-Undrained Shear Strength (ASTM D4767)		Consolidation (ASTM D2435)	
											Effective (C/ϕ)	Total (C/ϕ)	C_r	C_c
WCG-15	25-27	Shale	4			20	42	22	8					
WCG-15	30-32.5	CL-ML	3.1	52.8	147.5	22	28	6	50.5	1.10E-07				
WCG-16	17-19	Shale	15.5			25	39	14	88.9				0.018	0.108
WCG-16	20-25	Shale	14	98	124	21	50	29	32		936/35.8	1958/18.3		
WCG-18	15-17	Shale	10			19	39	20	65					
WCG-18	25-27	Shale	6			19	40	21	7					
WCG-19	17.5-20	ML	4.5	67.2	145	22	27	5	72.7	5.40E-09				
WCG-19	25-27.5	ML	5.5	83.7	145.2	23	27	4	71.8	7.80E-08				
No. of Tests			**26**	**12**	**12**	**24**	**24**	**24**	**26**	**10**	**3**	**3**	**2**	**2**
Max			**15.5**	**98**	**150.1**	**25**	**51**	**32**	**96.3**	**1.10E-07**	**936/55.2**	**1958/53.5**	**0.018**	**0.108**
Min			**2**	**52.8**	**121**	**15**	**18**	**4**	**5**	**1.40E-10**	**864/21.9**	**29/14.9**	**0.008**	**0.027**
Ave			**6.5**	**74.6**	**138.7**	**19.8**	**35.3**	**17.0**	**49.3**	**3.33E-08**	**912/37.6**	**916.7/86.7**	**0.013**	**0.068**
UNWEATHERED SHALE TEST RESULTS SUMMARY														
WCG-11	45-47	Shale	4			20	38	18	7					
WCG-11	45-47.5	Shale	5.3						34.8				0.006	0.013
WCG-12	36-37	Shale	5	96	148	17	32	15	2		749/57.2	2218/47.2		
WCG-15	45-47	Shale	8	92	137	20	43	23	4		878/59.2	2189/55.6		
WCG-15	67.5-70	Shale	2.6						55.2				0.012	0.004
WCG-15	68-70	Shale	2			18	34	16	23					
No. of Tests			**6**	**2**	**2**	**4**	**4**	**4**	**6**	**-**	**2**	**2**	**2**	**2**
Max			**8**	**96**	**148**	**20**	**43**	**23**	**55.2**	**-**	**878/59.2**	**2218/55.6**	**0.012**	**0.013**
Min			**2**	**92**	**137**	**17**	**32**	**15**	**2**	**-**	**749/57.2**	**2189/47.2**	**0.006**	**0.004**
Ave			**4.5**	**94.0**	**142.5**	**18.8**	**36.8**	**18.0**	**21.0**	**-**	**813.5/58.2**	**2203.5/51.4**	**0.009**	**0.0085**

2022/2023 TESTING

ALPHA TESTING
A Universal Engineering Sciences Company

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February 27, 2023

Weaver Consultants Group, LLC
6420 Southwest Boulevard, Suite 206
Fort Worth, Texas 76109

Attention: Mr. David Poe, P.E.

Re: Geotechnical Laboratory Testing
Laboratory Testing Services Only
ALPHA Report No. W223406

ALPHA TESTING, LLC performed laboratory testing on disturbed samples and Shelby tube samples provided to us from the Client. This study was authorized by Mr. David Poe, P.E. on November 29, 2022 and performed in accordance with ALPHA Proposal No. 94596-rev1 dated November 29, 2022.

The scope of work provided herewith consists of laboratory testing only. Shelby tube and disturbed soil specimens were provided to us for testing. Results of the laboratory testing are attached herewith.

Natural moisture content tests (ASTM D 2216), Atterberg-limit tests (ASTM D 4318) and percent material passing the No. 200 sieve tests (ASTMD 1140) were performed on samples provided to us by the Client. Six (6) consolidated undrained (CU) triaxial compression tests performed in general accordance with ASTM D 4767 were conducted on samples selected by the Client. Results from laboraotry testing are attached.

Engineering analyses and recommendations are outside the scope of this work. ALPHA is not responsible for interpretation of the data provided herewith by others. ALPHA appreciates the opportunity to be of service on this project. Please contact our office if you have any questions.

Sincerely,

ALPHA TESTING, LLC

Brian J. Hoyt, P.E.
Regional Manager

BJH/kc
Attachments: Index Properties
Report of Hydraulic Permeability Test
Reports of Consolidated Undrained Triaxial Compression Test

Laboratory Testing						
Boring No. and Depth	**Classification**	**Water Content (%)**	**Liquid Limit**	**Plastic Limit**	**Plasticity Index**	**Percentage Passing No. 200 Sieve (%)**
PWCG-1 20’-22.5’	Gray Shale	5	35	18	17	5
PWCG-2 5’-7’	Brown and Gray Shaly Clay (CH)	14	50	18	32	81
PWCG-2 15’-17’	Brown Clay with sand (CL)	8	44	15	29	76
PWCG-2 23’-25’	Tan Shaly Clay (CL)	9	45	15	30	84
PWCG-2 35’-37’	Gray Shale	6	48	17	31	32
PWCG-3 10’-12’	Tan and Gray Clayey Sand with gravel (SC)	15	38	14	24	48
PWCG-4 5’-7’	Tan and Gray Clay (CL)	18	46	15	31	81
PWCG-5 8’-10’	Tan Shaly Clay (CL)	12	48	18	30	85
PWCG-6 5’-7’	Brown and Gray Shaly Clay with sand (CH)	13	51	19	32	74
WCG-8 10’-12’	Brown Shaly Clay, sandy (CL)	6	30	18	12	56
WCG-8 30’-32’	Gray Shale	2	NP	NP	NP	13
WCG-9 10’-12’	Gray Shale	3	36	18	18	47
WCG-10 18’-20’	Gray Shale	4	34	16	18	16

Laboratory Testing						
Boring No. and Depth	**Classification**	**Water Content (%)**	**Liquid Limit**	**Plastic Limit**	**Plasticity Index**	**Percentage Passing No. 200 Sieve (%)**
WCG-11 13’-15’	Brown Sandy Clay (CL)	11	37	16	21	57
WCG-11 25’-27’	Gray Shale	7	44	20	24	31
WCG-11 45’-47’	Gray Shale	4	38	20	18	7
WCG-12 3’-5’	Brown Shaly Clay, sandy (CL)	7	24	17	7	59
WCG-12 15’-17’	Gray Shale	4	39	20	19	20
WCG-13 5’-7’	Reddish Brown Clayey Sand with gravel (SC)	13	31	15	16	39
WCG-15 8’-10’	Light Brown Clay (CL)	14	41	18	23	88
WCG-15 25’-27’	Gray Shale	4	42	20	22	8
WCG-15 68’-70’	Gray Shale	2	34	18	16	23
WCG-16 6’-8’	Tan and Gray Sandy Clay with clayey sand seams and layers (CL)	13	44	17	27	42
WCG-17 15’-17’	Gray Shaly Clay, sandy (CL)	10	39	20	19	65
WCG-17 20’-22’	Brown Shaly Clay (CL)	12	39	18	21	83
WCG-18 3’-5’	Tan and Gray Clay with sand (CH)	17	62	21	41	75

Laboratory Testing						
Boring No. and Depth	**Classification**	**Water Content (%)**	**Liquid Limit**	**Plastic Limit**	**Plasticity Index**	**Percentage Passing No. 200 Sieve (%)**
WCG-18 15’-17’	Gray Shale	10	39	19	20	65
WCG-18 25’-27’	Gray Shale	6	40	19	21	7
WCG-19 10’-12’	Gray Shale	13	36	17	19	23

REPORT OF HYDRAULIC PERMEABILITY TEST

Project Name	Laboratory Testing		
ALPHA Proj. No.	W223406	Sample Location	PWCG-1 20'-22.5'
Client	Weaver Consultants Group, LLC		
Sample Description	Gray Shale	USCS Classification	Shale
Test Start Date	December 14, 2022	Sampling Procedure	ASTM 420 D
Test Comp.Date	January 5, 2023	Specimen Type	Relatively Undisturbed
Test Description	Measurement of Hydraulic Conductivity of Saturated Porous Materials (ASTM D5804)		

		Specimen Information
Test Summary	Diameter (in)	2.54
	Height (in)	2.00
	Moisture Content (%)	5.0
	Burrette Length (cm)	50.8
	Cell Pressure (psi)	5.0
	Total Burrette Volume (cm^3)	10.00
	Permeant type used	Water

Soil Properties	LL/PL/PI	35	18	17
	#200 PASSING	5%		

Final Test Results	1.4×10^{-10} m/s

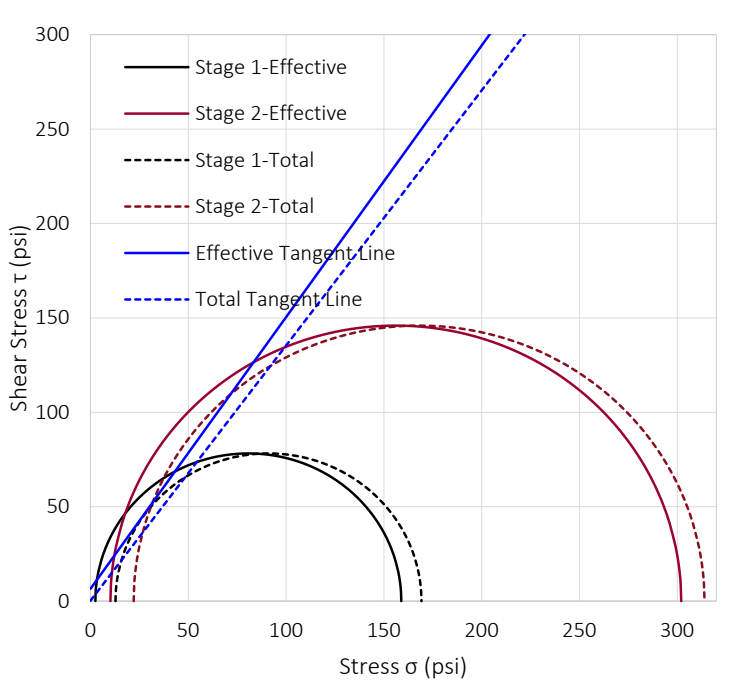
Tested by:	C.T.
Checked By:	K.C.
Approved by:	B.J.H.
Report Date:	2/24/2023 11:01

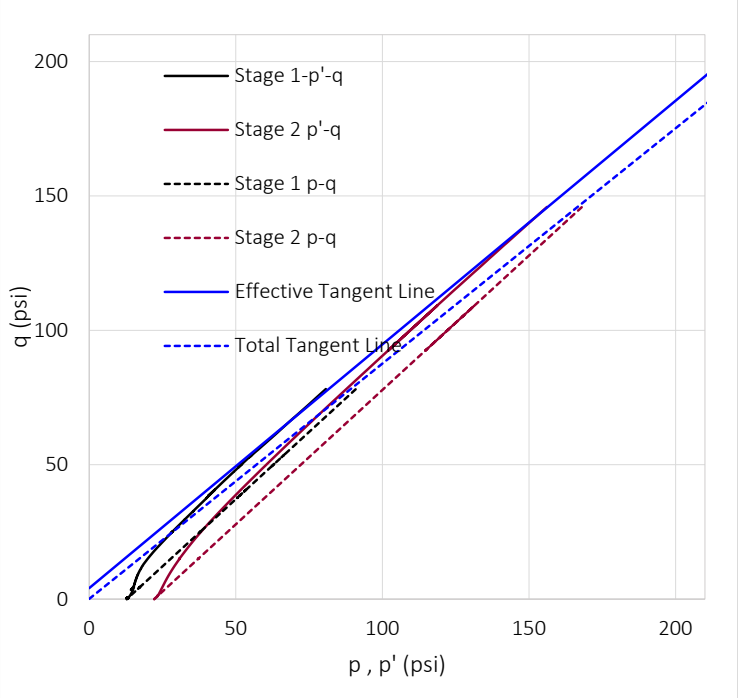
Report of Consolidated Undrained Triaxial Compression Test for Cohesive Soils (ASTM D4767) - Multi-Stage

Project Name	Laboratory Testing		
ALPHA Proj. No.	W223406	Sample Source	WCG-10 12'-14'
Client	Weaver Consultants, LLC		
Sample Description	Gray Shale	USCS Classification	Shale
Test Start Date	February 2, 2023	Sampling Procedure	ASTM 420 D
Test Comp.Date	February 22, 2023	Specimen Type	Relatively Undisturbed
Test Description	Consolidated Undrained Triaxial Compression Test for Cohesive Soils (ASTM D4767) - Multi-Stage		

		Stage 1		Stage 2	
Test Summary	Failure Criterion	Maximum σ_1/σ_3 Ratio		Maximum σ_1/σ_3 Ratio	
	Cell Press. (psi)	32.1		44.5	
	Back Press.(psi)	20.1		20.5	
	Effective Cons. Press.(psi)	12.0		24.0	
Test Data	Dev. Stress at Failure (psi)	183.5		316.7	
	σ_1 / σ'_1 at Failure (psi)	169.2	158.9	313.9	302.0
	σ_3 / σ'_3 at Failure (psi)	12.8	2.5	22.1	10.2
	Pore Press. at Failure (psi)	10.3		11.9	
	Rate of Strain (%/Hr)	1.0		1.0	
	Axial Strain at Failure (%)	4.0%		1.8%	

Specimen Information					
Ave. Dia. (in)					2.02
Ave. Height (in)					4.20
Ave. Water Content (%)					6%
Bulk Density (pcf)					155
Dry Density (pcf)					147
Initial Saturation (%)					98
Initial Void Ratio					0.16
Specific Gravity					2.72
B-Value (End of Sat.)					0.98
Percent Passing #200 (%)					10%
LL	30	PL	15	PI	15





		Mohr's Circle	p-q Line
Final Test Results	Effective Friction Angle (°)	55.2	42.2
	Effective Cohesion (psi)	6.5	4.1
	Total Friction Angle (°)	53.5	41.2
	Total Cohesion (psi)	0.2	0.1

Tested by:	K.C.
Checked By:	K.C.
Approved by:	B.J.H
Report Date:	2/24/2023 10:45

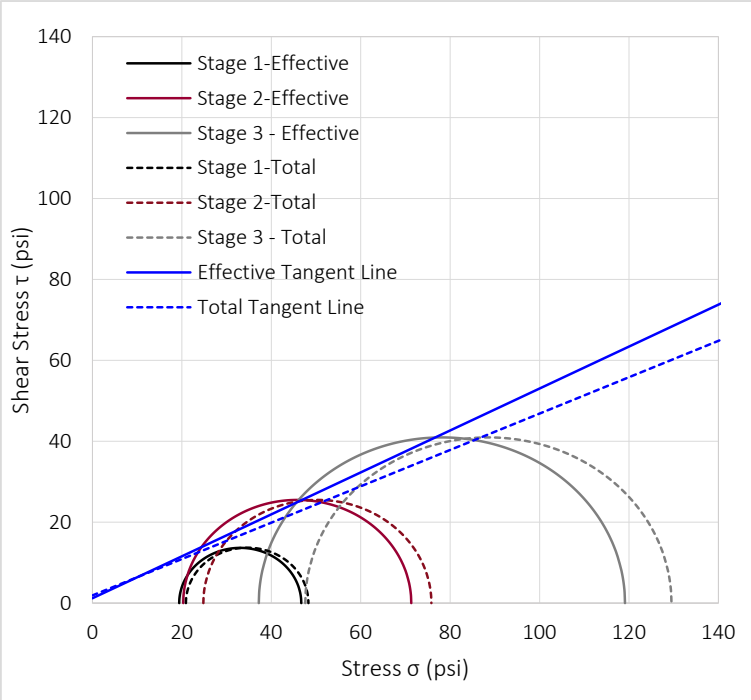
Comments: The specimen failed during the second shear. Therefore, Stage 3 could not be performed.

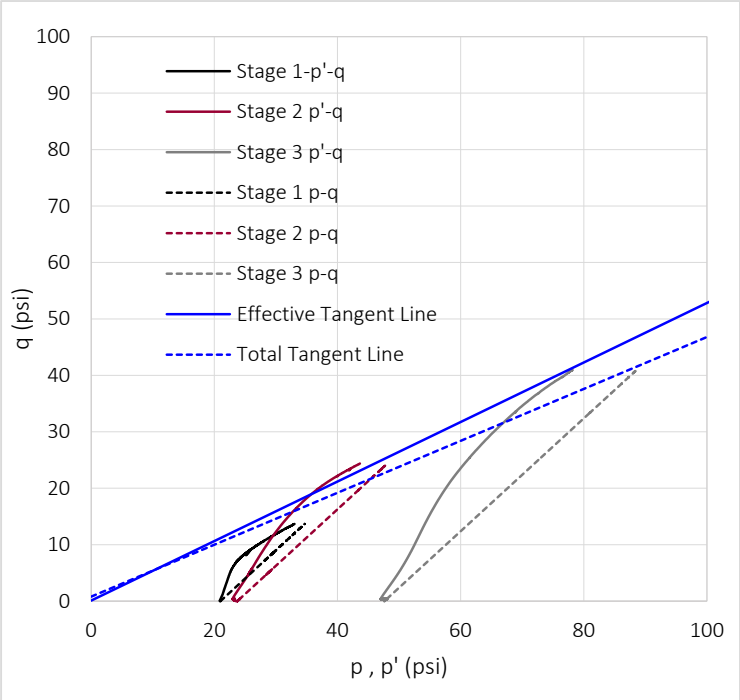
Report of Consolidated Undrained Triaxial Compression Test for Cohesive Soils (ASTM D4767) - Multi-Stage

Project Name	Laboratory Testing		
ALPHA Proj. No.	W223406	Sample Source	WCG-11 11'-13'
Client	Weaver Consultants, LLC		
Sample Description	Brown, Tan and Light Brown Sandy Clay	USCS Classification	CL
Test Start Date	December 1, 2022	Sampling Procedure	ASTM 420 D
Test Comp.Date	January 20, 2023	Specimen Type	Relatively Undisturbed
Test Description	Consolidated Undrained Triaxial Compression Test for Cohesive Soils (ASTM D4767) - Multi-Stage		

		Stage 1		Stage 2		Stage 3	
Test Summary	Failure Criterion	Maximum σ_1/σ_3 Ratio		Maximum σ_1/σ_3 Ratio		Maximum σ_1/σ_3 Ratio	
	Cell Press. (psi)	32.2		44.1		70.2	
	Back Press.(psi)	20.2		20.1		20.2	
	Effective Cons. Press.(psi)	12.0		24.0		50.0	
Test Data	Dev. Stress at Failure (psi)	27.7		51.0		81.9	
	σ_1 / σ'_1 at Failure (psi)	48.3	46.7	72.5	71.3	129.5	119.1
	σ_3 / σ'_3 at Failure (psi)	21.0	19.4	24.8	20.3	47.6	37.2
	Pore Press. at Failure (psi)	1.6		4.5		10.4	
	Rate of Strain (%/Hr)	1.0		1.0		1.0	
	Axial Strain at Failure (%)	2.4%		1.7%		1.9%	

Specimen Information					
Ave. Dia. (in)	2.80				
Ave. Height (in)	5.80				
Ave. Water Content (%)	12%				
Bulk Density (pcf)	133				
Dry Density (pcf)	119				
Initial Saturation (%)	74				
Initial Void Ratio	0.43				
Specific Gravity	2.72				
B-Value (End of Sat.)	0.97				
Percent Passing #200 (%)	54%				
LL	46	PL	17	PI	29





		Mohr's Circle	p-q Line
Final Test Results	Effective Friction Angle (°)	27.4	27.8
	Effective Cohesion (psi)	1.2	0.1
	Total Friction Angle (°)	24.2	24.7
	Total Cohesion (psi)	1.9	0.8

Tested by:	K.C.
Checked By:	K.C.
Approved by:	B.J.H
Report Date:	2/24/2023 9:30

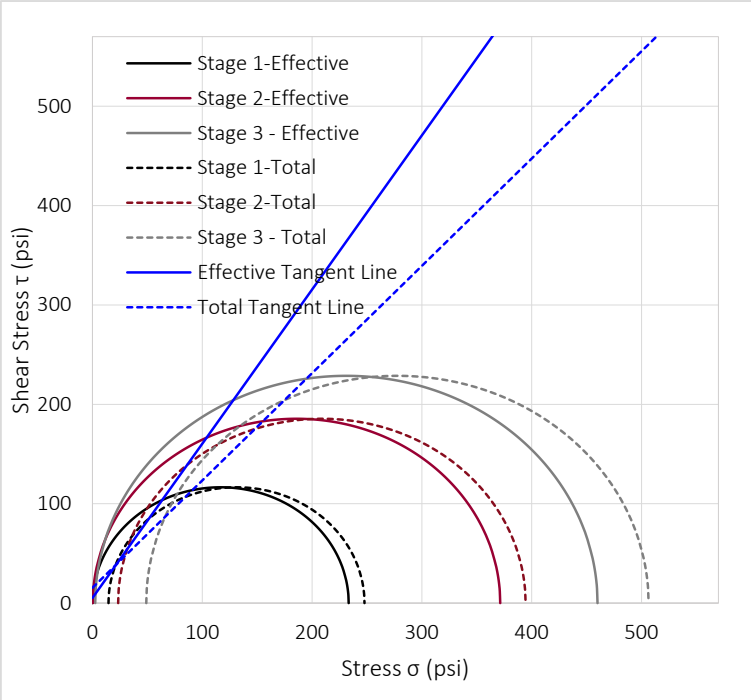
Comments:

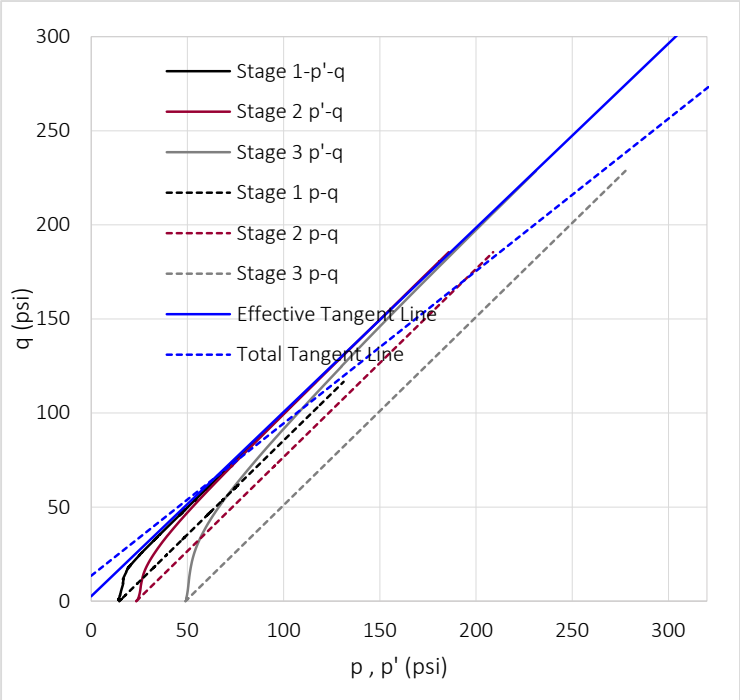
Report of Consolidated Undrained Triaxial Compression Test for Cohesive Soils (ASTM D4767) - Multi-Stage

Project Name	Laboratory Testing		
ALPHA Proj. No.	W223406	Sample Source	WCG-12 36'-37'
Client	Weaver Consultants, LLC		
Sample Description	Gray Shale	USCS Classification	Shale
Test Start Date	January 6, 2023	Sampling Procedure	ASTM 420 D
Test Comp.Date	February 15, 2023	Specimen Type	Relatively Undisturbed
Test Description	Consolidated Undrained Triaxial Compression Test for Cohesive Soils (ASTM D4767) - Multi-Stage		

		Stage 1		Stage 2		Stage 3	
Test Summary	Failure Criterion	Maximum σ_1/σ_3 Ratio		Maximum σ_1/σ_3 Ratio		Maximum σ_1/σ_3 Ratio	
	Cell Press. (psi)	37.4		49.5		75.6	
	Back Press.(psi)	25.4		25.5		25.6	
	Effective Cons. Press.(psi)	12.0		24.0		50.0	
Test Data	Dev. Stress at Failure (psi)	233.5		419.2		513.3	
	σ_1 / σ'_1 at Failure (psi)	247.7	233.3	394.4	371.3	506.4	459.9
	σ_3 / σ'_3 at Failure (psi)	14.6	0.2	23.4	0.3	49.0	2.5
	Pore Press. at Failure (psi)	14.4		23.1		46.5	
	Rate of Strain (%/Hr)	1.0		1.0		1.0	
	Axial Strain at Failure (%)	2.6%		1.6%		1.3%	

Specimen Information					
Ave. Dia. (in)	2.04				
Ave. Height (in)	4.08				
Ave. Water Content (%)	5%				
Bulk Density (pcf)	156				
Dry Density (pcf)	148				
Initial Saturation (%)	96				
Initial Void Ratio	0.15				
Specific Gravity	2.72				
B-Value (End of Sat.)	0.97				
Percent Passing #200 (%)	2%				
LL	32	PL	17	PI	15





		Mohr's Circle	p-q Line
Final Test Results	Effective Friction Angle (°)	57.2	44.4
	Effective Cohesion (psi)	5.2	2.6
	Total Friction Angle (°)	47.2	39
	Total Cohesion (psi)	15.4	13.5

Tested by:	K.C.
Checked By:	K.C.
Approved by:	B.J.H
Report Date:	2/24/2023 8:43

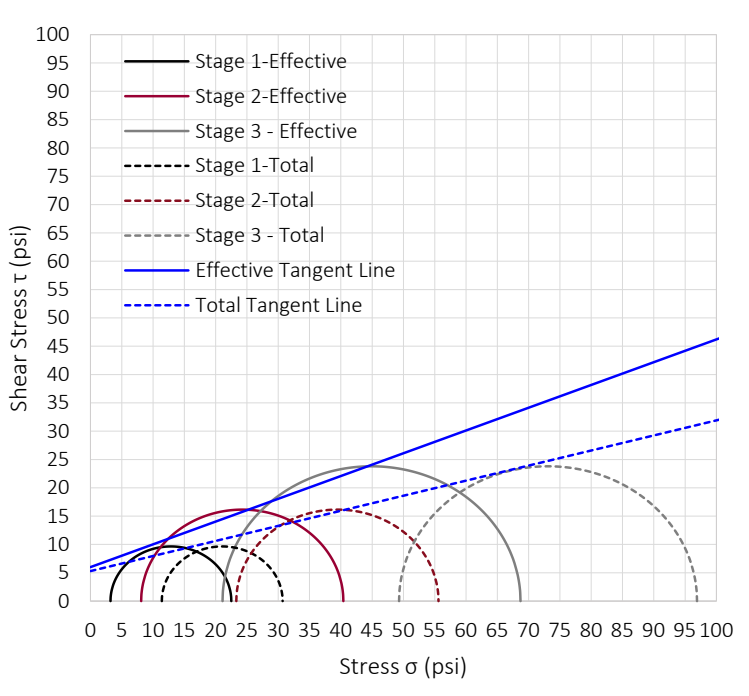
Comments:

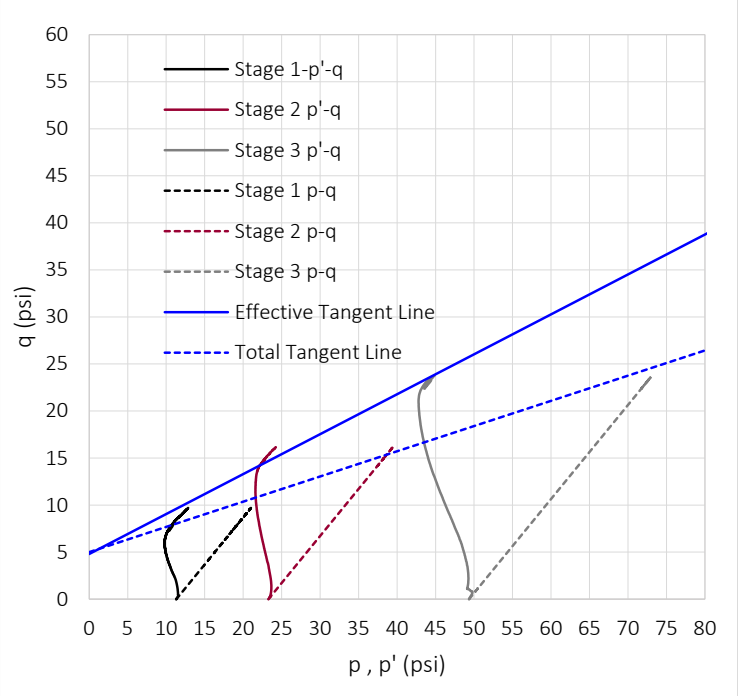
Report of Consolidated Undrained Triaxial Compression Test for Cohesive Soils (ASTM D4767) - Multi-Stage

Project Name	Laboratory Testing		
ALPHA Proj. No.	W223406	Sample Source	WCG-13 17'-19'
Client	Weaver Consultants, LLC		
Sample Description	Brown Clay	USCS Classification	CL
Test Start Date	December 1, 2022	Sampling Procedure	ASTM 420 D
Test Comp.Date	January 5, 2023	Specimen Type	Relatively Undisturbed
Test Description	Consolidated Undrained Triaxial Compression Test for Cohesive Soils (ASTM D4767) - Multi-Stage		

		Stage 1		Stage 2		Stage 3	
Test Summary	Failure Criterion	Maximum σ_1/σ_3 Ratio		Maximum σ_1/σ_3 Ratio		Maximum σ_1/σ_3 Ratio	
	Cell Press. (psi)	27.5		39.8		65.9	
	Back Press.(psi)	15.5		15.8		15.9	
	Effective Cons. Press.(psi)	12.0		24.0		50.0	
Test Data	Dev. Stress at Failure (psi)	19.8		33.7		48.5	
	σ_1 / σ'_1 at Failure (psi)	30.7	22.5	55.6	40.4	96.9	68.7
	σ_3 / σ'_3 at Failure (psi)	11.4	3.2	23.3	8.1	49.3	21.1
	Pore Press. at Failure (psi)	8.2		15.2		28.2	
	Rate of Strain (%/Hr)	1.0		1.0		1.0	
	Axial Strain at Failure (%)	2.2%		1.5%		1.4%	

Specimen Information					
Ave. Dia. (in)					2.80
Ave. Height (in)					4.68
Ave. Water Content (%)					12%
Bulk Density (pcf)					136
Dry Density (pcf)					121
Initial Saturation (%)					83
Initial Void Ratio					0.40
Specific Gravity					2.72
B-Value (End of Sat.)					0.99
Percent Passing #200 (%)					88%
LL	37	PL	18	PI	19





		Mohr's Circle	p-q Line
Final Test Results	Effective Friction Angle (°)	21.9	23
	Effective Cohesion (psi)	6	4.8
	Total Friction Angle (°)	14.9	15
	Total Cohesion (psi)	5.3	5

Tested by:	K.C.
Checked By:	K.C.
Approved by:	B.J.H
Report Date:	2/24/2023 8:16

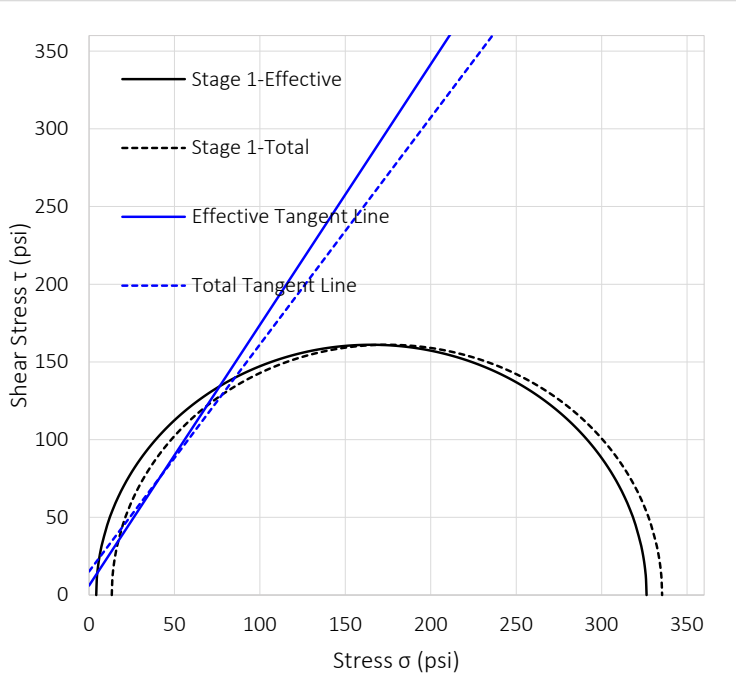
Comments:

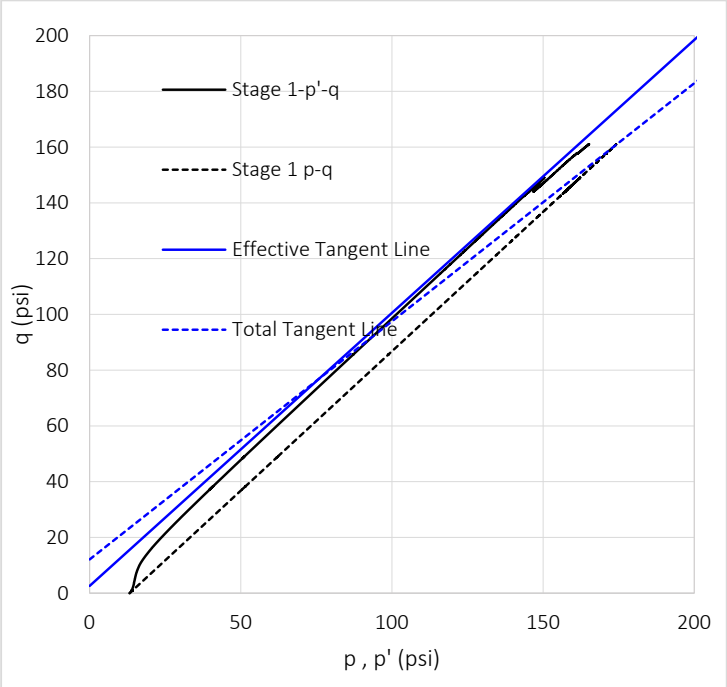
Report of Consolidated Undrained Triaxial Compression Test for Cohesive Soils (ASTM D4767) - Multi-Stage

Project Name	Laboratory Testing		
ALPHA Proj. No.	W223406	Sample Source	WCG-15 45'-47'
Client	Weaver Consultants, LLC		
Sample Description	Gray Shale	USCS Classification	Shale
Test Start Date	February 2, 2023	Sampling Procedure	ASTM 420 D
Test Comp.Date	February 23, 2023	Specimen Type	Relatively Undisturbed
Test Description	Consolidated Undrained Triaxial Compression Test for Cohesive Soils (ASTM D4767) - Multi-Stage		

		Stage 1	
Test Summary	Failure Criterion	Maximum σ_1/σ_3 Ratio	
	Cell Press. (psi)	32.1	
	Back Press.(psi)	20.1	
	Effective Cons. Press.(psi)	12.0	
Test Data	Dev. Stress at Failure (psi)	322.1	
	σ_1 / σ'_1 at Failure (psi)	335.4	326.3
	σ_3 / σ'_3 at Failure (psi)	13.3	4.2
	Pore Press. at Failure (psi)	9.1	
	Rate of Strain (%/Hr)	1.0	
	Axial Strain at Failure (%)	3.7%	

Specimen Information					
Ave. Dia. (in)	2.05				
Ave. Height (in)	4.61				
Ave. Water Content (%)	8%				
Bulk Density (pcf)	148				
Dry Density (pcf)	137				
Initial Saturation (%)	92				
Initial Void Ratio	0.24				
Specific Gravity	2.72				
B-Value (End of Sat.)	0.95				
Percent Passing #200 (%)	4%				
LL	43	PL	20	PI	23





		Mohr's Circle	p-q Line
Final Test Results	Effective Friction Angle (°)	59.2	44.4
	Effective Cohesion (psi)	6.1	2.6
	Total Friction Angle (°)	55.6	40.5
	Total Cohesion (psi)	15.2	12.1

Tested by:	K.C.
Checked By:	K.C.
Approved by:	B.J.H
Report Date:	2/27/2023 9:43

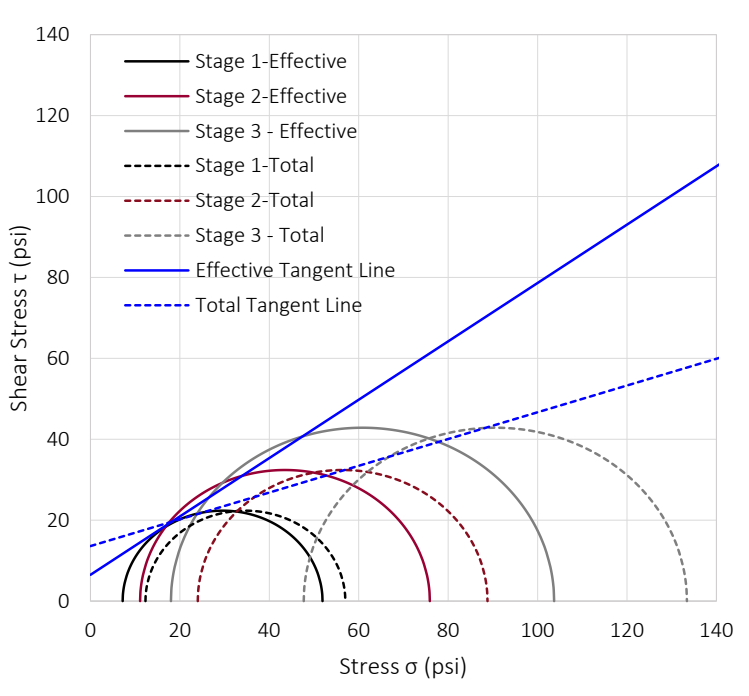
Comments: The specimen failed after Stage 1. Therefore, Stage 2 and 3 are excluded from this report

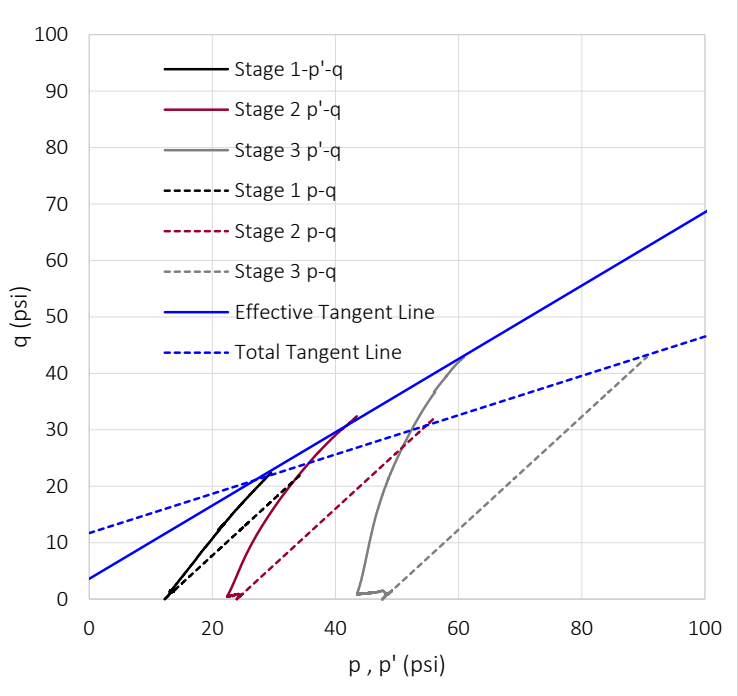
Report of Consolidated Undrained Triaxial Compression Test for Cohesive Soils (ASTM D4767) - Multi-Stage

Project Name	Laboratory Testing		
ALPHA Proj. No.	W223406	Sample Source	WCG-16 20'-25'
Client	Weaver Consultants, LLC		
Sample Description	Gray Shale	USCS Classification	Shale
Test Start Date	January 9, 2023	Sampling Procedure	ASTM 420 D
Test Comp.Date	February 1, 2023	Specimen Type	Relatively Undisturbed
Test Description	Consolidated Undrained Triaxial Compression Test for Cohesive Soils (ASTM D4767) - Multi-Stage		

		Stage 1		Stage 2		Stage 3	
Test Summary	Failure Criterion	Maximum σ_1/σ_3 Ratio		Maximum σ_1/σ_3 Ratio		Maximum σ_1/σ_3 Ratio	
	Cell Press. (psi)	27.5		39.4		65.5	
	Back Press.(psi)	15.5		15.4		15.5	
	Effective Cons. Press.(psi)	12.0		24.0		50.0	
Test Data	Dev. Stress at Failure (psi)	47.1		64.8		85.8	
	σ_1 / σ'_1 at Failure (psi)	57.0	51.9	88.8	75.9	133.4	103.7
	σ_3 / σ'_3 at Failure (psi)	12.3	7.1	24.0	11.1	47.7	18.0
	Pore Press. at Failure (psi)	5.1		12.9		29.7	
	Rate of Strain (%/Hr)	1.0		1.0		1.0	
	Axial Strain at Failure (%)	1.7%		2.3%		2.2%	

Specimen Information					
Ave. Dia. (in)	2.05				
Ave. Height (in)	2.39				
Ave. Water Content (%)	14%				
Bulk Density (pcf)	140				
Dry Density (pcf)	124				
Initial Saturation (%)	98				
Initial Void Ratio	0.38				
Specific Gravity	2.72				
B-Value (End of Sat.)	0.98				
Percent Passing #200 (%)	32%				
LL	50	PL	21	PI	29





		Mohr's Circle	p-q Line
Final Test Results	Effective Friction Angle (°)	35.8	33
	Effective Cohesion (psi)	6.5	3.6
	Total Friction Angle (°)	18.3	19.2
	Total Cohesion (psi)	13.6	11.7

Tested by:	K.C.
Checked By:	K.C.
Approved by:	B.J.H
Report Date:	2/20/2023 13:02

Comments:

Client: Weaver Consultants Group

TRI Log #: 23-000003

Project: 0086-364-11-19 Muskogee Landfill

Jeffrey A. Kuhn, Ph.D., P.E., 1/27/2023

Quality Review/Date

COC Line #	Sample Identification	Moisture Content (%)	Dry Unit Weight (pcf)	Fines (%)	Atterberg Limits		
					Liquid Limit	Plastic Limit	Plasticity Index
-	Test Method	ASTM D2216	ASTM D7263	ASTM D1140	ASTM D4318, Method A : Multipoint		
1	WCG-16 (17'- 19')	15.5	-	88.9	39	25	14
2	WCG-13 (11'- 13')	18.8	-	61.1	24	NP	-
3	WCG-10 (17'- 20')	3.7	-	55.3	-	-	-
4	WCG-11 (45'- 47.5')	5.3	-	34.8	-	-	-
5	WCG-15 (67.5'- 70')	2.6	-	55.2	-	-	-

Note: NL = No Liquid Limit; NP = No Plastic Limit

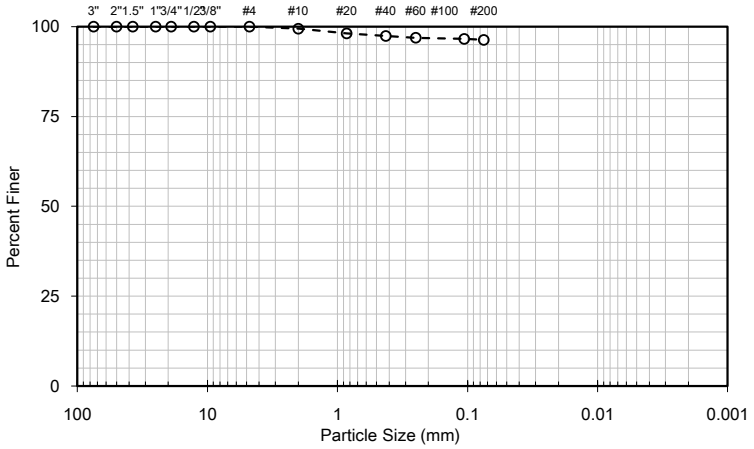
The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

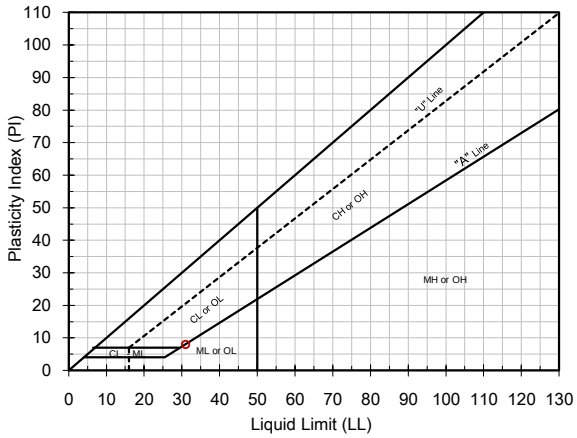
TRI ENVIRONMENTAL, INC.
9063 BEE CAVES RD. – AUSTIN, TX 78733 – USA | PH: 800.880.TEST OR 512.263.2101

Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: PWCG-3 (27-29)

TRI Log #: 22-000096.1





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	0.0	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	100.0	3.7	Hydrometer Log-Linear Interpolation			
No. 10	2.00	99.4		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	98.1		mm		mm	
No. 40	0.420	97.4					
No. 60	0.250	96.9		0.002	- -	0.002	- -
No. 140	0.106	96.6		N m,2μm,d	-	N m,2μm,nd	-
No. 200	0.074	96.3	96.3	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	31
Plastic Limit	23
Plastic Index	8
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	- -	- -	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Lean clay (CL)

Moisture Content (%)	ASTM D2216	- -
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

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Analysis & Quality Review/Date

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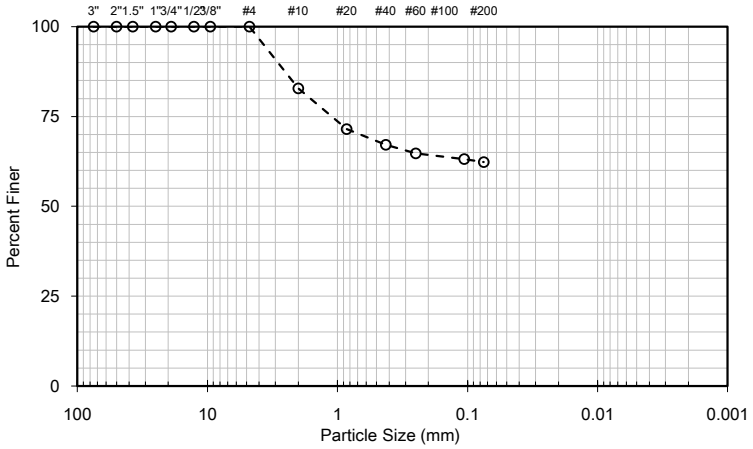
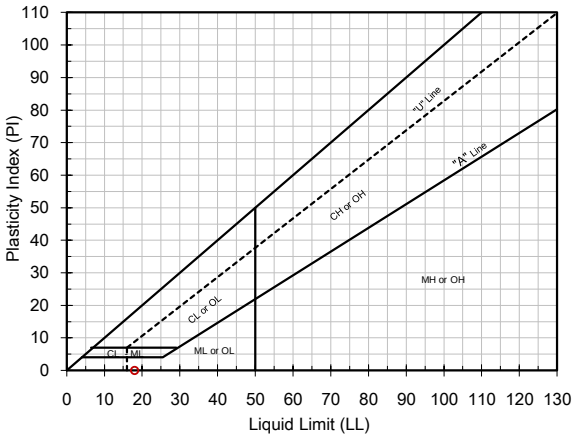
Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: PWCG-3 (38-40)

TRI Log #: 22-000096.2





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	0.0	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	100.0	37.7	Hydrometer Log-Linear Interpolation			
No. 10	2.00	82.8		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	71.5		mm		mm	
No. 40	0.420	67.1					
No. 60	0.250	64.7		0.002	- -	0.002	- -
No. 140	0.106	63.1		N m,2μm,d	-	N m,2μm,nd	-
No. 200	0.074	62.3	62.3	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	18
Plastic Limit	NP
Plastic Index	- -
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	2.2E+00	- -	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Sandy silt (ML)

Moisture Content (%)	ASTM D2216	- -
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

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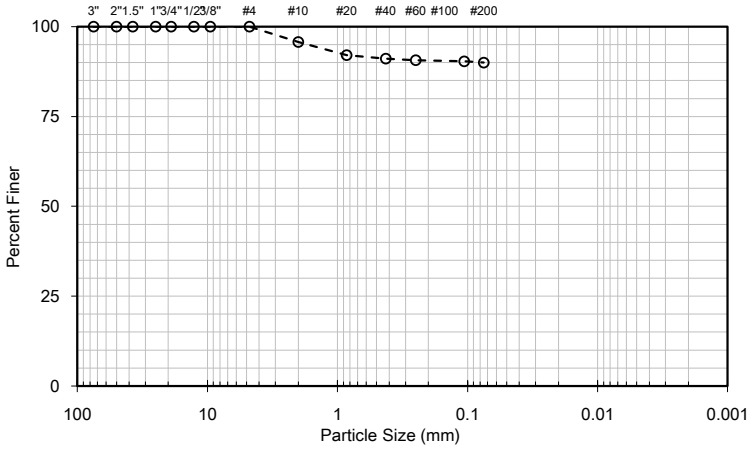
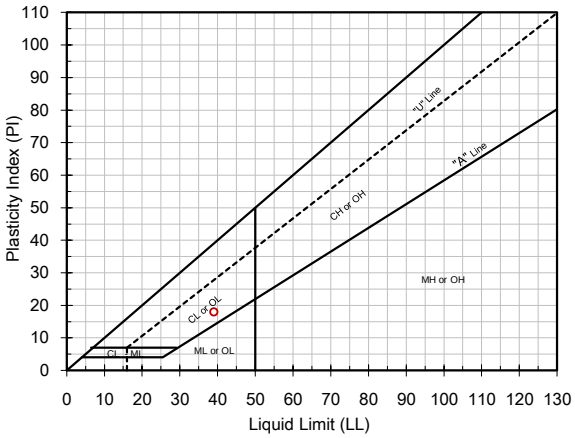
Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: PWCG-4 (25-30)

TRI Log #: 22-000096.3





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	0.0	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	100.0	10.0	Hydrometer Log-Linear Interpolation			
No. 10	2.00	95.7		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	92.1		mm		mm	
No. 40	0.420	91.1					
No. 60	0.250	90.7		0.002	- -	0.002	- -
No. 140	0.106	90.3		N m,2µm,d	-	N m,2µm,nd	-
No. 200	0.074	90.0	90.0	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	39
Plastic Limit	21
Plastic Index	18
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	- -	- -	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Lean clay (CL)

Moisture Content (%)	ASTM D2216	- -
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

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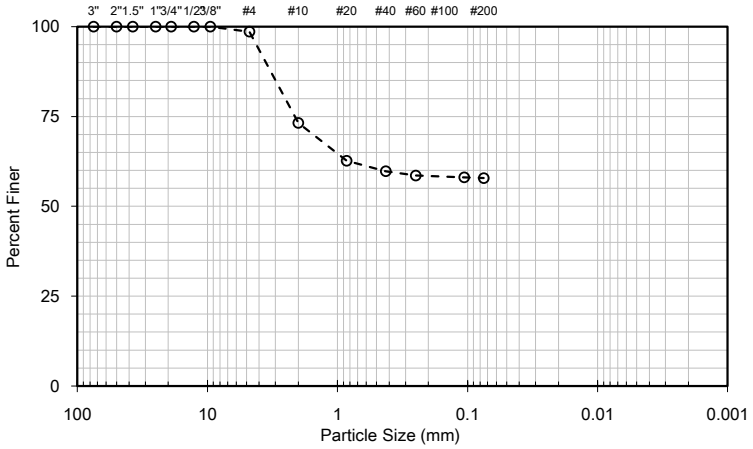
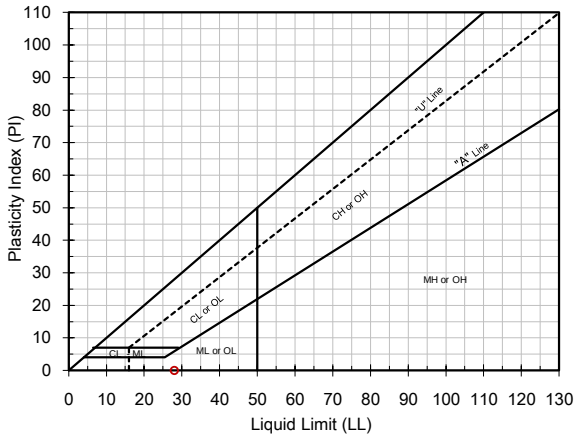
Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: PWCG-4 (37.5-40)

TRI Log #: 22-000096.4





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	1.4	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	98.6	40.8	Hydrometer Log-Linear Interpolation			
No. 10	2.00	73.2		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	62.7					
No. 40	0.420	59.8		mm		mm	
No. 60	0.250	58.6		0.002	- -	0.002	- -
No. 140	0.106	58.1		N m,2μm,d	-	N m,2μm,nd	-
No. 200	0.074	57.8	57.8	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	28
Plastic Limit	NP
Plastic Index	- -
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	3.0E+00	4.5E-01	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Sandy silt (ML)

Moisture Content (%)	ASTM D2216	- -
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

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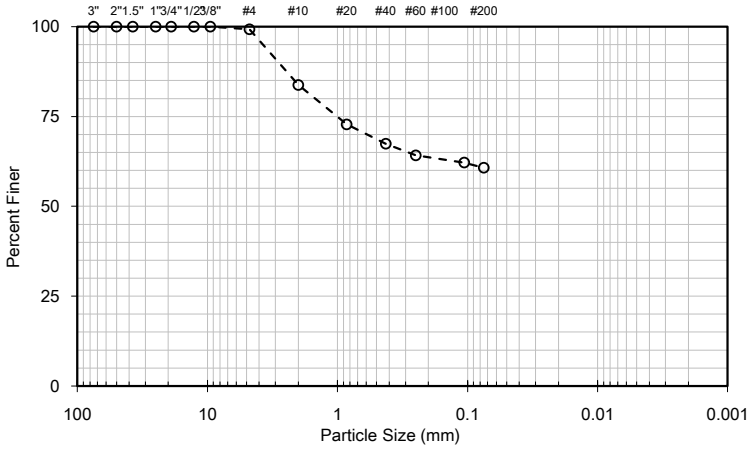
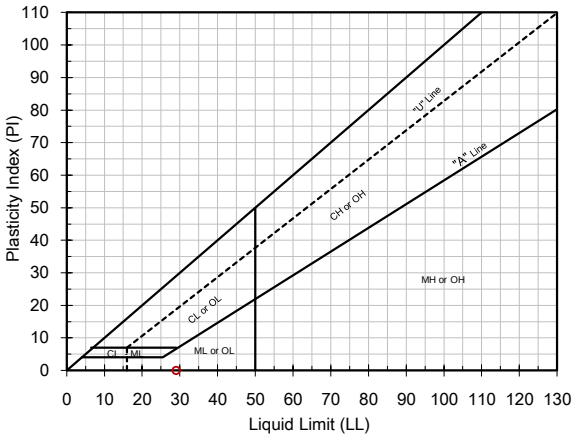
Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: PWCG-5 (25-30)

TRI Log #: 22-000096.5





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	0.7	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	99.3	38.6	Hydrometer Log-Linear Interpolation			
No. 10	2.00	83.8		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	72.8		mm		mm	
No. 40	0.420	67.4					
No. 60	0.250	64.2		0.002	- -	0.002	- -
No. 140	0.106	62.2		N m,2μm,d	-	N m,2μm,nd	-
No. 200	0.074	60.7	60.7	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	29
Plastic Limit	NP
Plastic Index	- -
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	2.1E+00	- -	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Sandy silt (ML)

Moisture Content (%)	ASTM D2216	- -
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

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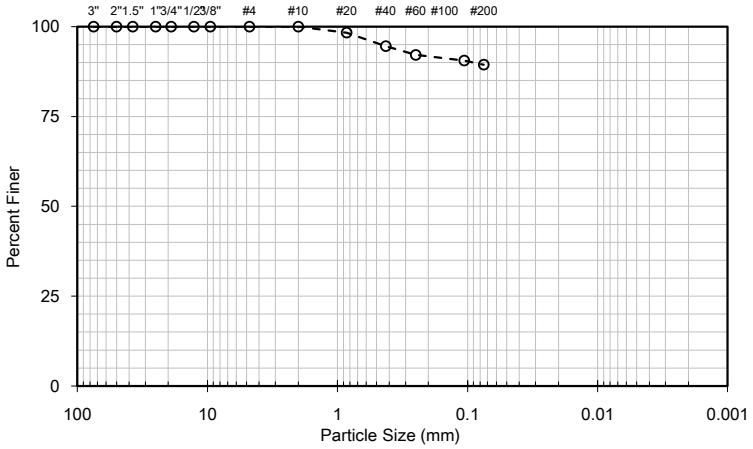
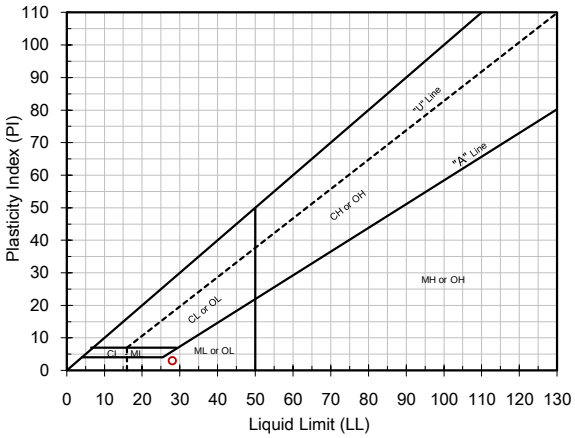
Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: PWCG-6 (9-11)

TRI Log #: 22-000096.6





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	0.0	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	100.0	10.6	Hydrometer Log-Linear Interpolation			
No. 10	2.00	100.0		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	98.3		mm		mm	
No. 40	0.420	94.6					
No. 60	0.250	92.1		0.002	- -	0.002	- -
No. 140	0.106	90.6		N m,2μm,d	-	N m,2μm,nd	-
No. 200	0.074	89.4	89.4	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	28
Plastic Limit	25
Plastic Index	3
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	- -	- -	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Silt (ML)

Moisture Content (%)	ASTM D2216	- -
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

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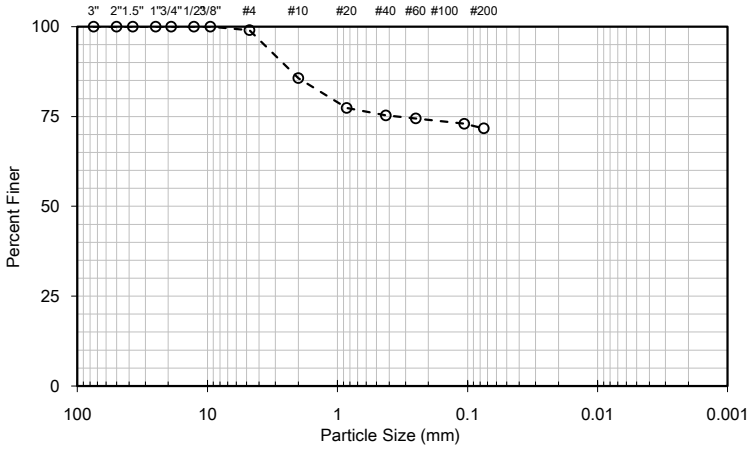
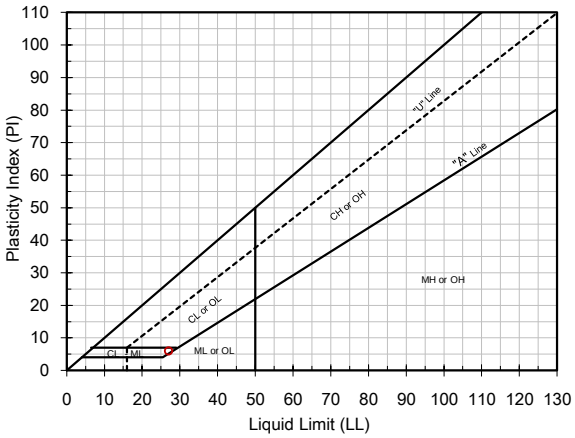
Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: WCG-10 (15-17.5)

TRI Log #: 22-000097.1





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	1.0	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	99.0	27.3	Hydrometer Log-Linear Interpolation			
No. 10	2.00	85.7		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	77.4		mm		mm	
No. 40	0.420	75.3					
No. 60	0.250	74.5		0.002	- -	0.002	- -
No. 140	0.106	73.0		N m,2μm,d	-	N m,2μm,nd	-
No. 200	0.074	71.7	71.7	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	27
Plastic Limit	21
Plastic Index	6
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	1.9E+00	- -	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Silty clay with sand (CL-ML)

Moisture Content (%)	ASTM D2216	3.6
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

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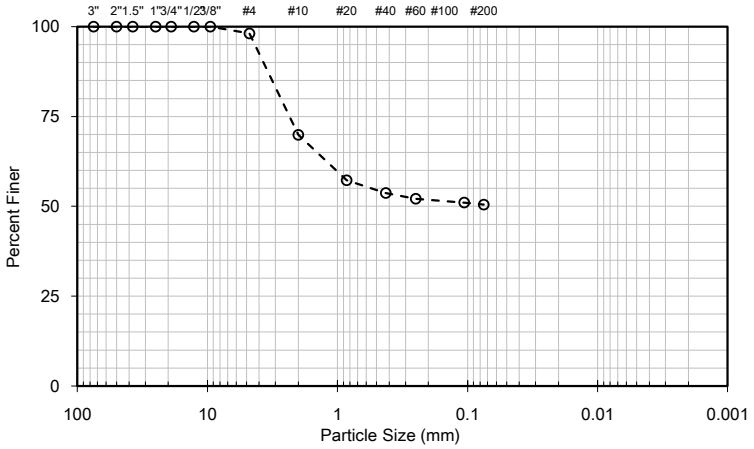
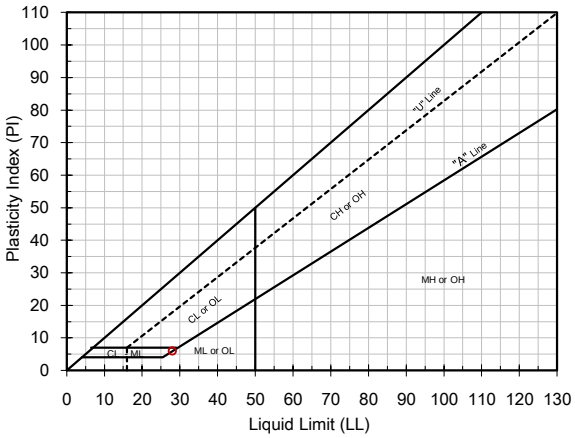
Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: WCG-15 (30-32.5)

TRI Log #: 22-000097.2





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	1.9	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	98.1	47.6	Hydrometer Log-Linear Interpolation			
No. 10	2.00	69.9		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	57.2					
No. 40	0.420	53.7		mm		mm	
No. 60	0.250	52.1		0.002	- -	0.002	- -
No. 140	0.106	51.1		N m,2μm,d	-	N m,2μm,nd	-
No. 200	0.074	50.5	50.5	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	28
Plastic Limit	22
Plastic Index	6
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	3.2E+00	1.0E+00	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Sandy silty clay (CL-ML)

Moisture Content (%)	ASTM D2216	3.7
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

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Analysis & Quality Review/Date

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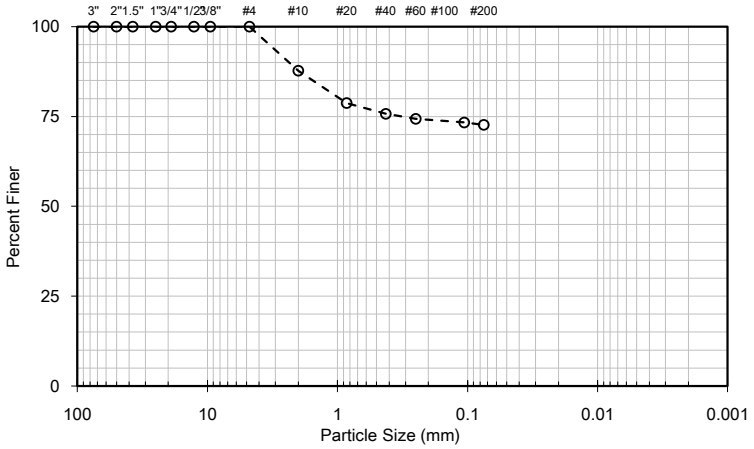
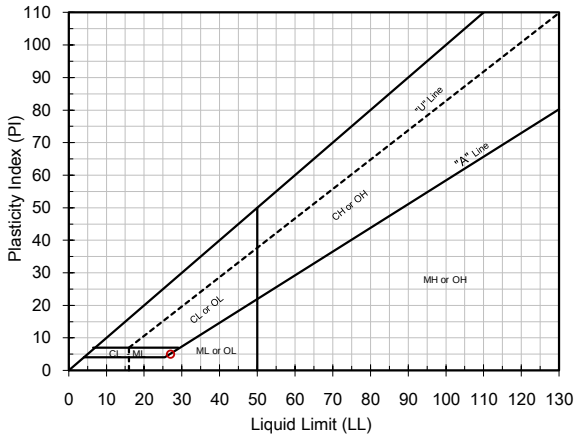
Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: WCG-19 (17.5-20)

TRI Log #: 22-000097.3





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	0.0	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	100.0	27.3	Hydrometer Log-Linear Interpolation			
No. 10	2.00	87.7		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	78.7		mm		mm	
No. 40	0.420	75.7					
No. 60	0.250	74.3		0.002	- -	0.002	- -
No. 140	0.106	73.3		N m,2μm,d	-	N m,2μm,nd	-
No. 200	0.074	72.7	72.7	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	27
Plastic Limit	22
Plastic Index	5
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	1.5E+00	- -	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Silt with sand (ML)

Moisture Content (%)	ASTM D2216	4.9
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

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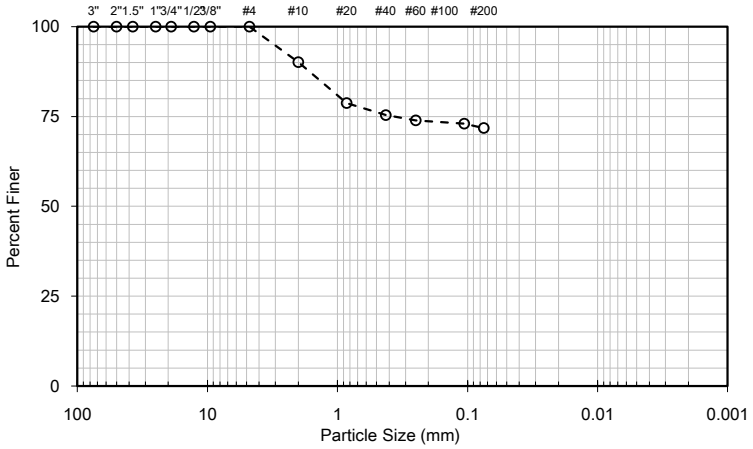
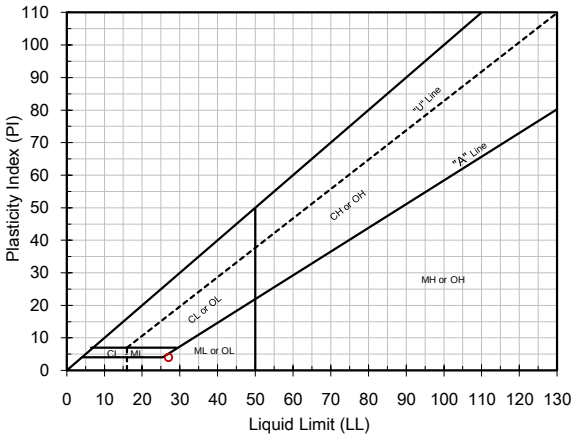
Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: WCG-19 (25-27.5)

TRI Log #: 22-000097.4





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	0.0	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	100.0	28.2	Hydrometer Log-Linear Interpolation			
No. 10	2.00	90.1		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	78.7		mm		mm	
No. 40	0.420	75.4					
No. 60	0.250	73.9		0.002	- -	0.002	- -
No. 140	0.106	73.0		N m,2μm,d	-	N m,2μm,nd	-
No. 200	0.074	71.8	71.8	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	27
Plastic Limit	23
Plastic Index	4
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	1.4E+00	- -	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Silt with sand (ML)

Moisture Content (%)	ASTM D2216	6.0
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

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Hydraulic Conductivity (ASTM D5084)

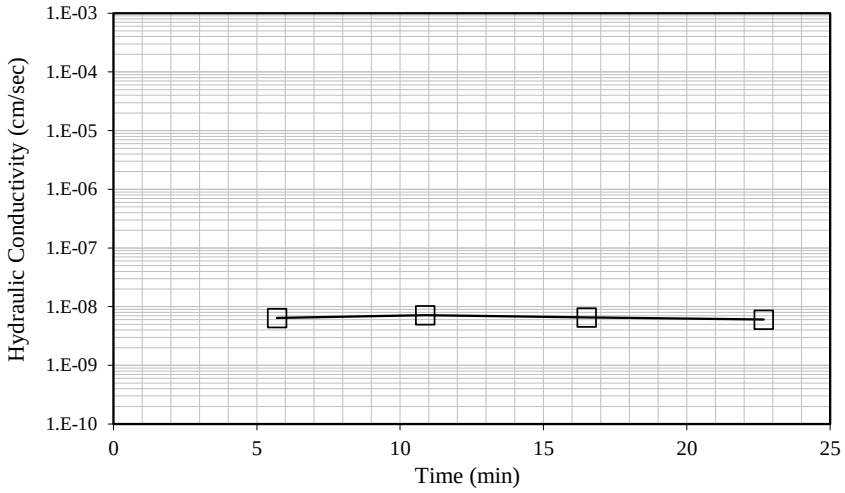
Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: PWCG-3 (27-29)

TRI Log #: 22-000096-01

Sample Condition	Initial	Final
	Intact	Post-Test
Diameter (in)	2.03	2.01
Height (in)	1.57	1.58
Mass (g)	181.8	184.7
Sample Area (in^2)	3.23	3.17
Water Content (%)	10.1	12.1
Total Unit Weight (pcf)	136.3	140.6
Dry Unit Weight (pcf)	123.8	125.5
Specific Gravity (Assumed)	2.75	
Degree of Saturation	72.1	90.3
Void Ratio	0.39	0.37
Porosity	0.28	0.27
1 Pore Volume (cc)	23.2	22.0

Eff. Confining Stress (psi)	5.0
Back-Pressure	80.0
B-Value Prior to Permeation	0.98
Permeant	De-Aired Tap Water

Method F—Constant Volume–Falling Head by mercury, rising tailwater elevation			
Manometer Constants		Aa (cm^2)	0.767
M1	0.0302	Ap (cm^2)	0.0314
M2	1.041	Z_p (cm)	0
Time, t	Trial Constant, Z_1	Gradient	K_{20}
Min	-	-	cm/s
5.7	20.2	63.4	6.5E-09
10.9	20.1	63.1	7.2E-09
16.5	20.0	62.8	6.6E-09
22.7	19.9	62.4	6.0E-09
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
Average, Last 2 Readings			**6.3E-09**



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Hydraulic Conductivity (ASTM D5084)

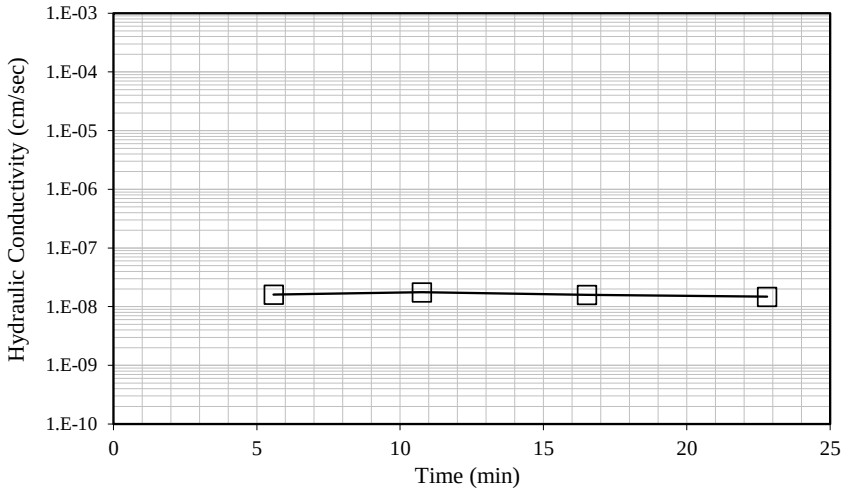
Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: PWCG-3 (38-40)

TRI Log #: 22-000096-02

Sample Condition	Initial	Final
	Intact	Post-Test
Diameter (in)	2.01	2.00
Height (in)	1.91	1.80
Mass (g)	234.2	235.2
Sample Area (in^2)	3.16	3.16
Water Content (%)	4.9	5.3
Total Unit Weight (pcf)	147.9	157.5
Dry Unit Weight (pcf)	141.0	149.6
Specific Gravity (Assumed)	2.75	
Degree of Saturation	62.2	99.4
Void Ratio	0.22	0.15
Porosity	0.18	0.13
1 Pore Volume (cc)	17.6	12.0

Eff. Confining Stress (psi)	5.0
Back-Pressure	80.0
B-Value Prior to Permeation	0.99
Permeant	De-Aired Tap Water

Method F—Constant Volume–Falling Head by mercury, rising tailwater elevation			
Manometer Constants		Aa (cm^2)	0.767
M1	0.0302	Ap (cm^2)	0.0314
M2	1.041	Z_p (cm)	0
Time, t	Trial Constant, Z_1	Gradient	K_{20}
Min	-	-	cm/s
5.6	20.4	52.9	1.6E-08
10.7	20.2	52.4	1.8E-08
16.5	20.0	51.8	1.6E-08
22.8	19.8	51.3	1.5E-08
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
Average, Last 2 Readings			**1.5E-08**



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M-1-28

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Hydraulic Conductivity (ASTM D5084)

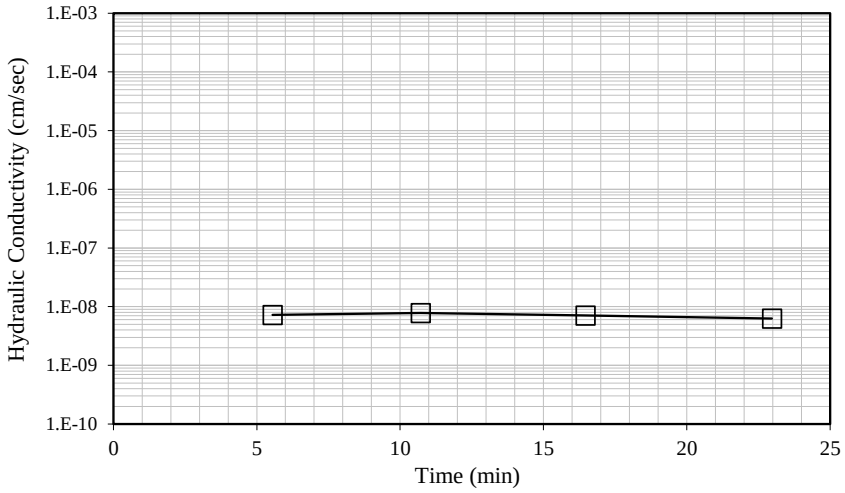
Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: PWCG-4 (25-30)

TRI Log #: 22-000096-03

Sample Condition	Initial	Final
	Intact	Post-Test
Diameter (in)	1.98	1.98
Height (in)	1.57	1.62
Mass (g)	180.0	182.6
Sample Area (in^2)	3.08	3.08
Water Content (%)	9.8	12.5
Total Unit Weight (pcf)	141.2	139.1
Dry Unit Weight (pcf)	128.5	123.6
Specific Gravity (Assumed)	2.75	
Degree of Saturation	80.7	88.5
Void Ratio	0.34	0.39
Porosity	0.25	0.28
1 Pore Volume (cc)	20.0	22.9

Eff. Confining Stress (psi)	5.0
Back-Pressure	80.0
B-Value Prior to Permeation	0.99
Permeant	De-Aired Tap Water

Method F—Constant Volume–Falling Head by mercury, rising tailwater elevation			
Manometer Constants		Aa (cm^2)	0.767
M1	0.0302	Ap (cm^2)	0.0314
M2	1.041	Z_p (cm)	0
Time, t	Trial Constant, Z_1	Gradient	K_{20}
Min	-	-	cm/s
5.5	19.4	60.8	7.2E-09
10.7	19.3	60.5	7.8E-09
16.5	19.2	60.1	7.1E-09
23.0	19.0	59.8	6.3E-09
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
Average, Last 2 Readings			**6.7E-09**



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Analysis & Quality Review/Date

M-1-29

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Hydraulic Conductivity (ASTM D5084)

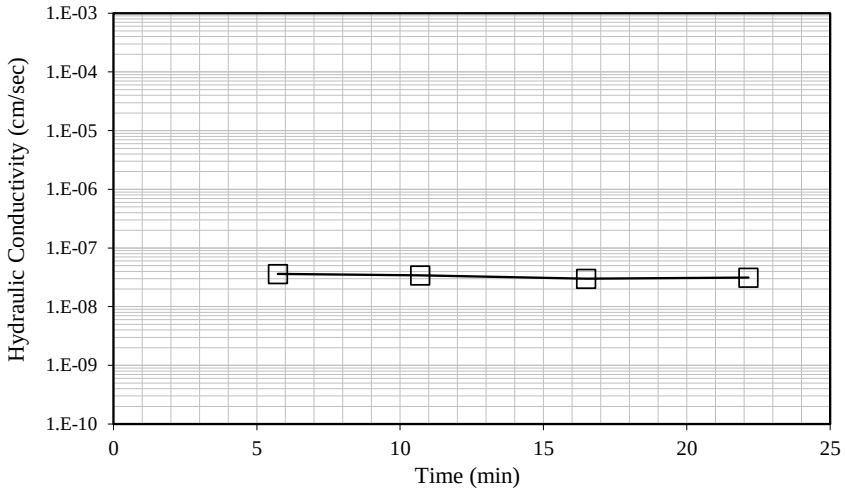
Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: PWCG-4 (37.5-40)

TRI Log #: 22-000096-04

Sample Condition	Initial	Final
	Intact	Post-Test
Diameter (in)	2.01	2.01
Height (in)	1.76	1.75
Mass (g)	220.6	222.4
Sample Area (in^2)	3.18	3.17
Water Content (%)	5.5	6.9
Total Unit Weight (pcf)	150.2	152.8
Dry Unit Weight (pcf)	142.3	142.9
Specific Gravity (Assumed)	2.75	
Degree of Saturation	73.8	94.9
Void Ratio	0.21	0.20
Porosity	0.17	0.17
1 Pore Volume (cc)	15.7	15.2

Eff. Confining Stress (psi)	5.0
Back-Pressure	80.0
B-Value Prior to Permeation	0.92
Permeant	De-Aired Tap Water

Method F—Constant Volume–Falling Head by mercury, rising tailwater elevation			
Manometer Constants		Aa (cm^2)	0.767
M1	0.0302	Ap (cm^2)	0.0314
M2	1.041	Z_p (cm)	0
Time, t	Trial Constant, Z_1	Gradient	K_{20}
Min	-	-	cm/s
5.7	20.5	57.6	3.6E-08
10.7	20.0	56.1	3.4E-08
16.5	19.6	55.0	3.0E-08
22.2	19.2	53.8	3.1E-08
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
Average, Last 2 Readings			**3.1E-08**



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Analysis & Quality Review/Date

M-1-30

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Hydraulic Conductivity (ASTM D5084)

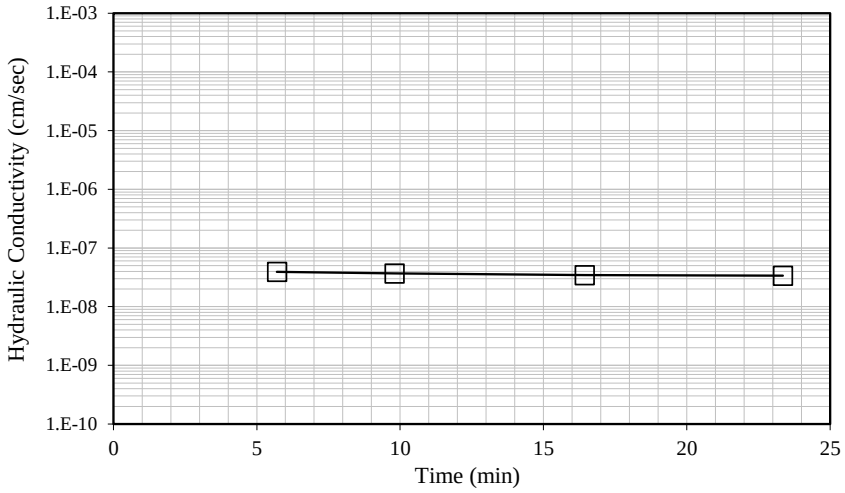
Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: PWCG-5 (25-30)

TRI Log #: 22-000096-05

Sample Condition	Initial	Final
	Intact	Post-Test
Diameter (in)	2.03	2.03
Height (in)	3.08	3.10
Mass (g)	401.5	405.2
Sample Area (in^2)	3.23	3.24
Water Content (%)	3.4	4.7
Total Unit Weight (pcf)	153.8	153.9
Dry Unit Weight (pcf)	148.7	146.9
Specific Gravity (Assumed)	2.75	
Degree of Saturation	61.2	77.6
Void Ratio	0.15	0.17
Porosity	0.13	0.14
1 Pore Volume (cc)	21.7	23.7

Eff. Confining Stress (psi)	5.0
Back-Pressure	80.0
B-Value Prior to Permeation	#NUM!
Permeant	De-Aired Tap Water

Method F—Constant Volume–Falling Head by mercury, rising tailwater elevation			
Manometer Constants		Aa (cm^2)	0.767
M1	0.0302	Ap (cm^2)	0.0314
M2	1.041	Z_p (cm)	0
Time, t	Trial Constant, Z_1	Gradient	K_{20}
Min	-	-	cm/s
5.7	19.6	31.4	3.9E-08
9.8	19.3	30.9	3.7E-08
16.4	19.0	30.6	3.5E-08
23.4	18.7	30.1	3.4E-08
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
Average, Last 2 Readings			**3.4E-08**



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Analysis & Quality Review/Date

M-1-31

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Hydraulic Conductivity (ASTM D5084)

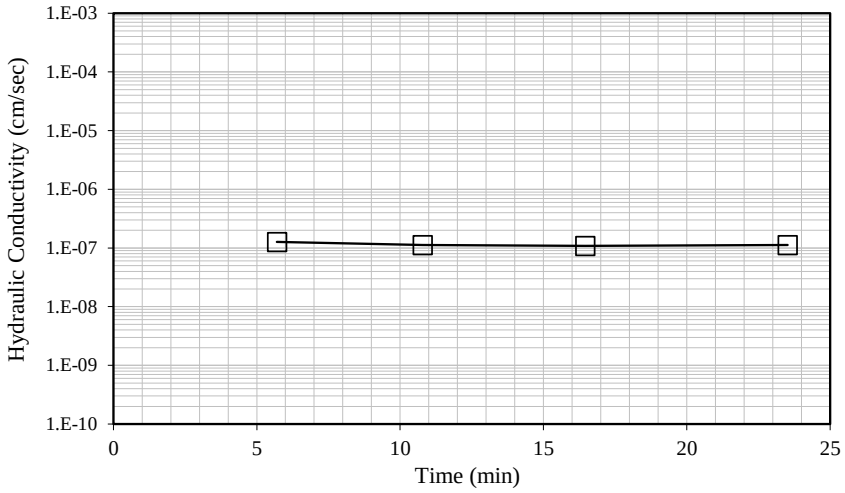
Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: PWCG-6 (9-11)

TRI Log #: 22-000096-06

Sample Condition	Initial	Final
	Intact	Post-Test
Diameter (in)	2.79	2.79
Height (in)	3.52	3.53
Mass (g)	761.5	776.5
Sample Area (in^2)	6.10	6.11
Water Content (%)	16.6	15.3
Total Unit Weight (pcf)	135.3	137.2
Dry Unit Weight (pcf)	116.0	119.0
Specific Gravity (Assumed)	2.75	
Degree of Saturation	95.4	95.4
Void Ratio	0.48	0.44
Porosity	0.32	0.31
1 Pore Volume (cc)	113.8	108.3

Eff. Confining Stress (psi)	5.0
Back-Pressure	80.0
B-Value Prior to Permeation	0.97
Permeant	De-Aired Tap Water

Method F—Constant Volume–Falling Head by mercury, rising tailwater elevation			
Manometer Constants		Aa (cm^2)	0.767
M1	0.0302	Ap (cm^2)	0.0314
M2	1.041	Z_p (cm)	0
Time, t	Trial Constant, Z_1	Gradient	K_{20}
Min	-	-	cm/s
5.7	18.9	26.6	1.3E-07
10.8	17.4	24.4	1.1E-07
16.5	16.2	22.8	1.1E-07
23.5	15.1	21.2	1.1E-07
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
Average, Last 2 Readings			**1.1E-07**



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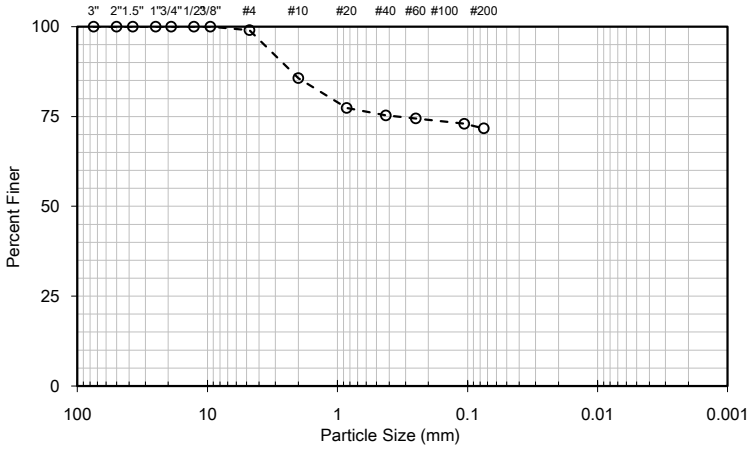
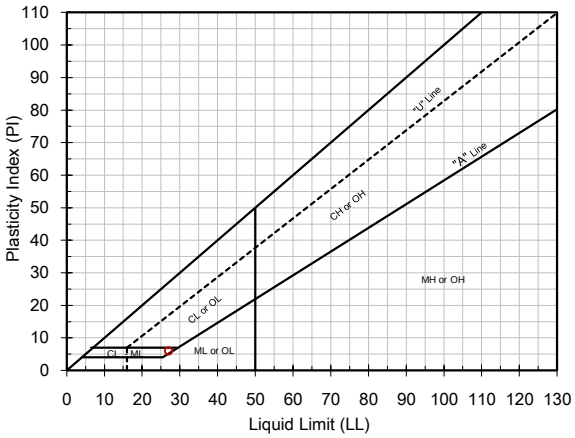
9063 BEE CAVES RD. – AUSTIN, TX 78733 – USA | PH: 800.880.TEST OR 512.263.2101

Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: WCG-10 (15-17.5)

TRI Log #: 22-000097.1





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	1.0	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	99.0	27.3	Hydrometer Log-Linear Interpolation			
No. 10	2.00	85.7		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	77.4		mm		mm	
No. 40	0.420	75.3					
No. 60	0.250	74.5		0.002	- -	0.002	- -
No. 140	0.106	73.0		N m,2μm,d	-	N m,2μm,nd	-
No. 200	0.074	71.7	71.7	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	27
Plastic Limit	21
Plastic Index	6
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	1.9E+00	- -	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Silty clay with sand (CL-ML)

Moisture Content (%)	ASTM D2216	3.6
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

Jeffrey A. Kuhn, Ph.D, P.E. 1/18/2023
Analysis & Quality Review/Date

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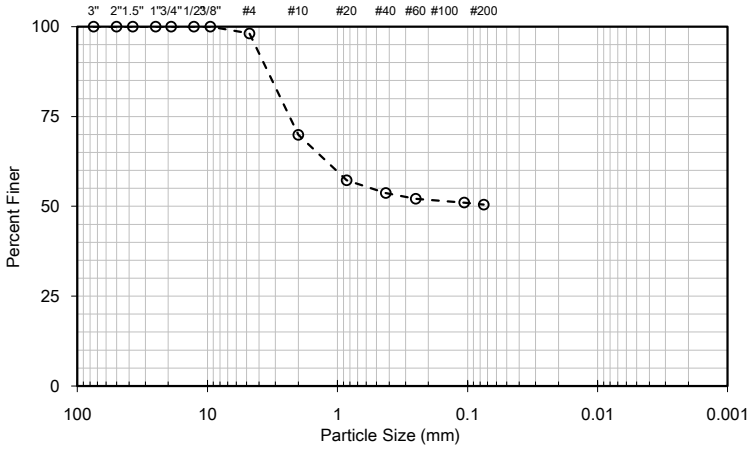
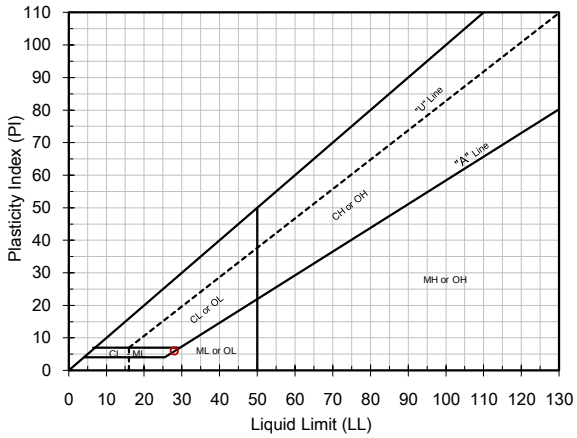
Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: WCG-15 (30-32.5)

TRI Log #: 22-000097.2





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	1.9	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	98.1	47.6	Hydrometer Log-Linear Interpolation			
No. 10	2.00	69.9		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	57.2					
No. 40	0.420	53.7		mm		mm	
No. 60	0.250	52.1		0.002	- -	0.002	- -
No. 140	0.106	51.1		N m,2μm,d	-	N m,2μm,nd	-
No. 200	0.074	50.5	50.5	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	28
Plastic Limit	22
Plastic Index	6
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	3.2E+00	1.0E+00	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Sandy silty clay (CL-ML)

Moisture Content (%)	ASTM D2216	3.7
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

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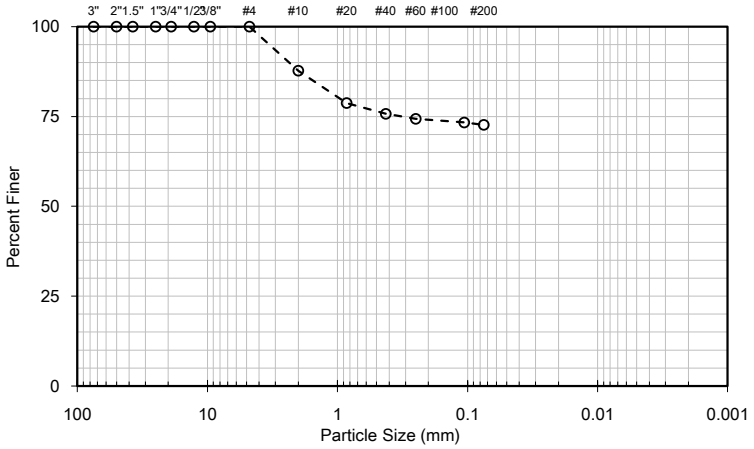
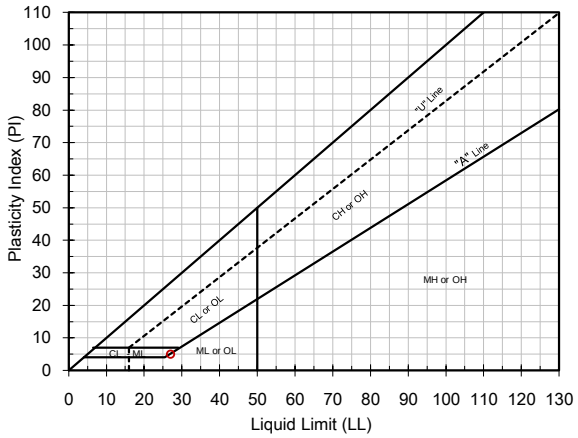
Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: WCG-19 (17.5-20)

