Module V - Design Report
Virginia Department of Environmental Quality
Part B Permit Application
Curley Hollow Solid Waste Management Facility
To Support The Virginia City Hybrid Energy Center
Wise County, Virginia

GAI Project Number: C060702.00.005

March 2008, Revised September 2008,
February 2009, January 2013, October 2013, December 2014,
February 2017, October 2017, and December 2019

Prepared for: Dominion
5000 Dominion Boulevard
Glen Allen, Virginia 23060

Prepared by: GAI Consultants, Inc.
Pittsburgh Office
385 East Waterfront Drive
Homestead, Pennsylvania 15120-5005
I, Precha Yodnane, Ph.D., P.E., being a Professional Engineer registered for practice in the Commonwealth of Virginia, do hereby certify to the best of my knowledge, information, and belief that the information in the subject report and drawings have been prepared in accordance with accepted practice of engineering, in accordance with the Commonwealth of Virginia Department of Environmental Quality Solid Waste Management Regulations, 9VAC20-80-10, and are true and correct.

Signature ______________________________ Date __________________
License Number 038818 Expiration Date ----
Address GAI Consultants, Inc.
   Pittsburgh Office
   385 East Waterfront Drive
   Homestead, Pennsylvania 15120-5005
Telephone No. 412-476-2000

(SEAL)
Table of Contents

Section I - General FACILITY INFORMATION ................................................................. 1

SECTION II - FACILITY DESIGN .................................................................................... 2
  A. Floodplain .................................................................................................................... 2
  B. Site Access ................................................................................................................ 3
  C. Shelter ...................................................................................................................... 3
  D. Aesthetics .................................................................................................................. 3
  E. Location of Cells ....................................................................................................... 4
  F. Benchmarks ............................................................................................................. 6
  G. Borrow and Stockpile Areas .................................................................................... 6
  H. Site Conditions ....................................................................................................... 7

SECTION III - SITE DESIGN............................................................................................. 8
  A. Regulatory Requirements ......................................................................................... 8
  B. Liner Foundation ...................................................................................................... 10
  C. Liner System ............................................................................................................. 14
  D. Leachate Collection and Removal System .............................................................. 15
  E. Leakage Monitoring System ..................................................................................... 16
  F. Collection and Storage Units .................................................................................... 16
  G. Run-on Control System ............................................................................................. 17
  H. Run-off Control System ............................................................................................ 17

Attachment 1 - Design Plans
Attachment 2 - Design Calculations
Attachment 3 - Part A Application Approval and Maps
Attachment 4 - Gas Management Plan
Attachment 5 - Technical Specifications
Attachment 6 - Construction Quality Assurance Plan

Appendix A - Mine Subsidence Investigation and Mitigation Measures
Appendix B - Laboratory Testing of On-Site Soils and FFP
SECTION I - GENERAL FACILITY INFORMATION

This Design Report, and attached documents, comprise a portion of the Part B Permit Application for the Virginia Electric and Power Company (Dominion) Curley Hollow Solid Waste Management Facility (CHSWMF) to be located near St. Paul, Wise County, Virginia. The CHSWMF will be constructed to support the operation of Dominion’s proposed Virginia City Hybrid Energy Center (VCHEC). These documents adhere to the format set forth in the Virginia Department of Environmental Quality (VDEQ) - Waste Division, Solid Waste Management Regulation (SWMR 9VAC20-80-10) and Submission Instructions to facilitate VDEQ’s review process. The Notice of Intent and Part A Permit Application for the CHSWMF is incorporated into this document by reference.

This Part B Application was prepared by GAI Consultants, Inc. (GAI) on behalf of Dominion, to fulfill the requirements for an Operations Permit as required by VDEQ regulations and Wise County Ordinance.

The proposed CHSWMF will occupy approximately 330 acres, which is a part of a larger collection of lands totaling near 1,700 acres currently owned by Dominion. The actual area for solid waste disposal is somewhat less, however, at about 160 acres. The proposed site is a captive facility for the exclusive disposal of fossil fuel combustion products (FFPs) and other non-hazardous, non-putrescible (excluding liquid hydrocarbons) waste materials associated with the operation and maintenance of the VCHEC CHSWMF.

"Fossil fuel combustion products" means coal combustion byproducts, coal combustion byproducts generated at facilities with fluidized bed combustion technology, petroleum coke combustion byproducts, byproducts from the combustion of oil, byproducts from the combustion of natural gas, and byproducts from the combustion of mixtures of coal and "other fuels" (i.e., co-burning of coal with "other fuels" where coal is at least 50% of the total fuel). For purposes of this definition, "other fuels" means waste-derived fuel product, auto shredder fluff, ground wood wastes, coal mill rejects, peat, tall oil, tire-derived fuel, deionizer resins, and used oil.

Other non-hazardous wastes from the VCHEC will include refractory waste, waste water treatment plant/pond sludge and solids, filter press sludge, limestone and/or hydrated lime, coal (waste from coal pile, incidental coal during construction, and coal dust), coal rock breaker waste, wood (ground waste from wood pile), ground wood rejects, tramp iron from magnetic separator, sedimentation pond dredgings, material handling runoff pond (coal pile and wood pile) dredgings, bag house fabric filters, non-hazardous used desiccants, non-hazardous blast media, coke derived solid fuel and its combustion ash, sand bags, straw bales, and non-putrescible construction and demolition materials (excluding liquid hydrocarbons) from the operation and maintenance of VCHEC and CHSWMF.

The facility will receive approximately 2,400,000 tons of FFPs per year at the power plant’s maximum FFP production rate. The facility will typically operate on a five-day, two (2), 10-hour shifts per day schedule, but extended hours may occur during heavy load periods. Lighting along the haul road and at the landfill will be provided as needed. Once at the landfill, the material will be compacted. The density and engineering characteristic of the VCHEC FFP will be confirmed once production of the materials occurs. The facility has a capacity of about 35 million cubic yards. As such, the expected site life is on the order of 17 years (at the maximum FFP production rate). To extend the site life, beneficial use of the FFPs will be pursued after the VCHEC is in operation.
The facility will be developed in phases as summarized below:

<table>
<thead>
<tr>
<th>Liner Construction Stage</th>
<th>Liner Area (acres)</th>
<th>Approximate Disposal Volume (cubic yards)</th>
<th>Approximate Stage Life (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>53.5(2)</td>
<td>4,841,500</td>
<td>2.7</td>
</tr>
<tr>
<td>1B</td>
<td>22</td>
<td>2,500,500</td>
<td>1.2</td>
</tr>
<tr>
<td>2A</td>
<td>33</td>
<td>(3)</td>
<td>(3)</td>
</tr>
<tr>
<td>2B</td>
<td>32</td>
<td>10,031,000</td>
<td>4.8</td>
</tr>
<tr>
<td>3A</td>
<td>13</td>
<td>(4)</td>
<td>(4)</td>
</tr>
<tr>
<td>3B</td>
<td>4</td>
<td>17,110,000</td>
<td>8.1</td>
</tr>
</tbody>
</table>

Notes:

(1) At maximum FFP production rate.

(2) 51-acres for disposal, 2.5 acres under haul road.

(3) Storage and site life included in Stage 2B

(4) Storage and site life included in Stage 3B

Refer to Permit Drawings 8, 9, 10, 11, and 12 for a depiction of the stages. Stage 1A is separated into two (2) phases, Phase 1 and Phase 2, as shown on Part B Drawing 8. Dominion may develop and operate Phase 1 and Phase 2 either sequentially or simultaneously. **Stage 2B may be developed prior to Stage 2A, as Stage 2A alone does not have significant disposal volume. The approximate storage volume of Stage 2B alone is approximately 2,000,000 cubic yards. This will allow for available storage volume while development of Stage 2A is completed.**

Dominion will be the sole user of the CHSWMF; therefore, no wastes will be accepted for disposal from any other sources and the operations personnel will be trained and directed to reject and exclude access to the CHSWMF by any vehicles hauling waste other than those authorized to haul FFP from the VCHEC plant.