TRI Log #: 22-000097.3





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	0.0	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	100.0	27.3	Hydrometer Log-Linear Interpolation			
No. 10	2.00	87.7		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	78.7		mm		mm	
No. 40	0.420	75.7					
No. 60	0.250	74.3		0.002	- -	0.002	- -
No. 140	0.106	73.3		N m,2μm,d	-	N m,2μm,nd	-
No. 200	0.074	72.7	72.7	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	27
Plastic Limit	22
Plastic Index	5
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	1.5E+00	- -	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Silt with sand (ML)

Moisture Content (%)	ASTM D2216	4.9
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

Jeffrey A. Kuhn, Ph.D, P.E. 1/18/2023
Analysis & Quality Review/Date

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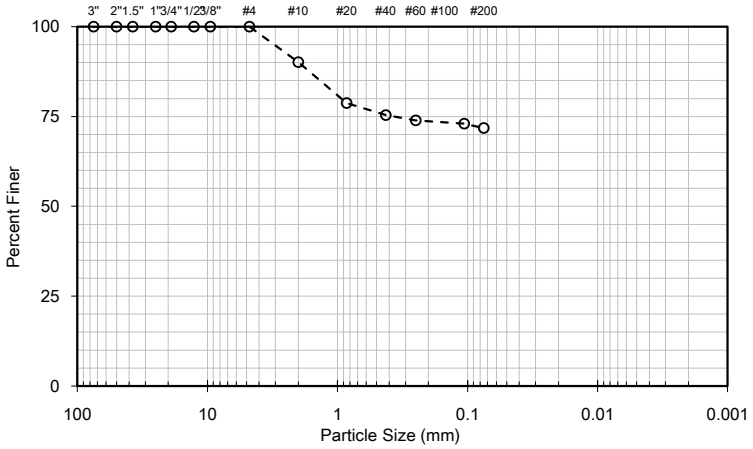
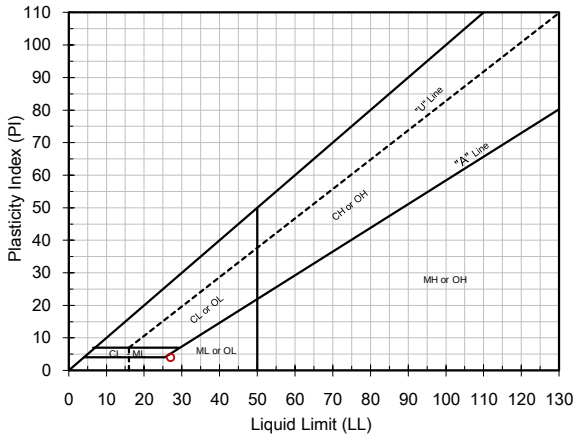
Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: Weaver Consultants Group
Project: 0086-364-1-19 Muskogee RDF Expansion
Sample ID: WCG-19 (25-27.5)

TRI Log #: 22-000097.4





Mechanical Sieve				Sedimentation (Hydrometer)			
ASTM D6913				ASTM D7928		ASTM D4221	
Sieve Designation		Percent Passing	Gravel / Sand / Fines	Particle Size	Percent Passing	Particle Size	Percent Passing
-	mm			mm		mm	
3 in.	76.2	100.0	0.0	- -	- -	- -	- -
2 in.	50.8	100.0		- -	- -	- -	- -
1.5 in.	38.1	100.0		- -	- -	- -	- -
1 in.	25.4	100.0		- -	- -	- -	- -
3/4 in.	19.0	100.0		- -	- -	- -	- -
1/2 in.	12.7	100.0		- -	- -	- -	- -
3/8 in.	9.51	100.0		- -	- -	- -	- -
No. 4	4.76	100.0	28.2	Hydrometer Log-Linear Interpolation			
No. 10	2.00	90.1		Particle Size	Percent Passing	Particle Size	Percent Passing
No. 20	0.841	78.7		mm		mm	
No. 40	0.420	75.4					
No. 60	0.250	73.9		0.002	- -	0.002	- -
No. 140	0.106	73.0		N m,2μm,d	-	N m,2μm,nd	-
No. 200	0.074	71.8	71.8	Percent Dispersion		-	

Atterberg Limits	
ASTM D4318, Method A : Multipoint, Air Dried	
Liquid Limit	27
Plastic Limit	23
Plastic Index	4
(NL = No Liquid Limit, NP = No Plastic Limit)	

Particle Size Log-Linear Interpolation					
D_x	85	60	50	30	10
mm	1.4E+00	- -	- -	- -	- -

Cu	- -	Cc	- -

USCS Classification (ASTM D2487)
Silt with sand (ML)

Moisture Content (%)	ASTM D2216	6.0
Organic Content (%)	ASTM D2974-C	- -
Carbonate Content (%)	ASTM D4373	- -
Specific Gravity	ASTM D854	- -

Jeffrey A. Kuhn, Ph.D, P.E. 1/18/2023
Analysis & Quality Review/Date

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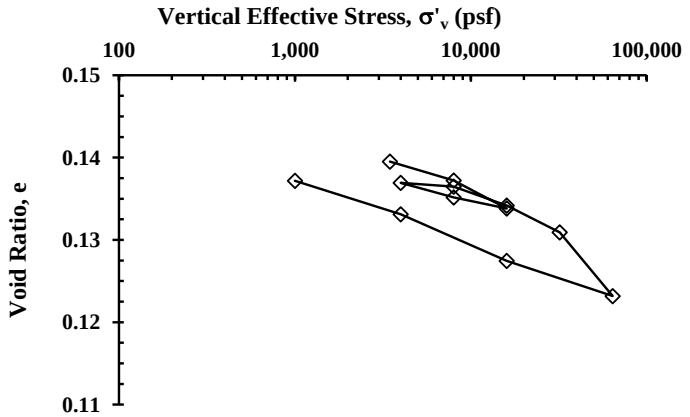
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

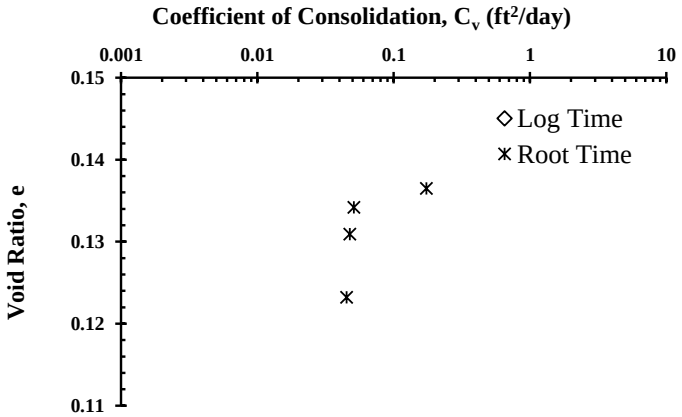
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-10 (17'- 20')

TRI Log No.: 23-00003.3
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

Soil Specimen Properties	Initial	Final
Water Content (%)	2.6	5.9
Diameter (in)	2.00	2.00
Height (in)	1.00	1.00
Dry Unit Weight, γ_o lb_f/ft^3	150.6	150.9
Specific Gravity (Assumed)	2.75	
Void Ratio, e	0.14	0.14
Degree of Saturation (%)	51.2	-

Test Setup		
Specimen Condition	●	Intact / "Undisturbed"
		Compacted/Remolded/Reconstituted
Test Water		Extracted Pore Water
	●	Potable Tap Water
		Demineralized Water
		Saline Water
		Other





Stage (#)	σ'_v (psf)	log (σ'_v) log (psf)	e (-)	Strain, ε (%)	$\delta e / \delta \log(\sigma'_v)$	C_α (x1,000)	t_{50} (min) Log Time	t_{50} (min) Root Time	C_v (ft^2/day) Log Time	C_v (ft^2/day) Root Time
1	3,466	3.54	0.140	0.00	-	-	-	-	-	-
2	8,000	3.90	0.137	0.20	-0.006	-	-	-	-	-
3	16,000	4.20	0.134	0.50	-0.011	-	-	-	-	-
4	8,000	3.90	0.135	0.38	-0.004	-	-	-	-	-
5	4,000	3.60	0.137	0.23	-0.006	-	-	-	-	-
6	8,000	3.90	0.136	0.27	-0.002	-	-	2.8	-	1.7E-01
7	16,000	4.20	0.134	0.47	-0.008	-	-	9.6	-	5.1E-02
8	32,000	4.51	0.131	0.76	-0.011	-	-	10.2	-	4.8E-02
9	64,000	4.81	0.123	1.43	-0.026	-	-	10.7	-	4.5E-02
10	16,000	4.20	0.127	1.06	-0.007	-	-	-	-	-
11	4,000	3.60	0.133	0.56	-0.009	-	-	-	-	-
12	1,000	3.00	0.137	0.21	-0.007	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-

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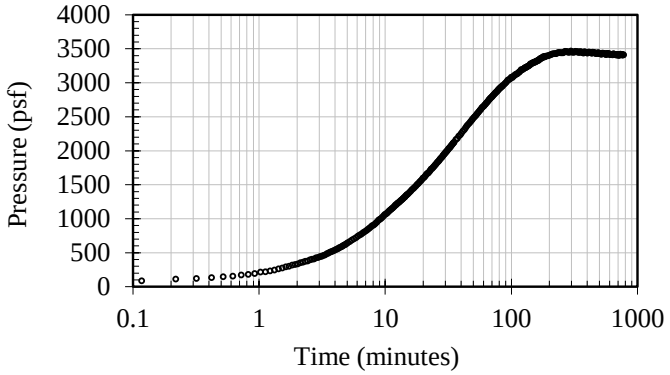
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

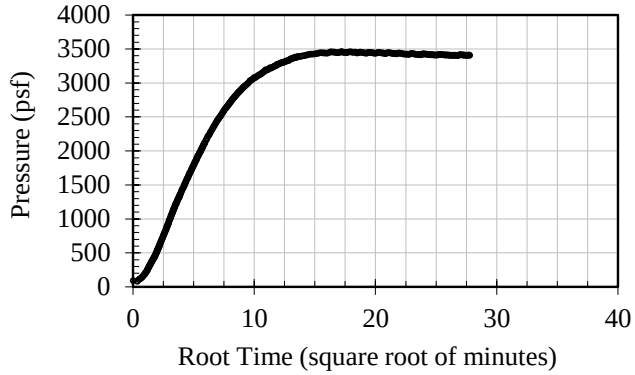
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-10 (17'- 20')

TRI Log No.: 23-00003.3
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

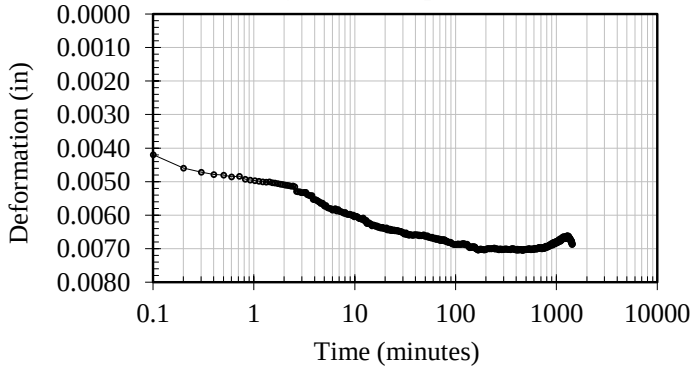
Stage 1: Swell Pressure Measurement



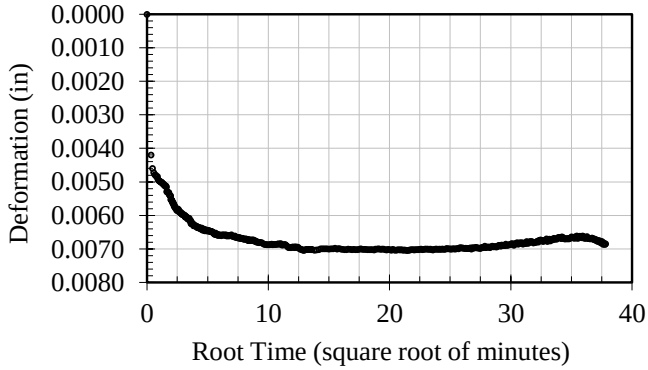
Stage 1: Swell Pressure Measurement



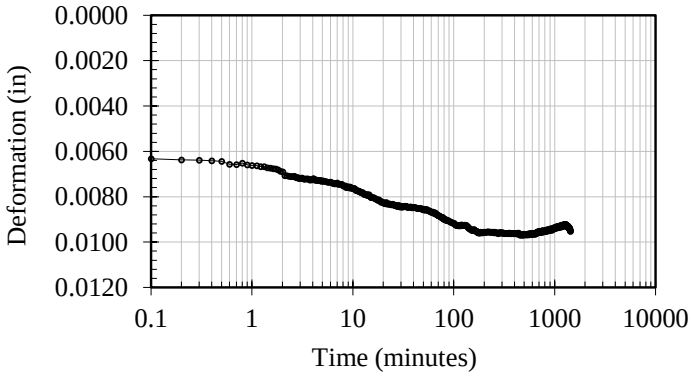
Stage 2: 8000 psf



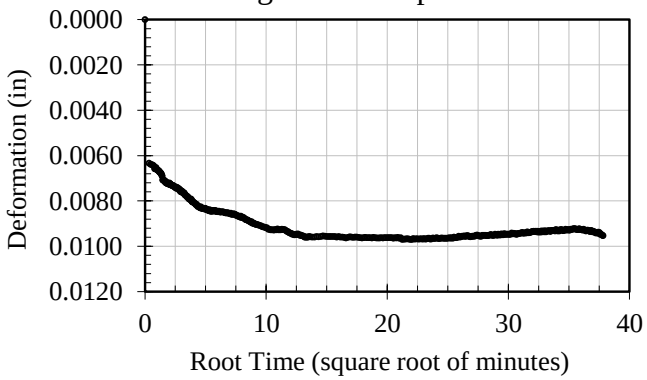
Stage 2: 8000 psf



Stage 3: 16000 psf



Stage 3: 16000 psf



M-1-38

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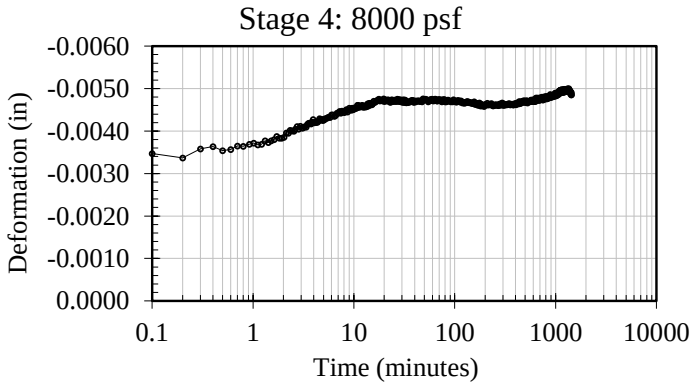
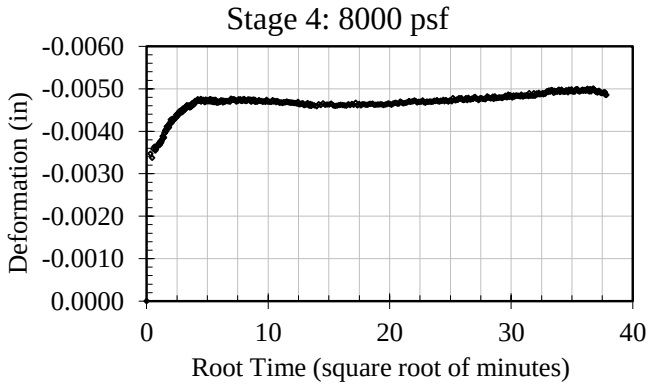
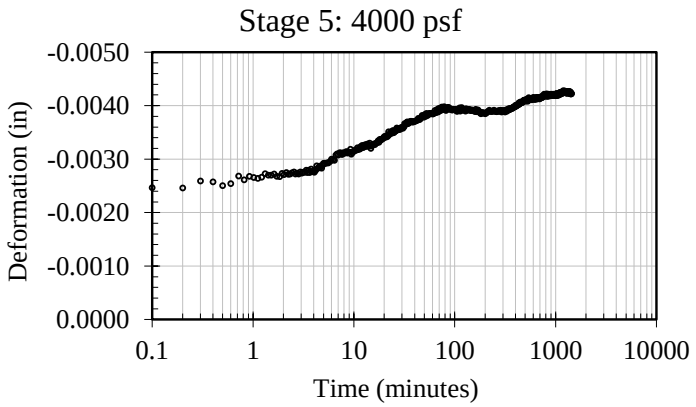
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

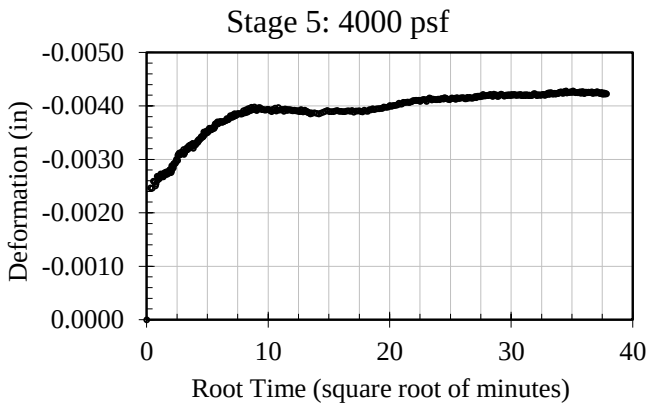
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-10 (17'- 20')

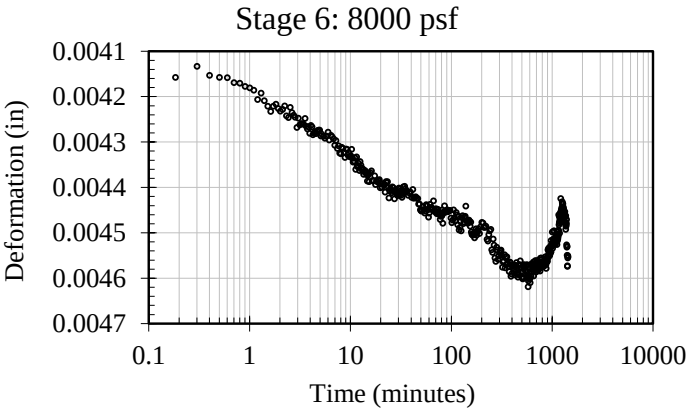
TRI Log No.: 23-00003.3
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

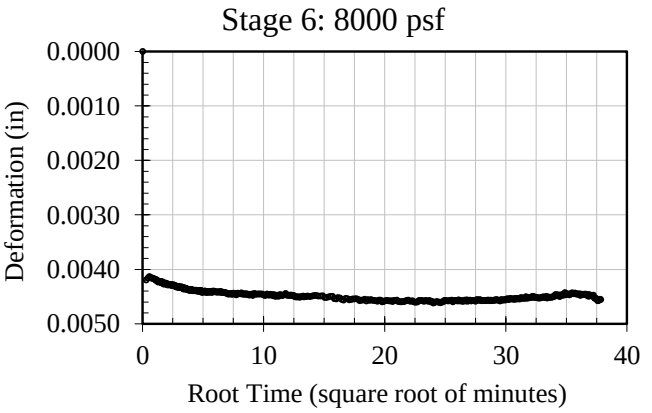












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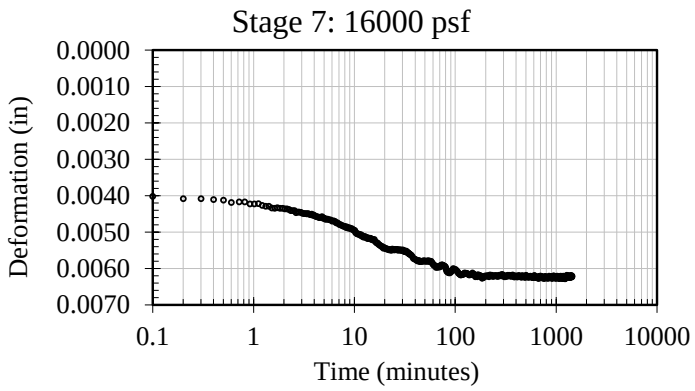
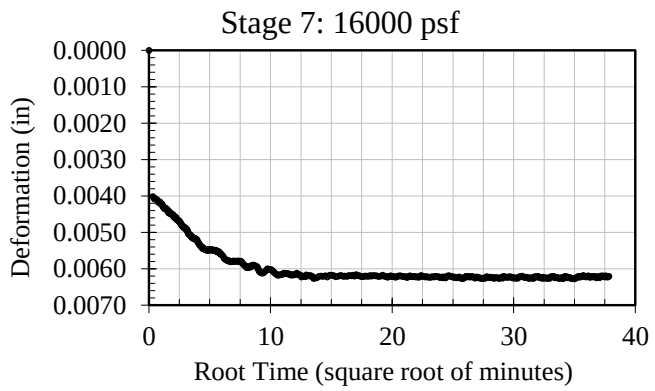
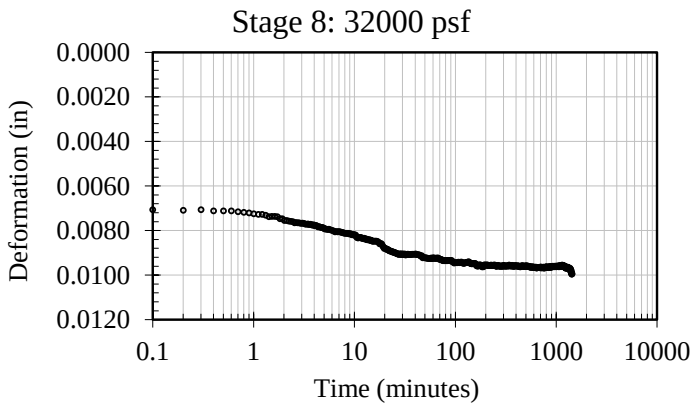
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

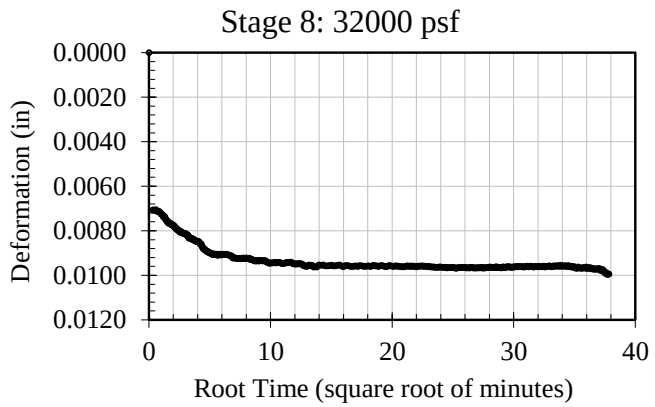
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-10 (17'- 20')

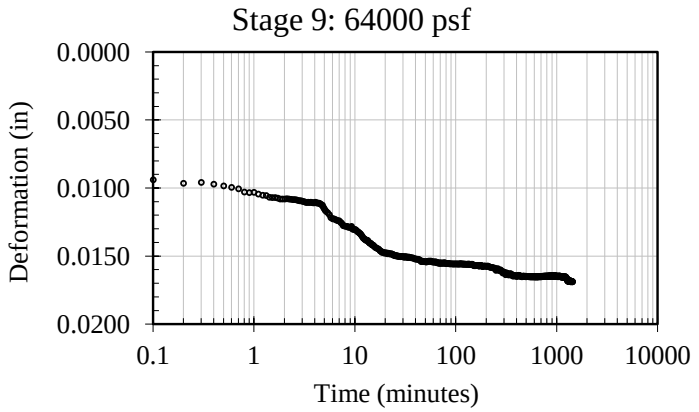
TRI Log No.: 23-00003.3
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

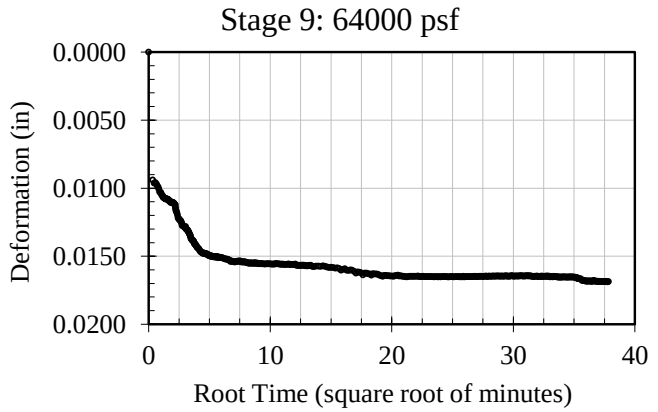












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One-Dimensional Consolidation Properties of Soil (ASTM D2435)

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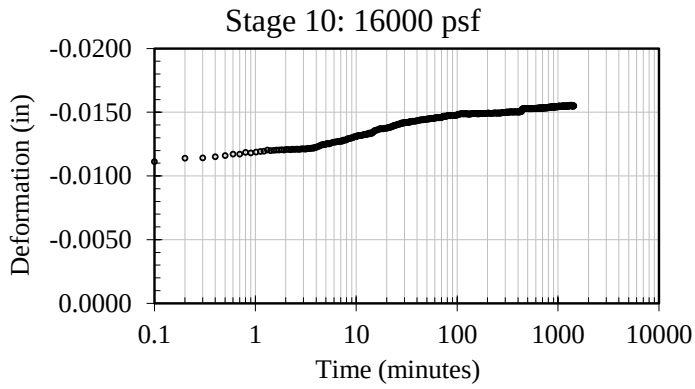
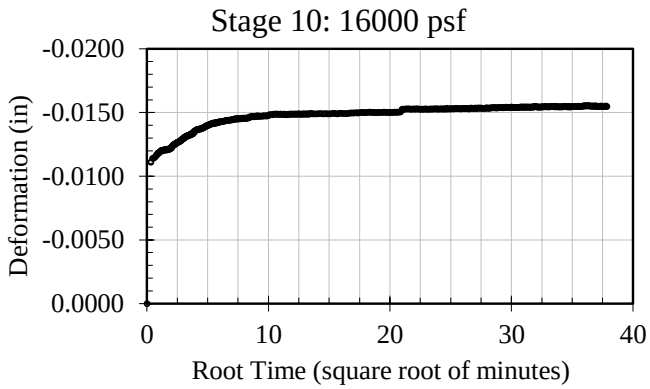
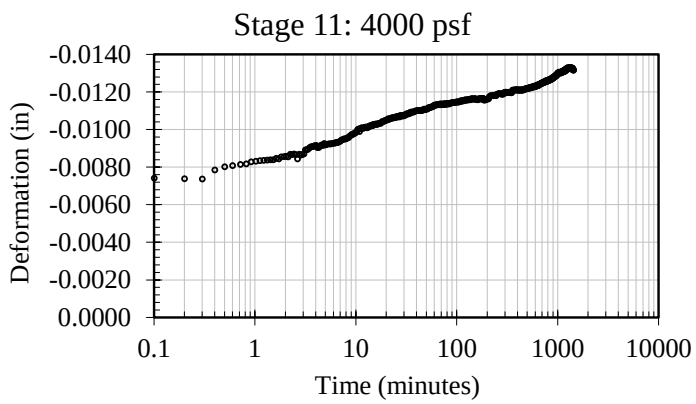
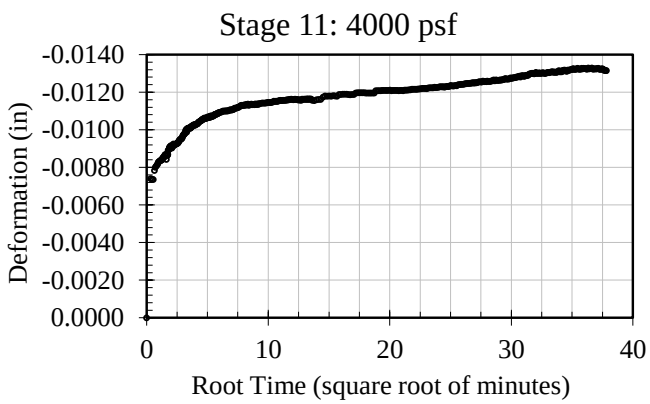
Specimen: WCG-10 (17'- 20')

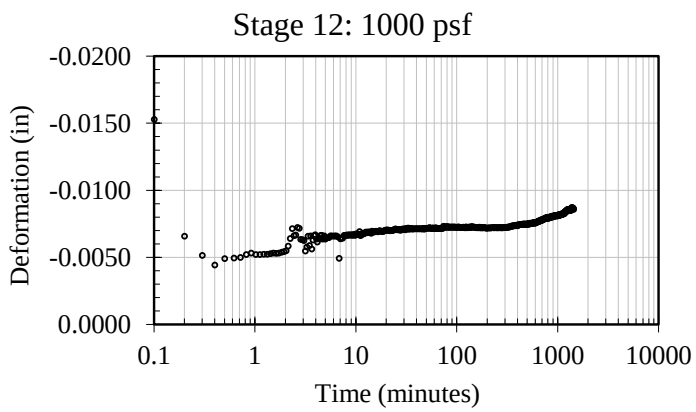
TRI Log No.: 23-00003.3
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

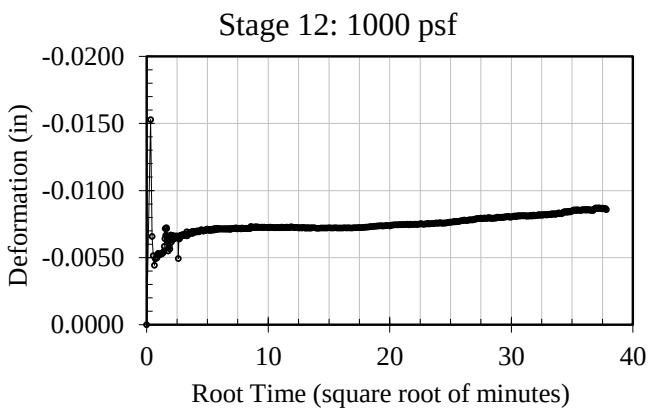












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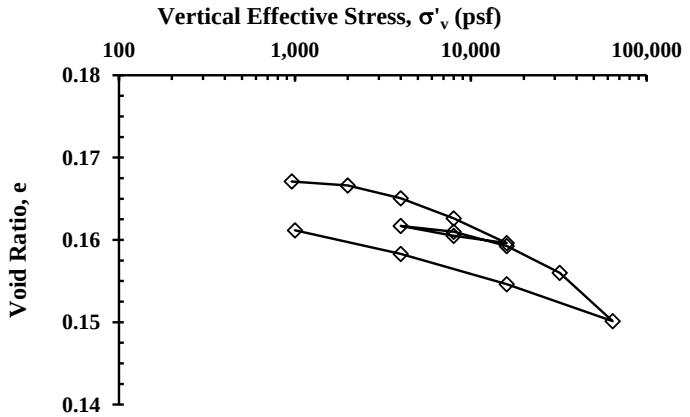
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

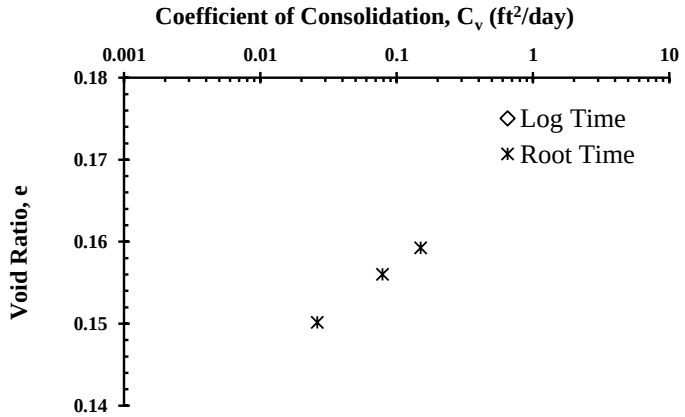
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-11 (45'- 47.5')

TRI Log No.: 23-00003.4
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

Soil Specimen Properties	Initial	Final
Water Content (%)	5.1	6.1
Diameter (in)	2.00	2.00
Height (in)	1.00	1.00
Dry Unit Weight, γ_o lb_f/ft^3	147.1	147.8
Specific Gravity (Assumed)	2.75	
Void Ratio, e	0.17	0.16
Degree of Saturation (%)	84.5	-

Test Setup		
Specimen Condition	●	Intact / "Undisturbed"
		Compacted/Remolded/Reconstituted
Test Water		Extracted Pore Water
	●	Potable Tap Water
		Demineralized Water
		Saline Water
		Other





Stage (#)	σ'_v (psf)	log (σ'_v) log (psf)	e (-)	Strain, ε (%)	$\delta e / \delta \log(\sigma'_v)$	C_α (x1,000)	t_{50} (min) Log Time	t_{50} (min) Root Time	C_v (ft^2/day) Log Time	C_v (ft^2/day) Root Time
1	959	2.98	0.167	0.00	-	-	-	-	-	-
2	2,000	3.30	0.167	0.04	-0.001	-	-	-	-	-
3	4,000	3.60	0.165	0.17	-0.005	-	-	-	-	-
4	8,000	3.90	0.163	0.38	-0.008	-	-	-	-	-
5	16,000	4.20	0.160	0.64	-0.010	-	-	-	-	-
6	8,000	3.90	0.161	0.56	-0.003	-	-	-	-	-
7	4,000	3.60	0.162	0.46	-0.004	-	-	-	-	-
8	8,000	3.90	0.161	0.52	-0.002	-	-	-	-	-
9	16,000	4.20	0.159	0.67	-0.006	-	-	3.3	-	1.5E-01
10	32,000	4.51	0.156	0.95	-0.011	-	-	6.2	-	7.8E-02
11	64,000	4.81	0.150	1.45	-0.019	-	-	18.5	-	2.6E-02
12	16,000	4.20	0.155	1.07	-0.007	-	-	-	-	-
13	4,000	3.60	0.158	0.75	-0.006	-	-	-	-	-
14	1,000	3.00	0.161	0.51	-0.005	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-

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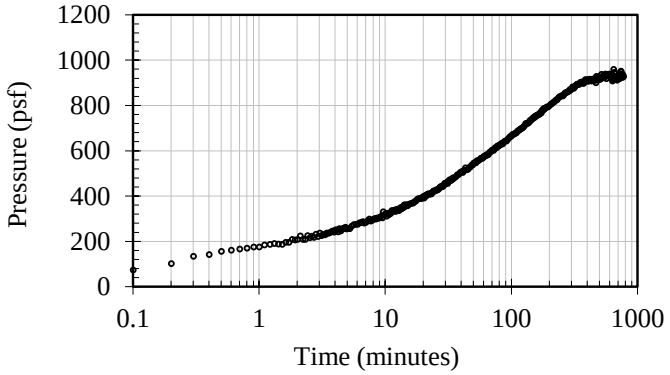
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

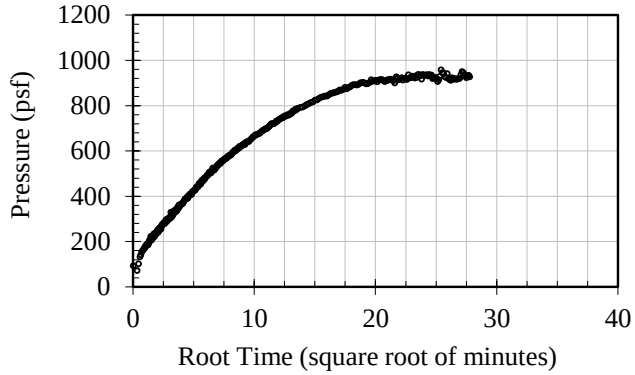
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-11 (45'- 47.5')

TRI Log No.: 23-00003.4
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

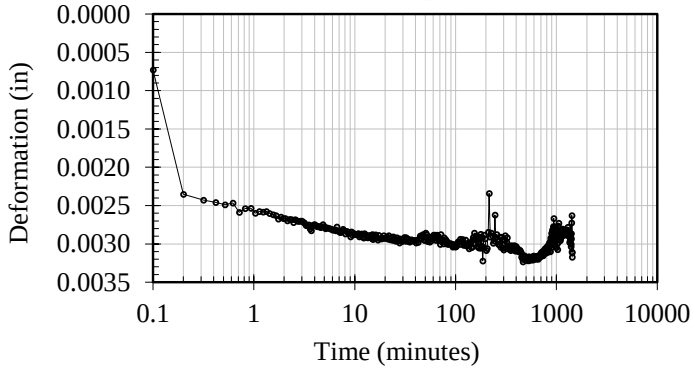
Stage 1: Swell Pressure Measurement



Stage 1: Swell Pressure Measurement



Stage 2: 2000 psf



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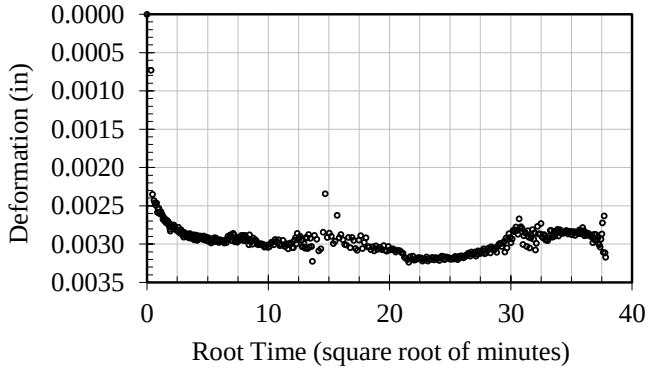
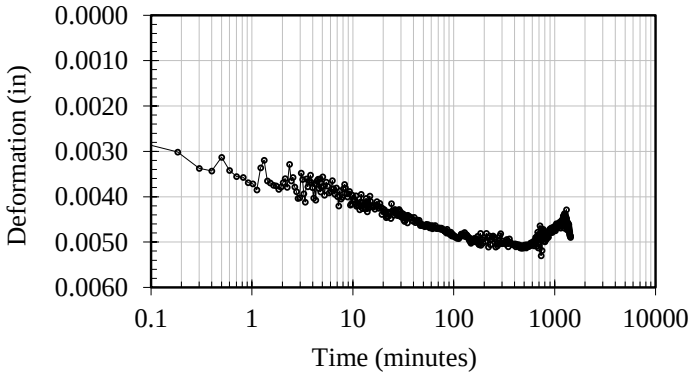
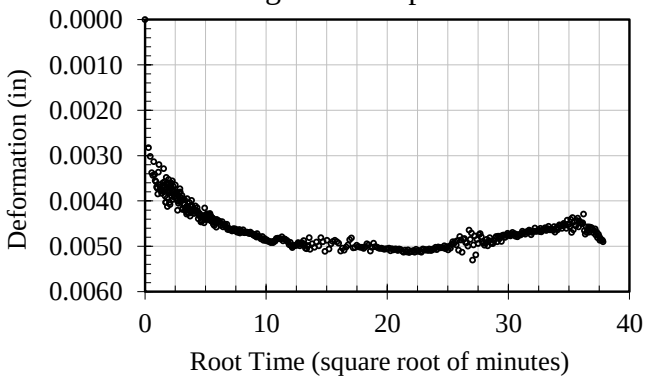


Stage 3: 4000 psf



Stage 3: 4000 psf



M-1-43

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One-Dimensional Consolidation Properties of Soil (ASTM D2435)

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Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-11 (45'- 47.5')

TRI Log No.: 23-00003.4
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
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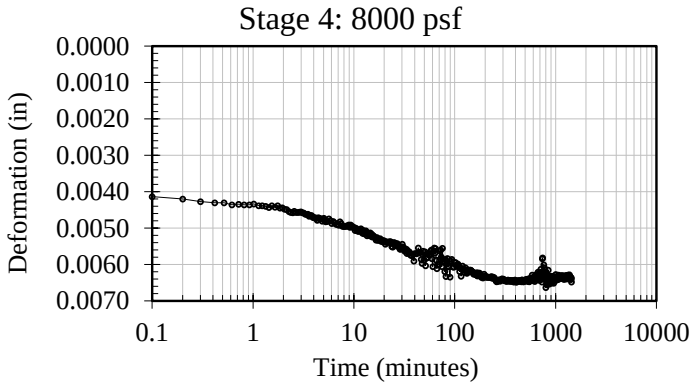

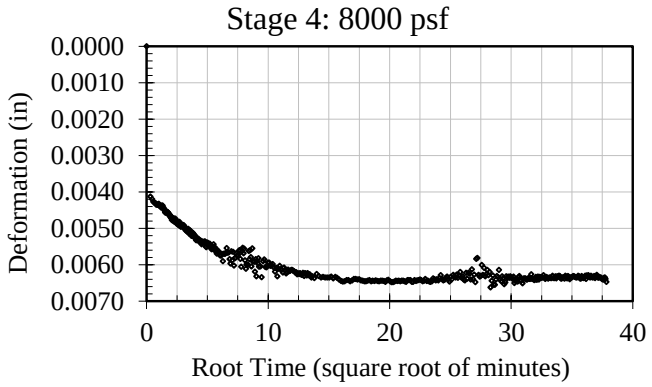

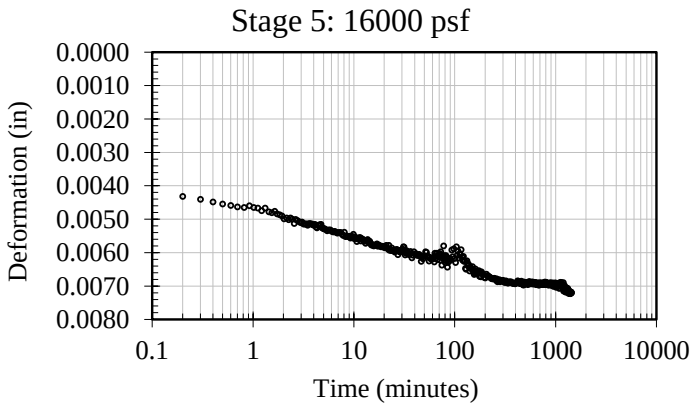

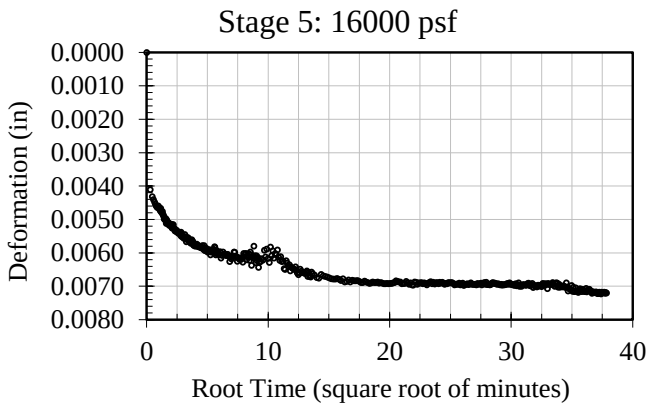

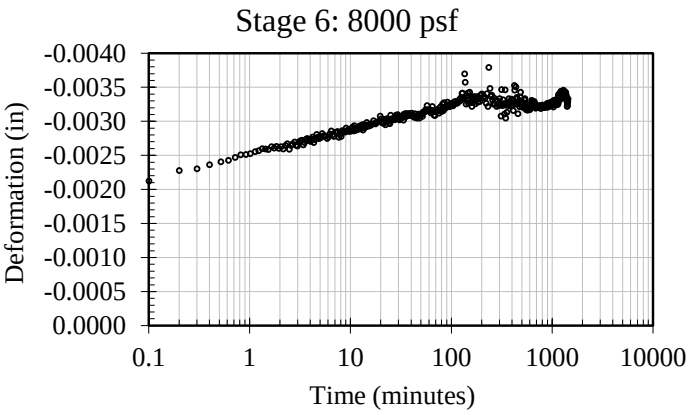

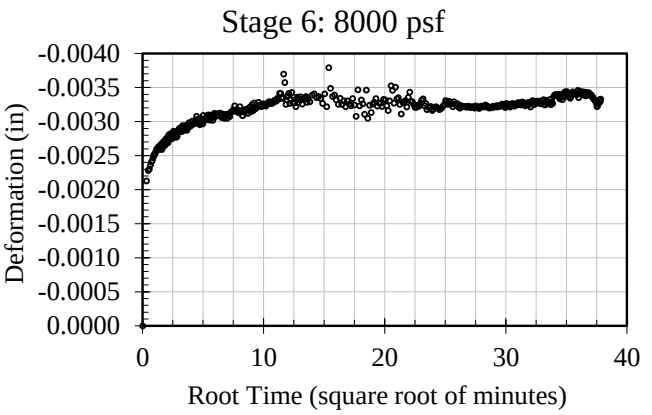

M-1-44

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One-Dimensional Consolidation Properties of Soil (ASTM D2435)

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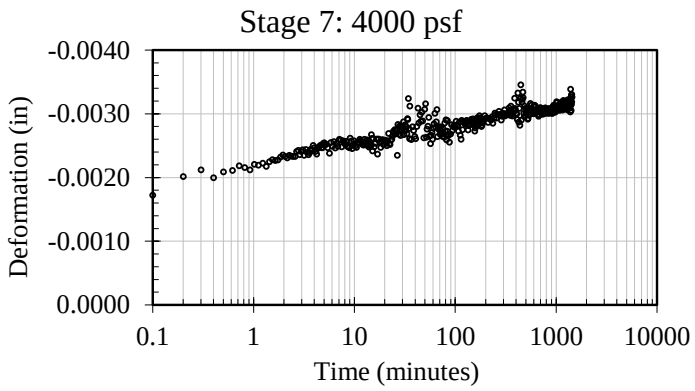
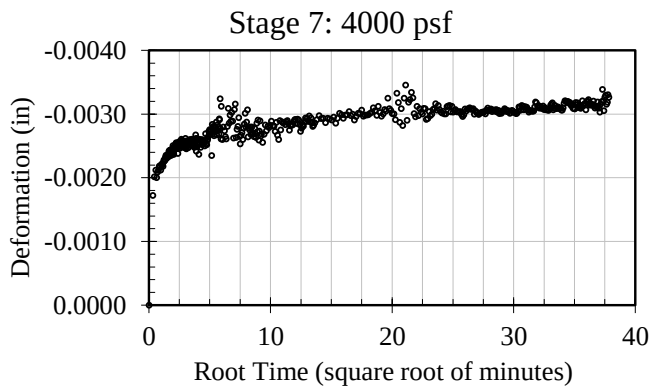
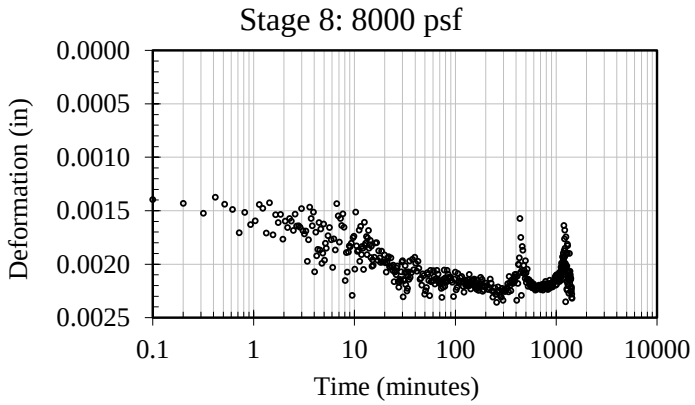
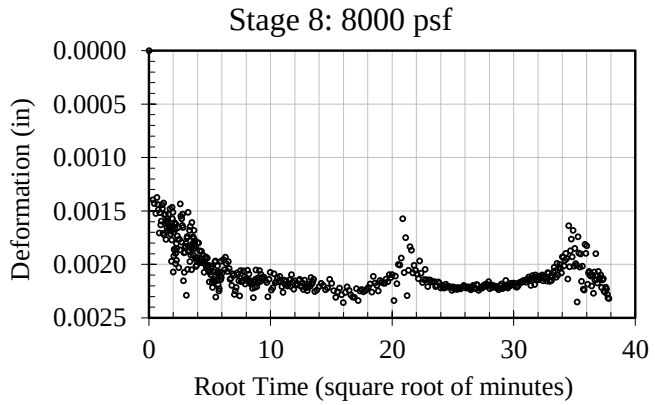
Specimen: WCG-11 (45'- 47.5')

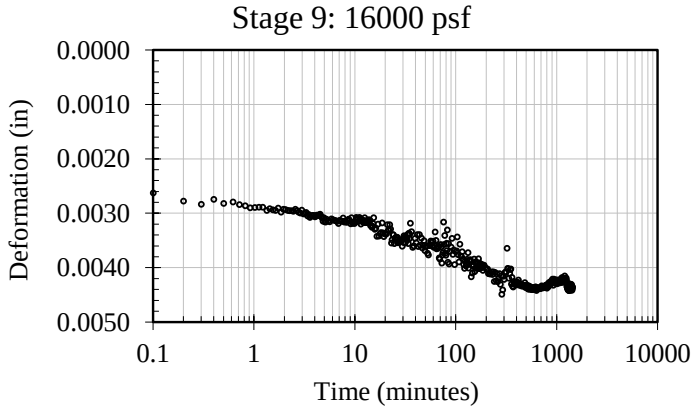
TRI Log No.: 23-00003.4
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

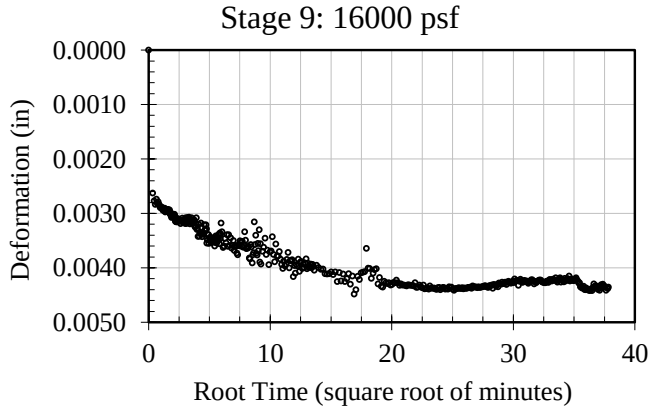












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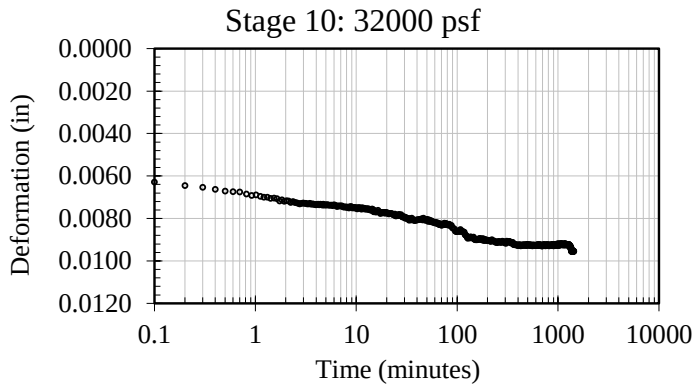

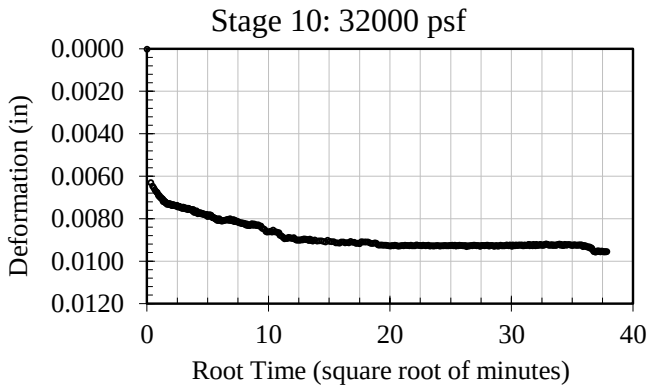

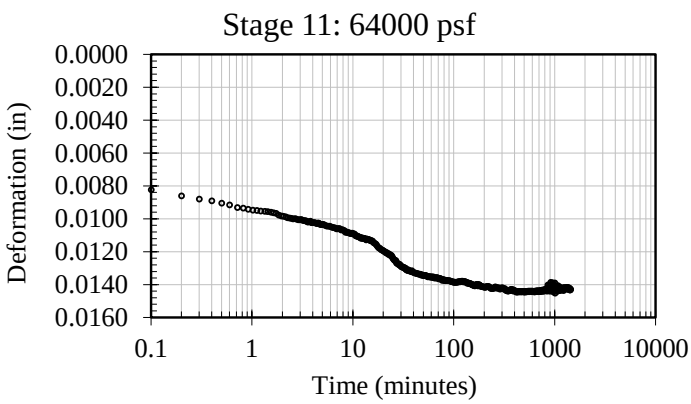

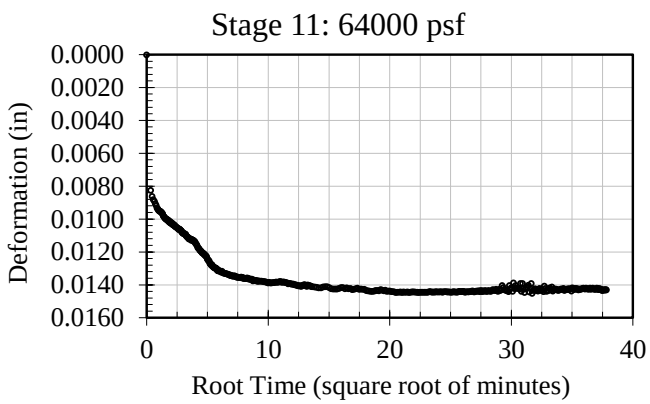

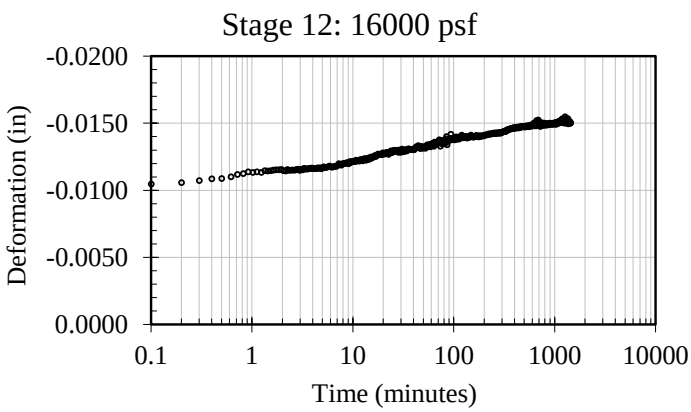

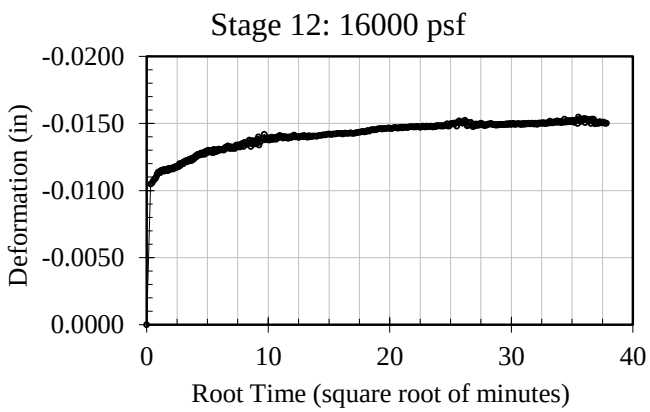

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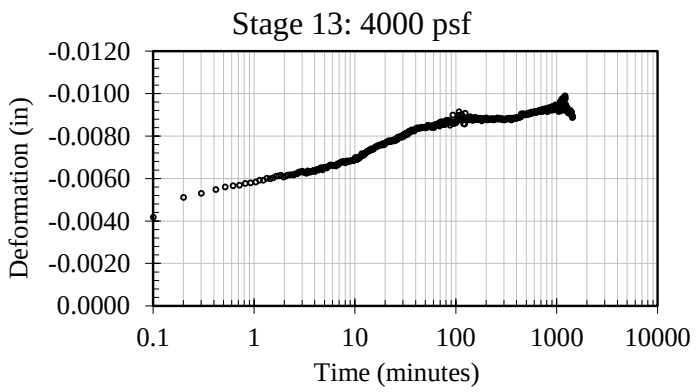
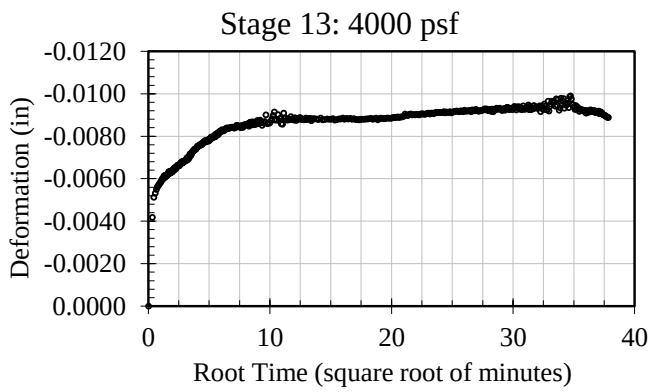
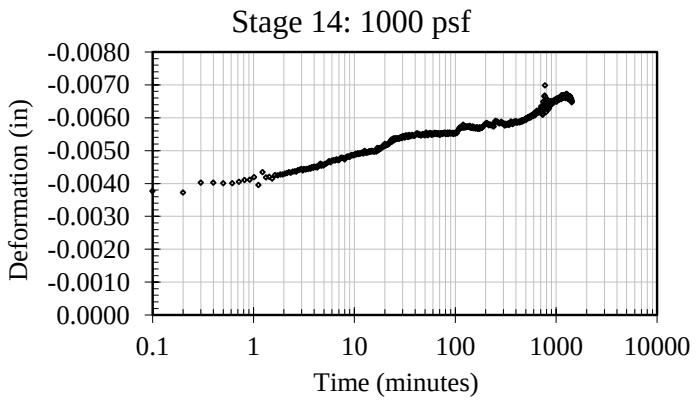
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

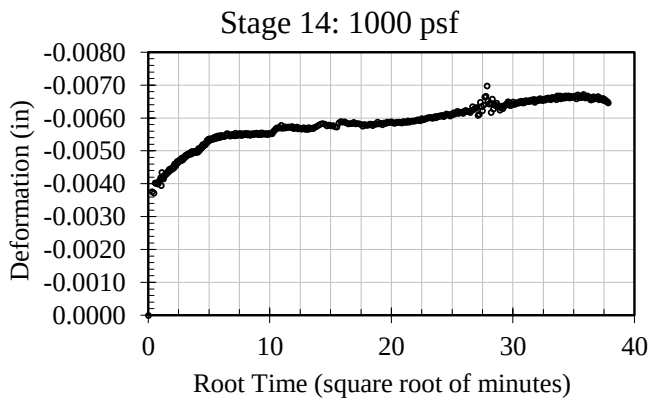
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-11 (45'- 47.5')

TRI Log No.: 23-00003.4
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date









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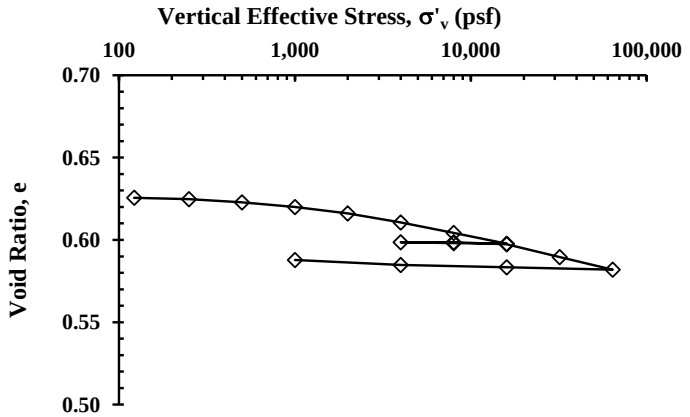
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

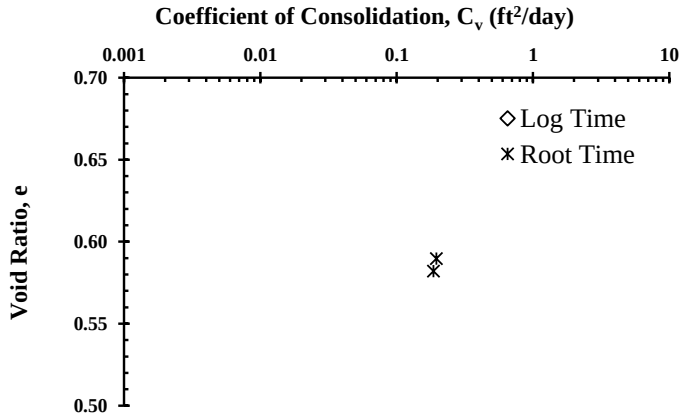
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-13 (11'- 13')

TRI Log No.: 23-00003.2
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

Soil Specimen Properties	Initial	Final
Water Content (%)	17.5	15.5
Diameter (in)	2.50	2.50
Height (in)	1.00	0.98
Dry Unit Weight, γ_o lb_f/ft^3	105.6	108.1
Specific Gravity (Assumed)	2.75	
Void Ratio, e	0.63	0.59
Degree of Saturation (%)	76.9	-

Test Setup		
Specimen Condition	●	Intact / "Undisturbed"
		Compacted/Remolded/Reconstituted
Test Water		Extracted Pore Water
	●	Potable Tap Water
		Demineralized Water
		Saline Water
		Other





Stage (#)	σ'_v (psf)	log (σ'_v) log (psf)	e (-)	Strain, ε (%)	$\delta e / \delta \log(\sigma'_v)$	C_α (x1,000)	t_{50} (min) Log Time	t_{50} (min) Root Time	C_v (ft^2/day) Log Time	C_v (ft^2/day) Root Time
1	122	2.09	0.626	0.00	-	-	-	-	-	-
2	250	2.40	0.625	0.05	-0.003	-	-	-	-	-
3	500	2.70	0.623	0.17	-0.006	-	-	-	-	-
4	1,000	3.00	0.620	0.34	-0.010	-	-	-	-	-
5	2,000	3.30	0.616	0.58	-0.013	-	-	-	-	-
6	4,000	3.60	0.611	0.91	-0.018	-	-	-	-	-
7	8,000	3.90	0.604	1.31	-0.021	-	-	-	-	-
8	16,000	4.20	0.598	1.72	-0.022	-	-	-	-	-
9	8,000	3.90	0.598	1.69	-0.001	-	-	-	-	-
10	4,000	3.60	0.599	1.66	-0.002	-	-	-	-	-
11	8,000	3.90	0.599	1.66	0.000	-	-	-	-	-
12	16,000	4.20	0.597	1.73	-0.004	-	-	-	-	-
13	32,000	4.51	0.590	2.21	-0.026	-	-	2.4	-	2.0E-01
14	64,000	4.81	0.582	2.68	-0.025	-	-	2.5	-	1.9E-01
15	16,000	4.20	0.583	2.59	-0.002	-	-	-	-	-
16	4,000	3.60	0.585	2.50	-0.002	-	-	-	-	-
17	1,000	3.00	0.588	2.33	-0.005	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-

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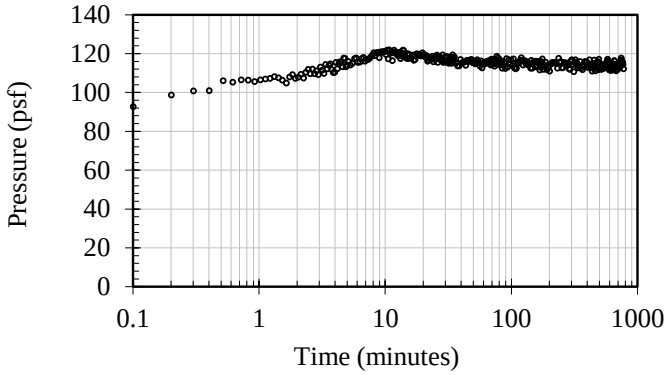
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

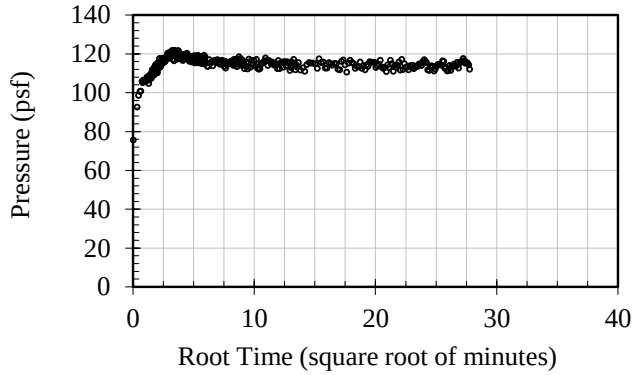
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-13 (11'- 13')

TRI Log No.: 23-00003.2
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

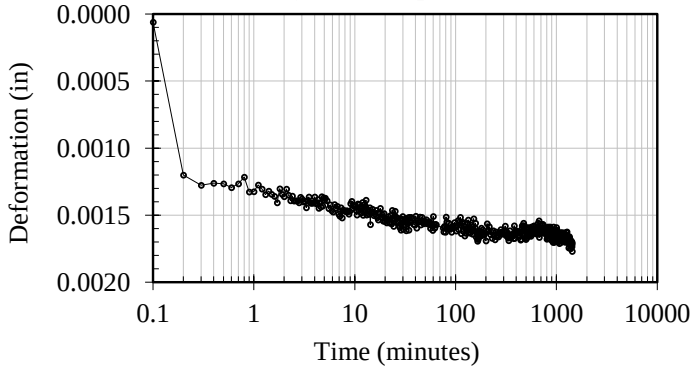
Stage 1: Swell Pressure Measurement



Stage 1: Swell Pressure Measurement



Stage 2: 250 psf



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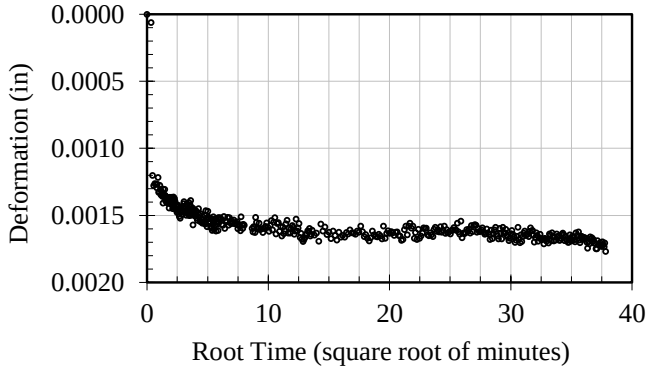
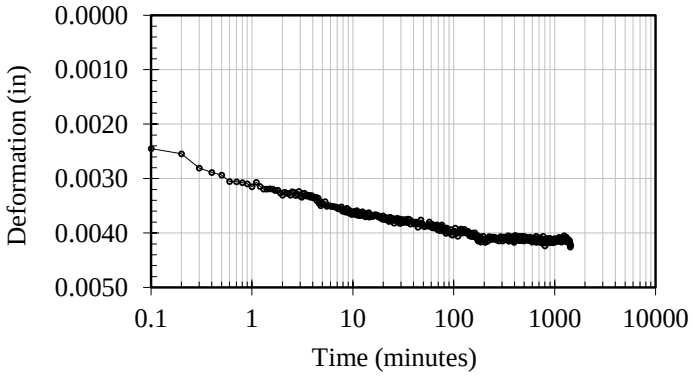
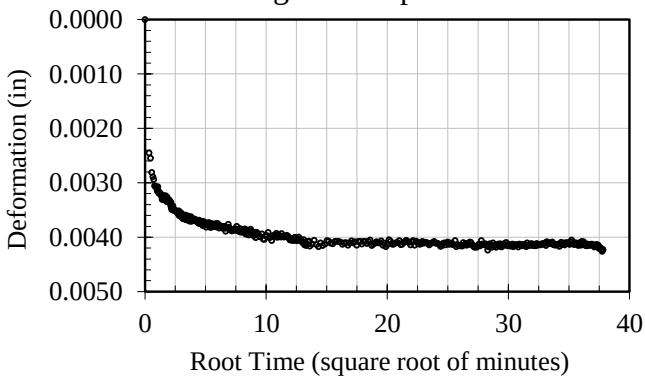


Stage 3: 500 psf



Stage 3: 500 psf



M-1-49

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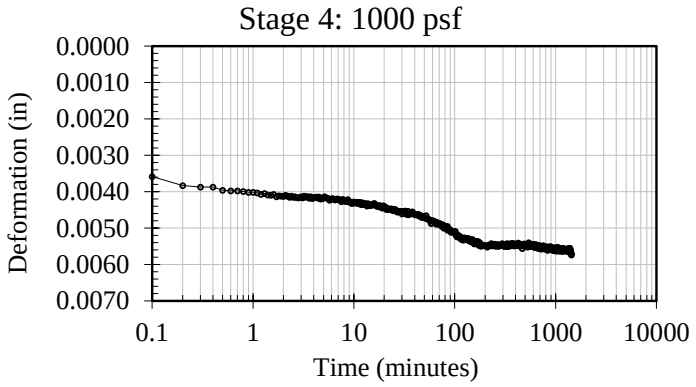
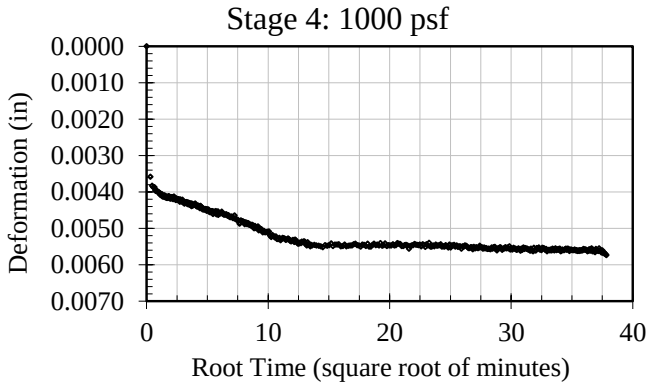
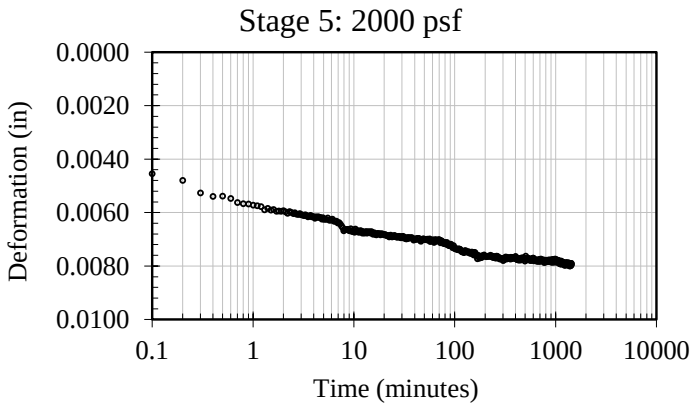
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

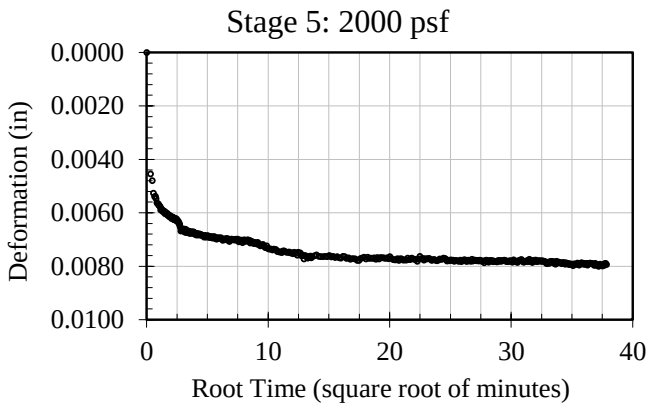
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-13 (11'- 13')

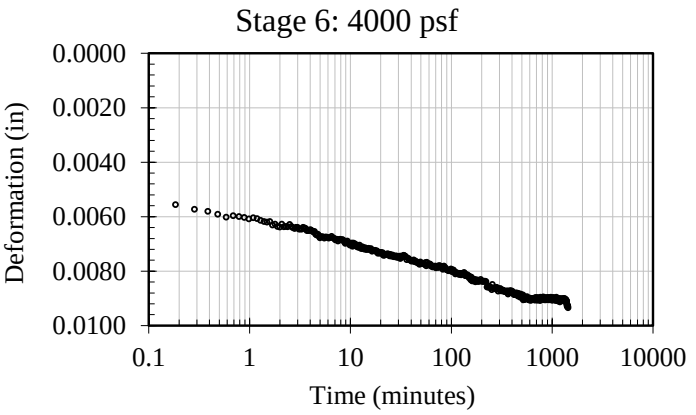
TRI Log No.: 23-00003.2
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

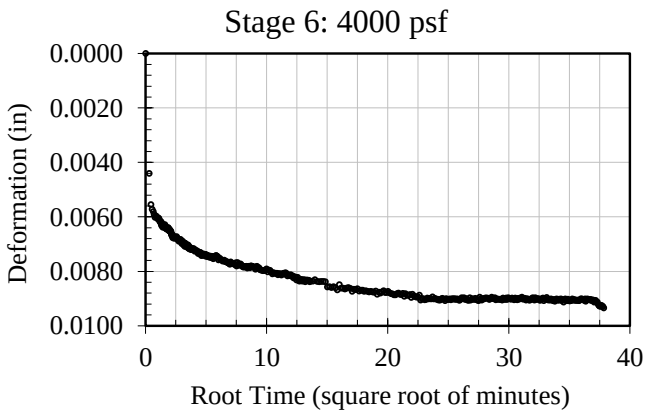












M-1-50

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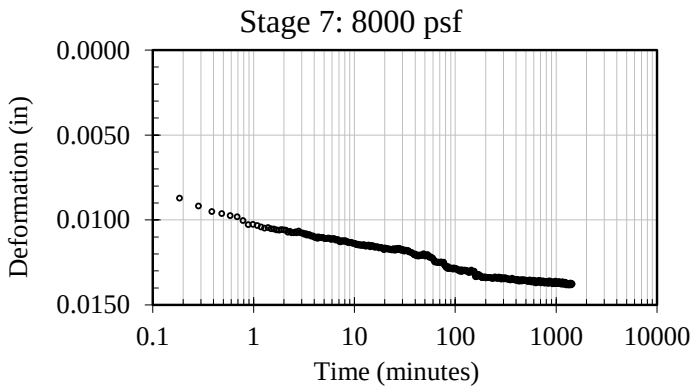
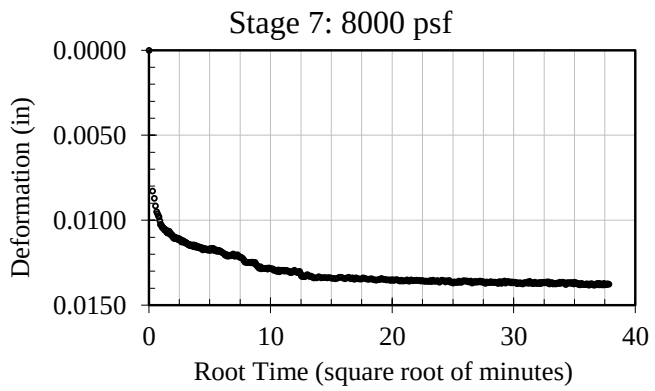
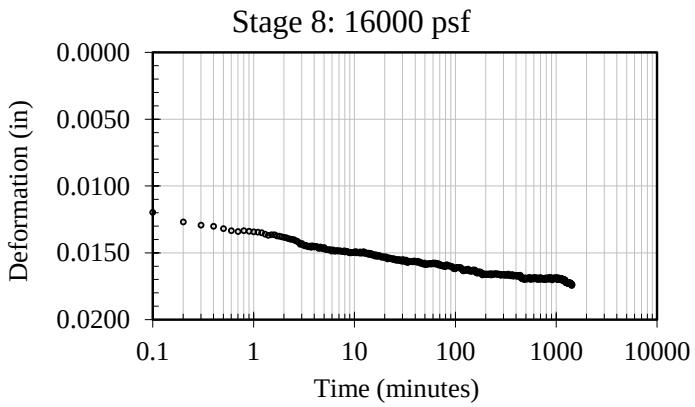
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

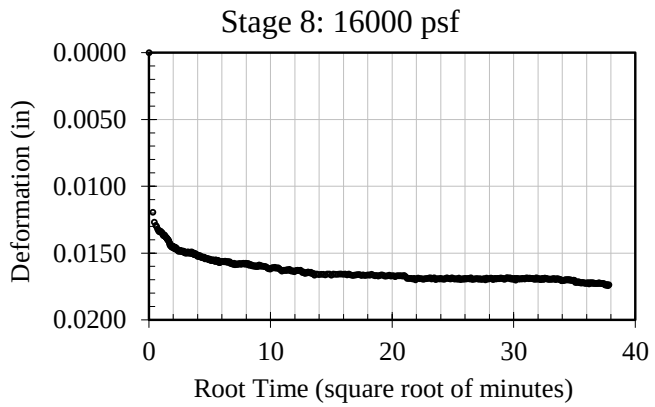
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-13 (11'- 13')

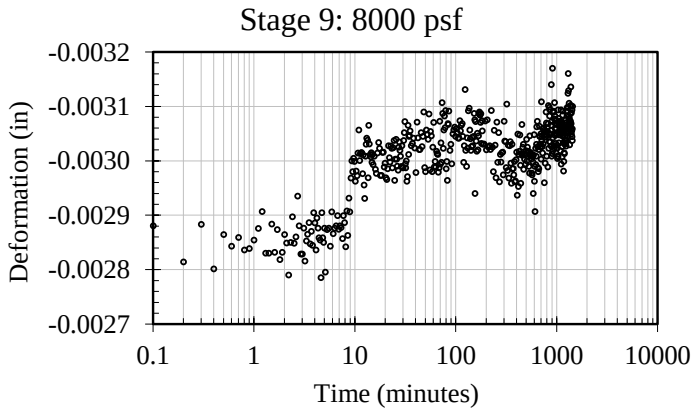
TRI Log No.: 23-00003.2
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

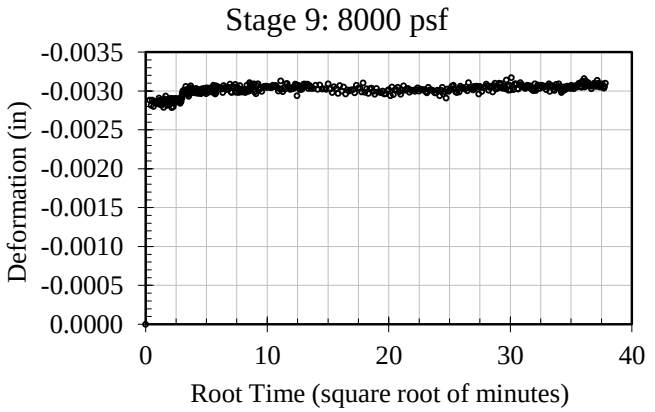












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One-Dimensional Consolidation Properties of Soil (ASTM D2435)

Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-13 (11'- 13')

TRI Log No.: 23-00003.2
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
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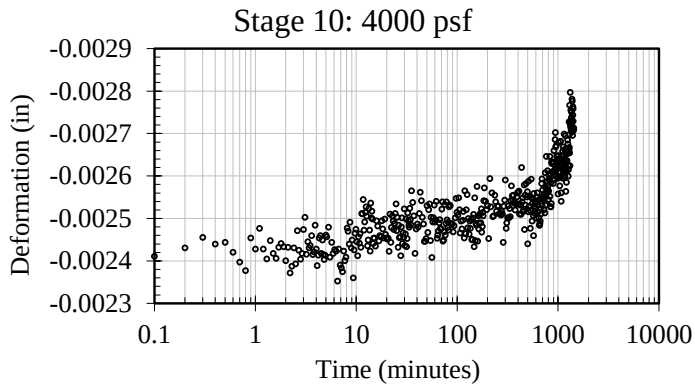

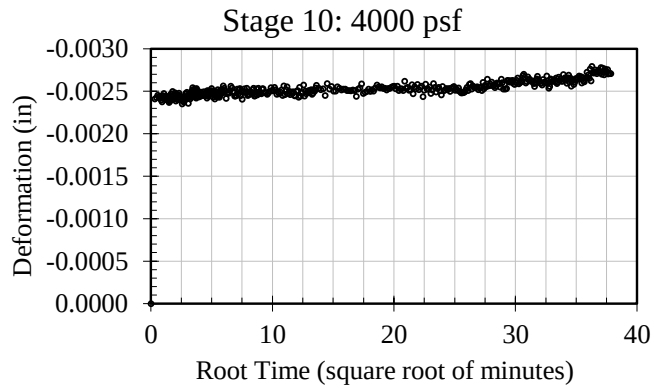

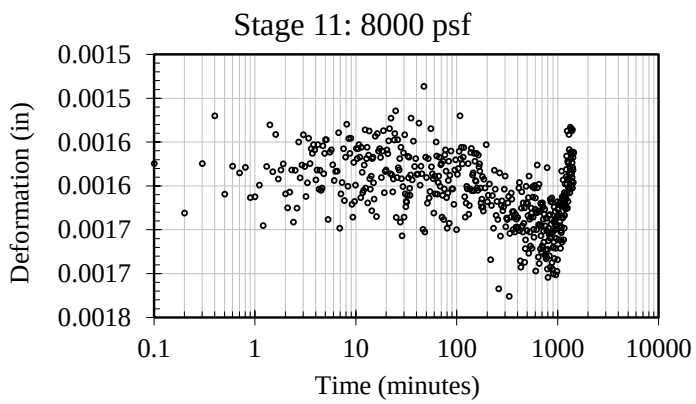

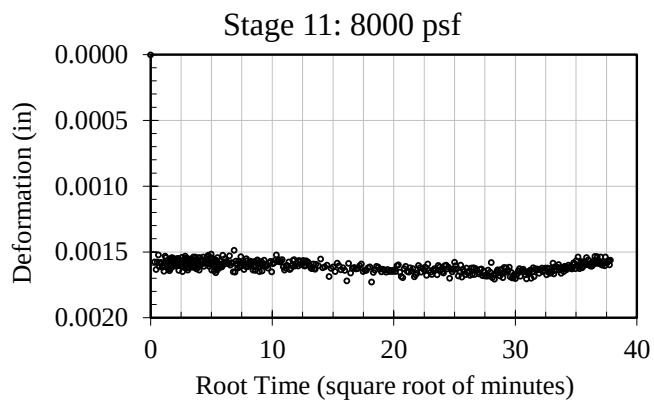

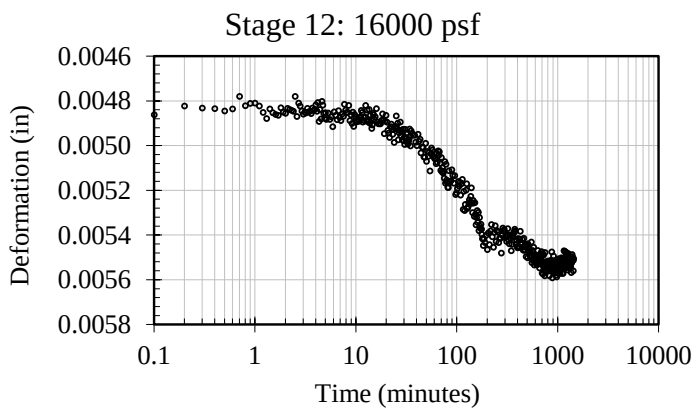

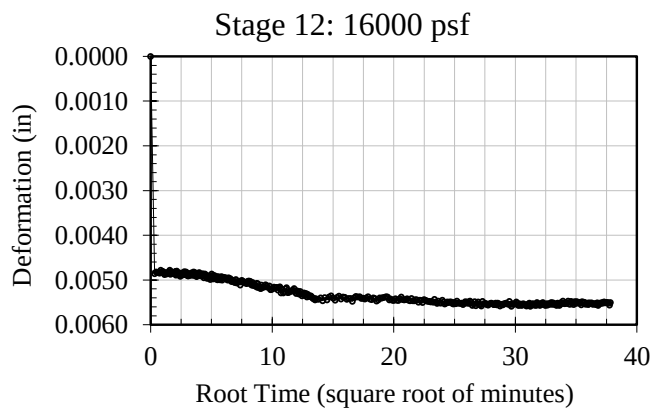

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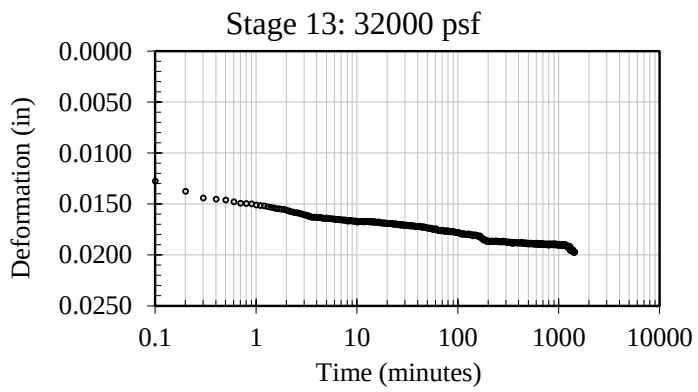
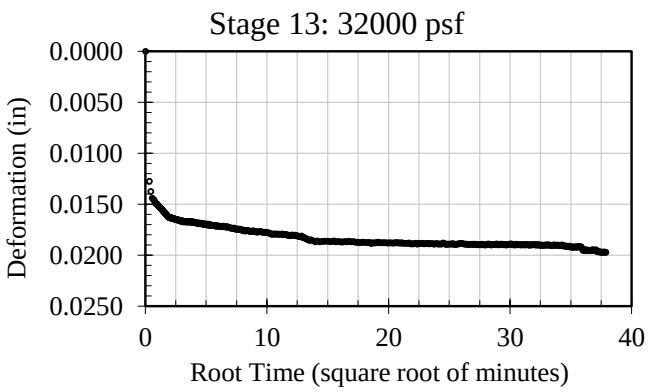
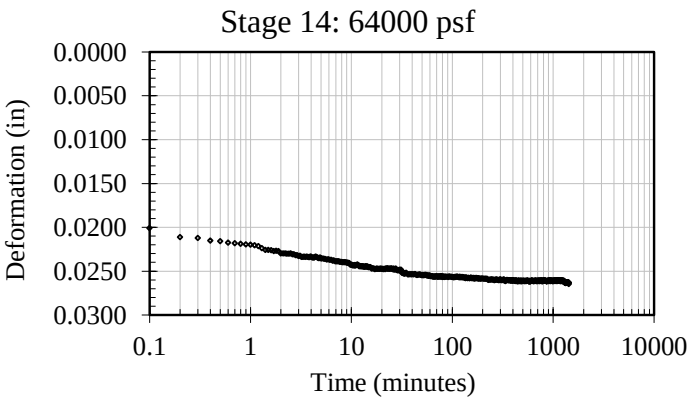
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

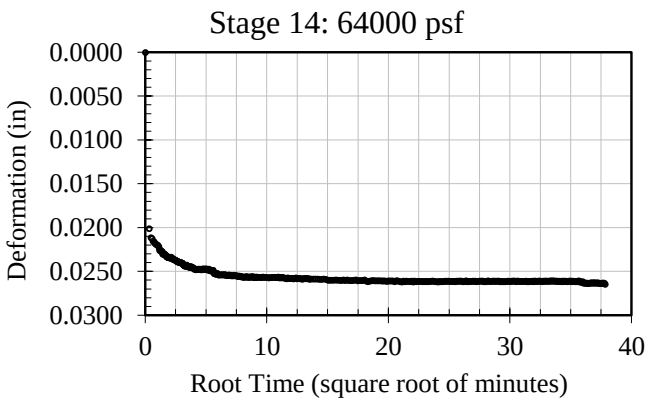
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-13 (11'- 13')

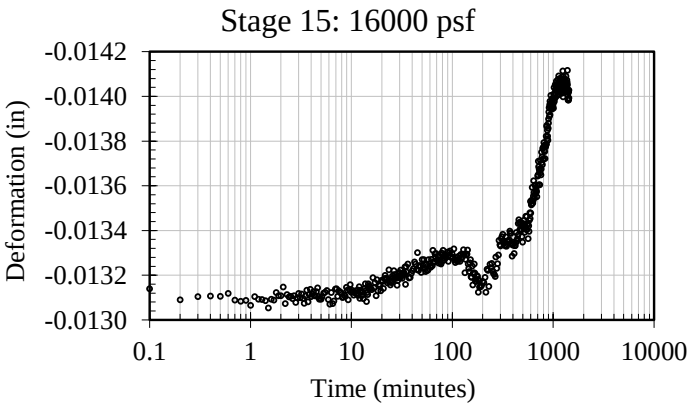
TRI Log No.: 23-00003.2
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

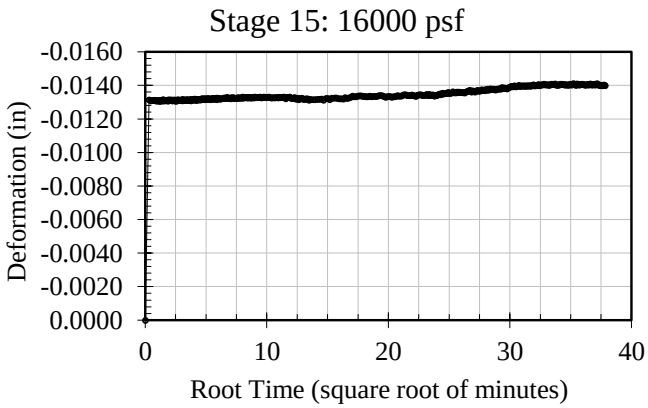












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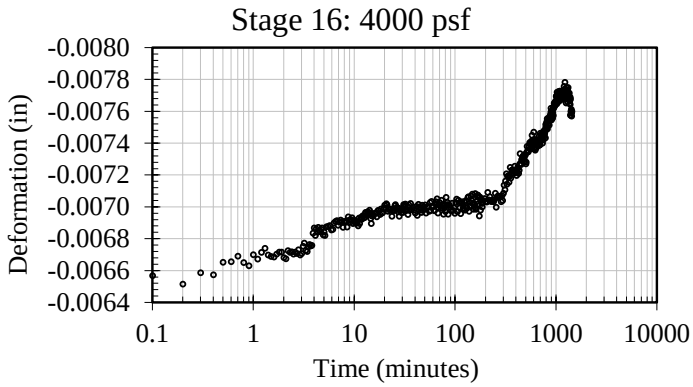
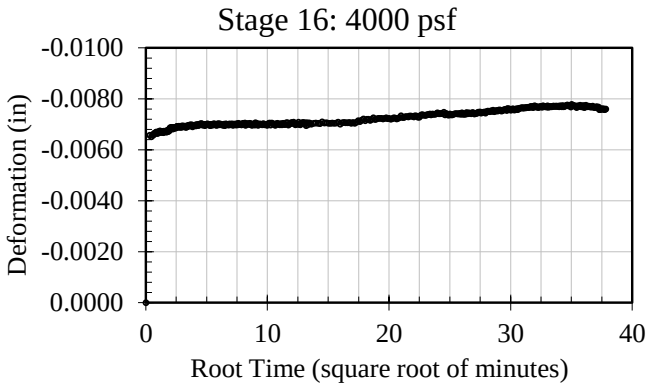
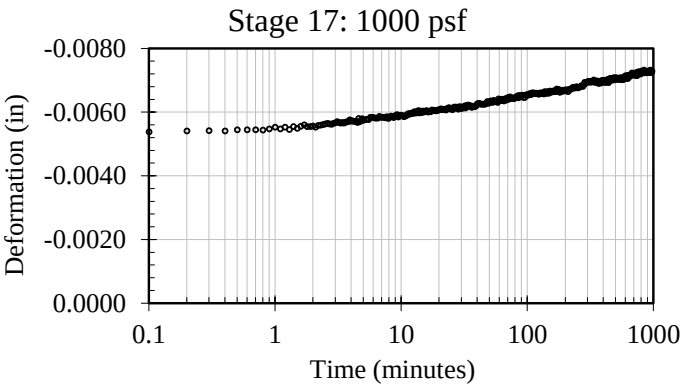
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