The CHSWMF will be a lined facility, constructed and operated in accordance with the documents comprising this Part B Application. Groundwater monitoring will be performed as proposed in the Monitoring Plan presented in Module X of this Part B Permit Application.

The CHSWMF is located on lands underlain by previously mined areas. Potential adverse impacts to the CHSWMF from these areas will be properly mitigated by employing proven methods. These methods include mine stabilization or over excavation of shallow mine workings and the utilization of Geosynthetic reinforcement materials in other areas. Additional information on potential mine subsidence and proposed mitigation measures are presented in Appendix A of this Part B Application. Because these mined areas will be properly mitigated, it is believed that a variance to the regulations is not needed to construct and operate the facility.

**SECTION II - FACILITY DESIGN**

A. Floodplain

The proposed disposal area of the facility is not located within a documented 100-year floodplain regulated by the Federal Emergency Management Agency (FEMA). Meade Creek is a stream situated to the south/southwest of the CHSWMF, flowing from the northwest to the southeast, and receives flow from Curley Hollow. Project specific stream modeling was performed for Meade Creek however, and the results show that the 100-year floodplain does
not extend to the proposed waste limits in Curley Hollow. However, the embankments for the Sedimentation Pond and the Final Leachate Pond located upstream of the mouth of Curley Hollow, as well as relocated Singapura Road (a private road on Dominion property), will encroach into the 100-year floodplain for Meade Creek. Singapura Road is presently in the floodplain in this vicinity.

Erosion protection will be provided on the outer slopes of the pond embankments for protection above the 100-year flood waters from Meade Creek. Hydraulic modeling was also performed to assess any impacts the embankments and relocated Singapura Road may have on flood levels in Meade Creek. The modeling indicates that the 100-year flood level will increase by 0.7 feet at the upstream limit of the final leachate pond as a result of the construction of the pond embankments and relocation of the road. This increase is less than 1.0 feet, occurs only on Dominion property, and therefore no mitigation is proposed. The elevation of the embankment and the emergency spillway elevations for the final Leachate pond and the sedimentation pond are set above the 100-year flood elevations on Meade Creek.

Calculations for the stream modeling are included in Attachment 2 - Design Calculations

B. Site Access

The CHSWMF is a captive facility and Dominion will be the sole user. The main haul road from the Station to the CHSWMF will be paved and have limited access, with primary access to the haul road being near the Station. Once filled at the silo area at the station, ash disposal trucks will depart the Station and proceed to the CHSWMF via the main haul road. After placing material in the active area, the trucks will make the return trip to the Station or maintenance area/shop/office as appropriate. It is anticipated that the maintenance/shop/office area will be located along the main haul road.

Additional limited access will be necessary for construction contractors during site development activities. Signs will be posted at the access points indicating that the solid waste management facility is private property and only authorized vehicles are allowed to enter.

C. Shelter

It is anticipated that construction offices or trailers, and a maintenance/shop/office area for disposal site contractor use will be provided near the CHSWMF. The trailers would be equipped with electric lighting, baseboard heat, window air conditioners, telephone, and sanitary facilities (Port-A-Johns). The maintenance/shop/office area will be located along the haul road and is expected to have more permanent utilities. All facilities will be located to accommodate construction and operation of the landfill. Further, the Station is located about one mile from the CHSWMF. Thus, nearby shelter will remain accessible and adequate during inclement weather.

D. Aesthetics

Site Screening. The CHSWMF is located on a reasonably remote site, situated in Curley Hollow, about 1 mile to the northwest of the proposed VCHEC. The facility is located on a nearly 1,700-acre parcel of land owned by Dominion. The site is surrounded by nearly 200-foot high ridges in many places, with a narrow valley opening on the south/southwest at the mouth of Curley Hollow. The final development elevation does however exceed the surrounding ridges. The sedimentation collection pond and final leachate collection pond will be located along relocated Singapura Road, a private road on Dominion property. Although
the sedimentation collection pond and final leachate collection pond and ultimate waste management facility may be visible from Alt. Route 58, a visual screen is not proposed.

**Noise.** Typical equipment used at landfills generate noise levels of less than 80 db(A) at 50 feet from the equipment. With no residences within 500 feet of the facility, noise is not expected to be an issue.

It is anticipated that after closure, the CHSWMF will remain a vegetated piece of land.

**E. Location of Cells**

A general concept for the development of the CHSWMF is that it will be phased, beginning at the northern end with Stage 1, and then moving to the south to the mouth of Curley Hollow with Stages 2 and 3, constructing a site liner to a nominal elevation of 1980, and from there increasing the liner in elevation above 1980, as Stages 2 and 3 progress. With reference to Drawings 8, 9, 10, 11, and 12, a more detailed summary, including major items for each phase is:

**Stage 1 Development:**
- Sedimentation Pond at the mouth of Curley Hollow.
  - *Mine grouting in the Jawbone seam where indicated for subsidence mitigation.*
- *Storm water diversions on east and west side of Curley Hollow as necessary.*
- *Earth fill in the lower part of Curley Hollow for haul road development.*
- *Haul road construction.*
- Stage 1A liner in the NW corner of site.
  - Mine Grouting in The Kennedy Seam where indicated for subsidence mitigation.
  - Geogrid Installation in subbase where indicated for subsidence mitigation.
  - *Develop Stage 1A liner, leachate collection, protective cover, and temporary rain cover layers.*
- Stage 1 Leachate Pond in Curley Hollow, including all appurtenant structures,
  - Leachate discharge by gravity to a manhole at the mouth of Curley Hollow, then to the Station WWTP.
- *Begin disposal in Stage 1A upon DEQ approval of construction certification.*
- *Install cap and final cover as required on areas reaching final grade.*
- *Construct Stage 1B to east of Stage 1A.*
  - Remove mine dewatering wells.
  - *Develop Stage 1B liner, leachate collection, protective cover and tie into Stage 1A.*
  - Install temporary rain cover.
- *Begin disposal in Stage 1B upon DEQ approval of construction certification.*
- *Install cap and final cover as required on areas reaching final grade.*
Stage 2 Development:

- **Construct the Final Leachate Pond outside of Curley Hollow.**
  - Mine grouting in the Jawbone Seam within the angle of draw.
  - Construct leachate pond liner, pumpstation and piping to prepare for transfer of leachate from the Stage 1 Leachate Pond.

- **Construct Stage 2B to the west of the haul road in the center of the valley.**
  - Construct diversion channel along west ridge above Stage 2B area.
  - Mine grouting in Kennedy Seam.
  - Shift haul road to the east along toe of slope on east side of valley to allow for construction of Stage 2B liner.
  - The Stage 1 leachate collection pond will be taken out of service to allow the area to be graded and lined and the leachate flows to be diverted to the Final Leachate Pond.
  - Develop Stage 2B liner, protective cover, and temporary rain cover. Tie in to Stage 1A.

- **Begin disposal in Stage 2B upon DEQ approval of construction certification.**
- **Install cap and final cover as required on areas reaching final grade.**
- Construct Stage 2A liner to the east of the haul road in the center of the valley.
  - Construct diversion channel **along east ridge above Stage 2A area.**
  - Mine grouting in Raven seam.
  - Develop Stage 2A liner, protective cover, and temporary rain cover. Tie in to Stage 1A, 1B, and 2B.

- Begin disposal in the Stage 2A area **upon DEQ approval of construction certification.**
- **Install cap and final cover as required on areas reaching final grade.**
- During the Stage 2B design and construction phase a decision was made to construct the Stage 3B area concurrently with Stage 2A.
- Construct Stage 3B to the final elevations on the eastern side of the valley
  - Construct final perimeter channel around outside of Stage 3B
  - Develop Stage 3B liner, leachate collection, protective cover, temporary rain cover and tie into Stage 1A and 2A.

- **Begin disposal in Stage 3B upon DEQ approval of construction certification.**
- **Install cap and final cover as required on areas reaching final grade.**

Stage 3 Development:

- Construct Stage 3A to the final elevations on the western side of the valley
  - Construct final perimeter channel around outside of Stage 3A
  - Develop Stage 3A liner, leachate collection, protective cover, temporary rain cover and tie into Stage 1A and 2B.

- **Begin disposal in Stage 3A upon DEQ approval of construction certification.**
- **Install cap and final cover as required on areas reaching final grade.**
The delineations of the Stages are shown on the drawings in both plan view and cross-section. Note, however, that Dominion may develop, operate, and close partial sections within each stage.

Typically, severe weather and special waste disposal areas are not required for FFPs. However, when sludges and other materials with a high water content are transported to the CHSWMF, they will be placed as far away from the front face of the facility as practicable at that time. The disposal of wood products, **bag house fabric filters, non-hazardous used desiccants**, and broken down non-putrescible materials from VCHEC and CHSWMF will not be allowed within 10’ of any geosynthetic materials. Groundwater underdrains and/or granular blanket drains are incorporated as appropriate as part of the site design to deal with groundwater and springs.

Further, for the type of material to be placed in the CHSWMF there is a minimum active surface area that will be required for disposal. The material must be placed and compacted and then allowed to develop sufficient strength to allow subsequent placement and compaction of the next layer. At other facilities involving similar material, this acreage is typically on the order of 30 acres minimum for all weather conditions. Thus, for the CHSWMF, the required minimum acreage area is estimated to be 30 acres.

**F. Benchmarks**

Benchmarks will be installed for construction control as shown on Drawing 4. A survey grid based on the Virginia State Plane Coordinate System is shown on all plan view drawings.

**G. Borrow and Stockpile Areas**

Dominion owns approximately 1,700 acres at the VCHEC site which will provide sufficient property for laydown, soil stockpile, soil borrow and soil spoil areas for the CHSWMF. Possible locations of the laydown, soil stockpile, soil borrow and soil spoil areas are shown on the Drawings. If needed, adjacent property may also be evaluated for these specific uses. All laydown, soil stockpile, borrow and spoil areas will be located on Dominion property or on property adjacent to Dominion property in the vicinity of CHSWMF. Access to these areas will be via private roads constructed on private property.

Most of the material excavated as part of site development activities to achieve base grade is anticipated to meet project specifications for use on-site as structural fill, cover soil, or other applications as appropriate. When feasible, the more durable rock excavated as part of subgrade preparation, may be stockpiled and processed (crushed and screened as necessary) for on-site use. Materials not meeting specifications for subsequent use, such as mine spoil from certain areas of Curley Hollow, will be transported and placed in a nearby spoils area or areas outside of the facility boundary.

Topsoil removed from disturbed areas of the CHSWMF will be stockpiled for future use. This amount of material is estimated to be 224,000 cubic yards. About 640,000 cubic yards of soils excavated from the site and processed are anticipated to be usable as cover soils. Thus the total volume available for cover soils use is estimated to be about 860,000 cubic yards. The CHSWMF will need approximately 550,000 cubic yards of cover soil in the final cap system to close the site to the final topography contours. This volume is based on covering the geosynthetic cap system with a total of 24 inches of cover soil (18 inches infiltration layer and 6 inches erosion layer for revegetation). The operation will also need about 51,000 cubic yards of intermediate cover soil in the Stage 1A and Stage 1B areas. It is expected that approximately 75% of the intermediate cover soil will be salvaged and stockpiled on Dominion property as shown on the Drawings to be reused as cover soil on other areas.
The facility will also need approximately 150,000 cubic yards of subbase soils (an average of 12 inches on the rock cut areas beneath the geosynthetic liner system. These materials are expected to come from the material excavation areas or other nearby borrow areas. Therefore, through excavation and processing, sufficient materials exists on-site for final cover and subbase.

The total mass earthwork summary for the CHSWMF development is 10,500,000 cubic yards of excavation and 6,500,000 cubic yards of required fill. Most of the excess material is due to the rock excavation required for the final leachate pond construction. The sedimentation pond embankment and the final leachate pond embankment will be built with the excess excavated soil and rock from the pond construction areas. Similarly, the base grade fills in the valley floors will primarily be from excess soil and rock from the excavation to prepare the base grade. Any excess material not immediately used, will be stockpiled as previously discussed. A summary of earthwork by stage is:

<table>
<thead>
<tr>
<th>Construction Stage</th>
<th>Approximate Excavation Volume (cubic yards)</th>
<th>Approximate Fill Volume (cubic yards)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>3,334,000</td>
<td>2,815,000</td>
</tr>
<tr>
<td>1B</td>
<td>591,000</td>
<td>1,226,000</td>
</tr>
<tr>
<td>2A</td>
<td>5,197,500(2)</td>
<td>0</td>
</tr>
<tr>
<td>2B</td>
<td>1,161,000</td>
<td>1,155,000</td>
</tr>
<tr>
<td>3A</td>
<td>109,500</td>
<td>834,000</td>
</tr>
<tr>
<td>3B</td>
<td>56,000</td>
<td>432,000</td>
</tr>
<tr>
<td>TOTALS</td>
<td>10,449,000</td>
<td>6,462,000</td>
</tr>
</tbody>
</table>

Notes:

(1) Does not include final cover material estimated to be 550,000 cy.

(2) Includes final leachate pond.

Earthen materials will be stockpiled as necessary for subsequent use in a future stage.

H. Site Conditions

Conditions of site development, as listed by VDEQ, will be incorporated into this section when received. The Part A approval letter and maps will be incorporated into Attachment 3.
SECTION III - SITE DESIGN

A. Regulatory Requirements

The liner requirements for industrial solid waste landfills are applicable to this site. The landfill will employ a regulatory compliant liner system (from top to bottom consisting of:

1. **Stage 1A, 1B, and 2B**

   A base liner system (for areas under greater fills):
   - Six-inch minimum layer of protective cover;
   - Twelve-inch minimum layer of aggregate forming the Leachate collection layer, with perforated 6-inch diameter collection pipes;
   - Non-woven geotextile, 16 ounce;
   - 50-mil PVC flexible membrane;
   - Non-woven geotextile, 16 ounce;
   - Six-inch minimum subbase, consisting of in-place soil, recompacted soil or non-durable rock;
   - Retention geotextile where required for mine subsidence mitigation;
   - Geogrid where required for mine subsidence mitigation; and
   - Groundwater underdrains as needed.

   Side slope liner system for area under less than 150 feet of FFP:
   - 12-inch minimum layer of aggregate protective cover;
   - Double-sided geocomposite drainage net;
   - 50-mil PVC flexible membrane;
   - Non-woven geotextile, 16 ounce;
   - Six-inch minimum subbase, consisting of in-place soil, recompacted soil or non-durable rock;
   - Retention geotextile where required for mine subsidence mitigation;
   - Geogrid where required (for mine subsidence mitigation); and
   - Groundwater underdrains as needed.

2. **Stage 2A and 3B**

   A base liner system (for areas under greater fills):
   - *Six-inch minimum layer of protective cover;*
   - *Twelve-inch minimum layer of aggregate forming the Leachate collection layer, with perforated 6-inch diameter collection pipes;*
   - *Non-woven geotextile, 16 ounce;*
   - *60-mil LLDPE flexible membrane;*
   - *Non-woven geotextile, 16 ounce;*
   - *Six-inch minimum subbase, consisting of in-place soil, recompacted soil or non-durable rock;*
• Retention geotextile where required for mine subsidence mitigation;
• Geogrid where required for mine subsidence mitigation; and
• Groundwater underdrain as needed.

Side slope liner system for area under less than 150 feet of FFP:
• 12-inch minimum layer of aggregate protective cover;
• Double-sided geocomposite drainage net;
• 60-mil LLDPE flexible membrane;
• Non-woven geotextile, 16 ounce;
• Six-inch minimum subbase, consisting of in-place soil, recompacted soil, or non-durable rock.
• Retention geotextile where required for mine subsidence mitigation;
• Geogrid where required (for mine subsidence mitigation); and
• Groundwater underdrains as needed.