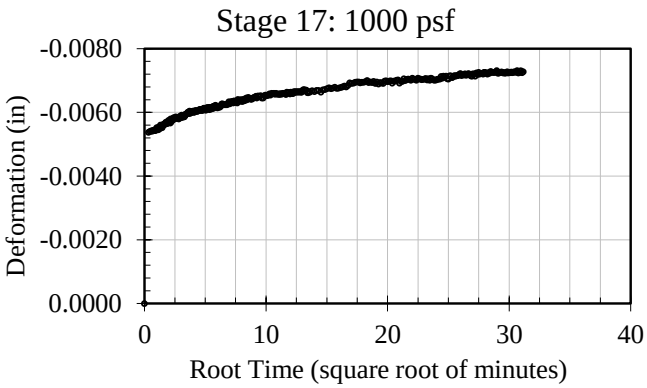
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-13 (11'- 13')

TRI Log No.: 23-00003.2
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date









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9063 Bee Caves Rd. – Austin, TX 78733 – USA | Ph: 800.880.TEST or 512.263.2101

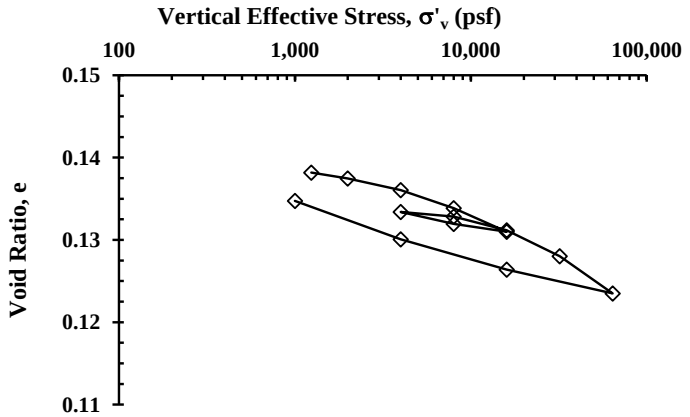
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

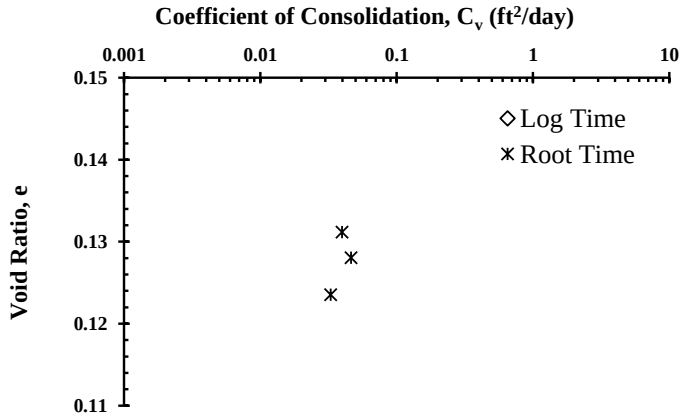
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-15 (67.5'- 70')

TRI Log No.: 23-000003.5
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

Soil Specimen Properties	Initial	Final
Water Content (%)	2.8	4.4
Diameter (in)	1.99	1.99
Height (in)	1.00	1.00
Dry Unit Weight, γ_o lb_f/ft^3	150.8	151.2
Specific Gravity (Assumed)	2.75	
Void Ratio, e	0.14	0.13
Degree of Saturation (%)	55.8	-

Test Setup		
Specimen Condition	●	Intact / "Undisturbed"
		Compacted/Remolded/Reconstituted
Test Water		Extracted Pore Water
	●	Potable Tap Water
		Demineralized Water
		Saline Water
		Other





Stage (#)	σ'_v (psf)	log (σ'_v) log (psf)	e (-)	Strain, ε (%)	$\delta e / \delta \log(\sigma'_v)$	C_α (x1,000)	t_{50} (min) Log Time	t_{50} (min) Root Time	C_v (ft^2/day) Log Time	C_v (ft^2/day) Root Time
1	1,242	3.09	0.138	0.00	-	-	-	-	-	-
2	2,000	3.30	0.137	0.06	-0.004	-	-	-	-	-
3	4,000	3.60	0.136	0.19	-0.005	-	-	-	-	-
4	8,000	3.90	0.134	0.38	-0.007	-	-	-	-	-
5	16,000	4.20	0.131	0.63	-0.010	-	-	-	-	-
6	8,000	3.90	0.132	0.55	-0.003	-	-	-	-	-
7	4,000	3.60	0.133	0.42	-0.005	-	-	-	-	-
8	8,000	3.90	0.133	0.47	-0.002	-	-	-	-	-
9	16,000	4.20	0.131	0.62	-0.006	-	-	12.3	-	4.0E-02
10	32,000	4.51	0.128	0.89	-0.010	-	-	10.5	-	4.6E-02
11	64,000	4.81	0.123	1.29	-0.015	-	-	14.7	-	3.3E-02
12	16,000	4.20	0.126	1.03	-0.005	-	-	-	-	-
13	4,000	3.60	0.130	0.71	-0.006	-	-	-	-	-
14	1,000	3.00	0.135	0.30	-0.008	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-

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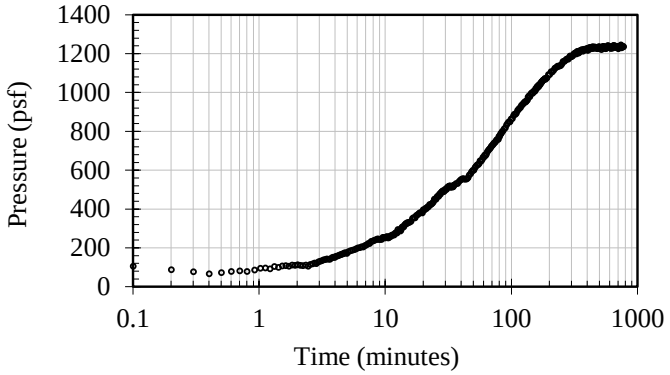
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

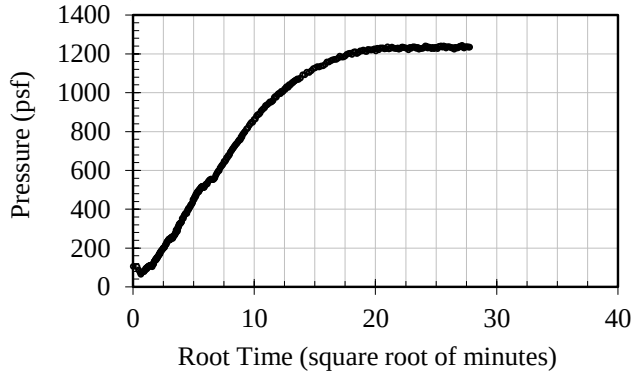
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-15 (67.5'- 70')

TRI Log No.: 23-000003.5
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

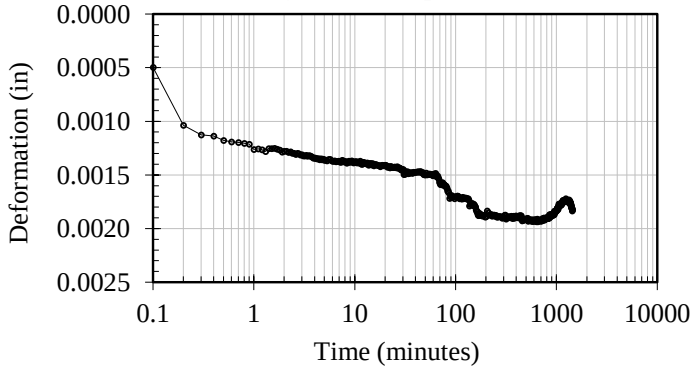
Stage 1: Swell Pressure Measurement



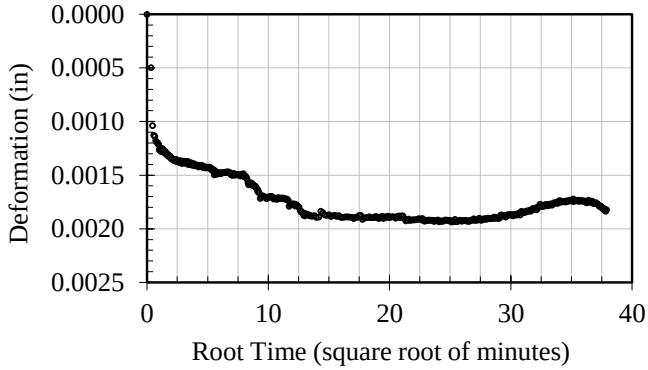
Stage 1: Swell Pressure Measurement



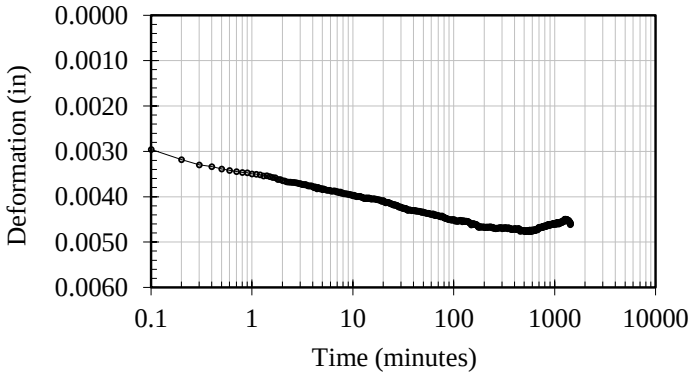
Stage 2: 2000 psf



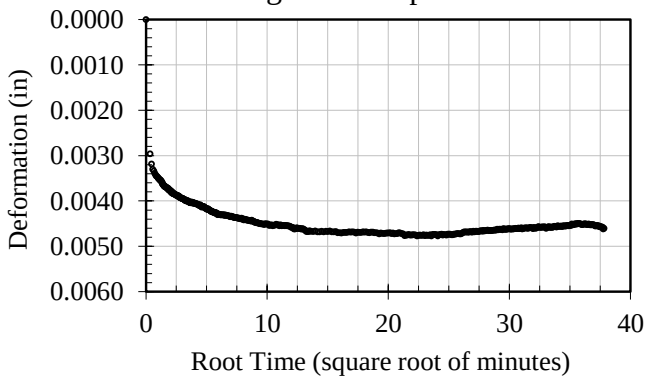
Stage 2: 2000 psf



Stage 3: 4000 psf



Stage 3: 4000 psf



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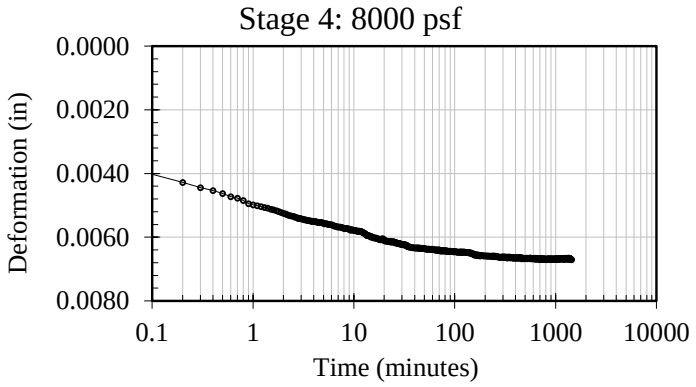

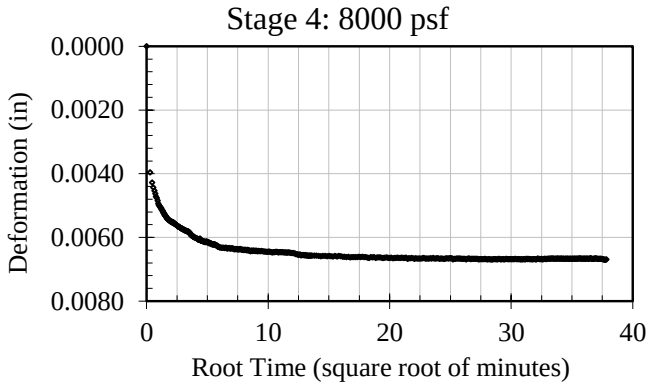

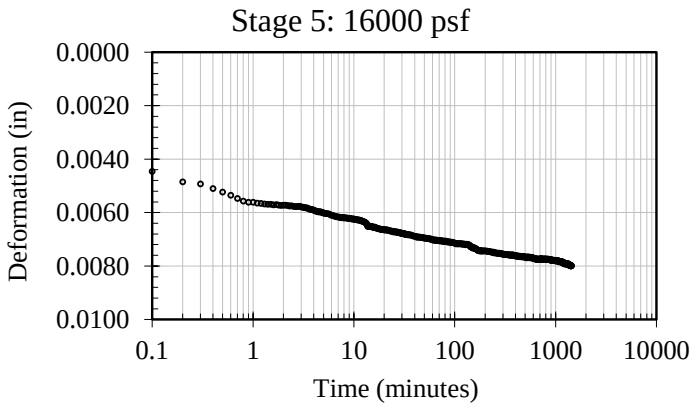

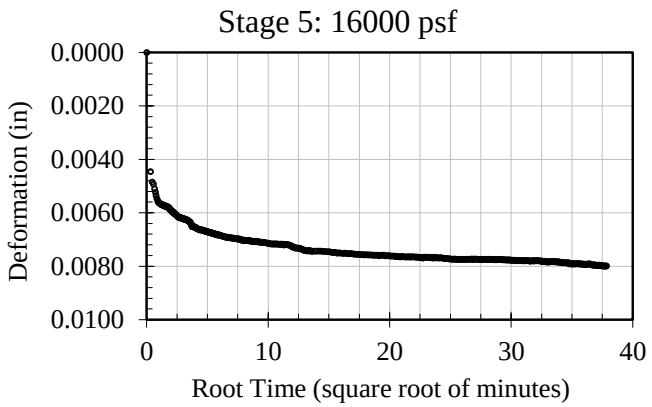

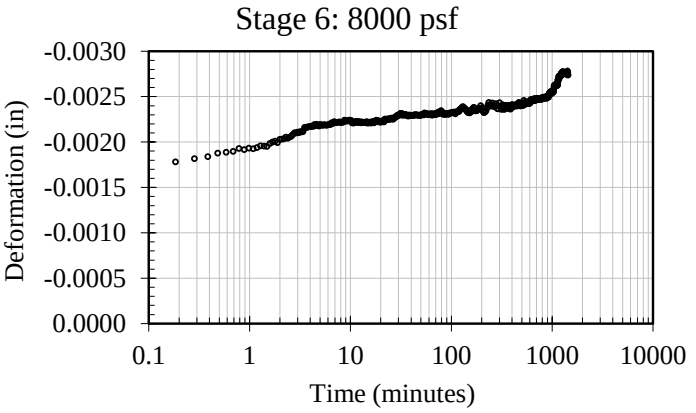

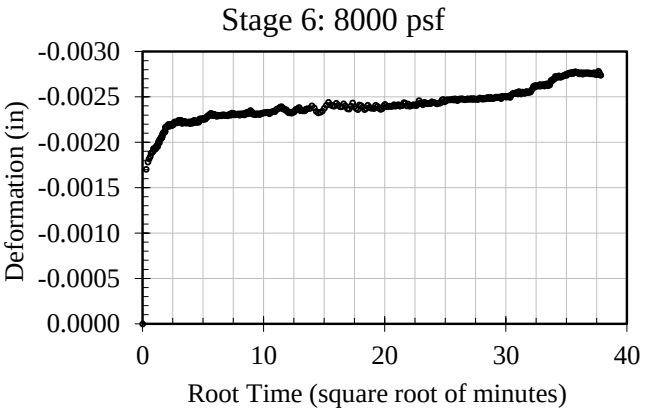

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One-Dimensional Consolidation Properties of Soil (ASTM D2435)

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Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-15 (67.5'- 70')

TRI Log No.: 23-000003.5
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
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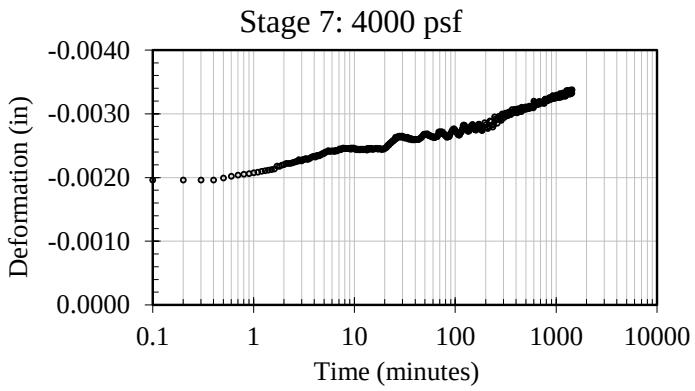

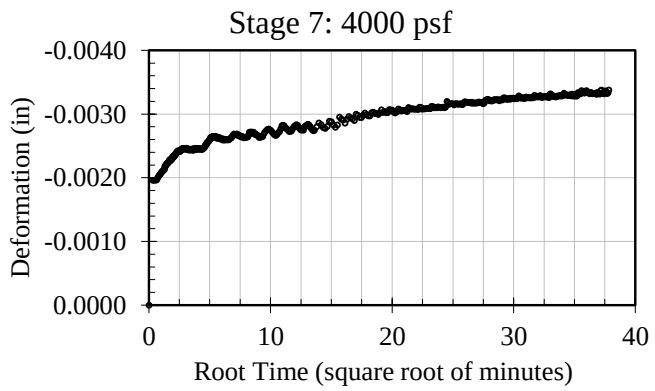

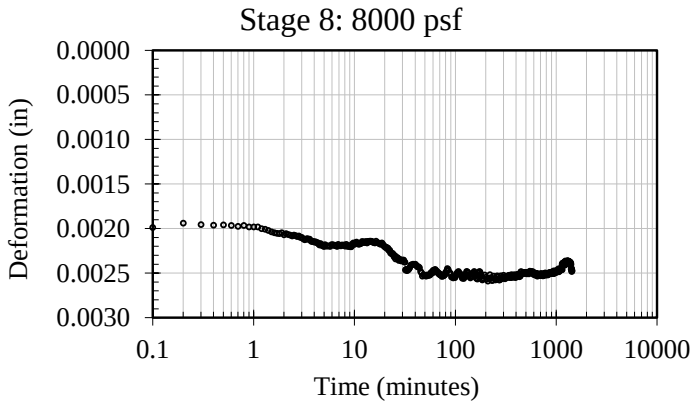

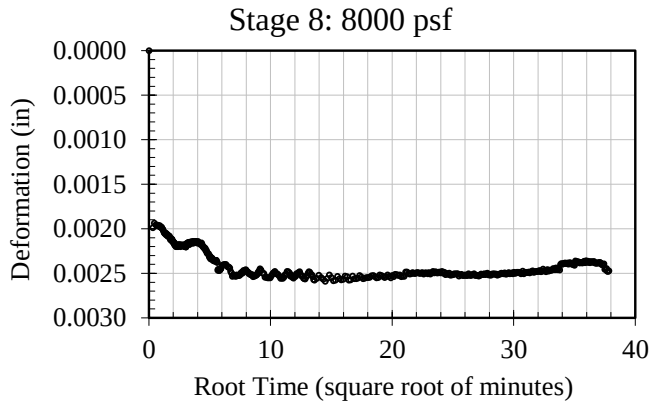

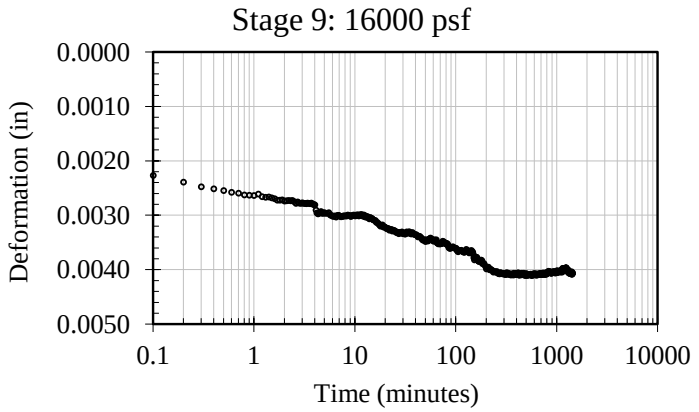

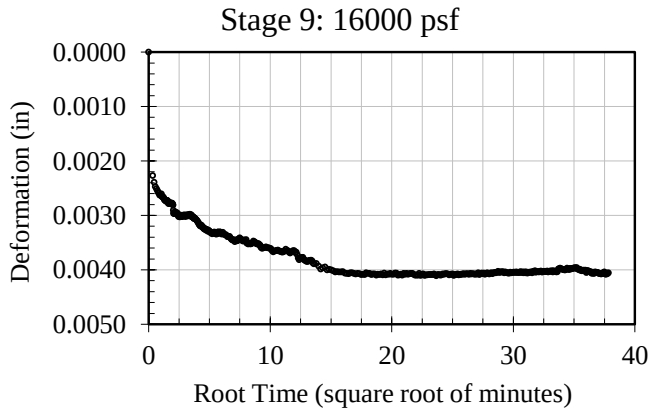

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One-Dimensional Consolidation Properties of Soil (ASTM D2435)

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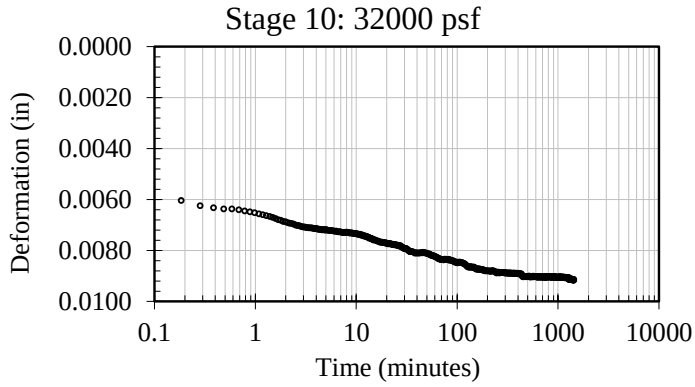
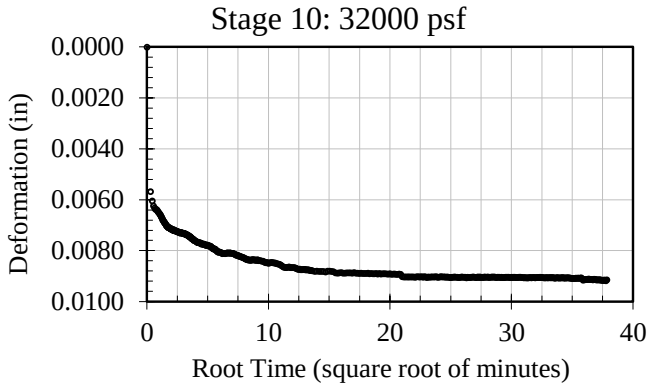
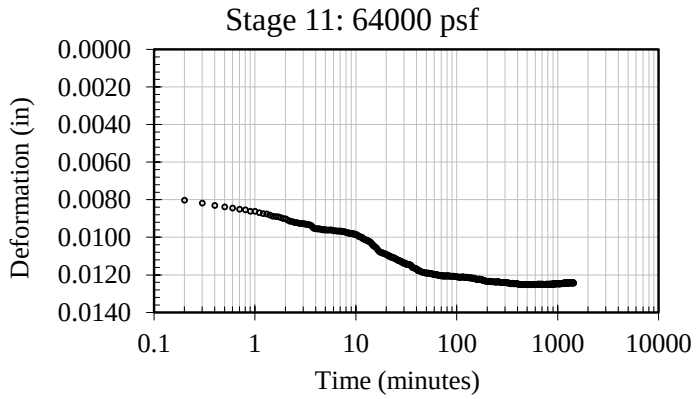
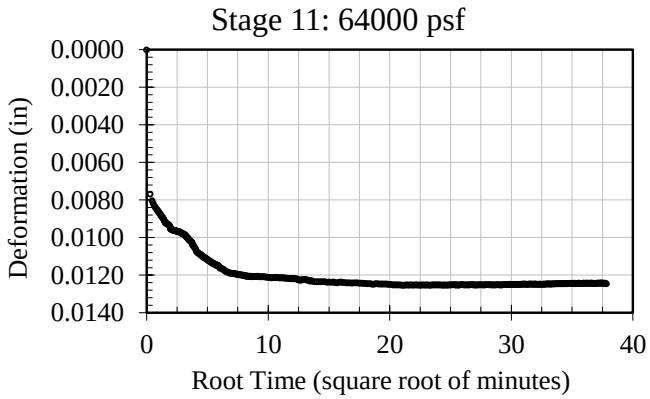
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-15 (67.5'- 70')

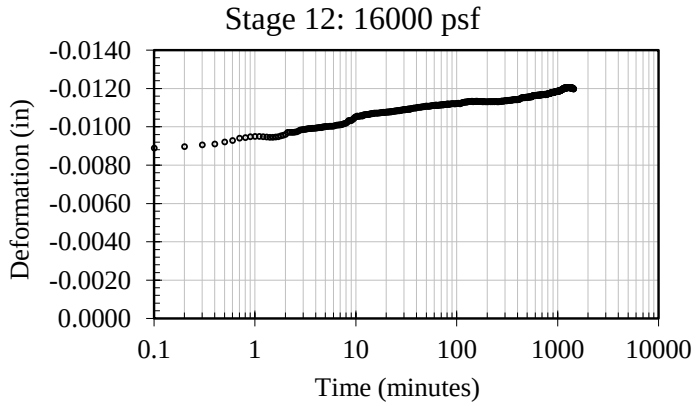
TRI Log No.: 23-000003.5
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

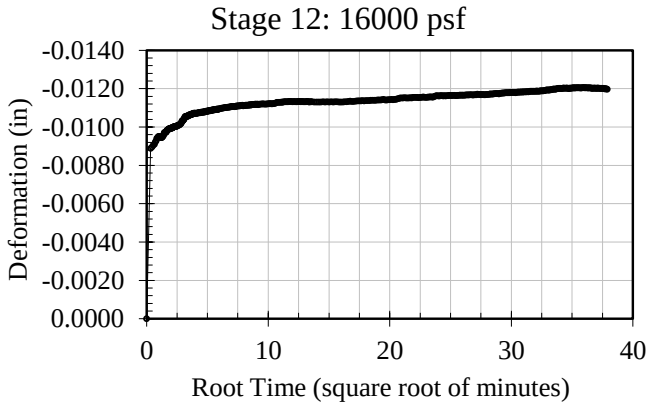












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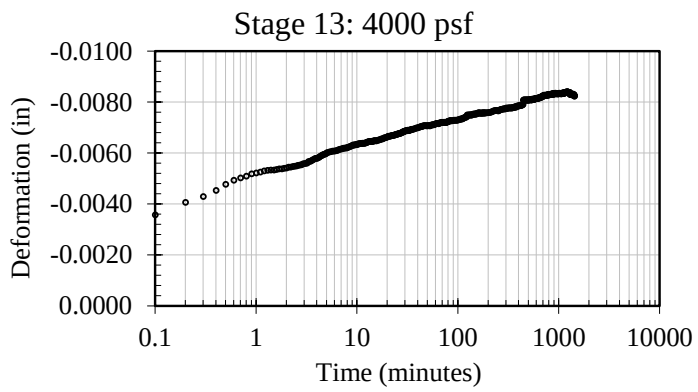
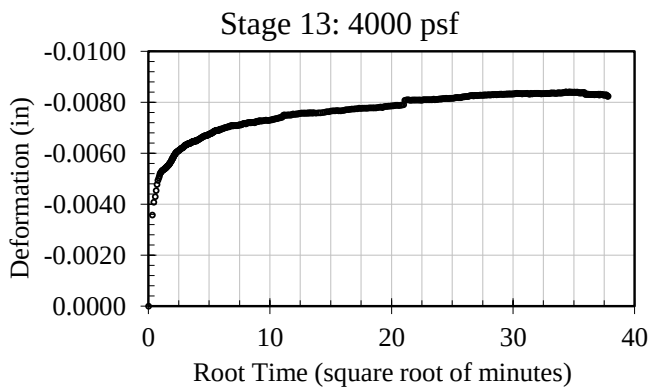
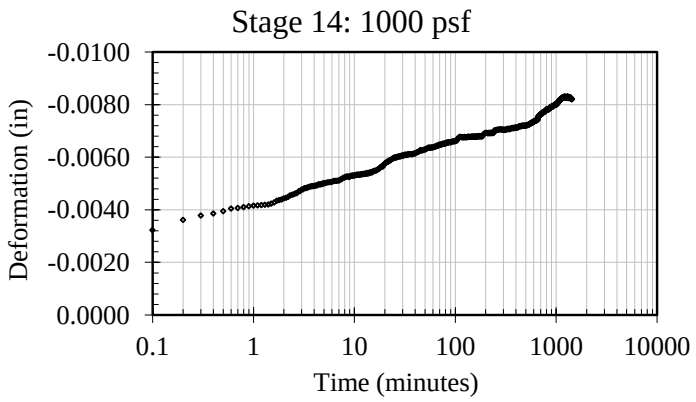
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

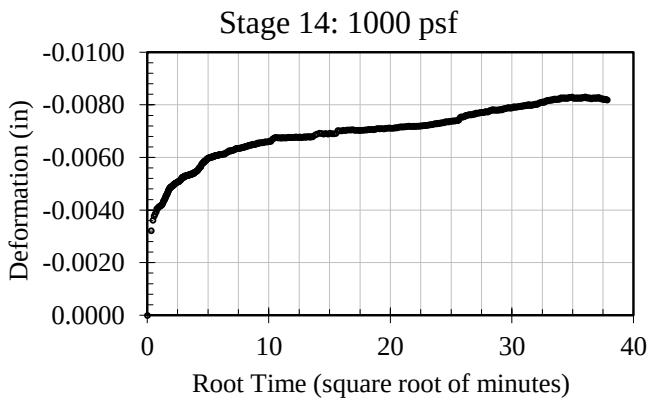
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-15 (67.5'- 70')

TRI Log No.: 23-000003.5
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date









M-1-60

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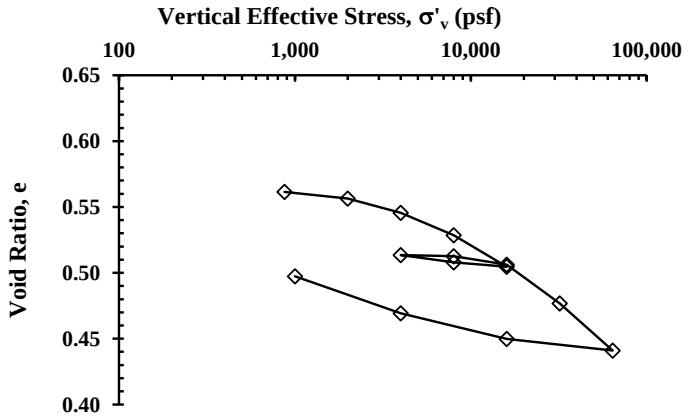
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

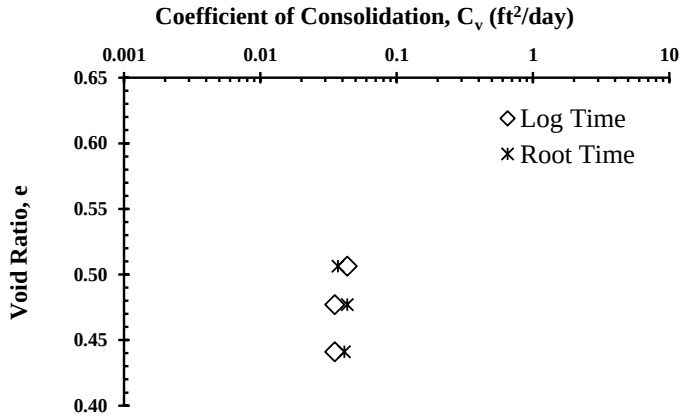
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-16 (17'- 19')

TRI Log No.: 23-000003.1
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

Soil Specimen Properties	Initial	Final
Water Content (%)	16.1	-
Diameter (in)	2.50	2.50
Height (in)	1.00	0.96
Dry Unit Weight, γ_o lb_f/ft^3	109.9	114.6
Specific Gravity (Assumed)	2.75	
Void Ratio, e	0.56	0.50
Degree of Saturation (%)	78.7	-

Test Setup		
Specimen Condition	●	Intact / "Undisturbed"
		Compacted/Remolded/Reconstituted
Test Water		Extracted Pore Water
	●	Potable Tap Water
		Demineralized Water
		Saline Water
		Other





Stage (#)	σ'_v (psf)	log (σ'_v) log (psf)	e (-)	Strain, ε (%)	$\delta e / \delta \log(\sigma'_v)$	C_α (x1,000)	t_{50} (min) Log Time	t_{50} (min) Root Time	C_v (ft^2/day) Log Time	C_v (ft^2/day) Root Time
1	873	2.94	0.561	0.00	-	-	-	-	-	-
2	2,000	3.30	0.556	0.32	-0.014	-	-	-	-	-
3	4,000	3.60	0.546	1.02	-0.036	-	-	-	-	-
4	8,000	3.90	0.529	2.10	-0.056	-	-	-	-	-
5	16,000	4.20	0.505	3.63	-0.079	-	-	-	-	-
6	8,000	3.90	0.508	3.42	-0.011	-	-	-	-	-
7	4,000	3.60	0.513	3.08	-0.018	-	-	-	-	-
8	8,000	3.90	0.513	3.13	-0.003	-	-	-	-	-
9	16,000	4.20	0.506	3.53	-0.021	-	10.5	12.3	4.3E-02	3.7E-02
10	32,000	4.51	0.477	5.42	-0.098	-	12.5	10.1	3.5E-02	4.3E-02
11	64,000	4.81	0.441	7.71	-0.119	-	11.9	10.1	3.5E-02	4.1E-02
12	16,000	4.20	0.450	7.15	-0.014	-	-	-	-	-
13	4,000	3.60	0.469	5.90	-0.032	-	-	-	-	-
14	1,000	3.00	0.497	4.11	-0.047	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-

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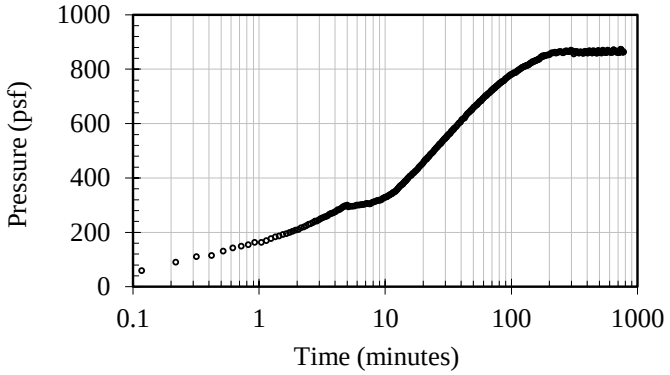
One-Dimensional Consolidation Properties of Soil (ASTM D2435)

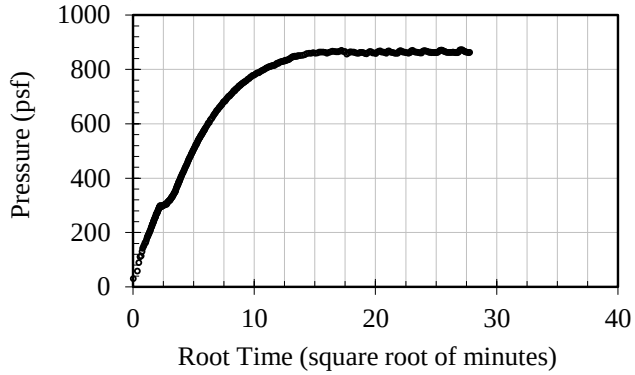
Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-16 (17'- 19')

TRI Log No.: 23-000003.1
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
Quality Review/Date

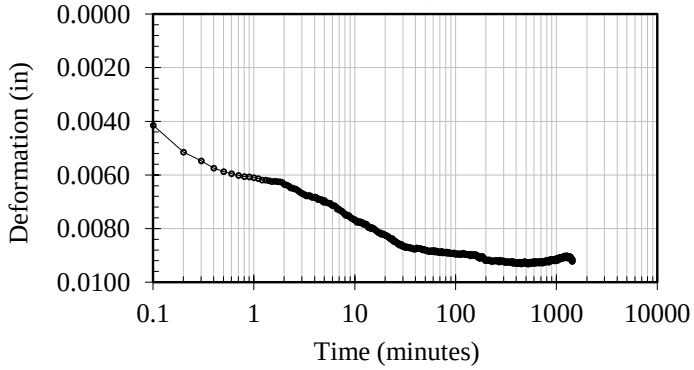
Stage 1: Swell Pressure Measurement



Stage 1: Swell Pressure Measurement



Stage 2: 2000 psf



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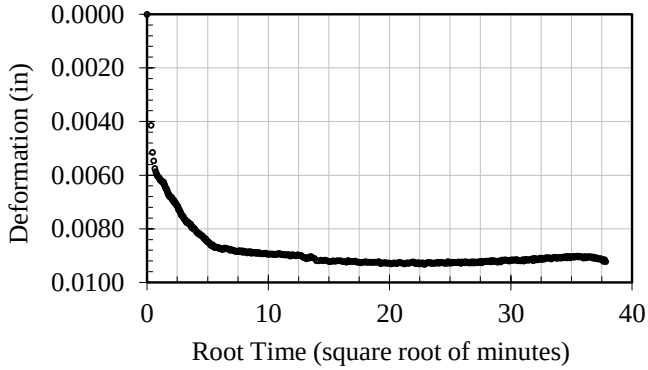

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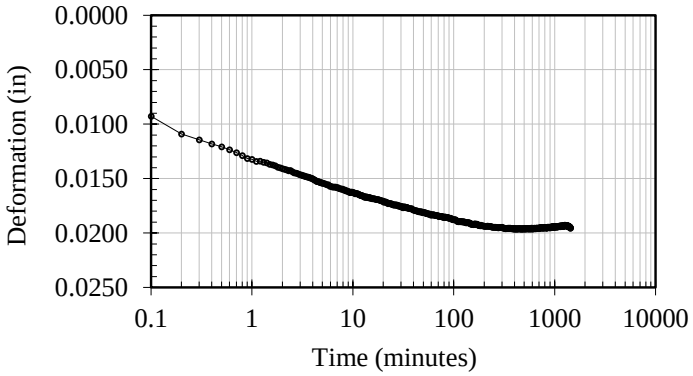

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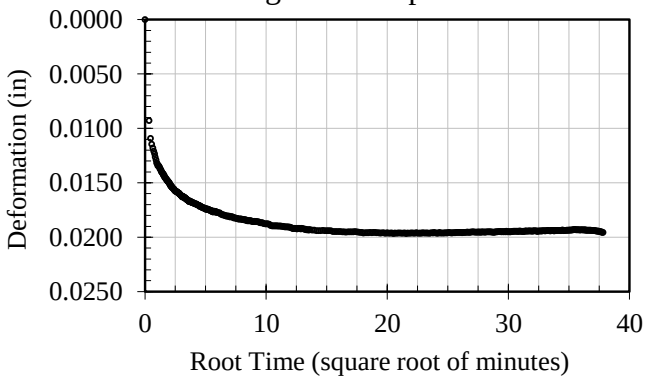

M-1-62

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One-Dimensional Consolidation Properties of Soil (ASTM D2435)

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TRI Log No.: 23-000003.1
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
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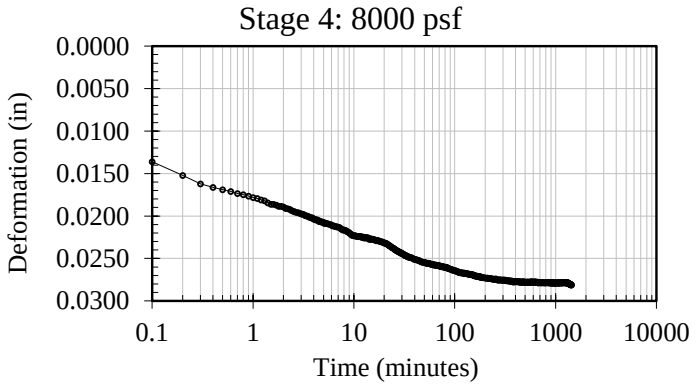

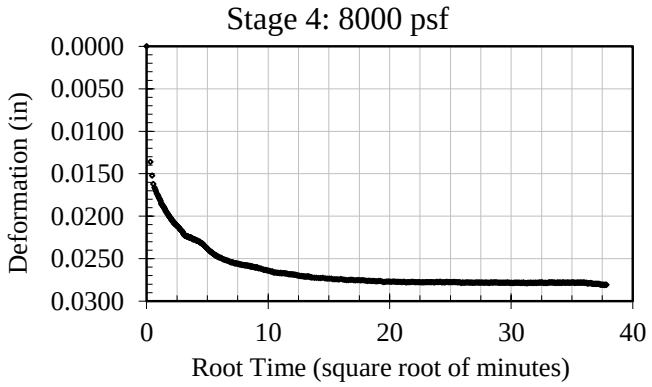

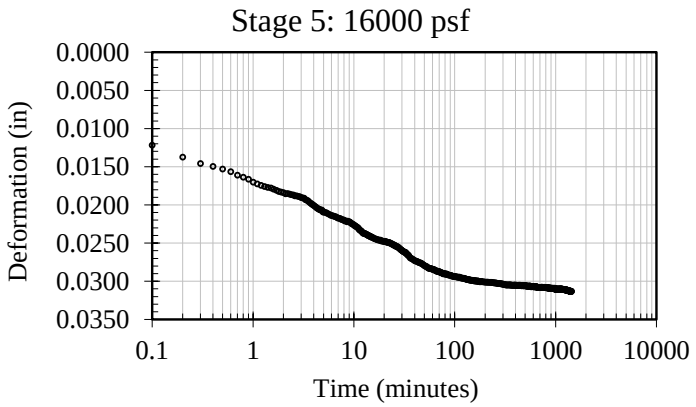

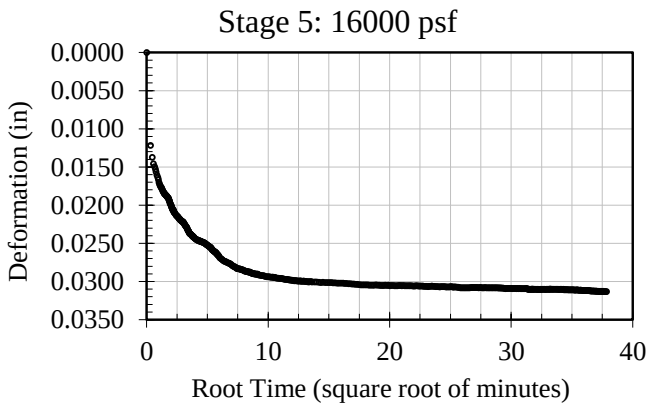

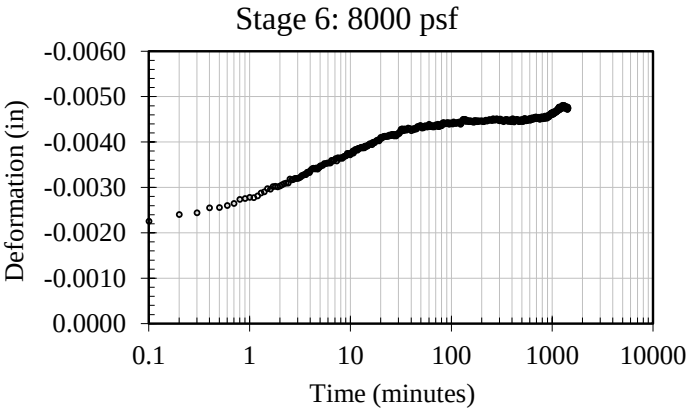

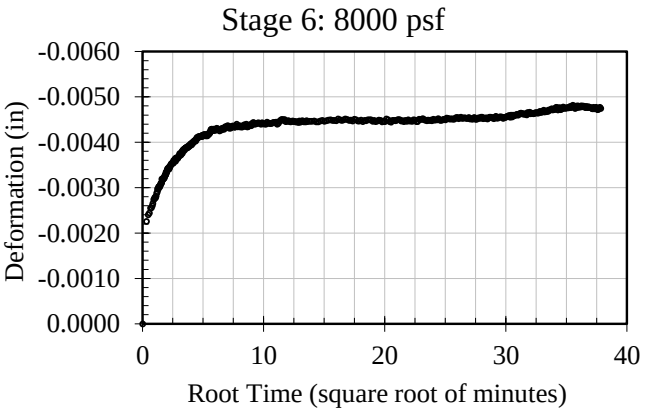

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One-Dimensional Consolidation Properties of Soil (ASTM D2435)

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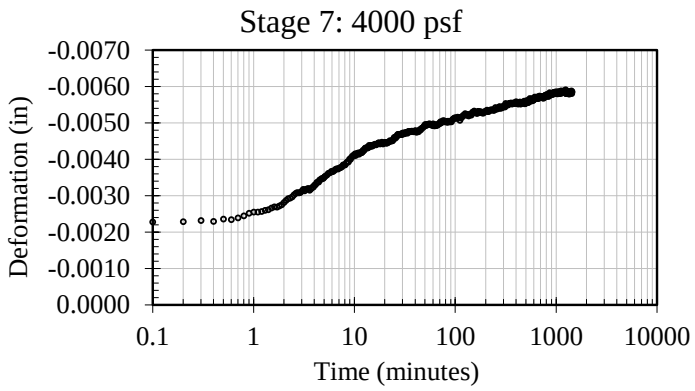

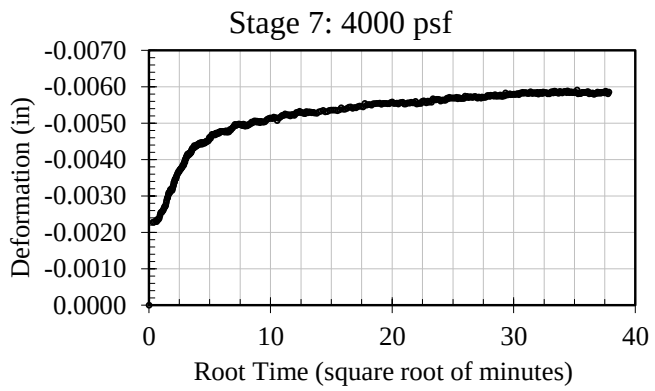

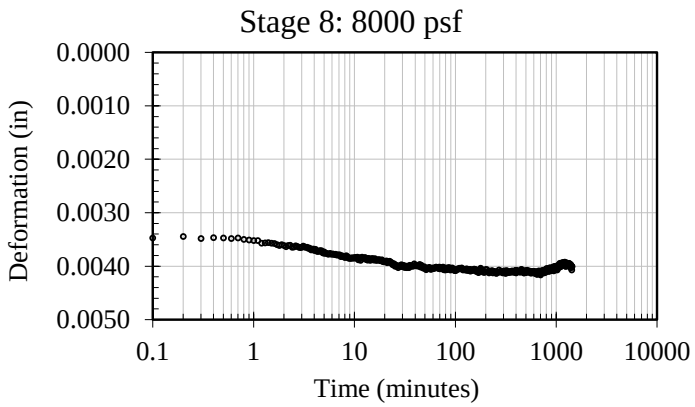

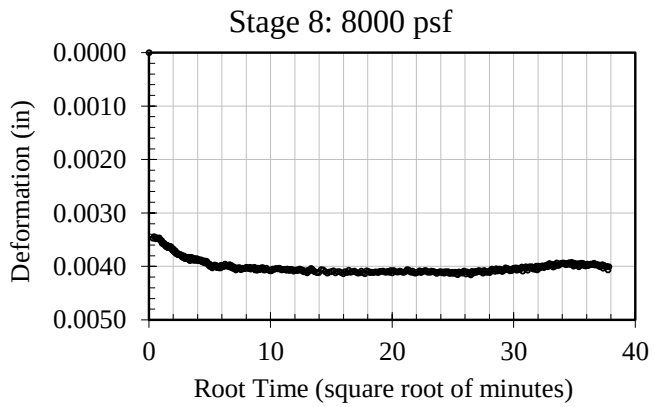

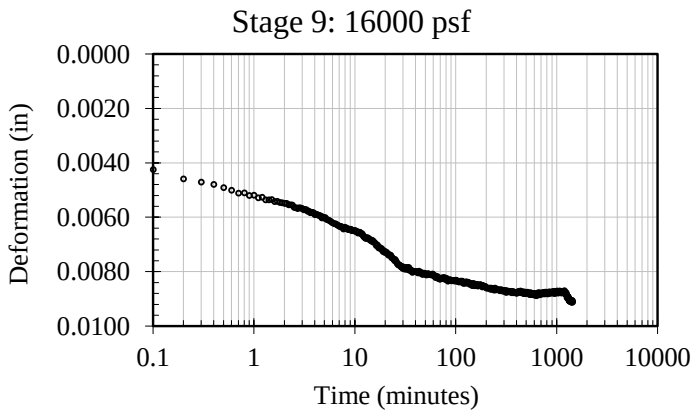

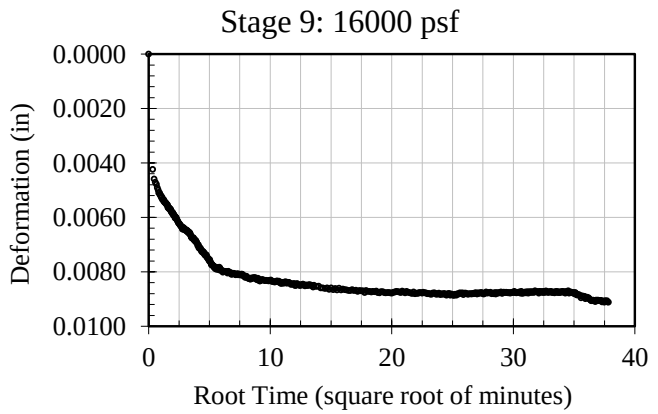

M-1-64

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One-Dimensional Consolidation Properties of Soil (ASTM D2435)

Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-16 (17'- 19')

TRI Log No.: 23-000003.1
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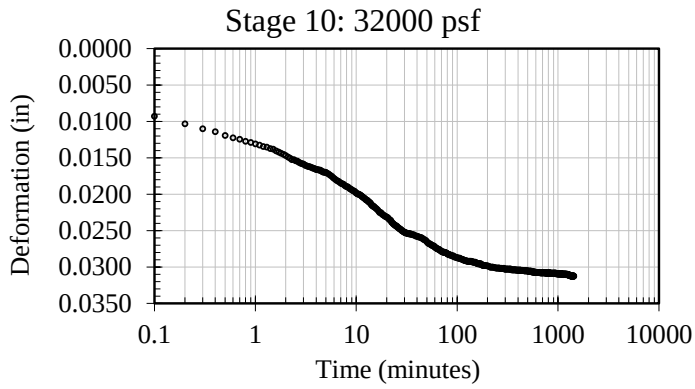
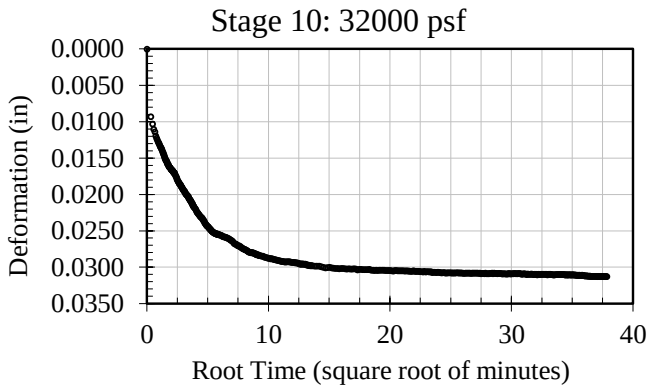
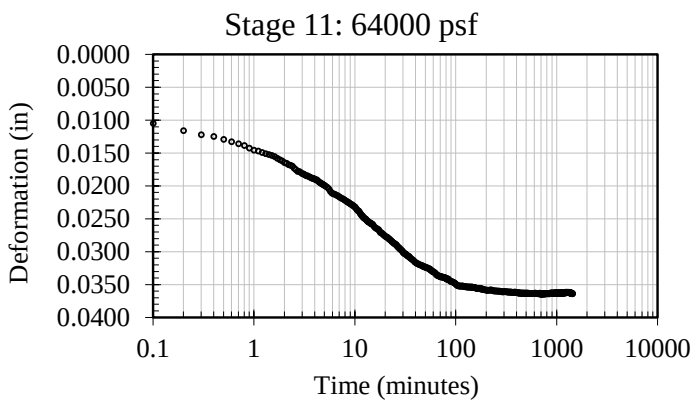
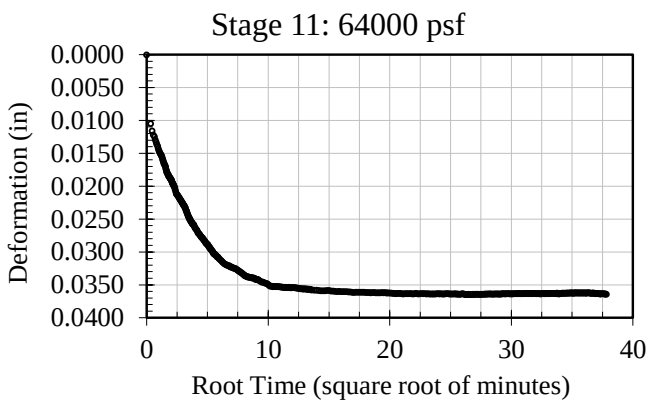
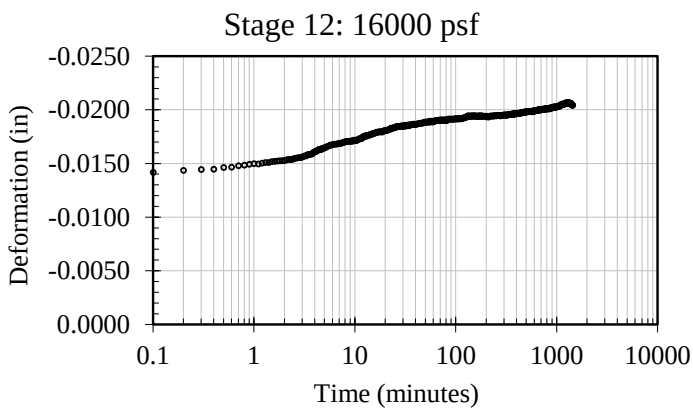
Quality Review/Date

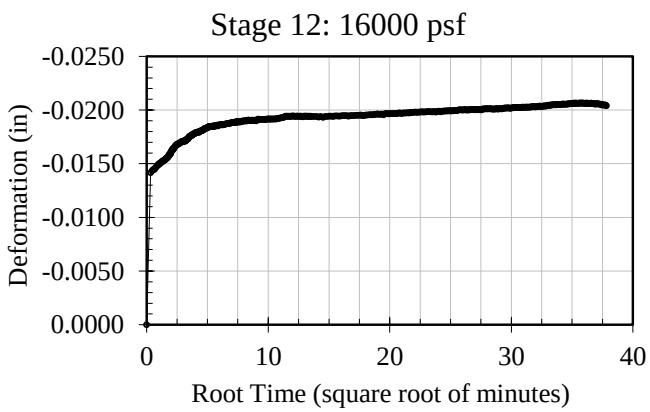












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One-Dimensional Consolidation Properties of Soil (ASTM D2435)

Client: Weaver Consultants Group
Project: 0086-364-11-19 Muskogee Landfill
Specimen: WCG-16 (17'- 19')

TRI Log No.: 23-000003.1
Jeffrey A. Kuhn, Ph.D., P.E., 2/14/2023
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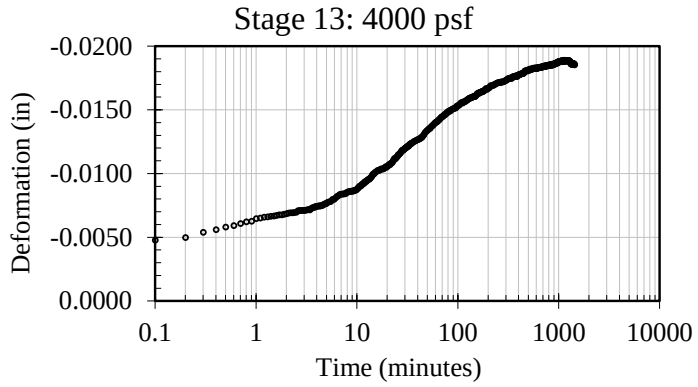

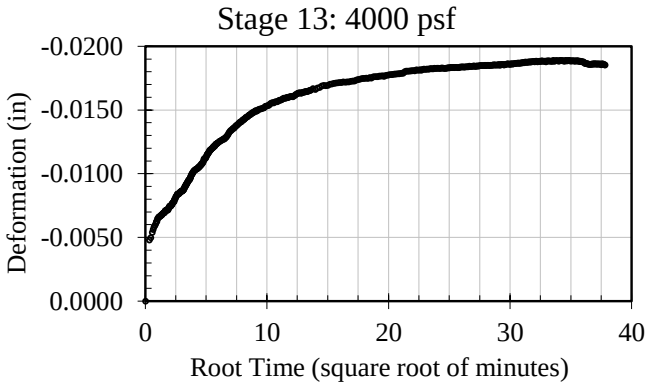

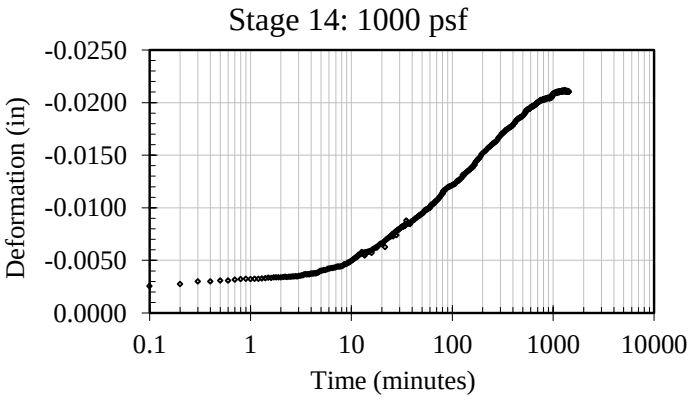

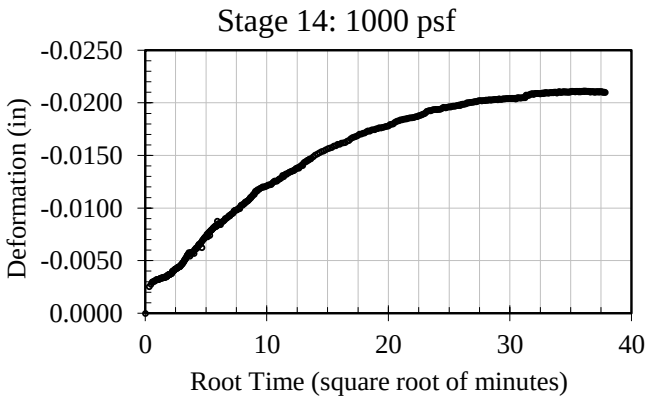

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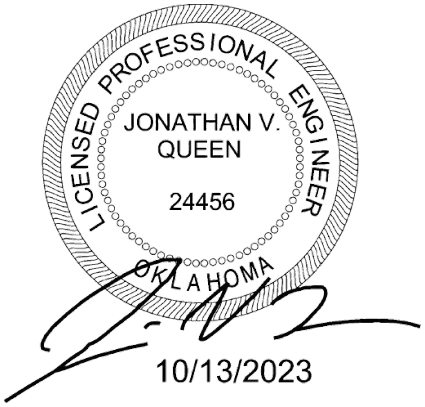
APPENDIX M-2

SLOPE STABILITY ANALYSIS



Required:

A. Evaluate the slope stability of the proposed landfill configuration including excavation grades, interim fill slopes, and final closure condition slopes.

B. Evaluate the veneer stability of the bottom liner, and final cover systems. Analysis is performed by the Infinite Slope Analysis Method.

For this slope stability analysis, the analysis description, input parameters, analysis section plans, and the sections analyzed (with analysis results) are presented in Appendix M-2. SLIDE2 computer model output files are presented in Appedices M-2A (Excavation Grades), M-2B (Interim Conditions) and M-2C (Final Closure Conditions). Infinite slope stability analyses are presented in Appendix M-2D.

Given:

1. Site plans showing the sections analyzed for this analysis are presented on Sheets M-2A-1, M-2B-1, and M-2C-1.

2. Modeling parameters were derived from field and laboratory testing, and are summarized in Table 1, below. The results of field and laboratory testing are discussed in Appendix M. Assumptions regarding waste density are discussed in Appendix M.

3. The proposed bottom liner system for the landfill will consist of (from the bottom up) 2-foot-thick compacted clay liner ($k < 1x10^{-7}$ cm/s), 60-mil HDPE geomembrane (smooth on floor and textured on sideslopes), geotextile drainage layer, and 2-foot-thick soil protective cover. The analyses presented in this appendix also consider the proposed alternative liner system which substitutes a geosynthetic clay liner (GCL) overlying a 1-foot-thick compacted clay liner for the 2-foot-thick compacted clay liner used in the proposed bottom liner system. Alternative infinite stability analysis results for the bottom liner system are presented in Appendix M-2D.

4. The proposed final cover system for the landfill will consist of (from the bottom up) a 1-foot-thick intermediate cover layer, 2-foot-thick vegetation support layer and 1-foot-thick vegetation layer. Infinite stability analysis results for the final cover system are presented in Appendix M-2D.

5. The bottom liner was analyzed for stability as a single (thickened) layer with assigned strength parameters of the weakest component of the proposed composite liner system.

Method:

A. Evaluate the slope stability of the proposed landfill configuration including excavation grades, interim fill slopes, and final landfill slopes.

1. Determine critical excavation, interim and final landfill configuration slopes in the proposed design.
2. Select a soil profile for each critical section using available boring logs and geologic cross sections near each section. Information for this effort was derived from Appendix E- Subsurface Investigation section of this report.
3. Select material properties using unit weights and strength parameters for the proposed sections (See Table 1, below).

4. Perform slope stability analyses:
    a. Analyze the excavation exterior and interior liner slopes using SLIDE2 computer model and the simplified Bishop method of circular failure surfaces. Analyses were performed for both effective (drained) stress conditions and total (undrained) stress conditions. The effective stress conditions represent long-term conditions, and the total stress conditions represent short-term conditions. Analysis section plans, analysis sections, and SLIDE2 output files are presented in Appendix M-2A.

    b. Analyze the landfill interim condition slopes using SLIDE2 computer model and the simplified Bishop method of circular failure surfaces and the Bishops method for block failure surfaces at the bottom liner interface. Circular failure plane analyses were performed for total (undrained) stress conditions. The total stress conditions represent interim short-term conditions. Analysis section plans, analysis sections, and SLIDE2 output files are presented in Appendix M-2B.

    c. Analyze the final closure condition slopes using SLIDE2 computer model and the simplified Bishop method of circular failure surfaces and the Bishops method for block failure surfaces at the bottom liner interface. Circular failure plane analyses were performed for total (undrained) stress and effective (drained, or long term) stress conditions. The effective stress conditions represent long-term conditions, and the total stress conditions represent short-term conditions. Analysis section plans, analysis sections, and SLIDE2 output files are presented in Appendix M-2C.

5. Evaluate the stability of the proposed bottom liner system and the final cover system using infinite slope stability analysis. The results of the infinite slope stability analyses are presented in Appendix M-2D.

    a. Verify that the tensile stress in the liner system will be less than the yield stress by using Koerner's method (reference 4) for determination of shear stress in liner systems considering cohesion/adhesion forces.

    b. Provide anchor trench design considering pullout of the geomembrane (incorporated into the bottom liner infinite slope stability analysis).

    c. Use Duncan and Buchignani's method for infinite stability analyses to evaluate the internal stability of the liner and final cover systems.

References:

1. Duncan, J.M. and Buchignani, A.L., *An Engineering Manual for Slope Stability Studies,* Department of Civil Engineering-University of California-Berkeley, 1975.
2. TRI, Interface Friction/Direct Shear Testing & Slope Stability Issues. Short Course, November 12-13, 1998. Austin, Texas.
3. US Army Corps of Engineers, *Slope Stability* , Engineering and Design Manual, EM 1110-2-1902, October 31, 2003.
4. Koerner, Robert M., *Designing with Geosynthetics* , 5th Ed., Prentice-Hall, Inc., 2005.
5. SLIDE 2 (computer program for slope stability analyses), Rocscience Inc.
6. Das, Braja M., *Principles of Geotechnical Engineering* , 5th Ed., Brooks/Cole, 2002.
7. Gilbert, Robert B, *Peak Versus Residual Strength for Waste Containment Systems,* Proceedings the 15th GRI Conference on Hot Topics in Geosynthetics-II (Peak/Residual; RECMs; Installation; Concerns)
8. Cetco Lining Technologies, Laboratory Data Reports, Bentomat Direct Shear Testing Summary, Summary of Bentomat Direct Shear Test Data Internal, Revised 08/02
9. Bouzza, A., Zornberg, J.G., and Adam, D. *Geosynthetics in Waste Containment Facilities: Recent Advances* , 2002.

Solution: A. Slope stability analyses of the proposed slopes.

1. The locations of the critical sections selected for the stability analysis for the proposed slopes are shown on Sheets M-2A-1, M-2B-1 and M-3B-1. Sections analyzed are also shown with the most critical failure surfaces for each of the analyses performed and the resulting factors of safety.

2. The soil profile used for each analysis was based on boring log data from previous site investigations from the undeveloped area of the site and the geologic cross sections (see Appendix E- Subsurface Investigation). Generalized soil profiles for the site also are shown in Appendix E of this application.

3. A summary table (Table 1) presents the assumed material weight and strength properties for the analyses performed for this appendix.

4. The material weight and strength parameter determination for each material type was based on laboratory testing results (Atterberg limits, natural moisture content, unit weight, percent finer than #200 sieve, and Standard Proctor), industry references and engineering judgment based on previous experience with similar materials. Laboratory testing results from subsurface investigations are included in Appendix M-1.
5. The output from the slope stability analyses are presented in Table 2, below.

B. Infinite slope stability of the proposed bottom liner and final cover systems.

1. Interface and internal strength parameters are provided on Sheet M-2D-3.
2. Verification that the tensile stress in the bottom liner system will be less than yield stress is provided on Sheets M-2D-4 through M-2D-7.
3. Anchor trench design is provided on Sheets M-2D-8 through M-2D-9.
4. Infinite stability analysis to evaluate the internal stability of the bottom liner and final cover systems is provided on Sheets M-2D-10 through M-2D-13.

Conclusion: Based on the slope stability analyses provided in this Appendix, the proposed critical slopes for the excavation, interim and final cover conditions have adquate factors of safety to be considered stable. In addition, the infinite stability analyses demonstrate that the proposed liner system has adequate factors of safety to be considered stable.

Table 1. Summary of Material Properties Used in the Slope Stability Analysis

Soil Description	Moist Unit Weight (pcf)	Saturated Unit Weight (pcf)	Effective Stress		Total Stress	
			Cohesion (psf)	Angle of Internal Friction (degrees)	Cohesion (psf)	Angle of Internal Friction (degrees)
Final Cover Material	116	120	80	25	80	25
Waste	60	65	288	33	288	33
Bottom Liner (1)	120	125	50	9.3	50	9.3
Silty Sand/Clay	128	148	864	21.9	763	14.9
Weathered Shale	124	146	936	35.8	1,958	18.3
Unweathered Shale	155	163	748	57.2	2,217	47.2

(1) The worst case shear strength interface for the bottom liner system was assumed to be the smooth geomembrane/geosynthetic clay liner (GCL) interface proposed in the alternative bottom liner system (for both cell bottom and sideslopes). For this interface, shear strength parameters of angle of internal friction (phi) = 9.3 degrees and cohesion = 50 psf were used for both effective (drained) and total (undrained conditions). All other interfaces within both the prescribed and alternative bottom liner system exceed these strength parameters. Note that the stability analyses assumes that a reinforced GCL is used for the alternative bottom liner, which exhibits internal shear strength parameters exceeding the values used in the modeling.

Table 2. SLIDE2 Stability Modeling Output

Analyzed Section-Run[1]	Method	Stress Condition				Factor of Safety Acceptable
		Effective Stress	Total Stress	Effective Stress	Total Stress	
Recommended Min. Factor of Safety		**1.5[2]**	**1.3[2]**	**1.5**	**1.3**	
Excavation Slope A-1-Exterior	Bishop-Circular	**3.85**	**4.42**	-	-	YES
Excavation Slope A-1-Interior	Bishop-Circular	**7.09**	**6.20**	-	-	YES
Interim Slope B-1 [3]	Bishop-Circular	-	**1.99**	-	-	YES
Interim Slope B-2 [3]	Rankine-Block	-	-	-	**1.41**	YES
Final Cover C-1	Bishop-Circular	**2.67**	**2.67**	-	-	YES
Final Cover C-2	Rankine-Block	-	-	**1.69**	**1.69**	YES
Final Cover D-1	Bishop-Circular	**2.44**	**2.53**	-	-	YES
Final Cover D-2	Rankine-Block	-	-	**1.69**	**1.69**	YES
Final Cover E-1	Bishop-Circular	**2.60**	**2.61**	-	-	YES
Final Cover E-2	Rankine-Block	-	-	**1.60**	**1.60**	YES

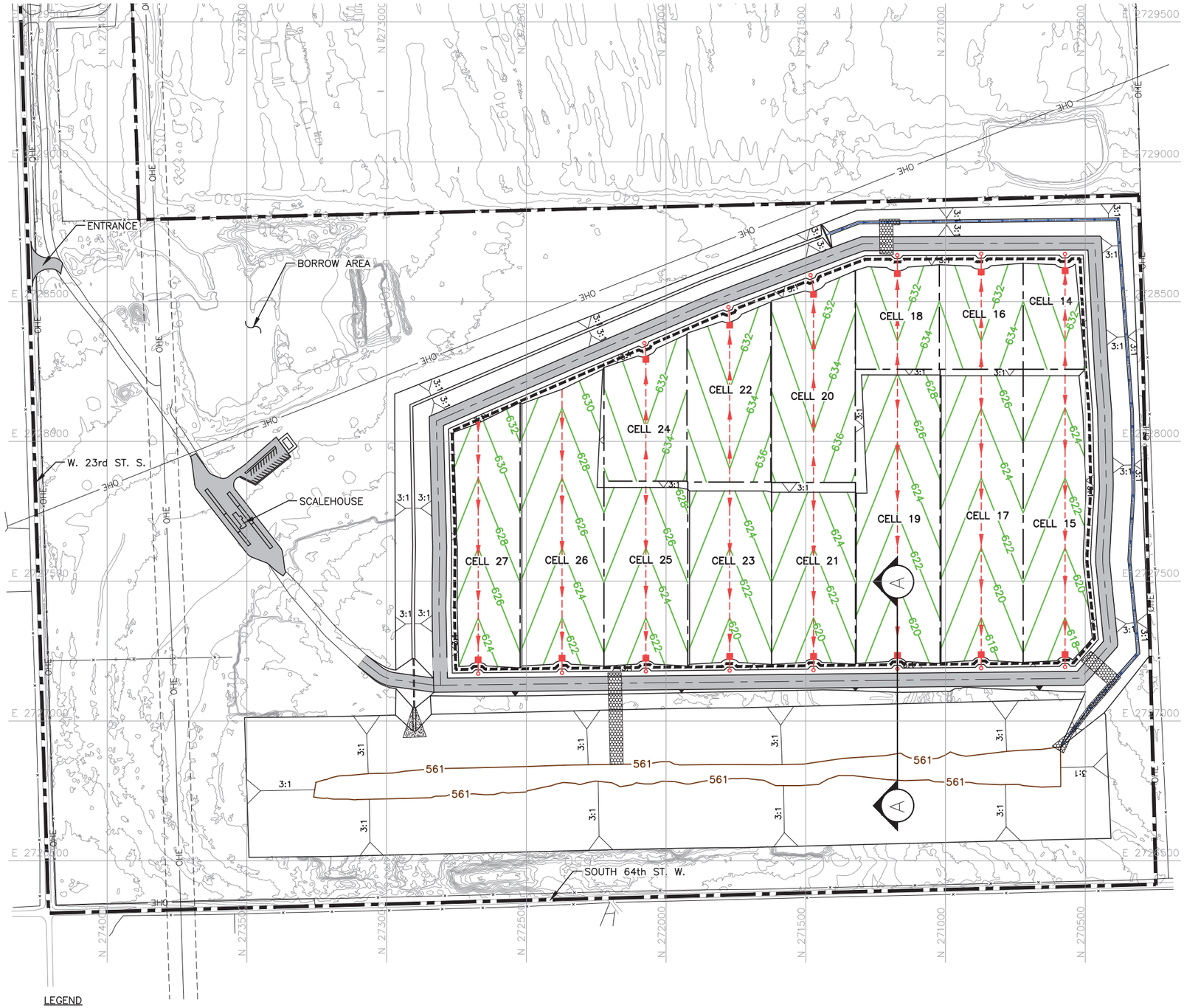
(1) For interim, and final cover configurations Run 1 represents circular failure, and Run 2 represents block failure.

(2) Recommended minimum factor of safety provided in Reference 3 on Sheet M-A-2.

(3) A minimum short-term (interim) factor of safety of 1.3 was assumed for the Interim Slopes B-1 and B-2.

APPENDIX M-2A

EXCAVATION STABILITY ANALYSIS



LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA

10/13/2023

LEGEND

- PROPOSED PERMIT BOUNDARY
- PROPOSED LIMITS OF WASTE
- N 273000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- OHE — EXISTING OVERHEAD EASEMENT
- 636 — EXCAVATION CONTOUR
- 561 — BORROW AREA CONTOUR
- A — A — SLOPE STABILITY SECTION

N

0 200 400
SCALE IN FEET

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NOTES:

1. EXISTING CONTOURS AND ELEVATIONS PROVIDED BY HYDREX ENVIRONMENTAL COMPILED FROM AERIAL PHOTOGRAPHY FLOWN 01-25-2023.

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DATE: 03/2023
FILE: 0086-364-11
CAD: SHEET M-2A-1.DWG

DRAWN BY: RAA
DESIGN BY: JBM
REVIEWED BY: DEP

Weaver Consultants Group
CA 3804 PE - 06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION EXCAVATION SLOPE STABILITY SECTION LOCATIONS

MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

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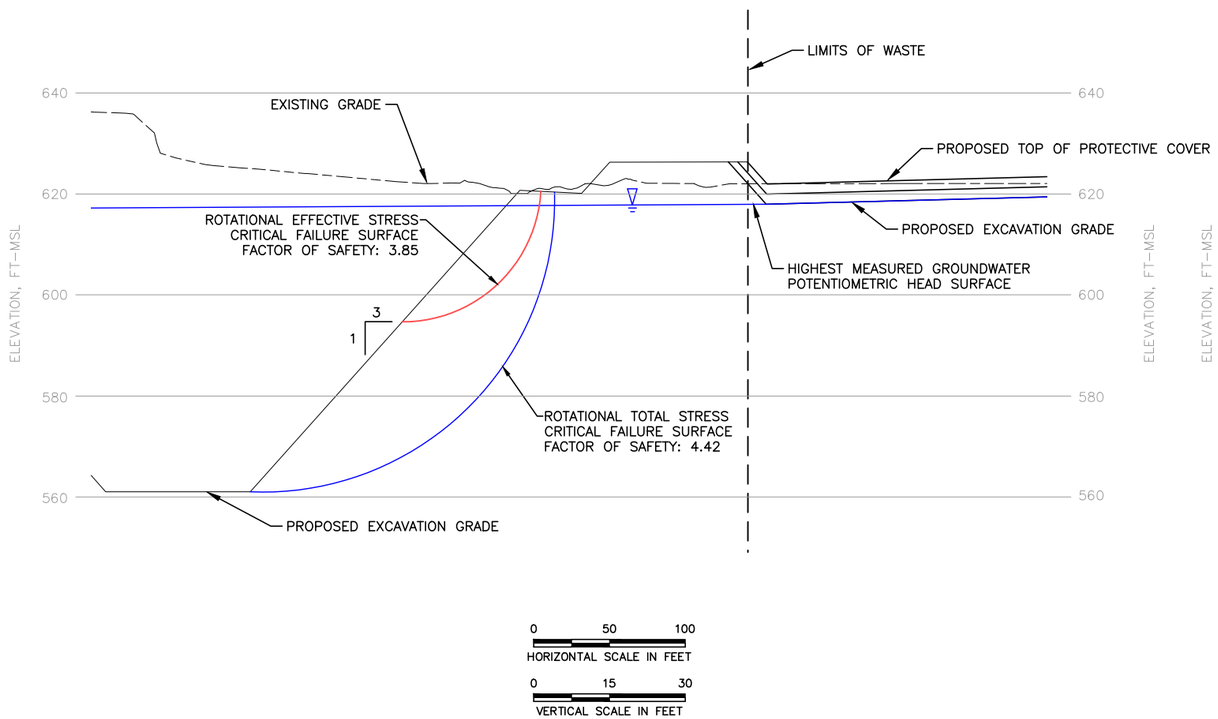
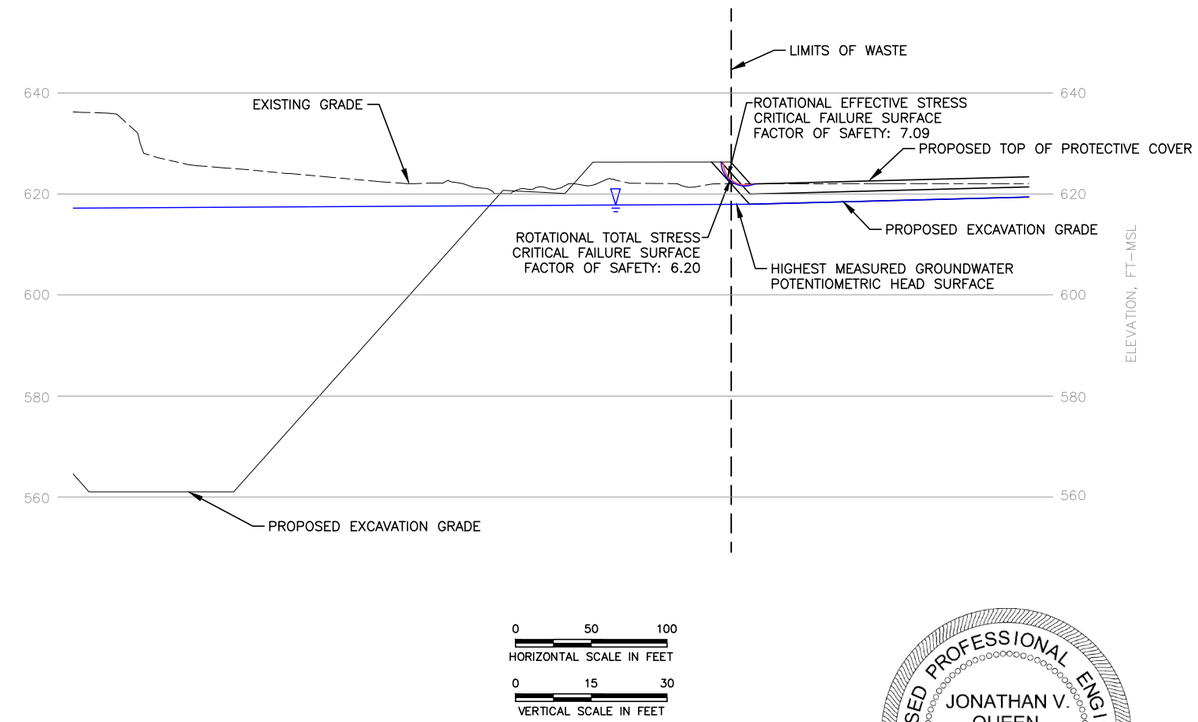
SHEET M-2A-1

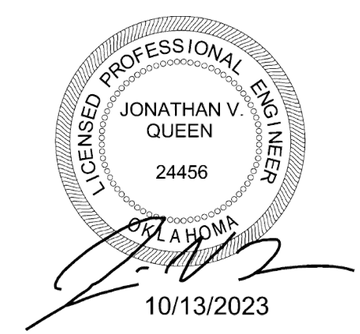
O:\0086\364\EXPANSION 2022\APPENDIX M\M-2A-1-SECTION LOCATIONS.dwg, jpdhr, 1:2

EXCAVATION SECTION A–A – EXTERIOR
MINIMUM FACTOR OF SAFETY (STATIC): 3.85



EXCAVATION SECTION A–A – INTERIOR
MINIMUM FACTOR OF SAFETY (STATIC): 6.20





NOTE: REFER TO SECTION 4 OF APPENDIX M FOR A COMPLETE DISCUSSION ON THE CONDITION ANALYZED AND FACTOR OF SAFETY VALUES.