3. Stage 3A
A base liner system (for areas under greater fills):
• Six-inch minimum layer of protective cover;
• Twelve-inch minimum layer of aggregate forming the Leachate collection layer, with perforated 6-inch diameter collection pipes;
• Non-woven geotextile, 16 ounce;
• 60-mil LLDPE flexible membrane;
• Geosynthetic clay liner;
• Six-inch minimum subbase, consisting of in-place soil, recompacted soil or non-durable rock.
• Retention geotextile where required for mine subsidence mitigation;
• Geogrid where required for mine subsidence mitigation; and
• Groundwater underdrain as needed.

Side slope liner system for area under less than 150 feet of FFP:
• 12-inch minimum layer of aggregate protective cover;
• Double-sided geocomposite drainage net;
• 60-mil LLDPE flexible membrane;
• Geosynthetic clay liner;
• Six-inch minimum subbase, consisting of in-place soil, recompacted soil, or non-durable rock.
• Retention geotextile where required for mine subsidence mitigation;
• Geogrid where required (for mine subsidence mitigation); and
• Groundwater underdrains as needed.
B. Liner Foundation

Design Description

The engineering analyses are based on data gathered through the subsurface exploration and testing program. The issues of settlement, short and long term stability, bearing capacity, bottom heave or blow out, and construction and operational loading have been addressed. The analyses demonstrate that acceptable factors of safety exist for all foreseeable operation conditions.

Bearing Capacity and Stability

The stability of the facility has been evaluated for the condition where the disposal facility is of maximum height. The stability of the liner has been evaluated for conditions during construction and before placing additional material. The stability of the final cover on 3H:1V slope has also been analyzed.

In the analysis of the facility foundation material, the factor of safety against deep circular failure was calculated using the Simplified Bishop method of analysis. The locations of the cross-section lines for analyses of the embankment stability and bearing capacity of liner foundation calculations are shown in the Calculations in Attachment 2. Cross-sections are presented on the Drawings titled Geotechnical Worksheet Nos. 1 and 2. Section A-A begins at Boring 07-001, Section B-B lies on the west side of Curley Hollow in the vicinity of Boring 07-015 and bisects a proposed rock buttress, Section C-C traverses a proposed rock buttress on the east side of the hollow adjacent to Borings 07-010 and 07-012, and Section PA is situated on the east side of the proposed Stage 1 leachate pond and begins near the center of the pond bottom and ends at the far side of the proposed haul road. The stability calculations demonstrate that the required minimum factor of safety of 1.5 is achieved. The strength parameters used in the analysis were based upon field, laboratory data, and published information. The most critical, static factors of safety for each section were: Section A-A, deep-seated rotation, 1.5; Section B-B, deep-seated rotation, 1.6; Section C-C, deep-seated rotation, 1.5; and Section PA, deep-seated rotation, 1.5. Results of the stability analyses are tabulated below.

Full Development Stability Analysis Results

<table>
<thead>
<tr>
<th>Section</th>
<th>File Name</th>
<th>Attachment</th>
<th>Failure</th>
<th>Type</th>
<th>FS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-A</td>
<td>lfsa-1.pl2</td>
<td>6</td>
<td>Rotational</td>
<td>Static</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>lfsa-2.pl2</td>
<td>6</td>
<td>Rotational</td>
<td>Static</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>lfsa-3.pl2</td>
<td>6</td>
<td>Rotational</td>
<td>Static</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>lfsa-1s.pl2</td>
<td>6</td>
<td>Rotational</td>
<td>Seismic</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>lfsa-4.pl2</td>
<td>6</td>
<td>Translational</td>
<td>Static</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>lfsa-5.pl2</td>
<td>6</td>
<td>Translational</td>
<td>Static</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>lfsa-5s.pl2</td>
<td>6</td>
<td>Translational</td>
<td>Seismic</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>lfsa-6.pl2</td>
<td>6</td>
<td>Translational</td>
<td>Static</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>lfsa-7.pl2</td>
<td>6</td>
<td>Translational</td>
<td>Static</td>
<td>5.6</td>
</tr>
<tr>
<td>B-B</td>
<td>lfsb-1.pl2</td>
<td>7</td>
<td>Rotational</td>
<td>Static</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>lfsb-2.pl2</td>
<td>7</td>
<td>Rotational</td>
<td>Static</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>lfsb-2s.pl2</td>
<td>7</td>
<td>Rotational</td>
<td>Seismic</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>lfsb-3.pl2</td>
<td>7</td>
<td>Rotational</td>
<td>Static</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>lfsb-4.pl2</td>
<td>7</td>
<td>Rotational</td>
<td>Static</td>
<td>1.7</td>
</tr>
<tr>
<td>C-C</td>
<td>lfsc-2.pl2</td>
<td>8</td>
<td>Rotational</td>
<td>Static</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>lfsc-2s.pl2</td>
<td>8</td>
<td>Rotational</td>
<td>Seismic</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>lfsc-3.pl2</td>
<td>8</td>
<td>Rotational</td>
<td>Static</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>lfsc-4.pl2</td>
<td>8</td>
<td>Rotational</td>
<td>Static</td>
<td>3.8</td>
</tr>
</tbody>
</table>
Stage 1A Stability Analysis

<table>
<thead>
<tr>
<th>Section</th>
<th>File Name</th>
<th>Attachment</th>
<th>Failure Type</th>
<th>Type</th>
<th>FS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-A</td>
<td>Lfsa1f1.pl2</td>
<td>9</td>
<td>Translational</td>
<td>Static</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>Lfsa1f2.pl2</td>
<td>9</td>
<td>Translational</td>
<td>Static</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>Lfsa1f3.pl2</td>
<td>9</td>
<td>Translational</td>
<td>Static</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>Lfsa1f4.pl2</td>
<td>9</td>
<td>Translational</td>
<td>Static</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>Lfsa1f5.pl2</td>
<td>9</td>
<td>Translational</td>
<td>Static</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>Lfsa1f6.pl2</td>
<td>9</td>
<td>Translational</td>
<td>Static</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>Lfsa1f7.pl2</td>
<td>9</td>
<td>Translational</td>
<td>Seismic</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Lfsa1f8.pl2</td>
<td>9</td>
<td>Translational</td>
<td>Seismic</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Stage 1 Pond Stability Analysis

<table>
<thead>
<tr>
<th>Section</th>
<th>File Name</th>
<th>Attachment</th>
<th>Failure Type</th>
<th>Type</th>
<th>FS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA-PA</td>
<td>pards2.pl2</td>
<td>10</td>
<td>Rotational</td>
<td>Static</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>Pards4.pl2</td>
<td>10</td>
<td>Rotational</td>
<td>Static</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Pards5.pl2</td>
<td>10</td>
<td>Rotational</td>
<td>Static</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Pards6.pl2</td>
<td>10</td>
<td>Rotational</td>
<td>Seismic</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The bearing capacity of the foundation materials beneath the facility is accounted for in the Simplified Bishop Method of stability analysis for sections previously discussed. Factor of safety against bearing capacity failure were analyzed at each test pit and boring location completed during the Part A Application subsurface exploration program. In addition, six additional locations were selected along the valley centerline. These six additional locations were selected because of the relatively thick layer of FFPs intended relative to the shear strength properties of the subsurface soils in the selected areas. Based on the proposed geometry, the most critical location analyzed is at Boring 07-016; factor of safety of 5.5. Calculations analyzing the stability of the liner system during construction and of the final cover against sliding are presented in Attachment 2. The minimum static factor of safety against sliding of the liner (without the buttress effect of the disposed material was in-place was calculated to be 1.2 (short-term conditions once the disposal material was in-place) and 1.6 (long-term conditions), respectively. The minimum static factor of safety for the final cover satisfies the 1.5 factor of safety criteria. Results of the veneer stability analyses are tabulated below:

Maximum Bottom Liner Slope Length Analysis Summary, $\phi = 21$ Degrees

<table>
<thead>
<tr>
<th>File Name</th>
<th>Slope Length</th>
<th>Analysis Conditions</th>
<th>Failure Plane Analyzed</th>
<th>FSmin</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-BTM-Liner-Dry-Static.slz</td>
<td>100 feet</td>
<td>Dry, Static</td>
<td>Through Various Layers</td>
<td>1.2</td>
</tr>
<tr>
<td>75-BTM-Liner-Dry-Static.slz</td>
<td>75 feet</td>
<td>Dry, Static</td>
<td>Through Various Layers</td>
<td>1.2</td>
</tr>
<tr>
<td>60-BTM-Liner-Dry-Static-1.slz</td>
<td>60 feet</td>
<td>Dry, Static</td>
<td>Liner Interface</td>
<td>1.2</td>
</tr>
<tr>
<td>60-BTM-Liner-Wet-Static-1.slz</td>
<td>60 feet</td>
<td>Wet, Static</td>
<td>Through various layers</td>
<td>1.2</td>
</tr>
<tr>
<td>60-BTM-Liner-Dry-Seismic.slz</td>
<td>60 feet</td>
<td>Dry, Seismic</td>
<td>Through various layers</td>
<td>1.2</td>
</tr>
</tbody>
</table>
Bottom Liner Slope Stability with Drainage Media

<table>
<thead>
<tr>
<th>File Name</th>
<th>Drainage Media Thickness</th>
<th>Analysis Conditions</th>
<th>Failure Plane Analyzed</th>
<th>FSmin</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-BTM-Liner-Dry-Static-1.slz</td>
<td>12 inches</td>
<td>Dry, Static</td>
<td>Drainage Layer</td>
<td>1.3</td>
</tr>
<tr>
<td>60-BTM-Liner-Wet-Static-1.slz</td>
<td>12 inches</td>
<td>Wet, Static</td>
<td>Drainage Layer</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Minimum Interface Friction Angle Analysis Summary

<table>
<thead>
<tr>
<th>File Name</th>
<th>Phi Angle</th>
<th>Analysis Conditions</th>
<th>Failure Plane Analyzed</th>
<th>FSmin</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-BTM-Liner-Phi-18.siz</td>
<td>18 degrees</td>
<td>Dry, Static</td>
<td>Liner Interface</td>
<td>1.0</td>
</tr>
<tr>
<td>60-BTM-Liner-Phi-19.siz</td>
<td>19 degrees</td>
<td>Dry, Static</td>
<td>Liner Interface</td>
<td>1.1</td>
</tr>
<tr>
<td>60-BTM-Liner-Phi-20.siz</td>
<td>20 degrees</td>
<td>Dry, Static</td>
<td>Liner Interface</td>
<td>1.1</td>
</tr>
<tr>
<td>60-BTM-Liner-Phi-21.siz</td>
<td>21 degrees</td>
<td>Dry, Static</td>
<td>Liner Interface</td>
<td>1.2</td>
</tr>
</tbody>
</table>

“Typical” Landfill Cap Cross-Section (3H:1.0V)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Analysis Conditions</th>
<th>Failure Plane Analyzed</th>
<th>FSmin</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 to 1, Dry, Static.slz</td>
<td>Dry – Static – Rotational</td>
<td>Soil/Liner/FFPs</td>
<td>1.7</td>
</tr>
<tr>
<td>3 to 1, Dry, Seismic.slz</td>
<td>Dry – Seismic – Rotational</td>
<td>Soil/Liner/FFPs</td>
<td>1.0</td>
</tr>
<tr>
<td>3 to 1, Wet, Static.slz</td>
<td>Wet – Static – Rotational</td>
<td>Soil/Liner/FFPs</td>
<td>1.7</td>
</tr>
<tr>
<td>3 to 1, Wet, Static-Block.slz</td>
<td>Dry – Static – Translational</td>
<td>Soil/Liner</td>
<td>1.7</td>
</tr>
<tr>
<td>3 to 1, Wet, Seismic-block.slz</td>
<td>Dry – Seismic – Translational</td>
<td>Soil/Liner</td>
<td>1.0</td>
</tr>
<tr>
<td>3 to 1, Wet, Static-Block.slz</td>
<td>Wet – Static – Translational</td>
<td>Soil/Liner</td>
<td>1.6</td>
</tr>
</tbody>
</table>

According to the 2002 National Seismic Hazard Map of Peak Acceleration (0.2 g) with 2% probability of exceedance in 50 years, the peak acceleration at the site is 0.2 g. Based upon the high percentage of plastic fines and high confining pressures resulting from placement of structural fill in the valley floors over the in-situ soils, the site is not susceptible to liquefaction or permanent ground deformation promulgated due to a seismic event.

Bottom Heave or Blow-out
Potentiometric levels associated with ground water beneath the site are located a minimum of 10 feet below the proposed liner elevation, except at two (2) locations, as shown on Part B Drawing 5. No deep excavations will be made that will produce steep gradients that could result in bottom heave or blowout. The potential for bottom heave or blow out conditions to develop at any time during or after construction of the facility is minimal. However, should springs and seeps be encountered during construction appropriate graded rock and pipe spring and seep drains and/or blanket drains will be employed to manage groundwater egress from beneath the lined disposed site.

Construction and Operational Loading
As indicated by the stability analyses, the foundation material is sufficiently competent that the factors of safety of the proposed facility against shear failure are acceptable at all stages of construction. Construction and operations equipment will consist of haul trucks; tracked vehicles, such as dozers; compaction equipment, such as vibratory rollers; and support vehicles, such as light trucks, road graders, etc. Loads from such conventional vehicles can readily be supported by the foundation soils. The placement of compacted fill over the foundation materials as construction progresses will enhance the overall bearing capacity of the foundation soils.

Restrictions have been made in the Technical Specifications on the passage of construction equipment over the liner and other critical areas so as to preclude damage during construction operations.

**Laboratory Data**

Laboratory tests were conducted on bag and composite jar samples of soil of the insitu soils; as well as, intact rock cores. Mechanical and engineering properties tests were conducted on soil samples collected from 11 test pits and two (2) borings at depths ranging from the ground surface to bedrock. Additional testing was conducted on rock cores from seven (7) borings.

Tests conducted on the soil included both index properties and engineering properties of insitu conditions. Index testing included Atterberg Limits, gradation, and visual classification while the engineering properties tests consisted of specific gravity, natural moisture content, and shear strength parameters. Shear strength parameters were determined from four (4) samples: 1) using a direct shear devise with composite jar samples obtained during split spoon sampling, 2) using a tri-axial compression with bag samples obtained during the test pit program.

As part of a Waste Characterization Study, tests were conducted on ash samples collected from power stations with similar boiler operations. Tests included both index properties and engineering properties. Index testing was limited to gradation and visual classification while the engineering properties tests consisted of natural moisture content, permeability, shear strength parameters, and Proctor compaction tests. A summary of the test results and raw data was submitted to the VDEQ in response to Part A review comments.

**Subsurface Exploration Data**

A geotechnical report and hydrogeologic report were provided in the Part A Application that fully describe the boring and test pit programs and discuss the geologic setting and hydrogeologic conditions on-site in detail. The boring logs, test pit logs, piezometers details and laboratory data on recovered samples are also provided in Part A.
C. Liner System

In 2019, an additional stability analysis was performed for addition of LLDPE as a geomembrane material for Stage 2A, Stage 3A and Stage 3B, and for addition of Geosynthetic Clay Liner (GCL) in the liner system for Stage 3A. The 2019 stability analysis was based on a shear normal function analysis of all the interfaces within the liner system based on the geometry of the liner system and proposed waste placement. The 2019 stability analysis updates the requirements of each liner component to a shear normal function, which has been incorporated into the technical specifications for the liner materials. The 2019 stability analysis is provided in the Design Calculations, Attachment 2. The 2019 stability analysis supersedes the previous analysis for Stage 2A, Stage 3A, and Stage 3B of the landfill.

Alternative Composite Liner

Liner Material

The Stage 1A, 1B, and 2B liner will consist of 50-mil PVC geomembrane; Stage 2A and Stage 3B liner will consist of 60-mil LLDPE geomembrane; and future construction of Stage 3A will consist of the 60-mil LLDPE geomembrane above a GCL. The PVC geomembrane, LLDPE geomembrane, and GCL will be obtained from an approved manufacturer who has shown their material to be chemically compatible with the anticipated leachate and has documented that their material meets the liner strength requirements as listed in the specifications. The GCL will have a liquid flow rate no greater than the liquid flow rate of two feet of compacted soil with a hydraulic conductivity of no more than 1x10^{-7} cm/sec.