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DATE: 03/2023
FILE: 0086–364–11
CAD: SHEET M–2A–2–SECTIONS.DWG

DRAWN BY: RAA
DESIGN BY: JBM
REVIEWED BY: DEP

Weaver Consultants Group
CA 3804–06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION
EXCAVATION SLOPE STABILITY SECTIONS

MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

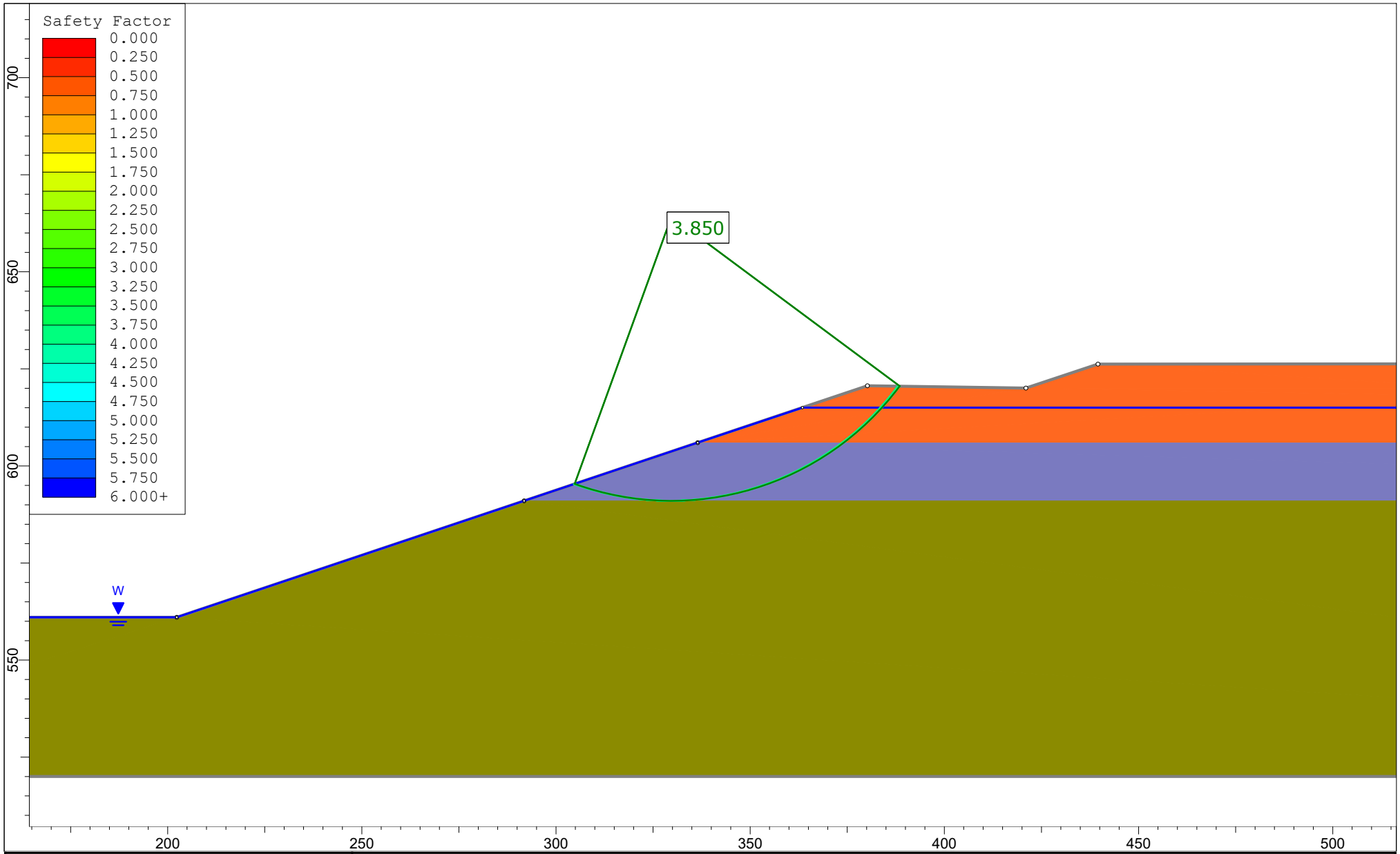
WWW.WCGRP.COM

SHEET M–2A–2

G:\0086\364\EXPANSION 2022\APPENDIX M\M-2A-2-EXCAVATION LINER SECTIONS.dwg, jpuhr, 1:2

SLIDE2 SLOPE STABILITY OUTPUT FILES

SECTION A-A



Weaver Consultants Group	Project	MUSKOGEE LANDFILL	
	Group	ENGINEERING	Scenario: EFFECTIVE-CIRCULAR-EXTERIOR
	Drawn By	PREP BY: JBM CHKD BY:DEP	Company: WEAVER CONSULTANTS GROUP
SLIDEINTERPRET 9.008	Date	3/2/2023	File Name: SEC A-Effective-Circular-Exterior.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

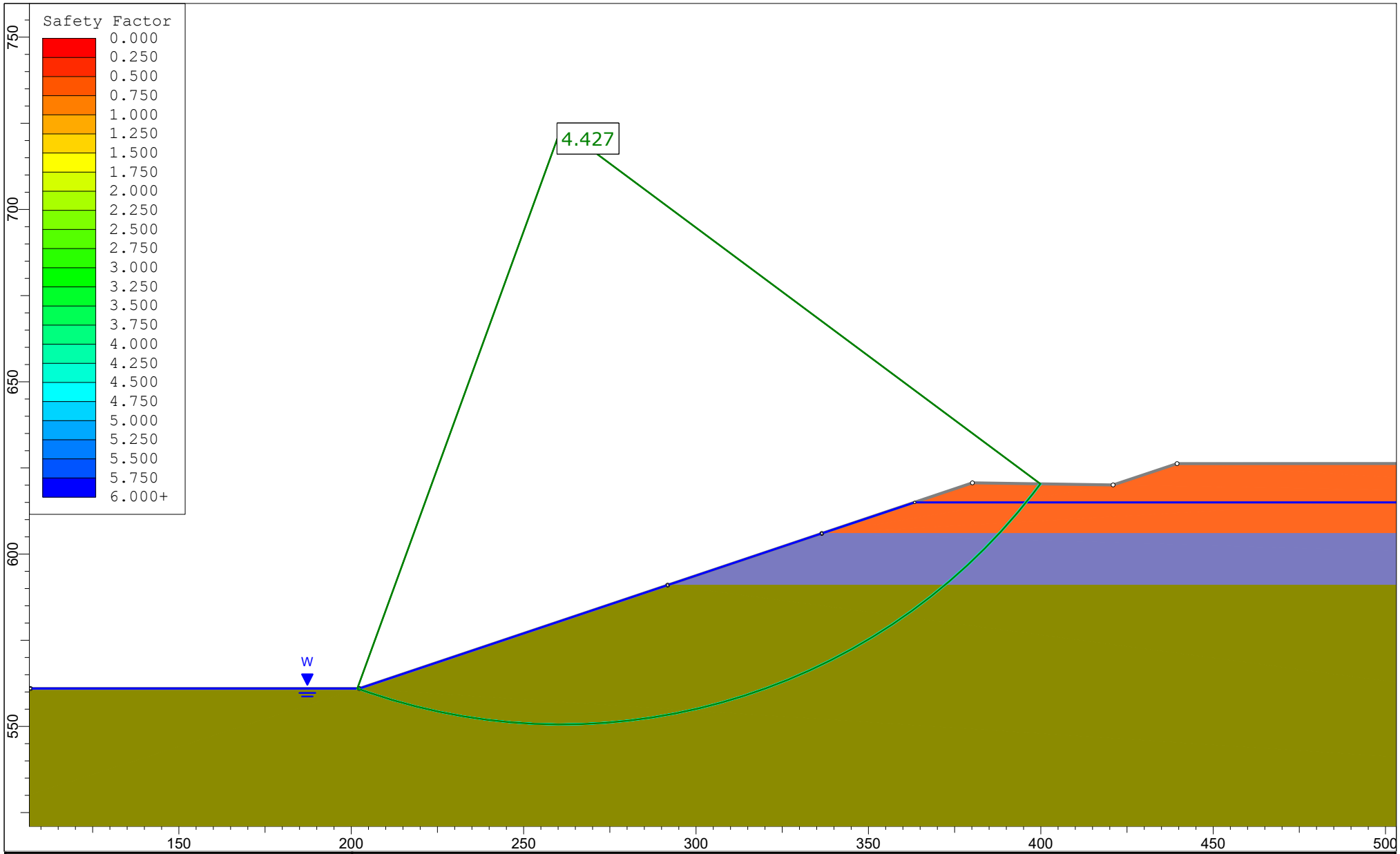
Materials

LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	100
Friction Angle [deg]	18
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	864
Friction Angle [deg]	21.9
Water Surface	Water Table
Hu Value	0
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	936
Friction Angle [deg]	35.8
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	748
Friction Angle [deg]	57.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	3.850250
Center:	329.728, 664.245
Radius:	73.250
Left Slip Surface Endpoint:	304.792, 595.370
Right Slip Surface Endpoint:	388.508, 620.536
Resisting Moment:	1.05314e+07 lb-ft
Driving Moment:	2.73525e+06 lb-ft
Total Slice Area:	970.98 ft2
Surface Horizontal Width:	83.7166 ft
Surface Average Height:	11.5984 ft



Weaver Consultants Group	Project	MUSKOGEE LANDFILL	
	Group	ENGINEERING	Scenario: TOTAL-CIRCULAR-EXTERIOR
	Drawn By	PREP BY: JBM CHKD BY:DEP	Company: WEAVER CONSULTANTS GROUP
SLIDEINTERPRET 9.008	Date	3/2/2023	File Name: SEC A-Total-Circular-Exterior.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

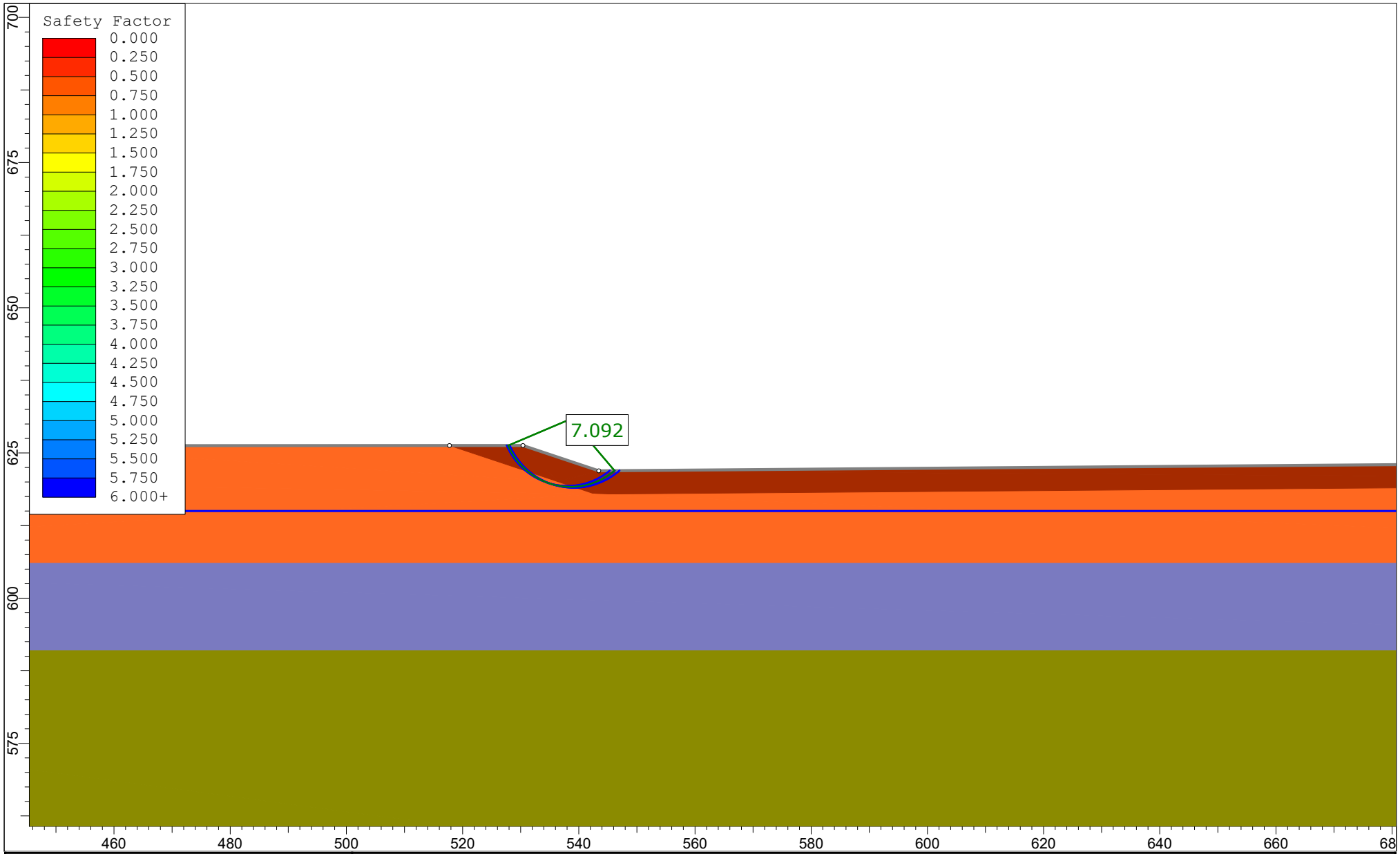
Materials

LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	100
Friction Angle [deg]	18
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	763
Friction Angle [deg]	14.9
Water Surface	Water Table
Hu Value	0
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	1958
Friction Angle [deg]	18.3
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	2217
Friction Angle [deg]	47.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	4.427250
Center:	260.965, 723.800
Radius:	173.231
Left Slip Surface Endpoint:	201.761, 561.000
Right Slip Surface Endpoint:	399.927, 620.366
Resisting Moment:	1.70208e+08 lb-ft
Driving Moment:	3.84456e+07 lb-ft
Total Slice Area:	5424.17 ft2
Surface Horizontal Width:	198.166 ft
Surface Average Height:	27.3719 ft



Weaver Consultants Group

SLIDEINTERPRET 9.008

Project	MUSKOGEE LANDFILL		
Group	ENGINEERING	*Scenario*	EFFECTIVE-CIRCULAR-INTERIOR
Drawn By	PREP BY: JBM CHKD BY:DEP	*Company*	WEAVER CONSULTANTS GROUP
Date	3/2/2023	*File Name*	SEC A-Effective-Circular-Interior.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Left to Right

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

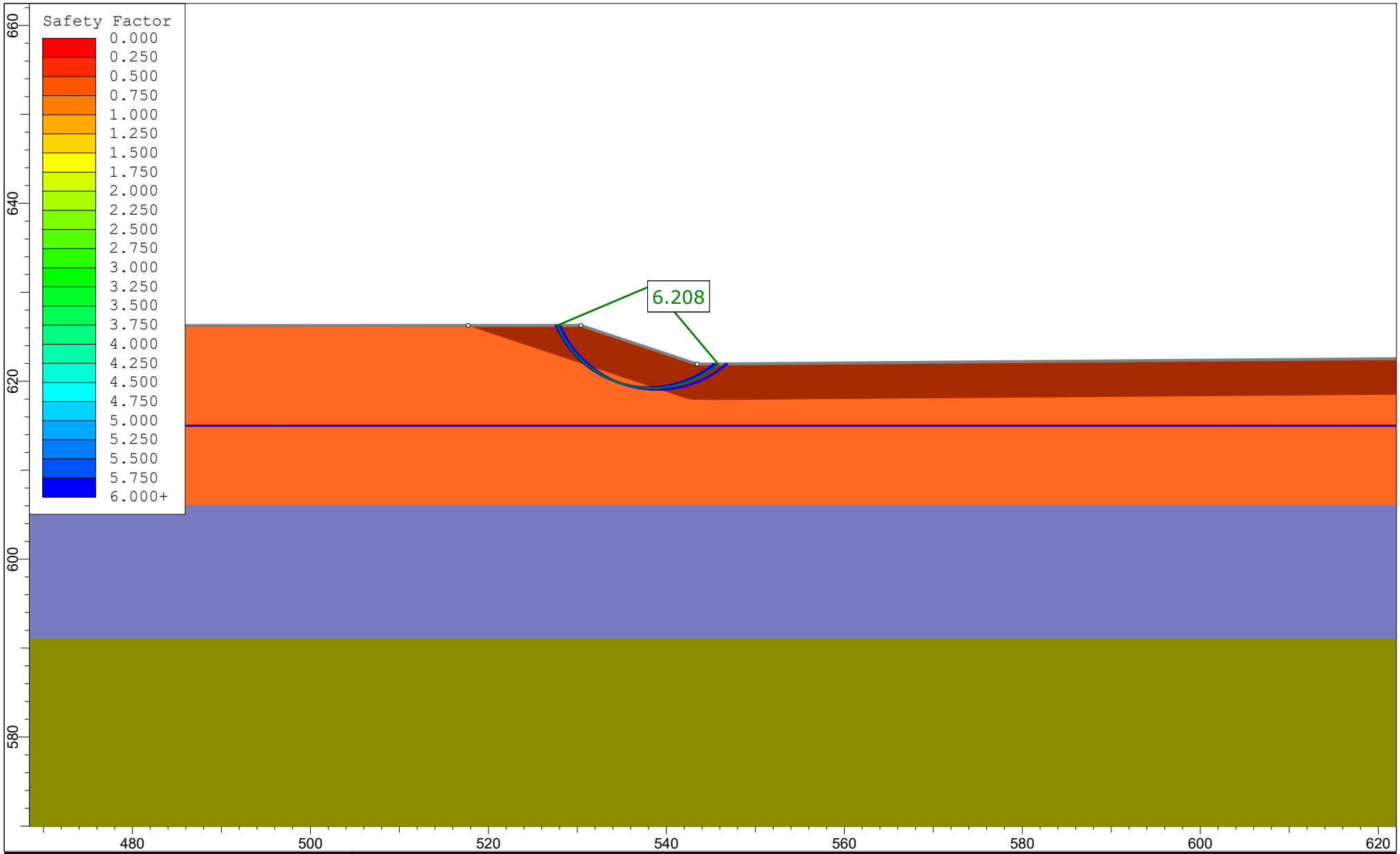
Materials

LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	100
Friction Angle [deg]	18
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	864
Friction Angle [deg]	21.9
Water Surface	Water Table
Hu Value	0
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	936
Friction Angle [deg]	35.8
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	748
Friction Angle [deg]	57.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	7.091900
Center:	538.604, 630.833
Radius:	11.667
Left Slip Surface Endpoint:	527.865, 626.274
Right Slip Surface Endpoint:	546.159, 621.943
Resisting Moment:	134087 lb-ft
Driving Moment:	18907 lb-ft
Total Slice Area:	61.9603 ft2
Surface Horizontal Width:	18.294 ft
Surface Average Height:	3.38692 ft



Weaver Consultants Group

SLIDEINTERPRET 9.008

Project	MUSKOGEE LANDFILL		
Group	ENGINEERING	*Scenario*	TOTAL-CIRCULAR-INTERIOR
Drawn By	PREP BY: JBM CHKD BY:DEP	*Company*	WEAVER CONSULTANTS GROUP
Date	3/2/2023	*File Name*	SEC A-Total-Circular-Interior.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Left to Right

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	100
Friction Angle [deg]	18
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	763
Friction Angle [deg]	14.9
Water Surface	Water Table
Hu Value	0
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	1958
Friction Angle [deg]	18.3
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	2217
Friction Angle [deg]	47.2
Water Surface	Water Table
Hu Value	1

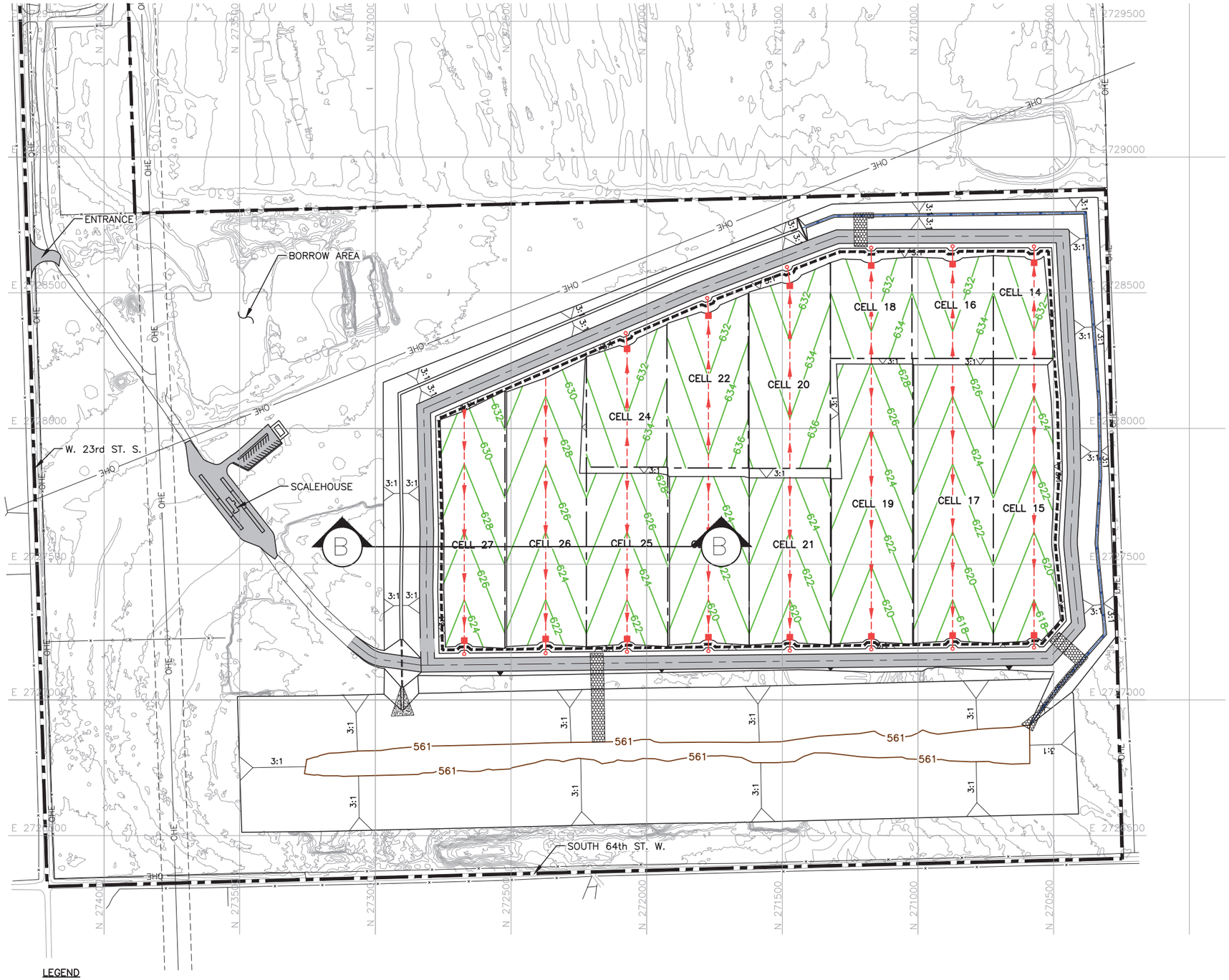
Global Minimums

Method: bishop simplified

FS	6.208080
Center:	538.384, 630.776
Radius:	11.546
Left Slip Surface Endpoint:	527.752, 626.274
Right Slip Surface Endpoint:	545.815, 621.940
Resisting Moment:	115210 lb-ft
Driving Moment:	18558 lb-ft
Total Slice Area:	61.3179 ft2
Surface Horizontal Width:	18.0632 ft
Surface Average Height:	3.39464 ft

APPENDIX M-2B

INTERIM SLOPE STABILITY ANALYSIS



LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA

10/13/2023

LEGEND

- PROPOSED PERMIT BOUNDARY
- PROPOSED LIMITS OF WASTE
- N 273000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- OHE — EXISTING OVERHEAD EASEMENT
- 636 — EXCAVATION CONTOUR
- 561 — BORROW AREA CONTOUR
- B — B — SLOPE STABILITY SECTION

N

0 200 400
SCALE IN FEET

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NOTES:

1. EXISTING CONTOURS AND ELEVATIONS PROVIDED BY HYDREX ENVIRONMENTAL COMPILED FROM AERIAL PHOTOGRAPHY FLOWN 01-25-2023.

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DATE: 03/2023
FILE: 0086-364-11
CAD: SHEET M-2B-1.DWG

DRAWN BY: RAA
DESIGN BY: JBM
REVIEWED BY: DEP

Weaver Consultants Group
CA 3804 PE - 06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION INTERIM SLOPE STABILITY SECTION LOCATIONS

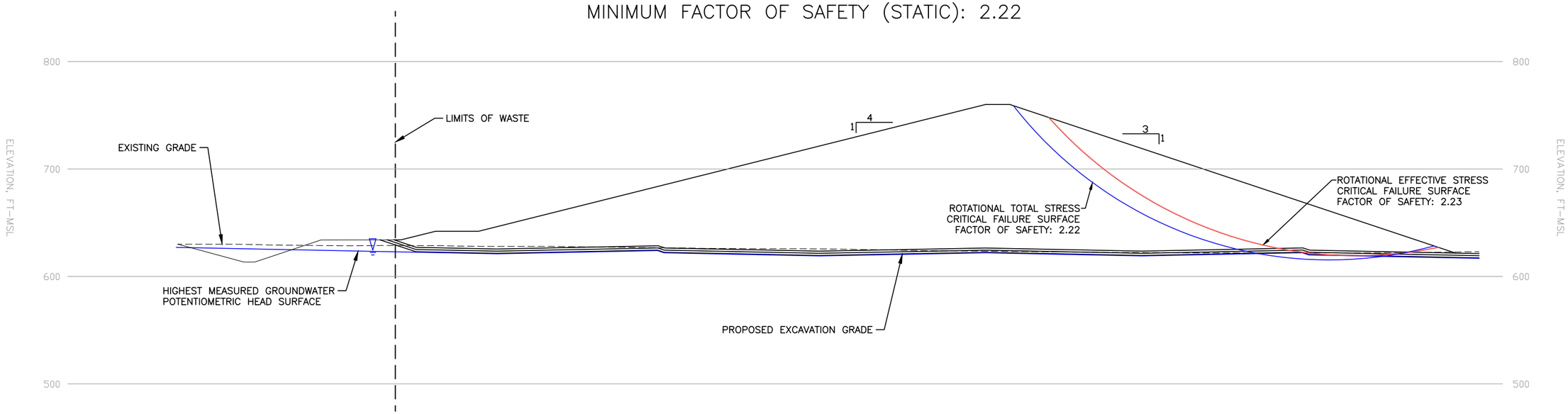
MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

WWW.WCGRP.COM

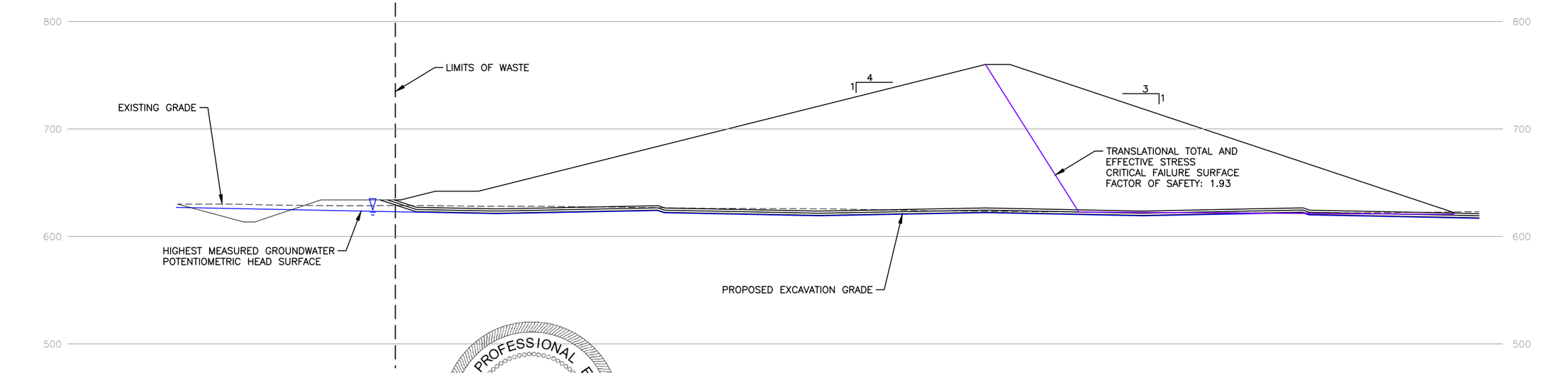
SHEET M-2B-1

O:\0086\364\EXPANSION 2022\APPENDIX M\M-2B-1-SECTION LOCATIONS.dwg, jpdhr, 1:2

INTERIM SECTION B–B
MINIMUM FACTOR OF SAFETY (STATIC): 2.22



INTERIM SECTION B–B
MINIMUM FACTOR OF SAFETY (STATIC): 1.93



NOTE: REFER TO SECTION 4 OF APPENDIX M FOR A COMPLETE DISCUSSION ON THE CONDITION ANALYZED AND FACTOR OF SAFETY VALUES.

LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA
10/13/2023

0 50 100
SCALE IN FEET

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DATE: 03/2023
FILE: 0086–364–11
CAD: SHEET M–2B–2–SECTIONS.DWG

DRAWN BY: RAA
DESIGN BY: JBM
REVIEWED BY: DEP

Weaver Consultants Group
CA 3804–06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION
INTERIM SLOPE STABILITY SECTIONS

MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

WWW.WCGRP.COM

SHEET M–2B–2

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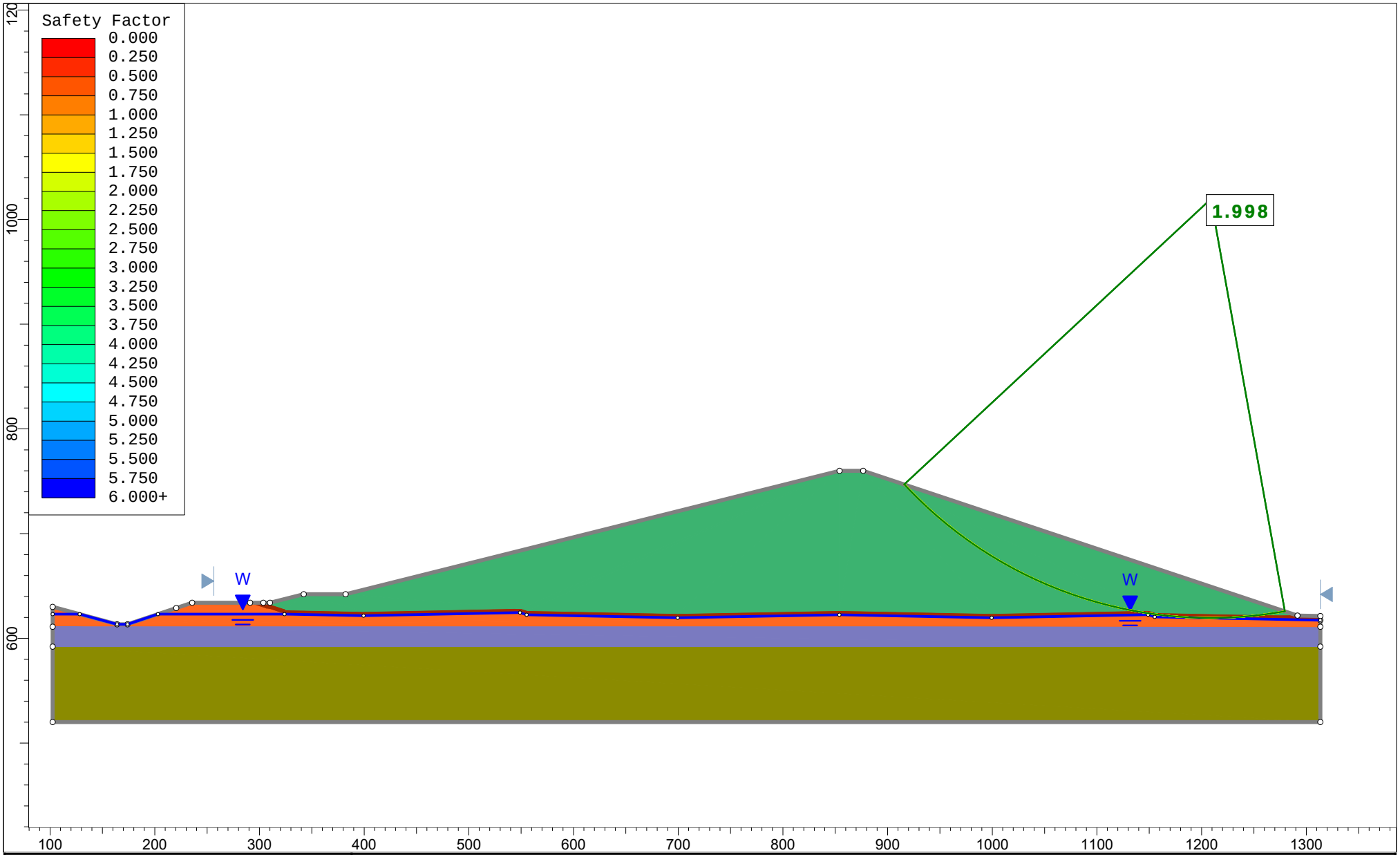
O:\0086\364\EXHIBITS\2023 APPENDIX M\M-2B-2-INTERIM SECTIONS.dwg, Tab: 2B-2, jpdhr, 22

SLIDE2 SLOPE STABILITY OUTPUT FILES

SECTION B-B



Weaver Consultants Group

SLIDEINTERPRET 9.018

Project	MUSKOGEE LANDFILL		
Group	ENGINEERING	*Scenario*	EFFECTIVE-CIRCULAR
Drawn By	PREP BY: MB CHKD BY:DEP	*Company*	WEAVER CONSULTANTS GROUP
Date	10/11/2023	*File Name*	SEC B-Effective-Circular.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Left to Right

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

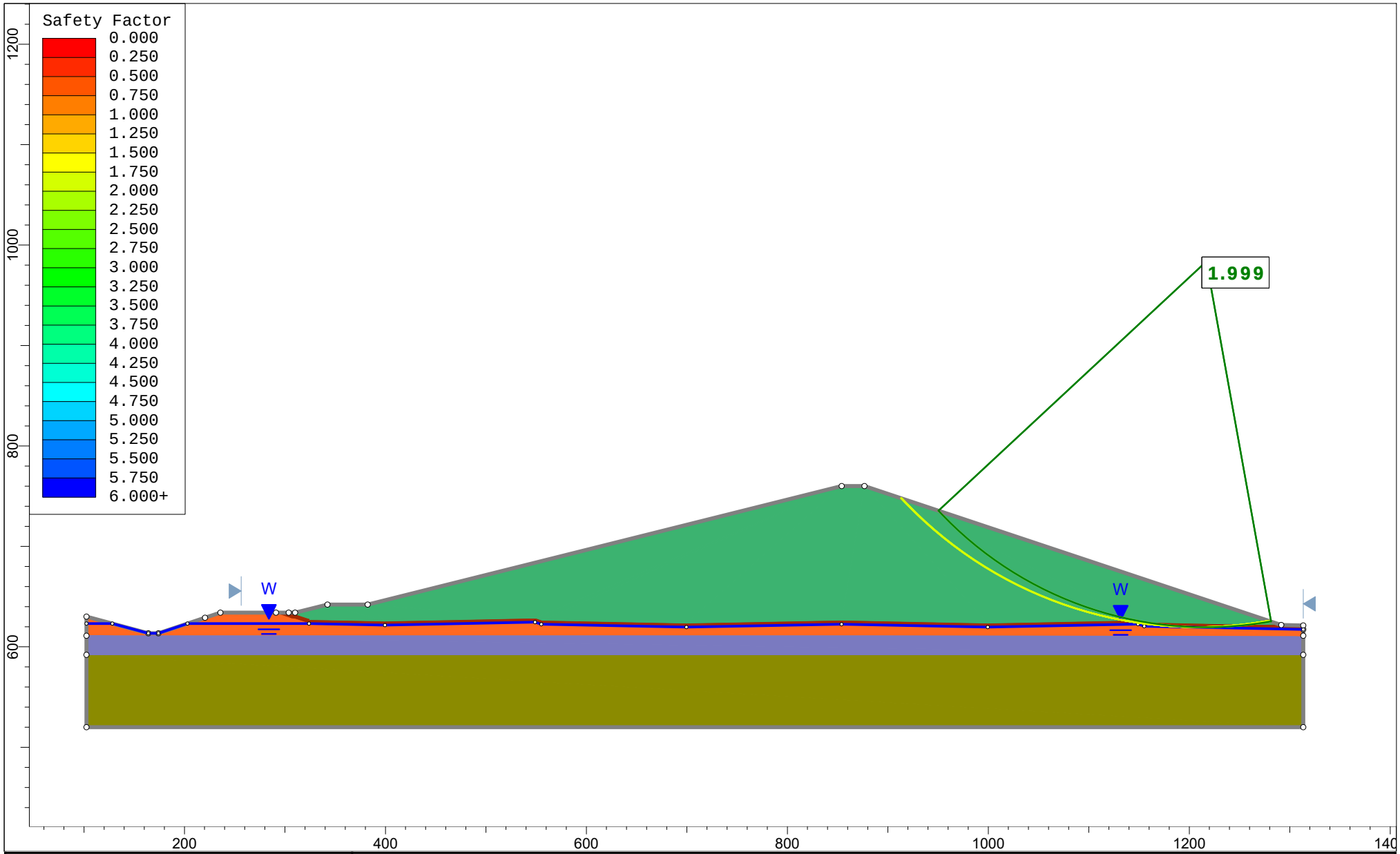
Materials

WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	None
Ru Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	864
Friction Angle [deg]	21.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	936
Friction Angle [deg]	35.8
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	748
Friction Angle [deg]	57.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	1.997700
Center:	1208.712, 1019.425
Radius:	400.003
Left Slip Surface Endpoint:	915.878, 746.934
Right Slip Surface Endpoint:	1279.486, 625.732
Resisting Moment:	1.78223e+08 lb-ft
Driving Moment:	8.92142e+07 lb-ft
Total Slice Area:	12649 ft2
Surface Horizontal Width:	363.607 ft
Surface Average Height:	34.7874 ft



Weaver Consultants Group	Project	MUSKOGEE LANDFILL	
	Group	ENGINEERING	Scenario: TOTAL-CIRCULAR
	Drawn By	PREP BY: MB CHKD BY:DEP	Company: WEAVER CONSULTANTS GROUP
SLIDEINTERPRET 9.018	Date	10/11/2023	File Name: SEC B-Total-Circular.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Left to Right

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

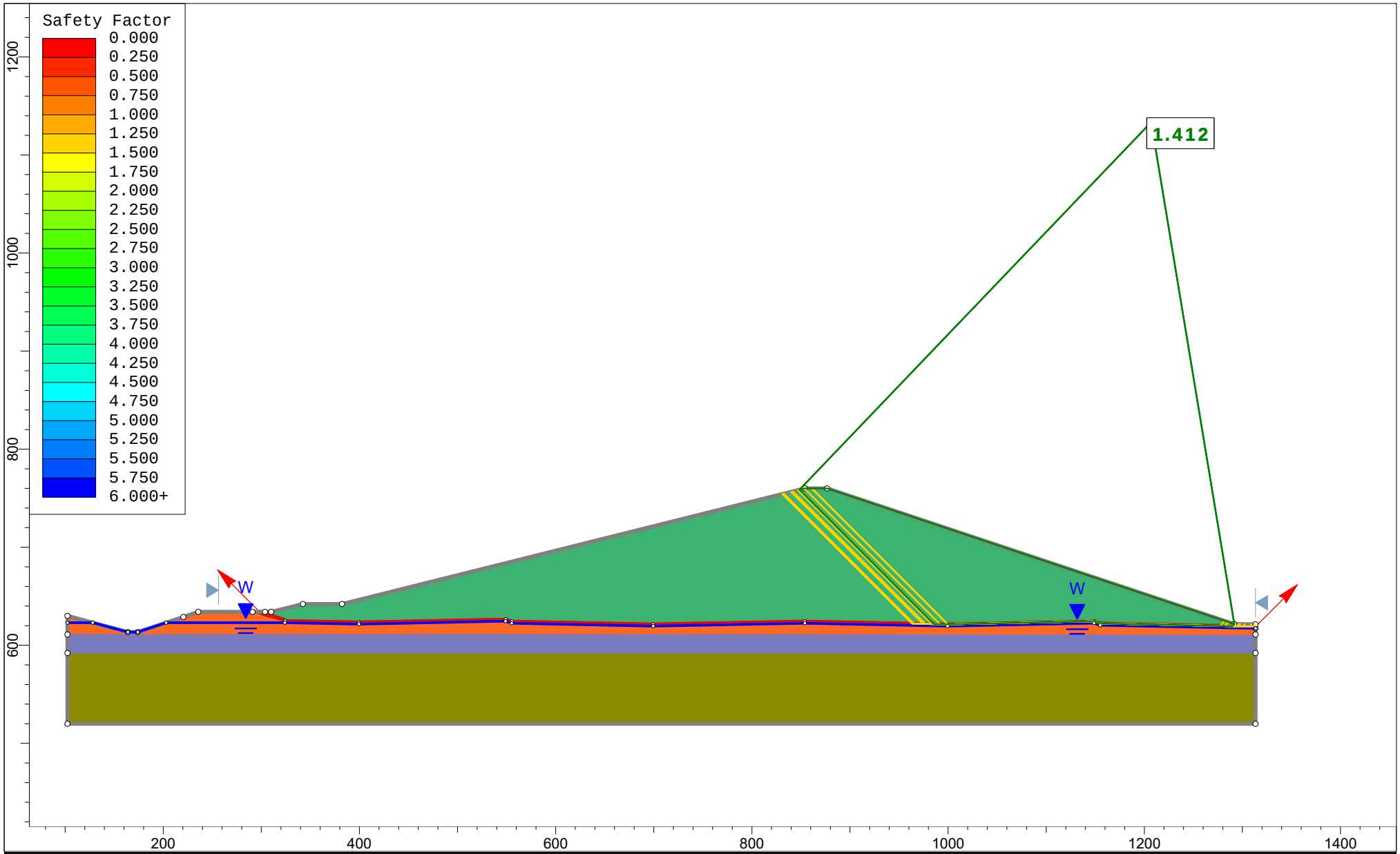
Materials

WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	None
Ru Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	763
Friction Angle [deg]	14.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	1958
Friction Angle [deg]	18.3
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	2217
Friction Angle [deg]	47.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	1.998510
Center:	1216.968, 983.581
Radius:	364.238
Left Slip Surface Endpoint:	950.317, 735.455
Right Slip Surface Endpoint:	1281.413, 625.089
Resisting Moment:	1.34535e+08 lb-ft
Driving Moment:	6.73178e+07 lb-ft
Total Slice Area:	10487.9 ft2
Surface Horizontal Width:	331.096 ft
Surface Average Height:	31.6762 ft



Weaver Consultants Group	Project	MUSKOGEE LANDFILL	
	Group	ENGINEERING	Scenario: EFFECTIVE-BLOCK
	Drawn By	PREP BY: MB CHKD BY:DEP	Company: WEAVER CONSULTANTS GROUP
SLIDEINTERPRET 9.018	Date	10/11/2023	File Name: SEC B-Effective-Block.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Left to Right

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

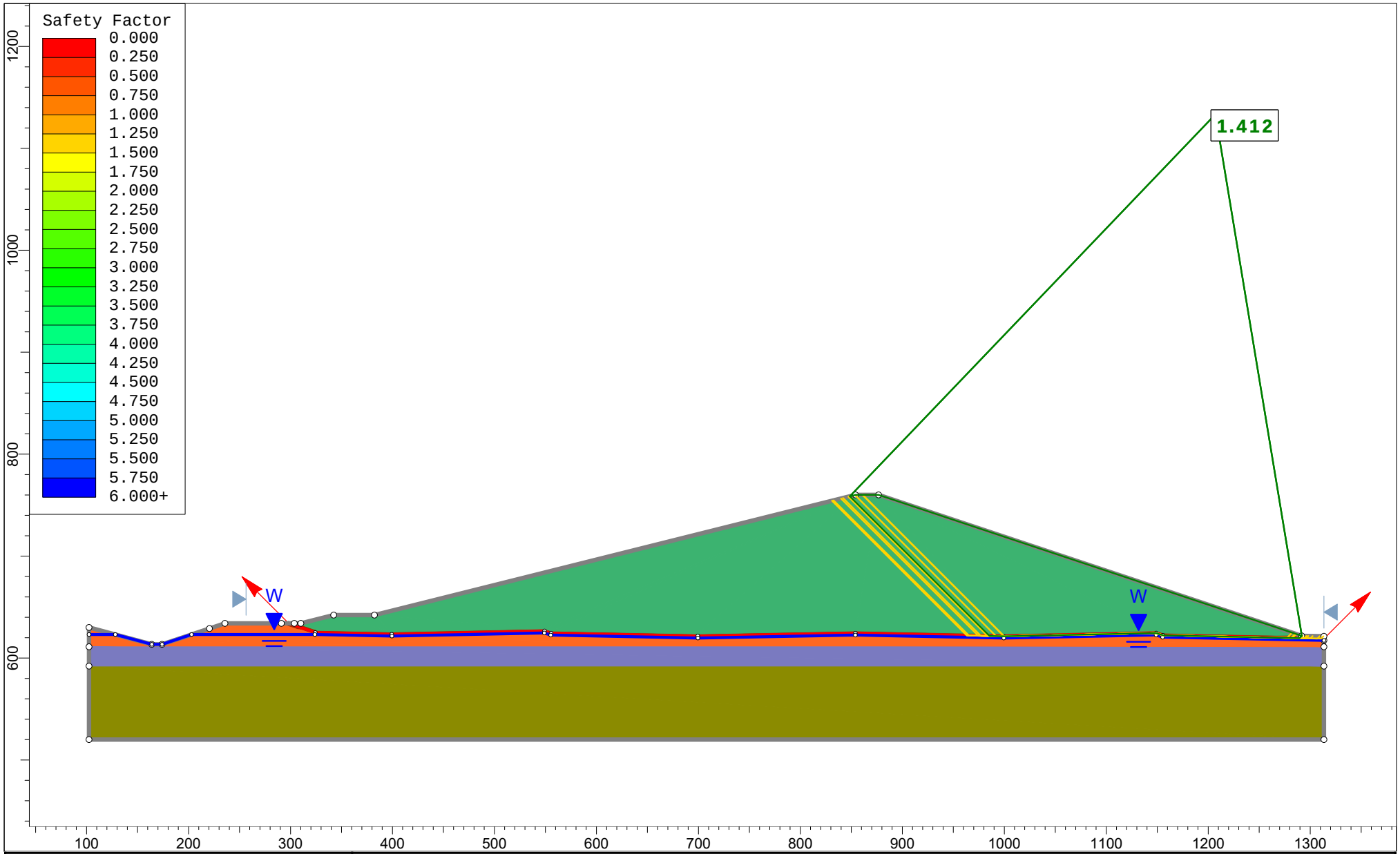
Materials

WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	None
Ru Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	864
Friction Angle [deg]	21.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	936
Friction Angle [deg]	35.8
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	748
Friction Angle [deg]	57.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	1.411810
Axis Location:	1207.000, 1133.379
Left Slip Surface Endpoint:	848.492, 758.610
Right Slip Surface Endpoint:	1291.711, 621.711
Resisting Moment:	2.54379e+08 lb-ft
Driving Moment:	1.80179e+08 lb-ft
Total Slice Area:	23142.8 ft2
Surface Horizontal Width:	443.219 ft
Surface Average Height:	52.2153 ft



Weaver Consultants Group

SLIDEINTERPRET 9.018

Project	MUSKOGEE LANDFILL		
Group	ENGINEERING	Scenario	TOTAL-CIRCULAR
Drawn By	PREP BY: MB CHKD BY:DEP	Company	WEAVER CONSULTANTS GROUP
Date	10/11/2023	File Name	SEC B-Total-Block.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Left to Right

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	None
Ru Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	763
Friction Angle [deg]	14.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	1958
Friction Angle [deg]	18.3
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	2217
Friction Angle [deg]	47.2
Water Surface	Water Table
Hu Value	1

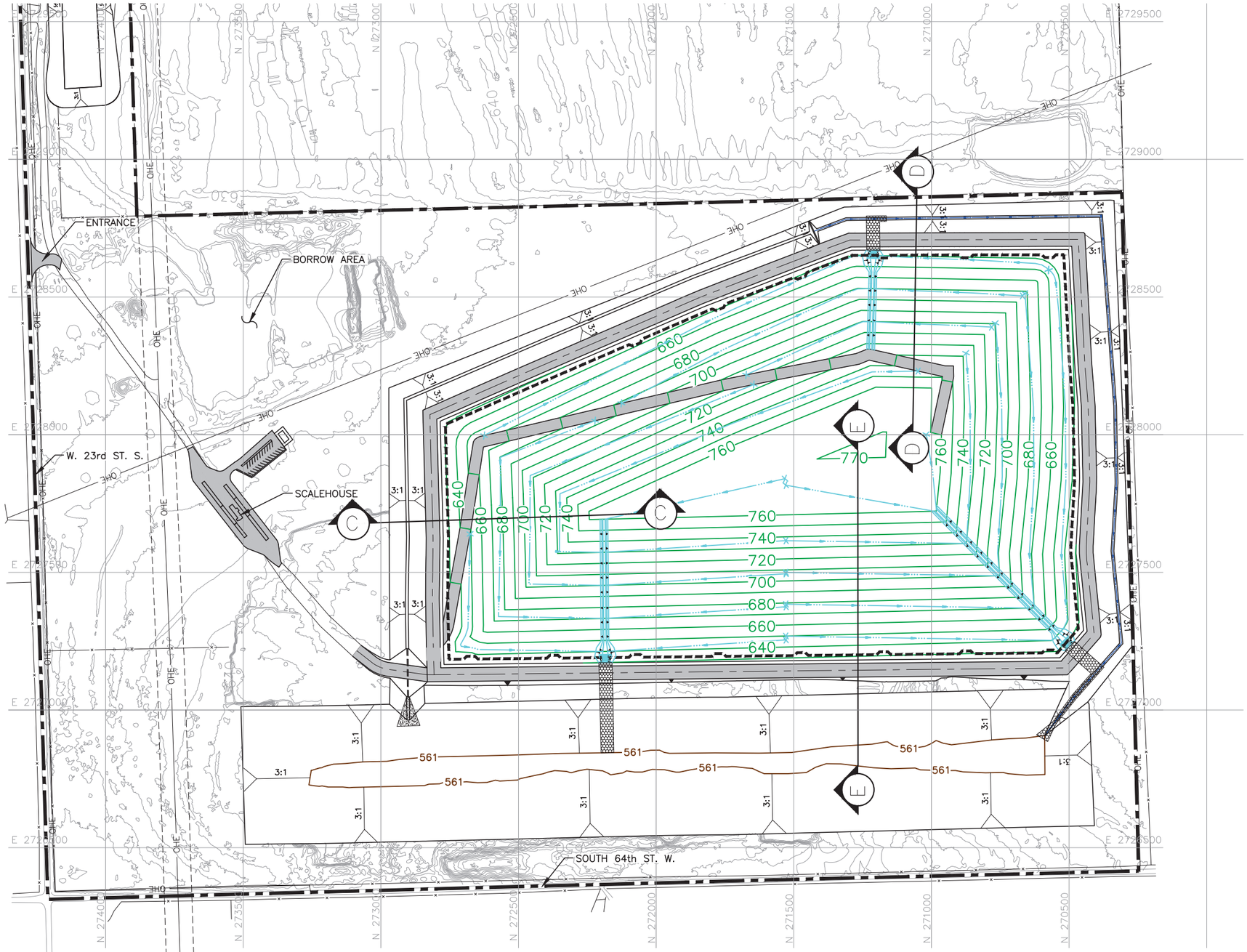
Global Minimums

Method: bishop simplified

FS	1.411810
Axis Location:	1207.000, 1133.379
Left Slip Surface Endpoint:	848.492, 758.610
Right Slip Surface Endpoint:	1291.711, 621.711
Resisting Moment:	2.54379e+08 lb-ft
Driving Moment:	1.80179e+08 lb-ft
Total Slice Area:	23142.8 ft2
Surface Horizontal Width:	443.219 ft
Surface Average Height:	52.2153 ft

APPENDIX M-2C

FINAL CLOSURE SLOPE STABILITY ANALYSIS



LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA
10/13/2023

LEGEND

- PROPOSED PERMIT BOUNDARY
- PROPOSED LIMITS OF WASTE
- N 273000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- OHE — EXISTING OVERHEAD EASEMENT
- 700 — FINAL COVER CONTOUR
- 561 — BORROW AREA CONTOUR
- C — C — SLOPE STABILITY SECTION

N

0 200 400
SCALE IN FEET

NOTES:

1. EXISTING CONTOURS AND ELEVATIONS PROVIDED BY HYDREX ENVIRONMENTAL COMPILED FROM AERIAL PHOTOGRAPHY FLOWN 01-25-2023.

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☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 03/2023
FILE: 0086-364-11
CAD: SHEET M-2C-1.DWG

DRAWN BY: RAA
DESIGN BY: JBM
REVIEWED BY: DEP

Weaver Consultants Group
CA 3804 PE - 06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION
FINAL COVER SLOPE STABILITY SECTION LOCATIONS

MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

WWW.WCGRP.COM

SHEET M-2C-1

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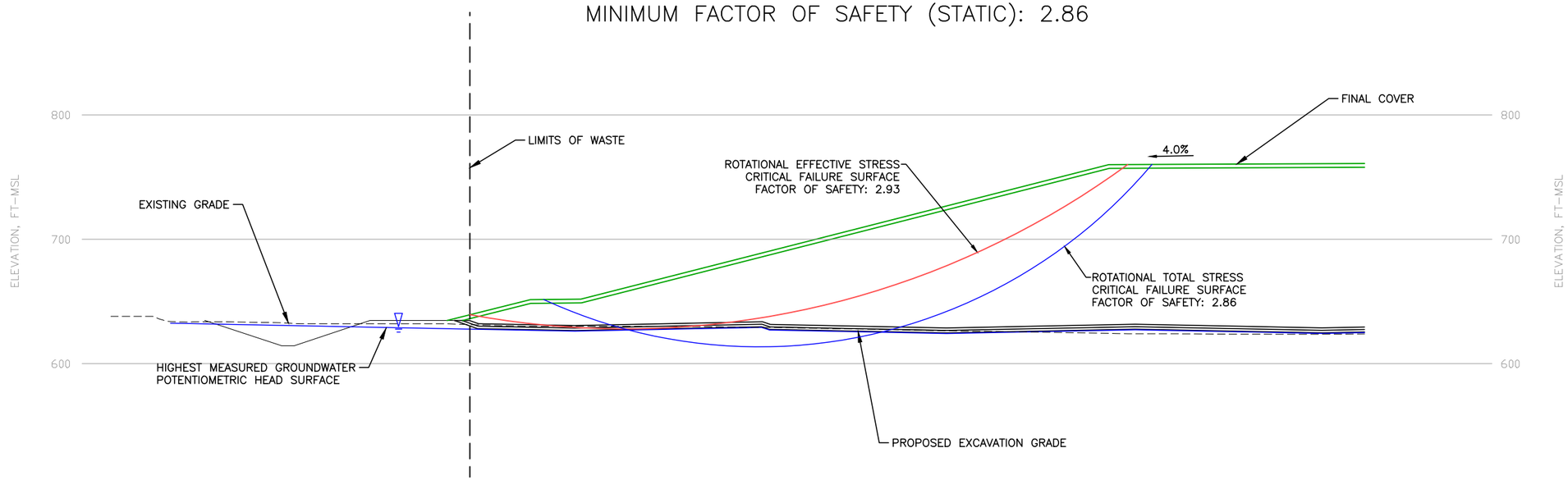
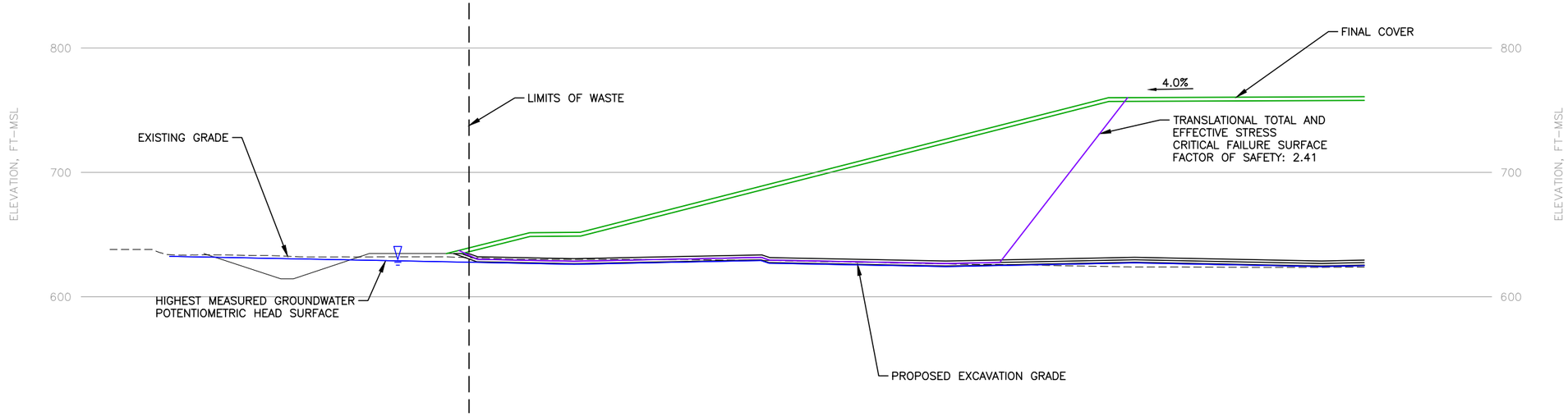
O:\0086\364\EXPANSION 2022\APPENDIX MWM-2C-1-SECTION LOCATIONS.dwg, jpuhr, 1:2

FINAL COVER SECTION C–C
MINIMUM FACTOR OF SAFETY (STATIC): 2.86



FINAL COVER SECTION C–C
MINIMUM FACTOR OF SAFETY (STATIC): 2.41



NOTE: REFER TO SECTION 4 OF APPENDIX M FOR A COMPLETE DISCUSSION ON THE CONDITION ANALYZED AND FACTOR OF SAFETY VALUES.

0 50 100
SCALE IN FEET

LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA
10/13/2023

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DATE: 03/2023
FILE: 0086–364–11
CAD: SHEET M–2C–2–SECTIONS.DWG

DRAWN BY: RAA
DESIGN BY: JBM
REVIEWED BY: DEP

Weaver Consultants Group
CA 3804–06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION
FINAL CONDITIONS SLOPE STABILITY
STABILITY SECTIONS
MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

WWW.WCGRP.COM

SHEET M–2C–2

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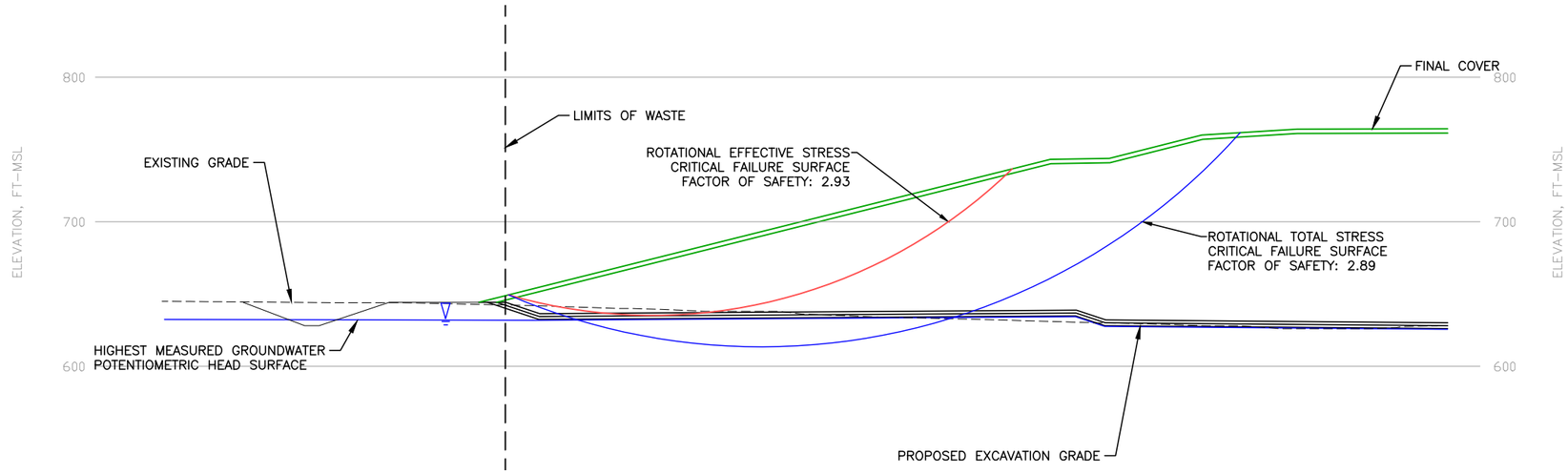
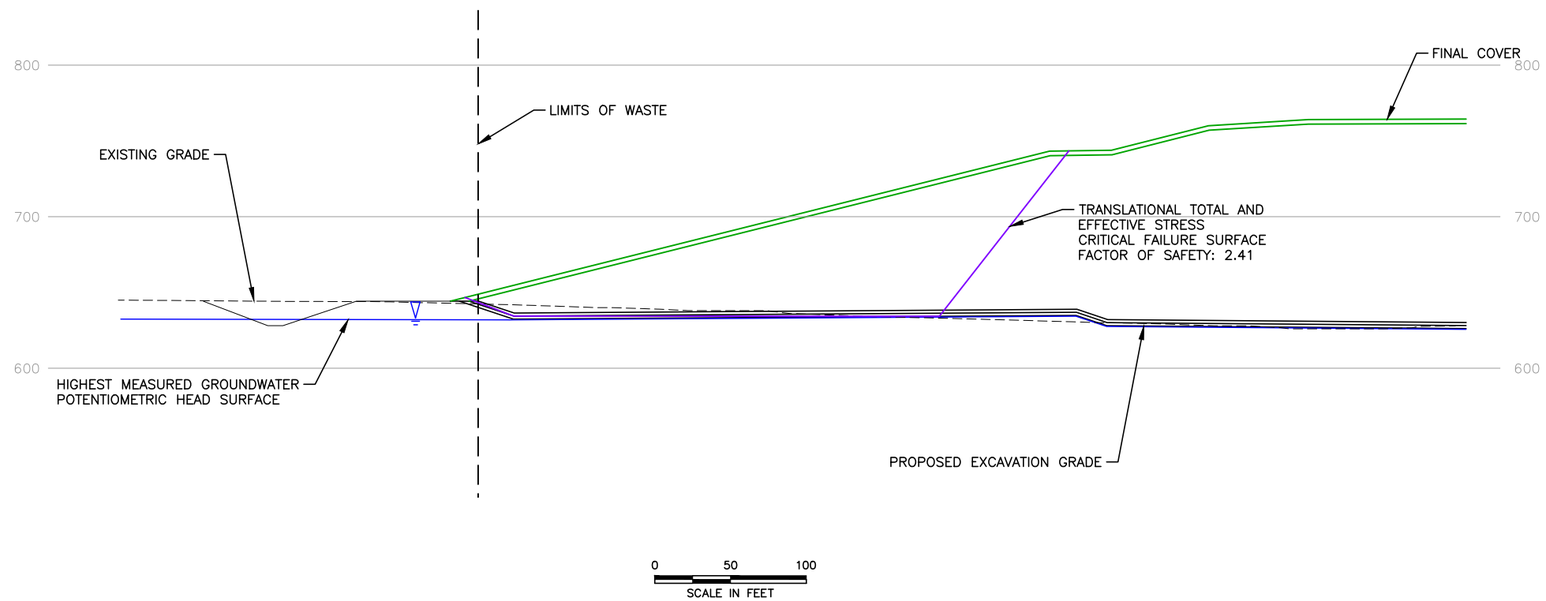
G:\0086\364\EXPANSION 2022\APPENDIX M\M-2C-2-SECTION LOCATIONS.dwg, jpmhr, 1:2

FINAL COVER SECTION D–D
MINIMUM FACTOR OF SAFETY (STATIC): 2.89



FINAL COVER SECTION D–D
MINIMUM FACTOR OF SAFETY (STATIC): 2.41



LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA
10/13/2023

NOTE: REFER TO SECTION 4 OF APPENDIX M FOR A COMPLETE DISCUSSION ON THE CONDITION ANALYZED AND FACTOR OF SAFETY VALUES.

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DATE: 03/2023
FILE: 0086–364–11
CAD: SHEET M–2C–3–SECTIONS.DWG

DRAWN BY: RAA
DESIGN BY: JBM
REVIEWED BY: DEP

Weaver Consultants Group
CA 3804–06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION
FINAL CONDITIONS SLOPE STABILITY
STABILITY SECTIONS
MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

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SHEET M–2C–3

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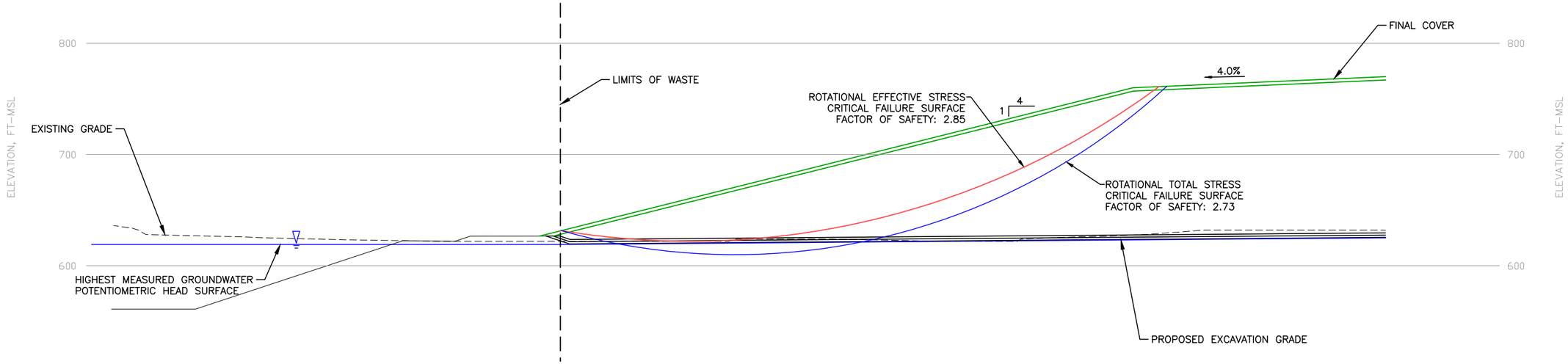
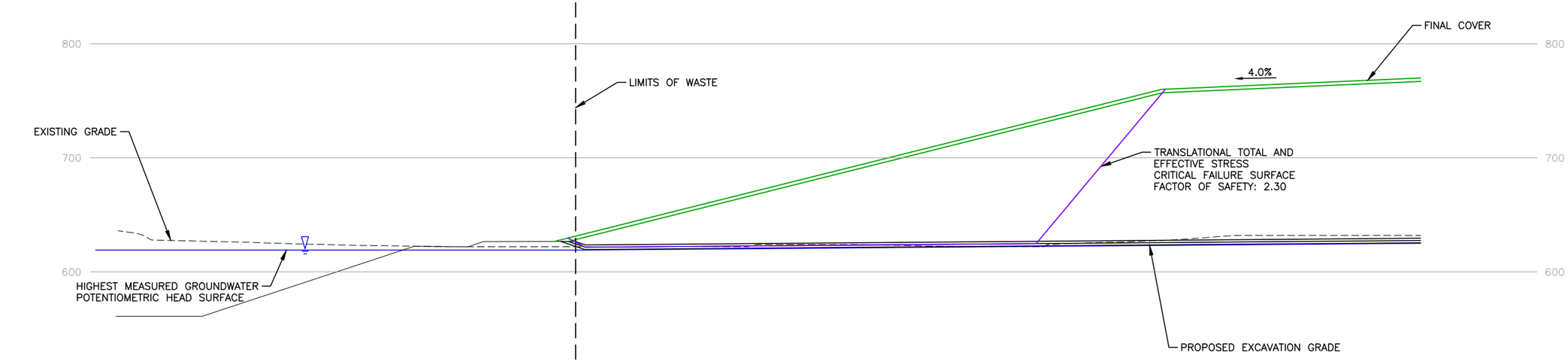
G:\0086\36\EXPANSION 2022\APPENDIX M\M-2C-3-FINAL COVER SECTIONS.dwg, jpdhr, 1:2

FINAL COVER SECTION E–E
MINIMUM FACTOR OF SAFETY (STATIC): 2.73



FINAL COVER SECTION E–E
MINIMUM FACTOR OF SAFETY (STATIC): 2.30



NOTE: REFER TO SECTION 4 OF APPENDIX M FOR A COMPLETE DISCUSSION ON THE CONDITION ANALYZED AND FACTOR OF SAFETY VALUES.

LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA

10/13/2023

0 50 100
SCALE IN FEET

- [ ] DRAFT
- [x] FOR PERMITTING PURPOSES ONLY
- [ ] ISSUED FOR CONSTRUCTION

DATE: 03/2023
FILE: 0086–364–11
CAD: SHEET M–2C–4–SECTIONS.DWG

DRAWN BY: RAA
DESIGN BY: JBM
REVIEWED BY: DEP

Weaver Consultants Group
CA 3804–06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION
FINAL CONDITIONS SLOPE STABILITY
STABILITY SECTIONS
MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

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SHEET M–2C–4

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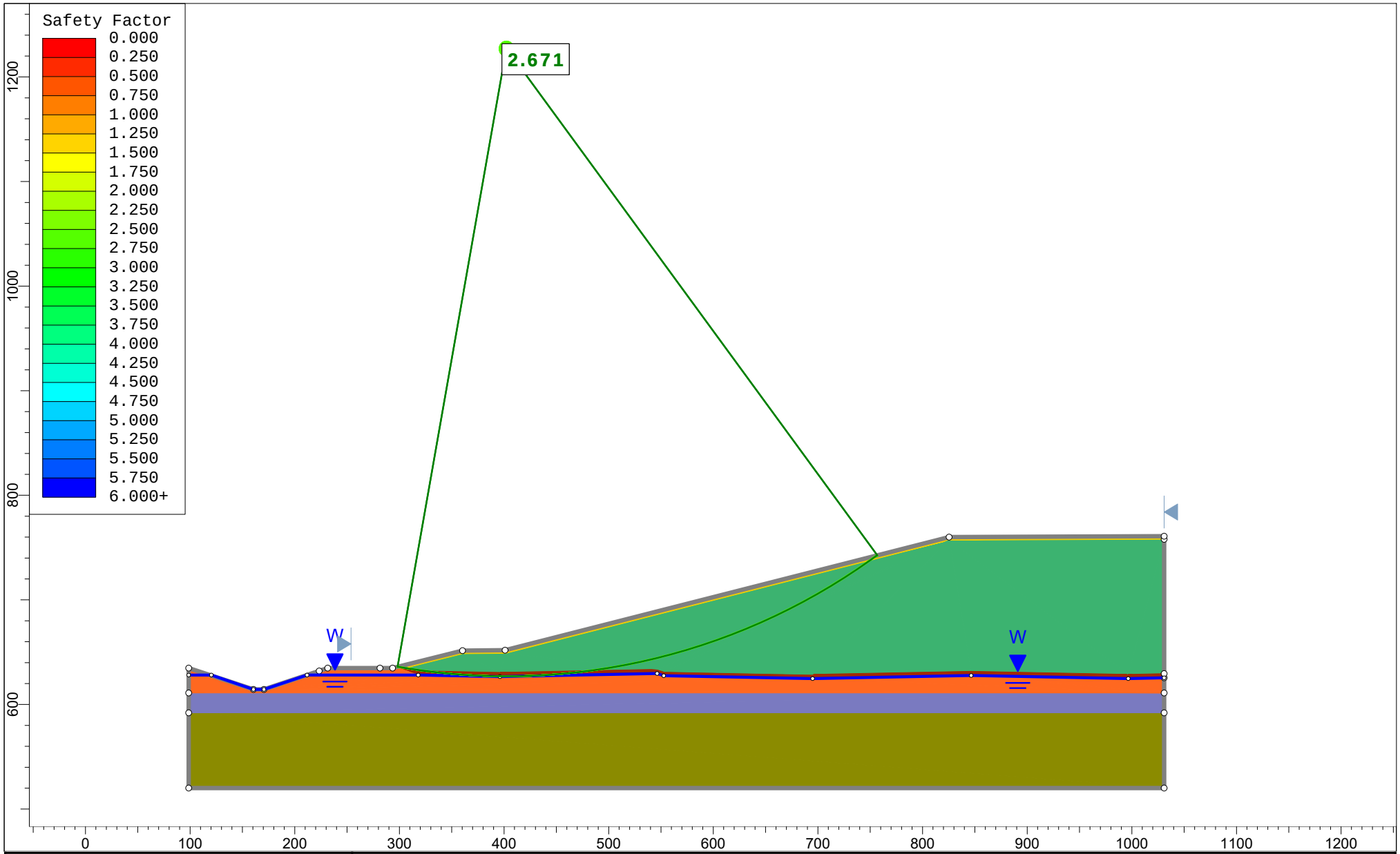
O:\0086\364\EXPANSION 2023\APPENDIX M\M-2C-4-FINAL COVER SECTIONS.dwg, jpulr, 1:2

SLIDE2 SLOPE STABILITY OUTPUT FILES

SECTION C-C



Weaver Consultants Group

SLIDEINTERPRET 9.018

Project	MUSKOGEE LANDFILL		
Group	ENGINEERING	Scenario	EFFECTIVE-CIRCULAR
Drawn By	PREP BY: MB CHKD BY:DEP	Company	WEAVER CONSULTANTS GROUP
Date	10/11/2023	File Name	SEC C-Effective-Circular.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

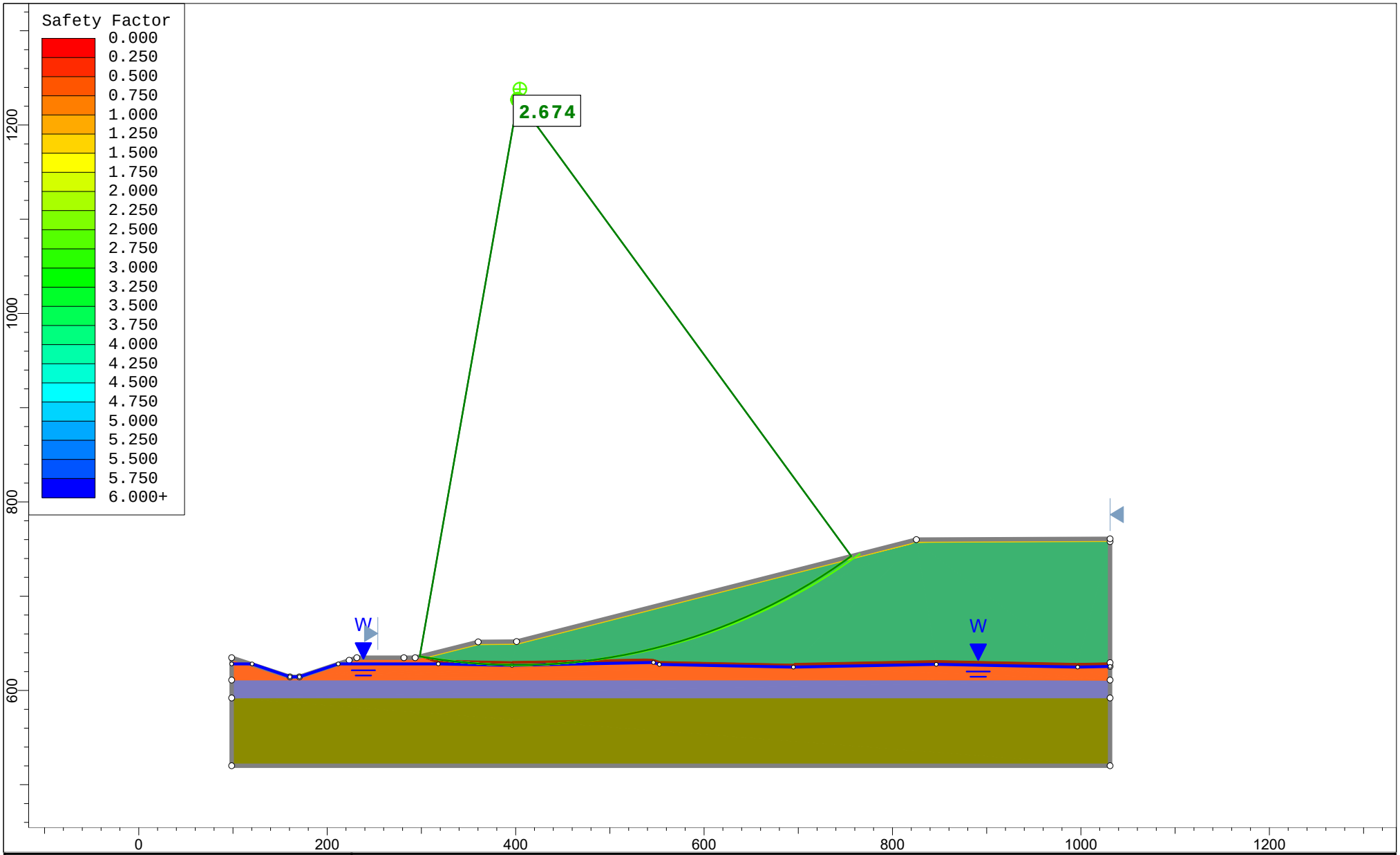
FINAL COVER	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	116
Saturated Unit Weight [lbs/ft3]	120
Cohesion [psf]	80
Friction Angle [deg]	25
Water Surface	None
Ru Value	0
WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	None
Ru Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	864
Friction Angle [deg]	21.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	936
Friction Angle [deg]	35.8
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	

Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	748
Friction Angle [deg]	57.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	2.671470
Center:	402.289, 1227.508
Radius:	600.718
Left Slip Surface Endpoint:	298.163, 635.883
Right Slip Surface Endpoint:	756.769, 742.527
Resisting Moment:	3.1523e+08 lb-ft
Driving Moment:	1.17999e+08 lb-ft
Total Slice Area:	13678.6 ft2
Surface Horizontal Width:	458.606 ft
Surface Average Height:	29.8266 ft



Weaver Consultants Group

SLIDEINTERPRET 9.018

Project	MUSKOGEE LANDFILL		
Group	ENGINEERING	Scenario	TOTAL-CIRCULAR
Drawn By	PREP BY: MB CHKD BY:DEP	Company	WEAVER CONSULTANTS GROUP
Date	10/11/2023	File Name	SEC C-Total-Circular.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

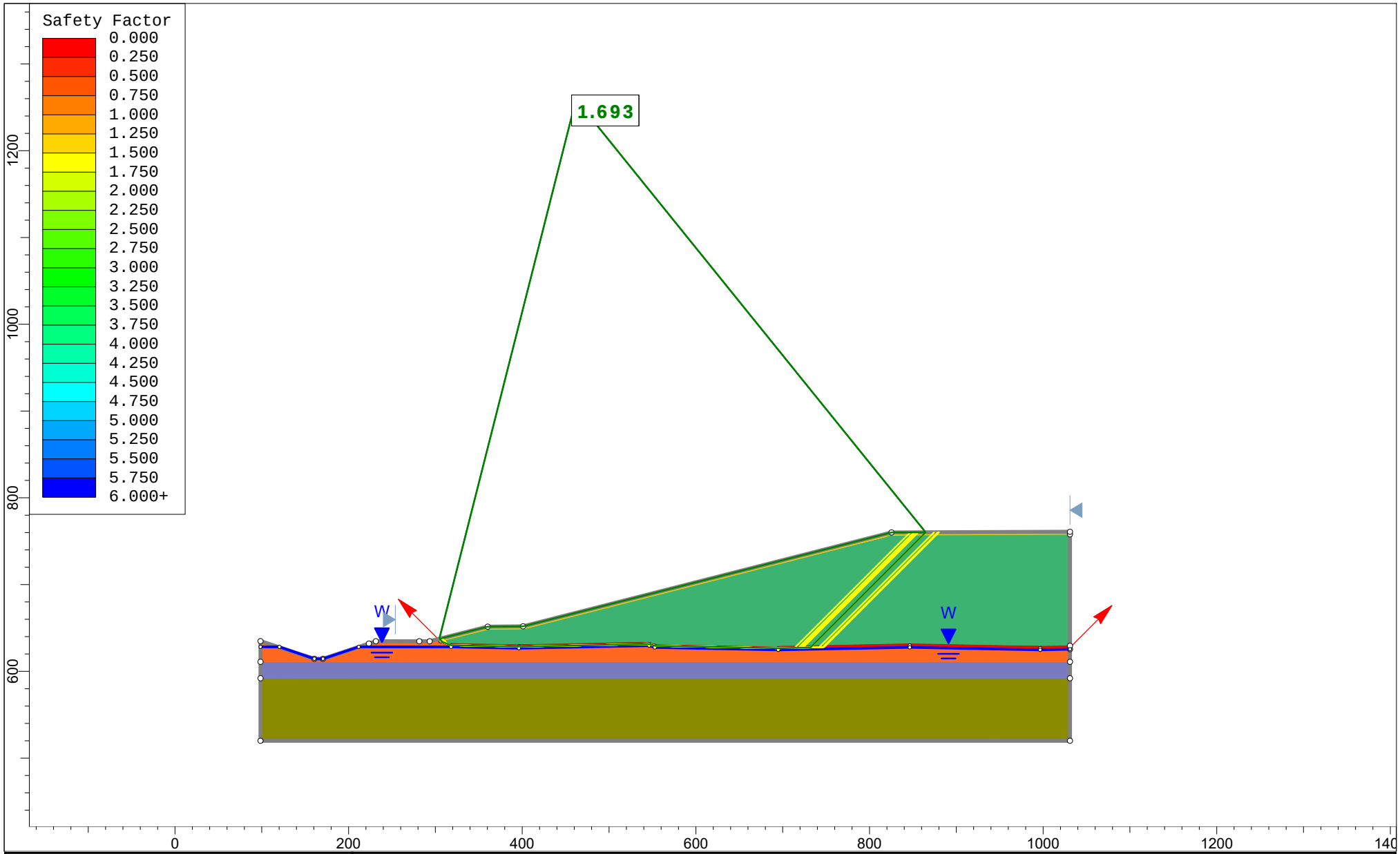
FINAL COVER	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	116
Saturated Unit Weight [lbs/ft3]	120
Cohesion [psf]	80
Friction Angle [deg]	25
Water Surface	None
Ru Value	0
WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	None
Ru Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	763
Friction Angle [deg]	14.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	1958
Friction Angle [deg]	18.3
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	

Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	2217
Friction Angle [deg]	47.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	2.673990
Center:	402.227, 1226.799
Radius:	599.990
Left Slip Surface Endpoint:	298.208, 635.895
Right Slip Surface Endpoint:	756.269, 742.400
Resisting Moment:	3.14368e+08 lb-ft
Driving Moment:	1.17565e+08 lb-ft
Total Slice Area:	13645.1 ft2
Surface Horizontal Width:	458.061 ft
Surface Average Height:	29.7889 ft



Weaver Consultants Group	Project	MUSKOGEE LANDFILL	
	Group	ENGINEERING	Scenario: EFFECTIVE-BLOCK
	Drawn By	PREP BY: MB CHKD BY:DEP	Company: WEAVER CONSULTANTS GROUP
SLIDEINTERPRET 9.018	Date	10/11/2023	File Name: SEC C-Effective-Block.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

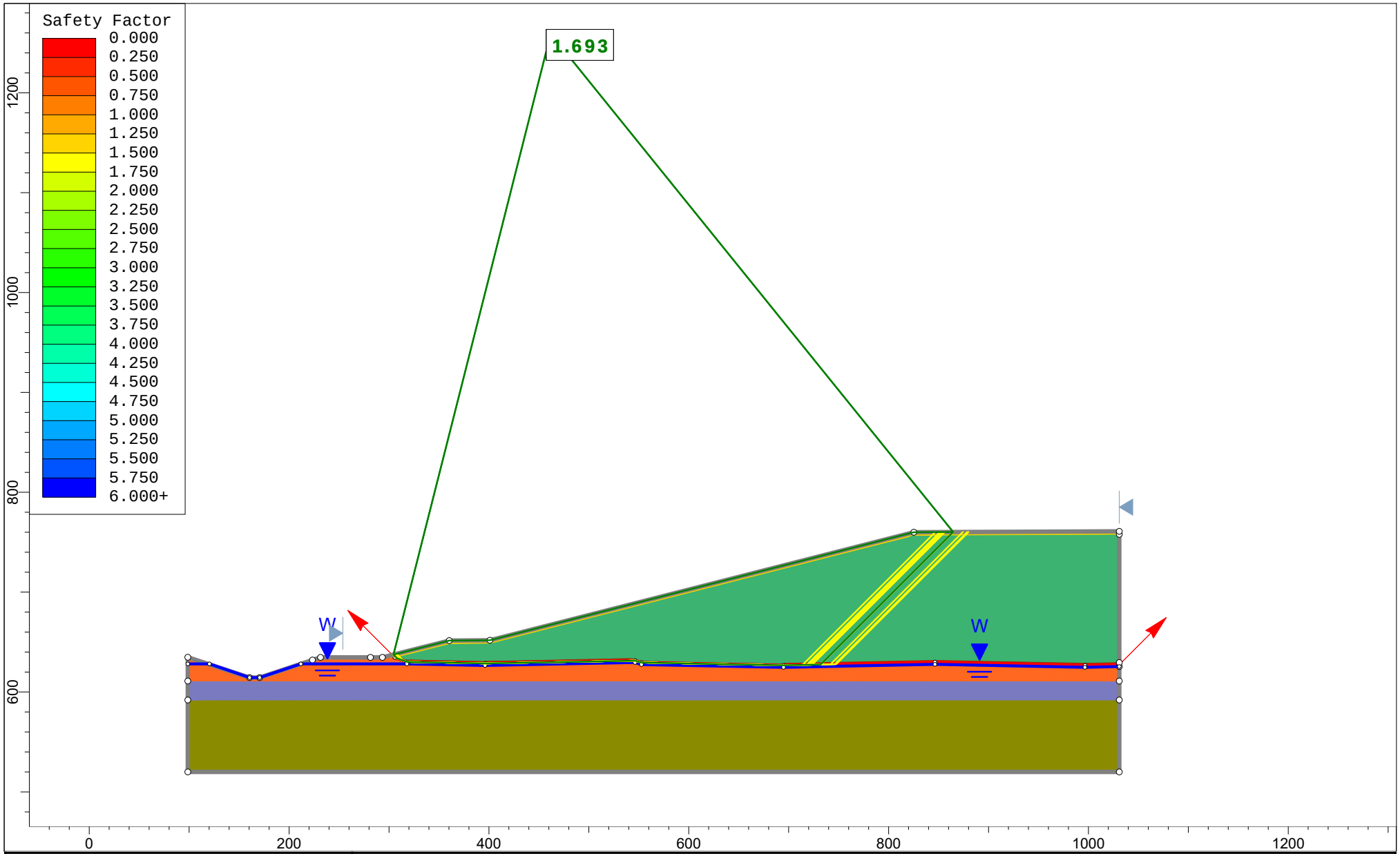
FINAL COVER	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	116
Saturated Unit Weight [lbs/ft3]	120
Cohesion [psf]	80
Friction Angle [deg]	25
Water Surface	None
Ru Value	0
WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	None
Ru Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	864
Friction Angle [deg]	21.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	936
Friction Angle [deg]	35.8
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	

Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	748
Friction Angle [deg]	57.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	1.692960
Axis Location:	461.877, 1258.987
Left Slip Surface Endpoint:	304.489, 637.466
Right Slip Surface Endpoint:	864.661, 760.165
Resisting Moment:	3.96017e+08 lb-ft
Driving Moment:	2.33919e+08 lb-ft
Total Slice Area:	30951.8 ft2
Surface Horizontal Width:	560.172 ft
Surface Average Height:	55.2541 ft



Weaver Consultants Group	Project	MUSKOGEE LANDFILL	
	Group	ENGINEERING	Scenario: TOTAL-BLOCK
	Drawn By	PREP BY: MB CHKD BY:DEP	Company: WEAVER CONSULTANTS GROUP
SLIDEINTERPRET 9.018	Date	10/11/2023	File Name: SEC C-Total-Block.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

FINAL COVER	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	116
Saturated Unit Weight [lbs/ft3]	120
Cohesion [psf]	80
Friction Angle [deg]	25
Water Surface	None
Ru Value	0
WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	None
Ru Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	763
Friction Angle [deg]	14.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	1958
Friction Angle [deg]	18.3
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	

Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	2217
Friction Angle [deg]	47.2
Water Surface	Water Table
Hu Value	1

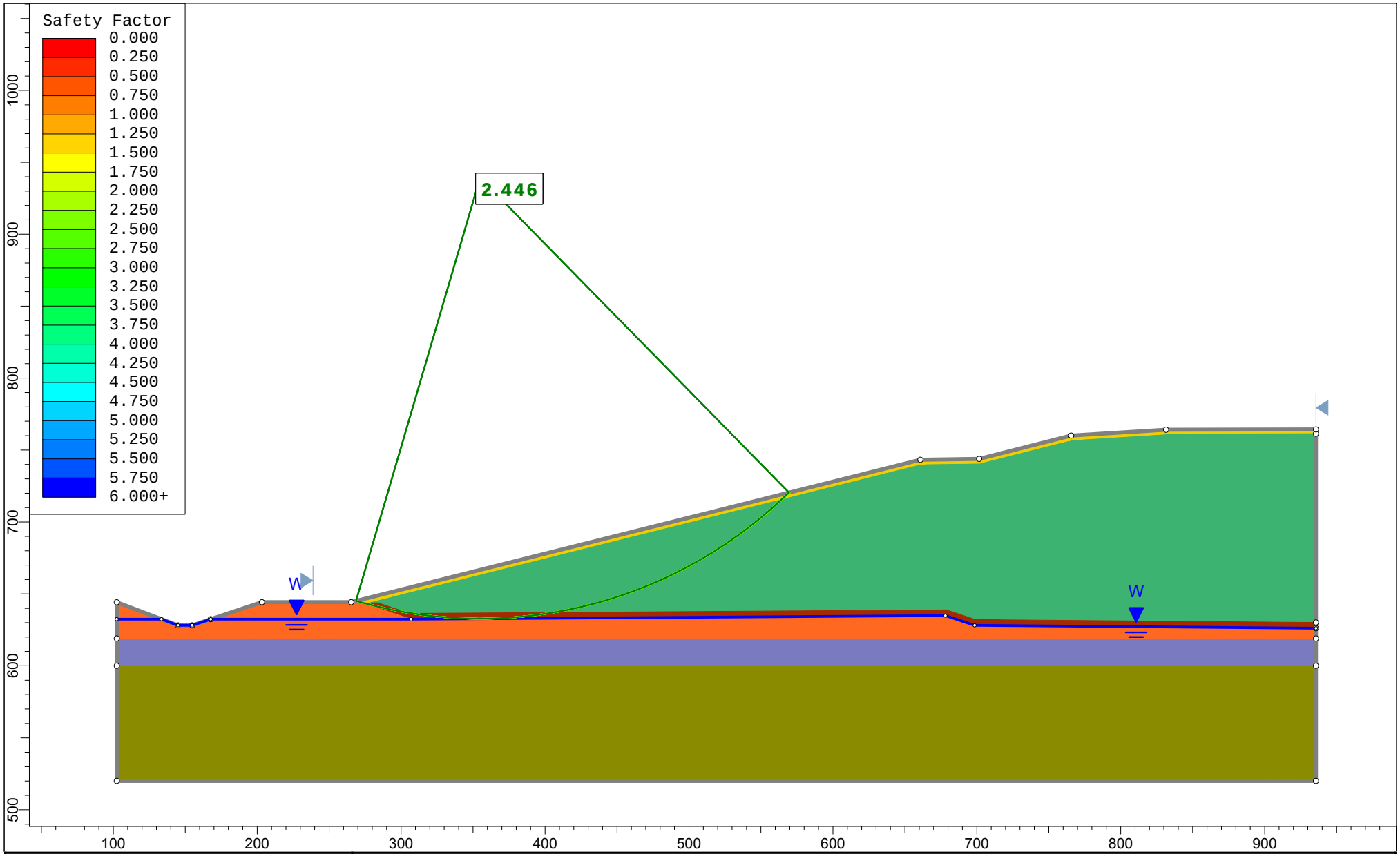
Global Minimums

Method: bishop simplified

FS	1.692960
Axis Location:	461.877, 1258.987
Left Slip Surface Endpoint:	304.489, 637.466
Right Slip Surface Endpoint:	864.661, 760.165
Resisting Moment:	3.96017e+08 lb-ft
Driving Moment:	2.33919e+08 lb-ft
Total Slice Area:	30951.8 ft2
Surface Horizontal Width:	560.172 ft
Surface Average Height:	55.2541 ft

SLIDE2 SLOPE STABILITY OUTPUT FILES

SECTION D-D



Weaver Consultants Group	Project	MUSKOGEE LANDFILL	
	Group	ENGINEERING	Scenario: EFFECTIVE-CIRCULAR
	Drawn By	PREP BY: MB CHKD BY:DEP	Company: WEAVER CONSULTANTS GROUP
SLIDEINTERPRET 9.018	Date	10/11/2023	File Name: SEC D-Effective-Circular.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

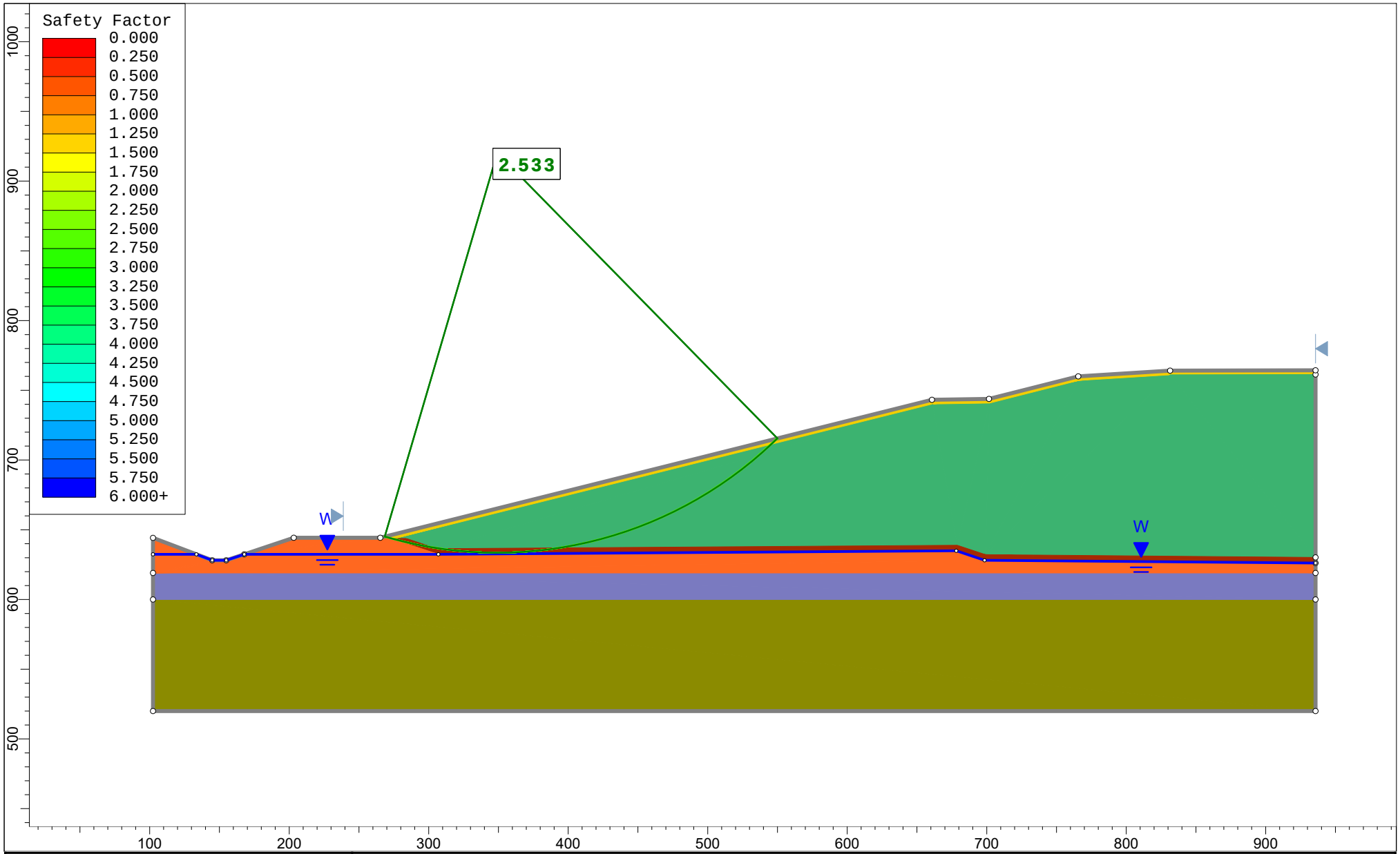
FINAL COVER	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	116
Saturated Unit Weight [lbs/ft3]	120
Cohesion [psf]	80
Friction Angle [deg]	25
Water Surface	None
Ru Value	0
WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	None
Ru Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	864
Friction Angle [deg]	21.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	936
Friction Angle [deg]	35.8
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	

Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	748
Friction Angle [deg]	57.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	2.446040
Center:	354.850, 939.358
Radius:	306.662
Left Slip Surface Endpoint:	268.600, 645.075
Right Slip Surface Endpoint:	569.516, 720.360
Resisting Moment:	9.61252e+07 lb-ft
Driving Moment:	3.92984e+07 lb-ft
Total Slice Area:	8831.57 ft2
Surface Horizontal Width:	300.916 ft
Surface Average Height:	29.3489 ft



Weaver Consultants Group

SLIDEINTERPRET 9.018

Project	MUSKOGEE LANDFILL		
Group	ENGINEERING	*Scenario*	TOTAL-CIRCULAR
Drawn By	PREP BY: MB CHKD BY:DEP	*Company*	WEAVER CONSULTANTS GROUP
Date	10/11/2023	*File Name*	SEC D-Total-Circular.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

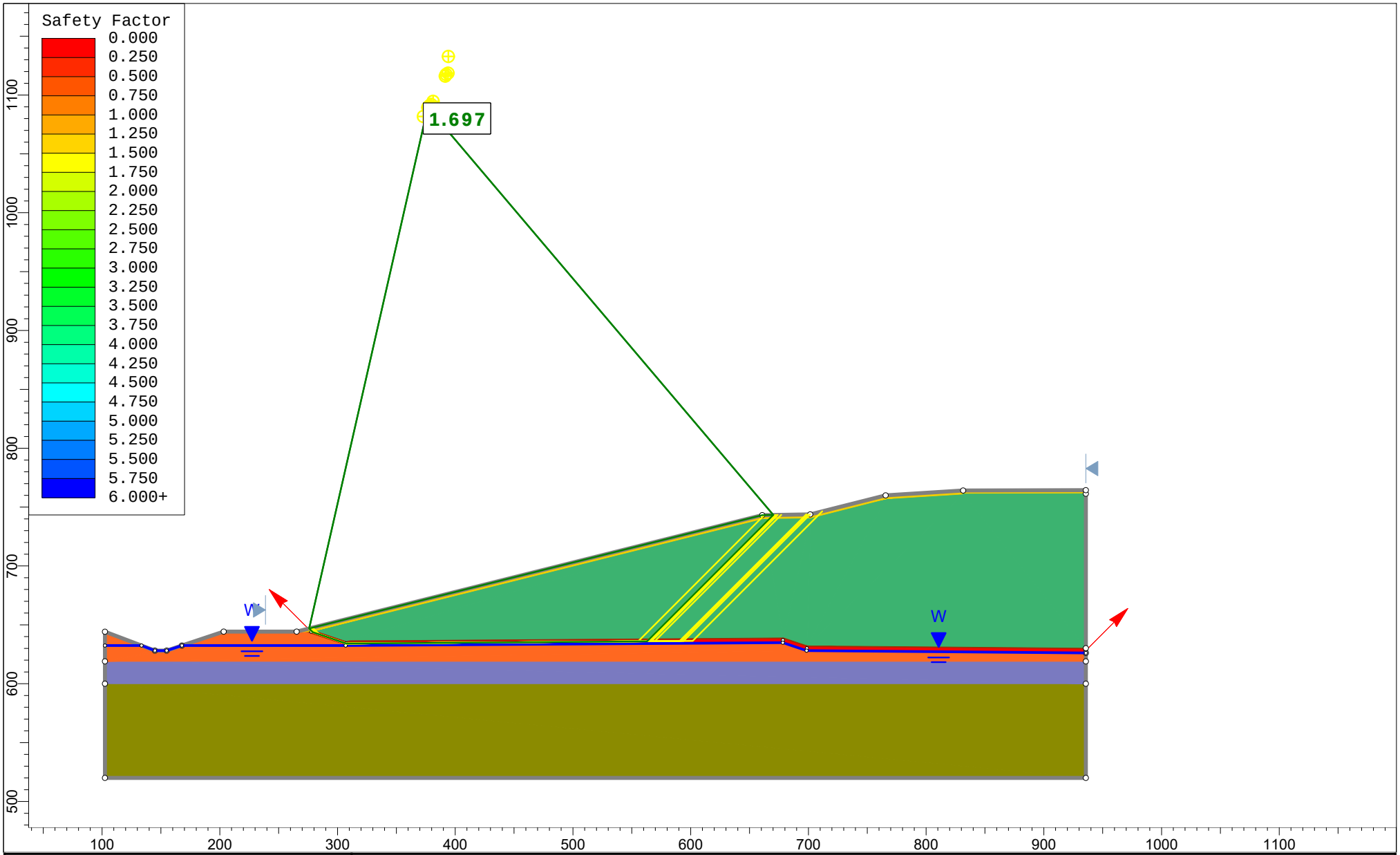
FINAL COVER	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	116
Saturated Unit Weight [lbs/ft3]	120
Cohesion [psf]	80
Friction Angle [deg]	25
Water Surface	None
Ru Value	0
WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	None
Ru Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	763
Friction Angle [deg]	14.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	1958
Friction Angle [deg]	18.3
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	

Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	2217
Friction Angle [deg]	47.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	2.533410
Center:	349.187, 920.321
Radius:	286.848
Left Slip Surface Endpoint:	268.510, 645.052
Right Slip Surface Endpoint:	549.983, 715.474
Resisting Moment:	8.18796e+07 lb-ft
Driving Moment:	3.23199e+07 lb-ft
Total Slice Area:	7726.99 ft2
Surface Horizontal Width:	281.473 ft
Surface Average Height:	27.452 ft



Weaver Consultants Group

SLIDEINTERPRET 9.018

Project	MUSKOGEE LANDFILL		
Group	ENGINEERING	Scenario	EFFECTIVE-BLOCK
Drawn By	PREP BY: MB CHKD BY:DEP	Company	WEAVER CONSULTANTS GROUP
Date	10/11/2023	File Name	SEC D-Effective-Block.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

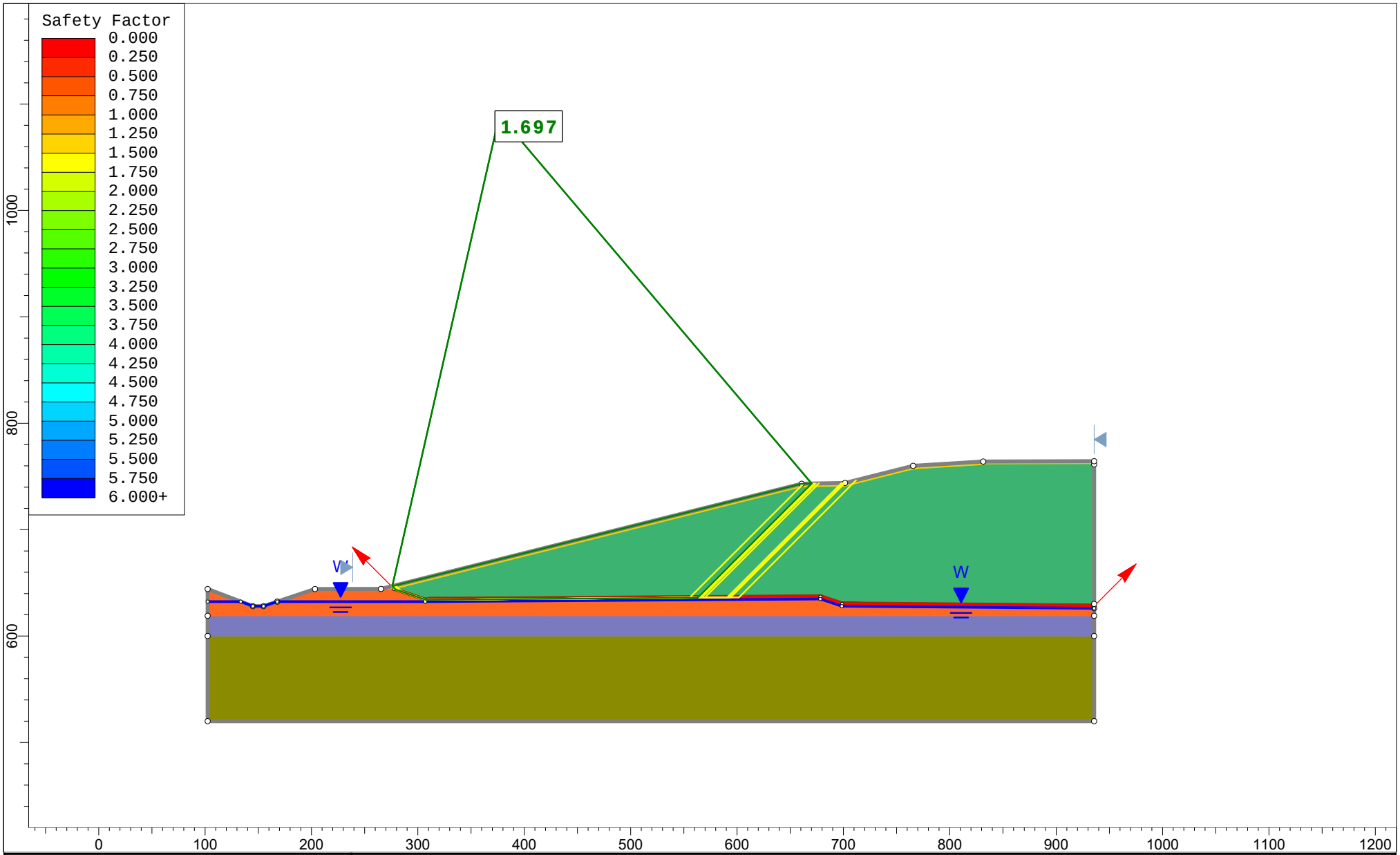
FINAL COVER	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	116
Saturated Unit Weight [lbs/ft3]	120
Cohesion [psf]	80
Friction Angle [deg]	25
Water Surface	None
Ru Value	0
WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	None
Ru Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	864
Friction Angle [deg]	21.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	936
Friction Angle [deg]	35.8
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	

Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	748
Friction Angle [deg]	57.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	1.696580
Axis Location:	376.621, 1089.397
Left Slip Surface Endpoint:	275.911, 646.904
Right Slip Surface Endpoint:	670.189, 743.333
Resisting Moment:	1.73084e+08 lb-ft
Driving Moment:	1.02019e+08 lb-ft
Total Slice Area:	18105.8 ft2
Surface Horizontal Width:	394.279 ft
Surface Average Height:	45.9212 ft



Weaver Consultants Group	Project	MUSKOGEE LANDFILL	
	Group	ENGINEERING	Scenario: RESIDUAL-BLOCK
	Drawn By	PREP BY: MB CHKD BY:DEP	Company: WEAVER CONSULTANTS GROUP
SLIDEINTERPRET 9.018	Date	10/11/2023	File Name: SEC D-Total-Block.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

FINAL COVER	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	116
Saturated Unit Weight [lbs/ft3]	120
Cohesion [psf]	80
Friction Angle [deg]	25
Water Surface	None
Ru Value	0
WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	None
Ru Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	None
Ru Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	763
Friction Angle [deg]	14.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	1958
Friction Angle [deg]	18.3
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	

Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	2217
Friction Angle [deg]	47.2
Water Surface	Water Table
Hu Value	1

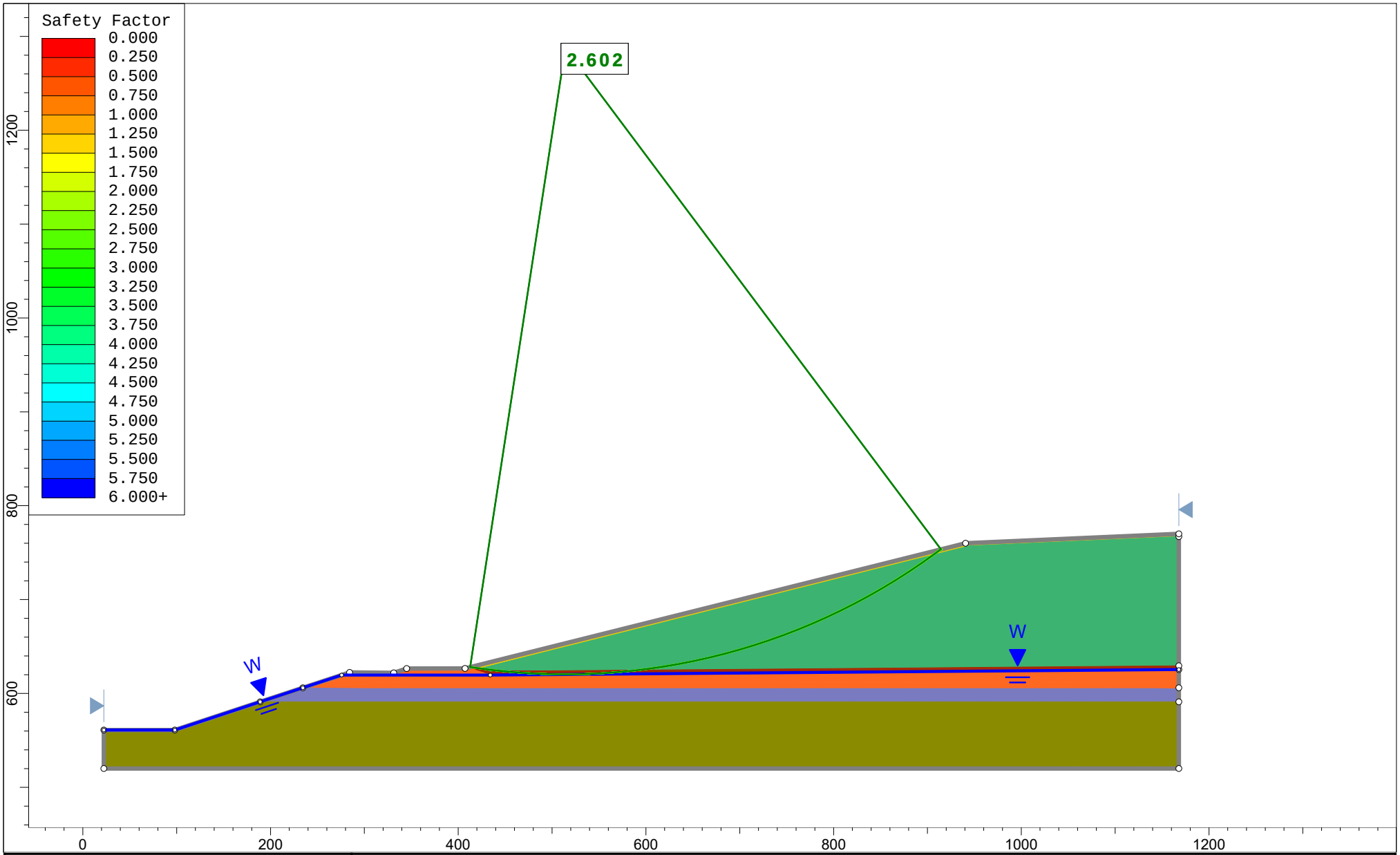
Global Minimums

Method: bishop simplified

FS	1.696580
Axis Location:	376.621, 1089.397
Left Slip Surface Endpoint:	275.911, 646.904
Right Slip Surface Endpoint:	670.189, 743.333
Resisting Moment:	1.73084e+08 lb-ft
Driving Moment:	1.02019e+08 lb-ft
Total Slice Area:	18105.8 ft2
Surface Horizontal Width:	394.279 ft
Surface Average Height:	45.9212 ft

SLIDE2 SLOPE STABILITY OUTPUT FILES

SECTION E-E



Weaver Consultants Group	Project	MUSKOGEE LANDFILL	
	Group	ENGINEERING	Scenario: EFFECTIVE-CIRCULAR
	Drawn By	PREP BY: MB CHKD BY:DEP	Company: WEAVER CONSULTANTS GROUP
SLIDEINTERPRET 9.018	Date	10/11/2023	File Name: SEC E-Effective-Circular.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

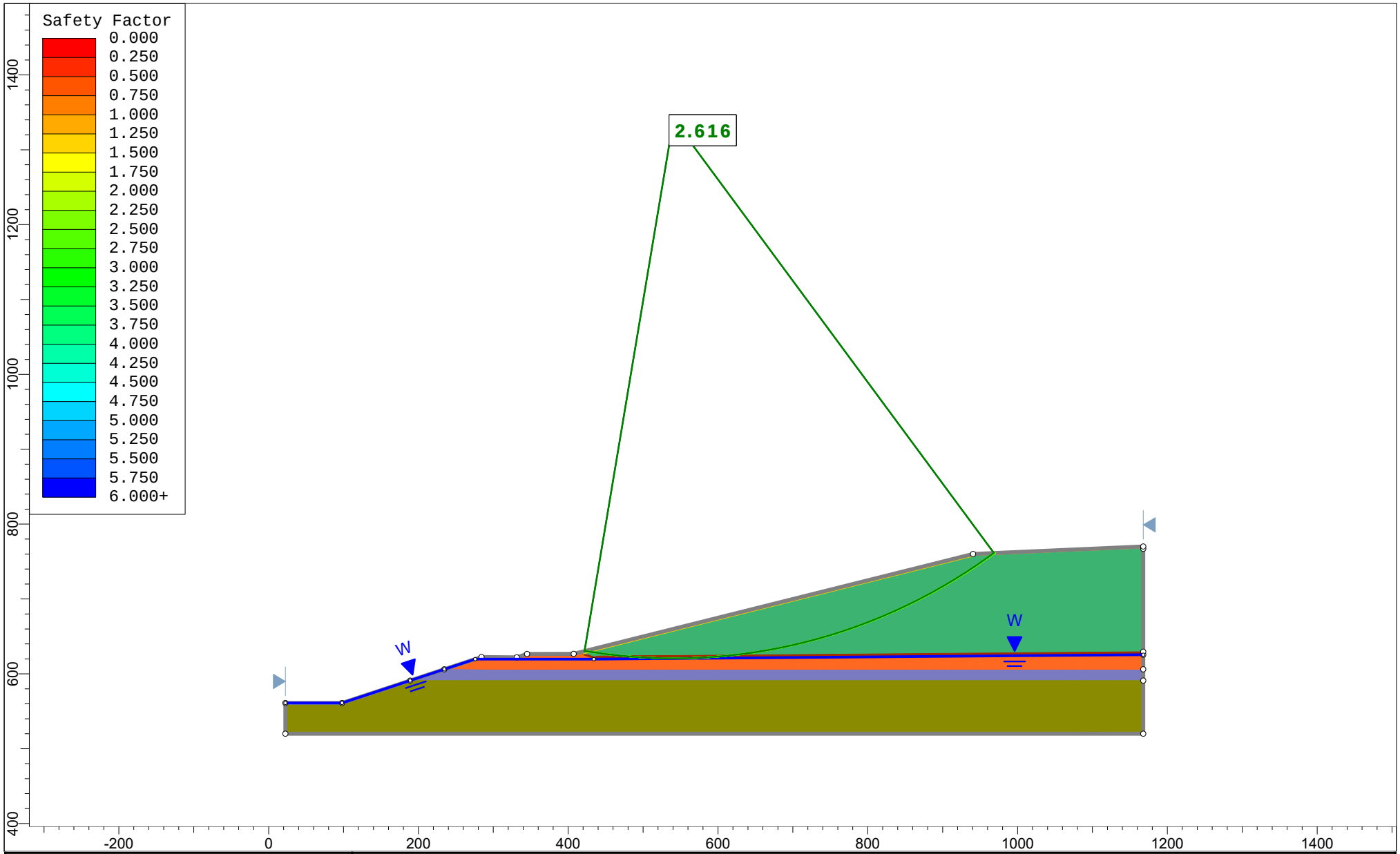
FINAL COVER	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	116
Saturated Unit Weight [lbs/ft3]	120
Cohesion [psf]	80
Friction Angle [deg]	25
Water Surface	Water Table
Hu Value	0
WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	Water Table
Hu Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	Water Table
Hu Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	864
Friction Angle [deg]	21.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	936
Friction Angle [deg]	35.8
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	

Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	748
Friction Angle [deg]	57.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	2.602330
Center:	514.249, 1287.852
Radius:	667.621
Left Slip Surface Endpoint:	412.666, 628.005
Right Slip Surface Endpoint:	914.411, 753.448
Resisting Moment:	4.70041e+08 lb-ft
Driving Moment:	1.80623e+08 lb-ft
Total Slice Area:	18106.2 ft2
Surface Horizontal Width:	501.745 ft
Surface Average Height:	36.0865 ft



Weaver Consultants Group	Project	MUSKOGEE LANDFILL	
	Group	ENGINEERING	Scenario: TOTAL-CIRCULAR
	Drawn By	PREP BY: MB CHKD BY:DEP	Company: WEAVER CONSULTANTS GROUP
SLIDEINTERPRET 9.018	Date	10/11/2023	File Name: SEC E-Total-Circular.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

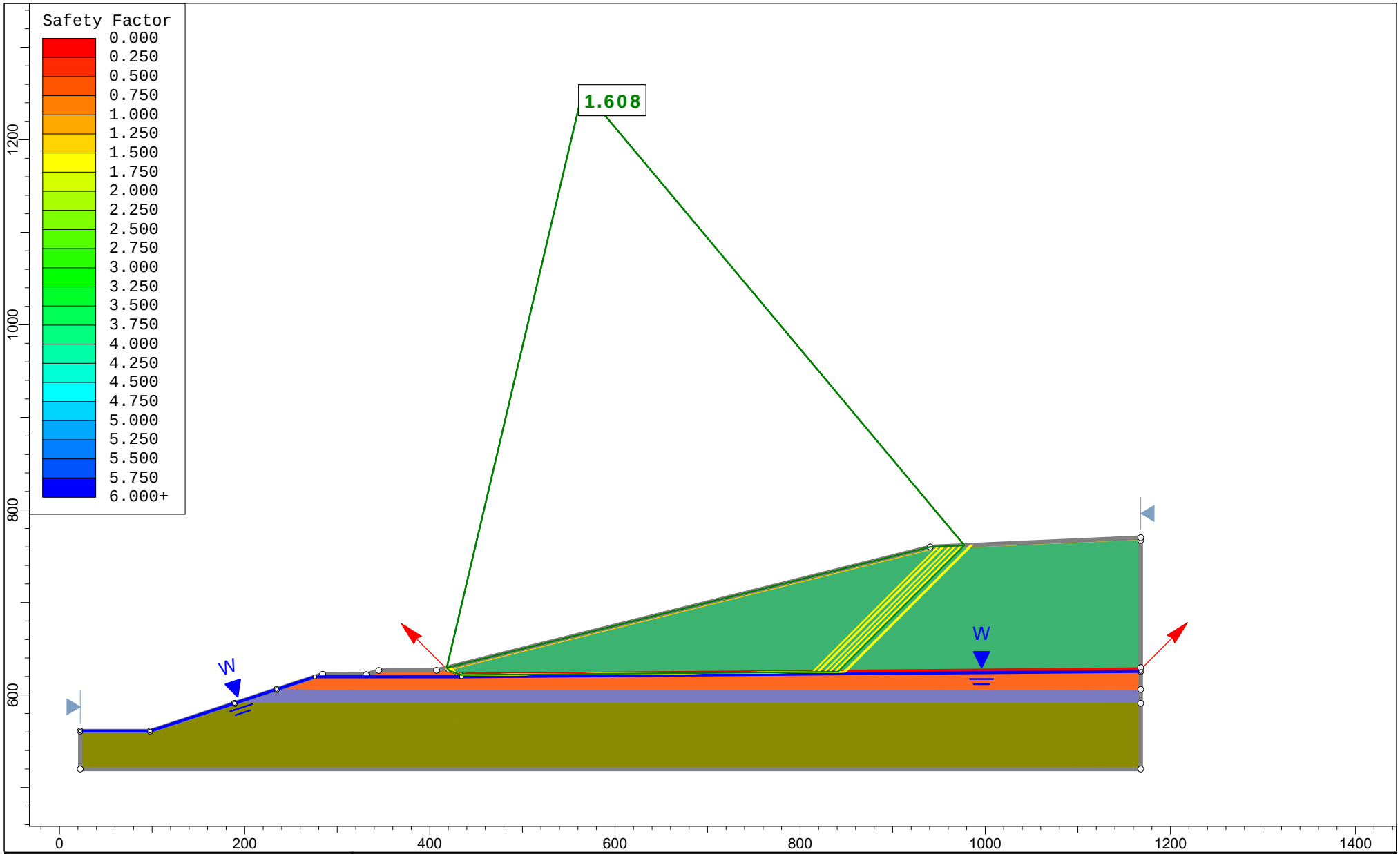
FINAL COVER	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	116
Saturated Unit Weight [lbs/ft3]	120
Cohesion [psf]	80
Friction Angle [deg]	25
Water Surface	Water Table
Hu Value	0
WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	Water Table
Hu Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	Water Table
Hu Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	763
Friction Angle [deg]	14.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	1958
Friction Angle [deg]	18.3
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	

Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	2217
Friction Angle [deg]	47.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	2.615760
Center:	540.578, 1340.871
Radius:	720.431
Left Slip Surface Endpoint:	421.826, 630.295
Right Slip Surface Endpoint:	968.396, 761.222
Resisting Moment:	6.33972e+08 lb-ft
Driving Moment:	2.42367e+08 lb-ft
Total Slice Area:	23033.1 ft2
Surface Horizontal Width:	546.57 ft
Surface Average Height:	42.1412 ft



Weaver Consultants Group	Project	MUSKOGEE LANDFILL	
	Group	ENGINEERING	Scenario: EFFECTIVE-BLOCK
	Drawn By	PREP BY: MB CHKD BY:DEP	Company: WEAVER CONSULTANTS GROUP
	Date	10/11/2023	File Name: SEC E-Effective-Block.slmd

SLIDEINTERPRET 9.018

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

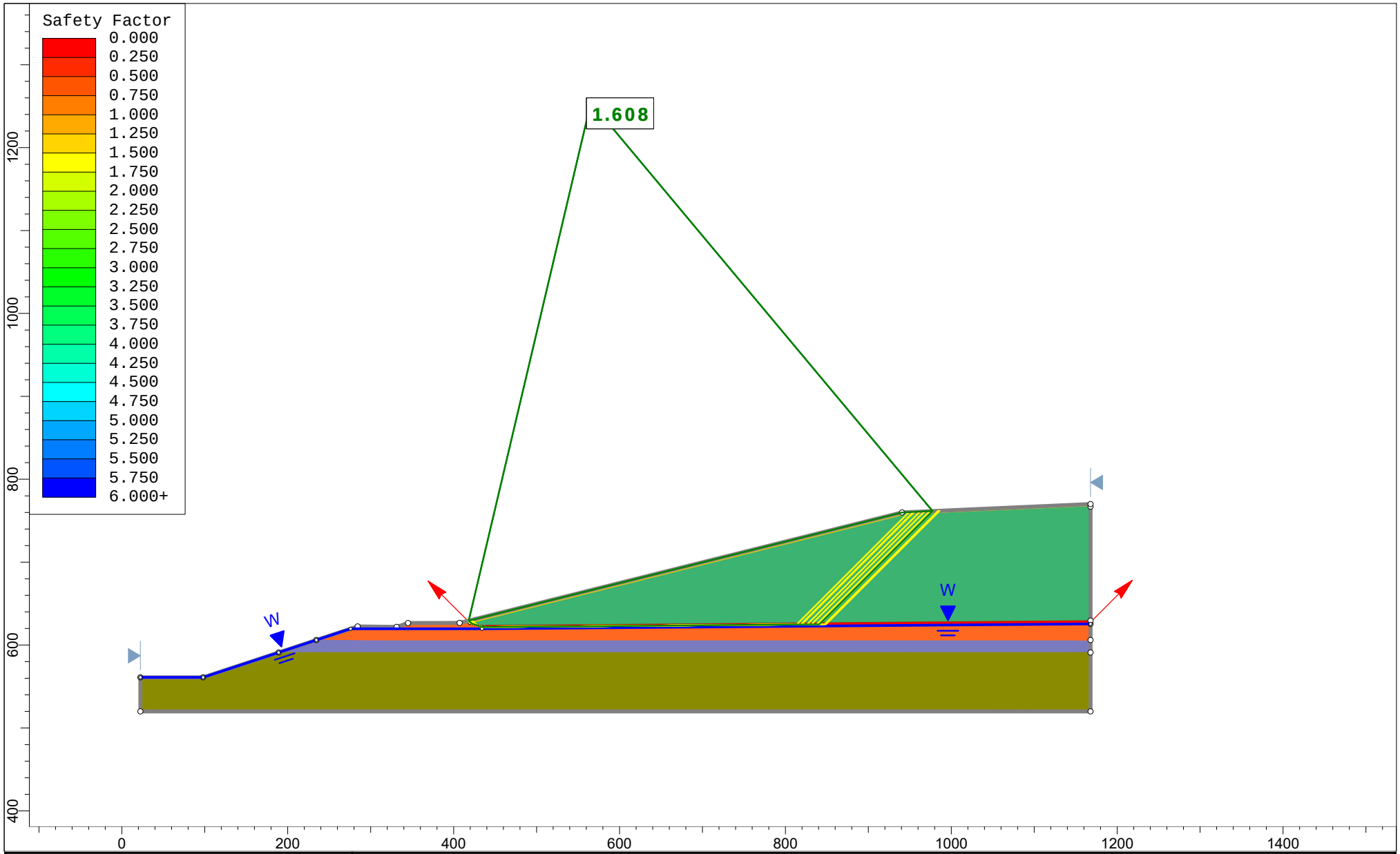
FINAL COVER	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	116
Saturated Unit Weight [lbs/ft3]	120
Cohesion [psf]	80
Friction Angle [deg]	25
Water Surface	Water Table
Hu Value	0
WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	Water Table
Hu Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	Water Table
Hu Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	864
Friction Angle [deg]	21.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	936
Friction Angle [deg]	35.8
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	

Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	748
Friction Angle [deg]	57.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	1.608050
Axis Location:	565.576, 1254.644
Left Slip Surface Endpoint:	418.229, 629.395
Right Slip Surface Endpoint:	977.366, 761.617
Resisting Moment:	4.09742e+08 lb-ft
Driving Moment:	2.54806e+08 lb-ft
Total Slice Area:	32751.9 ft2
Surface Horizontal Width:	559.138 ft
Surface Average Height:	58.5757 ft



Weaver Consultants Group	Project	MUSKOGEE LANDFILL	
	Group	ENGINEERING	Scenario: RESIDUAL-BLOCK
	Drawn By	PREP BY: MB CHKD BY:DEP	Company: WEAVER CONSULTANTS GROUP
SLIDEINTERPRET 9.018	Date	10/11/2023	File Name: SEC E-Total-Block.slmd

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Materials

FINAL COVER	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	116
Saturated Unit Weight [lbs/ft3]	120
Cohesion [psf]	80
Friction Angle [deg]	25
Water Surface	Water Table
Hu Value	0
WASTE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	60
Saturated Unit Weight [lbs/ft3]	65
Cohesion [psf]	288
Friction Angle [deg]	33
Water Surface	Water Table
Hu Value	0
LINER MATERIAL	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	120
Saturated Unit Weight [lbs/ft3]	125
Cohesion [psf]	50
Friction Angle [deg]	9.3
Water Surface	Water Table
Hu Value	0
Silty Sand/Clay	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	128
Saturated Unit Weight [lbs/ft3]	148
Cohesion [psf]	763
Friction Angle [deg]	14.9
Water Surface	Water Table
Hu Value	1
WEATHERED SHALE	
Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	124
Saturated Unit Weight [lbs/ft3]	146
Cohesion [psf]	1958
Friction Angle [deg]	18.3
Water Surface	Water Table
Hu Value	1
UNWEATHERED SHALE	

Color	
Strength Type	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	155
Saturated Unit Weight [lbs/ft3]	163
Cohesion [psf]	2217
Friction Angle [deg]	47.2
Water Surface	Water Table
Hu Value	1

Global Minimums

Method: bishop simplified

FS	1.608050
Axis Location:	565.576, 1254.644
Left Slip Surface Endpoint:	418.229, 629.395
Right Slip Surface Endpoint:	977.366, 761.617
Resisting Moment:	4.09742e+08 lb-ft
Driving Moment:	2.54806e+08 lb-ft
Total Slice Area:	32751.9 ft2
Surface Horizontal Width:	559.138 ft
Surface Average Height:	58.5757 ft

APPENDIX M-2D

INFINITE SLOPE STABILITY ANALYSIS

Includes pages M-2D-1 through M-2D-14

INFINITE SLOPE STABILITY ANALYSIS FOR THE LINER SYSTEM

The following appendix presents the veneer stability analyses of the bottom liner and final cover systems, including analysis of the bottom liner anchor trench design. The analyses were performed using interface and material strength parameters representative of the respective material properties. As demonstrated by the analyses results, the landfill bottom liner, anchor trench and final cover designs are stable.

Required: Evaluate the stability of the bottom liner system components.

Procedure:

A. Bottom Liner System Stability - Sideslope and Anchor Trench Design
   1. Verify that the tensile stress in the liner system will be less than the yield stress by using Koerner's method for determination of shear stress in liner systems considering cohesion/ adhesion forces.
   2. Provide liner anchor trench design considering pullout of the geomembrane.

B. Infinite Slope Stability Analysis
   1. Use Duncan and Buchignani's method for infinite stability analyses to evaluate the internal stability of the bottom liner and final cover systems using peak and residual shear strength values.

Contents:

- Interface and internal strength parameters are provided on Sheet M-2D-3.
- Verification that the tensile stress in the bottom liner system will be less than yield stress is provided on Sheets M-2D-4 through M-2D-7.
- Anchor trench design is provided on Sheets M-2D-8 through M-2D-9.
- Infinite stability analysis to evaluate the internal stability of the bottom liner and final cover systems is provided on Sheets M-2D-10 through M-2D-13.

References:

1. Koerner, Robert M., *Designing with Geosynthetics* , 3rd Edition, Prentice-Hall Inc., 1994.
2. Duncan, J.M. and Buchignani, A. L., *An Engineering Manual for Slope Stability Studies,* Department of Civil Engineering - University of California-Berkeley, 1975.
3. USACE, *Slope Stability* , Engineering and Design Manual, EM 1110-2-1902, October 31, 2003.
4. Koerner, Robert M., *Analysis and Design of Veneer Cover Soils* , 1998 Sixth International Conference of Geosynthetics.
5. Koerner, George R. and Narejo, Dhani, *Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces,* GRI Report #30, June 14, 2005.
6. Gilbert, Robert B., *Peak Versus Residual Strength for Waste Containment Systems,*
7. Proceedings of the 15th GRI Conference, December 13, 2001.
8. NAVFAC Design Manual 7.01, September 1986.

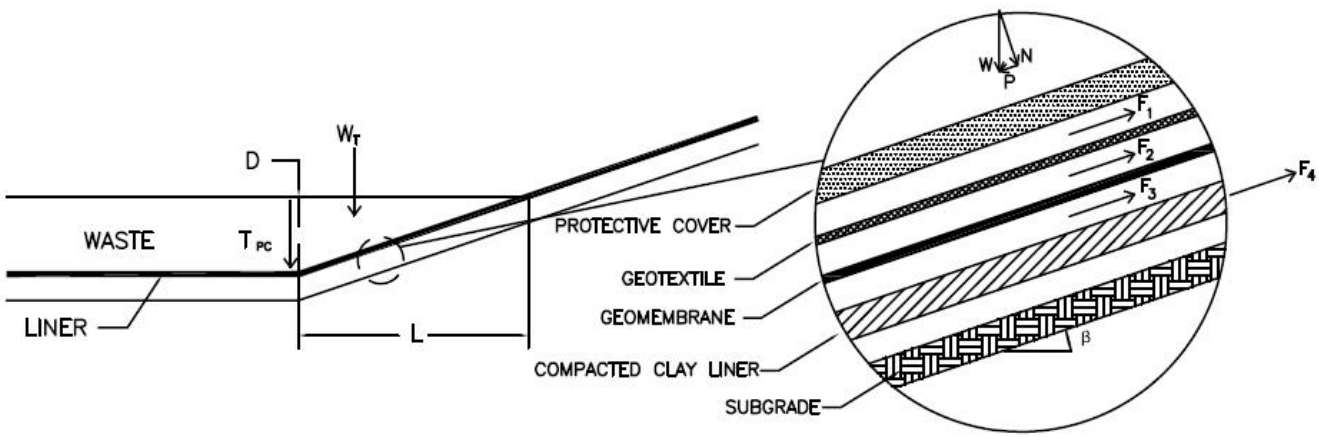
Liner System Component/Interface:		Adhesion, psf	Friction Angle, degree
Protective Cover/Non-woven Geotextile	Peak	100	18
	Residual	80	14
Non-woven Geotextile/Textured Geomembrane	Peak	100	25
	Residual	50	12
Texured Geomembrane/CCL	Peak	200	18
	Residual	80	14
Textured Geomembrane/GCL	Peak	80	16
	Residual	50	8
GCL Internal (Reinforced Only)	Peak	800	16
	Residual	380	8
GCL/Compacted Clay Liner	Peak	100	16
	Residual	50	8
Compacted Clay Liner Internal	Peak	100	18
	Residual	-	-

A. Liner System Stability - Anchor Trench Design

Note: The liner system includes a 2-foot-thick protective cover, drainage geotextile, textured geomembrane, and a 2-foot-thick Compacted Clay Liner (CCL).

1. Verify that tensile stress in liner system is less than yield stress for the liner system.

CCL (Sideslope areas) (Alternative Liner Substitutes GCL for upper 1-foot CCL)



Definition of terms/variables:

W_E = Weight of equipment, lb/ft

Assume a Caterpillar D8T WH Track-Type Tractor

Operational Weight =	85,150 lb
Number of Tracks =	2
Track Width =	1.84 ft

W_W = Weight of solid waste, lb/ft
W_{PC} = Weight of protective cover, lb/ft
W_T = Combined weight of equipment, solid waste, and protective cover, lb/ft
T_{PC} = Friction force on edge of protective cover, lb/ft
W = Net force of equipment, waste, and protective cover on liner system, lb/ft
N = Normal force on liner system, lb/ft
P = Shearing force on liner system, lb/ft
β = Slope angle, deg
F_n = Resisting force, lb/ft, calculated using the equation:
$(N * \tan(\Delta_n)) + (C_{an} * L / \cos(\beta))$

F_1 = Resistance of protective cover/geotextile interface, lb/ft
F_2 = Resistance of non-woven geotextile/textured geomembrane interface, lb/ft
F_3 = Resistance of textured geomembrane/compacted clay liner (CCL) interface, lb/ft
F_4 = Resistance of textured geomembrane/geosynthetic clay liner (GCL) interface, lb/ft (alternative liner)
F_5 = Resistance of internal GCL, lb/ft
F_6 = Resistance of internal CCL, lb/ft

Δ_n = Interface friction angle of interface "n", deg
C_{an} = Adhesion of interface "n", psf
ϕ_n = Internal friction angle of material "n", deg
C_n = Cohesion of material "n", psf

γ_{was} = Unit weight of solid waste (including daily cover), pcf
D_{was} = Individual lift height, ft
ϕ_{was} = Internal friction angle of waste, deg
γ_{pc} = Unit weight of protective cover, pcf
D_{pc} = Thickness of protective cover, ft
ϕ_{pc} = Internal friction angle of protective cover, deg
L = Horizontal length of lift, ft

Parameters:

$\beta_{sideslope}$ =	18.43	deg	γ_{was} =	65	pcf
Δ_1 =	18	deg	D_{was} =	10	ft
C_{a1} =	100	psf	ϕ_{was} =	33	deg
Δ_2 =	25	deg	γ_{pc} =	120	pcf
C_{a2} =	100	psf	D_{pc} =	2	ft
Δ_3 =	18	deg	ϕ_{pc} =	18	deg
C_{a3} =	200	psf	L =	30	ft
ϕ_4 =	16	deg			
C_4 =	80	psf			
ϕ_5 =	16	deg			
C_5 =	800	psf			
ϕ_6 =	16	deg			
C_6 =	100	psf			

Note:
Interface friction strength values are selected conservatively from laboratory testing of similar material/interfaces.

Weight of Equipment

$$W_E = \frac{\text{Operational Weight}}{\text{Number of Tracks x Width of Track}}$$

W_E = 23,139 lb/ft

Weight of Solid Waste

$$W_W = \frac{D_{was} \times L \times \gamma_{was}}{2}$$

W_W = 9,750 lb/ft

Weight of Protective Cover

$$W_{PC} = D_{pc} \times \gamma_{pc} \times \frac{L}{\cos(\beta_{sideslope})}$$

W_{PC} = 7,589 lb/ft

Combined Weight of Equipment, Solid Waste, and Protective Cover,

$W_T = W_E + W_W + W_{PC}$ $W_T =$ 40,478 lb/ft

Friction Force on Edge of Protective Cover

$T_{PC} = k_o \times \sigma_v \times \tan \phi_{pc} \times D_{pc}$

where: $k_o = 1 - \sin \phi_{pc}$

$\sigma_v = \frac{D_{pc} \times \gamma_{pc}}{2}$ $T_{PC} =$ 54 lb/ft

Net Force of Equipment, Waste, and Protective Cover on Liner System

$W = W_T - T_{PC}$ $W =$ 40,424 lb/ft

$N = W \cos(\beta)$ $N =$ 38,351 lb/ft

$P_{sideslope} = W \sin(\beta)$ $P_{sideslope} =$ 12,780 lb/ft

LINER SYSTEM COMPONENTS

Protective Cover/Geotextile Interface

Resistance of Protective Cover/Geotextile Interface = F_1 = 15,623 lb/ft

$P_{sideslope} < F_1$ Therefore, protective cover soil/geotextile interface is stable and a driving force equal to P is transferred to the next interface.

Geotextile/Textured Geomembrane Interface

Resistance of Geotextile/Textured Geomembrane Interface = F_2 = 21,045 lb/ft

$P_{sideslope} < F_2$ Therefore, geotextile/textured geomembrane interface is stable and a driving force equal to P is transferred to the next interface.

Textured Geomembrane/Clay Liner Interface

Resistance of Textured Geomembrane/Clay Liner Interface = F_3 = 18,785 lb/ft

$P_{sideslope} < F_3$ Therefore, the textured geomembrane/clay liner interface is stable and a driving force equal to P is transferred to the next interface.

Textured Geomembrane/GCL

Resistance of Textured Geomembrane/GCL Interface = F_4 = 13,527 lb/ft

$P_{sideslope} < F_4$ Therefore, the textured geomembrane/GCL interface is stable and a driving force equal to P is transferred to the next interface.

Internal GCL

Resistance of Internal GCL Layer = F_5 = 36,294 lb/ft

$P_{sideslope} < F_5$ Therefore, the GCL internal strength is stable and a driving force equal to P is transferred to the next interface.

Internal Clay Liner

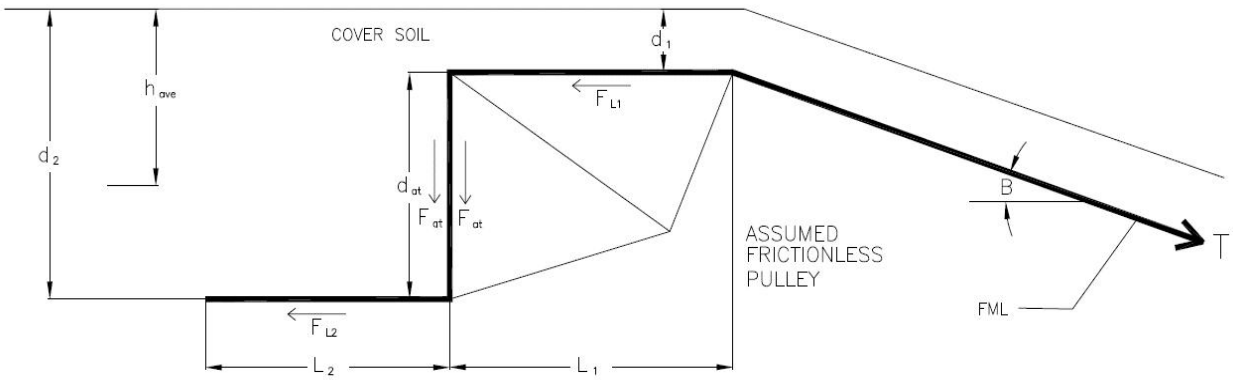
Resistance of Clay Liner layer = F_6 = 14,159 lb/ft

$P_{sideslope} < F_6$ Therefore, clay liner is stable and a driving force equal to P is transferred to the next interface.

The Actual Tensile Force on liner system (T_{act}) = 0 lb/ft

2. Provide liner anchor trench design considering pullout of the geomembrane.

Force Diagram for Liner System (analyzed for worst case Liner System interface)



$T = F_{L1} + F_{L2} + F_{at}$

Where T is the tensile force necessary for pullout

$F_{L1} = (q_1 \tan\Delta)(L_1)$

q_1 = Surcharge pressure = $d_1 \times \gamma_{soil}$
d_1 = Depth of soil, ft
γ_{soil} = Unit weight of soil, pcf
Δ = Interface friction angle, degrees
L_1 = Length of runout, ft

$F_{L2} = (q_2 \tan\Delta)(L_2)$

q_2 = Surcharge pressure = $d_2 \times \gamma_{soil}$
d_2 = Depth of soil, ft
γ_{soil} = Unit weight of soil, pcf
Δ = Interface friction angle, degrees
L_2 = Length of runout, ft

$F_{at} = (V \tan\Delta)(d_{at})$

V = Average horizontal stress = $K_o \times y$
K_o = 1 - sin(r)
r = Internal friction angle of soil, degrees
y = $\gamma_{soil} \times h_{ave}$
γ_{soil} = Unit weight of soil, pcf
h_{ave} = Average depth of trench, ft
Δ = Interface friction angle, degrees
d_{at} = Depth of trench, ft

Parameters:

γ_{soil} =	120	pcf	d_1 =	1.0	ft
Δ =	16	deg	L_1 =	6.0	ft
r =	18	deg	d_2 =	3.0	ft
			L_2 =	2.0	ft
			d_{at} =	2.0	ft
			h_{ave} =	2.0	ft

Calculations:

F_{L1} = 206.5 lb / ft

F_{L2} = 206.5 lb / ft

F_{at} = 95.1 lb / ft

T = 508.0 lb / ft

Compare force required for pullout (T) with the actual tensile force in the geomembrane from Part 1:

T = 508 lb / ft

T_{act} = 0 lb / ft

$T > T_{act}$

Therefore, the runout lengths are sufficient to prevent pullout.

B. Infinite Slope Stability Analysis

Interface friction strength values are selected conservatively from laboratory testing of similar material/interfaces. Prior to construction, laboratory tests will be performed to verify the assumed values for interface adhesion (or cohesion) and friction angle using project-specific soil and synthetic materials. The interface friction testing will be performed for the specific conditions analyzed. If test results differ from the assumed values, this analysis will be updated for acceptable factor of safety values using the procedure presented in the following sections.

The liner and final cover systems are described below.

LINER SYSTEM

The liner system includes a 2-foot-thick protective cover (12-inch soil and 12-inch sand), non-woven geotextile, textured geomembrane, and a 2-foot-thick compacted clay liner (CCL). The alternative liner system subsitutes a geosynthetic clay liner (GCL) for the upper 12 inches of the CCL.

FINAL COVER SYSTEM

The final cover system includes a 1-foot-thick vegetation layer, 2-foot thick vegetation support layer, and a 1-foot thick intermediate cover layer.

1. Use Duncan and Buchignani's method for infinite stability analyses to evaluate the internal stability of the liner, overliner, and final cover systems using peak and residual shear strength values.

The factor of safety is calculated using the following equation:

$$F.S. = A\frac{\tan\Delta}{\tan\beta} + B\frac{C_a}{\gamma H}$$

where:
- Δ = Interface friction angle, deg
- C_a = Adhesion, psf
- β = Slope angle, deg
- A = Parameter A from chart on page M-2D-14
- B = Parameter B from chart on page M-2D-14
- γ = Unit weight of soil, pcf
- H = Thickness of material above interface, ft

An example using the protective cover/geotextile interface of the liner system is provided below.

A. Define the shear strength parameters (peak shear strength parameters will be used for this example).

Δ =	18	deg
C_a =	100	psf

B. Calculate the pore pressure, r_u, using the following equation:

$$r_u = (T \times \gamma_w \times \cos^2\beta) / (H \times \gamma)$$

where:
H = Thickness of material above interface, ft
γ_w = Unit weight of water, pcf
β = Slope angle, deg
T = Maximum head above interface, ft
γ = Unit weight of soil, pcf

H =	2	ft
γ_w =	62.4	pcf
β =	18.43	deg (3H:1V)
T =	0	ft
γ =	120	pcf

r_u = 0.00

Since T=0, there is no pore pressure build-up in the protective cover. If the soil material is assumed to be saturated, use a unit weight of 125 pcf for soil.

C. Calculate the slope ratio, b.

b = cot β = 3.0

D. Using r_u and b, determine Parameters A and B from the charts on page M-2D-14.

A =	1.0
B =	3.3

E. Calculate the factor of safety and compare against the minimum recommended factor of safety.

F.S. =	2.35	>	$F.S._{min}$ =	1.5

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008 -3 4-11-19
APPENDIX M-2D
INFINITE SLOPE STABILITY ANALYSIS SUMMARY

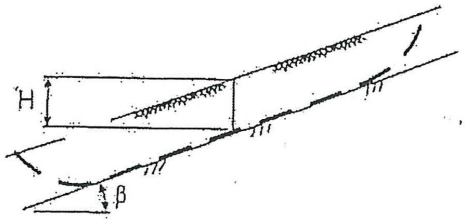
Component/Interface	Strength Parameters				H (ft)	γ (pcf)	β (deg)	T (ft)	r_u	b	A	B	Factor of Safety Generated		Recommended Minimum Factor of Safety		Acceptable Factor of Safety	
	Cohesion/Adhesion (psf)		Friction Angle (deg)															
	Peak	Residual	Peak	Residual									Peak	Residual	Peak	Residual	Peak	Residual
Liner System (3H:1V Maximum Slope)																		
Composite Liner																		
Protective Cover/Non-woven Geotextile	100	80	18	14	2	120	18.43	0	0.00	3.0	1.0	3.3	2.35	1.85	1.5	1.0	YES	YES
Non-woven Geotextile/Textured Geomembrane	100	50	25	12	2	120	18.43	0	0.00	3.0	1.0	3.3	2.77	1.33	1.5	1.0	YES	YES
Textured Geomembrane / CCL	200	80	18	14	2	120	18.43	0	0.00	3.0	1.0	3.3	3.72	1.85	1.5	1.0	YES	YES
Textured Geomembrane / GCL	80	50	16	8	2	120	18.43	0	0.00	3.0	1.0	3.3	1.96	1.11	1.5	1.0	YES	YES
GCL Internal (reinforced only)	800	380	16	8	2	120	18.43	0	0.00	3.0	1.0	3.3	11.86	5.65	1.5	1.0	YES	YES
GCL / Compacted Clay Liner	100	80	16	8	3	120	18.43	0	0.00	3.0	1.0	3.3	1.78	1.15	1.5	1.0	YES	YES
Compacted Clay Liner Internal	100	-	18	-	3	120	18.43	0	0.00	3.0	1.0	3.3	1.89	NA	1.5	1.0	YES	YES

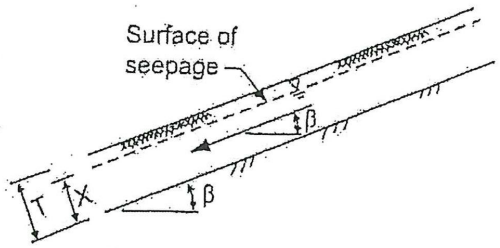
CCL = Compacted Clay Liner

GCL = Geosynthetic Clay Liner

MUSKOGEE COMMUNITY RDF
008 -3 4-11-19
APPENDIX M-2D
INFINITE SLOPE STABILITY ANALYSIS SUMMARY

Component/Interface	Strength Parameters				H (ft)	γ (pcf)	β (deg)	T (ft)	r_u	b	A	B	Factor of Safety Generated		Recommended Minimum Factor of Safety		Acceptable Factor of Safety	
	Cohesion/Adhesion (psf)		Friction Angle (deg)															
	Peak	Residual	Peak	Residual									Peak	Residual	Peak	Residual	Peak	Residual
Final Cover System (4H:1V Maximum Sideslope)																		
(Saturated Erosion Layer)																		
Vegetation/Vegetation Support Layers	100	80	18	12	1	120	15.95	2	0.96	3.5	0.45	3.75	3.64	2.83	1.5	1.0	YES	YES
Vegetation Support/Intermediate Cover Layer	100	80	18	12	3	120	15.95	2	0.32	3.5	0.45	3.75	1.55	1.17	1.5	1.0	YES	YES
All Soil Layers Internal	100	80	16	10	3	120	15.95	2	0.32	3.5	1.0	3.75	2.05	1.45	1.5	1.0	YES	YES





γ = total unit weight of soil

γ_w = unit weight of water

c' = cohesion intercept

ϕ' = friction angle

r_u = pore pressure ratio = $u/\gamma H$

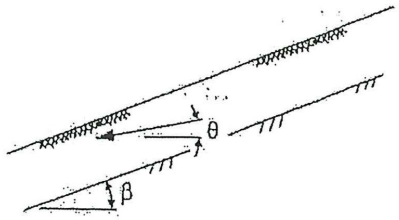
u = pore pressure at depth H

Steps.

1. Determine r_u from measured pore pressure or formulas at right.
2. Determine A and B from charts below.
3. Calculate $F = A\dfrac{\tan\phi'}{\tan\beta} + B\dfrac{c'}{\gamma H}$

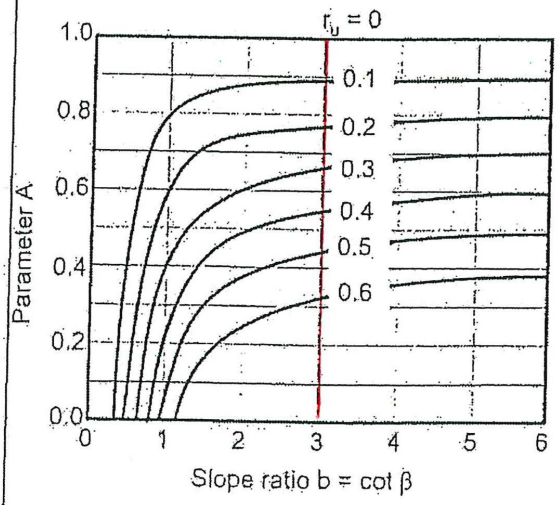
Seepage parallel to slope

$$r_u = \frac{X}{T}\frac{\gamma_w}{\gamma}\cos^2\beta$$



Seepage emerging from slope

$$r_u = \frac{\gamma_w}{\gamma}\frac{1}{1+\tan\beta\tan\theta}$$



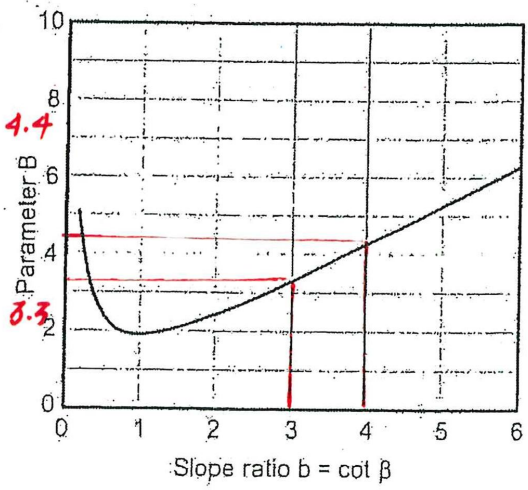
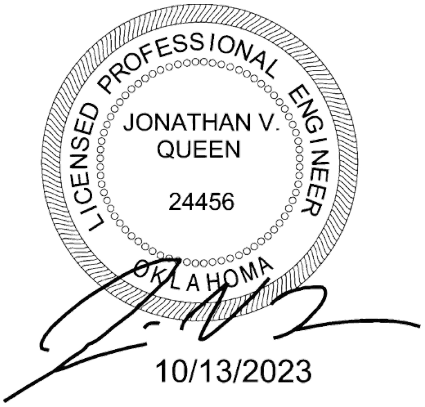


Figure E-7. Slope stability charts for infinite slopes (after Duncan, Buchlanani, and DeWet 1987)

APPENDIX M-3

SETTLEMENT, STRAIN, AND HEAVE ANALYSES



SETTLEMENT, STRAIN, AND HEAVE ANALYSIS

This appendix includes the settlement analysis for foundation soils and final cover system. Settlement and heave analyses for foundation soils. A description of the analysis method is presented in Section 5 of this Appendix M.

- Appendix M-3A presents the settlement and stain analysis of the bottom liner system.
- Appendix M-3B presents the settlement and strain analysis of the final cover system.
- Appendix M-3C presents the heave analysis.

The strain analyses presented in Appendices M-3A and M-3B demonstrate that the liner and leachate collection system will maintain their integrity and perform as designed when subjected to landfill stresses and settlement.

APPENDIX M-3A

BOTTOM LINER SYSTEM SETTLEMENT AND STRAIN ANALYSIS

Includes pages M-3A-1 through M-3A-38

Required: Determine the post-settlement slope of the bottom liner system and verify that the strain induced on the bottom liner system due to settlement is within acceptable limits.

Method:

A. Estimate settlement of subsurface below the bottom liner system. Settlement calculated by consolidation theory using SETTLE3. The program uses the Boussinesq method to approximate 2-dimensional consolidation of the foundation strata.

1. Waste filling and liner and final cover installation will result in loading of the foundation soils causing consolidation and potential differential settlement. The magnitude of consolidation and settlement will be a function of the net stress increase and properties of the foundation soils. Net stress increase is assumed to result from loading of the foundation soils during landfilling.

2. Modeling was performed using SETTLE3, RocScience, Inc (2021). Procedures are described below. Primary settlement (only) was analyzed. Secondary settlement within the shale formation is assumed negligible.

2a. The subgrade conditions were developed from the available boring logs, normalized to the excavation grades proposed for the landfill. Normalization refers to inputting boring information from the proposed excavation grade downward, based on recorded elevations shown on the logs. The borehole locations used to establish the subgrade conditions are shown on Sheet M-3A-8. For the analysis vertical loads were applied for the closed condition at the locations shown on Sheet M-3A-9.

2b. Load polygons were developed for input into SETTLE3, for the loading conditions proposed for the landfill. Vertical loads were estimated for each polygon vertex (at the locations shown on Sheet M-3A-9), and this information inputted into SETTLE3. The load polygons are shown on Sheet M-3A-10. Loads at the polygon vertices were estimated based on waste fill height and an assumed unit weight of waste (varies based on total waste depth).

2c. The SETTLE3 program calculated total settlement based on Boussinesq equation. The model output files are included in this Appendix. The settlement isopach created by SETTLE3 is presented on Sheet M-3A-11.

3. Utilizing the settlement values calculated by SETTLE3, post-settlement slopes and strains are calculated, as presented on Sheets M-3A-5 through M-3A-7. An example of the calculation method is presented on Sheets M-3A-3 and M-3A-4.

Description of Contents:

Sheet M-3A-1 presents the method used for the settlement analyses.
Sheets M-3A-3 and M-3A-4 present the method of analysis for post-settlement slopes and strain between designated Evaluation Points.

Sheet M-3A-8 presents the borehole locations used to develop the subsurface profile for the SETTLE3 model.

Sheet M-3A-9 presents the final configuration load locations incorporated into the SETTLE3 model.

Sheet M-3A-10 presents the SETTLE3 load polygons incorporated into model.
Sheet M-3A-11 presents the SETTLE3 settlement isopach.
Sheet M-3A-12 presents the Evaluation Points and Evaluation Lines used in analysis of the strain and post-settlement slopes for the bottom liner.

Tables 1A and 1B present the settlement results at the Evaluation Points and distances between the Evaluation Points.

Table 2 presents slope and strain summary results from the analysis.

References:

1. Sowers, George F., Settlement of Solid Waste, *Proceedings of the Eighth International Conference on Soil Mechanics and Foundations Engineering, 1973* .
2. Quian, Xuede, R.M. Koerner, D. H. Gray, Geotechnical Aspects of Landfill Design and Construction, Prentice-Hall, Inc., New Jersey, 2002.
3. Koerner, Robert M., Designing with Geosynthetics, Third Edition. Prentice-Hall, New Jersey, 1994.
4. Acar, Yalcin B. & Daniel, David E., *Geoenvironment 2000 Characterization, Containment, Remediation, and Performance in Environmental Geotechnics,* Volume 2, American Society of Civil Engineers, 1995.
5. Zornberg, Jorge G., et al., *Retention of Free Liquids in Landfills Undergoing* Vertical Expansion, Journal of Geotechnical and Geoenvironmental Engineering, July 1999.
6. Fassett, Jeffrey B., et al., Geotechnical Properties of Municipal Solid Wastes and Their Use in Landfill Design, Waste Tech, 1994.
7. SETTLE3, Version 5.009 Copyright © 2008-2021 Rocscience Inc.
8. Beggs, Ian D. et al, Assessment of Maximum Allowable Strains in Polyethylene and Polypropylene Geomembranes, Geo-Frontiers Congress, Austin, TX, 2005.

Solution: **A) Estimate settlement of bottom liner system.**

The SETTLE3 model was used to determine waste loading-induced settlement in the bottom liner system. The vertices and polygons developed for the modeling are shown on Sheet M-3A-10. The analysis was performed for the final contours (at build-out) of the landfill.

Post-settlement slopes were calculated between the points shown on Sheet M-3A-12. The pre- and post-settlement elevations were determined from AutoCAD surfaces for the design condition and the post-settlement conditions from the SETTLE3 model. The post-settlement condition was generated as output from SETTLE3, which was used to develop the post-settlement surface (isopach) shown on Sheet M-3A-11. The pre and post-settlement point elevations are presented in Table 1A and 1B, and the strain and slope calculations are presented in Table 2.

B) Verify that strain induced on the bottom liner system components due to settlement is within acceptable limits.

Determine the post-settlement slope of the bottom liner and verify the strain induced on the geocomposite due to settlement is within acceptable limits.

Note that negative values indicate the components are in compression.

$$\text{Strain} = \frac{L_f - L_o}{L_o} x100$$ (Reference 2, Page 472)

L_f = Final distance between evaluation points after total settlement (ft)
L_o = Initial distance between evaluation points before total settlement (ft)

An example calculation of the estimated strain is shown below for Evaluation Points BL2 and BL4. The estimated strain for all evaluation points is shown in Table 2.

Evaluation Point BL2 to Evaluation Point BL4:

Initial Distance:

Evaluation Point BL2 Elev. =	624.0	ft-msl
Evaluation Point BL4 Elev. =	627.5	ft-msl
Plan View Distance=	162.5	ft
L_o=	162.5	ft

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APPENDIX M-3A
BOTTOM LINER SYSTEM
SETTLEMENT AND STRAIN

Total Settlement:

Total Settlement Point BL2=	0.62	ft
Total Settlement Point BL4=	0.54	ft

Final Distance (after settlement):

Evaluation Point BL2 Elev. =	623.4	ft-msl
Evaluation Point BL4 Elev. =	627.0	ft-msl
Plan View Distance=	162.5	ft
L_f=	162.5	ft

Strain= 0.001%

Conclusions:

- Compacted clay liner component of bottom liner has the smallest allowable tensile strain value which is 0.5 percent (Reference 2, page 469).
- The allowable tensile strain for geosynthetic clay liner is 10 percent (ranges from 10 to 22 percent, Koerner et.al., 1996).
- The allowable tensile strain for an HDPE geomembrane is 6 to 8 percent (Reference 8).
- The allowable tensile strain for a drainage geocomposite (if used) is more than 20 percent for the geotextile (reference 3, page 112) and 200 percent for the geonet (reference 3, page 400).
- The maximum calculated strain (0.03%) represents tensile strain and is acceptable, therefore the system will be stable. The maximium compressive strain is -0.006%.

TABLE 1A. BOTTOM LINER SYSTEM - SETTLEMENT SUMMARY

Evaluation Point[1]	Initial Top of Bottom Liner Elevation (ft-msl)	Post-Settlement Top of Bottom Liner Elevation (ft-msl)	Total Top of Bottom Liner Settlement (ft)
BL1	635.7	635.6	0.06
BL2	624.0	623.4	0.62
BL3	618.0	617.9	0.06
BL4	627.5	627.0	0.54
BL5	624.0	623.5	0.47
BL6	620.9	620.6	0.27
BL7	646.0	646.0	0.01
BL8	632.8	632.7	0.05
BL9	633.7	633.2	0.47
BL10	636.0	635.5	0.53
BL11	638.0	637.4	0.55
BL12	626.3	625.8	0.55
BL13	632.6	632.6	0.04
BL14	636.3	635.8	0.50
BL15	633.0	632.6	0.35
BL16	628.7	628.2	0.51
BL17	623.6	623.6	0.02
BL18	627.3	627.1	0.17
BL19	624.0	623.6	0.36
BL20	632.6	632.2	0.42

[1] Refer to Sheet M-3A-12 for Evaluation Point locations BL1 thru BL20. Initial Top of Bottom Liner Elevations shown on Sheet M-3A-12.

TABLE 1B. DISTANCES BETWEEN SETTLEMENT EVALUATION POINTS

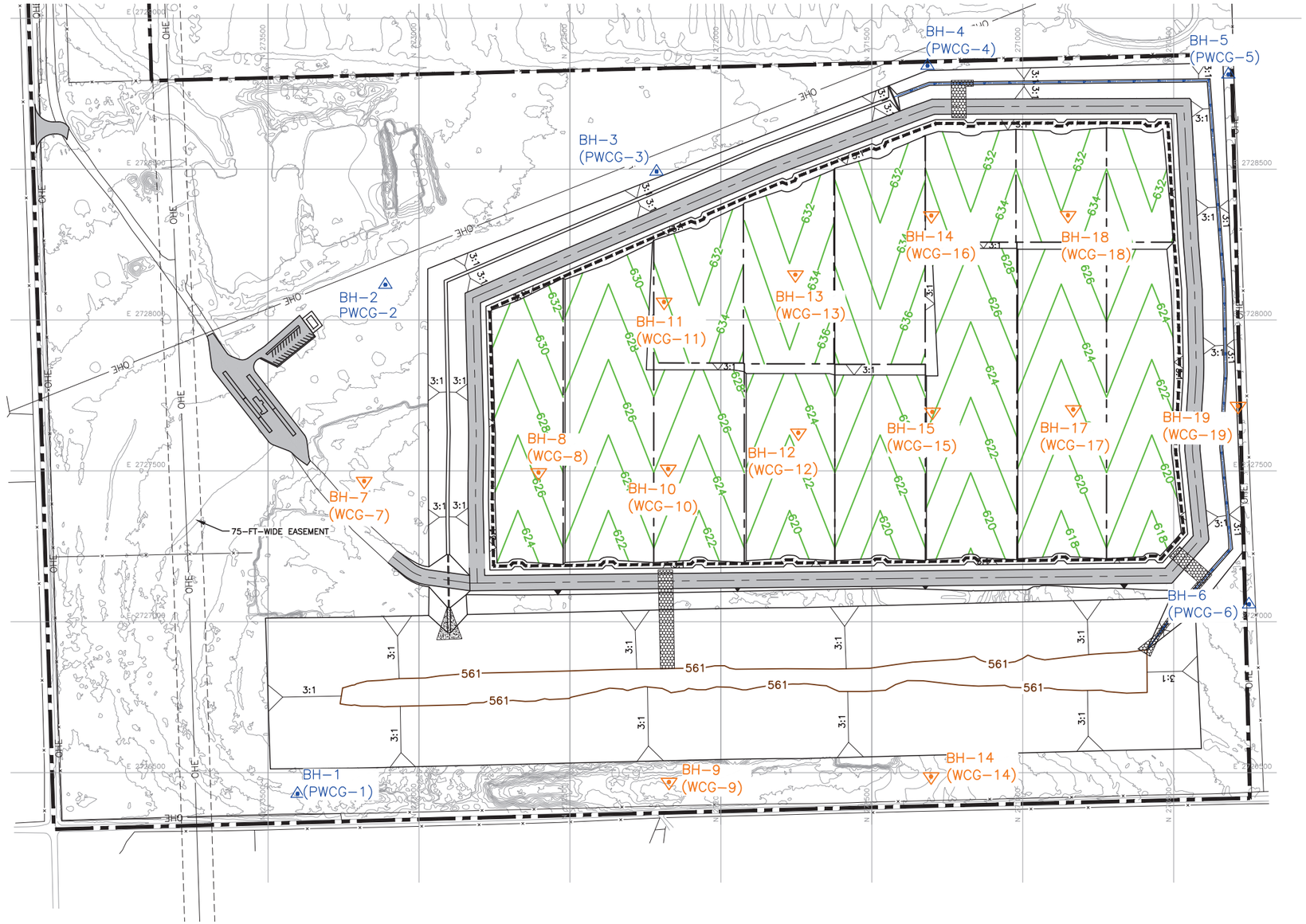
Evaluation Points[1]		Distance (ft)
From	**To**	
BL1	BL20	339.4
BL2	BL3	750.1
BL2	BL4	162.5
BL5	BL6	144.4
BL7	BL8	39.6
BL9	BL10	109.8
BL11	BL12	35.0
BL13	BL14	525.7
BL14	BL15	155.7
BL16	BL17	632.4
BL18	BL19	154.0

[1] Refer to Sheet M-3A-12 for Evaluation Points BL1 through BL20.

TABLE 2. BOTTOM LINER SYSTEM - SLOPE AND STRAIN SUMMARY

Evaluation Point[1]		Initial Top of Bottom Liner Elevation (ft-msl)		Post-Settlement Top of Bottom Liner Elevation (ft-msl)		Plan View Distance (ft)	L_o (ft)	L_f (ft)	Initial Slope (ft/ft)	Post-Settlement Slope (ft/ft)	Tensile Strain (%)
A	B	A	B	A	B						
BL1	BL20	635.7	632.6	635.6	632.2	339.4	339.414	339.418	0.009	0.010	0.001
BL2	BL3	624.0	618.0	623.4	617.9	750.1	750.1	750.1	0.008	0.007	-0.001
BL2	BL4	624.0	627.5	623.4	627.0	162.5	162.5	162.5	-0.022	-0.022	0.001
BL5	BL6	624.0	620.9	623.5	620.6	144.4	144.4	144.4	0.022	0.020	-0.003
BL7	BL8	646.0	632.8	646.0	632.7	39.6	41.7	41.7	0.333	0.334	0.030
BL9	BL10	633.7	636.0	633.2	635.5	109.8	109.8	109.8	-0.021	-0.021	-0.001
BL11	BL12	638.0	626.3	637.4	625.8	35.0	36.9	36.9	0.333	0.333	-0.006
BL13	BL14	632.6	636.3	632.6	635.8	525.7	525.7	525.7	-0.007	-0.006	-0.001
BL14	BL15	636.3	633.0	635.8	632.6	155.7	155.8	155.8	0.021	0.020	-0.002
BL16	BL17	628.7	623.6	628.2	623.6	632.4	632.4	632.4	0.008	0.007	-0.001
BL18	BL19	627.3	624.0	627.1	623.6	154.0	154.0	154.0	0.022	0.023	0.003

[1] Refer to Sheet M-3A-12 for Evaluation Point locations. The "A" and "B" points represent the upgradient and downgradient endpoints, respectively.



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SCALE IN FEET

LEGEND

	PROPERTY BOUNDARY
	PERMIT BOUNDARY
	PERMITTED LIMITS OF WASTE
N 273000	STATE PLANE COORDINATE GRID
700	EXISTING CONTOUR
636	EXCAVATION CONTOUR
561	SOIL BORROW CONTOUR
	SECTOR BOUNDARY
BH-6 (PWCG-6)	BOREHOLE AND PIEZOMETER DESIGNATION (BORING DESIGNATION)
BH-17 (WCG-17)	BOREHOLE ONLY DESIGNATION (BORING DESIGNATION)

NOTES:

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MUSKOGEE COUNTY, OKLAHOMA

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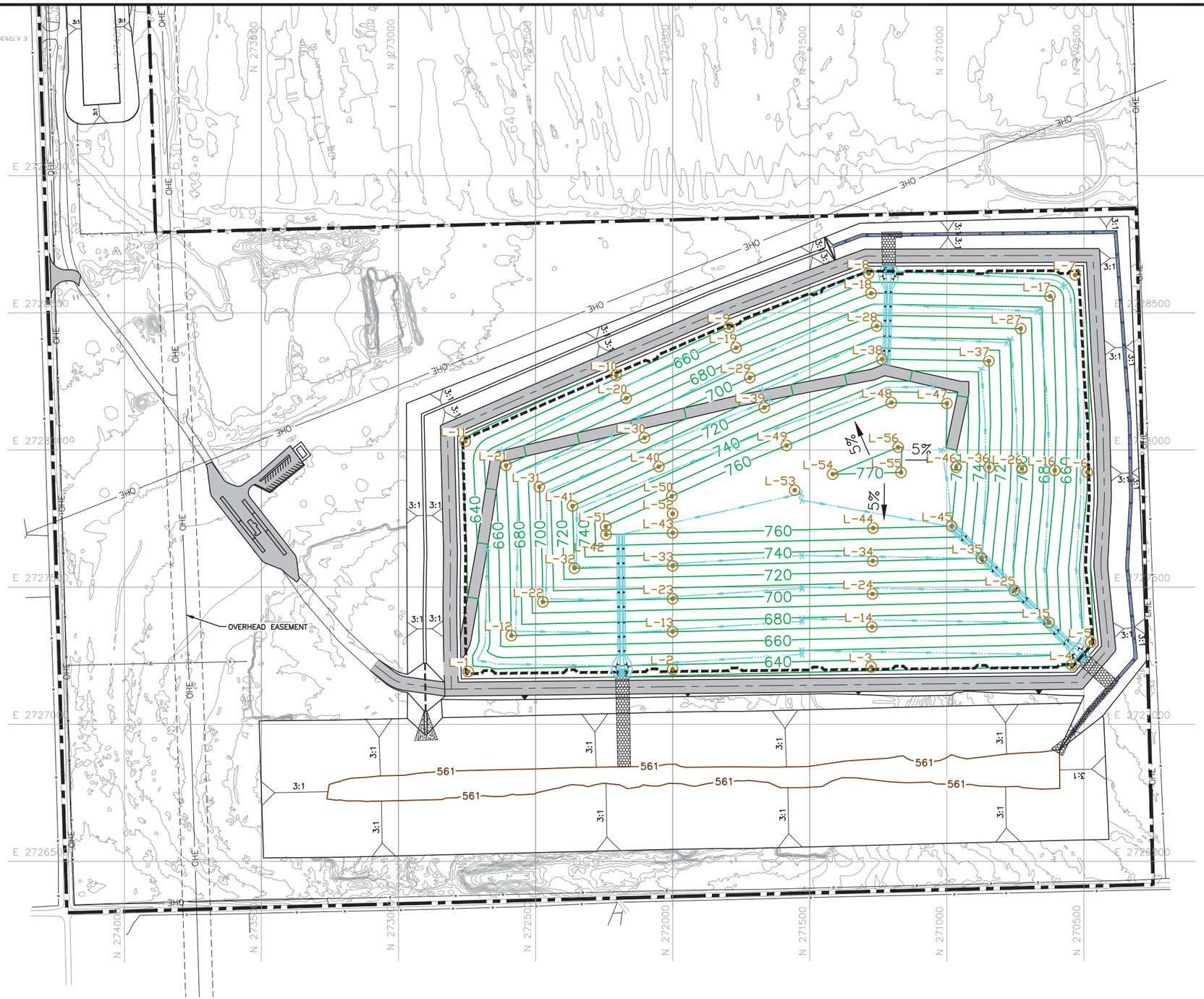

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SCALE IN FEET

LEGEND

- PROPOSED PERMIT BOUNDARY
- PROPOSED LIMITS OF WASTE
- N 273,000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- 561 — BORROW AREA CONTOUR
- 770 — FINAL COVER CONTOUR
- PROPOSED DRAINAGE SWALE
- PROPOSED DRAINAGE CHUTE
- PROPOSED DRAINAGE CHANNEL
- RIPRAP/GABIONS
- OHE — EXISTING OVERHEAD EASEMENT
- L-1 — LOAD ANALYSIS POINT

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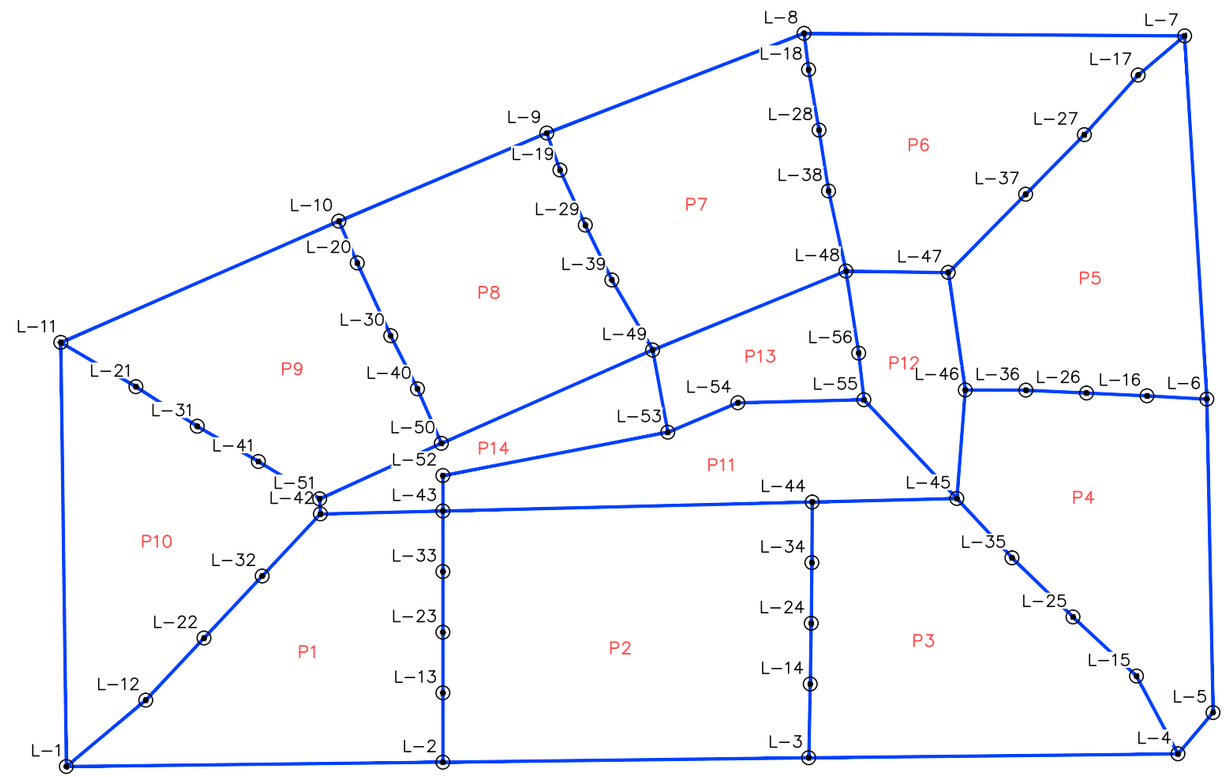

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PROPOSED PERMIT BOUNDARY

PROPOSED LIMITS OF WASTE

L-1 LOAD ANALYSIS POINT

LOAD POLYGONS

P1 POLYGON NO.

0 150 300
SCALE IN FEET

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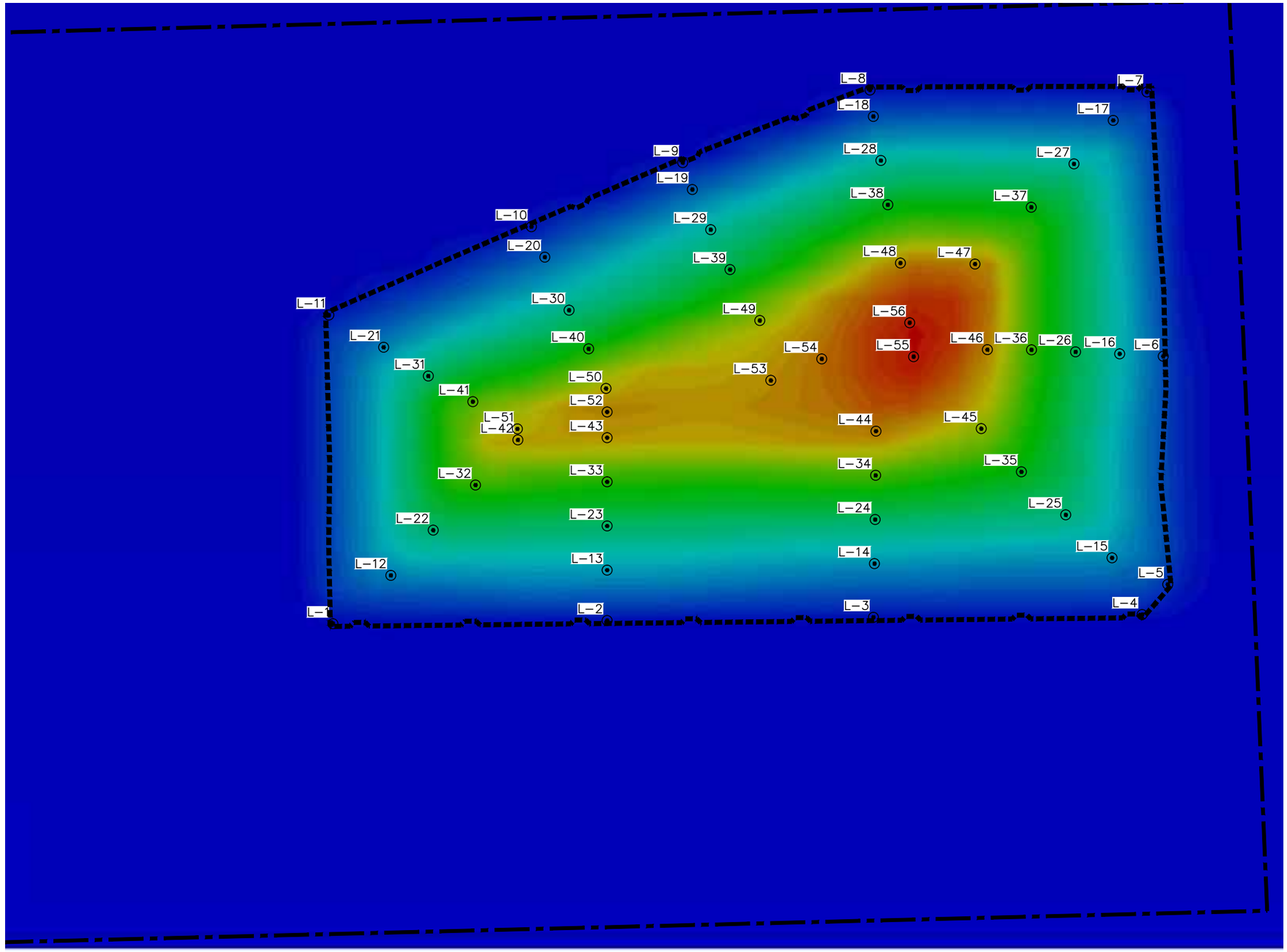

0 150 300
SCALE IN FEET

LEGEND

PROPOSED PERMIT BOUNDARY

PROPOSED LIMITS OF WASTE

L-1 LOAD ANALYSIS POINT

Total Settlement (ft)

0.000
0.062
0.124
0.186
0.248
0.310
0.372
0.434
0.496
0.558
0.620

max (stage): 0.615 ft
max (all): 0.615 ft

(SEE NOTE 1)

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NOTES:

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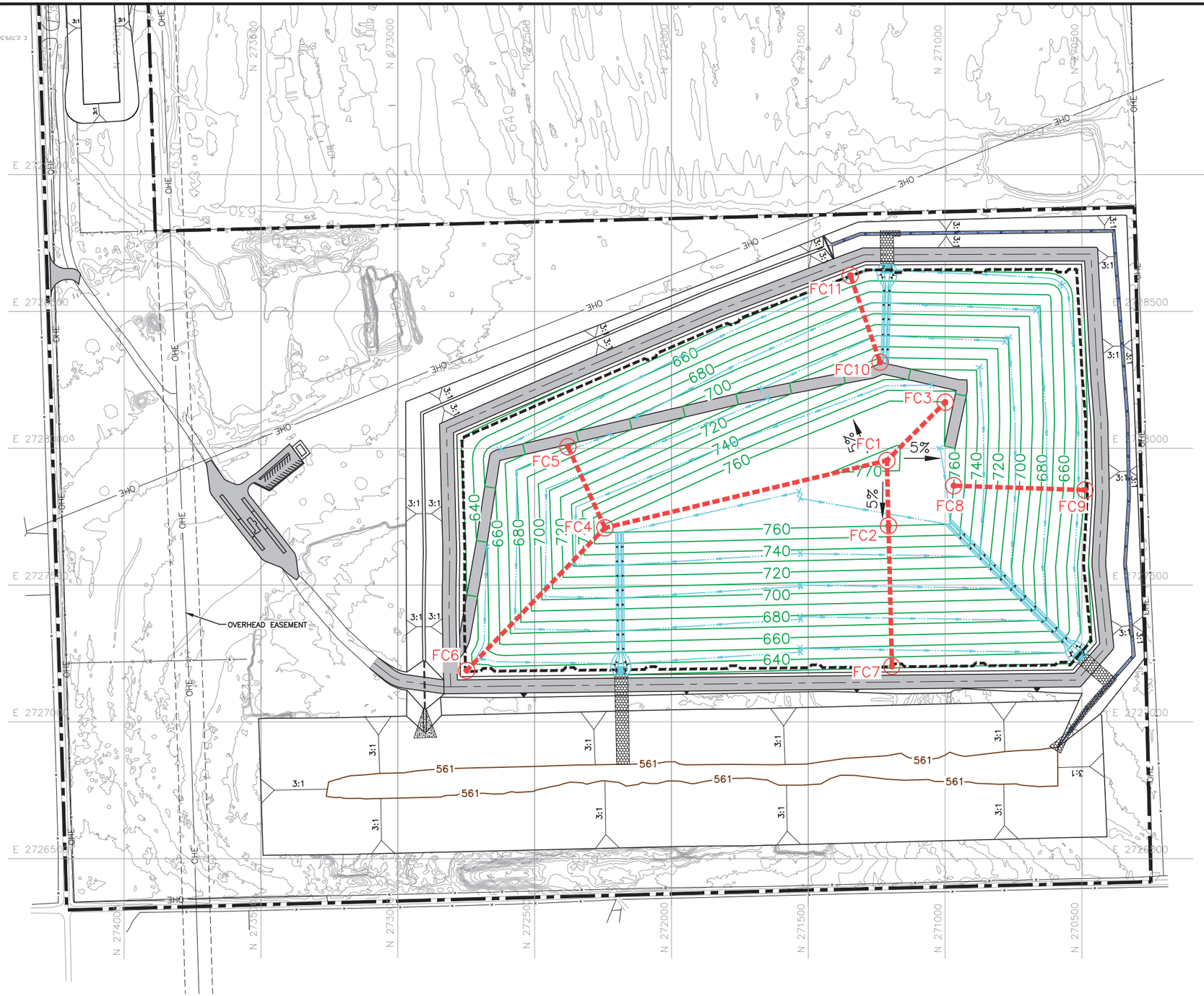

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SCALE IN FEET

LEGEND

	PROPOSED PERMIT BOUNDARY
	PROPOSED LIMITS OF WASTE
N 273,000	STATE PLANE COORDINATE GRID
640	EXISTING CONTOUR
561	BORROW AREA CONTOUR
770	FINAL COVER CONTOUR
	PROPOSED DRAINAGE SWALE
	PROPOSED DRAINAGE CHUTE
	PROPOSED DRAINAGE CHANNEL
	RIPRAP/GABIONS
OHE	EXISTING OVERHEAD EASEMENT
FC2	FINAL COVER EVALUATION POINT
	FINAL COVER EVALUATION LINE

NOTES:

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Muskogee Landfill Settlement Calculation
Weaver Consultants Group
Report Creation Date: 2023/02/21, 09:55:22

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Settle3 Analysis Information

Muskogee Landfill Setttlement Calculation

Project Settings

Document Name	MUSKOGEE_LANDFILL_SETTLEMENT.s3z
Project Title	Muskogee Landfill Setttlement Calculation
Author	MB
Company	Weaver Consultants Group
Date Created	12/22/2022, 9:52:59 AM
Stress Computation Method	Boussinesq
Minimum settlement ratio for subgrade modulus	0.9
Use average properties to calculate layered stresses	
Improve consolidation accuracy	
Ignore negative effective stresses in settlement calculations	

Stage Settings

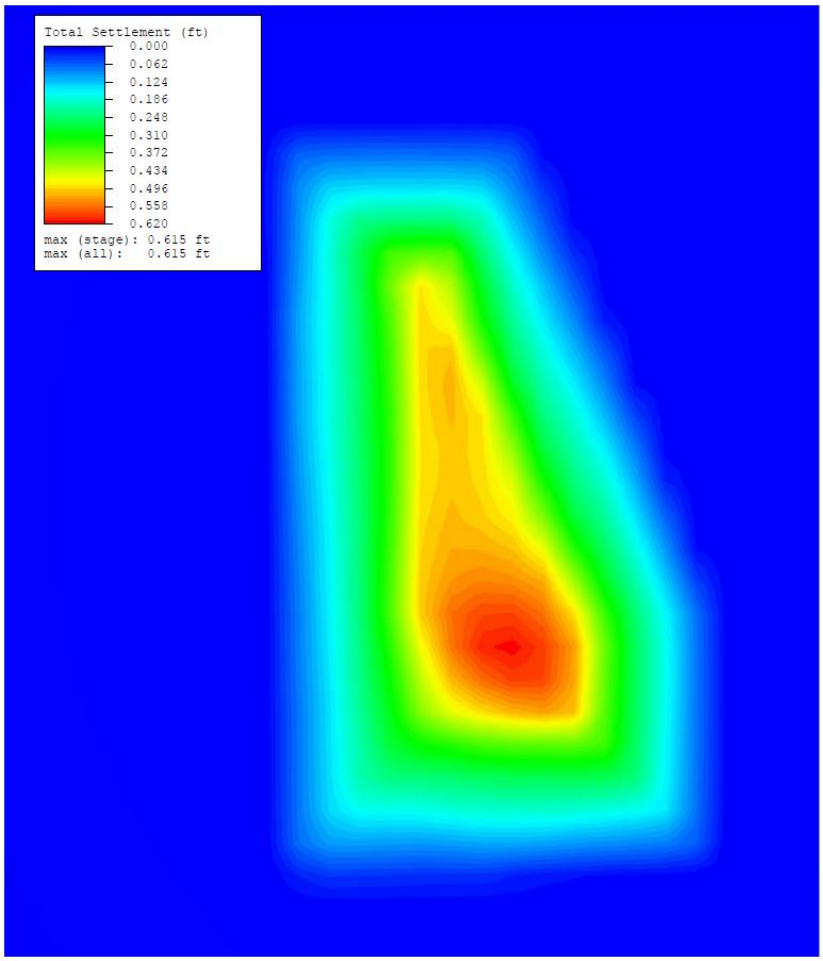
Stage #	Name
1	Stage 1

Results

Time taken to compute: 17.4687 seconds

Stage: Stage 1

Data Type	Minimum	Maximum
Total Settlement [ft]	0	0.614744
Total Consolidation Settlement [ft]	0	0.614744
Virgin Consolidation Settlement [ft]	0	0.491931
Recompression Consolidation Settlement [ft]	0	0.15952
Immediate Settlement [ft]	0	0
Loading Stress ZZ [ksf]	-0.00273051	9.10334
Loading Stress XX [ksf]	-2.03779	10.6436
Loading Stress YY [ksf]	-2.15046	9.27591
Total Stress ZZ [ksf]	-0.00253889	23.2107
Total Stress XX [ksf]	-1.20285	25.2961
Total Stress YY [ksf]	-1.2052	23.8654
Modulus of Subgrade Reaction (Total) [ksf/ft]	-0.245854	23.6831
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	0
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	-0.245854	23.6831
Total Strain	-2.1785e-05	0.0180777
Degree of Consolidation [%]	0	100
Pre-consolidation Stress [ksf]	3	23.2057
Over-consolidation Ratio	1	2875.03
Void Ratio	0.165666	0.630036
Hydroconsolidation Settlement [ft]	0	0
Undrained Shear Strength	0	0.609077


Total Settlement (ft)
0.000
0.062
0.124
0.186
0.248
0.310
0.372
0.434
0.496
0.558
0.620
max (stage): 0.615 ft
max (all): 0.615 ft

Loads

1. Fill Load: "Fill Load 1"

Label	Fill Load 1
Load Type	Flexible
Area of Load	238237 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
2.7272e+06	272000	0.49316
2.72734e+06	272000	2.15114
2.72746e+06	272000	3.91434
2.72758e+06	272000	5.86492
2.7277e+06	272000	8.04793
2.72769e+06	272243	7.98051
2.72757e+06	272358	5.93457
2.72745e+06	272473	3.88871
2.72732e+06	272588	2.00648
2.72719e+06	272746	0.392209

2. Fill Load: "Fill Load 2"

Label	Fill Load 2
Load Type	Flexible
Area of Load	365420 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
2.72721e+06	271276	0.504542
2.72736e+06	271273	2.26106
2.72748e+06	271271	4.03762
2.7276e+06	271270	5.99886
2.72772e+06	271269	8.19246
2.7277e+06	272000	8.04793
2.72758e+06	272000	5.86492
2.72746e+06	272000	3.91434
2.72734e+06	272000	2.15114
2.7272e+06	272000	0.49316

3. Fill Load: "Fill Load 3"

Label	Fill Load 3
Load Type	Flexible
Area of Load	269537 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
2.72722e+06	270545	0.470299
2.72737e+06	270627	2.34714
2.72749e+06	270753	4.06296
2.7276e+06	270873	6.26946
2.72772e+06	270982	8.23326
2.72772e+06	271269	8.19246
2.7276e+06	271270	5.99886
2.72748e+06	271271	4.03762
2.72736e+06	271273	2.26106
2.72721e+06	271276	0.504542

4. Fill Load: "Fill Load 4"

Label	Fill Load 4
Load Type	Flexible
Area of Load	231863 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
2.7273e+06	270475	0.383834
2.72792e+06	270488	0.429715
2.72793e+06	270606	2.15394
2.72793e+06	270726	3.77403
2.72794e+06	270846	5.98106
2.72794e+06	270966	8.1486
2.72772e+06	270982	8.23326
2.7276e+06	270873	6.26946
2.72749e+06	270753	4.06296
2.72737e+06	270627	2.34714
2.72722e+06	270545	0.470299

5. Fill Load: "Fill Load 5"

Label	Fill Load 5
Load Type	Flexible
Area of Load	234709 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
2.72864e+06	270532	0.415582
2.72856e+06	270623	1.67498
2.72844e+06	270730	3.25126
2.72832e+06	270846	5.33391
2.72817e+06	271000	7.99398
2.72794e+06	270966	8.1486
2.72794e+06	270846	5.98106
2.72793e+06	270726	3.77403
2.72793e+06	270606	2.15394
2.72792e+06	270488	0.429715

6. Fill Load: "Fill Load 6"

Label	Fill Load 6
Load Type	Flexible
Area of Load	224884 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
2.72864e+06	271285	0.478619
2.72857e+06	271276	1.62959
2.72845e+06	271255	3.38
2.72833e+06	271236	5.29368
2.72817e+06	271202	8.05041
2.72817e+06	271000	7.99398
2.72832e+06	270846	5.33391
2.72844e+06	270730	3.25126
2.72856e+06	270623	1.67498
2.72864e+06	270532	0.415582

7. Fill Load: "Fill Load 7"

Label	Fill Load 7
Load Type	Flexible
Area of Load	228719 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
2.72845e+06	271794	0.526147
2.72837e+06	271768	1.74943
2.72826e+06	271718	3.40359
2.72815e+06	271666	4.51748
2.72802e+06	271585	7.29672
2.72817e+06	271202	8.05041
2.72833e+06	271236	5.29368
2.72845e+06	271255	3.38
2.72857e+06	271276	1.62959
2.72864e+06	271285	0.478619

8. Fill Load: "Fill Load 8"

Label	Fill Load 8
Load Type	Flexible
Area of Load	213717 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
2.72827e+06	272206	0.507776
2.72819e+06	272170	1.61165
2.72804e+06	272103	3.39833
2.72794e+06	272050	5.30872
2.72783e+06	272003	7.98611
2.72802e+06	271585	7.29672
2.72815e+06	271666	4.51748
2.72826e+06	271718	3.40359
2.72837e+06	271768	1.74943
2.72845e+06	271794	0.526147

9. Fill Load: "Fill Load 9"

Label	Fill Load 9
Load Type	Flexible
Area of Load	210682 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
2.72803e+06	272757	0.341149
2.72794e+06	272608	1.7915
2.72787e+06	272486	3.62707
2.7278e+06	272365	5.8396
2.72772e+06	272244	7.96753
2.72783e+06	272003	7.98611
2.72794e+06	272050	5.30872
2.72804e+06	272103	3.39833
2.72819e+06	272170	1.61165
2.72827e+06	272206	0.507776

10. Fill Load: "Fill Load 11"

Label	Fill Load 11
Load Type	Flexible
Area of Load	140173 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
2.72772e+06	271269	8.19246
2.72772e+06	270982	8.23326
2.72792e+06	271167	9.10334
2.72791e+06	271416	8.05257
2.72785e+06	271555	7.82771
2.72777e+06	272000	8.19309
2.7277e+06	272000	8.04793

11. Fill Load: "Fill Load 12"

Label	Fill Load 12
Load Type	Flexible
Area of Load	70525 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
2.72794e+06	270966	8.1486
2.72817e+06	271000	7.99398
2.72817e+06	271202	8.05041
2.72801e+06	271177	9.05806
2.72792e+06	271167	9.10334
2.72772e+06	270982	8.23326

12. Fill Load: "Fill Load 13"

Label	Fill Load 13
Load Type	Flexible
Area of Load	77532.4 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
2.72791e+06	271416	8.05257
2.72792e+06	271167	9.10334
2.72801e+06	271177	9.05806
2.72817e+06	271202	8.05041
2.72802e+06	271585	7.29672
2.72785e+06	271555	7.82771

13. Fill Load: "Fill Load 14"

Label	Fill Load 14
Load Type	Flexible
Area of Load	71216.4 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

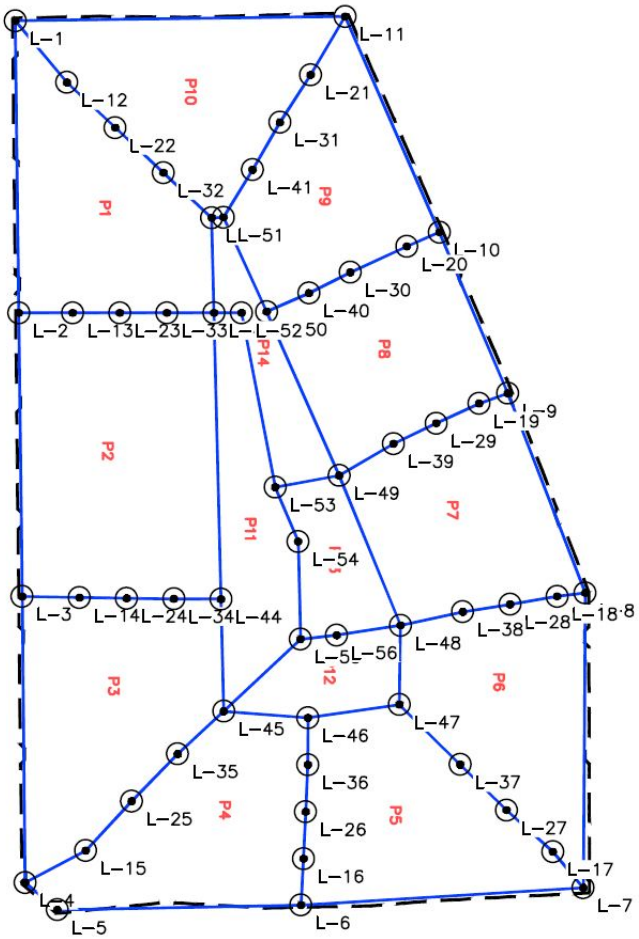
X [ft]	Y [ft]	Load Magnitude [ksf]
2.72777e+06	272000	8.19309
2.72785e+06	271555	7.82771
2.72802e+06	271585	7.29672
2.72783e+06	272003	7.98611
2.72772e+06	272244	7.96753
2.72769e+06	272243	7.98051
2.7277e+06	272000	8.04793

14. Fill Load: "Fill Load 10"

Label	Fill Load 10
Load Type	Flexible
Area of Load	227689 ft2
Elevation	628 ft
Installation Stage	Stage 1

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
2.72732e+06	272588	2.00648
2.72745e+06	272473	3.88871
2.72757e+06	272358	5.93457
2.72769e+06	272243	7.98051
2.72772e+06	272244	7.96753
2.7278e+06	272365	5.8396
2.72787e+06	272486	3.62707
2.72794e+06	272608	1.7915
2.72803e+06	272757	0.341149
2.72719e+06	272746	0.392209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L-12
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50
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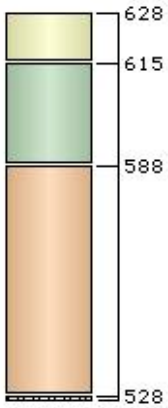
L-5
L-6
L-7
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
P13
P14

Soil Layers

BH-1 (PWCG-1)

XY Location: BH-1 (PWCG-1): (2.72643e+06, 273403)

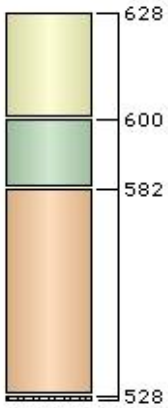
Layer #	Type	Thickness [ft]	Elevation [ft]
1	Silty Sand/Clay	13	628
2	Weathered Shale	27	615
3	Unweathered Shale	60	588



BH-2 (PWCG-2)

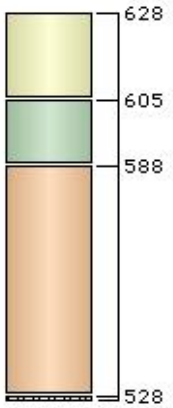
XY Location: BH-2 (PWCG-2): (2.72812e+06, 273111)

Layer #	Type	Thickness [ft]	Elevation [ft]
1	Silty Sand/Clay	28	628
2	Weathered Shale	18	600
3	Unweathered Shale	54	582



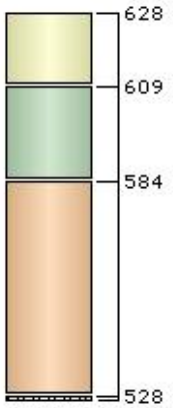
BH-3 (PWCG-3)

XY Location:		BH-3 (PWCG-3): (2.72849e+06, 272213)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	23	628
2	Weathered Shale	17	605
3	Unweathered Shale	60	588



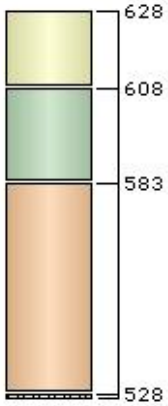
BH-4 (PWCG-4)

XY Location:		BH-4 (PWCG-4): (2.72884e+06, 271315)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	19	628
2	Weathered Shale	25	609
3	Unweathered Shale	56	584



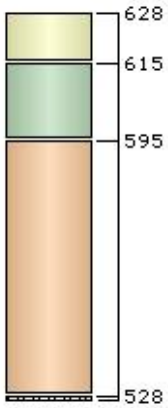
BH-5 (PWCG-5)

XY Location:		BH-5 (PWCG-5): (2.72881e+06, 270319)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	20	628
2	Weathered Shale	25	608
3	Unweathered Shale	55	583



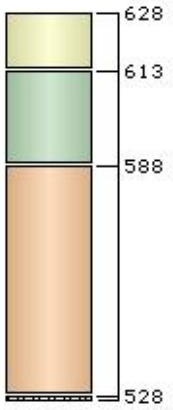
BH-6 (PWCG-6)

XY Location:		BH-6 (PWCG-6): (2.72706e+06, 270250)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	13	628
2	Weathered Shale	20	615
3	Unweathered Shale	67	595



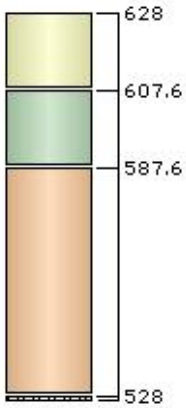
BH-7 (WCG-7)

XY Location:		BH-7 (WCG-7): (2.72747e+06, 273181)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	15	628
2	Weathered Shale	25	613
3	Unweathered Shale	60	588



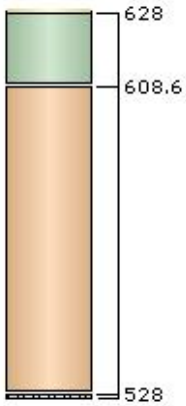
BH-8 (WCG-8)

XY Location:		BH-8 (WCG-8): (2.72749e+06, 272598)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	20.4	628
2	Weathered Shale	20	607.6
3	Unweathered Shale	59.6	587.6



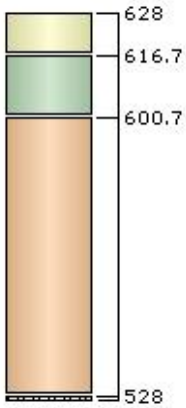
BH-9 (WCG-9)

XY Location:		BH-9 (WCG-9): (2.72646e+06, 272172)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	0	628
2	Weathered Shale	19.4	628
3	Unweathered Shale	80.6	608.6



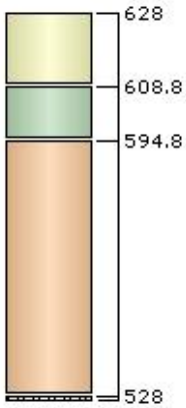
BH-10 (WCG-10)

XY Location:		BH-10 (WCG-10): (2.72751e+06, 272168)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	11.3	628
2	Weathered Shale	16	616.7
3	Unweathered Shale	72.7	600.7



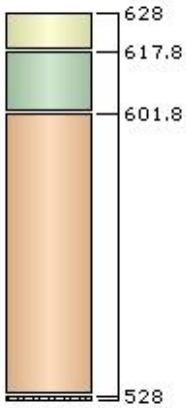
BH-11 (WCG-11)

XY Location:		BH-11 (WCG-11): (2.72806e+06, 272184)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	19.2	628
2	Weathered Shale	14	608.8
3	Unweathered Shale	66.8	594.8



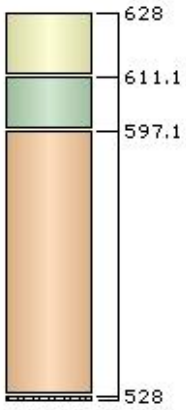
BH-12 (WCG-12)

XY Location:		BH-12 (WCG-12): (2.72763e+06, 271740)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	10.2	628
2	Weathered Shale	16	617.8
3	Unweathered Shale	73.8	601.8



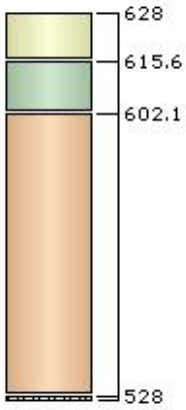
BH-13 (WCG-13)

XY Location:		BH-13 (WCG-13): (2.72815e+06, 271749)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	16.9	628
2	Weathered Shale	14	611.1
3	Unweathered Shale	69.1	597.1



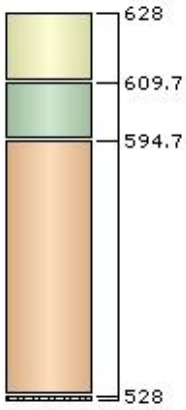
BH-14 (WCG-14)

XY Location:		BH-14 (WCG-14): (2.72649e+06, 271302)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	12.4	628
2	Weathered Shale	13.5	615.6
3	Unweathered Shale	74.1	602.1



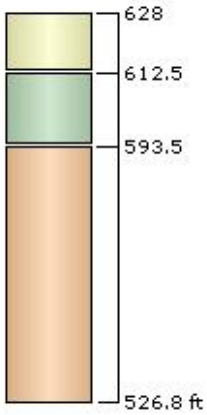
BH-15 (WCG-15)

XY Location:		BH-15 (WCG-15): (2.72769e+06, 271295)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	18.3	628
2	Weathered Shale	15	609.7
3	Unweathered Shale	66.7	594.7



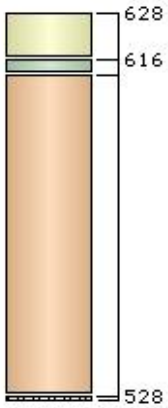
BH-16 (WCG-16)

XY Location:		BH-16 (WCG-16): (2.72834e+06, 271300)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	15.5	628
2	Weathered Shale	19	612.5
3	Unweathered Shale	66.7	593.5



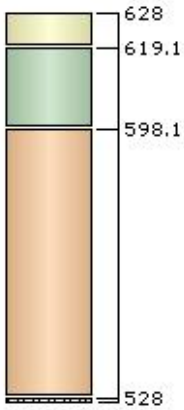
BH-17 (WCG-17)

XY Location:		BH-17 (WCG-17): (2.7277e+06, 270830)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	12	628
2	Weathered Shale	4	616
3	Unweathered Shale	84	612



BH-18 (WCG-18)

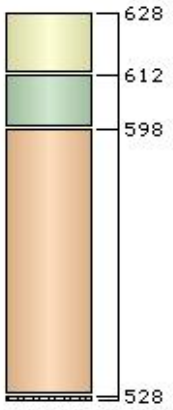
XY Location:		BH-18 (WCG-18): (2.72834e+06, 270842)	
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**
1	Silty Sand/Clay	8.9	628
2	Weathered Shale	21	619.1
3	Unweathered Shale	70.1	598.1



BH-19 (WCG-19)

XY Location: BH-19 (WCG-19): (2.72771e+06, 270288)

Layer #	Type	Thickness [ft]	Elevation [ft]
1	Silty Sand/Clay	16	628
2	Weathered Shale	14	612
3	Unweathered Shale	70	598



Soil Properties

Property	Silty Sand/Clay	Weathered Shale	Unweathered Shale
Color			
Unit Weight [kips/ft3]	0.128	0.124	0.155
K0	1	1	1
Primary Consolidation	Enabled	Enabled	Enabled
Material Type	Non-Linear	Non-Linear	Non-Linear
Cc	0.019	0.108	0.013
Cr	0.003	0.018	0.006
e0	0.63	0.56	0.17
Pc [ksf]	3	8	8.5
Undrained Su A [kips/ft2]	0	0	0
Undrained Su S	0.2	0.2	0.2
Undrained Su m	0.8	0.8	0.8

Borehole	Designation	Easting	Northing	Exacavation/topo Grade	Weathered Shale	Unweathered Shale	Bottom of Borehole	Silty Sand/Clay	Weathered Shale Depth	Unweathered Shale Depth
BH-1	PWCG-1	2726430.1590	273402.6090	629.8	616.8	589.8	529.8	13	27	60
BH-2	PWCG-2	2728116.7090	273111.0495	633.8	605.8	587.8	533.8	28	18	54
BH-3	PWCG-3	2728491.6620	272212.6947	635.3	612.3	595.3	535.3	23	17	60
BH-4	PWCG-4	2728842.5120	271315.2124	642.8	623.8	598.8	542.8	19	25	56
BH-5	PWCG-5	2728813.7790	270318.5801	637.7	617.7	592.7	537.7	20	25	55
BH-6	PWCG-6	2727057.6150	270250.0888	612.3	599.3	579.3	512.3	13	20	67
BH-7	WCG-7	2727466.2950	273181.0580	628.1	613.1	588.1	528.1	15	25	60
BH-8	WCG-8	2727494.9270	272597.9954	626.5	606.1	586.1	526.5	20.4	20	59.6
BH-9	WCG-9	2726462.7400	272172.1772	626.0	626	606.6	526	0	19.4	80.6
BH-10	WCG-10	2727505.6000	272168.2738	625.0	613.7	597.7	525	11.3	16	72.7
BH-11	WCG-11	2728056.9170	272183.9107	634.2	615.0	601.0	534.2	19.2	14	66.8
BH-12	WCG-12	2727625.7180	271740.1783	622.7	612.5	596.5	522.7	10.2	16	73.8
BH-13	WCG-13	2728147.6500	271749.3322	632.7	615.8	601.8	532.7	16.9	14	69.1
BH-14	WCG-14	2726487.8000	271301.9742	626.0	613.6	600.1	526	12.4	13.5	74.1
BH-15	WCG-15	2727693.7110	271295.4115	624.1	605.8	590.8	524.1	18.3	15	66.7
BH-16	WCG-16	2728344.3160	271299.5249	634.6	619.1	600.1	534.6	15.5	19	65.5
BH-17	WCG-17	2727698.1310	270830.4497	621.5	609.5	605.5	521.5	12	4	84
BH-18	WCG-18	2728342.9940	270842.2674	632.7	623.8	602.8	532.7	8.9	21	70.1
BH-19	WCG-19	2727710.2230	270287.8099	620.3	604.3	590.3	520.3	16	14	70

Layer	C_c	C_r	e_0	Unit Wieght (k/ft^3)	P_c (Psf)
Silty Sand/Clay	0.019	0.003	0.63	0.128	3000
Weathered Shale	0.108	0.018	0.56	0.124	8000
Unweathered Shale	0.013	0.006	0.17	0.155	8500

Transfer to 628 ft

Borehole	Designation	Easting	Northing	Tranferred Grade to 628	Weathered Shale	Unweathered Shale	Bottom of Borehole	Silty Sand/Clay	Weathered Shale Depth	Unweathered Shale Depth
BH-1	PWCG-1	2726430.1590	273402.6090	628	615	588	528	13	27	60
BH-2	PWCG-2	2728116.7090	273111.0495	628	600	582	528	28	18	54
BH-3	PWCG-3	2728491.6620	272212.6947	628	605	588	528	23	17	60
BH-4	PWCG-4	2728842.5120	271315.2124	628	609	584	528	19	25	56
BH-5	PWCG-5	2728813.7790	270318.5801	628	608	583	528	20	25	55
BH-6	PWCG-6	2727057.6150	270250.0888	628	615	595	528	13	20	67
BH-7	WCG-7	2727466.2950	273181.0580	628	613	588	528	15	25	60
BH-8	WCG-8	2727494.9270	272597.9954	628	607.6	587.6	528	20.4	20	59.6
BH-9	WCG-9	2726462.7400	272172.1772	628	628	608.6	528	0	19.4	80.6
BH-10	WCG-10	2727505.6000	272168.2738	628	616.7	600.7	528	11.3	16	72.7
BH-11	WCG-11	2728056.9170	272183.9107	628	608.8	594.8	528	19.2	14	66.8
BH-12	WCG-12	2727625.7180	271740.1783	628	617.8	601.8	528	10.2	16	73.8
BH-13	WCG-13	2728147.6500	271749.3322	628	611.1	597.1	528	16.9	14	69.1
BH-14	WCG-14	2726487.8000	271301.9742	628	615.6	602.1	528	12.4	13.5	74.1
BH-15	WCG-15	2727693.7110	271295.4115	628	609.7	594.7	528	18.3	15	66.7
BH-16	WCG-16	2728344.3160	271299.5249	628	612.5	593.5	528	15.5	19	65.5

Polygon 1			
Point	x	y	Adjusted Height
L-1	2727191.622	272745.6106	9.3383
L-2	2727200.309	272000.0000	11.7419
L-13	2727337.359	272000.0000	51.2177
L-23	2727457.395	272000.0000	93.1985
L-33	2727577.43	272000.0000	139.6410
L-43	2727697.465	272000.0000	191.6174
L-42	2727691.575	272242.5989	190.0122
L-32	2727568.741	272357.8259	141.2992
L-22	2727445.908	272473.0529	92.5884
L-12	2727323.075	272588.2799	47.7733
L-1	2727191.622	272745.6106	9.3383

Polygon 2			
Point	x	y	Adjusted Height
L-2	2727200.309	272000.0000	11.7419
L-3	2727208.997	271275.6980	12.0129
L-14	2727355.017	271272.8323	53.8347
L-24	2727475.099	271270.8901	96.1337
L-34	2727595.165	271269.6367	142.8301
L-44	2727715.223	271268.7002	195.0585
L-43	2727697.465	272000.0000	191.6174
L-33	2727577.43	272000.0000	139.6410
L-23	2727457.395	272000.0000	93.1985
L-13	2727337.359	272000.0000	51.2177
L-2	2727200.309	272000.0000	11.7419

Polygon 3			
Point	x	y	Adjusted Height
L-3	2727208.997	271275.6980	12.0129
L-4	2727216.591	270544.8309	11.1976
L-15	2727370.706	270626.7020	55.8842
L-25	2727487.685	270752.5770	96.7371
L-35	2727604.79	270873.2351	149.2729
L-45	2727722.173	270982.4708	196.0299
L-44	2727715.223	271268.7002	195.0585
L-34	2727595.165	271269.6367	142.8301
L-24	2727475.099	271270.8901	96.1337
L-14	2727355.017	271272.8323	53.8347
L-3	2727208.997	271275.6980	12.0129

Polygon 4			
Point	x	y	Adjusted Height
L-4	2727216.591	270544.8309	11.1976
L-5	2727298.458	270475.2403	9.1389
L-6	2727918.928	270487.5326	10.2313
L-16	2727925.503	270605.9623	51.2842
L-26	2727931.045	270725.8442	89.8579
L-36	2727936.586	270845.7262	142.4061
L-46	2727936.893	270965.7668	194.0144
L-45	2727722.173	270982.4708	196.0299
L-35	2727604.79	270873.2351	149.2729
L-25	2727487.685	270752.5770	96.7371
L-15	2727370.706	270626.7020	55.8842
L-4	2727216.591	270544.8309	11.1976

Polygon 5			
Point	x	y	Adjusted Height
L-6	2727918.928	270487.5326	10.2313
L-7	2728637.942	270531.6732	9.8948
L-17	2728560.497	270623.4978	39.8805
L-27	2728442.323	270730.1720	77.4110
L-37	2728324.312	270846.3555	126.9979
L-47	2728169.705	270999.5209	190.3329
L-46	2727936.893	270965.7668	194.0144
L-36	2727936.586	270845.7262	142.4061
L-26	2727931.045	270725.8442	89.8579
L-16	2727925.503	270605.9623	51.2842
L-6	2727918.928	270487.5326	10.2313

Polygon 6			
Point	x	y	Adjusted Height
L-7	2728637.942	270531.6732	9.8948
L-8	2728642.98	271284.9346	11.3957
L-18	2728571.176	271276.0513	38.7997
L-28	2728451.399	271255.4135	80.4763
L-38	2728331.053	271236.4354	126.0399
L-48	2728172.49	271202.1438	191.6765
L-47	2728169.705	270999.5209	190.3329
L-37	2728324.312	270846.3555	126.9979
L-27	2728442.323	270730.1720	77.4110
L-17	2728560.497	270623.4978	39.8805
L-7	2728637.942	270531.6732	9.8948

Polygon 7			
Point	x	y	Adjusted Height
L-8	2728642.98	271284.9346	11.3957
L-9	2728445.746	271794.3317	12.5273
L-19	2728372.454	271768.2861	41.6531
L-29	2728263.323	271718.1392	81.0378
L-39	2728154.737	271665.6069	107.5591
L-49	2728016.186	271584.6833	173.7314
L-48	2728172.49	271202.1438	191.6765
L-38	2728331.053	271236.4354	126.0399
L-28	2728451.399	271255.4135	80.4763
L-18	2728571.176	271276.0513	38.7997
L-8	2728642.98	271284.9346	11.3957

Polygon 8			
Point	x	y	Adjusted Height
L-9	2728445.746	271794.3317	12.5273
L-10	2728271.262	272205.9648	12.0899
L-20	2728188.53	272169.5169	38.3727
L-30	2728044.332	272103.3423	80.9126
L-40	2727939.178	272050.2768	126.3981
L-50	2727831.407	272003.0367	190.1454
L-49	2728016.186	271584.6833	173.7314
L-39	2728154.737	271665.6069	107.5591
L-29	2728263.323	271718.1392	81.0378
L-19	2728372.454	271768.2861	41.6531
L-9	2728445.746	271794.3317	12.5273

Polygon 9			
Point	x	y	Adjusted Height
L-10	2728271.262	272205.9648	12.0899
L-11	2728031.135	272756.6273	8.1226
L-21	2727943.442	272607.7798	42.6547
L-31	2727865.126	272486.2876	86.3588
L-41	2727795.517	272365.2258	139.0382
L-51	2727721.555	272243.9488	189.7030
L-50	2727831.407	272003.0367	190.1454
L-40	2727939.178	272050.2768	126.3981
L-30	2728044.332	272103.3423	80.9126
L-20	2728188.53	272169.5169	38.3727
L-10	2728271.262	272205.9648	12.0899

Polygon 10			
Point	x	y	Adjusted Height
L-1	2727191.622	272745.6106	9.3383
L-12	2727323.075	272588.2799	47.7733
L-22	2727445.908	272473.0529	92.5884
L-32	2727568.741	272357.8259	141.2992
L-42	2727691.575	272242.5989	190.0122
L-51	2727721.555	272243.9488	189.7030
L-41	2727795.517	272365.2258	139.0382
L-31	2727865.126	272486.2876	86.3588
L-21	2727943.442	272607.7798	42.6547
L-11	2728031.135	272756.6273	8.1226
L-1	2727191.622	272745.6106	9.3383

Polygon 11			
Point	x	y	Adjusted Height
L-43	2727697.465	272000.0000	191.6174
L-44	2727715.223	271268.7002	195.0585
L-45	2727722.173	270982.4708	196.0299
L-55	2727917.763	271166.5308	216.7461
L-54	2727911.702	271416.1455	191.7278
L-53	2727853.354	271554.7329	186.3740
L-52	2727767.578	272000.0000	195.0735
L-43	2727697.465	272000.0000	191.6174

Polygon 12			
Point	x	y	Adjusted Height
L-45	2727722.173	270982.4708	196.0299
L-46	2727936.893	270965.7668	194.0144
L-47	2728169.705	270999.5209	190.3329
L-48	2728172.49	271202.1438	191.6765
L-56	2728009.976	271176.9147	215.6682
L-55	2727917.763	271166.5308	216.7461
L-45	2727722.173	270982.4708	196.0299

Polygon 13			
Point	x	y	Adjusted Height
L-53	2727853.354	271554.7329	186.3740
L-54	2727911.702	271416.1455	191.7278
L-55	2727917.763	271166.5308	216.7461
L-56	2728009.976	271176.9147	215.6682
L-48	2728172.49	271202.1438	191.6765
L-49	2728016.186	271584.6833	173.7314
L-53	2727853.354	271554.7329	186.3740

Polygon 14			
Point	x	y	Adjusted Height
L-43	2727697.465	272000.0000	191.6174
L-52	2727767.578	272000.0000	195.0735
L-53	2727853.354	271554.7329	186.3740
L-49	2728016.186	271584.6833	173.7314
L-50	2727831.407	272003.0367	190.1454
L-51	2727721.555	272243.9488	189.7030
L-42	2727691.575	272242.5989	190.0122
L-43	2727697.465	272000.0000	191.6174

APPENDIX M-3B

FINAL COVER SYSTEM SETTLEMENT AND STRAIN ANALYSIS

Includes pages M-3B-1 through M-3B-12

Required: Determine the post-settlement slope of the final cover system and verify that the strain induced on the final cover due to settlement is within acceptable limits.

Method:

A. Estimate primary settlement of waste below the final cover system.
B. Estimate secondary settlement of waste below the final cover system.
C. Estimate total settlement of waste below the final cover system.
D. Verify that strain induced on the final cover due to settlement is within acceptable limits.

Description of Contents:

- Sheets M-3B-3 thru M-3B-8 present example calculations.
- Table 1 presents the final cover settlement point parameters. and analysis results.
- Table 2 presents the strain calculations along the evaluation lines.
- Sheet M-3B-9 presents the analysis conclusions.
- Sheet M-3B-12 provides the final cover analysis points and evaluation lines supporting the strain calculations.

References:

1. Sowers, George F., Settlement of Solid Waste, *Proceedings of the Eighth International Conference on Soil Mechanics and Foundations Engineering, 1973* .
2. Quian, Xuede, R.M. Koerner, D. H. Gray, Geotechnical Aspects of Landfill Design and Construction, Prentice-Hall, Inc., New Jersey, 2002.
3. Koerner, Robert M., Designing with Geosynthetics, Third Edition. Prentice-Hall, New Jersey, 1994.
4. Acar, Yalcin B. & Daniel, David E., *Geoenvironment 2000 Characterization, Containment, Remediation, and Performance in Environmental Geotechnics,* Volume 2, American Society of Civil Engineers, 1995.
5. Zornberg, Jorge G., et al., *Retention of Free Liquids in Landfills Undergoing* Vertical Expansion, Journal of Geotechnical and Geoenvironmental Engineering, July 1999.
6. Fassett, Jeffrey B., et al., Geotechnical Properties of Municipal Solid Wastes and Their Use in Landfill Design, Waste Tech, 1994.
7. SETTLE3, Version 5.009, Copyright 2008-2021, Rockscience Inc.
8. Beggs, Ian D. et al, Assessment of Maximum Allowable Strains in Polyethylene and Polypropylene Geomembranes, Geo-Frontiers Congress, Austin, TX, 2005.

Solution:

A) Estimate primary settlement of waste below the final cover system.

MSW will undergo primary consolidation due to its own weight, final cover, equipment, etc. Primary consolidation occurs quickly, generally within the first month after loading. Therefore, the weight of the final cover system is the only remaining factor that contributes to primary consolidation. In addition, by the time the construction of the final cover is complete, settlement of the waste due to the weight of the final cover will be complete.

Primary settlement is calculated using the following equation:

$$S_p = \frac{H_o C_c}{1+e_o} \log\left(\frac{\sigma'_o + \Delta\sigma}{\sigma'_o}\right)$$

S_p = primary settlement, ft
H_o = waste thickness below the final cover system, ft
C_c = compression index
e_o = void ratio of the waste layer below final cover before settlement (i.e., before final cover placement)
$\Delta\sigma$ = change in loading/increase in overburden pressure, psf
σ'_o = overburden pressure acting at mid-height of refuse below the final cover, psf

For this site assume: C_c = 0.35 x e_o (Ref. 1, p. 210)

The compression index is a function of the void ratio. The compression index can range from C_c=0.15e_o to C_c=0.55e_o for fills that are low and high in organic content, respectively. An average compression index value was chosen because it is consistent with the types of waste accepted in the past. It is also representative of the minimal amount of settlement the site has experienced.

The average void ratio of waste below the final cover is estimated by determining the void ratio at the midpoint of the waste column below the final cover system. The void ratio is calculated for each settlement evaluation point using the following equation.

$e_o = 1.86 - 0.00102\ \sigma'_o$ (Ref. 5, p. 590)

where: σ'_o = overburden pressure in kPa

$\sigma'_o = 0.5\ \gamma_{msw}\ H_o$
$\Delta\sigma = \gamma_{cov}\ T_c$
γ_{msw} = unit weight of waste below the final cover system, pcf
γ_{cov} = unit weight of cover, pcf
T_c = thickness of final cover system, ft

Parameters:

γ_{cov} =	120	pcf
T_c =	3	feet (See Note 1, below)
γ_{msw} =	varies (see Note 2, below)	

Notes: 1. Tc value includes protective and final cover soils, intermediate cover, and grading soils
2. The value γ_{msw} is selected based on the midpoint of the waste thicknesses below the final cover system using the Unit Weight Profile for Waste/Daily Cover within an MSW Landfill chart developed from Ref. 4.

Example Calculations:

A) Estimate primary settlement of waste below the final cover system.

The settlement points analyzed are shown on Sheet M-3B-12. An example calculation of the estimated primary settlement is shown below for Evaluation Points FC10 and FC11. The estimated primary settlement for all evaluation points is shown in Table 1.

At Evaluation Point FC10:

Top of Final Cover Elevation (ft-msl)=	733.0	
Bottom of Waste Elevation (ft-msl)=	633.6	
H_o =	96.4	ft
γ_{msw} =	56.0	pcf

$\sigma'_o = 0.5\ \gamma_{msw}\ H_o$

σ'_o =	2699.8	psf
σ'_o =	129.3	kPa

$e_o = 1.86 - 0.00102\ \sigma'_o$

e_o = 1.73

$C_c = 0.35\ e_o$
$C_c =$ 0.60

$\Delta\sigma =$ 360.0 psf

$$S_p = \frac{96.4 \times 0.6}{1 + 1.73} \log\left(\frac{2699.8 + 360}{2699.8}\right)$$

$S_p =$ 1.2 ft

At Evaluation Point FC11:

Top of Final Cover Elevation (ft-msl)= 650.0
Bottom of Waste Elevation (ft-msl)= 642.5
$H_o =$ 4.5 ft
$\gamma_{msw} =$ 42.0 pcf

$\sigma'_o = 0.5\ \gamma_{msw}\ H_o$
$\sigma'_o =$ 95.2 psf
$\sigma'_o =$ 4.6 kPa

$e_o = 1.86 - 0.00102\ \sigma'_o$
$e_o =$ 1.86

$C_c = 0.35\ e_o$
$C_c =$ 0.65

$\Delta\sigma =$ 360.0 psf

$$S_p = \frac{4.5 \times 0.65}{1 + 1.86} \log\left(\frac{95.2 + 360}{95.2}\right)$$

$S_p =$ 0.7 ft

B) Estimate secondary settlement of waste below the final cover system.

Secondary consolidation continues at substantial rates for periods of time well beyond primary settlement. It is a combination of mechanical secondary compression, physico-chemical reaction, and bio-chemical decay. The settlement-log time relationship is similar to secondary compression of soils and can be expressed by:

$$S_c = \frac{H'_o\ \alpha}{1 + e'_o} \log\ (t_2/t_1)$$ (Ref. 2, p. 451)

Parameters:

S_c = secondary settlement, ft
α = secondary compression index
e'_o = void ratio of the waste layer below the final cover after primary settlement has occurred due to the final cover
H'_o = waste thickness below the final cover system after settlement, ft
t_1 = starting time of secondary settlement in years
t_2 = time at which settlement is determined in years

For this site assume: α = 0.03 x e'_o (Ref. 1, p. 210)

As reported by Sowers (Ref. 1), the secondary compression index is used to estimate waste decomposition. The secondary compression index ranges from $\alpha = 0.03e'_o$ to $\alpha = 0.09e'_o$ for conditions that are unfavorable and favorable to decay, respectively. An average secondary compression index value was chosen because it is consistent with the types of waste accepted in the past. It is also representative of the minimal amount of settlement the site has experienced.

The void ratio of the waste below the final cover at closure is a function of the overburden pressure caused by placement of the final cover system. The void ratio is calculated for each settlement evaluation point using the following equation.

$$e'_o = 1.86 - 0.00102\ \sigma''_o$$ (Ref. 5, p. 590)

where: σ''_o = overburden pressure in kPa

$\sigma''_o = 0.5\ \gamma'_{msw}\ H'_o$
γ'_{msw} = unit weight of waste below the final cover after primary settlement has occurred, pcf

For this site, the void ratio after primary settlement for the waste/cover soils below the final cover system varies between 1.5 to 1.9. Therefore, the secondary compression index will range between 0.09 to 0.11. Most literature sources report the secondary compression index in terms of the "modified secondary compression index" (Refs. 2, 6). The modified secondary compression index is defined by the following equation:

$$C'_\alpha = \frac{\alpha}{1 + e'_o}$$

The secondary compression index calculated for this site translates to a modified secondary compression index of 0.03 to 0.04 (for a void ratio of 1.5 to 1.9). These values are consistent with reported values for the modified secondary compression index which vary from 0.03 to 0.1 (Refs. 2, 6).

Time frame used for this analysis:

t_1 =	0.083	years
t_2 =	30.0	years (postclosure period)

An example calculation of the estimated secondary settlement using the above secondary settlement period is shown below for Evaluation Points FC10 and FC11. The estimated secondary settlement for all evaluation points is shown in Table 1.

At Evaluation Point FC10:

$H'_o = H_o - S_p$

H_o' = 95.2 ft

$\sigma''_o = 0.5\ \gamma'_{msw}\ H'_o$

γ'_{msw} = 56.0 pcf

σ''_o = 2666.2 psf

σ''_o = 127.7 kPa

$e'_o = 1.86 - 0.00102\ \sigma''_o$

e'_o = 1.73

$\alpha = 0.03\ e'_o$

α = 0.05

$$S_c = \frac{H'_o\ \alpha}{1 + e'_o} \log\ (t_2/t_1)$$

$$S_c = \frac{95.2 \times 0.05}{1 + 1.73} \log\left(\frac{30}{0.083}\right)$$

S_c = 4.6 ft

At Evaluation Point FC11:

$H'_o = H_o - S_p$

$H_o' =$ 3.8 ft

$\sigma''_o = 0.5\ \gamma'_{msw}\ H'_o$

$\gamma'_{msw} =$ 42.0 pcf

$\sigma''_o =$ 80.5 psf

$\sigma''_o =$ 3.9 kPa

$e'_o = 1.86 - 0.00102\ \sigma''_o$

$e'_o =$ 1.86

$\alpha = 0.03\ e'_o$

$\alpha =$ 0.06

$$S_c = \frac{H'_o\ \alpha}{1 + e'_o} \log\ (t_2/t_1)$$

$$S_c = \frac{3.8 \times 0.06}{1 + 1.86} \log\left(\frac{30}{0.083}\right)$$

$S_c =$ 0.2 ft

C) Estimate total settlement of waste below the final cover system.

Total settlement is the combination of primary and secondary settlement. An example calculation of the estimated total settlement is shown below for Evaluation Points FC10 and FC11. The estimated total settlement for all evaluation points is shown in Table 1.

At Evaluation Point FC10:				
Thickness of waste column, ft =	96.4	Primary Settlement =	1.2	ft
		Secondary Settlement =	4.6	ft
		Total Settlement =	5.8	ft
At Evaluation Point FC11:				
Thickness of waste column, ft=	4.5	Primary Settlement =	0.7	ft
		Secondary Settlement =	0.2	ft
		Total Settlement =	0.9	ft

D) Verify that strain induced on the final cover due to settlement is within acceptable limits.

Determine the post-settlement slope of the final cover system and verify the strain induced on the geocomposite due to settlement is within acceptable limits.

Note that negative values indicate the components are in compression.

$$\text{Strain} = \frac{L_f - L_o}{L_o} x100$$

(Reference 2, Page 472)

L_f = Final distance between evaluation points after total settlement (ft)
L_o = Initial distance between evaluation points before total settlement (ft)

An example calculation of the estimated strain is shown below for Evaluation Points FC10 and FC11. The estimated strain for all evaluation points is shown in Table 2.

Evaluation Point FC10 to Evaluation Point FC11:

Initial Distance:

Evaluation Point FC10 Elev. =	733.0	ft-msl
Evaluation Point FC11 Elev. =	650.0	ft-msl
Plan View Distance=	335.4	ft
L_o=	345.5	ft

Total Settlement:

Total Settlement Point 10=	5.8	ft
Total Settlement Point 11=	0.9	ft

Final Distance (after settlement):

Evaluation Point 10 Elev. =	727.2	ft-msl
Evaluation Point 11 Elev. =	649.1	ft-msl
Plan View Distance=	335.4	ft
L_f=	344.3	ft

Strain= -0.33%

Conclusions:

Strain is acceptable.

- Compacted clay component of final cover has the smallest average allowable tensile strain value which is 0.5 percent (Reference 2, Page 469).
- The allowable tensile strain for an LDPE and LLDPE geomembrane is 8 to 12 percent (Reference 8).
- The allowable tensile strain for a drainage geocomposite is more than 20 percent for the geotextile (reference 3, page 112) and 200 percent for the geonet (reference 3, page 400).
- The maximum calculated strain (-0.33%) represents compression versus tensile strain and is acceptable, therefore the system will be stable. No tensile strain was observed in the analysis results.

TABLE 1. FINAL COVER EVALUATION - SETTLEMENT SUMMARY[2]

Evaluation Point[1]	Initial Top of Final Cover Elevation (ft-msl)	Initial Top of Waste Elevation (ft-msl)	Bottom of Waste Elevation (ft-msl)	H_o (ft)	γ_{msw} (pcf)	σ'_o (psf)	$\Delta\sigma$ (psf)	e_o	C_c	S_p (ft)	H'_o (ft)	γ'_{msw} (pcf)	σ''_o (psf)	e'_o	α	S_c (ft)	Total Settlement (ft)	Post-Settlement Top of Final Cover Elevation (ft-msl)
FC1	770.0	767.0	624.5	142.5	62.0	4,417.7	360.0	1.64	0.58	1.1	141.4	62.0	4,383.6	1.65	0.05	6.8	7.9	762.1
FC2	760.0	757.0	622.5	134.5	61.0	4,103.2	360.0	1.66	0.58	1.1	133.4	61.0	4,069.6	1.66	0.05	6.4	7.5	752.5
FC3	760.0	757.0	626.9	130.1	61.0	3,967.0	360.0	1.67	0.58	1.1	129.0	61.0	3,933.4	1.67	0.05	6.2	7.3	752.7
FC4	760.0	757.0	627.3	129.7	61.0	3,955.9	360.0	1.67	0.58	1.1	128.6	61.0	3,922.4	1.67	0.05	6.2	7.3	752.7
FC5	680.0	677.0	627.2	49.8	49.0	1,220.2	360.0	1.80	0.63	1.3	48.5	48.0	1,164.1	1.80	0.05	2.4	3.7	676.3
FC6	635.8	632.8	626.2	6.5	43.0	140.3	360.0	1.85	0.65	0.8	5.7	43.0	123.1	1.85	0.06	0.3	1.1	634.7
FC7	631.5	628.5	622.7	5.7	43.0	123.3	360.0	1.85	0.65	0.8	4.9	42.0	103.7	1.85	0.06	0.2	1.0	630.5
FC8	760.0	757.0	623.9	133.1	61.0	4,060.5	360.0	1.66	0.58	1.1	132.0	61.0	4,026.9	1.66	0.05	6.3	7.4	752.6
FC9	640.0	637.0	626.5	10.5	43.0	224.9	360.0	1.85	0.65	1.0	9.5	43.0	203.4	1.85	0.06	0.5	1.5	638.5
FC10	733.0	730.0	633.6	96.4	56.0	2,699.8	360.0	1.73	0.60	1.2	95.2	56.0	2,666.2	1.73	0.05	4.60	5.8	727.2
FC11	650.0	647.0	642.5	4.5	42.0	95.2	360.0	1.86	0.65	0.7	3.8	42.0	80.5	1.86	0.06	0.20	0.9	649.1

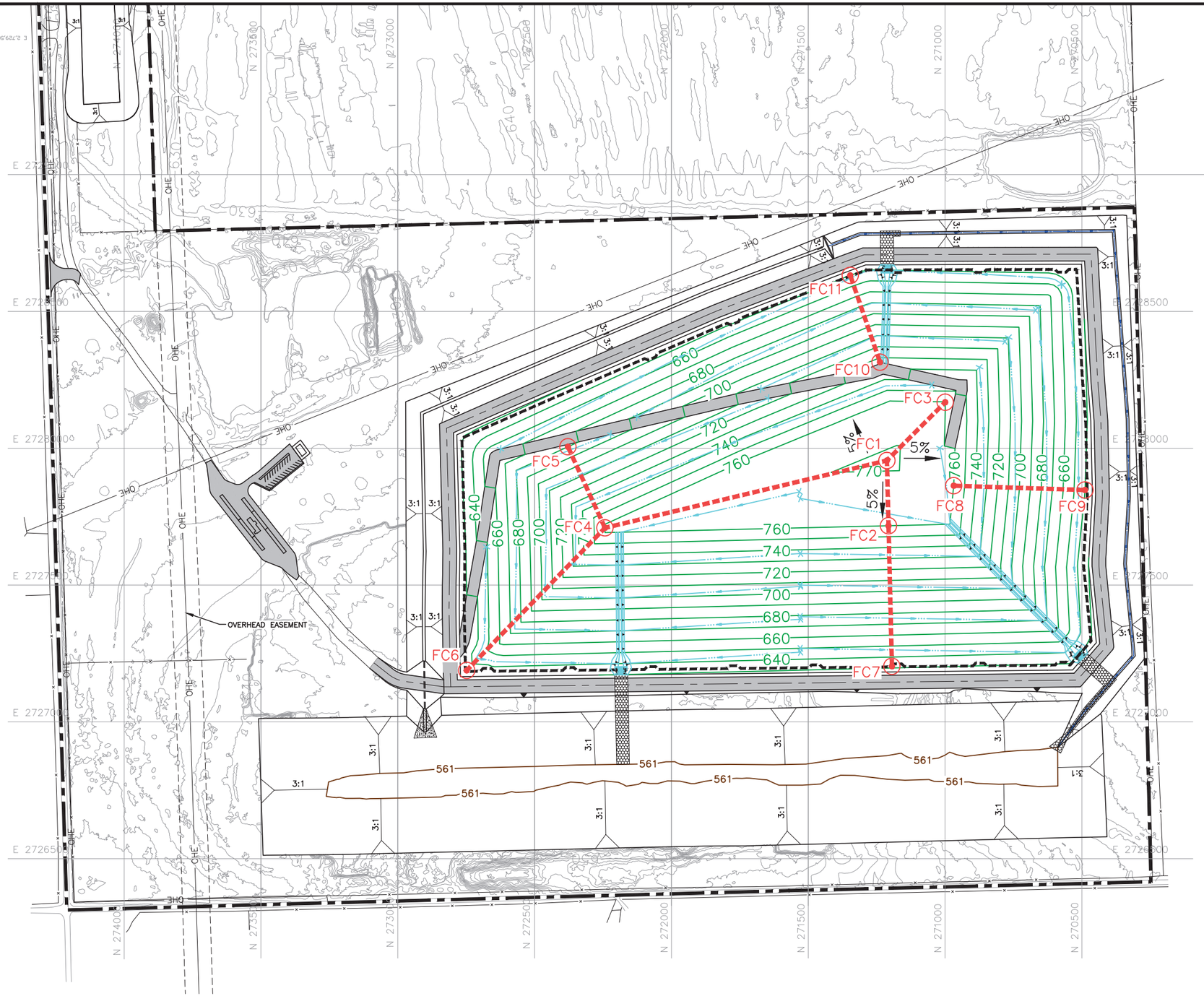
[1] Refer to Sheet M-3B-12 for Evaluation Point locations (FC1 thru FC11).

[2] Settlement calculations in above table rounded to one significant figure.

TABLE 2. FINAL COVER EVALUATION - FINAL GRADES AND STRAIN SUMMARY

Evaluation Point[1]		Initial Top of Final Cover Elevation (ft-msl)		Post-Settlement Top of Final Cover Elevation (ft-msl)		Plan View Distance (ft)	L_o (ft)	L_f (ft)	Initial Slope (ft/ft)	Post-Settlement Slope (ft/ft)	Tensile Strain (%)
A	B	A	B	A	B						
FC1	FC2	770.0	760.0	762.1	752.5	238.4	238.6	238.6	0.04	0.04	-0.01
FC1	FC3	770.0	760.0	762.1	752.7	301.0	301.1	301.1	0.03	0.03	-0.01
FC1	FC4	770.0	760.0	762.1	752.7	1,059.4	1,059.5	1,059.5	0.01	0.01	0.00
FC4	FC5	760.0	680.0	752.7	676.3	325.8	335.5	334.6	0.25	0.23	-0.25
FC4	FC6	760.0	635.8	752.7	634.7	725.7	736.2	735.2	0.17	0.16	-0.14
FC2	FC7	760.0	631.5	752.5	630.5	514.1	529.9	528.3	0.25	0.24	-0.29
FC8	FC9	760.0	640.0	752.6	638.5	480.0	494.8	493.4	0.25	0.24	-0.28
FC10	FC11	733.0	650.0	727.2	649.1	335.4	345.5	344.3	0.25	0.23	-0.33

[1] Refer to Sheet M-3B-12 for Evaluation Point locations. The "A" and "B" points represent the upgradient and downgradient endpoints, respectively.



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SCALE IN FEET

LEGEND

	PROPOSED PERMIT BOUNDARY
	PROPOSED LIMITS OF WASTE
N 273,000	STATE PLANE COORDINATE GRID
640	EXISTING CONTOUR
561	BORROW AREA CONTOUR
770	FINAL COVER CONTOUR
	PROPOSED DRAINAGE SWALE
	PROPOSED DRAINAGE CHUTE
	PROPOSED DRAINAGE CHANNEL
	RIPRAP/GABIONS
OHE	EXISTING OVERHEAD EASEMENT
FC2	FINAL COVER EVALUATION POINT
	FINAL COVER EVALUATION LINE

NOTES:

1. EXISTING CONTOURS AND ELEVATIONS PROVIDED BY HYDREX ENVIRONMENTAL COMPILED FROM AERIAL PHOTOGRAPHY FLOWN 01-25-2023.

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10/13/2023

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DESIGN BY: MB
REVIEWED BY: DEP

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PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION
SETTLE3 SETTLEMENT ANALYSIS
FINAL COVER ANALYSIS POINT PLAN

MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

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SHEET M-3B-12

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APPENDIX M-3C

HEAVE ANALYSIS

Includes pages M-3C-1 through M-3C-4

Required: Estimate the potential heave of the bottom of excavation resulting from the removal of overburden soils during liner construction.

Method: Heave will be analyzed for the proposed excavation at point HP-1 in Cell 19.

References:

1. Terzaghi, Karl and Peck, Ralph, Soil Mechanics in Engineering Principle, Third Edition, John Wiley and Sons, Inc, New York, 1996.
2. Das, Braja M., Principles of Geotechnical Engineering, Fourth Edition, PWS, Boston, 1998.
3. Day, Robert W., *Geotechnical Engineer's Portable Handbook*, McGraw-Hill, New York, 2000.
4. Dunn, I.S., Anderson, L.R., and Kiefer, F.W., Fundamentals of Geotechnical Analysis, 1st Edition, 1980.
5. Coduto, Donald P., Geotechnical Engineering Principles and Practices, 1999.
6. Acar, Yalcin B.& Daniel, David E., *Geoenvironment 2000 Characterization, Containment, Remediation, and Performance in Environmental Geotechnics,* Volume 2, American Society of Civil Engineers, 1995.

Foundation Heave Calculations

Estimate the potential heave of the excavation bottom in Cell 19.

Note: Evaluation location for the heave analysis is the shown as on Figure M-3C-4 (Heave Analysis Point 1)

Method: Excavation for liner construction will result in reduced overburden pressure on subgrade strata which may result in heave.

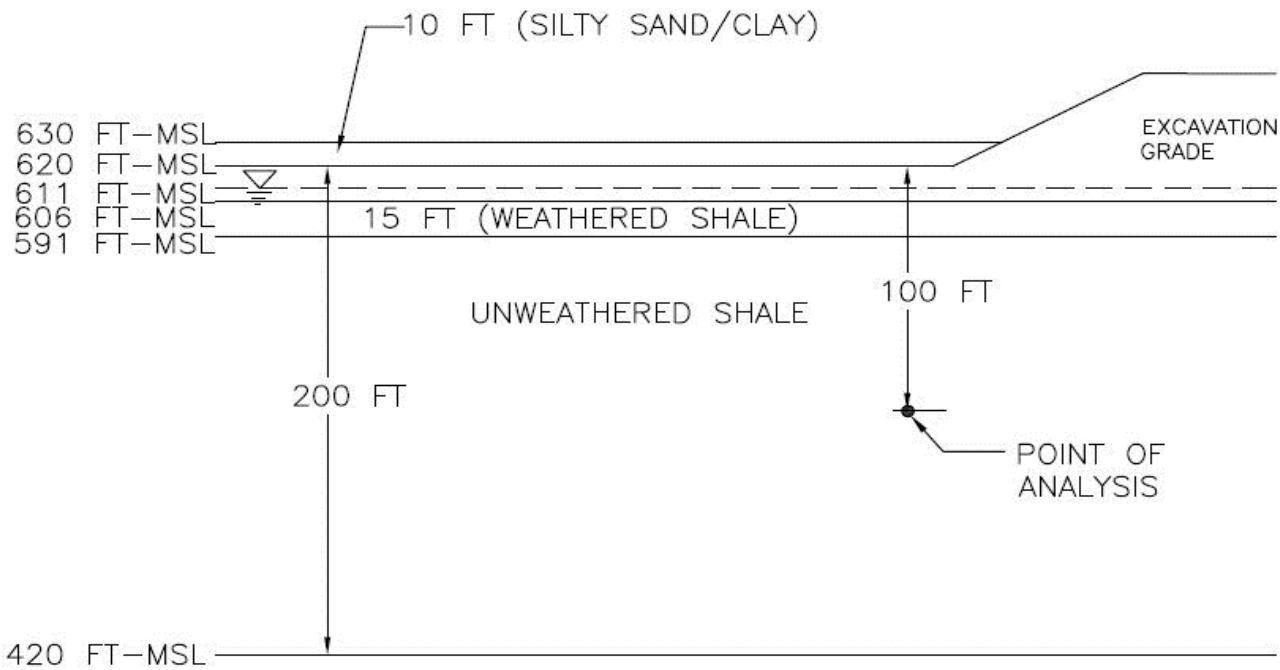
A. Select critical location for heave. The critical location is established as the location that has the estimated highest overburden pressure relief resulting from landfill excavation prior to liner installation. For this analysis it was assumed this point (HP-1) is in Cell 19.

B. Use unit weight values for the excavated soils and consolidation parameter values derived from available field and laboratory results presented in Appendix M-1.

C. Stratum elevations, thicknesses, and water table are shown on the below diagram.

Solution:

Diagram for Heave Analysis in Cell 19



Definition of Terms/Variables:

e_o = initial void ratio
γ_d = Dry Unit Weight (pcf)
γ_{moist} = Moist Unit Weight (pcf)
γ_{sat} = Saturated Unit Weight (pcf)
γ_w = Unit Weight of Water (pcf)
γ_{waste} = Unit Weight of Waste (pcf)
γ_I = Assumed Unit Weight Stratum I (pcf)
γ_{II} = Assumed Unit Weight Stratum II (pcf)
γ_{III} = Assumed Unit Weight Stratum III (pcf)
P_o = Initial Average Effective Overburden Pressure (psf)
P_c = Preconsolidation Pressure (psf) (pressure in excess of overburden pressure, assumed zero)
ΔP = Change in Vertical Pressure (psf)
D = depth of excavation
D_I = Overburden depth of Stratum I (ft)
D_{II} = Overburden depth of Stratum II (ft)
H_i = thickness of soil layer (Stratum II thickness analyzed for heave)
C_r = Recompression index (rebound portion of consolidation curve during unloading)
C_c = Compression Index

Based on the laboratory test results included in Appendix M-1, the material properties of the soil overburden material to be excavated during liner construction are shown in following table:

	e_0	γ_d (pcf)	γ_m (pcf)	γ_{sat} (pcf)	C_c	C_r
Stratum I (Silty Sand/Clay))	0.63		128	148	0.019	0.003
Stratum II (Weathered Shale)	0.56		124	146	0.108	0.018
Stratum III (Unweathered Shale)	0.17		155	163	0.013	0.006

[1]Average unit weight for four layers is used.

[2]Consolidation parameters are not needed for Stratum I as this analysis assumes stratum will be removed entirely from the landfill floor during excavations.

The following parameters were used for Stratum I, II and III heave calculations:

H_1 =	14	ft	C_r =	0.003	
H_2 =	15	ft	C_r =	0.018	
H_3 =	171	ft	C_r =	0.006	

Estimate Potential Maximum Heave of the Excavation Bottom

The change in loading is due to the excavation of overburden soils.

$\Delta P = (D_I - 9) * \gamma_{I,\,moist}$

D_I =	19	ft
D_{II} =	15	ft
D_{III} =	71	ft
ΔP =	1,280	psf

Using the standard consolidation theory:

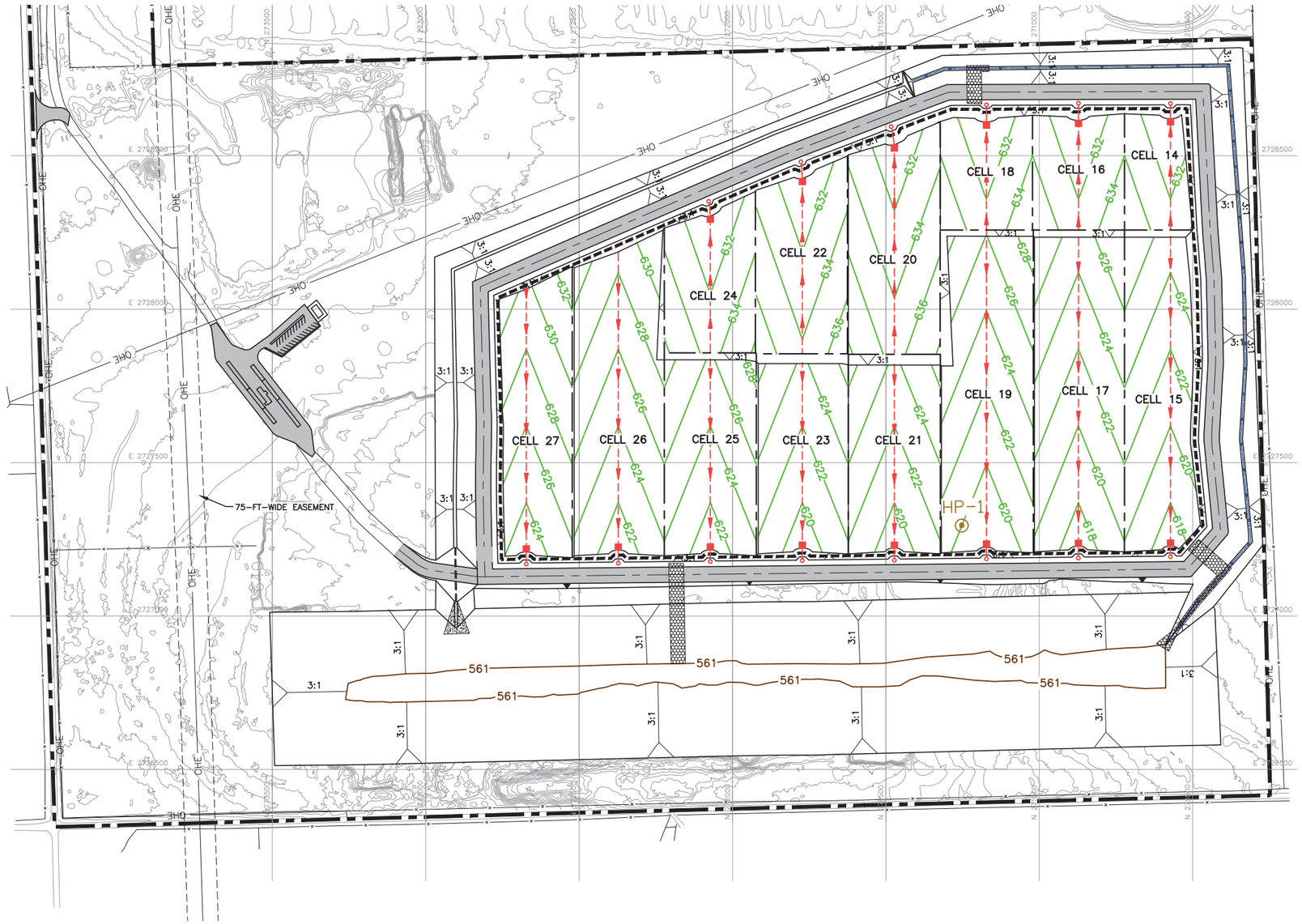
$S = C_r H_i \log((P_o - \Delta P) / P_o)$ (at midpoint of Stratum III)

$P_o = ((H_i/2-15-5-9)*(\gamma_{III(sat)} - \gamma_{(w)}) + 15' * (\gamma_{II(sat)} - \gamma_{(w)}) + 5*(\gamma_{I(sat)} - \gamma_{(w)} + 9*\gamma_{I(moist)} + \Delta P$

P_o =	11,256.60	psf
S =	-0.07	ft

Projected Heave[1] =	**-0.07**	**ft**	**or**	**-0.8**	**inches**

[1] Negative value represents heave or uplift of excavated foundation. Note that heave will be recovered during settlement of the cell. As the settlement analysis conservatively does not incorporate actual preconsolidation stresses on formation, the actual heave and settlement will be less than calculated.



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SCALE IN FEET

LEGEND

	PROPERTY BOUNDARY
	PERMIT BOUNDARY
	PERMITTED LIMITS OF WASTE
N 273000	STATE PLANE COORDINATE GRID
700	EXISTING CONTOUR
636	EXCAVATION CONTOUR
561	SOIL BORROW CONTOUR
	SECTOR BOUNDARY
	PROPOSED LEACHATE LINE
	PROPOSED LEACHATE SUMP
HP-1	HEAVE ANALYSIS POINT

NOTES:

1. EXISTING CONTOURS AND ELEVATIONS PROVIDED BY HYDREX ENVIRONMENTAL COMPILED FROM AERIAL PHOTOGRAPHY FLOWN 01-25-2023.

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DESIGN BY: MB
REVIEWED BY: DEP

Weaver Consultants Group
CA 3804 PE - 06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION
SETTLE3 SETTLEMENT ANALYSIS
HEAVE ANALYSIS POINT PLAN

MUSKOGEE COMMUNITY RDF
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O:\0086\364\EXPANSION 2022\APPENDIX M\M-3C-4 HEAVE.dwg, jpuhr, 1:2

MUSKOGEE COMMUNITY RECYCLING AND DISPOSAL FACILITY
MUSKOGEE COUNTY, OKLAHOMA
ODEQ PERMIT NO. 3551020

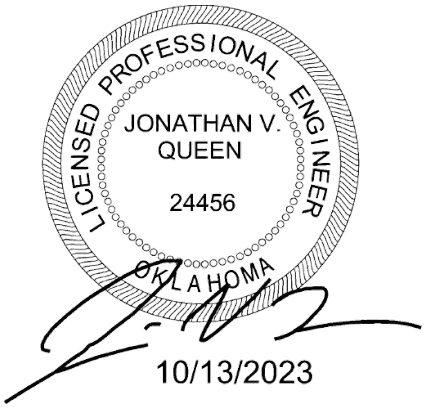
APPENDIX N

ALTERNATIVE LINER AND LEACHATE COLLECTION SYSTEM DESIGNS

Prepared for

Waste Management of Oklahoma, Inc.

October 2023



Prepared by

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WCG Project No. 0086-364-11-19

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2.2 Demonstration Methodology N-2
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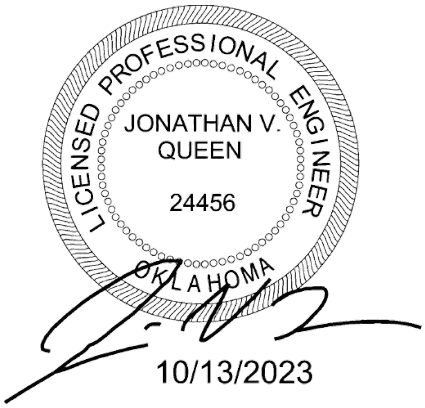
2.6 MULTIMED Model Results N-6

APPENDIX N-1
Figures

APPENDIX N-2
Alternative Liner System Modeling



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1 INTRODUCTION

This appendix provides the design and details for the alternative liner system which consists of replacing the top 1-foot-thick compacted clay component of the currently permitted composite liner system with a geosynthetic clay liner (GCL). The alternative liner, which includes a GCL component, will require a demonstration that shows that maximum concentration levels (MCLs) of the Appendix B constituents referenced in OAC 252:515-11-2(c) will not be exceeded at the relevant point of compliance (POC). This demonstration is made by calculating the Dilution Attenuation Factor (DAF) using MULTIMED. The DAF must be higher than 500 to ensure that the constituents of concern will not exceed the MCLs at the point of compliance. The demonstration is discussed in Section 2.

2 ALTERNATIVE LINER SYSTEM DESIGN DEMONSTRATION

2.1 Purpose

The purpose of this demonstration is to ensure the alternative liner design exceeds the requirements of OAC 252:515-11-2(c). The top of liner plan and excavation plan, as well as typical details of the alternative liner system, are provided in Appendix N-1. The slope stability of the alternative liner system is presented in Appendix M. Construction specifications are provided in Appendix K – QA/QC Plan for Liner and Leachate Collection System Installation and Testing. The following sections outline the demonstration methodology and results.

2.2 Demonstration Methodology

The demonstration was conducted by showing that the proposed liner system design would not allow Appendix B concentrations values to be exceeded at the relevant point of compliance. This is done by computing a Dilution Attenuation Factor (DAF), defined as the initial input leachate concentration, Co, divided by the concentration at the point of compliance, Cp:

The required DAF for each Appendix B constituent is found by dividing the input leachate concentration by the Appendix B MCLs. The input leachate concentrations are based on recommended input concentrations from USEPA's "Draft Background Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics: July 1988," and the Toxicity Characteristic Leaching Procedure (TCLP) in 40 CFR 261.24. The greater of the two values for each constituent were used as the recommended input concentration. Table 2-1 lists this data.

A single simulation can account for all 24 Appendix B constituents by assuming the constituents act as conservative tracers that do not experience carbon absorption, or chemical or biological decay. This very conservative assumption discounts natural physical processes that normally act to reduce chemical concentrations. The dilution required to meet ODEQ standards is a function of both the expected input leachate concentration and the Appendix B MCLs. Table 2-1 data show that arsenic is the most critical constituent because it has the highest DAF. In other words, trichloroethylene requires the most dilution in order to comply with Appendix B

MCLs. If the input leachate concentration is assumed to be 1, then the DAF at the POC becomes the reciprocal of the output concentration calculated by MULTIMED. The reciprocal of the MULTIMED result must then equal or exceed the most critical DAF to meet ODEQ requirements.

Table 2-1
ODEQ Appendix B Leachate Input Concentrations

Constituent	MCL (mg/L)	Recommended Input Concentration (mg/L)	Minimum Dilution Attenuation Factor
Arsenic	0.01	5.0	500.0
Barium	1.0	100.0	100.0
Benzene	0.005	1.08	216.0
Cadmium	0.01	1.0	100.0
Carbon tetrachloride	0.005	0.5	100.0
Chromium (hexavalent)	0.05	5.0	100.0
2,4-Dichlorophenoxy acetic acid	0.1	10.0	100.0
1,4-Dichlorobenzene	0.075	7.5	100.0
1,2-Dichloroehane	0.005	0.5	100.0
1,1-Dichloroethylene	0.007	0.7	100.0
Endrin	0.0002	0.05	250.0
Fluoride	4.0	302.0	75.5
Lindane	0.004	0.4	100.0
Lead	0.05	5.0	100.0
Mercury	0.002	0.2	100.0
Methoxychlor	0.1	10.0	100.0
Nitrate	10.0	Data Not Available	Data Not Available
Selenium	0.01	1.0	100.0
Silver	0.05	5.0	100.0
Toxaphene	0.005	0.5	100.0
1,1,1-Trichloromethane	0.2	13.0	65.0
Trichloroethylene	0.005	1.3	260.0
2,4,5-Trichlorophenoxy acetic acid	0.01	1.0	100.0
Vinyl Chloride	0.002	0.2	100.0

2.3 Estimating Percolation Through Liner

The Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3.07 was used to estimate the rate of percolation through the alternative liner system. The percolation rate was determined for various landfill configurations as discussed in Section 2.4. The HELP Model is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of the landfill. The model uses climate, soil, and landfill design data to perform a solution technique that accounts for the effects of surface storage, run-off, infiltration, percolation, soil moisture storage, evapotranspiration, and lateral drainage. The HELP modeling output is included in Appendix N-2-1. The percolation rates through the alternative liner as predicted by

the HELP model are used as input for the MULTIMED model as discussed in Section 2.5.2.

2.4 Landfill Configuration Analyzed

The top of liner plan and typical cross-sections that summarize the landfill configurations analyzed are provided in Appendix N-2-2A. The following two landfill configurations were modeled in the alternative liner design demonstration.

- Interim Landfill Configuration. This configuration includes the alternative liner system with 50 feet of waste placed above it. As shown in Appendix N-2-1 (page N-2-1-4), the interim case with 50 feet of waste above the alternative liner represents the worst-case scenario (i.e. the case that predicts the highest leachate percolation rate through the alternative liner system).

- Closed Landfill Configuration. This configuration includes the alternative liner system with 150 feet of waste placed above it and final cover installed. This configuration represents the final condition of the landfill with the thickest waste column above the alternative liner system.

HELP model results for all landfill configurations modeled are provided in Appendix N-2-1.

2.5 MULTIMED Model

MULTIMED Model Version 1.01 was used to assess contaminant fate and transport between the landfill base and the POC. MULTIMED was developed by the Athens Environmental Research Laboratory for the EPA. MULTIMED estimates the capacity of the hydrogeologic system modeled to dilute and attenuate contaminant concentrations. The model can be used to simulate the fate and transport processes in both the unsaturated and the saturated subsurface environments. In this application, only the saturated environment was modeled. This modeling is provided in Appendix N-2-2.

2.5.1 Site Geology and Hydrogeology

The geology and hydrogeology information used was obtained from Appendix E – Subsurface Investigation. Site-specific data was used as much as possible. Other values were obtained by selecting default values provided by the MULTIMED documentation.

2.5.2 MULTIMED Model Input Parameters

In general, environmentally conservative assumptions were made in determining the percolation rate and the dilution attenuation factor (DAF). A list of the major assumptions used in this demonstration is presented in Table 2-2. In addition, the table shows actual site conditions to provide a comparison with the assumptions made for modeling purposes. The criteria used to develop the percolation rate were selected to maximize the percolation. As a result, the DAF calculated for the landfill would be significantly larger if less conservative assumptions were used to develop the input parameters.

By making the assumptions listed in Table 2-2, a single MULTIMED simulation accounts for all 24 constituents identified by the EPA as requiring landfill design protection criteria because the constituent concentration at the POC is independent of chemical-specific properties. The model result is then expressed in terms of the DAF, which is defined as the ratio of the input concentration to the concentration at the POC. MULTIMED can be used to find the DAF by using an input concentration of 1.0 mg/L. The DAF is the reciprocal of the resulting concentration at the POC. The POC for this study is shown on Figure N-2-2A-1.

The required minimum DAFs for the 24 EPA constituents are given in Table 2-1. The largest DAF listed is 500. Therefore, if MULTIMED modeling results in a DAF higher than 500 for a generic chemical that is conservatively modeled with no carbon absorption, no chemical or biological decay, it can be concluded that the proposed liner system design is acceptable. The actual DAF for a specific chemical would be higher than the result calculated by MULTIMED under these circumstances, since real-world physical processes of carbon absorption would act to reduce chemical concentrations at the POC to less than those predicted by MULTIMED.

Table 2-2
Major Assumptions Used to Determine Model Input Parameters

Input Parameters	Assumption	Actual Site Condition
Unsaturated Zone Thickness	0	The unsaturated zone above the groundwater table is variable in thickness but is always greater than 5 feet (by rule). The attenuating effects of this zone have been conservatively ignored in this demonstration.
Organic Carbon Content	0	Organic carbon was assumed to be 0, although most subsurface formations are at least partly carbonaceous. The attenuating effects of carbon absorption have been conservatively ignored in this model.
Model Source Type	Steady State	A potential leachate release would typically be released as a pulse, not a steady-state continuous source.
Biodegradation	No biodegradation	Biodegradation is active in hydrogeologic environments.
Chemical Decay	No chemical decay	Chemical decay will occur with most contaminants.

2.6 MULTIMED Model Results

Modeling was performed using MULTIMED to evaluate the design of the alternative liner system by estimating constituent concentrations at the POC for (1) the interim landfill configuration with the highest predicted percolation rate calculated in HELP and (2) the closed landfill configuration. The constituent concentrations at the base of the landfill liner and at the POC were used to calculate the DAF. Per DEQ guidance information, the Appendix B MCLs must not be exceeded. This is equivalent to calculating a DAF of more than 500.

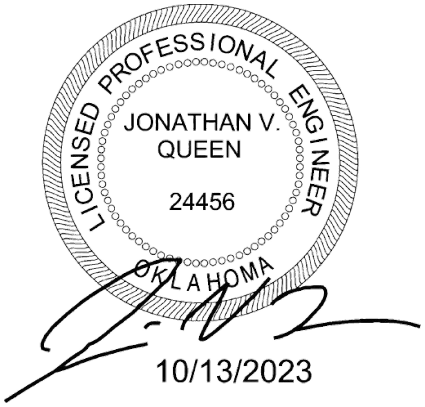
Table 2-3
MULTIMED Model Results for Alternative Liner Design Demonstration

Modeling Condition	Concentration at POC (mg/L)	DAF
Interim Condition (50 ft)	0.9478×10^{-4}	10,550
Closed Condition (150 ft)	0.1916×10^{-3}	5,219

The lowest calculated DAF is 5,219. The results demonstrate that the proposed liner system exceeds the requirements of OAC 252:515-11-2(c) because the DAF calculated is in excess of the 500 minimum criterion. The actual DAF is expected to be higher than the DAF predicted by this modeling investigation because the model input parameters were conservatively estimated as discussed in previous sections of this report.

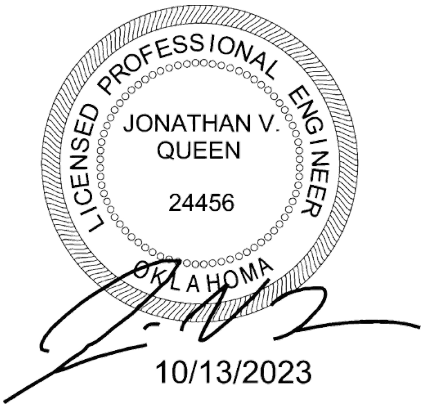
APPENDIX N-1

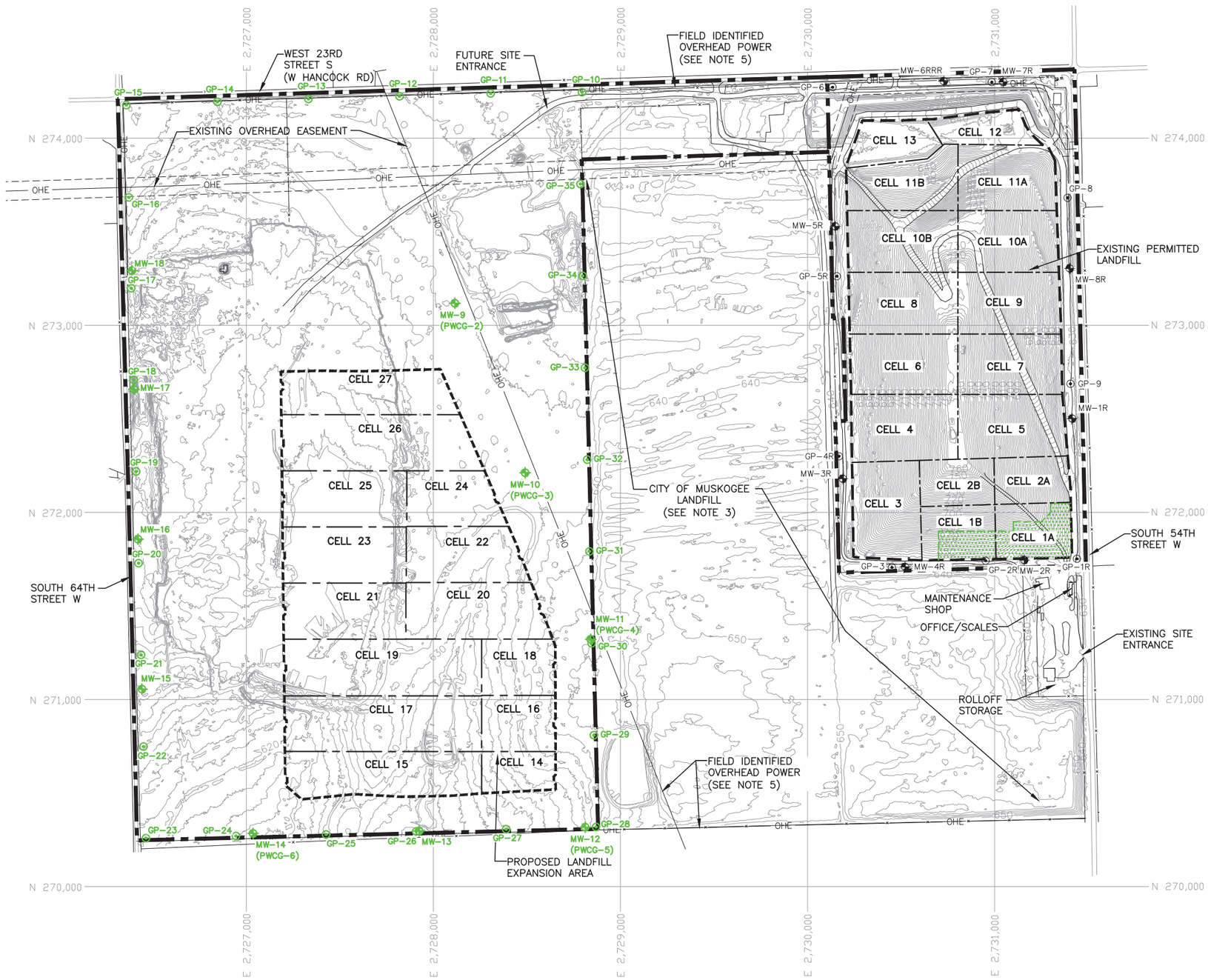
FIGURES

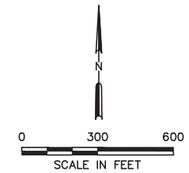


CONTENTS

Figure N-1-1 Site Plan
Figure N-1-2 Excavation Plan GCL Option
Figure N-1-3 Top of Liner Plan GCL Option
Figure N-1-4 Top of Leachate Collection Layer Plan GCL Option
Figure N-1-5 Liner System Details







LEGEND

- EXISTING PERMIT BOUNDARY
- PROPOSED PERMIT BOUNDARY
- PERMITTED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- N 273,000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- OHE — EXISTING OVERHEAD EASEMENT
- IN-PLACE FINAL COVER
- CELL BOUNDARY
- MW-5R — EXISTING GROUNDWATER MONITORING WELL
- MW-9 (PWCG-1) — PROPOSED GROUNDWATER MONITORING WELL
- GP-5 — EXISTING LANDFILL GAS MONITORING PROBE
- GP-10 — PROPOSED LANDFILL GAS MONITORING PROBE

NOTES:

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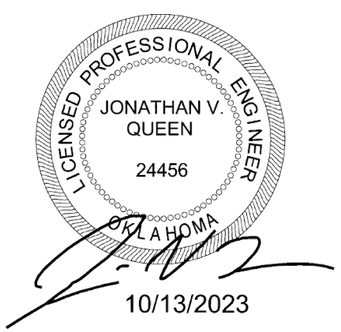

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FIGURE N-1-1

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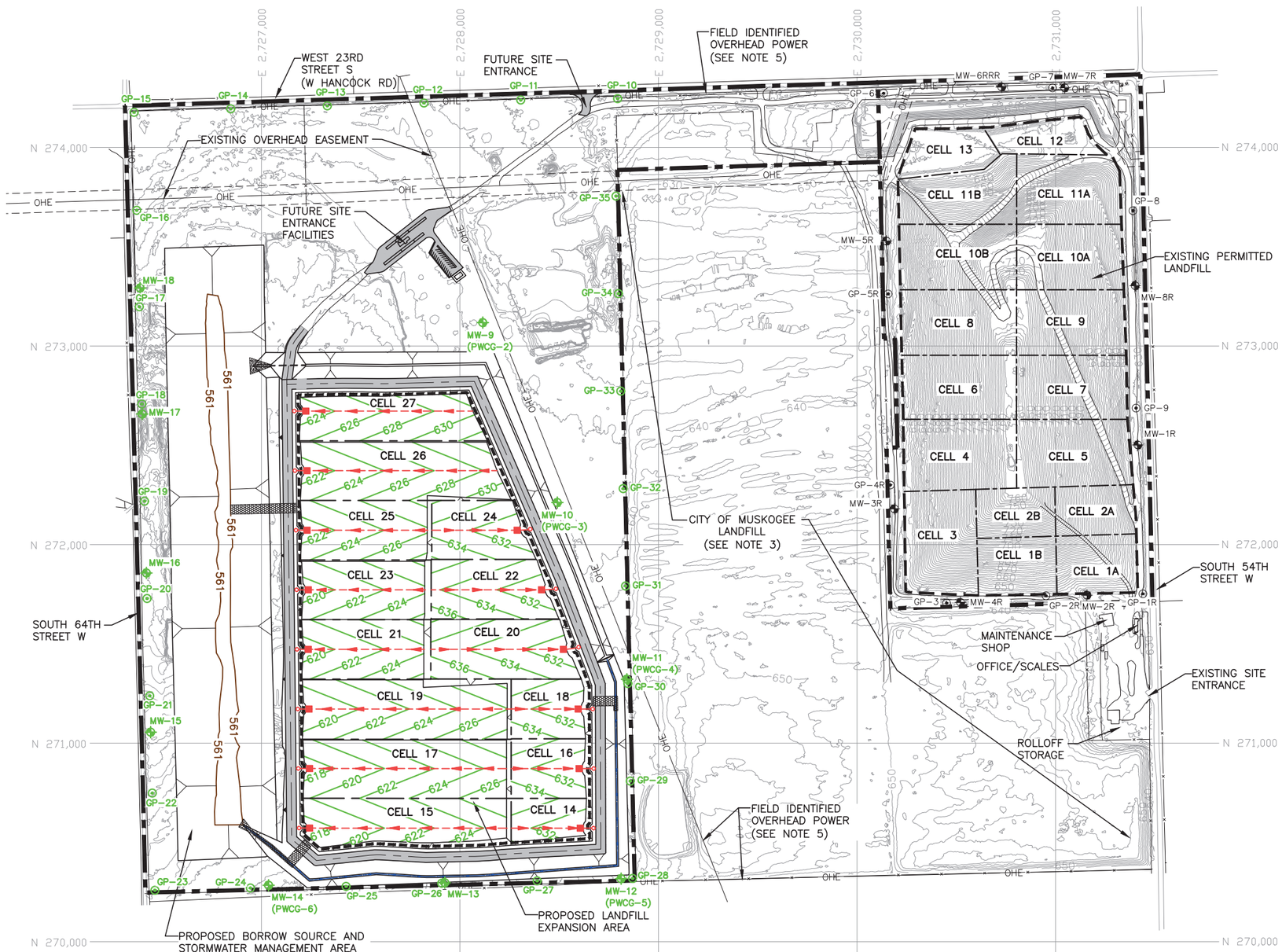

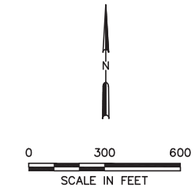

LEGEND

- EXISTING PERMIT BOUNDARY
- PROPOSED PERMIT BOUNDARY
- PERMITTED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- N 273,000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- 636 — EXCAVATION CONTOUR
- 561 — SOIL BORROW CONTOUR
- CELL BOUNDARY
- PROPOSED LEACHATE LINE
- PROPOSED LEACHATE SUMP
- PROPOSED LEACHATE CLEANOUT RISER
- PROPOSED DRAINAGE CHANNEL
- OHE — EXISTING OVERHEAD EASEMENT
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FIGURE N-1-2

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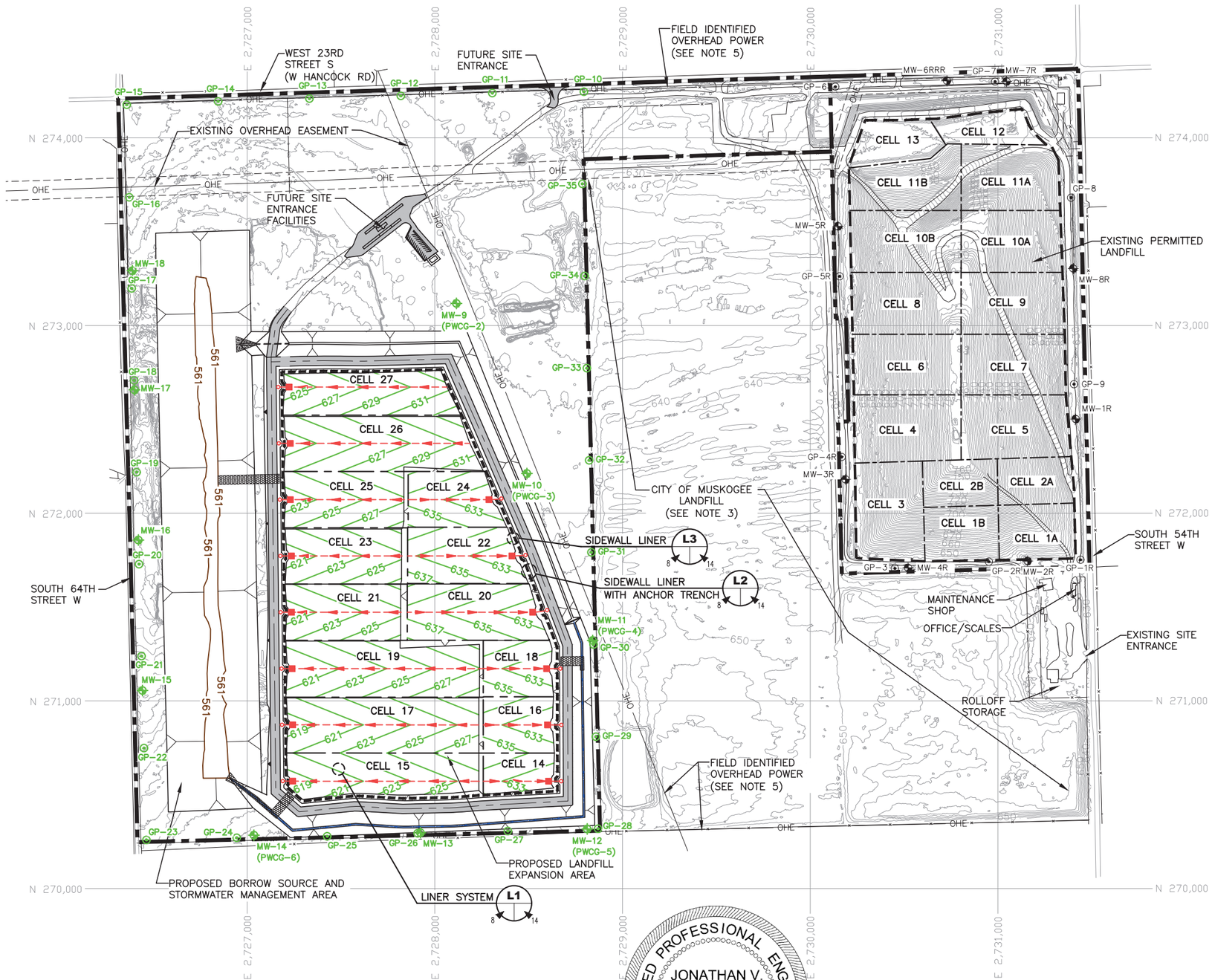

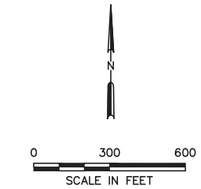

LEGEND

- EXISTING PERMIT BOUNDARY
- PROPOSED PERMIT BOUNDARY
- PERMITTED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- N 273,000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- 638 — TOP OF LINER CONTOUR
- 561 — SOIL BORROW CONTOUR
- CELL BOUNDARY
- PROPOSED LEACHATE LINE
- PROPOSED LEACHATE SUMP
- PROPOSED DRAINAGE CHANNEL
- OHE — EXISTING OVERHEAD EASEMENT
- MW-5R — EXISTING GROUNDWATER MONITORING WELL
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- GP-10 — PROPOSED LANDFILL GAS MONITORING PROBE

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FIGURE N-1-3

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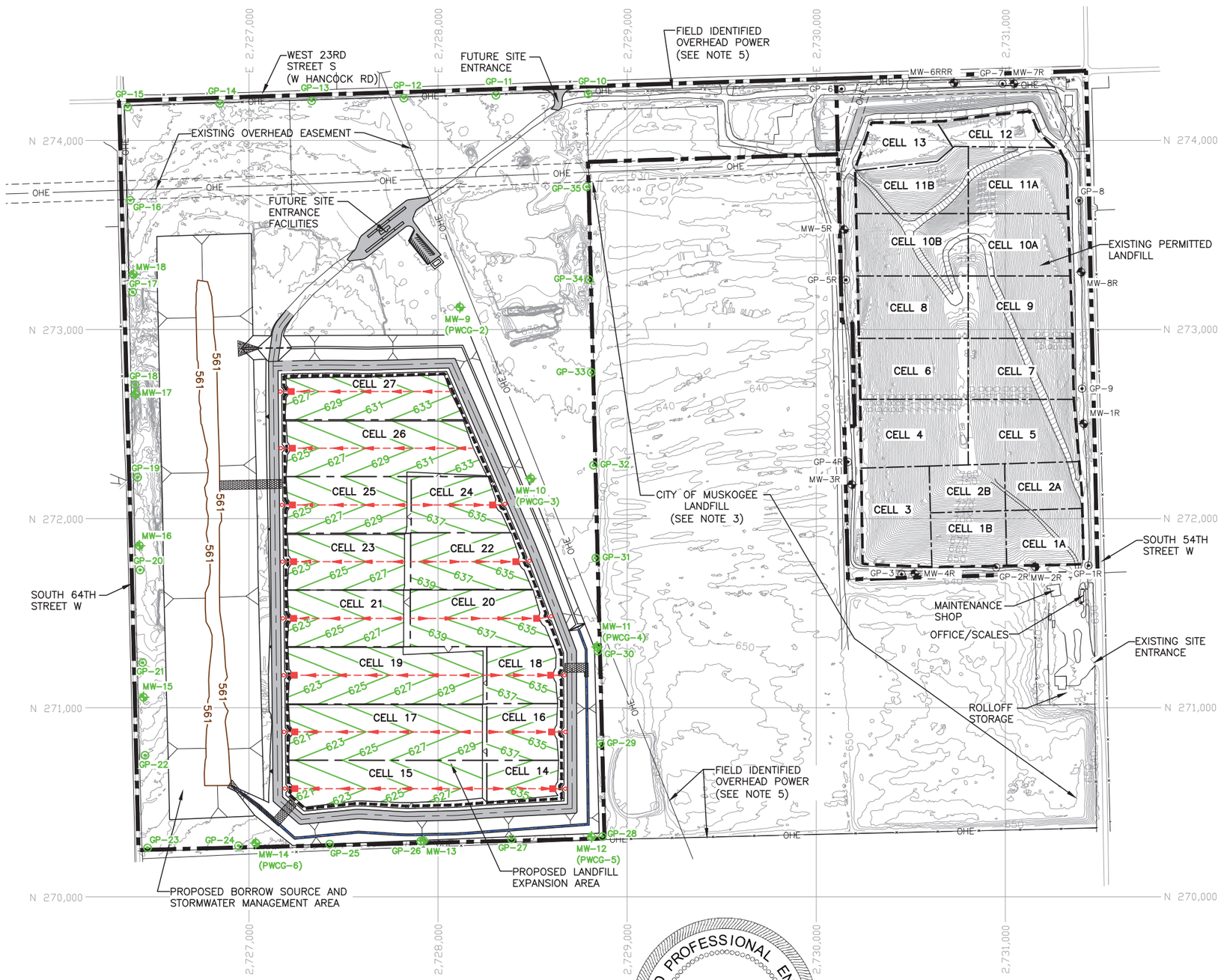

N

0 300 600
SCALE IN FEET

LEGEND

- EXISTING PERMIT BOUNDARY
- PROPOSED PERMIT BOUNDARY
- PERMITTED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- N 273,000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- 640 — TOP OF PROTECTIVE COVER CONTOUR
- 561 — SOIL BORROW CONTOUR
- CELL BOUNDARY
- PROPOSED LEACHATE LINE
- PROPOSED LEACHATE SUMP
- PROPOSED DRAINAGE CHANNEL
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FIGURE N-1-4

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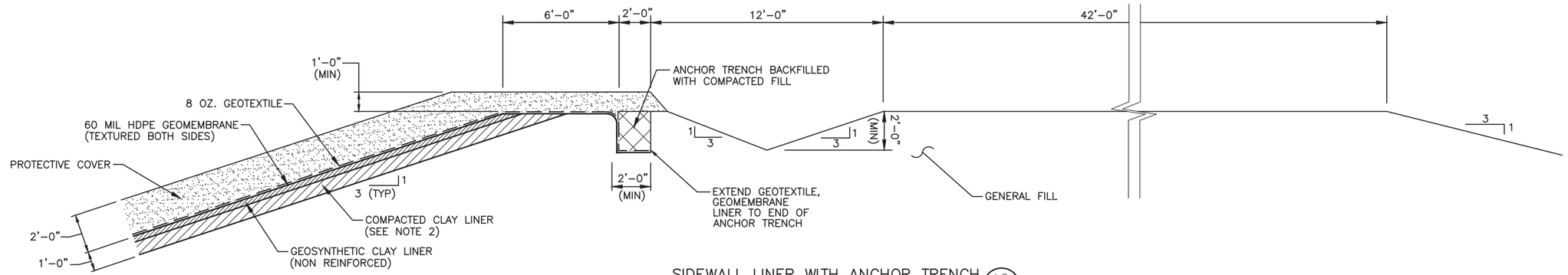

SIDEWALL LINER WITH ANCHOR TRENCH (L2)

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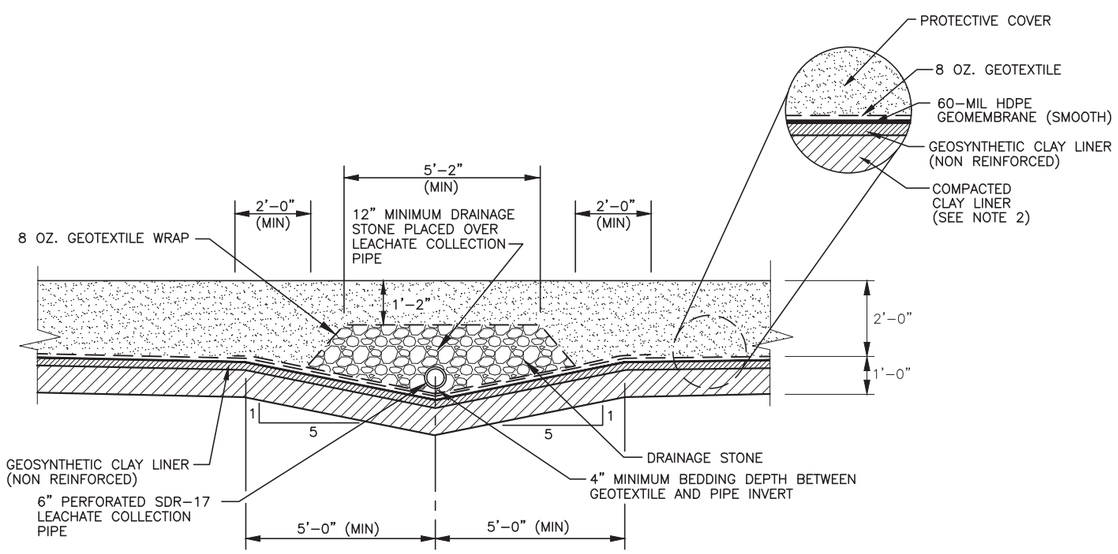

LINER SYSTEM (L1)

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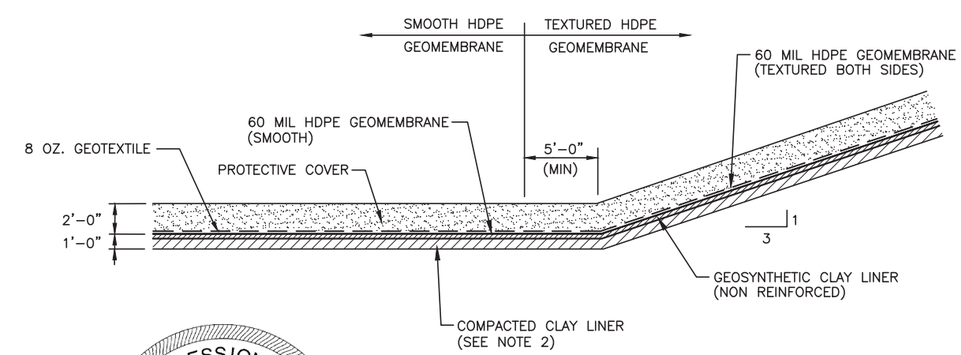
SCALE IN FEET



SIDEWALL LINER (L3)

0 5 10
SCALE IN FEET

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NOTE:

1. MATERIAL PROPERTIES AND QA/QC REQUIREMENTS FOR EACH OF THE LINER COMPONENTS ARE SPECIFIED IN APPENDIX K.
2. AN ALTERNATE TO THE 2 FEET OF CLAY IS 1 FOOT OF CLAY OVERLAIN BY A GCL.