Liner Thickness

The 50-mil PVC and 60-mil LLDPE geomembrane thicknesses were selected to withstand tensile stresses due to differential settlement of the liner foundation and to resist penetration due to exposure to rock particles in the liner subgrade and leachate collection drainage layer. This thickness will also facilitate thermo-fusion welding during construction.

Strength Demonstration

The Technical Specifications list minimum geomembrane material requirements. Before any geomembrane is used, documentation shall be required from the manufacturer to certify that all requirements in the specifications have been met.

Flow Rate Demonstration

The Technical Specifications list minimum GCL material requirements. Before any GCL is used, documentation shall be required to certify that the liquid flow rate through the GCL is not greater than the liquid flow rate of two feet of compacted soil with a hydraulic conductivity of 1 x10^{-7} cm/sec.

Installation

The geomembrane shall be seamed by thermo-fusion welding and/or bodied solvent bonding lap joints in accordance with the manufacturer’s recommendations. All installation requirements and inspection, monitoring, sampling and testing methods shall be in accordance with the manufacturer’s recommendations and as described in the Technical Specifications and the CQA Plan attached herein as part of this Part B submittal.
Coverage

The drawings depict the installation of the liner covering all areas that have the potential to be in contact with waste or leachate.

All leachate will be collected within the bounds of the liner and conveyed to the leachate collection pond. All surface run-off from active areas of the site will be directed along with the leachate into the leachate collection pond(s).

Prevention of Exposure

As described by the installation requirements for geomembrane liner in the Technical Specifications, the geomembrane will be covered by GDN and, where applicable, leachate collection layer material as soon as the field seams are completed, tested and approved. Immediately after the liner is placed, but prior to seaming, the liner shall be anchored at all edges by sandbags to prevent wind from lifting the liner and causing damage. Upon the recommendation of the liner manufacturer’s representative, the liner will not be placed on excessively windy days. Any liner exposed to the sun longer than the liner manufacturer’s recommendation before being covered will be removed and replaced.

D. Leachate Collection and Removal System

The leachate collection system will consist of a drainage layer of either a 250-mil GDN or a 12-inch thick aggregate drainage layer, depending on the depth of overlaying waste. The aggregate drainage layer aggregate will have a hydraulic conductivity greater than $1 \times 10^{-3}$ cm/sec. The drainage layer contains a pipe network which collects and discharges leachate into a leachate storage pond. The leachate will then be conveyed to the water treatment facility at the power station.

The aggregate drainage layer will be underlain by a 16-oz protective geotextile to protect the liner. The GDN will be overlain by a 12-inch thick protective cover layer and the aggregate drainage layer will be overlain by a 6-inch thick protective cover layer. This protective cover layer will be aggregate having a hydraulic conductivity greater than $1 \times 10^{-3}$ cm/sec. Station bed ash, may be used in place of aggregate for the protective cover layer, provided the material meets or exceeds the design permeability and material characterization criteria.
Leachate Flow

Average monthly and annual, as well as, daily peak leachate flow for typical active facility conditions were estimated using the HELP computer model. For the open conditions, results of the HELP analysis indicated an average 30-day leachate flow of 6,877 ft³ of leachate per acre while highest monthly flows are provided in the following table.

<table>
<thead>
<tr>
<th>Month</th>
<th>Side Slopes (Per Acre)</th>
<th>Floor Slope (Per Acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>1,353</td>
<td>1,388</td>
</tr>
<tr>
<td>February</td>
<td>1,047</td>
<td>1,128</td>
</tr>
<tr>
<td>March</td>
<td>1,028</td>
<td>989</td>
</tr>
<tr>
<td>April</td>
<td>1,889</td>
<td>3,434</td>
</tr>
<tr>
<td>May</td>
<td>1,552</td>
<td>3,035</td>
</tr>
<tr>
<td>June</td>
<td>4,865</td>
<td>5,116</td>
</tr>
<tr>
<td>July</td>
<td>4,122</td>
<td>4,163</td>
</tr>
<tr>
<td>August</td>
<td>2,730</td>
<td>2,815</td>
</tr>
<tr>
<td>September</td>
<td>2,202</td>
<td>2,113</td>
</tr>
<tr>
<td>October</td>
<td>1,889</td>
<td>1,895</td>
</tr>
<tr>
<td>November</td>
<td>1,552</td>
<td>1,560</td>
</tr>
<tr>
<td>December</td>
<td>1,469</td>
<td>1,365</td>
</tr>
</tbody>
</table>

Leachate generation results of the HELP analysis for the permanently closed condition averaged 0.879 ft³ per acre/year and for peak daily leachate flow, 0.005 ft³ per acre/day. A summary of these results along with the HELP model analyses are contained in Attachment 2. The HELP computer model was also used to evaluate maximum leachate head on the liner. The HELP model results showed that with the proposed pipe drainage network installed within the proposed drainage layer material, a maximum of 2.08 inches of head would build up on the liner for maximum head conditions (i.e., minimum liner slope, maximum flow length). This demonstrates that the drainage layer has sufficient drainage capacity and meets the regulatory requirement of having a maximum leachate head of less than one foot.

Calculations demonstrating the stability of the leachate collection system are included in Attachment 2. For short-term conditions (construction and initial operations), an acceptable minimum factor of safety (FSMIN=1.2) was used for the worst-case cross-section analyzed. These analyses were based on incrementally decreasing the maximum slope length beginning with the longest, uninterrupted subgrade slope. Results of these analyses indicate the maximum unbenched slope length may be as long as 200 feet. Thus, the incorporation of the small earthen berms in the subbase as shown on Drawing 22.

E. Leakage Monitoring System

The CHSWMF will employ a regulatory compliant single liner system and groundwater monitoring. As such, there is no leak detection system proposed for the facility.

F. Collection and Storage Units

Leachate and storm-generated contact water will flow via the leachate collection pipe system and/or lined channels to one of the leachate collection ponds. Regulatory requirements state that the ponds be sized to contain 7 days of anticipated leachate production from phases of the facility appropriate to the particular pond (Stage 1 Leachate Pond versus Final Leachate
Pond). Additional storage will be provided to allow for sedimentation (wet volume) and to contain the runoff resulting from a 25-year, 24-hour storm, from active areas of disposal and from the portions of the haul road within the landfill boundary. Additional storage has been provided in the leachate ponds so that, should the water level in the ponds be at the sediment storage (wet volume) level at the beginning of a storm, the Stage 1 leachate pond could contain runoff from a 400-year, 24-hour storm and the final leachate pond could contain runoff from the 1000-year, 24-hour storm. Given an anticipated life of five years for the Stage 1 pond and 17 years for the final pond, the likelihood of emergency spillway discharge occurring when starting at the wet volume level is 1.2% and 1.7%, respectively, over the life of the ponds.

From the ponds, leachate will be conveyed to the Station WWTP either by pumping (final leachate pond) or by gravity (Stage 1 pond leachate), dependent on the pond. Emergency spillways will be used to maintain the integrity of the leachate collection ponds during high flow events by discharging flow up to one half of the probable maximum precipitation.

G. Run-on Control System

Phasing of the proposed solid waste facility will be utilized to minimize the potential for storm water run-on. Development of the facility will begin in the upgradient portions of the watershed and will extend to near existing ridge lines. A perimeter road will also be situated around the facility and road drainage channels will prevent upgradient run-on.

Where significant watersheds would produce uncontrolled run-on, diversion channels will be constructed according to the current VDEQ Solid Waste Regulations. The channels will be sized and have lining designed to safely convey the peak flow resulting from runoff from the 25-year 24-hour storm. For example, a temporary diversion channel will be used to prevent run-on to the Stage 1 Leachate Collection Pond from a watershed to the west.

H. Run-off Control System

The status of a runoff area (for example, active waste disposal or reclaimed face) will determine the destination of the runoff. Runoff from active waste disposal areas will be directed to a collection channel located along the haul road, sized to pass the peak flow resulting from a 25-year, 24-hour storm. This runoff, plus the runoff from the portion of the haul road located within the landfill limits, will be conveyed to the leachate collection pond in use for that phase of development, which will capture and hold without discharging the 25-year 24-hour storm event runoff volume.

Runoff from soil-covered areas of the landfill will be conveyed via benches and, where necessary, slope drains, to perimeter channels located along the landfill. This runoff will be directed to the Sedimentation Pond. Due to landfill configuration, it is likely that revegetated portions of the landfill will also be conveyed to the Sedimentation Pond, but these areas can be diverted from the pond if possible. These conveyances will all be sized to pass the peak flow resulting from the 25-year, 24-hour storm.

Both the Stage 1 Leachate Collection Pond/Sediment Collection Pond area and the Final Leachate Collection Pond will be classified as dams based on Virginia Dam Safety regulations. As such, the stability of the structures as well as the discharge capabilities will meet Dam Safety criteria, and a dam permit will be obtained for the structures.

Channels and Culverts

Channels and culverts for the landfill, and the site in general, have been designed to convey the peak flow from the 25-year, 24-hour storm with a minimum of 12-inches of freeboard.
However, when the full flow capacity of a drainage channel is evaluated, all channels are capable of conveying the peak flow from a 100-year, 24-hour storm. Site channels are typically trapezoidal or rectangular in cross-section, and lined with grass, turf reinforcement mat, concrete, articulated concrete block, or fabric-formed concrete to resist the predicted flow velocities and shear forces. On the landfill, the channels are situated along either side of the haul road, with culverts used to cross the roads as needed. Runoff from reclaimed sloped areas of the landfill embankment will drain to benches which are sloped to the channels along the haul roads or to the site perimeter.

**Benches**

The landfill will be terraced with 20-foot wide benches every 25 feet in height and back-sloped at 5 percent to create a one foot deep channel. The benches have sufficient hydraulic capacity to convey the 25-year, 24-hour peak flow from the slope above to the site channels. Where necessary, the benches will be armored with a turf-reinforcement mat to reduce erosion.

**Subgrade Underdrain Pipes**

A site underdrain will be placed in the bottom of Curley Hollow or with laterals as shown on the drawings, or as determined to be required during construction. This underdrain will collect and convey water from seeps and springs beneath the base grade fill to downstream of the facility toe area.
MODULE V
ATTACHMENT 1 - DESIGN PLANS
A reduced size copy of the Part B Permit Drawings follows.
MODULE V
ATTACHMENT 2 - CALCULATIONS
(VOLUMES 3 OF 4 AND 4 OF 4)
Purpose/Statement of Problem:

Due to changes made to the Curley Hollow Landfill Stage 2A, Stage 3B, and future Stage 3A bottom liner system, the closure cap system is being evaluated to verify that the closure cap is still in compliance with the Virginia Solid Waste Regulations and the CCR Rule.

Based on Virginia Solid Waste Regulations, 9VAC20-81-160, the final closure cap system must minimize infiltration through the closed disposal unit by the use of an infiltration layer which has a hydraulic conductivity less than or equal to the hydraulic conductivity of the bottom liner system or no greater than 1x10^(-5) cm/sec. This evaluation will compare the proposed 60-mil LLDPE geomembrane bottom liner system with the previous 40-mil PVC or 60-mil HDPE cap system.

Equivalency Parameters:

The Giroud leakage equation may be used for evaluating leakage through a composite liner system. This equation was developed through empirical testing and is explained in “Equations for calculating the rate of liquid migration through composite liner due to geomembrane defects.” Giroud, J.P. (1997). The empirical equation is as follows:

\[ Q = C \left[1+0.1(h_w/t)^{0.95}\right] a^{0.1} h_w^{0.9} k_s^{0.74} \]

- **Q** = Rate of leakage through a defect
- **C** = a dimensionless constant related to the quality of the intimate contact between geomembrane and underlying clay liner or geosynthetic clay liner (GCL)
- **h_w** = Liquid head on top of the geomembrane (m)
- **t** = Underlaying soil (compacted soil subbase) thickness of the composite liner (m)
- **a** = defect area in geomembrane (m²)
- **k_s** = Clay soil or GCL element hydraulic conductivity of the composite liner (m/s)

For the purposes of this evaluation, the hydraulic conductivity through the liner system is proportional to the rate of leakage through a defect. Also, the hydraulic conductivity through the cap must be less than or equal to the hydraulic conductivity through the bottom liner system. Therefore, we will compare the rate of leakage of the cap to the rate of leakage of the liner system.

\[ Q_C \leq Q_L \]

- **Q_C** = hydraulic conductivity of cap system
- **Q_L** = hydraulic conductivity of liner system
Therefore:

\[ C_C [1+0.1(h_{w_C}/t_C)^{0.95}] a_C^{0.1} h_{w_C}^{0.9} k_{s_C}^{0.74} \leq C_L [1+0.1(h_{w_L}/t_L)^{0.95}] a_L^{0.1} h_{w_L}^{0.9} k_{s_L}^{0.74} \]

As this is a comparison of two geomembrane systems, the equation can be simplified by removing equivalent variables.

The liner system and cap system assume a cushion geotextile between the subbase and geomembrane material so the intimate contact between geomembrane and underlying subbase is equivalent. Therefore, the dimensionless constant related to the quality of intimate contact between the subbase and geomembrane is equivalent.

\[ C_C = C_L \]

The liner system and cap system are assumed to be installed with the same care and level of construction quality assurance. Therefore, it is assumed that number of defects and defect area in the geomembrane will be equivalent.

\[ a_C = a_L \]

Removing these equivalent variables simplifies the equation:

\[ [1+0.1(h_{w_C}/t_C)^{0.95}] h_{w_C}^{0.9} k_{s_C}^{0.74} \leq [1+0.1(h_{w_L}/t_L)^{0.95}] h_{w_L}^{0.9} k_{s_L}^{0.74} \]

The resulting equation contains a comparison of the parameters which affect the equivalency of the bottom liner and cap system. These controlling parameters for this hydraulic conductivity equivalency are the liquid head (hw), the underlying soil thickness (t), and the hydraulic conductivity of the composite liner (ks).

Liquid head affects the drainage through each defect based on the hydraulic head on top of the geomembrane in the system. Per Module V, HELP Model Analysis, the HELP model for Permanent Closure, 3.5% [bottom] Slope, the max liquid head on the bottom liner geomembrane is 0.179 inches (0.005 m) and the max liquid head on the cap liner geomembrane is 0.089 inches (0.0023 m). Even though Stage 2A, Stage 3B, and Stage 3A have areas with 3H:1V liner slopes, the HELP model for Permanent Closure, 3.5% [bottom] Slope is used because it represents the floor of the landfill where leachate will accumulate.

The underlying soil thickness controls the seepage rate through each defect. The underlying soil thickness is 6 inches (0.152 m) for the designed bottom liner system and 12 inches (0.3048 m) for the cap system.

The hydraulic conductivity of the geomembranes is based on the geomembrane material. The hydraulic conductivity of different materials used in geomembranes has been empirically calculated and studies...
performed by J. P. Giroud and R. Bonaparte have shown that the geomembrane thickness has little impact on the hydraulic conductivity of the geomembrane. Data from these studies has been used to provide conservative values for different geomembrane material types used by the HELP model. The values for hydraulic conductivity of geomembrane by material type used in the HELP model will be assumed for the geomembranes in this evaluation. These materials have the following hydraulic conductivity values:

- Bottom Liner LLDPE: \(4 \times 10^{-15} \text{ m/s}\)
- Cap Geomembrane HDPE: \(2 \times 10^{-15} \text{ m/s}\)
- or PVC: \(2 \times 10^{-13} \text{ m/s}\)

**Cap and Liner Equivalency:**

For the cap system option using 40-mil PVC cap above the 60-mil LLDPE bottom liner system, the resulting equivalency is determined:

\[
[1 + 0.1(0.0023/0.3048)^{0.95}][0.0023]^{0.9}(2\times10^{-13})^{0.74} \leq [1 + 0.1(0.0045/0.1524)^{0.95}][0.0045]^{0.9}(4\times10^{-15})^{0.74}
\]

\[
1.693\times10^{-12} \leq 1.718\times10^{-13}
\]

As this statement is untrue, the PVC cap system does not mathematically have a hydraulic conductivity less than or equal to the hydraulic conductivity of the bottom liner system. Therefore, the PVC cap system does not actually meet the requirement for a capping system over the LLDPE liner system.