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FIGURE N-1-5

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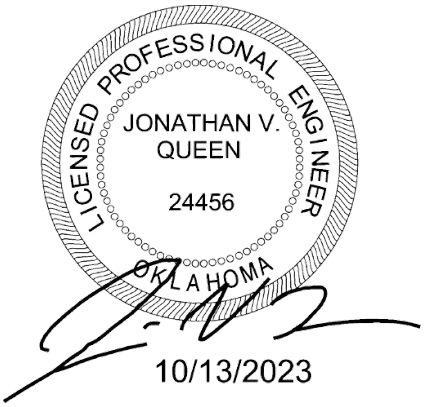
APPENDIX N-2

ALTERNATIVE LINER SYSTEM MODELING



APPENDIX N-2-1

HELP MODEL

Includes pages N-2-1-1 through N-2-1-54

CONTENTS

1	**LEACHATE GENERATION MODEL**		**N-2-1-1**
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	1.3	Climate Data Input	N-2-1-2
	1.4	Landfill Profile	N-2-1-2
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		1.4.2 Leachate Collection Layer/Protective Cover Material System	N-2-1-2
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1 LEACHATE GENERATION MODEL

1.1 HELP Model

The Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3.07, was used to estimate the quantity of leachate that will be generated during the active life and postclosure period of the Muskogee Community RDF. The HELP Model is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of the landfill. The model uses climate, soil, and landfill design data to perform a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, soil moisture storage, evapotranspiration, and lateral drainage.

1.2 Model Setup

The site was modeled using 1-acre unit areas for the following stages of landfill development for the alternative liner system and leachate collection layer/protective cover material system:

- Working face with 10 feet of waste (pages N-2-1-6 through N-2-1-14)
- 50 feet of waste with cover soils (pages N-2-1-15 through N-2-1-24)
- 100 feet of waste with cover soils (pages N-2-1-25 through N-2-1-34)
- 150 feet of waste with cover soils (pages N-2-1-35 through N-2-1-44)
- 150 feet of waste with final cover (pages N-2-1-45 through N-2-1-54)

To provide for a conservative demonstration, the active stage was modeled for 1 year. The interim stages with 50, 100, and 150 feet of waste were modeled for various timeframes depending on expected conditions. The closed landfill condition was modeled for 30 years. Initial moisture content values were initialized in the HELP model to steady-state moisture conditions. The evaporative zone depth was chosen to be 6 inches for the active case and interim cases and 12 inches for the closed case. The leaf area index ranges from 0 for the active case to 2.0 for the interim cases to 3.5 for the closed case. In addition, the HELP Model calculated the Soil Conservation Service (SCS) runoff curve numbers based on soil data and expected ground cover, surface slope, and slope length.

1.3 Climate Data Input

Mean monthly precipitation values for the City of Muskogee obtained from the National Oceanic and Atmospheric Administration (NOAA) 1991-2020 U.S. Climate Normals were entered into HELP. The HELP model synthetically generated precipitation data using program default coefficients for Tulsa, Oklahoma. The average annual precipitation over the modeled 30-year period was 42.46 inches. The HELP model also synthetically generated temperature and solar radiation data using program defaults for Tulsa, Oklahoma.

1.4 Landfill Profile

The landfill profiles for the active, interim, and closed stages of the landfill development are presented in the attached HELP Model summary sheet (page N-2-1-4). The profiles presented below represent the alternative composite liner system and the alternative final cover system.

1.4.1 Alternative Liner System

The composite liner consists of a 12-inch clay layer overlain by a GCL and 60-mil high-density polyethylene (HDPE) geomembrane. The 12-inch-thick clay layer will have a hydraulic conductivity of $1x10^{-7}$ cm/s. Default soil characteristics from the HELP model were selected for the 12-inch-thick clay liner. The GCL will have a hydraulic conductivity of $5x10^{-9}$ cm/s. Default characteristics from the HELP model were selected for the 0.25-inch GCL. The geomembrane liner was modeled for good installation quality, 1 defect per acre, and a pinhole density of 0.5 hole/acre.

1.4.2 Leachate Collection Layer/Protective Cover Material System

The leachate collection/protective cover system consists of a 24-inch sand layer with a permeability of $1x10^{-3}$ cm/sec or greater. An 8-oz/sy geotextile will underlie the 24-inch leachate collection layer.

The HELP model demonstration utilized recirculation. One hundred percent of leachate generated at the site may be recirculated as demonstrated in the HELP modeling. Actual leachate application rates will be limited to prevent surface runoff or erosion, or ponding of dispersed leachate.

1.4.3 Waste Layers

Waste layers of 10, 50, 100, and 150 feet were used to represent the active, interim, and closed stages of landfill development. The default characteristics were selected from HELP to represent municipal solid waste. The first 5 feet of waste will not

include large appliances or other large, bulky items, and will serve as the upper component of the leachate collection layer/protective cover material system.

1.4.4 Cover Soils

The cover soils consist of a 6-inch-thick layer for the active case and interim cases of soil placed over the waste. Default soil characteristics from the HELP Version 3.07 table were selected to represent the available onsite soils.

1.4.5 Final Cover

The alternative final cover system consists of a 12-inch-thick vegetative topsoil layer capable of sustaining growth of vegetation, and a 24-inch-thick vegetative support layer.

1.5 HELP Model Output

The HELP summary table and output files for the active, interim, and closed stages of landfill development for the alternative liner design are presented beginning on pages N-2-1-4.

Prep By: JBP
Date: 10/11/2023

MUSKOGEE RDF
WESTERN LANDFILL UNIT
0086-364-11-18
HELP VERSION 3.07 SUMMARY SHEET

Chkd By: JVQ
Date: 10/11/2023

		ACTIVE (10 FT WASTE)	INTERIM (50 FT WASTE)	INTERIM (100 FT WASTE)	INTERIM (150 FT WASTE)	CLOSED (150 FT WASTE)
GENERAL	Case No.	1	2	3	4	5
INFORMATION	No. of Years	1	10	10	10	30
	Ground Cover	BARE	FAIR	FAIR	FAIR	GOOD
	SCS Runoff Curve No.	97.1	91.2	91.2	91.2	89.5
	Model Area (acre)	1	1	1	1	1
	Runoff Area (%)	70	85	85	85	100
	Maximum Leaf Area Index	0.0	2.0	2.0	2.0	3.5
	Evaporative Zone Depth (inch)	6	6	6	6	12
VEGETATIVE TOPSOIL	Thickness (in)	---	---	---	---	12
LAYER	Porosity (vol/vol)	---	---	---	---	0.4450
(Texture = 26)	Field Capacity (vol/vol)	---	---	---	---	0.3930
	Wilting Point (vol/vol)	---	---	---	---	0.2770
	Init. Moisture Content (vol/vol)	---	---	---	---	0.3000
	Hyd. Conductivity (cm/s)	---	---	---	---	1.9E-06
VEGETATIVE SUPPORT	Thickness (in)	---	---	---	---	24
LAYER	Porosity (vol/vol)	---	---	---	---	0.4370
(Texture = 25)	Field Capacity (vol/vol)	---	---	---	---	0.3730
	Wilting Point (vol/vol)	---	---	---	---	0.2660
	Init. Moisture Content (vol/vol)	---	---	---	---	0.3730
	Hyd. Conductivity (cm/s)	---	---	---	---	3.6E-06
Cover	Thickness (in)	6	6	6	6	12
Soils	Porosity (vol/vol)	0.4450	0.4450	0.4450	0.4450	0.4450
(Texture = 26)	Field Capacity (vol/vol)	0.3930	0.3930	0.3930	0.3930	0.3930
	Wilting Point (vol/vol)	0.2770	0.2770	0.2770	0.2770	0.2770
	Init. Moisture Content (vol/vol)	0.2770	0.2770	0.2770	0.2770	0.3930
	Hyd. Conductivity (cm/s)	1.9E-06	1.9E-06	1.9E-06	1.9E-06	1.9E-06
WASTE	Thickness (in)	120	600	1200	1800	1800
(Texture = 18)	Porosity (vol/vol)	0.6710	0.6710	0.6710	0.6710	0.6710
	Field Capacity (vol/vol)	0.2920	0.2920	0.2920	0.2920	0.2920
	Wilting Point (vol/vol)	0.0770	0.0770	0.0770	0.0770	0.0770
	Init. Moisture Content (vol/vol)	0.2920	0.2920	0.2920	0.2920	0.2920
	Hyd. Conductivity (cm/s)	1.0E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03
PROTECTIVE COVER/LEACHATE	Thickness (in)	24	24	24	24	24
COLLECTION LAYER	Porosity (vol/vol)	0.4370	0.4370	0.4370	0.4370	0.4370
(Texture = 0)	Field Capacity (vol/vol)	0.0620	0.0620	0.0620	0.0620	0.0620
	Wilting Point (vol/vol)	0.0240	0.0240	0.0240	0.0240	0.0240
	Init. Moisture Content (vol/vol)	0.0620	0.0622	0.0622	0.0622	0.0622
	Hyd. Conductivity (cm/s)	1.0E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03
	Slope (%)	0.0.20.	2.0	2.0	2.0	2.0
	Slope Length (ft)	162	162	162	162	162
FLEXIBLE	Thickness (in)	0.06	0.06	0.06	0.06	0.06
MEMBRANE	Hyd. Conductivity (cm/s)	2.0E-13	2.0E-13	2.0E-13	2.0E-13	2.0E-13
LINER	Pinhole Density (holes/acre)	0.5	0.5	0.5	0.5	0.5
(Texture = 35)	Install. Defects (holes/acre)	1	1	1	1	1
	Placement Quality	GOOD	GOOD	GOOD	GOOD	GOOD
GEOSYNTHETIC	Thickness (in)	0.25	0.25	0.25	0.25	0.25
CLAY LINER	Porosity (vol/vol)	0.7500	0.7500	0.7500	0.7500	0.7500
(Texture = 0)	Field Capacity (vol/vol)	0.7470	0.7470	0.7470	0.7470	0.7470
	Wilting Point (vol/vol)	0.4000	0.4000	0.4000	0.4000	0.4000
	Init. Moisture Content (vol/vol)	0.7470	0.7470	0.7470	0.7470	0.7470
	Hyd. Conductivity (cm/s)	5.0E-09	5.0E-09	5.0E-09	5.0E-09	5.0E-09
COMPACTED	Thickness (in)	12	12	12	12	12
CLAY LINER	Porosity (vol/vol)	0.4270	0.4270	0.4270	0.4270	0.4270
(Texture = 16)	Field Capacity (vol/vol)	0.4180	0.4180	0.4180	0.4180	0.4180
	Wilting Point (vol/vol)	0.3670	0.3670	0.3670	0.3670	0.3670
	Init. Moisture Content (vol/vol)	0.4270	0.4270	0.4270	0.4270	0.4270
	Hyd. Conductivity (cm/s)	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07
PRECIPITATION	Average Annual (in)	55.18	42.46	42.46	42.46	41.05
RUNOFF	Average Annual (in)	38.04	23.10	23.10	23.10	20.28
EVAPOTRANSPIRATION	Average Annual (in)	17.14	19.11	19.11	19.11	20.22
LATERAL	Average Annual (cf/acre/year)	1.699	894.266	894.260	894.260	1,825.230
DRAINAGE COLLECTED (1)	Peak Daily (cf/acre/day)	0.000	8.262	8.262	8.262	11.405
LATERAL	Average Annual (cf/acre/year)		894.266	894.260	894.260	
DRAINAGE RECIRCULATED	Peak Daily (cf/acre/day)		8.262	8.262	8.262	
PERCOLATION	Average Annual (cf/yr)	0.009	0.327	0.327	0.327	0.661
THROUGH COMPACTED CLAY LINER	Average Annual (m/yr)	6.30E-08	2.29E-06	2.29E-06	2.29E-06	4.63E-06

(1) Drainage collected includes actual leachate pumped by the leachate pumps (i.e. the total of the collected and recirculated leachate).

HELP MODELING OUTPUT

ACTIVE CASE (10 FEET OF WASTE)

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


PRECIPITATION DATA FILE:    C:\MUSK\ALT\A10\DATA4.D4
TEMPERATURE DATA FILE:      C:\MUSK\ALT\A10\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MUSK\ALT\A10\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MUSK\ALT\A10\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MUSK\ALT\A10\DATA10.D10
OUTPUT DATA FILE:           C:\MUSK\ALT\A10\OUTPUT1.OUT


TIME:  15:47     DATE:   3/ 7/2023


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

     TITLE:  MUSKOGEE LANDFILL - ACTIVE 10' WASTE

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


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


                                   LAYER  1
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  26
          THICKNESS                   =      6.00   INCHES
```

```
POROSITY                    =      0.4450 VOL/VOL
FIELD CAPACITY              =      0.3930 VOL/VOL
WILTING POINT               =      0.2770 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2770 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.190000003000E-05 CM/SEC


                        LAYER  2
                        --------

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


                        LAYER  3
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4370 VOL/VOL
FIELD CAPACITY              =      0.0620 VOL/VOL
WILTING POINT               =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0620 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    162.0    FEET


                        LAYER  4
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      0.50   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD
```

```
                        LAYER  5
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.25   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7470 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC
```

```
                        LAYER  6
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC
```

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #26 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF 25.% AND
          A SLOPE LENGTH OF  120. FEET.

SCS RUNOFF CURVE NUMBER             =     97.10
FRACTION OF AREA ALLOWING RUNOFF    =     70.0    PERCENT
```

```
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =      6.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      1.662  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      2.670  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.662  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     48.625  INCHES
TOTAL INITIAL WATER                 =     48.625  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

```
NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         TULSA                OKLAHOMA

    STATION LATITUDE                        =  36.12 DEGREES
    MAXIMUM LEAF AREA INDEX                 =   0.00
    START OF GROWING SEASON (JULIAN DATE)   =     85
    END OF GROWING SEASON (JULIAN DATE)     =    311
    EVAPORATIVE ZONE DEPTH                  =   6.0  INCHES
    AVERAGE ANNUAL WIND SPEED               =  10.50 MPH
    AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  64.00 %
    AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  67.00 %
    AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  66.00 %
    AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  68.00 %
```

```
NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    TULSA               OKLAHOMA
```

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.94	2.36	3.09	4.88	5.25	5.00
3.32	3.14	4.31	4.07	3.23	2.56

```
NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    TULSA               OKLAHOMA
```

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

37.50	41.90	51.20	59.90	69.00	77.50
82.30	81.20	73.20	61.50	49.80	40.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA
AND STATION LATITUDE = 36.12 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 30 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.50	1.02	3.02	6.57	5.05	6.95
	1.63	3.07	7.29	6.89	10.39	1.80
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.521	0.242	1.852	3.979	3.391	5.261
	0.904	1.954	4.880	5.453	8.383	1.222
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.608	1.091	1.047	2.437	1.924	1.754
	0.728	1.097	2.134	1.487	1.666	1.163
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001

```
  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

 PERCOLATION/LEAKAGE THROUGH LAYER  4
 -------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

 PERCOLATION/LEAKAGE THROUGH LAYER  6
 -------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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


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


 DAILY AVERAGE HEAD ON TOP OF LAYER  4
 -------------------------------------
  AVERAGES               0.0010   0.0012   0.0013   0.0015   0.0017   0.0018
                         0.0019   0.0021   0.0022   0.0023   0.0024   0.0025

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

 DAILY AVERAGE HEAD ON TOP OF LAYER  6
 -------------------------------------
  AVERAGES               0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

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


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

    AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS   30 THROUGH   30
-------------------------------------------------------------------------------
```

	INCHES		CU. FEET	PERCENT
PRECIPITATION	55.18	(0.000)	200303.4	100.00
RUNOFF	38.041	(0.0000)	138088.36	68.940
EVAPOTRANSPIRATION	17.136	(0.0000)	62204.68	31.055
LATERAL DRAINAGE COLLECTED FROM LAYER 3	0.00047	(0.00000)	1.699	0.00085
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00000	(0.00000)	0.009	0.00000
AVERAGE HEAD ON TOP OF LAYER 4	0.002	(0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000	(0.00000)	0.009	0.00000
AVERAGE HEAD ON TOP OF LAYER 6	0.000	(0.000)		
CHANGE IN WATER STORAGE	0.002	(0.0000)	8.61	0.004

****

****

PEAK DAILY VALUES FOR YEARS 30 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	4.58	16625.400
RUNOFF	4.012	14563.5879
DRAINAGE COLLECTED FROM LAYER 3	0.00000	0.00653
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 4	0.003	
MAXIMUM HEAD ON TOP OF LAYER 4	0.006	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	

```
PERCOLATION/LEAKAGE THROUGH LAYER  6       0.000000         0.00003

AVERAGE HEAD ON TOP OF LAYER  6            0.000

SNOW WATER                                 0.83          3030.9639


MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.3584

MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.2770


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

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

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

                 FINAL WATER STORAGE AT END OF YEAR   30
   ------------------------------------------------------------------
                  LAYER        (INCHES)       (VOL/VOL)
                  -----        --------       ---------
                    1            1.6620         0.2770

                    2           35.0399         0.2920

                    3            1.4911         0.0621

                    4            0.0000         0.0000

                    5            0.1867         0.7470

                    6           10.2480         0.4270

                SNOW WATER       0.000

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

INTERIM CASE (50 FEET OF WASTE)

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



PRECIPITATION DATA FILE:    C:\MUSK\ALT\I50\DATA4.D4
TEMPERATURE DATA FILE:      C:\MUSK\ALT\I50\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MUSK\ALT\I50\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MUSK\ALT\I50\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MUSK\ALT\I50\DATA10.D10
OUTPUT DATA FILE:           C:\MUSK\ALT\I50\OUTPUT1.OUT



TIME:  12:55     DATE:   3/ 8/2023



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     TITLE:  MUSKOGEE LANDFILL - INTERIM 50

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



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



                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  26
          THICKNESS                   =      6.00   INCHES
```

```
  POROSITY                    =      0.4450 VOL/VOL
  FIELD CAPACITY              =      0.3930 VOL/VOL
  WILTING POINT               =      0.2770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2770 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.190000003000E-05 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  18
  THICKNESS                   =    600.00   INCHES
  POROSITY                    =      0.6710 VOL/VOL
  FIELD CAPACITY              =      0.2920 VOL/VOL
  WILTING POINT               =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2920 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
NOTE:  100.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 3
         IS RECIRCULATED INTO THIS LAYER.


                          LAYER  3
                          --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   0
  THICKNESS                   =     24.00   INCHES
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.0622 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
  SLOPE                       =      2.00   PERCENT
  DRAINAGE LENGTH             =    162.0    FEET
NOTE:  100.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
         LAYER IS RECIRCULATED INTO LAYER #  2.


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

```
            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      0.50   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  5
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.25   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7470 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC


                        LAYER  6
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


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

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
```

SOIL DATA BASE USING SOIL TEXTURE #26 WITH A
FAIR STAND OF GRASS, A SURFACE SLOPE OF 25.%
AND A SLOPE LENGTH OF 120. FEET.

SCS RUNOFF CURVE NUMBER	=	91.20	
FRACTION OF AREA ALLOWING RUNOFF	=	85.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.662	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.670	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.662	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	188.790	INCHES
TOTAL INITIAL WATER	=	188.790	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
TULSA OKLAHOMA

STATION LATITUDE	=	36.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	85	
END OF GROWING SEASON (JULIAN DATE)	=	311	
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	10.50	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	66.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	68.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.94	2.36	3.09	4.88	5.25	5.00
3.32	3.14	4.31	4.07	3.23	2.56

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	41.90	51.20	59.90	69.00	77.50
82.30	81.20	73.20	61.50	49.80	40.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA
AND STATION LATITUDE = 36.12 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 17 THROUGH 26

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.04	2.63	3.77	5.42	6.61	5.15
	3.00	3.29	2.68	4.41	1.82	1.63
STD. DEVIATIONS	0.82	2.07	2.13	2.57	3.31	2.57
	1.46	2.15	1.47	3.65	1.13	0.99
RUNOFF						
TOTALS	0.821	1.235	2.069	3.070	3.838	3.041
	1.472	1.547	1.330	3.053	0.851	0.768
STD. DEVIATIONS	0.525	1.311	1.285	1.742	2.378	1.778
	0.887	1.351	0.990	2.973	0.696	0.778
EVAPOTRANSPIRATION						
TOTALS	0.965	1.411	1.795	2.351	2.698	2.145
	1.573	1.624	1.372	1.392	0.898	0.886
STD. DEVIATIONS	0.396	0.757	0.763	0.821	1.039	0.993

```
                        0.535    1.034    0.494    0.640    0.406    0.391

  LATERAL DRAINAGE RECIRCULATED INTO LAYER  2
  -------------------------------------------
    TOTALS                 0.0156   0.0149   0.0193   0.0203   0.0217   0.0214
                           0.0222   0.0224   0.0217   0.0225   0.0218   0.0225

    STD. DEVIATIONS        0.0234   0.0214   0.0254   0.0262   0.0279   0.0272
                           0.0283   0.0283   0.0274   0.0284   0.0275   0.0284

  LATERAL DRAINAGE COLLECTED FROM LAYER  3
  ----------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

  LATERAL DRAINAGE RECIRCULATED FROM LAYER  3
  --------------------------------------------
    TOTALS                 0.0156   0.0149   0.0193   0.0203   0.0217   0.0214
                           0.0222   0.0224   0.0217   0.0225   0.0218   0.0225

    STD. DEVIATIONS        0.0234   0.0214   0.0254   0.0262   0.0279   0.0272
                           0.0283   0.0283   0.0274   0.0284   0.0275   0.0284

  PERCOLATION/LEAKAGE THROUGH LAYER  4
  -------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

  PERCOLATION/LEAKAGE THROUGH LAYER  6
  -------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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


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


  DAILY AVERAGE HEAD ON TOP OF LAYER  4
  -------------------------------------
```

```
   AVERAGES               0.7208   0.7541   0.8877   0.9693   1.0020   1.0176
                          1.0257   1.0306   1.0338   1.0364   1.0382   1.0396

   STD. DEVIATIONS        1.0778   1.0815   1.1706   1.2493   1.2842   1.2983
                          1.3040   1.3065   1.3076   1.3083   1.3082   1.3078

 DAILY AVERAGE HEAD ON TOP OF LAYER  6
 -------------------------------------
   AVERAGES               0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

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


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

    AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS   17 THROUGH   26
-------------------------------------------------------------------------------
                                     INCHES            CU. FEET       PERCENT
                                 -------------------   -------------   ---------
 PRECIPITATION                    42.46    (   8.916)     154126.2     100.00

 RUNOFF                           23.097   (  6.6218)      83840.30     54.397

 EVAPOTRANSPIRATION               19.109   (  3.0783)      69366.81     45.007

 DRAINAGE RECIRCULATED             0.24635 (  0.31608)       894.266    0.58022
   INTO LAYER  2

 LATERAL DRAINAGE COLLECTED        0.00000 (  0.00000)         0.000    0.00000
   FROM LAYER  3

 DRAINAGE RECIRCULATED             0.24635 (  0.31608)       894.266    0.58022
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH       0.00009 (  0.00012)         0.327     0.00021
   LAYER  4

 AVERAGE HEAD ON TOP               0.963 (    1.236)
   OF LAYER  4

 PERCOLATION/LEAKAGE THROUGH       0.00009 (  0.00012)         0.327     0.00021
   LAYER  6

 AVERAGE HEAD ON TOP               0.000 (    0.000)
   OF LAYER  6
```

```
 CHANGE IN WATER STORAGE         0.253   (  0.2754)        917.91      0.596

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



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

              PEAK DAILY VALUES FOR YEARS   17 THROUGH   26
   ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------   -------------
      PRECIPITATION                              5.50         19965.000

      RUNOFF                                     4.887        17738.2227

      DRAINAGE RECIRCULATED INTO LAYER  2        0.00228          8.26182

      DRAINAGE COLLECTED FROM LAYER  3           0.00000          0.00000

      DRAINAGE RECIRCULATED FROM LAYER  3        0.00228          8.26182

      PERCOLATION/LEAKAGE THROUGH LAYER  4       0.000001         0.00316

      AVERAGE HEAD ON TOP OF LAYER  4            3.253

      MAXIMUM HEAD ON TOP OF LAYER  4            5.092

      LOCATION OF MAXIMUM HEAD IN LAYER  3
            (DISTANCE FROM DRAIN)               35.2 FEET

      PERCOLATION/LEAKAGE THROUGH LAYER  6       0.000001         0.00316

      AVERAGE HEAD ON TOP OF LAYER  6            0.000

      SNOW WATER                                 1.18          4284.5435


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.4426

      MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.2770


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

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

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FINAL WATER STORAGE AT END OF YEAR 26

LAYER	(INCHES)	(VOL/VOL)
1	2.0789	0.3465
2	175.1999	0.2920
3	3.6051	0.1502
4	0.0000	0.0000
5	0.1867	0.7470
6	10.2480	0.4270
SNOW WATER	0.000	

****
****

INTERIM CASE (100 FEET OF WASTE)

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



PRECIPITATION DATA FILE:    C:\MUSK\ALT\I100\DATA4.D4
TEMPERATURE DATA FILE:      C:\MUSK\ALT\I100\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MUSK\ALT\I100\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MUSK\ALT\I100\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MUSK\ALT\I100\DATA10.D10
OUTPUT DATA FILE:           C:\MUSK\ALT\I100\OUTPUT1.OUT



TIME:  12:56     DATE:   3/ 8/2023



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

     TITLE:  MUSKOGEE LANDFILL - INTERIM 100 FT WASTE

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



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



                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  26
          THICKNESS                   =      6.00   INCHES
```

```
  POROSITY                    =      0.4450 VOL/VOL
  FIELD CAPACITY              =      0.3930 VOL/VOL
  WILTING POINT               =      0.2770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2770 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.190000003000E-05 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  18
  THICKNESS                   =   1200.00   INCHES
  POROSITY                    =      0.6710 VOL/VOL
  FIELD CAPACITY              =      0.2920 VOL/VOL
  WILTING POINT               =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2920 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
NOTE:  100.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 3
         IS RECIRCULATED INTO THIS LAYER.


                          LAYER  3
                          --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   0
  THICKNESS                   =     24.00   INCHES
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.0622 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
  SLOPE                       =      2.00   PERCENT
  DRAINAGE LENGTH             =    162.0    FEET
NOTE:  100.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
         LAYER IS RECIRCULATED INTO LAYER #  2.


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

```
            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      0.50   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  5
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.25   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7470 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC


                        LAYER  6
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


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

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
```

SOIL DATA BASE USING SOIL TEXTURE #26 WITH A
FAIR STAND OF GRASS, A SURFACE SLOPE OF 25.%
AND A SLOPE LENGTH OF 120. FEET.

SCS RUNOFF CURVE NUMBER	=	91.20	
FRACTION OF AREA ALLOWING RUNOFF	=	85.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.662	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.670	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.662	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	363.990	INCHES
TOTAL INITIAL WATER	=	363.990	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
TULSA OKLAHOMA

STATION LATITUDE	=	36.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	85	
END OF GROWING SEASON (JULIAN DATE)	=	311	
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	10.50	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	66.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	68.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.94	2.36	3.09	4.88	5.25	5.00
3.32	3.14	4.31	4.07	3.23	2.56

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	41.90	51.20	59.90	69.00	77.50
82.30	81.20	73.20	61.50	49.80	40.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA
AND STATION LATITUDE = 36.12 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 17 THROUGH 26

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.04	2.63	3.77	5.42	6.61	5.15
	3.00	3.29	2.68	4.41	1.82	1.63
STD. DEVIATIONS	0.82	2.07	2.13	2.57	3.31	2.57
	1.46	2.15	1.47	3.65	1.13	0.99
RUNOFF						
TOTALS	0.821	1.235	2.069	3.070	3.838	3.041
	1.472	1.547	1.330	3.053	0.851	0.768
STD. DEVIATIONS	0.525	1.311	1.285	1.742	2.378	1.778
	0.887	1.351	0.990	2.973	0.696	0.778
EVAPOTRANSPIRATION						
TOTALS	0.965	1.411	1.795	2.351	2.698	2.145
	1.573	1.624	1.372	1.392	0.898	0.886
STD. DEVIATIONS	0.396	0.757	0.763	0.821	1.039	0.993

```
                        0.535    1.034    0.494    0.640    0.406    0.391

  LATERAL DRAINAGE RECIRCULATED INTO LAYER  2
  -------------------------------------------
    TOTALS                 0.0156   0.0149   0.0193   0.0203   0.0217   0.0214
                           0.0222   0.0224   0.0217   0.0225   0.0218   0.0225

    STD. DEVIATIONS        0.0234   0.0214   0.0254   0.0262   0.0279   0.0272
                           0.0283   0.0283   0.0274   0.0284   0.0275   0.0284

  LATERAL DRAINAGE COLLECTED FROM LAYER  3
  ----------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

  LATERAL DRAINAGE RECIRCULATED FROM LAYER  3
  --------------------------------------------
    TOTALS                 0.0156   0.0149   0.0193   0.0203   0.0217   0.0214
                           0.0222   0.0224   0.0217   0.0225   0.0218   0.0225

    STD. DEVIATIONS        0.0234   0.0214   0.0254   0.0262   0.0279   0.0272
                           0.0283   0.0283   0.0274   0.0284   0.0275   0.0284

  PERCOLATION/LEAKAGE THROUGH LAYER  4
  -------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

  PERCOLATION/LEAKAGE THROUGH LAYER  6
  -------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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


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


  DAILY AVERAGE HEAD ON TOP OF LAYER  4
  -------------------------------------
```

```
   AVERAGES               0.7208   0.7541   0.8876   0.9693   1.0020   1.0176
                          1.0257   1.0306   1.0338   1.0364   1.0382   1.0396

   STD. DEVIATIONS        1.0778   1.0815   1.1705   1.2493   1.2842   1.2983
                          1.3040   1.3065   1.3076   1.3083   1.3082   1.3078

 DAILY AVERAGE HEAD ON TOP OF LAYER  6
 -------------------------------------
   AVERAGES               0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

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


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

    AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS   17 THROUGH   26
-------------------------------------------------------------------------------
                                     INCHES            CU. FEET       PERCENT
                                 -------------------   -------------   ---------
 PRECIPITATION                    42.46    (   8.916)     154126.2     100.00

 RUNOFF                           23.097   (  6.6218)      83840.30     54.397

 EVAPOTRANSPIRATION               19.109   (  3.0783)      69366.81     45.007

 DRAINAGE RECIRCULATED             0.24635 (  0.31608)       894.260    0.58021
   INTO LAYER  2

 LATERAL DRAINAGE COLLECTED        0.00000 (  0.00000)         0.000    0.00000
   FROM LAYER  3

 DRAINAGE RECIRCULATED             0.24635 (  0.31608)       894.260    0.58021
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH       0.00009 (  0.00012)         0.327     0.00021
   LAYER  4

 AVERAGE HEAD ON TOP               0.963 (    1.236)
   OF LAYER  4

 PERCOLATION/LEAKAGE THROUGH       0.00009 (  0.00012)         0.327     0.00021
   LAYER  6

 AVERAGE HEAD ON TOP               0.000 (    0.000)
   OF LAYER  6
```

```
 CHANGE IN WATER STORAGE         0.253   (  0.2754)        917.92      0.596

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



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

              PEAK DAILY VALUES FOR YEARS   17 THROUGH   26
   ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------   -------------
      PRECIPITATION                              5.50         19965.000

      RUNOFF                                     4.887        17738.2227

      DRAINAGE RECIRCULATED INTO LAYER  2        0.00228          8.26182

      DRAINAGE COLLECTED FROM LAYER  3           0.00000          0.00000

      DRAINAGE RECIRCULATED FROM LAYER  3        0.00228          8.26182

      PERCOLATION/LEAKAGE THROUGH LAYER  4       0.000001         0.00316

      AVERAGE HEAD ON TOP OF LAYER  4            3.253

      MAXIMUM HEAD ON TOP OF LAYER  4            5.092

      LOCATION OF MAXIMUM HEAD IN LAYER  3
            (DISTANCE FROM DRAIN)               35.2 FEET

      PERCOLATION/LEAKAGE THROUGH LAYER  6       0.000001         0.00316

      AVERAGE HEAD ON TOP OF LAYER  6            0.000

      SNOW WATER                                 1.18          4284.5435


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.4426

      MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.2770


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

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

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FINAL WATER STORAGE AT END OF YEAR 26

LAYER	(INCHES)	(VOL/VOL)
1	2.0789	0.3465
2	350.3999	0.2920
3	3.6051	0.1502
4	0.0000	0.0000
5	0.1867	0.7470
6	10.2480	0.4270
SNOW WATER	0.000	

****
****

INTERIM CASE (150 FEET OF WASTE)

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



PRECIPITATION DATA FILE:    C:\MUSK\ALT\I150\DATA4.D4
TEMPERATURE DATA FILE:      C:\MUSK\ALT\I150\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MUSK\ALT\I150\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MUSK\ALT\I150\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MUSK\ALT\I150\DATA10.D10
OUTPUT DATA FILE:           C:\MUSK\ALT\I150\OUTPUT1.OUT



TIME:  12:58     DATE:   3/ 8/2023



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

     TITLE:  MUSKOGEE LANDFILL - INTERIM 150 FT WASTE

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



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



                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  26
          THICKNESS                   =      6.00   INCHES
```

```
  POROSITY                    =      0.4450 VOL/VOL
  FIELD CAPACITY              =      0.3930 VOL/VOL
  WILTING POINT               =      0.2770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2770 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.190000003000E-05 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  18
  THICKNESS                   =   1800.00   INCHES
  POROSITY                    =      0.6710 VOL/VOL
  FIELD CAPACITY              =      0.2920 VOL/VOL
  WILTING POINT               =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2920 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
NOTE:  100.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 3
         IS RECIRCULATED INTO THIS LAYER.


                          LAYER  3
                          --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   0
  THICKNESS                   =     24.00   INCHES
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.0620 VOL/VOL
  WILTING POINT               =      0.0240 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.0622 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
  SLOPE                       =      2.00   PERCENT
  DRAINAGE LENGTH             =    162.0    FEET
NOTE:  100.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
         LAYER IS RECIRCULATED INTO LAYER #  2.


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

```
            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      0.50   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  5
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.25   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7470 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC


                        LAYER  6
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


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

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
```

SOIL DATA BASE USING SOIL TEXTURE #26 WITH A
FAIR STAND OF GRASS, A SURFACE SLOPE OF 25.%
AND A SLOPE LENGTH OF 120. FEET.

SCS RUNOFF CURVE NUMBER	=	91.20	
FRACTION OF AREA ALLOWING RUNOFF	=	85.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.662	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.670	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.662	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	539.190	INCHES
TOTAL INITIAL WATER	=	539.190	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
TULSA OKLAHOMA

STATION LATITUDE	=	36.12	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	85	
END OF GROWING SEASON (JULIAN DATE)	=	311	
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	10.50	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	66.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	68.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.94	2.36	3.09	4.88	5.25	5.00
3.32	3.14	4.31	4.07	3.23	2.56

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	41.90	51.20	59.90	69.00	77.50
82.30	81.20	73.20	61.50	49.80	40.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA
AND STATION LATITUDE = 36.12 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 17 THROUGH 26

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.04	2.63	3.77	5.42	6.61	5.15
	3.00	3.29	2.68	4.41	1.82	1.63
STD. DEVIATIONS	0.82	2.07	2.13	2.57	3.31	2.57
	1.46	2.15	1.47	3.65	1.13	0.99
RUNOFF						
TOTALS	0.821	1.235	2.069	3.070	3.838	3.041
	1.472	1.547	1.330	3.053	0.851	0.768
STD. DEVIATIONS	0.525	1.311	1.285	1.742	2.378	1.778
	0.887	1.351	0.990	2.973	0.696	0.778
EVAPOTRANSPIRATION						
TOTALS	0.965	1.411	1.795	2.351	2.698	2.145
	1.573	1.624	1.372	1.392	0.898	0.886
STD. DEVIATIONS	0.396	0.757	0.763	0.821	1.039	0.993

```
                        0.535    1.034    0.494    0.640    0.406    0.391

  LATERAL DRAINAGE RECIRCULATED INTO LAYER  2
  -------------------------------------------
    TOTALS                 0.0156   0.0149   0.0193   0.0203   0.0217   0.0214
                           0.0222   0.0224   0.0217   0.0225   0.0218   0.0225

    STD. DEVIATIONS        0.0234   0.0214   0.0254   0.0262   0.0279   0.0272
                           0.0283   0.0283   0.0274   0.0284   0.0275   0.0284

  LATERAL DRAINAGE COLLECTED FROM LAYER  3
  ----------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

  LATERAL DRAINAGE RECIRCULATED FROM LAYER  3
  --------------------------------------------
    TOTALS                 0.0156   0.0149   0.0193   0.0203   0.0217   0.0214
                           0.0222   0.0224   0.0217   0.0225   0.0218   0.0225

    STD. DEVIATIONS        0.0234   0.0214   0.0254   0.0262   0.0279   0.0272
                           0.0283   0.0283   0.0274   0.0284   0.0275   0.0284

  PERCOLATION/LEAKAGE THROUGH LAYER  4
  -------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

  PERCOLATION/LEAKAGE THROUGH LAYER  6
  -------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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


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


  DAILY AVERAGE HEAD ON TOP OF LAYER  4
  -------------------------------------
```

```
   AVERAGES               0.7208   0.7541   0.8876   0.9693   1.0020   1.0176
                          1.0257   1.0306   1.0338   1.0364   1.0382   1.0396

   STD. DEVIATIONS        1.0778   1.0815   1.1705   1.2493   1.2842   1.2983
                          1.3040   1.3065   1.3076   1.3083   1.3082   1.3078

 DAILY AVERAGE HEAD ON TOP OF LAYER  6
 -------------------------------------
   AVERAGES               0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

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


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

    AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS   17 THROUGH   26
-------------------------------------------------------------------------------
                                     INCHES            CU. FEET       PERCENT
                                 -------------------   -------------   ---------
 PRECIPITATION                    42.46    (   8.916)     154126.2     100.00

 RUNOFF                           23.097   (  6.6218)      83840.30     54.397

 EVAPOTRANSPIRATION               19.109   (  3.0783)      69366.81     45.007

 DRAINAGE RECIRCULATED             0.24635 (  0.31608)       894.260    0.58021
   INTO LAYER  2

 LATERAL DRAINAGE COLLECTED        0.00000 (  0.00000)         0.000    0.00000
   FROM LAYER  3

 DRAINAGE RECIRCULATED             0.24635 (  0.31608)       894.260    0.58021
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH       0.00009 (  0.00012)         0.327     0.00021
   LAYER  4

 AVERAGE HEAD ON TOP               0.963 (    1.236)
   OF LAYER  4

 PERCOLATION/LEAKAGE THROUGH       0.00009 (  0.00012)         0.327     0.00021
   LAYER  6

 AVERAGE HEAD ON TOP               0.000 (    0.000)
   OF LAYER  6
```

```
 CHANGE IN WATER STORAGE         0.253   (  0.2754)        917.89      0.596

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



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

              PEAK DAILY VALUES FOR YEARS   17 THROUGH   26
   ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------   -------------
      PRECIPITATION                              5.50         19965.000

      RUNOFF                                     4.887        17738.2227

      DRAINAGE RECIRCULATED INTO LAYER  2        0.00228          8.26182

      DRAINAGE COLLECTED FROM LAYER  3           0.00000          0.00000

      DRAINAGE RECIRCULATED FROM LAYER  3        0.00228          8.26182

      PERCOLATION/LEAKAGE THROUGH LAYER  4       0.000001         0.00316

      AVERAGE HEAD ON TOP OF LAYER  4            3.253

      MAXIMUM HEAD ON TOP OF LAYER  4            5.092

      LOCATION OF MAXIMUM HEAD IN LAYER  3
            (DISTANCE FROM DRAIN)               35.2 FEET

      PERCOLATION/LEAKAGE THROUGH LAYER  6       0.000001         0.00316

      AVERAGE HEAD ON TOP OF LAYER  6            0.000

      SNOW WATER                                 1.18          4284.5435


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.4426

      MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.2770


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

            Reference:  Maximum Saturated Depth over Landfill Liner
                        by Bruce M. McEnroe, University of Kansas
                        ASCE Journal of Environmental Engineering
```

Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 26

LAYER	(INCHES)	(VOL/VOL)
1	2.0789	0.3465
2	525.6000	0.2920
3	3.6051	0.1502
4	0.0000	0.0000
5	0.1867	0.7470
6	10.2480	0.4270
SNOW WATER	0.000	

****
****

CLOSED CASE (150 FEET OF WASTE)

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


PRECIPITATION DATA FILE:    C:\MUSK\ALT\CL\DATA4.D4
TEMPERATURE DATA FILE:      C:\MUSK\ALT\CL\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MUSK\ALT\CL\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MUSK\ALT\CL\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MUSK\ALT\CL\DATA10.D10
OUTPUT DATA FILE:           C:\MUSK\ALT\CL\OUTPUT1.OUT


TIME:  13:10     DATE:   3/ 8/2023


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

     TITLE:  MUSKOGEE LANDFILL - CLOSED 150 FT WASTE

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


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


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  26
          THICKNESS                   =     12.00   INCHES
```

```
  POROSITY                    =      0.4450 VOL/VOL
  FIELD CAPACITY              =      0.3930 VOL/VOL
  WILTING POINT               =      0.2770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.3000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.190000003000E-05 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
        FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                        LAYER  2
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  25
  THICKNESS                   =     24.00   INCHES
  POROSITY                    =      0.4370 VOL/VOL
  FIELD CAPACITY              =      0.3730 VOL/VOL
  WILTING POINT               =      0.2660 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.3730 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.359999990000E-05 CM/SEC


                        LAYER  3
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  26
  THICKNESS                   =     12.00   INCHES
  POROSITY                    =      0.4450 VOL/VOL
  FIELD CAPACITY              =      0.3930 VOL/VOL
  WILTING POINT               =      0.2770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.3930 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.190000003000E-05 CM/SEC


                        LAYER  4
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  18
  THICKNESS                   =   1800.00   INCHES
  POROSITY                    =      0.6710 VOL/VOL
  FIELD CAPACITY              =      0.2920 VOL/VOL
  WILTING POINT               =      0.0770 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =      0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC


                        LAYER  5
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4370 VOL/VOL
FIELD CAPACITY              =      0.0620 VOL/VOL
WILTING POINT               =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0665 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    162.0    FEET


                        LAYER  6
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      0.50   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  7
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.25   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =      0.7470 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC


                        LAYER  8
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #26 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF 25.%
          AND A SLOPE LENGTH OF   12. FEET.

SCS RUNOFF CURVE NUMBER             =     89.50
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     12.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      3.600  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      5.340  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      3.324  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    554.100  INCHES
TOTAL INITIAL WATER                 =    554.100  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


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

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          TULSA                 OKLAHOMA
```

```
STATION LATITUDE                        =  36.12 DEGREES
MAXIMUM LEAF AREA INDEX                 =   3.50
START OF GROWING SEASON (JULIAN DATE)   =     85
END OF GROWING SEASON (JULIAN DATE)     =    311
EVAPORATIVE ZONE DEPTH                  =  12.0  INCHES
AVERAGE ANNUAL WIND SPEED               =  10.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  66.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  68.00 %
```

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.94	2.36	3.09	4.88	5.25	5.00
3.32	3.14	4.31	4.07	3.23	2.56

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	41.90	51.20	59.90	69.00	77.50
82.30	81.20	73.20	61.50	49.80	40.60

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TULSA OKLAHOMA
AND STATION LATITUDE = 36.12 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.05	2.33	3.11	4.71	5.48	4.62
	2.60	2.65	4.10	4.32	2.97	2.13
STD. DEVIATIONS	1.19	1.53	2.00	2.45	2.85	2.75
	1.27	1.51	2.45	3.07	2.71	1.45
RUNOFF						
TOTALS	0.730	0.943	1.407	2.258	2.791	2.465
	1.079	1.077	2.180	2.705	1.604	1.038
STD. DEVIATIONS	0.705	0.980	1.236	1.571	2.217	1.906
	0.787	0.956	1.772	2.512	2.038	0.958
EVAPOTRANSPIRATION						
TOTALS	1.069	1.416	1.879	2.628	2.810	2.272
	1.501	1.547	1.806	1.337	1.058	0.893
STD. DEVIATIONS	0.290	0.478	0.722	0.965	0.903	1.066
	0.634	0.721	0.860	0.578	0.372	0.291
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	0.0346	0.0342	0.0419	0.0461	0.0507	0.0482
	0.0477	0.0451	0.0412	0.0402	0.0368	0.0362
STD. DEVIATIONS	0.0175	0.0166	0.0197	0.0212	0.0248	0.0239
	0.0238	0.0225	0.0205	0.0200	0.0183	0.0177
PERCOLATION/LEAKAGE THROUGH LAYER 6						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 8						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

```
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


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


  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES              1.5945   1.7326   1.9298   2.1978   2.3384   2.2964
                          2.2009   2.0773   1.9625   1.8542   1.7520   1.6669

    STD. DEVIATIONS       0.8055   0.8374   0.9081   1.0079   1.1448   1.1390
                          1.0972   1.0357   0.9783   0.9244   0.8733   0.8171

  DAILY AVERAGE HEAD ON TOP OF LAYER  8
  -------------------------------------
    AVERAGES              0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

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



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

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   30
-------------------------------------------------------------------------------
                                     INCHES            CU. FEET       PERCENT
                                 -------------------   -------------   ---------
 PRECIPITATION                    41.05    (   7.375)     149028.5     100.00

 RUNOFF                           20.276   (  5.5350)      73602.29     49.388

 EVAPOTRANSPIRATION               20.218   (  2.6577)      73390.15     49.246

 LATERAL DRAINAGE COLLECTED        0.50282 (  0.22238)      1825.230    1.22475
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH       0.00018 (  0.00009)         0.661     0.00044
   LAYER  6

 AVERAGE HEAD ON TOP               1.967 (    0.869)
   OF LAYER  6

 PERCOLATION/LEAKAGE THROUGH       0.00018 (  0.00009)         0.661     0.00044
```

```
  LAYER  8

 AVERAGE HEAD ON TOP            0.000 (    0.000)
   OF LAYER  8

 CHANGE IN WATER STORAGE        0.058   (  0.8709)        210.13      0.141
******************************************************************************



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

               PEAK DAILY VALUES FOR YEARS    1 THROUGH   30
   ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------   -------------
      PRECIPITATION                              5.50         19965.000

      RUNOFF                                     5.104        18529.0293

      DRAINAGE COLLECTED FROM LAYER  5           0.00314         11.40497

      PERCOLATION/LEAKAGE THROUGH LAYER  6       0.000001         0.00473

      AVERAGE HEAD ON TOP OF LAYER  6            4.491

      MAXIMUM HEAD ON TOP OF LAYER  6            6.695

      LOCATION OF MAXIMUM HEAD IN LAYER  5
            (DISTANCE FROM DRAIN)               41.2 FEET

      PERCOLATION/LEAKAGE THROUGH LAYER  8       0.000001         0.00473

      AVERAGE HEAD ON TOP OF LAYER  8            0.000

      SNOW WATER                                 3.24         11773.0791


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.4433

      MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.2770


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

            Reference:  Maximum Saturated Depth over Landfill Liner
                        by Bruce M. McEnroe, University of Kansas
                        ASCE Journal of Environmental Engineering
```

Vol. 119, No. 2, March 1993, pp. 262-270.

****

****

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	3.9590	0.3299
2	9.6503	0.4021
3	5.0197	0.4183
4	525.6000	0.2920
5	1.1729	0.0977
6	0.0000	0.0000
7	0.1867	0.7470
8	10.2480	0.4270
SNOW WATER	0.000	

****
****

APPENDIX N-2-2

MULTIMED MODEL

CONTENTS

1 ALTERNATIVE LINER SYSTEM DESIGN DEMONSTRATION MODELING PARAMETERS **N-2-2-1**
1.1 Chemical Modeling Parameters N-2-2-1
1.2 Source Modeling Data N-2-2-1
1.3 Unsaturated Zone Modeling Data N-2-2-1
1.4 Aquifer Modeling Data N-2-2-1

2 MULTIMED MODEL RESULTS **N-2-2-4**

APPENDIX N-2-2A
Alternative Liner System Design Demonstration Figures

APPENDIX N-2-2B
MULTIMED Program Output

1 ALTERNATIVE LINER SYSTEM DESIGN DEMONSTRATION MODELING PARAMETERS

1.1 Chemical Modeling Parameters

Chemical decay was not modeled for the purposes of this demonstration. Such processes would, in fact, act to naturally reduce chemical concentrations, but these processes were conservatively disregarded. All chemical decay process constants were set to zero in the MULTIMED model in order to deactivate those portions of the model.

1.2 Source Modeling Data

Source data are listed in Table 1-1 of this appendix. The estimated percolation through the alternative liner was calculated in Appendix N-2-1.

1.3 Unsaturated Zone Modeling Data

The unsaturated zone was not modeled as part of this alternative liner design demonstration. The attenuating effects of the unsaturated zone were conservatively disregarded.

1.4 Aquifer Modeling Data

Aquifer data are listed in Table 1-2 of this appendix.

Table 1-1
Source-Specific Modeling Data

Variable Name		Units	Value	Comments
Infiltration Rate	Interim 50 ft	m/yr	2.29×10^{-6}	Calculated using HELP Model (Appendix N-2-1)
	Closed 150 ft	m/yr	4.63×10^{-6}	Calculated using HELP Model (Appendix N-2-1)
Area of Waste Disposal Unit		m^2	265,069	65.5 acres (area of alternative liner)
Spread of Contaminant Source		m		Derived by MULTIMED
Recharge Rate		m/yr	0.108	Diluting effects of rainfall were conservatively assumed to be 10% of the average annual rainfall (10% of average annual rainfall = 4.246 inches or 0.108 m).
Initial Concentration at Landfill		mg/l	1.0	Set at 1.0 to find DAF
Length Scale of Facility		m		Derived by MULTIMED
Width Scale of Facility		m		Derived by MULTIMED

Table 1-2
Aquifer-Specific Modeling Data

Variable Name	Units	Value	Comments
Particle Diameter	cm	--	Not used when user specifies porosity
Aquifer Porosity	Unitless	0.10	From Appendix E, Subsurface Investigation
Bulk Density	g/cc	2.53	From Ref. 1, Table 6-11, p. 99, Bulk density for various geologic materials
Aquifer Thickness	m	1.26	From Appendix E, Subsurface Investigation and groundwater study (average saturate thickness, 4.14 ft)
Mixing Zone Depth	m		Derived by MULTIMED
Hydraulic Conductivity	m/yr	918.0	From Appendix E, Subsurface Investigation and Groundwater Study (9.18×10^{-3} cm/s). This value represents the maximum of the reported horizontal hydraulic conductivity values for the northern expansion area (Appendix E, Table 3-5).
Hydraulic Gradient	m	0.014	From Appendix E, Subsurface Investigation and Groundwater Study
Groundwater Seepage Velocity	m/yr		Derived by MULTIMED
Retardation Coefficient	Unitless		Derived by MULTIMED
Longitudinal Dispersivity	m		Derived by MULTIMED
Transversal Dispersivity	m		Derived by MULTIMED
Vertical Dispersivity	m		Derived by MULTIMED
Organic Carbon Content	%	0	Conservative assumption.
Receptor Distance From Site	m	91.4	This represents the shortest distance between a undeveloped and the nearest monitor well. In this case, the distance was measured from the southwestern toe of excavation of Cell 15 to the hypothetical downgradient POC well, MW-11 (approximately 230 ft or 70.1 m).
Z-Distance From Water Table	m	0	Assume water table at bottom of liner. To be conservative the attenuating effect of an unsaturated zone is not considered.

1. Sharp-Hansen, S., Travers, C., Hummel, P., and Allison, T., 1990. *A Subtitle D Landfill Application Manual For The Multimedia Exposure Model (MULTIMED)*, U.S. Environmental Protection Agency, p. 470.

2 MULTIMED MODEL RESULTS

Modeling was performed using MULTIMED to evaluate the design of the alternative liner system by estimating constituent concentrations at the POC for (1) the interim landfill configuration with the highest predicted percolation rate calculated in HELP and (2) the closed landfill configuration. The constituent concentrations at the base of the landfill liner and at the POC were used to calculate the DAF. Per DEQ guidance information, the Appendix B MCLs must not be exceeded. This is equivalent to calculating a DAF of more than 500.

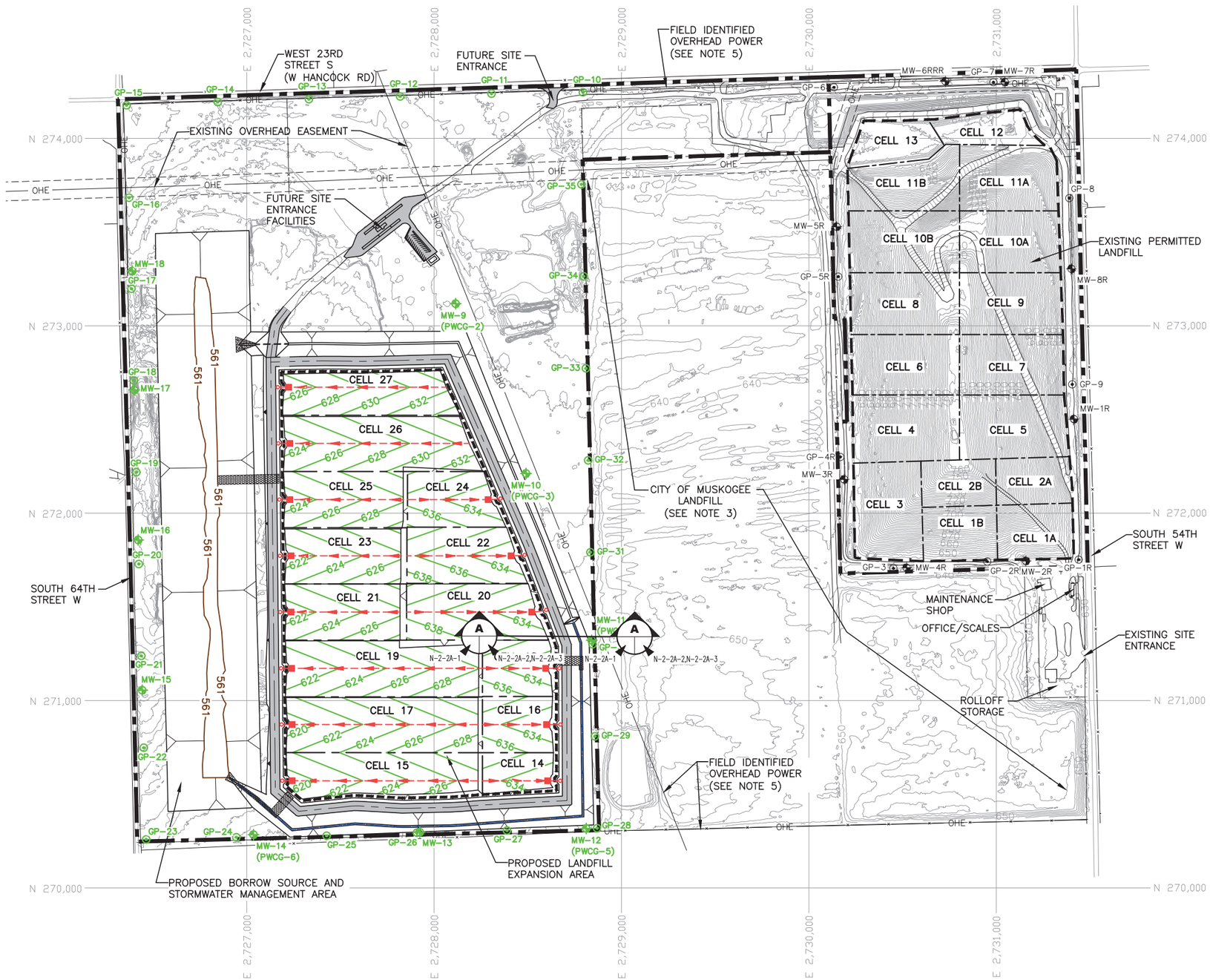
Table 2-1
MULTIMED Model Results for Alternative Liner Design Demonstration

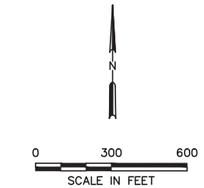
Modeling Condition	Concentration at POC (mg/L)	DAF
Interim Condition (50 ft)	0.1073×10^{-3}	9,320
Closed Condition (150 ft)	0.2080×10^{-3}	4,808

The lowest calculated DAF is 4,808. The results demonstrate that the proposed liner system exceeds the requirements of OAC 252:515-11-2(c) because the DAF calculated is in excess of the 500 minimum criterion. The actual DAF is expected to be higher than the DAF predicted by this modeling investigation because the model input parameters were conservatively estimated as discussed in previous sections of this report.

APPENDIX N-2-2A

ALTERNATIVE LINER SYSTEM DESIGN DEMONSTRATION FIGURES





LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA
10/13/2023

LEGEND

- EXISTING PERMIT BOUNDARY
- PROPOSED PERMIT BOUNDARY
- PERMITTED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- N 273,000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- 638 — TOP OF LINER CONTOUR
- 561 — SOIL BORROW CONTOUR
- CELL BOUNDARY
- PROPOSED LEACHATE LINE
- PROPOSED LEACHATE SUMP
- PROPOSED DRAINAGE CHANNEL
- OHE — EXISTING OVERHEAD EASEMENT
- MW-5R — EXISTING GROUNDWATER MONITORING WELL
- MW-9 (PWCG-1) — PROPOSED GROUNDWATER MONITORING WELL
- GP-5 — EXISTING LANDFILL GAS MONITORING PROBE
- GP-10 — PROPOSED LANDFILL GAS MONITORING PROBE

NOTES:

1. EXISTING CONTOURS AND ELEVATIONS PROVIDED BY HYDREX ENVIRONMENTAL COMPILED FROM AERIAL PHOTOGRAPHY FLOWN 01-25-2023.
2. THE EXPANSION WILL ADD A SEPARATE UNIT TO THE WEST OF THE EXISTING LANDFILL. NO CHANGES ARE PROPOSED TO THE EASTERN UNIT.
3. THE CITY OF MUSKOGEE LANDFILL IS NOT PART OF THE PROPOSED EXPANSION AND IS SHOWN FOR REFERENCE PURPOSES.
4. PERMIT BOUNDARY AND EXISTING OVERHEAD EASEMENTS WERE REPRODUCED FROM LEGAL DESCRIPTION PREPARED BY WEAVER CONSULTANTS GROUP, SIGNED BY MICHAEL D BYTNER, LLS# 1986.
5. AN EASEMENT RECORD WAS NOT FOUND OR PROVIDED TO THE SURVEYOR. THE OVERHEAD POWER RUNNING ALONG THE NORTHERN AND SOUTHERN PROPERTY LINE AND NORTHWEST/SOUTHEAST ACROSS THE PROPERTY WAS FIELD IDENTIFIED AND SURVEYED.

☐ DRAFT
☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 10/2023
FILE: 0086-364-11
CAD: N-2-2A-1-LINER PLAN.DWG

DRAWN BY: JDW
DESIGN BY: JBP
REVIEWED BY: JVQ

Weaver Consultants Group
CA 3804 PE - 06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION
TOP OF LINER PLAN

MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

WWW.WCGRP.COM

FIGURE N-2-2A-1

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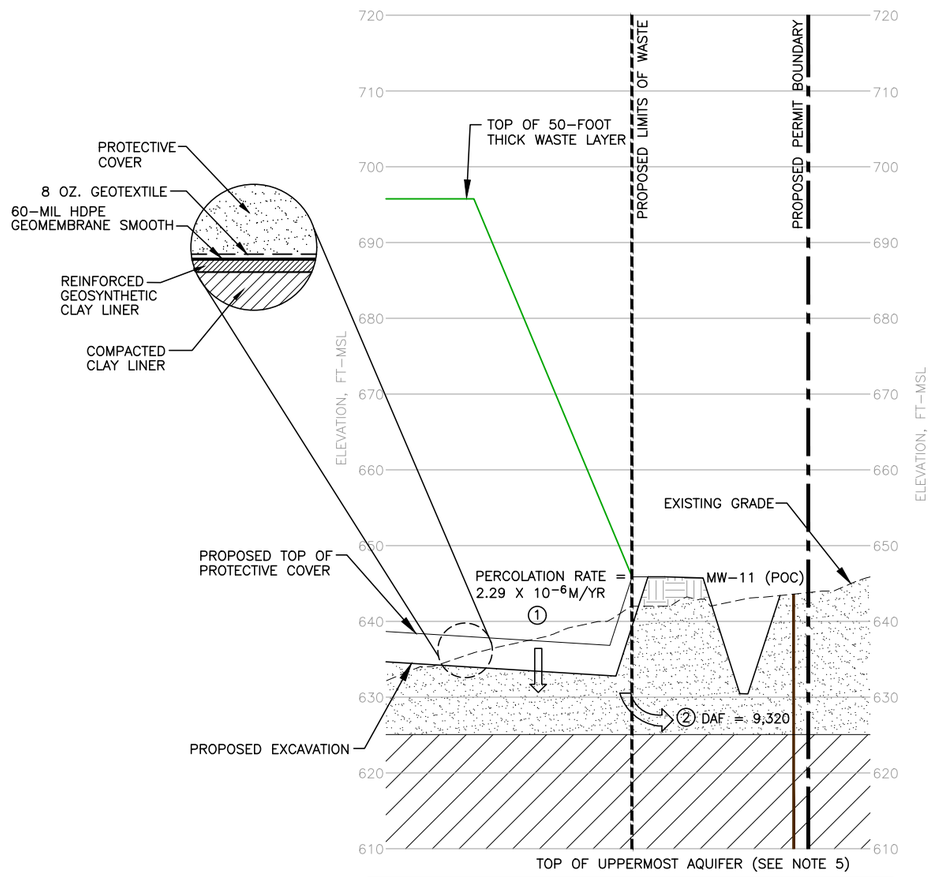
O:\0086\364\EXPANSION 2022\APPENDIX NN-2-2A-1-TOP OF LINER PLAN.dwg, jpdhr, 1:2

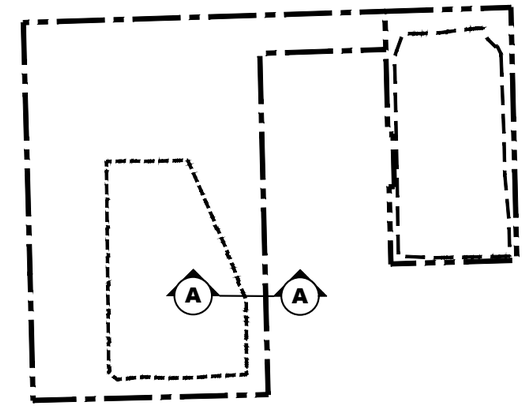


MULTIMED INFORMATION	
AVERAGE AQUIFER THICKNESS	1.26 M (10 FT)
HYDRAULIC CONDUCTIVITY	918 M/YR (2.53 X 10^{-3} CM/S)
HYDRAULIC GRADIENT	0.014
DISTANCE TO POINT OF COMPLIANCE	70.1 M (300 FT)

SECTION A
(EXAGGERATED VERTICAL SCALE)
A

0 100 200
HORIZONTAL SCALE IN FEET

0 10 20
VERTICAL SCALE IN FEET



KEY MAP
(NTS)

LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA
10/13/2023

LEGEND

- EXISTING PERMIT BOUNDARY
- PROPOSED PERMIT BOUNDARY
- PERMITTED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- EXISTING GRADE
- SURFICIAL SEDIMENTS
- WEATHERED SHALE
- FILL MATERIAL

DEMONSTRATION PROCEDURE

1. CALCULATE PERCOLATION RATE USING HELP.
2. CALCULATE DILUTION ATTENUATION FACTOR (DAF) USING MULTIMED.

NOTES:

1. EXISTING CONTOURS AND ELEVATIONS PROVIDED BY HYDREX ENVIRONMENTAL COMPILED FROM AERIAL PHOTOGRAPHY FLOWN 01-25-2023.
2. SEE TABLE 2-2 FOR DISCUSSION OF ASSUMPTIONS.
3. GEOLOGY SHOWN REPRESENTS MODEL CONDITIONS, NOT ACTUAL SITE CONDITIONS.
4. SEE APPENDICES L-2 AND N-2-2 FOR HELP AND MULTIMED MODELING DEMONSTRATION CALCULATIONS.
5. THE TOP OF UPPERMOST AQUIFER RANGES FROM 601 FT-MSL TO 600 FT-MSL AS SHOWN ON FIGURE E-1-11 IN APPENDIX E.

☐ DRAFT
☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 10/2023
FILE: 0086-364-11
CAD: N-2-2A-2-INTERIM CON. PROFILE.DWG

DRAWN BY: JDW
DESIGN BY: JBP
REVIEWED BY: JVQ

Weaver Consultants Group
CA 3804 PE - 06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION
TYPICAL PROFILE
INTERIM CONDITION (50 FOOT OF WASTE)

MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

WWW.WCGRP.COM

FIGURE N-2-2A-2

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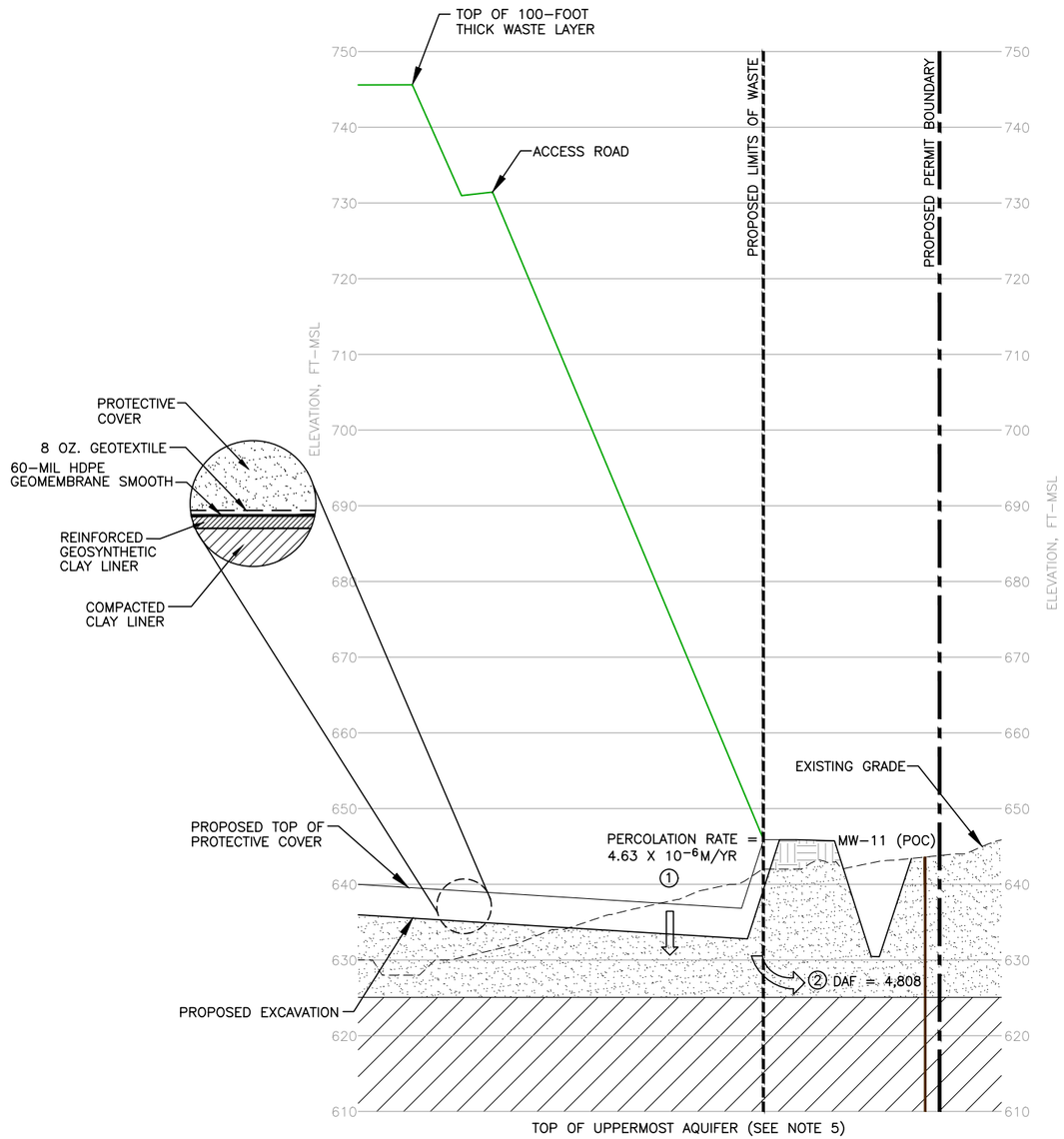
G:\0086\364\EXPANSION 2022\APPENDIX N\N-2-2A-2-INTERIM CONDITIONS PROFILE.dwg, jpnbr, 1:2

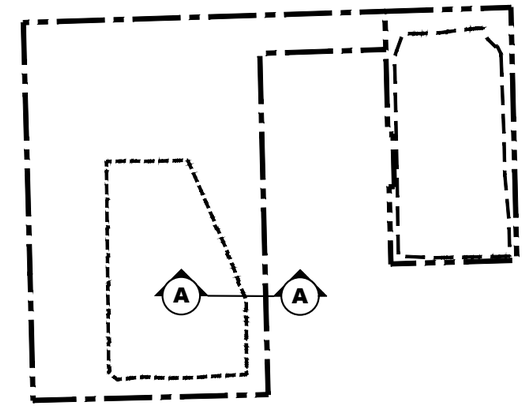


MULTIMED INFORMATION	
AVERAGE AQUIFER THICKNESS	1.26 M (10 FT)
HYDRAULIC CONDUCTIVITY	918 M/YR (2.53 X 10^{-3} CM/S)
HYDRAULIC GRADIENT	0.014
DISTANCE TO POINT OF COMPLIANCE	70.1 M (300 FT)

SECTION A (EXAGGERATED VERTICAL SCALE) **A**

0 100 200
HORIZONTAL SCALE IN FEET

0 10 20
VERTICAL SCALE IN FEET



KEY MAP
(NTS)

LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA
10/13/2023

LEGEND

- EXISTING PERMIT BOUNDARY
- PROPOSED PERMIT BOUNDARY
- PERMITTED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- EXISTING GRADE
- SURFICIAL SEDIMENTS
- WEATHERED SHALE
- FILL MATERIAL

DEMONSTRATION PROCEDURE

1. CALCULATE PERCOLATION RATE USING HELP.
2. CALCULATE DILUTION ATTENUATION FACTOR (DAF) USING MULTIMED.

NOTES:

1. EXISTING CONTOURS AND ELEVATIONS PROVIDED BY HYDREX ENVIRONMENTAL COMPILED FROM AERIAL PHOTOGRAPHY FLOWN 01-25-2023.
2. SEE TABLE 2-2 FOR DISCUSSION OF ASSUMPTIONS.
3. GEOLOGY SHOWN REPRESENTS MODEL CONDITIONS, NOT ACTUAL SITE CONDITIONS.
4. SEE APPENDICES L-2 AND N-2-2 FOR HELP AND MULTIMED MODELING DEMONSTRATION CALCULATIONS.
5. THE TOP OF UPPERMOST AQUIFER RANGES FROM 601 FT-MSL TO 600 FT-MSL AS SHOWN ON FIGURE E-1-11 IN APPENDIX E.

☐ DRAFT
☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 10/2023
FILE: 0086-364-11
CAD: N-2-2A-3-INTERIM CON. PROFILE.DWG

DRAWN BY: JDW
DESIGN BY: JBP
REVIEWED BY: JVQ

Weaver Consultants Group
CA 3804 PE - 06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION
TYPICAL PROFILE
INTERIM CONDITION (100 FOOT OF WASTE)

MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

WWW.WCGRP.COM

FIGURE N-2-2A-3

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O:\0086\364\EXPANSION 2022\APPENDIX N\N-2-2A-3-INTERIM CONDITIONS PROFILE.dwg, jpuhr, 1:2

APPENDIX N-2-2B

MULTIMED PROGRAM OUTPUT

Includes pages N-2-2B-1 through N-2-2B-6

INTERIM LANDFILL CONFIGURATION
(50-FOOT WASTE)

U. S. E N V I R O N M E N T A L P R O T E C T I O N A G E N C Y

E X P O S U R E A S S E S S M E N T

M U L T I M E D I A M O D E L

MULTIMED (Version 1.01, June 1991)

1

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

MUSKOGEE - ALTERNATIVE LINER

INTERIM 50 FT
Chemical simulated is DEFAULT CHEMICAL

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

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Reference temperature	C	CONSTANT	20.0	-999.	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Henry`s law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.229E-05	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.256E+06	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.108	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.200E-03	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.100	-999.	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	2.53	-999.	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	1.26	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	918.	-999.	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.140E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	20.0	-999.	0.000E+00	100.
pH	--	CONSTANT	7.00	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.100E-05	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	70.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.1073E-03

CLOSED LANDFILL CONFIGURATION
(150-FOOT WASTE)

U. S. E N V I R O N M E N T A L P R O T E C T I O N A G E N C Y

E X P O S U R E A S S E S S M E N T

M U L T I M E D I A M O D E L

MULTIMED (Version 1.01, June 1991)

1

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

MUSKOGEE - ALTERNATIVE LINER

CLOSED 150 FT
Chemical simulated is DEFAULT CHEMICAL

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

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Reference temperature	C	CONSTANT	20.0	-999.	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	-999.	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Molecular weight	g/M	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	0.000E+00	-999.	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	0.000E+00	-999.	0.000E+00	100.
Henry`s law constant	atm-m^3/M	CONSTANT	0.000E+00	-999.	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00
Not currently used		CONSTANT	-999.	-999.	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.436E-05	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.265E+06	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.108	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.200E-03	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.100	-999.	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	2.53	-999.	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	1.26	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	918.	-999.	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.140E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Transverse dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Vertical dispersivity	m	FUNCTION OF X	-999.	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	20.0	-999.	0.000E+00	100.
pH	--	CONSTANT	7.00	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.100E-05	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	70.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

CONCENTRATION AFTER SATURATED ZONE MODEL 0.2080E-03

APPENDIX O

WASTE EXCLUSION PLAN

Note: This appendix includes the following:

- ODEQ approval letter for the current Waste Exclusion Plan (WEP) dated September 22, 2014.
- WEP submitted to ODEQ on September 9, 2014.

SCOTT A. THOMPSON
Executive Director

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

MARY FALLIN
Governor

September 22, 2014

Ms. Paula Carboni
Waste Management, Inc.
2801 S. 54th St.
Muskogee, OK 74401

Re: Updated Waste Exclusion Plan (WEP)
Muskogee Community Recycling & Disposal Facility (Permit No. 3551020)
Muskogee County, OK

Dear Ms. Carboni:

The Oklahoma Department of Environmental Quality (DEQ) received the Updated Waste Exclusion Plan (WEP) for Muskogee Community Recycling & Disposal Facility on September 12, 2014. The WEP was updated to include management procedures for oil-field waste. These procedures incorporate the non-hazardous industrial waste requirements set forth in the July 19, 2014 DEQ letter.

The WEP is accepted as submitted. If you have any questions, please contact Rachel Hanigan at (405) 702-5196.

Sincerely,

Hillary Young

Hillary Young, P.E.
Chief Engineer
Land Protection Division

HY/rh

707 NORTH ROBINSON, P.O. BOX 1677, OKLAHOMA CITY, OKLAHOMA 73101-1677

printed on recycled paper with soy ink

WASTE MANAGEMENT

MUSKOGEE COMMUNITY RECYCLING
AND DISPOSAL FACILITY

2801 S. 54TH Street
Muskogee, Oklahoma 74401
(918) 682-7284
Fax (918) 682-2867

September 9, 2014

Hillary Young., P.E.
Engineering Manager
Solid Waste Permitting
Oklahoma Department of Environmental Quality
707 North Robinson
Oklahoma City, OK 73101

SUBJECT: Updated Waste Exclusion Plan (WEP)
Tier I Permit Modification
Muskogee Recycling and Disposal Facility, MSW Permit No. 3551020
Muskogee County, Oklahoma

Dear Ms. Young:

The purpose of this permit modification, submitted on behalf of Waste Management of Oklahoma, Inc., (WMO) and Muskogee Recycling and Disposal Facility (RDF), is to update the waste exclusion plan. The modification has been prepared as required by Oklahoma Administrative Code (OAC) 252:515-29-2(b). This plan is being submitted to the agency to replace the current WEP that was submitted in 2012. A copy of this plan will be put in the site's operating record.

If you have any questions, or need any additional information, please call me at (214)796-8710 or email me at pcarboni@wm.com.

Sincerely,

Paula Carboni
Area Environmental Manager
Waste Management of Oklahoma, Inc

cc: Pete Schultze, WMO (operating record)

WASTE MANAGEMENT

Updated Waste Exclusion Plan

For
Muskogee Recycling & Disposal Facility
Muskogee, Oklahoma
Permit # 3551020

June 2004
Revised September 2014

Muskogee
September 2014

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1.0 TABLE OF CONTENTS

2.0 PRE-ACCEPTANCE PROCEDURES

3.0 INCOMING WASTE PROCEDURES

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7.0 RECORDKEEPING AND MONTHLY REPORTING

8.0 ASBESTOS MANAGEMENT

9.0 OIL-FIELD WASTE MANAGEMENT

ATTACHMENTS

ATTACHMENT A	DOCUMENTATION USED FOR NHIW APPROVALS
ATTACHMENT B	APPENDIX F NHIW WASTESTREAMS
ATTACHEMENT C	WRITTEN APPROVAL
ATTACHMENT D	NHIW WASTE TRACKING FORM
ATTACHMENT E	RANDOM LOAD INSPECTION FORM
ATTACHMENT F	TRAINING DOCUMENT FORM

1.0 Introduction

The purpose of this document is to present an updated Waste Exclusion Plan (WEP) for nonhazardous industrial waste (NHIW) acceptance at Quarry Recycling & Disposal Facility (RDF) in accordance with Subchapter 29 and 31 of the OAC 252:515. The WEP specifically provides pre-acceptance procedures to determine the acceptability of a waste pursuant to facility permit conditions, operational capabilities, and state and federal regulations. The program sets forth procedures to monitor incoming waste loads and verify that the incoming waste corresponds with the pre-acceptance waste characterization and the provisions of the facility permit.

This WEP additionally sets forth methods as precautions and controls to determine record and monitor incoming wastes to detect and prevent entry or disposal of regulated hazardous wastes, regulated polychlorinated biphenyl's (PCB) wastes, radioactive, regulated infectious biomedical wastes, or other unpermitted wastes. Hazardous wastes are wastes defined as hazardous waste in OAC 252:515 and/or by the Federal government under the Resource Conservation and Recovery Act (RCRA) and subsequent amendments. Additionally, this program includes a control and record keeping system for tabulation of information obtained from these procedures. The program sets forth for the notification to the administrative authority of the rejection and removal of any wastes that may be reclassified as an excluded waste subsequent to acceptance and/or disposal.

2.0 Pre-Acceptance Procedures

Pre-acceptance procedures are used to determine the acceptability of a waste into the facility. These procedures reasonably ensure that (1) regulated hazardous wastes, (2) PCB wastes, (3) radioactive wastes, (4) untreated regulated infectious biomedical wastes, and (5) other unpermitted wastes are excluded from disposal at Quarry RDF. The pre-acceptance procedure is the process by which a decision to accept or reject a particular waste is made prior to its shipment to the facility. The procedure is based on provisions of the facility permit, current state and federal regulations, employee health/safety, and the environment. Pre-acceptance requirements specify what information regarding the waste a generator must provide before a determination can be made pertaining to acceptability for disposal. Pre-acceptance requirements may include, but are not limited to, laboratory analysis and associated quality assurance/quality control data, material safety data sheets, process flow diagrams, and generator process knowledge information. Whether or not the above information is required is based upon type of industrial generator, and characteristics of each individual waste stream. Information pertaining to the waste is submitted to Waste Management's (WM) designated Waste Evaluation Program for disposal consideration.

The generator of a NHIW that will be considered for disposal will complete WM's Waste Profile Form, the ODEQ NHIW Certification Form, if applicable, and supply any process knowledge information, material safety data sheets, laboratory results, or other documentation/certifications as required by the Waste Evaluation Program in order to determine the waste is non-hazardous. **Attachment A** contains copies of typical WCDF, ODEQ NHIW Certification Form, and other forms that may be used in the approval process. Based on this information, the Waste Evaluation Program will determine if the waste is acceptable or if additional testing or information is necessary before a decision can be made. Analytical test methods will be consistent with Federal and State approved methods.

As per OAC 252:515:31-2a, 3a, & 3b, the generator who generates waste streams identified in 515:31 Appendix F, **Attachment B**, and generate >10 cubic yards per month are required to complete the ODEQ NHIW Certification form.

Prior to acceptance, the following shall be completed through the Waste Evaluation Program:

- review waste profiles and associated documentation to ensure acceptability of waste into the landfill
- review landfill permits, state, and federal requirements regarding acceptance of NHIW
- issue waste specific approvals after reviewing necessary data and waste is determined to be acceptable NHIW

Waste Evaluation Personnel have experience and/or training in the following areas:

- waste evaluation and approval procedures
- analytical tests necessary for waste determination
- interpreting analytical results and significance of laboratory QA/QC
- definition of hazardous waste and exclusions
- basic chemistry
- definition of NHIW and current regulatory procedures for managing NHIW

- facility's approved programs and procedures including WEP
- notification and recordkeeping requirements
- asbestos acceptance
- sources of radiation and radiation safety

If a waste is shown to be characteristically hazardous, listed hazardous, radioactive, untreated regulated infectious biomedical, or to contain regulated concentrations of PCB, the waste will not be approved for disposal. A nonhazardous waste may not be approved for disposal based on physical characteristics such as extreme odor or incompatibility with other waste streams. Waste Management reserves the right to reject any NHIW waste stream.

If the waste is deemed acceptable by the Waste Evaluation Program, a copy of the approval is sent to the facility. The approval includes the generator and waste name, volume approved, if applicable, any acceptance conditions, restrictions, or applicable operational requirements thought necessary to protect human health and the environment, analytical data, expiration date and ODEQ NHIW Certification Form. **Attachment C** contains a typical written approval. The expiration date will not exceed three years from the date of approval. The generator is responsible for notifying the ODEQ and Waste Management immediately if the NHIW generating process or waste stream changes.

The Waste Evaluation Program also identify any special management procedures that may be required for disposal. For example, a dusty waste may be required to be containerized before shipment to the landfill and the landfill operators may be instructed to bury the container rather than directly compacting to reduce blowing dust on the working face.

After approval from the Waste Evaluation Program is obtained, the generator/customer is required to sign a Service Agreement that lists terms and conditions that include waste restrictions. Every customer who has an account with the facility, including residential trash-hauling companies, signs a Service Agreement that includes waste restrictions. As a reminder to every incoming vehicle at the facility, signs indicating restricted wastes are posted along the landfill entrance.

The Waste Evaluation Program will conduct periodic reviews of each approved NHIW at least every three years based upon the variability and quantity of waste. For these periodic reviews, the NHIW generator will complete either a new waste profile or a Recertification of Generator's Waste Profile Sheet, **Attachment A**. On a periodic basis, for each approved NHIW, current analyses will be requested from the generator as necessary. The frequency at which updated analytical testing will be requested will be determined by the Waste Evaluation Program and based upon potential variability and quantity of the waste received at the site. If analyses are determined to be necessary, new analytical testing will be provided at least every four years. As per OAC 252:515-3c, in the event a NHIW process or waste stream changes, the generator shall immediately notify the DEQ and WM of such change and update appropriate paperwork.

3.0 Incoming Waste Procedures

After the waste approval has been obtained from the Waste Evaluation Program and the generator has been notified of any restrictions/requirements associated with the waste, necessary information is communicated to the disposal facility. Information regarding each approved NHIW is available at the disposal facility. When an NHIW load arrives at the landfill it is required to be accompanied by a signed tracking document which specifies generator and waste information if the generator disposes greater than ten cubic yards in a calendar month. **Attachment D** contains a typical NHIW tracking document. Scale house personnel review the tracking document and ensure that the corresponding approval is valid.

All NHIW waste is viewed at the scalehouse and/or as it is off-loaded at the active work face by facility personnel. If an inconsistency in the waste or any potentially hazardous waste is identified, the material will not be processed and the generator and Waste Evaluation Personnel will be notified. If the discrepancy cannot be reasonably explained by the generator and approved immediately by WM Waste Evaluation Program, the waste will be reloaded and rejected or properly managed by WM. See Section 5.0 for further information.

All waste, including residential and commercial trash, is viewed while processing at the work face for identification of potentially hazardous, radioactive, PCB bearing, free liquids (unless previously approved as a liquid waste stream for solidification), unapproved NHIW, and potentially regulated infectious waste. Facility personnel are trained, as described in Section 6.0, to identify potentially unacceptable waste.

As required by OAC 252:515 29-3(a)(b) random load inspections of incoming waste will be conducted on a regular basis to ensure that incoming loads do not contain prohibited wastes. Random load inspections will be conducted at a frequency of five inspections per month. The inspections shall include at a minimum the date and time of inspection, the person conducting the inspection and the result of the inspection. **Attachment E** contains a typical random load inspection. Random load inspections will be maintained in the operating record for review.

If WM personnel identify any hazardous waste, radioactive waste, PCB bearing, or regulated infectious waste, the waste will be rejected and the Department will be notified as indicated in Section 5.0.

4.0 Waste Restrictions

Waste defined as characteristically hazardous or listed hazardous by 40 CFR 261 will not be approved for disposal at the facility. Regulated PCB, untreated infectious biomedical, or radioactive wastes will also not be approved for disposal at the facility.

All wastes defined in OAC 252:515-31-2 will be managed with the pre-acceptance approval process described in Section 3.0. The following wastes may not be subject to the pre-acceptance approval process but may require special handling at the landfill:

- uncontaminated asbestos (will still require manifest & waste shipment record)
- slaughterhouse waste, dead animals (may be required to be buried before compacting)

Also, as defined in OAC 252:515-31-1, generators disposing of less than 10 cubic yards of NHIW per calendar month may be excluded from the approval process described in Section 3.0. However, verification that the waste is not hazardous may still be required.

Transporters will be asked to communicate what type of waste they are carrying while at the scalehouse. Any waste requiring special handling will be identified and communication will be made to the disposal area. Operators at the disposal area will view all loads.

Friable asbestos containing waste is managed at the facility in accordance with state and federal regulation. Friable asbestos containing waste will be managed in accordance with all applicable regulations, including OAC 252:515-19-31. See Section 8.0 for further information.

5.0 Waste Rejection and Notification Procedures

As per OAC 252:515 29-3e, the Solid Waste Management Division of the Oklahoma DEQ will be notified by the end of the next working day if any waste identified and rejected prior to receipt as a prohibited waste; or any load identified and rejected at the gate, during random inspections, or upon disposal at the working face, as a prohibited waste.

The notification will include the reason for rejection, date of rejection, the name, address, phone number and contact person of the waste generator when such data can be obtained; and/or the name of driver, tag number of the vehicle, carrier name, address, telephone number, and contact person if such information can be obtained.

If radioactive waste is identified in incoming waste at the landfill, it will be isolated and DEQ Radiation Management will be notified immediately. The waste will not be transported from the landfill until a DOT exemption can be issued.

As per OAC 252:515 29-3f, if WM is unable to determine the generator of the restricted waste, the waste will be segregated and covered with a tarp or earthen material (if can be accomplished safely) or put in a container and tarped until proper characterization and disposal can be implemented.

As per OAC 252:515 29-3g, if WM must properly handle the rejected waste for proper disposal, a hazardous waste determination will be made on the waste. Once determination is completed, WM will properly manage the waste.

As per OAC 252:515 29-3h, WM will submit verification of proper disposal to the DEQ and a copy will be filed in the site operating record.

6.0 Training of On-Site Personnel

As per OAC 252:515 29-3(c)(d), landfill personnel responsible for waste acceptance will receive training in waste acceptance/exclusion procedures. The training will include the following topics:

- review of the WEP and WEP implementation procedures
- discussion of employees responsibilities pertaining to waste exclusion
- discussion of approval/pre-acceptance procedures
- definition and examples of NHIW
- discussion of necessary documentation for NHIW
- discussion of inspection procedures
- definition, recognition, and specific examples of hazardous waste, regulated infectious waste, radioactive waste, and PCB waste.
- operating procedure when a potentially hazardous/dangerous waste is identified
- internal notification procedure when a questionable waste is identified
- notification requirements
- recordkeeping and reporting requirements (including monthly reports)

This training may be conducted in several segments throughout the year. Facility personnel will receive at least eight hours of initial training per year. Annual refresher training will be done a minimum of 4 hours per year for each employee. Each training session will be documented and a record will be kept for each employee. **Attachment F** contains a typical training documentation form. Trained personnel will be on site during landfill operating hours.

7.0 Recordkeeping and Monthly Reporting

As per OAC 252:515 29-4 and 252:515 31-4, all information required to approve NHIW will be maintained at the disposal facility. This information will include the WCDF, written approval from the Waste Evaluation Program, and may include any of the following used to characterize the waste;

- ODEQ NHIW Certification Form
- laboratory analysis
- MSDS
- process knowledge information
- certifications
- manifests
- DEQ approval letters if WM chooses to gain DEQ approval of a particular NHIW

Monthly NHIW reports will be submitted to the Oklahoma DEQ including waste type, quantity, and source of waste disposed during the month. The monthly NHIW report will include, at a minimum, all generators who dispose of greater than ten cubic yards per month. These reports will be submitted no later than the last day of the month following the reporting period.

8.0 Asbestos Management

The information in this section discusses proper management of asbestos containing waste that is received by the WM Quarry Landfill. WM used the ODEQ Guidance on Asbestos Management for this section of the WEP.

The definition of regulated asbestos-containing material (RACM) includes the following:

- Friable asbestos material
- Category I nonfriable asbestos-containing material (ACM) that becomes friable
- Category 1 nonfriable ACM that will be or has been subjected to sanding, grinding, cutting, or abrading
- Category II nonfriable ACM that has a high probability of becoming or has become crumbled, pulverized, or reduced to powder

Friable asbestos received at the landfill must be wetted and packaged as described below:

- Double bagged in 6-mil plastic bags: or
- Single bagged in one 6-mil plastic bag and placed in a disposable drum; or
- Contained in any other manner approved in advance, by Air Quality Division director of the DEQ.

Bulk components containing friable asbestos received at the landfill must be:

- Wrapped with at least two layers of 6-mil plastic and duct tape (or other securing medium)

Any time RACM is off-loaded, vehicles or trailers must have the following:

- Warning signs visible from all sides with minimum 20 inches by 14 inches upright format that reads:

DANGER
ASBESTOS DUST HAZARD
CANCER AND LUNG DISEASE HAZARD
Authorized Personnel Only

- U.S. DOT Class 9 placards are required on each side and each end of any vehicle or trailer transporting quantities greater that 3 disposal bags, 1 disposal drum, or any amount of wrapped bulk RACM on public roadways.

The following are disposal procedures to be followed at the landfill:

- Trucks are to approach the disposal locations as closely as possible for unloading of ACM waste;
- Bags, drums, and wrapped components shall be examined as the are off-loaded;
- Bags, drums, and wrapped components shall be placed on the ground at the disposal site, not pushed or thrown out of the trucks; and
- Personnel off-loading containers shall wear protective equipment consisting of head, body and foot protection and, at a minimum, half face-piece, air purifying, and dual-cartridge respirators equipped with high-efficiency filters.

All RACM must be covered with a minimum of 6 inches of compacted nonasbestos-containing material (i.e. uncontaminated soil) at the end of each operating day. Municipal solid waste, tarps, and alternate daily cover materials do not classify as nonasbestos-containing material.

All nonfriable asbestos material must cover with a minimum of 6 inches of nonasbestos-containing material prior to compaction or other landfill activities that could create RACM. In event RACM is created, the facility is responsible for fulfilling all NESHAP requirements.

The facility must comply with the following reporting requirements:

- Report in writing by the following working day is any significant amount of RACM is received improperly packaged or uncovered during landfill operations. A copy of the Waste Shipment Record (WSR) shall be included with report.
- A copy of the signed WSR must be sent to the generator within 30 days of receipt of the waste.
- If a discrepancy between quantity on the WSR and that actually received is not resolved within 15 days of receipt of the RACM, the facility must immediately report in writing to the DEQ. The report should include the discrepancy and attempts to reconcile it along with a copy of the WSR.

The WSR is required for RACM and contain the following information:

- Name, address, and phone number of the waste generator;
- Name, address, and phone number of the transporter(s);
- Quantity of RACM in cubic yards;
- Presence of improperly packaged RACM;
- Date of receipt

The WSRs and documentation of discrepancies shall between WSR and actual amounts be maintained in the facility's operating record for a minimum of two years.

The facility must maintain in operating records, until closure, the location of all RACM including the following:

- The depth and area;
- Quantity in cubic yards;
- A map of diagram depicting the location of the ACM waste.

The facility must notify the ODEQ in writing at least 45 days prior to excavation or otherwise disturbing any RACM that has been deposited and covered.

- Scheduled staring and completion dates;
- Reason for disturbing waste;
- Procedures to be used to control emissions, during the excavation, storage, transport, and ultimate disposal of the excavated RACM; and
- Location of any temporary storage site and the final disposal site,

9.0 Oil-Field Waste Management

The information in this section discusses proper receipt of oil-field waste that is received by the WM Quarry Landfill. WM used the July 19, 2014 ODEQ letter for this section of the WEP.

- NHIW certification form, **Attachment A**, must be submitted to the DEQ and WM by the generator and maintained in operating record of the disposal site.
- Each waste stream must have a separate NHIW certification for each type of waste material at each well site or other site from which waste is received.
- Recordkeeping for these wastes will follow Section 7.0 of the WEP
- NHIW certification forms should coincide with generator documentation required by OCC.

ATTACHMENT A

DOCUMENTATION USED FOR NHIW APPROVALS

- **Waste Management Profile Form**
- **Waste Management Process Knowledge Form**
- **Profile Addendum: State of Oklahoma**
  - **Non-Hazardous Industrial Waste Notification/Certification Form**
  - **Letter of Authorization for Permission to Characterize, Ship, Dispose and Otherwise Represent Waste Streams**
- **Profile Amendment Request Form**
- **Profile Renewal Form**

WASTE MANAGEMENT

EZ Profile™

Requested Facility: _____ ❑ Unsure Profile Number: _____

❑ Check if there are multiple generator locations. Attach locations.

❑ COD ❑ Renewal? Original Profile Number: _____

A. GENERATOR INFORMATION (MATERIAL ORIGIN)

1. Generator Name _____
2. Site Address: _____
   (City, State, ZIP) _____
3. County: _____
4. Contact Name: _____
5. Email: _____
6. Phone: _____ 7. Fax: _____
8. Generator EPA ID: _____ ❑ N/A
9. State ID: _____ ❑ N/A

B. BILLING INFORMATION

❑ SAME AS GENERATOR

1. Billing Name: _____
2. Billing Address: _____
   (City, State, ZIP) _____
3. Contact Name: _____
4. Email: _____
5. Phone: _____ 6. Fax: _____
7. WM Hauled? ❑ Yes ❑ No
8. P.O. Number: _____

C. MATERIAL INFORMATION

1. Common Name: _____
   Describe Process Generating Material: ❑ See Attached
2. Material Composition and Contaminants: ❑ See Attached

1.	
2.	
3.	
4	
	≥100%

3. State Waste Codes: _____ ❑ N/A
4. Color: _____
5. Physical State at 70°F: ❑ Solid ❑ Liquid ❑ Other: _____
6. Free Liquid Range Percentage: _____ to _____ ❑ N/A (Solid)
7. pH: _____ to _____ ❑ N/A (Solid)
8. Strong Odor: ❑ Yes ❑ No Describe: _____
9. Flash Point: ❑ <140°F ❑ 140°–199°F ❑ ≥200° ❑ N/A (Solid)

D. REGULATORY INFORMATION

1. EPA Hazardous Waste? ❑ Yes* ❑ No
   Code: _____
2. State Hazardous Waste? ❑ Yes ❑ No
   Code: _____
3. Is this material non-hazardous due to Treatment, Delisting, or an Exclusion? ❑ Yes* ❑ No
4. Contains Underlying Hazardous Constituents? ❑ Yes* ❑ No
5. Contains benzene and subject to Benzene NESHAP? ❑ Yes* ❑ No
6. Facility remediation subject to 40 CFR 63 GGGGG? ❑ Yes* ❑ No
7. CERCLA or State-mandated clean-up? ❑ Yes* ❑ No
8. NRC or State-regulated radioactive or NORM waste? ❑ Yes* ❑ No

***If Yes, see Addendum (page 2) for additional questions and space.**

9. Contains PCBs? → If Yes, answer a, b and c. ❑ Yes ❑ No
   a. Regulated by 40 CFR 761? ❑ Yes ❑ No
   b. Remediation under 40 CFR 761.61 (a)? ❑ Yes ❑ No
   c. Were PCB imported into the US? ❑ Yes ❑ No
10. Regulated and/or Untreated Medical/Infectious Waste? ❑ Yes ❑ No
11. Contains Asbestos? ❑ Yes ❑ No
    → If Yes: ❑ Non-Friable ❑ Non-Friable – Regulated ❑ Friable

E. ANALYTICAL AND OTHER REPRESENTATIVE INFORMATION

1. Analytical attached ❑ Yes
   Please identify applicable samples and/or lab reports:
2. Other information attached (such as MSDS)? ❑ Yes

F. SHIPPING AND DOT INFORMATION

1. ❑ One-Time Event ❑ Repeat Event/Ongoing Business
2. Estimated Quantity/Unit of Measure: _____
   ❑ Tons ❑ Yards ❑ Drums ❑ Gallons ❑ Other: _____
3. Container Type and Size: _____
4. USDOT Proper Shipping Name: ❑ N/A

G. GENERATOR CERTIFICATION (PLEASE READ AND CERTIFY BY SIGNATURE)

By signing this EZ Profile form, I hereby certify that the information contained in this and all attachments is complete and relevant information necessary for proper material characterization and to identify hazards and potential hazards. I have sampled the material represented in this profile and/or have knowledge of the sampling and analytical methods used to have analytical data performed by the Generator and/or Waste Management Lab.

If I am an agent signing on behalf of the Generator, I have confirmed with the Generator that information contained in this Profile is accurate and complete.

Certification Signature

Name (Print): _____ Date: _____

Title: _____

Company: _____

THINK GREEN.

QUESTIONS? CALL 800.963.4776 FOR ASSISTANCE

WASTE MANAGEMENT PROCESS KNOWLEDGE FORM

Name of Waste: _____ Waste Code: _____

For all waste classes please indicate, based on process knowledge, that analysis for the following chemical constituents is **NOT REQUIRED:**

- ❑ TCLP Metals (Arsenic, Barium, Cadmium, Chromium, Lead, Mercury, Selenium, Silver)
- ❑ TCLP Volatiles (Benzene, Carbon Tetrachloride, Chlorobenzene, Chloroform, 1,2-Dicholorethane, 1,1-Dichloroethylene, Methyl Ethyl Ketone, Tetrachloroethylene, Trichloroethylene, Vinyl Chloride)
- ❑ TCLP Semi-Volatiles (o-Cresol, m-Cresol, p-Cresol, Cresol (total), Pentachlorophenol, 2,4,5-Trichlorophenol, 2,4,6-Tricholorophenol, 1-4, Dichlorobenzene, 2,4-Dinitritoluene, Hexachlorobenzene, Hexachlorobutadiene, Hexachloroethane, Nitrobenzene, Pyridine)
- ❑ TCLP Pesticides/Herbicides (Chlorodane, Endrin, Heptachlor, Heptachlor epoxide, Lindane, Methoxychlor, Toxaphane, 2,4-D, 2,4,5-TP (Silvex))
- ❑ R,C,I (Reactivity, Corrosivity, Ignitability Characteristics)
- ❑ Polychlorinated Biphenyls (TSCA regulated and as otherwise defined by federal, state, and/or local regulations)
- ❑ Radioactive Materials (as defined by federal, state, and/or local regulations)
- ❑ All applicable UHC (underlying hazardous constituents) and LDR (land disposal restrictions) regulatory issues have been evaluated and it has been determined that UHCs and LDRs are either not applicable or have been met.

Additionally, for Texas CLASS 2 INDUSTRIAL WASTES, please indicate based on process knowledge that analysis for the following constituents is **NOT REQUIRED:**

- ❑ TAC 335 Subchapter R, Appendix 1, Table 1, Constituents Not Listed Above or Analyzed For
- ❑ Class I Ignitable
- ❑ Class I Corrosive
- ❑ If waste is a petroleum substance or contains contamination from petroleum substances (as defined in TAC 335.1), total petroleum hydrocarbon (TPH) concentration is less than or equal to 1500 parts per million (ppm)

PLEASE DESCRIBE IN DETAIL PROCESS GENERATING WASTE/PROCESS KNOWLEDGE USED TO ELIMINATE PARAMETERS/CONSTITUENTS NOT TESTED FOR:

I certify that the above mentioned information contains true and accurate descriptions of the waste and that all relevant information regarding known or suspected hazards has been disclosed. I further certify that the waste describe above is not a "Hazardous Waste" as defined by USEPA regulations and/or State regulations.

Print Name: _____ Signature: _____

Title: _____ Date: _____

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March 2008

Profile Addendum: State of Oklahoma
NON-HAZARDOUS INDUSTRIAL WASTE NOTIFICATION/CERTIFICATION FORM

Generator Name: _____

Mailing Address: _____

City: _____ State: _____ Zip Code: _____

Point of Generation

General Contact: _____ Title: _____

Address: _____ City: _____

State: _____ Zip Code: _____ Telephone: ( ) _____

Waste Information

Waste Name: _____

If waste was generated out-of-state, is it classified as hazardous in the state of origin? Yes No NA-Okla Waste

The waste stream is: New Previously approved (Previous Approval Number _____)

Approximate amount of waste to be disposed under this disposal plan?

_____ Tons Pounds Cubic Yards Drum Other _____

Disposal Frequency?

One-time Weekly Monthly Annually

Physical Characteristics?

Solid Sludge Liquid Combination

Method used to determine waste is non-hazardous: Analysis Generator Knowledge Both

Process generating waste (be specific and use additional sheets if necessary):

_____

_____

Disposal Facility Information

Facility name: _____ Permit #: _____

Generator Certification

I understand this form must be signed by the original waste generator or other persons authorized by 27A O.S. §2-10-501(H).

To the best of my knowledge, I certify:

- The information contained herein is accurate, complete, and representative of the waste to be disposed;
- The waste identified above is not a characteristically hazardous waste as identified by 40 CFR 261, Subpart C, is not a listed hazardous waste as identified by 40 CFR 261, Subpart D or contaminated with a listed hazardous waste, and is not otherwise identified as a hazardous waste by the Department of Environmental Quality; and
- This waste will be managed in accordance with all applicable statutes and rules of the Department of Environmental Quality.

Generator's Signature: _____ **Title:** _____

Name: (Print) _____ **Date:** _____

FOR DEQ USE ONLY: Approved by: _____ Date: _____

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Profile Addendum: State of Oklahoma NON-HAZARDOUS INDUSTRIAL WASTE NOTIFICATION/CERTIFICATION FORM

Instructions for Completing the NHIW Certification

Enter the name of the generating facility, generator mailing address, address where the waste was generated, contact name and title of person at the generating facility who is knowledgeable about the waste, and phone number.

Detailed Waste Description

1. Identify the name of the waste.
2. Identify the approximate amount of waste to be disposed under the plan, its frequency of disposal, and its physical characteristics.
3. Identify if the waste was determined to be non-hazardous by either knowledge of process, testing, or both. If requested by DEQ, the generator must be able to provide information about the waste, such as a list of chemical constituents entering into the waste and a list of chemical constituents likely to be in the waste, laboratory analyses, MSDS sheets, and other information used by the generator to determine the waste is non-hazardous.
4. Identify the process generating the waste. Please note that the waste generating description must be specific and sufficient to demonstrate the waste is non-hazardous.

Designated Receiving Landfill

Identify the name of the landfill to receive the waste and its DEQ permit number.

Generator Certification

Read the certification and sign and date the form. **Please note that the certification may only be dated and signed by one of the following:** 1) the original waste generator; 2) a person who identifies and is under contract with a generator and whose activities under the contract cause the waste to be generated; 3) a party to a remediation project under an order of the DEQ or under the auspices for the Oklahoma Energy Resources Board or other agencies of other states; or 4) a person responding to an environmental emergency.

The completed notification from should be submitted to the DEQ at the following address. Once submitted, the generator may dispose of the waste at the designated landfill.

Department of Environmental Quality
Solid Waste Compliance Unit
P.O. Box 1677
Oklahoma City, OK 73102

Phone (405) 702-5100
Fax (405) 702-5101

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Profile Addendum: State of Oklahoma
LETTER OF AUTHORIZATION FOR PERMISSION TO CHARACTERIZE, SHIP, DISPOSE AND OTHERWISE REPRESENT WASTE STREAMS

F. Additional Waste Stream Information

This letter is being submitted to reflect and document that the Generator listed below has granted full and complete authorization, for

_____ (an) employee(s) of _____ company to sign all waste documents on
(Delegated individual or all) (Broker)

behalf of Generator. This document hereby authorizes _____ company
(Broker)

to function in the capacity of "generator" (as that term defined in state and federal rules and regulations) with regard to legally proper waste classification, representation, shipment and disposal and to otherwise act as Generator's agent to characterize, ship, dispose and otherwise represent all waste streams in accordance with all local, state and federal rules and regulations. Such authorization includes but is not limited to execution of the following types of waste-related documents:

- Waste Characterization Data (WCD) Forms/Waste Profiles
- Waste Manifests – Uniform Hazardous Waste Manifests and Non-Hazardous Manifests
- Process Knowledge Forms or Letters
- Waste Profile Amendment Request Forms
- WCD/Profile Recertification Forms
- Land Ban Forms
- One Time Waste Shipment Forms/Authorizations

_____ company is required to provide Generator with copies of all documents executed in accordance
(Broker)

with this authorization.

This authorization will expire on _____ or when written notice is provided by the generator to
(Expiration Date)

Waste Management revoking this authorization.

Respectfully,

Company Name: _____ Date: _____

Name (Print): _____

Signature: _____ Title: _____

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Profile Amendment Request Form

_____ hereby requests an amendment to WMI profile #: _____
(Contact Name)

to include the following:

Amendment Type: ❑ One Time Only Request (Event) ❑ Permanent Addition to Profile (Base)

❑ Additional Analytical/MSDS to be added to profile (see attached)

❑ Volume Increase (specify volume) _____ ❑ Tons ❑ Cubic Yards ❑ Drums ❑ Gallons ❑ Other (specify) _____

❑ Constituent(s) to be added and/or modify current range in chemical composition:

Chemicals or constituents to be added/modify	Low	High	Units
_____	____	____	____
_____	____	____	____
_____	____	____	____

❑ Change current ranges on profile (specify below)

pH Range _____ to _____ Free Liquid Range _____ to _____

❑ Other (specify) _____

GENERATOR CERTIFICATION

By signing this form, the Generator hereby certifies:
The information provided in this document, the referenced Waste Management Generator's Waste Profile Sheet, and all other referenced documents contain true and accurate descriptions of the waste material. All information regarding known or suspected hazards in the possession of the Generator has been disclosed.

Generator/Customer Signature: _____ Date: _____

Company Name: _____

Name (Print): _____ Title: _____

FOR WASTE MANAGEMENT USE ONLY

Submitted By: _____ Date: _____ Time: _____
(W.M. Initials)

WM Approval: _____ Date: _____

Agency Approval Required: ❑ Yes ❑ No

❑ Profile Extension

Original Expiration Date _____

Requested Extension _____

New Expiration Date _____

❑ Analytical Extension

Analytical Due Date _____

Requested Extension _____

New Analytical Due Date _____

Conditions/Precautions: _____

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August 2010

WASTE MANAGEMENT

EZ Profile™ Addendum

Only complete this Addendum if prompted by responses on EZ Profile™ (page 1) or to provide additional information. Sections and question numbers correspond to EZ Profile™.

Profile Number _____

C. MATERIAL INFORMATION

Describe Process Generating Material (Continued from page 1): If more space is needed, please attach additional pages.

Material Composition and Contaminants (Continued from page 1): If more space is needed, please attach additional pages.

5	
6	
7	
8	
9.	
10.	
	≥100%

D. REGULATORY INFORMATION

Only questions with a "Yes" response in Section D on the EZ Profile™ form (page 1) need to be answered here.

1. EPA Hazardous Waste
   a. Please list all USEPA listed and characteristic waste code numbers:
   b. Is the material subject to the Alternative Debris standards (40 CFR 268.45)? ☐ Yes ☐ No
   c. Is the material subject to the Alternative Soil standards (40 CFR 268.49)? → If Yes, complete question 4. ☐ Yes ☐ No
   d. Is the material exempt from Subpart CC Controls (40 CFR 264.1083 and 265.1084)? ☐ Yes ☐ No
   → If Yes, please select one of the following:
   ☐ Waste has been determined to be LDR exempt [265.1083(c)(4) and 265.1084(c)(4)] based on the fact that it meets all applicable organic treatment standards (including UHCs for D-coded characteristic wastes) or a Specified Technology has been utilized.
   ☐ Waste does not qualify for a LDR exemption, but the average VOC at the point of origination is <500 ppmw and this determination was based on analytical testing (upload copy of analysis) or generator knowledge.
2. State Hazardous Waste → Please list all state waste codes: _____
3. For material that is Treated, Delisted, or Excluded → Please indicate the category, below:
   ☐ Delisted Hazardous Waste ☐ Excluded Waste under 40 CFR 261.4 → Specify Exclusion: _____
   ☐ Treated Hazardous Waste Debris ☐ Treated Characteristic Hazardous Waste → If checked, complete question 4.
4. Underlying Hazardous Constituents → Please list all Underlying Hazardous Constituents:
5. Benzene NESHAP → Please include percent water/moisture in chemical composition.
   a. Are you a TSDF? → If yes, please complete Benzene NESHAP questionnaire. If not, continue.
   b. What is your facility's current total annual benzene quantity in Megagrams? ☐ <1 Mg ☐ 1-9.99 Mg ☐ ≥10 Mg
      1. Flow weighted average benzene concentration is _____ ppmw.
   c. Is this waste soil from remediation at a closed facility? ☐ Yes ☐ No
      1. Benzene concentration in remediation waste is _____ ppmw.
   d. Has material been treated to remove 99% of the benzene or to achieve <10 ppmw? ☐ Yes ☐ No
   e. Is material exempt from controls in accordance with 40 CFR 61.342? ☐ Yes ☐ No
   → If yes, specify exemption _____
   f. Based on your knowledge of your waste and the BWON regulations, do you believe that this waste stream is subject to treatment and control requirements at an off-site TSDF? ☐ Yes ☐ No
6. 40 CFR 63 GGGGG → Does the material contain <500 ppmw VOHAPs at the point of determination? ☐ Yes ☐ No
7. CERCLA or State-Mandated clean up → Please submit the Record of Decision or other documentation to assist others in the evaluation for proper disposal.
8. NRC or state regulated radioactive or NORM Waste → Please identify isotopes and pCi/g. _____

Additional Profile Information

Profile Number. _____

C. MATERIAL INFORMATION

Material Composition and Contaminants (Continued from page 2): If more space is needed, please attach additional pages.

11.	
12.	
13.	
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32.	
33.	
34.	
35.	
36.	
37.	
38.	
39.	
40.	
	≥100%

D. REGULATORY INFORMATION

1. EPA Hazardous Waste

a. Please list all USEPA listed and characteristic waste code numbers (Continued from page 2)

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EZ Profile Renewal Form

Profile Number: _____

Common Name: _____

Generator Name: _____

Disposal Site: _____

1. **Are there ANY changes in the raw materials used in the generating process or in the process itself?**

   ❑ Yes ❑ No

2. **Have you obtained any laboratory analysis or new applicable documents for this material?**

   ❑ Yes ❑ No

   → **If Yes, please attach and identify the new documents noting representative sample IDs and changes:**

RECERTIFICATION STATEMENT

By signing this form, the generator hereby certifies: The information provided in this document, the attached Waste Management's Generator's Waste Profile Sheet, and all other attached documents contain true and accurate descriptions of this material. All new information regarding known or suspected hazards in the possession of the generator have been disclosed.

Name: _____

Date: _____

Position/Title: _____

Company: _____

Certification Signature

THINK GREEN

ATTACHMENT B
APPENDIX F NHIW WASTE STREAMS

Muskogee
September 2014

APPENDIX F. NHIW WASTESTREAMS

(1) Air pollution control equipment residues
(2) Arsenically-treated wood that meets the exemption criteria of 40 CFR 261.4(b)(9)
(3) Auto shredder fluff
(4) Blasting media and other abrasives used to remove surface coatings
(5) Coal combustion ash per 40 CFR 261.4(b)(4)
(6) [illegible]
(7) Containers which are RCRA empty in accordance with 40 CFR [illegible] (e.g., empty containers which have held pesticides (i.e., herbicides, fungicides, or rodenticides)
(8) Cooling tower waters and other cooling process related wastes
(9) Incinerator ash
(10) Industrial sludges and industrial mud trap residues
(11) Industrial wastewater treatment plant sludge (excluding sludge that is exclusively sanitary sewage)
(12) Ink wastes
(13) Lab related wastes, including lab packs
(14) Lighting fixture ballasts containing non-TSCA regulated PCBs per 40 CFR Part 761
(15) Miscellaneous chemical spill residue, primarily non-fuel related
(16) Municipal and non-industrial wastewater treatment plant sludges
(17) Non-hazardous pesticides (i.e., herbicides, fungicides, & rodenticides)
(18) Oil filters meeting the requirements of 40 CFR 261.4(b)(13)
(19) Outdated and off-specification products
(20) Outdated, off-specification, or mislabeled over-the-counter medicines which are not hazardous in accordance with 40 CFR 261, Subparts C or D
(21) Paint waste and related solvents
(22) Petroleum contaminated soil and debris, oily rags and absorbents with > 1000 ppm TPH
(23) Pharmaceutical waste not identified in (20)
(24) Refractory & foundry sands and slag, retort, fly ash, cement kiln dust
(25) Resins, polymers, and adhesives
(26) Sludges containing materials washed from the interior of bulk materials carriers such as tank trucks or railroad tank cars
(27) Wastes exempted by the RCRA Bevill waste exclusion in 40 CFR 261.4(b)(7)
(28) Wastes rendered non-hazardous that were formerly hazardous pursuant to 40 CFR 261, Subpart C
(29) Unknowns
(30) Wastes from metal plating processes

ATTACHMENT C
WRITTEN APPROVAL

WASTE MANAGEMENT

Non-Hazardous WAM Approval

Requested Management Facility:

Profile Number: _____ Waste Approval Expiration Date: _____

APPROVAL DETAILS

Approval Decision ☐ Approved ☐ Not Approved Profile Renewal ☐ Yes ☐ No

Management Method _____

Generator Name _____

Management Facility Precautions, Special Handling Procedures or Limitation on approval.

[illegible] _____ [illegible] _____

[illegible] _____ [illegible] _____

Agency Authorization (if required) _____ [illegible] _____

THINK GREEN

ATTACHMENT D
NHIW WASTE TRACKING FORM

WASTE MANAGEMENT

NON-HAZARDOUS MANIFEST

NON-HAZARDOUS MANIFEST	1. Generator's US EPA ID No. Manifest Doc No.	2. Page 1 of	
3. Generator's Mailing Address: 4. Generator's Phone	Generator's Site Address (If different than mailing): SAME	A. Manifest Number WMNA	«number»
		B. State Generator's ID	
5. Transporter 1 Company Name WASTE MANAGEMENT	6. US EPA ID Number	C. State Transporter's ID D. Transporter's Phone	
7. Transporter 2 Company Name	8. US EPA ID Number	E. State Transporter's ID F. Transporter's Phone	
9. Designated Facility Name and Site Address	10. US EPA ID Number	G. State Facility ID H. State Facility Phone	

GENERATOR

11. Description of Waste Materials	12. Containers No	12. Containers Type	13. Total Quantity	14. Unit Wt./Vol.	I. Misc. / Waste Code
a. WM Profile #				Y	
b. WM Profile #					
c. WM Profile #					
d. WM Profile #					

J. Additional Descriptions for Materials Listed Above	K. Disposal Location			
	Cell		Level	
	Grid			

15. Special Handling Instructions and Additional Information

Purchase Order # EMERGENCY CONTACT / PHONE NO.:

16. GENERATOR'S CERTIFICATE:

I hereby certify that the above-described materials are not hazardous wastes as defined by CFR Part 261 or any applicable state law, have been fully and accurately described, classified and packaged and are in proper condition for transportation according to applicable regulations.

Printed Name	Signature	Month	Day	Year

TRANSPORTER

17. Transporter 1 Acknowledgement of Receipt of Materials

Printed Name	Signature	Month	Day	Year

18. Transporter 2 Acknowledgement of Receipt of Materials

Printed Name	Signature	Month	Day	Year

FACILITY

19. Certificate of Final Treatment/Disposal

I certify, on behalf of the above listed treatment facility, that to the best of my knowledge, the above-described waste was managed in compliance with all applicable laws, regulations, permits and licenses on the dates listed above.

20. Facility Owner or Operator: Certification of receipt of non-hazardous materials covered by this manifest.

Printed Name	Signature	Month	Day	Year

White- ORIGINAL Blue- TREATMENT, STORAGE, DISPOSAL FACILITY COPY Yellow- TRANSPORTER #2 COPY

Pink- TRANSPORTER #1 COPY Gold- GENERATOR #1 COPY

ATTACHMENT E
RANDOM INSPECTION FORM

Muskogee LF

LOAD CHECK INSPECTION REPORT

Hauler Company Name _____ Date _____ Time _____
(or "private citizen")
Driver 's Name _____ Vehicle license number and state _____
Telephone Number (___)_____

1. Type of vehicle:
   - ___Drop Box
   - ___Compactor
   - ___Dump Truck
   - ___Other _____
   - ___Pick up
   - ___Trailer
   - ___Car

2. Size of load:
   - ___cubic yards

3 Types of wastes:
   - ___Food waste
   - ___Paper waste
   - ___Yard debris
   - ___Cardboard
   - ___Wood
   - ___Sheetrock

4. Prohibited wastes which can be recycled:
   - ___Appliances
   - ___Lead acid batteries
   - ___Motor oil
   - ___Tires

5. Prohibited wastes:
   - ___None present
   - ___Liquid:

   type:_____
   _____
   _____
   amount_____gallons
   Solid: _____
   type:_____
   _____
   _____
   amount:_____

6. Action taken (*if prohibited or unauthorized wastes found*): _____
_____
_____

7. Additional comments (*if any*): _____
_____
_____

8. Name of Inspector:
_____

9. Signature of Inspector:
_____date_____

10. Name of Hauler:
_____

11. Signature of Hauler:
_____date_____

ATTACHMENT F
TRAINING DOCUMENTATION FORM

LIFCHGR

MEETING ATTENDANCE SHEET

(Photocopy this sheet prior to your safety meeting and place it in the room for employees to sign as they enter)

Date: Time: _____

Topic: _____

Presenter: _____ Department: _____

Printed Name	Signature	Printed Name	Signature

Instructions:
1. This form must be completed at each safety meeting.
2. Make additional copies as required.
3. Keep a copy of the completed attendance sheets in this binder.

Absent: ***Date Covered:***

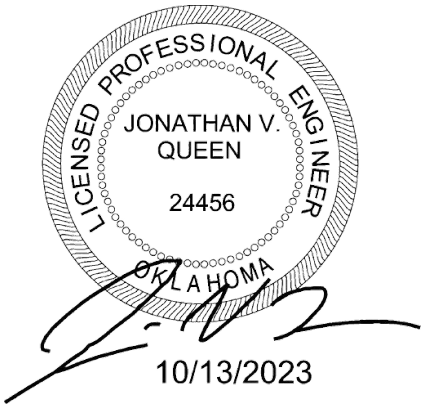
MUSKOGEE COMMUNITY RECYCLING AND DISPOSAL FACILITY
MUSKOGEE COUNTY, OKLAHOMA
ODEQ PERMIT NO. 3551020

APPENDIX P
CLOSURE AND POSTCLOSURE PLAN

Prepared for

Waste Management of Oklahoma, Inc.

October 2023



Prepared by

Weaver Consultants Group, LLC
CA 3804 PE – 06/30/2025
6420 Southwest Boulevard, Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0086-364-11-19

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LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA
10/13/2023

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3-1 Site Plan

5-1 Final Closure Schedule

1 INTRODUCTION

The Closure Plan will include the necessary actions to be completed at the site before the facility can be certified as closed. In accordance with Oklahoma Administrative Code (OAC) 252:515-25-3, copies of all closure documentation will be maintained on file at the site or at the owner/operator's place of business through the postclosure monitoring period. The Postclosure Plan sets forth the maintenance and monitoring during the postclosure period.

The Postclosure Plan will be in effect for a minimum 30-year period to ensure that the closed landfill facility will continue to retain its integrity and will not pose a threat to human health or the environment. Costs associated with the postclosure care period, and the unit costs will be updated per Oklahoma Administrative Code (OAC) 252:515-27-4. If the permit is transferred, the facility shall adhere to the requirements of OAC 252:515-27-5 to comply with permit transfers.

2 REGULATIONS

This Closure and Postclosure Plan has been prepared pursuant to OAC 252:515-25.

2.1 Closure Requirements

OAC 252:515-25 requires that all municipal solid waste landfills (MSWLF) install a final cover system that is designed to minimize infiltration and erosion. The final cover system will consist of an vegetation layer underlain by an vegetative support layer. The facility will be closed in accordance with the provisions included in this Closure Plan and in a manner that minimizes the need for further maintenance and controls and minimizes post-closure escape of waste and waste constituents into the environment.

Prior to beginning final closure of the landfill, the owner/operator is required to give notice of intent to close the site. Oklahoma Department of Environmental Quality (ODEQ) regulations require closure to begin a minimum of 30 days after final receipt of wastes, and further require 6 months minimum notice prior to beginning closure activities. The site must provide public notice of intent to close no later than 90 days prior to closure. ODEQ requires completion of all closure activities within 180 days following the beginning of closure unless otherwise approved.

OAC 252:515-25-34(c) requires closure to be certified by an independent registered engineer and OAC 252:515-25-36(a) requires that a notice be recorded in the deed to the property noting that the land has been used as a solid waste disposal facility.

ODEQ also requires third party closure/postclosure cost estimates to be updated if additional active areas are constructed, if final cover is constructed, or the landfill gas collection and control system (GCCS) is expanded (if applicable). The cost estimates will be updated annually consistent with OAC 252:515-27-34. The facility will maintain financial assurance based on the annual cost updates.

2.2 Postclosure Requirements

For landfills closing after October 9, 1993, OAC 252:515-25-51 requires a 30-year minimum postclosure maintenance period including maintenance of the integrity and effectiveness of the final cover system, maintaining and operating the leachate

collection system, monitoring groundwater, and maintaining any gas venting, collection, or monitoring systems. OAC 252:515-25-2 requires submittal of a postclosure monitoring and maintenance plan for the final cover, groundwater monitoring, and gas control systems. The Landfill Gas Management Plan (LGMP) is included in Appendix G. The Groundwater Sampling and Analysis Plan (GWSAP) was prepared by Biggs and Matthews Environmental and is included in Attachment F. These monitoring systems will remain in-place throughout the postclosure period.

3 FINAL COVER SYSTEM

3.1 Introduction

The final cover system for the Muskogee Community Recycling and Disposal Facility (RDF) has been developed to incorporate the requirements of OAC 252:515-25-32(b)(2)(D). OAC 252:515-25-33(c) states that within 180 days after closure activities are initiated, the owner shall complete the installation of the final cover system as well as other closure requirements as described in OAC 252:515-25-32. A site plan is included as Figure 3-1.

3.2 Final Cover System Design

The final cover system design includes an evapotranspiration (ET) monolithic soil alternative final cover system. The detailed design of the final cover system is in the ODEQ approved Alternative Final Cover (AFC) Design (see Appendix J), prepared by Weaver Boos Consultants, LLC – Southwest, dated September 2008 and summarized below.

ET Monolithic Soil Alternative Final Cover System
• A vegetative layer consisting of a 12-inch layer of earthen material capable of sustaining plant growth • A 24-inch vegetative support layer • A 12-inch intermediate layer

3.3 Final Cover System Installation

3.3.1 Construction Procedures

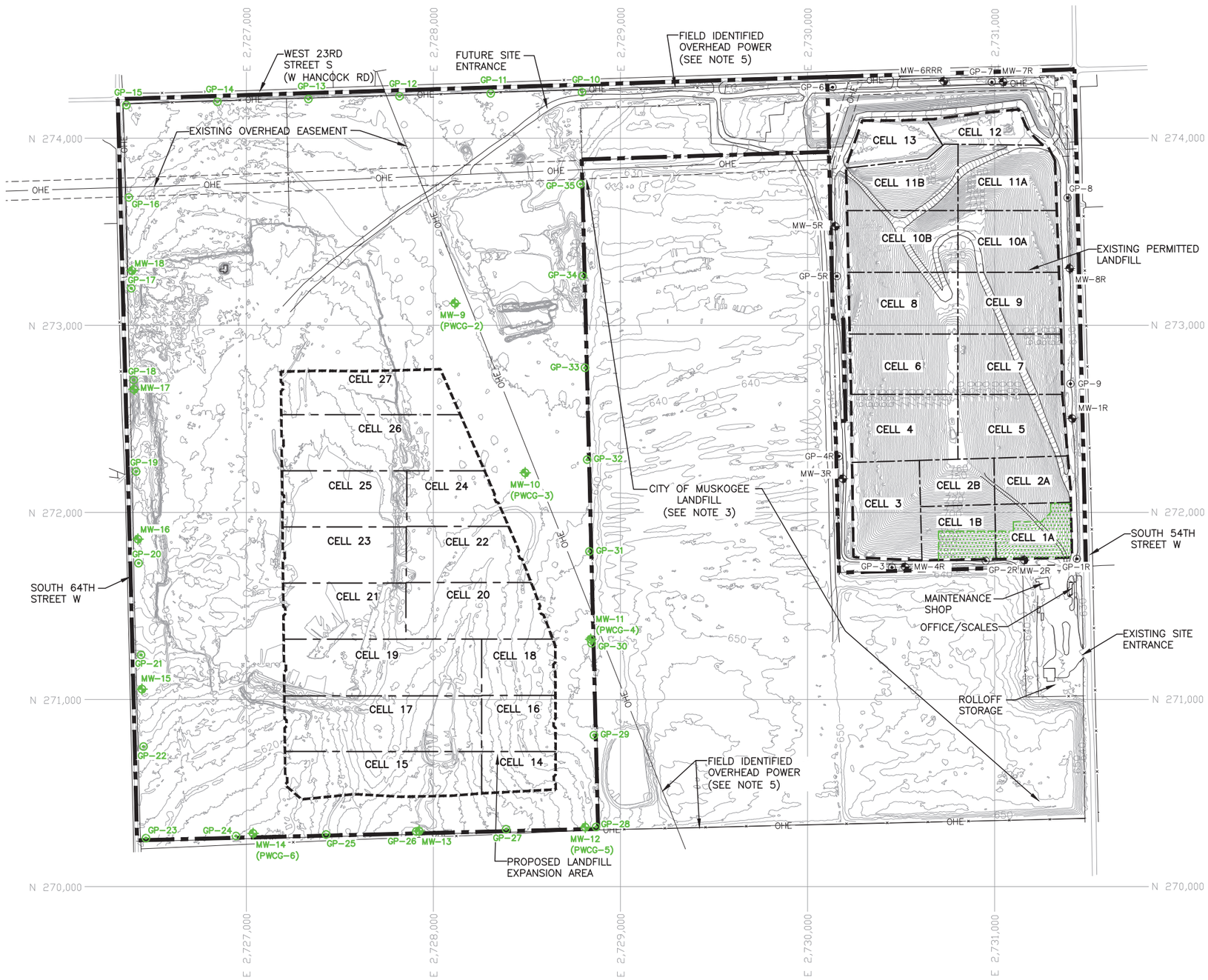
As noted in the Quality Assurance/Quality Control (QA/QC) Plan (refer to Appendix D of the AFC Design Modification, dated September 2008, included in Appendix J), appropriate field survey controls will be implemented to control the final lift of solid waste as well as the successive soil layers of the final cover system. The material used for the vegetation support layer shall classify as CL, CH, ML, SM, or SC according to the Unified Soil Classification System. Soil will be obtained from on-site and off-site sources. The vegetation support layer material should be placed in one

24-inch lift. The material will be compacted by "tracking-in" the material 2 to 4 passes of the low pressure earth moving equipment.

The vegetation layer will be placed over the vegetation support layer. This layer consists of soil capable of supporting vegetative growth. The soil is placed in one lift (12-inch minimum thickness) over the entire surface of the final cover system and is compacted in place with low pressure earth moving equipment. The vegetation layer will be seeded per the sites approved Vegetation Plan.

3.3.2 Final Cover System Testing Procedures

As noted in Appendix D of the AFC Design Modification, dated September 2008 (see Appendix J), aspects of the final cover system installation will be observed and approved by an independent registered professional engineer licensed in the State of Oklahoma. A certification report, attesting to completion of the installation of the final cover system and to implementation of the QA/QC Plan will be signed and sealed by a registered professional engineer and submitted to the ODEQ. Testing will be conducted, as outlined in Appendix D of the AFC Design Modification dated September 2008 (see Appendix J), to provide control and verification during construction of the final cover.



N

0 300 600
SCALE IN FEET

LEGEND

- EXISTING PERMIT BOUNDARY
- PROPOSED PERMIT BOUNDARY
- PERMITTED LIMITS OF WASTE
- PROPOSED LIMITS OF WASTE
- N 273,000 — STATE PLANE COORDINATE GRID
- 640 — EXISTING CONTOUR
- OHE — EXISTING OVERHEAD EASEMENT
- IN-PLACE FINAL COVER
- CELL BOUNDARY
- MW-5R — EXISTING GROUNDWATER MONITORING WELL
- MW-9 (PWCG-1) — PROPOSED GROUNDWATER MONITORING WELL
- GP-5 — EXISTING LANDFILL GAS MONITORING PROBE
- GP-10 — PROPOSED LANDFILL GAS MONITORING PROBE

NOTES:

1. EXISTING CONTOURS AND ELEVATIONS PROVIDED BY HYDREX ENVIRONMENTAL COMPILED FROM AERIAL PHOTOGRAPHY FLOWN 01-25-2023.
2. THE EXPANSION WILL ADD A SEPARATE UNIT TO THE WEST OF THE EXISTING LANDFILL. NO CHANGES ARE PROPOSED TO THE EASTERN UNIT.
3. THE CITY OF MUSKOGEE LANDFILL IS NOT PART OF THE PROPOSED EXPANSION AND IS SHOWN FOR REFERENCE PURPOSES.
4. PERMIT BOUNDARY AND EXISTING OVERHEAD EASEMENTS WERE REPRODUCED FROM LEGAL DESCRIPTION PREPARED BY WEAVER CONSULTANTS GROUP, SIGNED BY MICHAEL D BYTNER, LLS# 1986.
6. AN EASEMENT RECORD WAS NOT FOUND OR PROVIDED TO THE SURVEYOR. THE OVERHEAD POWER RUNNING ALONG THE NORTHERN AND SOUTHERN PROPERTY LINE AND NORTHWEST/SOUTHEAST ACROSS THE PROPERTY WAS FIELD IDENTIFIED AND SURVEYED.

LICENSED PROFESSIONAL ENGINEER
JONATHAN V. QUEEN
24456
OKLAHOMA
10/13/2023

- [ ] DRAFT
- [x] FOR INFORMATIONAL PURPOSES ONLY
- [ ] ISSUED FOR CONSTRUCTION

DATE: 10/2023
FILE: 0086-364-11
CAD: 3-1-SITE PLAN.DWG

DRAWN BY: JDW
DESIGN BY: JBP
REVIEWED BY: JVQ

Weaver Consultants Group
CA 3804 PE - 06/30/2025

PREPARED FOR
WASTE MANAGEMENT OF OKLAHOMA, INC.

REVISIONS

NO.	DATE	DESCRIPTION

TIER III PERMIT MODIFICATION SITE PLAN

MUSKOGEE COMMUNITY RDF
MUSKOGEE COUNTY, OKLAHOMA

WWW.WCGRP.COM

FIGURE 3-1

COPYRIGHT © 2023 WEAVER CONSULTANTS GROUP. ALL RIGHTS RESERVED.

O:\0086\364\EXPANSION 2022\APPENDIX PV3-1-SITE PLAN.dwg, jpuhr, 1:2

4 CLOSURE PROCEDURES

4.1 Closure Sequence

Waste Management of Oklahoma, Inc., will conduct ongoing closure of the landfill throughout its active life. This procedure allows for successive closure of fill areas by placement of final cover, construction of drainage and erosion control features, and establishment of vegetative cover. This procedure will be followed until all phases have been closed.

The active area of the landfill is approximately 60.9 acres. Approximately 3.0 acres of final cover has been constructed. The closure area and construction time associated with placing the final cover system over the area is detailed below.

The final cover will consist of an ET monolithic soil alternative final cover system. Soil will be obtained from on-site or from local offsite sources.

4.2 Closure During Active Life

As described above, the final cover system will be constructed as fill areas achieve the design grades. Should closure of the landfill become necessary at any time during the active life of the landfill, the following steps will be taken:

- Engineering plans will be developed to address site closure at the time of discontinued waste filling.
- The final waste received will be placed and properly compacted.
- Excavations will be filled with suitable material, and the site will be graded to promote runoff and prevent ponding.
- The final cover system will be constructed according to specifications.
- The top of the landfill will be regraded and reshaped as needed to provide the proper slope for positive drainage.
- During the first growing season following application of final cover system, the site will be vegetated with permanent vegetation, using the methods included in the approved Vegetation Plan.
- Additional soil will be added to the sideslopes, as needed, and the soil will be processed using a disc to prepare the soil for seeding.

- A surface water management system will be constructed to minimize erosion.
- A closure certification will be prepared by an independent registered professional engineer and submitted to ODEQ for approval.
- All proper notices and documentations will be filed with the appropriate agencies.

4.3 Additional Closure Information

The area for refuse disposal encompasses approximately 126.4 acres excluding the buffer zones, drainage areas, and unsuitable areas. To date, Oklahoma Waste Disposal, Inc., has utilized approximately 60.9 acres of the permitted area of the site. Approximately 65.5 acres of the operating area has yet to be developed. The estimated maximum capacity of the landfill units is 13,307,889 cubic yards.

The facility is classified as a MSWLF and accepts residential and commercial waste, construction and demolition waste, non-hazardous "other" industrial waste, encapsulated asbestos waste, vegetative waste, semi-solid waste, and sludges. Special waste is handled under the requirements set forth in this permit. No hazardous, radioactive, or polychlorinated biphenyls waste will be knowingly accepted at this facility.

There are currently two permanent on-site structures, a maintenance shop and a scalehouse. These structures will remain throughout the closure period. All other structures that are on site at the time of final closure will be removed or decommissioned. All equipment used during the operation and closure of the landfill will be removed from the site after final closure has been certified as complete.

The access roads will be maintained throughout the active life and postclosure period of the landfill. Facilities at the site, including the perimeter fencing, will be maintained throughout the postclosure period.

Final wastes or affected soils remaining on-site at the time final closure has been completed will be transported to a facility permitted to handle the wastes and/or affected soils. Currently, only ODEQ approved closure activities have occurred at the site and, therefore, a plan for remedying all former improper closure at the site is not applicable.

Prior to initiating closure, the existing conditions and applicable regulations will be reevaluated to ensure that this Closure Plan is still applicable.

5 CLOSURE SCHEDULE

The site will be closed in an orderly fashion, consistent with OAC 252:515-25-33. The final closure schedule is presented in Figure 5-1.

Figure 5-1: Final Closure Schedule
Muskogee RDF

Action	30 Days	30 Days	30 Days	30 Days	30 Days	30 Days	30 Days	30 Days	30 Days	30 Days	30 Days
Written notification of closure to ODEQ											
Initiation of final closure activities											
Time intervals for commencement of final closure activities											
Submit engineering certification of final closure to ODEQ											
Submit certified copies of modified deed to ODEQ											

Note: Schedule is based on anticipated date of beginning final closure activities.
Heavy vertical line signifies final receipt of waste.

6 POSTCLOSURE ACTIVITIES

6.1 Introduction

This Postclosure Plan has been prepared for the Muskogee RDF consistent with OAC 252:515-25-53. In accordance with OAC 252:515-25-51(b) postclosure care maintenance will commence immediately upon completion of final closure requirements. Postclosure activities will continue for a period of 30 years minimum, unless the ODEQ approves a postclosure period of a different duration or if ODEQ extends the postclosure period (consistent with OAC 252:515-25-52).

6.2 Monitoring and Maintenance

Postclosure inspections shall be performed on a quarterly basis during the first three years of the postclosure period. Subsequent inspections will be performed semi-annually for the next two years and annually for the remainder of the postclosure period. Additional inspections may be conducted to observe repairs or evaluate problem areas discovered during prior inspections.

The quarterly, semi-annual, and annual postclosure inspections will consist of the inspection and evaluation of the final cover system and vegetative cover, the drainage and erosion control structures, the leachate collection system, and the security system. The frequency and specific inspections associated with the groundwater monitoring and gas monitoring programs are addressed in the LGMP in Appendix G and GWSAP in Attachment F.

6.2.1 Final Cover System

Postclosure care will verify the integrity of the final cover system and its ability to minimize infiltration and erosion. The following conditions should be examined during the inspection:

- Settlement
- Cracking
- Erosion
- Animal burrows

- Other disturbances affecting either the thickness or configuration of the final cover system

Maintenance and repairs should be conducted as soon as practical and may consist of filling in areas of settlement, regrading, and slope restabilization. In areas of substantial settlement or displacement of the final cover system, the integrity of the cap should be reevaluated and any necessary repairs made. The final cover system should be maintained to provide the proper slope, to promote surface water runoff, and to assure continuity of the final cover components to minimize infiltration and leachate production.

Included as part of the final cover system inspection, the integrity of the vegetation and its ability to minimize infiltration and erosion will be determined. The following conditions should be examined during the inspection:

- Erosion
- Overgrowth of shrubs, trees, and other deep-rooted vegetation
- Patches of dead vegetation

Maintenance and repairs of the vegetative cover may consist of the following activities:

- Reseeding, fertilizing, liming, and mulching of washed out areas
- Brush removal
- Mowing

Reseeding should be conducted as necessary to assure proper vegetative growth over all areas of the final cover system. Mowing and removal of deep-rooted brush and vegetation will be performed as needed.

6.2.2 Drainage and Erosion Controls Structures

Drainage and erosion controls will be inspected throughout the postclosure period to ensure that surface water is conveyed away from the landfill to the perimeter drainage system. Items or conditions to be examined include the following:

- Erosion
- Settlement
- Structural integrity of berms, letdown structures, and other drainage and erosion control structures
- Silt and sediment buildup

Maintenance and repairs should be conducted as soon as practical, and may consist of the following activities:

- Replacement of riprap, gabions, or other structural lining installed for erosion protection
- Removal of obstructions to permit conveyance of surface water
- Placement of fill and regarding
- Removal of silt and sediment
- Repairs to berms
- Repair of replacement of stacked hay bales or silt fencing

6.2.3 Leachate Collection System

Postclosure care of the leachate collection system consists of operation and maintenance of the leachate collection system, as well as any storage, pumping, or conveyance systems. As required by OAC 252:515-25-54(b)(2)(B), the leachate collection system will be equipped with a system for automatic and continuous leachate removal.

The leachate collection system will be observed during each scheduled inspection event throughout the postclosure period. Based on the results of the inspections, more frequent or less frequent monitoring may be required due to problems with the system or changes in the rate of production of leachate. During these inspections, leachate collection sumps and/or piping, clean-outs, or inspection points will be observed to determine the effectiveness of the system in removing leachate and minimizing the head on the liner system.

Maintenance, on an annual or otherwise as-needed basis, may include flushing and pressure cleaning of the leachate collection and removal pipes.

6.2.4 Groundwater Monitoring System

The GWSAP includes a discussion of the procedures for monitoring the groundwater monitoring wells. At a minimum, groundwater sampling will be performed every six months in accordance with OAC 252:515-25-54(b)(1)(A) and the GWSAP.

6.2.5 Surface Water Monitoring Program

The postclosure monitoring activities will adhere to the requirements of the Oklahoma Pollution Discharge Elimination System (OPDES) Multi-Sector General Permit.

6.2.6 Landfill Gas Monitoring System

The LGMP provides a description of the procedures to be followed for monitoring the perimeter probes. At a minimum, landfill gas monitoring probes will be sampled every six months in accordance with OAC 252:515-25-54(b)(1)(B).

6.2.7 Site Security and Access Control

Postclosure care of the security system is necessary to control unauthorized access and prevent illegal dumping of wastes. Inspection of the security system at the site should be performed during the postclosure inspections. Signs shall be posted on the outer perimeter indicating that the site is a closed MSWLF, as required by OAC 252:515-25-54(a)(1). The closed facility will be maintained as necessary to provide access to the closed areas throughout the postclosure period.

Maintenance and repairs should be implemented as soon as practical and may include the repair of access roads and repairs or replacement of fencing and locks.

7 POSTCLOSURE LAND USE

There are no current planned uses for Muskogee RDF after closure. Should use of the closed landfill not associated with solid waste activities be considered, plans will be prepared and submitted to ODEQ for review and approval per OAC:252-515-25-57.

8 POSTCLOSURE REPORTING REQUIREMENTS

8.1 Annual Postclosure Report

Beginning one year after the ODEQ's approval of the certification of final closure, Waste Management of Oklahoma, Inc., will submit an annual postclosure maintenance and monitoring report to the ODEQ until the postclosure period ends. This report will document the maintenance performed at the site and summarize all monitoring data for the previous year. The report shall be submitted annually each year after ODEQ's certification of final closure.

8.2 Certification of Postclosure Performance

At the conclusion of the postclosure period, Waste Management of Oklahoma, Inc., will submit, in lieu of the annual postclosure report, a certification, signed by both Waste Management of Oklahoma, Inc., and a professional engineer registered in the State of Oklahoma, indicating that the MSWLF was maintained and monitored in accordance with the approved postclosure plan, the permit, and applicable regulations. This certification will also indicate whether monitoring throughout the postclosure period has shown the presence of elevated levels of any constituent or if any evidence of contamination related to site operations has been found and if so, what corrective measures were taken. The certification will be maintained in the Site Operating Record.

APPENDIX Q

CLOSURE AND POSTCLOSURE COST ESTIMATES

This appendix includes the following:

- The ODEQ approval letter for the current closure and postclosure estimates dated March 28, 2023.
- The Closure and Postclosure Cost Estimates submitted to ODEQ dated February 15, 2023.

Scott A. Thompson
Executive Director

OKLAHOMA Environmental Quality

Kevin Stitt
Governor

March 28, 2023

Mr. Pete Schultze
Waste Management, Inc.
2801 S. 54th St.
Muskogee, OK 74401

Re: Closure and Post-Closure Cost Update and Economic Life Estimate
Muskogee Community Recycling & Disposal Facility, Muskogee County
Solid Waste Permit No. 3551020

Dear Mr. Schultze:

The Oklahoma Department of Environmental Quality (DEQ) received the Closure and Post-Closure Cost Update and Economic Life Estimate dated February 15 and February 17, 2023, respectively, for the Muskogee Community Recycling and Disposal Facility (RDF).

The 2023 cost estimates were updated to include the annual inflation factor of 6.98% and additional costs associated with the landfill gas collection and control system. DEQ has reviewed the submittal and accepts the following cost estimates:

Closure:	$ 2,874,462.91
Post-Closure:	$ 3,720,791.73
Total:	$ 6,595,254.64

Muskogee Community RDF has met the requirements of Oklahoma Administrative Code (OAC) 252:515-27-34(a). Please adjust the financial assurance mechanism to reflect the above costs within 30 days in accordance with OAC 252:515-27-34(b).

The economic life was calculated in accordance with OAC 252:515-27-8 and was found to be approximately 4 years as of December 31, 2022. This estimate was based on a remaining constructed airspace of 918,145 cubic yards (CY); a waste disposal rate of 135,827 tons in 2022; and a site-specific density of 1,477 lbs/CY.

If you have any questions, please contact Jeff Biddick at (405) 702-5141 or jeff.biddick@deq.ok.gov.

Sincerely,

Hillary Young, P.E.
Chief Engineer
Land Protection Division

HY/jb

Table H.1 Site Data

FACILITY NAME: Muskogee Community RDF
COUNTY: Muskogee County
PERMIT NUMBER 3551020
Updated: February 15, 2023

DESCRIPTION	QUANTITY	UNITS
Total Permitted Area	60.9	acres
Active Portion		
Composite Lined [1]	50.90	acres
Soil Lined [1]	10.00	acres
Final Cover Area		
Composite Lined [1]	50.90	acres
Soil Lined [1]	10.00	acres
Perimeter Fencing	7,600	linear feet
Groundwater Monitoring Wells	315.0	linear feet
Methane Gas Probes	180.0	linear feet
Terraces	2,940	linear feet
Letdown Channels	800	linear feet
Perimeter Drainage Ditches	5,700	linear feet
Average Daily Flow	533	tons/day
Landfill Disposal Cost	$25.00	$/ton
Off-Site Borrow Area	100.00	acres
On-site Borrow Area	1.00	acres
Number of Groundwater Monitoring Wells	9	wells
Number of LFG Monitoring Probes	9	probes
Total Cost of LFG System	$1,740,000	lump sum

Notes: [1] Please note that of the acreage that comprises the active portion, approximately 2.48 acres have been certified with Final Cover.

P:\Solid waste\WM\Muskogee LF\CPC\2023\
Muskogee H 1 H 2 I 1(2023 Costs and LFG)

Table H.2 Closure Cost Estimate

FACILITY NAME: Muskogee Community RDF
FACILITY TYPE: MSWLF
FACILITY LOCATION: Muskogee County
Updated: February 15, 2023

	Task/Service	Quantity	Units	Multiplier	2023 Unit Cost	Subtotal
1	**PRELIMINARY SITE WORK**					
1.1	Conduct Site Evaluation		lump sum	1	$4,222.39	$4,222.39
1.2	Dispose Final Waste					
	Average Daily Flow	533	tons/day			
	Disposal Cost	533	$/ton	5 days of waste	$25.00	$66,625.00
1.3	Remove Temporary Building(s)	1	lump sum	1	$3,871.95	$3,871.95
1.4	Remove Equipment	1	lump sum	1	$3,160.64	$3,160.64
1.5	Repair/Replace Perimeter Fencing	7,600	linear feet	25% of fencing	$4.14	$7,866.00
1.6	Clean Leachate Line(s)	1	lump sum	1	$1,921.44	$1,921.44
2	**MONITORING EQUIPMENT**					
2.1	Rework/Replace Monitoring Well(s)	315.0	VLF	25% of wells	$88.78	$6,991.43
2.2	Plug Abondoned Monitoring Well(s)	315.0	VLF	25% of wells	$35.54	$2,798.78
2.3	Rework/Replace Methane Probe(s)	180.0	VLF	25% of probes	$76.68	$3,450.60
2.4	Plug Abondoned Methane Probe(s)	180.0	VLF	25% of probes	$28.02	$1,260.90
2.5	Rework/Replace Remediation and/or Gas Control Equipment	5% of equipment capital cost	lump sum	1	$1,740,000.00	$87,000.00
3	**CONSTRUCTION**					
3.1a	Complete Site Grading	60.90	acres	1	$1,674.07	$101,950.86
3.1b	Borrow Area Site Grading (On-site and Off-site)	101.00	acres	1	$1,674.07	$169,081.07
3.2	Construct Final Cap					
	Compacted On-site Clay Cap or	188,502	cubic yards	1	$6.01	$1,132,896.22
	Compacted Off-site Clay Cap or		cubic yards		$9.77	
	Install Geosynthetic Clay Liner Cap		square feet		$0.63	
3.3	Construct Landfill Gas Venting Layer					
	Place Sand or		acres	1	$44,762.88	
	Install Net and Geotextile		square feet	1	$0.44	$0.00
3.4	Install Passive Landfill Gas Vents		acres	1	$1,072.36	$0.00
3.5	Install Flexible Membrane Liner		square feet	1	$0.49	$0.00
3.6	Drainage Layer					
	Place Sand or		acres	1	$44,762.88	
	Install Net and Geonet		square feet	1	$0.44	$0.00

Table H.2 Closure Cost Estimate (Continued)

FACILITY NAME: Muskogee Community RDF
FACILITY TYPE: MSWLF
FACILITY LOCATION: Muskogee County

	Task/Service	Quantity	Units	Multiplier	2023 Unit Cost	Subtotal
3.7	Place On-site Topsoil	94,251	cubic yards	1	$2.59	$244,109.92
	Place Off-site Topsoil		cubic yards	1	$20.69	
3.8	Establish Vegetative Cover	58.42	acres	1	$1,193.06	$69,698.57
3.8a	ODEQ/ODM Off-Site Soil Borrow Area	100.00	acres	1	$1,193.06	$119,306.00
3.8b	ODEQ/ODM On-Site Soil Borrow Area	1.00	acres	1	$1,193.06	$1,193.06
4	**DRAINAGE/EROSION CONTROL**					
4.1	Construct Terraces	2,940	linear feet	1	$10.84	$31,869.60
4.2	Construct Letdown Channels	800	linear feet	1	$118.51	$94,808.00
4.3	Clean Perimeter Drainage Ditches	5,700	linear feet	50% of ditches	$8.26	$23,541.00
5	**TASKS NOT IDENTIFED**					
6	**SUBTOTAL**					$2,177,623.41
7	**ADMINISTRATIVE SERVICES**	1	lump sum	1	10%	$217,762.34
8	**TECHNICAL and PROFESSIONAL SERVICES**	1	lump sum	1	12%	$261,314.81
9	**CLOSURE CONTINGENCY**	1	lump sum	1	10%	$217,762.34
10	**TOTAL FINAL CLOSURE**					**$2,874,462.91**

Table I.1 Post Closure Estimate

FACILITY NAME: Muskogee Community RDF
FACILITY TYPE: MSWLF
FACILITY LOCATION: Muskogee County
Updated: February 15, 2023

	Task/Service	Quantity	Units	Multiplier	2023 Unit Cost	Subtotal
1	**SITE MAINTENANCE**					
1.1	Site Inspection	4	per year	30 yrs	$768.10	$92,172.00
1.2	General Maintenance	1	lump sum	30 years	$2,302.81	$69,084.30
1.3	Remediation and/or Gas Control Equipment	5% of equipment capital cost	lump sum	one per 5 yrs for 30 years	$1,740,000.00	$522,000.00
2	**MONITORING EQUIPMENT**					
2.1	Rework/Replace Monitoring Well(s)	315.0	VLF	25% of wells	$88.78	$6,991.43
2.2	Plug Abandoned Well(s)	315.0	VLF	25% of wells	$35.54	$2,798.78
2.3	Final Plugging of Monitoring Wells	315.0	VLF	1	$35.54	$11,195.10
2.4	Rework/Replace Methane Probe(s)	180.0	VLF	25% of wells	$76.68	$3,450.60
2.5	Plug Abandoned Probe(s)	180.0	VLF	25% of wells	$28.02	$1,260.90
2.6	Final Plugging of Methane Probes	180.0	VLF	1	$28.02	$5,043.60
2.7	Final Plugging of Piezometer(s)	0	VLF	1	$28.02	$0.00
3	**SAMPLING and ANALYSIS**					
3.1	Groundwater Monitoring Wells	9	wells	2/yr for 30 years	$828.23	$447,244.20
3.2	Methane Gas Probes	9	probes	2/yr for 30 years	$53.75	$29,025.00
3.3	Surface Water Monitoring Points	2	points	2/yr for 30 years	$99.81	$11,977.20
3.4	Leachate	1	sample	2/yr for 30 years	$160.84	$9,650.40
4	**FINAL COVER MAINTENANCE**					
4.1	Mow and Fertilize Vegetative Cover	60.90	acres	30 years	$254.10	$464,240.70
4.2	Repair Erosion, Settlement, and Subsidence for On-site Soils	60.90	acres	2 CY/acre for 30 years	$3.69	$13,483.26
	Repair Erosion, Settlement, and Subsidence for Off-site Soils		acres	2 CY/acre for 30 years	$22.04	
4.3	Re-seed Vegetative Cover	60.90	acres	20% of area for 30 years	$1,193.06	$14,531.47
5	**LEACHATE MANAGEMENT**					
5.1	Clean Leachate Line(s)	1	lump sum	30 years	$1,969.62	$59,088.60

Table I.1 Post Closure Estimate (Continued)

FACILITY NAME: Muskogee Community RDF
FACILITY TYPE: MSWLF
FACILITY LOCATION: Muskogee County

	Task/Service	Quantity	Units	Multiplier	2023 Unit Cost	Subtotal
5.2	Maintain Leachate Collection Systems and Equipment	1	lump sum	30 years	$3,059.88	$91,796.40
5.3	Collect, Treat, Transport and Dispose Leachate	100,000	gallons/year	30 years	$0.39	$1,170,000.00
6	**TASKS NOT IDENTIFIED**					
7	**SUBTOTAL**					$3,025,033.93
8	**ADMINISTRATIVE SERVICES**		lump sum	1	6%	$181,502.04
9	**TECHNICAL and PROFESSIONAL SERVICES**		lump sum	1	7%	$211,752.38
10	**POST-CLOSURE CONTINGENCY**		lump sum	1	10%	$302,503.39
11	**TOTAL POST CLOSURE**					**$3,720,791.73**

APPENDIX R

ECONOMIC LIFE ESTIMATE

This appendix includes the following:

- The ODEQ approval letter for the Economic Life Estimate dated March 28, 2023.
- The Economic Life Estimate submitted to ODEQ dated February 17, 2023.

Scott A. Thompson
Executive Director

OKLAHOMA Environmental Quality

Kevin Stitt
Governor

March 28, 2023

Mr. Pete Schultze
Waste Management, Inc.
2801 S. 54th St.
Muskogee, OK 74401

Re: Closure and Post-Closure Cost Update and Economic Life Estimate
Muskogee Community Recycling & Disposal Facility, Muskogee County
Solid Waste Permit No. 3551020

Dear Mr. Schultze:

The Oklahoma Department of Environmental Quality (DEQ) received the Closure and Post-Closure Cost Update and Economic Life Estimate dated February 15 and February 17, 2023, respectively, for the Muskogee Community Recycling and Disposal Facility (RDF).

The 2023 cost estimates were updated to include the annual inflation factor of 6.98% and additional costs associated with the landfill gas collection and control system. DEQ has reviewed the submittal and accepts the following cost estimates:

Closure:	$ 2,874,462.91
Post-Closure:	$ 3,720,791.73
Total:	$ 6,595,254.64

Muskogee Community RDF has met the requirements of Oklahoma Administrative Code (OAC) 252:515-27-34(a). Please adjust the financial assurance mechanism to reflect the above costs within 30 days in accordance with OAC 252:515-27-34(b).

The economic life was calculated in accordance with OAC 252:515-27-8 and was found to be approximately 4 years as of December 31, 2022. This estimate was based on a remaining constructed airspace of 918,145 cubic yards (CY); a waste disposal rate of 135,827 tons in 2022; and a site-specific density of 1,477 lbs/CY.

If you have any questions, please contact Jeff Biddick at (405) 702-5141 or jeff.biddick@deq.ok.gov.

Sincerely,

Hillary Young, P.E.
Chief Engineer
Land Protection Division

HY/jb

707 N. ROBINSON ST., OKLAHOMA CITY, OK 73102 · OFFICE: 405-702-0100
STATE OF OKLAHOMA · OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY · DEQ.OK.GOV

Prep By: GRC
Date: 02-17-2023

MUSKOGEE COMMUNITY RDF
2022 ECONOMIC LIFE OF SITE CALCULATION

Purpose: Estimate the economic life of the site as of December 31, 2022 consistent with OAC 252:515-27-8.

Reference:
1. Title 252 Department of Environmental Quality, Chapter 515 Management of Solid Waste, OAC 252:515-27-8 (Economic life of disposal facility), effective June 1, 2003.
2. Information Provided by WASTE MANAGEMENT OF OKLAHOMA and third party estimates.

Method:
1. Estimate the constructed remaining airspace as of January 24, 2022.
2. Estimate the constructed remaining airspace as of January 31, 2022.
3. Estimate the constructed remaining airspace as of December 31, 2022.
4. Determine the annual waste acceptance rate from January 1, 2022 through December 31, 2022.
5. Determine the economic life of the site as of December 31, 2022.

Solution:

1. Estimate the constructed remaining airspace as of January 24, 2022.

Constructed Remaining Airspace: 1,092,560 cy as of the January 24, 2022 aerial.

DAS compiled a topographic map for this facility from aerial photography. The volume of remaining capacity (waste and daily/intermediate cover) was determined using an AutoCAD-based software package. Existing contours as of January 24, 2022 were compared to the intermediate contour plan.

2. Estimate the constructed remaining airspace as of January 31, 2022.

- To determine the amount of waste consumed between January 24, 2022 and January 31, 2022, the actual tonnage for January was prorated and converted to cubic yards. Please note that for the entire month of January there are 21-business days (6 business days/week) and between January 24, 2022 and January 31, 2022, there are only business days. 6 days

Based on gate receipts for the Muskogee Community RDF, the facility received: 9,829.90 tons of waste during January 2022. A prorated waste acceptance rate for the remainder of January will be used to estimate the amount of airspace consumed between January 24, 2022 aerial and January 31, 2022.

Amount of waste accepted in January = 9,829.9 tons/21 business days in January = 468.09 tons/day

Using an in-place density rate (i.e., site specific density) = 1,477 lb/cy

Airspace consumed between 1/24/2022 and 1/31/2022

$$\frac{468.09 \text{ tons/day} \times 6 \text{ days} \times 2{,}000 \text{ lb/ton}}{1{,}477 \text{ lb/cy}}$$

Airspace consumed = 3,803 cy

Constructed Remaining Airspace: 1,088,757 cy as of January 31, 2022

3. Estimate the constructed remaining airspace as of December 31, 2022.

Tons of waste received between January 31, 2022 and December 31, 2022:

Tons received = 125,997.10 tons (based on 2022 gate receipts)

Using an in-place density rate (i.e., site specific density) = 1,477 lb/cy

Airspace consumed between 1/31/2022 and 12/31/2022

$$\frac{125{,}997.10 \text{ tons} \times 2{,}000 \text{ lb/ton}}{1{,}477 \text{ lb/cy}}$$

Airspace consumed = 170,612 cy

Constructed Remaining Airspace: 918,145 cy as of December 31, 2022.

4.

Determine the annual waste acceptance rate from January 1, 2022 through December 31, 2022.
The acceptance rate is based on gate receipts for the site between January 2022 and December 2022.

W = 135,827.0 tons
271,654,000 lb

5. Determine the economic life of the site as of December 31, 2022.

$$L = \{[V - (P \times V)] \times D\} / W$$ (Ref 1)

L = Life of the site, years ("Life of the Site" is defined as the remaining life of the capacity over the currently constructed fill areas)
V = Volume of remaining airspace, cy
P = Amount of remaining airspace consumed by daily cover, %
D = In-place density of waste, lb/cy
W = Expected annual waste acceptance rate, lb/yr

V =	918,145	cy (refer to Section 3)
P =	0.2	(per OAC 252:515-27-8)
D =	1,477	lb/cy (Site specific density)
W =	271,654,000	lb (refer to Section 4)

L =	4.0	years

APPENDIX S

RECORDKEEPING AND REPORTING EXAMPLE FORMS

Note: This appendix includes an example Monthly and Quarterly Report for Solid Waste Disposal Facilities included on the ODEQ, Land Protection Division, Solid Waste Management web page.

MONTHLY REPORT FOR SOLID WASTE DISPOSAL FACILITIES

(Please see instructions prior to completing this form)

Please Remit Original Report to:
Solid Waste Compliance and Enforcement
Land Protection Division
P. O. Box 1677
Oklahoma City, OK 73101-1677
Solidwastereports@deq.ok.gov

And

Please Remit Copy of Report to:
Revenue Management Section
Administrative Services Division
P.O. Box 2036
Oklahoma City, OK 73101-2036
Bernice.Green@deq.ok.gov

Facility Physical Address: _____

Report month/year:_____
Permit No.:_____

Facility Name:_____

Mailing Address: _____ Phone No.:( )_____

_____ Number of Operating days: _____

Day	(1) Total weight accepted (tons)	(2) Weight which is reused or recycled in accordance with facility permit (tons)	(3) Weight accepted from a DEQ approved emergency or special event (tons)	(4) Weight accepted from large industrial waste generators with DEQ exemption certificate (tons)	(5) Time scales placed out-of-service	(6) Time scales placed into service	(7) Total volume accepted (yd^3)	(8) Volume which is reused or recycled in accordance with facility permit (yd^3)	(9) Volume accepted from a DEQ approved emergency or special event (yd^3)	(10) Volume accepted from large industrial waste generators with DEQ exemption certificate (yd^3)
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										
Total	0	0	0	0	0	0	0	0	0	0

I hereby certify that the information reported above is accurate and correct to the best of my knowledge and includes all solid waste received at this facility.

Signature of authorized agent:_____ Date:_____

April 2017: DEQ Form # 515-031

INSTRUCTIONS FOR COMPLETING THE MONTHLY REPORT FOR SOLID WASTE DISPOSAL FACILITIES

The monthly report for solid waste disposal facilities should be submitted to DEQ no later than the 15th of the month following the reporting month and should include all solid waste received during the month. **If no solid waste is received in a given month, a monthly report is still required. Please include a notation that no solid waste was received during the month. If submitting report electronically, please send to solidwastereports@deq.ok.gov and bernice.green@deq.ok.gov.**

1. In the spaces provided, enter the month and year covered by the report, the facility name, permit number, mailing address, and phone number.

2. For each operating day of the month, provide the following and identify which days during the month the facility was closed.

Column 1: **Total weight accepted:** Enter the total weight, **in tons,** of all waste accepted at the facility for each day. The total must include weights to be reported in columns 2, 3, and 4.

Column 2: (Only applicable to landfill disposal facilities) **Weight which is reused or recycled in accordance with facility permit:** Enter the weight, **in tons,** of waste accepted at the facility which was productively reused at the facility in accordance with the facility's permit OR was recovered and sold in accordance with the facility's permit.

Column 3: (Only applicable to landfill disposal facilities) **Weight accepted from a DEQ approved emergency or special event:** Enter the weight, **in tons,** of waste accepted at the facility from an emergency or special event for which the facility received prior approval from the DEQ to waive the state disposal fee.

Column 4: (Only applicable to landfill disposal facilities) **Weight accepted from large industrial waste generators with DEQ exemption certificate:** Enter the weight, **in tons**, of waste received from large industrial waste generators **which was accompanied by a large industrial waste generator fee exemption certificate issued by the DEQ.**

Column 5: (Only applicable to landfill disposal facilities) **Time scales placed out-of-service:** Enter the approximate time (hour:minute) the scales became inoperative.

Column 6: (Only applicable to landfill disposal facilities) **Time scales placed into service:** Enter the approximate time (hour:minute) the scales were placed into service.

Note: Section 2-10-802 of the Oklahoma Solid Waste Management Act requires operators of certain landfill disposal facilities to weigh all solid waste received at the landfill. ***Only when the scales are inoperative may a landfill record the volume of waste received****.*

Column 7: **Total volume accepted:** Enter the total volume **in cubic yards** of all waste accepted at the facility. The total must include volumes to be reported in columns 8, 9, and 10.

Column 8: (Only applicable to landfill disposal facilities) **Volume which is reused or recycled in accordance with facility permit:** Enter the volume, **in cubic yards,** of waste accepted at the facility which was productively reused at the facility in accordance with the facility's permit OR was recovered and sold in accordance with the facility's permit.

Column 9: (Only applicable to landfill disposal facilities) **Volume accepted from a DEQ approved emergency or special event:** Enter the volume, **in cubic yards,** of waste accepted at the facility from an emergency or special event for which the facility received prior approval from the DEQ to waive the state disposal fee.

Column 10: (Only applicable to landfill disposal facilities) **Volume accepted from large industrial waste generators with DEQ exemption certificate:** Enter the volume, **in cubic yards**, of waste received from large industrial waste generators **which was accompanied by a large industrial waste generator fee exemption certificate issued by the DEQ.**

3. At the end of the month, calculate the total down time for the scales (hours:minutes) and include in the space provided. Sum each column and include in the appropriate column.

QUARTERLY RETURN FOR SOLID WASTE LANDFILLS

Due no later than 30 days after the end of each calendar quarter

Permit Number	Quarter	Year	DEQ Invoice Number

For Office Use Only

Facilty Name: _____

Mailing Address: _____

1.	Number of operating days this quarter (see instructions)		days
2.	Total weight, in tons, of waste received during this quarter		tons
2a.	Weight received, in tons, which was productively reused or recovered and sold (see instructions)		tons
2b.	Weight received, in tons, from a DEQ approved emergency or special event (see instructions)		tons
2c.	Weight received, in tons, from large industrial waste generators under the large industrial waste generator exemption (see instructions)		tons
3.	Weight subject to state disposal fees (line 2 minus sum of lines 2a, 2b, and 2c)	0.00	tons
4.	Total volume, in cubic yards, of waste received during this quarter		yd3
4a.	Weight received, in cubic yards, which was productively reused or recovered and sold (see instructions)		yd3
4b.	Weight received, in cubic yards, from a DEQ approved emergency or special event (see instructions)		yd3
4c.	Weight received, in cubic yards, from large industrial waste generators under the large industrial waste generator exemption (see instructions)		yd3
5.	Volume subject to state disposal fee (line 4 minus sum of lines 4a, 4b, and 4c)	0.00	yd3
6.	Volume weight subject to state disposal fee (multiply line 5 by 0.33)	0.00	tons
7.	Determine volume weight from total volume (multiply line 4 by 0.33)	0.00	tons
8.	Total weight received (add line 2 and line 7)	0.00	tons
9.	Average weight received per operating day (divide line 8 by line 1)	0.00	tons/day
10.	Weight received subject to state disposal fee (add line 3 and line 6)	0.00	tons
10a.	See instructions		
11.	Enter state disposal fee (If line 10a < $40,000, line 10 x $1.50, otherwise, line 10 x $1.25)	0.00	
12.	Enter capital investment waiver (see instructions)	0.00	
13.	Determine total capital investment waiver to date (see instructions)		
14.	Enter handling waiver (see instructions)	0.00	
15.	Enter total allowable waivers (add line 12 and line 14)	0.00	
16.	Penalties (see instructions)		
17.	**TOTAL STATE DISPOSAL FEE DUE** (line 11 plus line 16 minus line 15)	0.00	

Typed/Printed Name of Authorized Agent: _____ Date: _____

Signature of Authorized agent: _____ Phone No.: _____

Email Address: _____

Remit original report with payment to:

Oklahoma Department of Environmental Quality
Administrative Service - Accounts Receivable
P.O. Box 2036
Oklahoma City, OK 73101-2036

Remit copy of report to:

Oklahoma Department of Environmental Quality
Land Protection Division
P.O. Box 1677
Oklahoma City, OK 73101-1677

Electronic submissions should be submitted to: solidwastereports@deq.ok.gov bernice.green@deq.ok.gov

DEQ Form #515-030 Jan-18

INSTRUCTIONS FOR COMPLETING THE QUARTERLY RETURN FOR SOLID WASTE LANDFILLS

GENERAL INSTRUCTIONS

All solid waste landfills, except generator owned and operated non-hazardous industrial waste monofills, are required by 27A O.S. §2-10-802 to collect fees on solid waste received at the landfill.

This return should be completed and returned to the Financial and Human Resources Division of the Department of Environmental Quality no later than 30 days after the end of each calendar quarter. Calendar quarters are: 1st quarter--January 1 through March 31, 2nd quarter--April 1 through June 30, 3rd quarter--July 1 through September 30, 4th quarter--October 1 through December 31.

If the return and fees cannot be submitted within 30 days of the end of the quarter, an extension for up to 30 days may be granted by the Department. A request for an extension must be submitted no later than the due date of the return and must include a detailed description of why the extension is needed. The Department will notify you if the extension is granted or not. Please note that extensions cannot be granted which will result in a due date of more than 60 days after the end of the quarter.

SPECIFIC LINE INSTRUCTIONS

Line 1: Enter the number of days during the quarter the landfill was open to receive waste.

Line 2a & 4a: The activities must be included in, and conducted in accordance with, the landfill's permit. Records pertaining to this fee exemption must be included with the quarterly return. Exemption documentation is to include: 1) waste types and 2) weight/volume recycled and method of recycling for each waste type. **If this information is not included, the claim may be disallowed.**

Line 2b & 4b: A copy of the DEQ's written approval waiving the fee must be included with the quarterly return. **If a copy is not included, the claim may be disallowed.**

Line 2c & 4c: Enter the amount of waste received from large industrial waste generators **which was accompanied by a large industrial waste generator fee exemption certificate issued by the DEQ.**

Line 10a: If utilizing the capital investment waiver, enter line 13 from previous quarter, otherwise enter $40,000.00.

Line 12: **If not utilizing the capital investment waiver, enter $0.00, otherwise see below.**
If line 13 of last quarter's return is $40,000, enter $0.00, otherwise:
If line 9 is less than 100 tons/day, multiply line 8 by $0.50.
If line 9 is equal to or more than 100 tons/day, multiply line 8 by $0.25.

NOTE: Records documenting the capital investment and the use of the funds must be included with the quarterly return.

Line 13: **If not utilizing the capital investment wiaver, enter $0.00, otherwise, see below.**
If line 13 of last quarter's return is less than $40,000, add line 13 of last quarter's return and line 12 of this quarter's return. return. If line 13 of last quarter's return is $40,000, enter $40,000.00.

Line 14: **If not utilizing the capital investment wiaver, enter $0.00, otherwise see below.**
If line 13 of last quarter's return is less than $40,000.00, enter $0.00.
If line 13 of last quarter's return is $40,000 AND this return is filed on time, multiply line 11 by 0.10. Otherwise, enter $0.00.

PENALTIES

There is a 5% penalty for returns postmarked more than 30 days after the last day of the reporting quarter (or filed after the extension date). Your penalty is determined by multiplying line 11 of the return by 0.05 and including this figure on line 16.

There is a 15% penalty per month for returns postmarked more than 60 days after the last day of the reporting quarter. Your penalty is determined by multiplying line 11 of the return by 0.15, then by the number of months which have elapsed after the due date (or the extension date if applicable) and including this figure on line 16.

If you have any questions, please contact Amber Edwards, Land Protection Division Solid Waste Unit (405) 702-5133.

APPENDIX T

COPY OF SURETY BOND

Note: This appendix includes a copy of the current Surety Bond previously approved by the ODEQ.

Description: Muskogee Sanitary Landfill

RIDER TO SURETY BOND

PURPOSE: **INCREASE**

To be attached to Surety Bond Number 800438 issued by Evergreen National Indemnity Company, as Surety, in the amount of be Five Million Four Hundred Forty Six Thousand Seven Hundred Thirty Seven and 27/100 Dollars ($5,446,737.27) (Closure: $2,585,687.15/ Post-Closure: $2,861,050.12), on behalf of Waste Management of Oklahoma, Inc., in favor of the Oklahoma Department of Environmental Quality.

In consideration of the premium charged for the attached bond, it is mutually understood and agreed by the Principal and the Surety that the bond shall be modified to read as follows:

The above said bond amount shall be Six Million Five Hundred Ninety Five Thousand Two Hundred Fifty Four and 64/100 Dollars ($6,595,254.64) (Closure: $2,874,462.91/ Post-Closure: $3,720,791.73), effective the 1st day of March 2023.

All other items, limitations and conditions of said bond except as herein expressly modified shall remain unchanged.

Signed, sealed and dated this 28th day of February 2023.

Principal: **Waste Management of Oklahoma, Inc.**

By: Julie K Bowers
Julie K. Bowers, Attorney-In-Fact

Surety: **Evergreen National Indemnity Company**

By: Denise M. Borowy
Denise M. Borowy, Attorney-In-Fact

POWER OF ATTORNEY

KNOWN ALL MEN BY THESE PRESENTS that Waste Management, Inc. and each of its direct and indirect majority owned subsidiaries (the "WM Entities"), have constituted and appointed and do hereby appoint Kathleen P. Price, Denise M. Borowy, Hilarie D. Frankenberry, and Julie K. Bowers of Evergreen National Indemnity Company, each its true and lawful Attorney-in-fact to execute under such designation in its name, to affix the corporate seal approved by the WM Entities for such purpose, and to deliver for and on its behalf as surety thereon or otherwise, bonds of any of the following classes, to wit:

1. Surety bonds to the United States of America or any agency thereof, and lease and miscellaneous surety bonds required or permitted under the laws, ordinances or regulations of any State, City, Town, Village, Board or any other body or organization, public or private.

2. Bonds on behalf of WM Entities in connection with bids, proposals or contracts.

The foregoing powers granted by the WM Entities shall be subject to and conditional upon the written direction of a duly appointed officer of the applicable WM Entity (or any designee of any such officer) to execute and deliver any such bonds.

The signatures and attestations of such Attorneys-in-fact and the seal of the WM Entity may be affixed to any such bond, policy or to any certificate relating thereto by facsimile and any such bond, policy or certificate bearing such facsimile signatures or facsimile seal shall be valid and binding upon the applicable WM Entity when so affixed.

IN WITNESS WHEREOF, the WM Entities have caused these presents to be signed by the Vice President and Treasurer and its corporate seal to be hereto affixed. This power of attorney is in effect as of February 28, 2023.

Witness:

On behalf of Waste Management, Inc. and each of the other WM Entities

David Reed
Vice President and Treasurer

EVERGREEN NATIONAL INDEMNITY COMPANY

Independence, Ohio

POWER OF ATTORNEY

Bond No.**800438**

KNOW ALL MEN BY THESE PRESENTS: That the Evergreen National Indemnity Company, a corporation in the State of Ohio does hereby nominate, constitute and appoint: **Denise M. Borowy**

its true and lawful Attorney(s)-In-Fact to make, execute, attest, seal and deliver for and on its behalf, as Surety, and as its act and deed, where required, any and all bonds, undertakings, recognizances and written obligations in the nature thereof, PROVIDED, however, that the obligation of the Company under this Power of Attorney shall not exceed TWENTY-FIVE MILLION AND 00/100 DOLLARS ($25,000,000.00)

This Power of Attorney is granted and is signed by facsimile pursuant to the following Resolution adopted by its Board of Directors on the 23rd day of July, 2004:

> "RESOLVED, That any two officers of the Company have the authority to make, execute and deliver a Power of Attorney constituting as Attorney(s)-in-fact such persons, firms, or corporations as may be selected from time to time.
> FURTHER RESOLVED, that the signatures of such officers and the Seal of the Company may be affixed to any such Power of Attorney or any certificate relating thereto by facsimile; and any such Power of Attorney or certificate bearing such facsimile signatures or facsimile seal shall be valid and binding upon the Company; and any such powers so executed and certified by facsimile signatures and facsimile seal shall be valid and binding upon the Company in the future with respect to any bond or undertaking to which it is attached."

IN WITNESS WHEREOF, the Evergreen National Indemnity Company has caused its corporate seal to be affixed hereunto, and these presents to be signed by its duly authorized officers this 1st day of April, 2022.

EVERGREEN NATIONAL INDEMNITY COMPANY

By: _____
Matthew T. Tucker , President

By: _____
David A. Canzone, CFO

Notary Public)
State of Ohio) SS:

On this 1st day of April, 2022, before the subscriber, a Notary for the State of Ohio, duly commissioned and qualified, personally came Matthew T. Tucker and David A. Canzone of the Evergreen National Indemnity Company, to me personally known to be the individuals and officers described herein, and who executed the preceding instrument and acknowledged the execution of the same and being by me duly sworn, deposed and said that they are the officers of said Company aforesaid, and that the seal affixed to the preceding instrument is the Corporate Seal of said Company, and the said Corporate Seal and signatures as officers were duly affixed and subscribed to the said instrument by the authority and direction of said Corporation, and that the resolution of said Company, referred to in the preceding instrument, is now in force.

IN TESTIMONY WHEREOF, I have hereunto set my hand and affixed my official seal at Cleveland, Ohio, the day and year above written.

Julie K Bowers
Notary Public
In and For the State of Ohio
My Commission Expires
August 13, 2024

_____
Julie K. Bowers, Notary Public
My Commission Expires August 13, 2024

State of Ohio) SS:

I, the undersigned, Secretary of the Evergreen National Indemnity Company, a stock corporation of the State of Ohio, DO HEREBY CERTIFY that the foregoing Power of Attorney remains in full force and has not been revoked; and furthermore that the Resolution of the Board of Directors, set forth herein above, is now in force.

Signed and sealed in Independence, Ohio, this 28th day of February, 2023.

_____
Wan C. Collier, Secretary

Standby Trust Agreement Dated January 26, 2011
Waste Management of Oklahoma, Inc., Grantor
U.S. Bank, N.A., Successor Trustee

EXHIBIT A
(Revised 3/1/2023)

Name of Facility:	Muskogee Community Landfill & Recycling Center
Address:	2801 54th Street West Muskogee, Oklahoma 74401
Name of Surety:	Evergreen National Indemnity Company
Address:	6140 Parkland Blvd., Suite 321 Cleveland, OH 44124
Surety's Bond Number:	800438
Amount:	$ 6,595,254.64

Persons Designated as Muskogee Community Landfill & Recycling Center's representatives:

David Reed, Vice President and Treasurer
Diana Seng, Authorized Representative
Jeff Bennett, Assistant Treasurer

EVERGREEN
FLEXIBLE SURETY SOLUTIONS

February 28, 2023

Ms. Carol Bartlett, Environmental Programs Specialist
Oklahoma Department of Environmental Quality
Land Protection Division
707 North Robinson
Oklahoma City, OK 73101
(405) 702-5109

RE: East Oak RDF, Permit # 3555036, Bond 800437
Muskogee Community RDF, Permit # 3551020, Bond 800438
Quarry RDF, Permit # 3572042, Bond 800439

Dear Ms. Bartlett,

The following enclosures provide updated financial assurance for the above-referenced facilities:

- Riders to be attached to the applicable existing bond
- Revised Exhibit A's to the applicable Standby Trust Agreement
-

If you have any questions, feel free to contact -

Diana Seng, Director of Treasury and Financial Assurance
Waste Management
800 Capitol Street, Suite 3000
Houston, TX 77002
(713) 265-1322
dseng@wm.com

Sincerely,

Denise M. Borowy
Evergreen UNI, LLC – Agent for Surety

cc: Guy Campbell, WMI