For the cap system option using 60-mil HDPE cap above the 60-mil LLDPE bottom liner system, the resulting equivalency is determined:

\[
[1 + 0.1(0.0023/0.3048)^{0.95}][0.0023]^{0.9}(2\times10^{-15})^{0.74} \leq [1 + 0.1(0.0045/0.1524)^{0.95}][0.0045]^{0.9}(4\times10^{-15})^{0.74}
\]

\[
5.607\times10^{-14} \leq 1.718\times10^{-13}
\]

As this statement is true, the HDPE cap system has a hydraulic conductivity less than or equal to the hydraulic conductivity of the bottom liner system. Therefore, the HDPE cap system meets the requirements for a capping system over the LLDPE liner system.

**Conclusion**

As Stage 2A, Stage 3B, and future Stage 3A plan to use LLDPE for the bottom liner system, the HDPE capping option will be required in order to meet the requirements of the Virginia Solid Waste Regulations and the CCR Rule. In theory the PVC capping option is no longer a valid option with the change to using LLDPE in the bottom liner system and is removed from the proposed closure cap design.
Purpose/Statement of Problem:

Due to the change of Curley Hollow’s Stage 2A, Stage 3B, and future Stage 3A bottom liner system to a LLDPE geomembrane instead of the previous PVC geomembrane, there needs to be a transition connection between the two geomembranes. Where applicable, the transition from the LLDPE liner system to existing PVC liner system represents a challenge in connecting the LLDPE geomembrane to the PVC geomembrane. There is no viable way to adhere or weld the LLDPE geomembrane directly to the PVC geomembrane due to the chemical composition of the materials involved. Solvent bonding is available for PVC but not applicable for LLDPE and though thermal fusion welds work on both PVC and LLDPE the materials themselves are not compatible with each other and are not able to be welded together. Due to the inability to join the PVC and LLDPE directly, as at other landfills in multiple states, an overlapping connection has been developed to connect these dissimilar materials together in a fashion that meets the regulatory requirements for Virginia and the CCR Rule regulations.

Design basis:

The following parameters were considered as the design basis for the connection of LLDPE to PVC by means of overlapping:

- The Virginia Solid Waste Regulations and the CCR Rule require a geomembrane layer as part of the liner system. This would require keeping a minimum of one geomembrane layer through the connection overlap.
  - The overlapping of LLDPE below and above the PVC will maintain a minimum of two geomembrane layers through the transition.
- Overlapping will be shingled in such a way to minimize potential flow between layers of geomembrane.
- A GCL layer will be placed between geomembrane layers to reduce potential hydraulic conductivity between the shingled layers of the connection overlap.
- The flow path through the connection overlap will be long enough that the liquid flow rate through the GCL is less than or equal to the liquid flow rate through the liner system.
  - Leakage through the geomembrane is due to defects in the liner system. Per the HELP models in Module V, the PVC appears to have a higher hydraulic conductivity than the LLDPE; therefore, the leakage flow rate through the PVC geomembrane will be used for this comparison.

Design:

The PVC liner system to LLDPE liner system connection is made by thermal fusion welding a geomembrane flap to the upgradient geomembrane and creating a “sandwich” of three geomembrane with GCL between the layers. The upgradient geomembrane would be the bottom and top layer, with
the downgradient geomembrane overlapping in the middle. The orientation of the overlap will be in the direction of leachate flow such that the geomembrane flap shingles over the connection.

The geomembrane flap is designed to overlap the downgradient geomembrane by five feet, with an additional GCL to GCL overlap of two feet for joining the GCL. This creates a flow path through the GCL with a minimum length of 10 feet. The two-foot overlap between the GCL layers allows enough room for the GCL layers to either be created by one roll width of GCL folded over or two separate layers of GCL sewn together in the two-foot overlapped area.

**Regulatory geomembrane requirement:**

The Virginia Solid Waste regulation and the CCR Rule require a minimum 30-mil flexible membrane liner (60 mil if HDPE) through the liner system. We interpret this to mean a minimum of one layer of flexible membrane throughout the landfill cell including through the connection. Through the overlapped section there is a top layer of geomembrane flap, a bottom layer of the upgradient geomembrane, and a middle layer of the downgradient geomembrane. Therefore, there are three geomembrane layers through the overlap area meeting the regulatory requirements for Virginia and the CCR Rule regulations.

**Shingling of Overlap:**

The overlap connection shall be oriented such that the upgradient geomembrane, which in Stage 2A, Stage 3B and future Stage 3A is the LLDPE geomembrane, is installed below the downgradient geomembrane and a LLDPE flap is attached to shingle above the downgradient geomembrane. This orientation allows leachate flow traveling along the upgradient geomembrane to flow over the geomembrane flap and past the connection overlap continuing away from the connection overlap on the downgradient geomembrane. This aligns the entrance of the flow path of the GCL to the downhill side or to a sidehill side, away from the driving head of the leachate. Making the flow path of leachate through the GCL layer less likely to occur.

**Hydraulic Conductivity through overlap connection:**

As stated in the design basis, the liquid flow rate through the GCL layer needs to be less than or equivalent to the liquid flow rate through the geomembrane. Liquid flow through a geomembrane is due to defects in the installation of the liner system. In Module V, HELP Model Analysis, the HELP Model for the liner system established assumptions for defects due to installation. These assumptions are a pin hole at a density of 1 hole per acre, installation defects at a density of 4 holes per acre, and good quality installation.

Based on Giroud’s equation for leakage through circular defects described in “Equations for calculating the rate of liquid migration through composite liners due to geomembrane defects” Giroud, J.P. (1997)
and the assumptions for density of defects in the liner system, a liquid flow rate through the geomembrane can be estimated. Giroud’s leakage equation is as follows:

$$Q = C \left[1+0.1\left(\frac{hw}{t}\right)^{0.95}\right] a^{0.1} hw^{0.9} ks^{0.74}$$

- $Q$ = Rate of leakage through a defect
- $C$ = A dimensionless constant related to the quality of the intimate contact between geomembrane and underlying clay liner or geosynthetic clay liner (GCL)
- $hw$ = Liquid head on top of the geomembrane (m)
- $t$ = Underlaying soil (compacted soil subbase) thickness of the composite liner (m)
- $a$ = Defect area in geomembrane ($m^2$)
- $ks$ = Clay soil or GCL element hydraulic conductivity of the composite liner (m/s)

For this calculation the following assumptions were made:

- $C = 0.21$ assumes good contact
- $hw = 0.179$ inches ($0.0045$ m) based on the HELP model for Permanent Closure, 3.5% [bottom] Slope
- $t = 6$ inches ($0.1524$ m) per the liner detail
- $a = 0.00001$ m$^2$ assuming defects are pinhole sized
- $ks = 2 \times 10^{-13}$ m/s based on the PVC liner

Based on these assumed values, the rate of leakage through a defect is:

$$Q = 0.21\left[1+0.1\left(\frac{0.0045}{0.1524}\right)^{0.95}\right] (0.00001)^{0.1}(0.0045)^{0.9} (2 \times 10^{-13})^{0.74}$$

$$Q = 1.574 \times 10^{-13}$$

Therefore, assuming 5 defects per acre the liquid flow rate through the geomembrane due to defects is:

$$Q = 5 \times 1.574 \times 10^{-13}$$

$$Q = 7.871 \times 10^{-13} \text{ m}^3/\text{s per acre}$$

For the liquid flow rate through the GCL flow path, Darcy’s law is used in the reduced form represented as:

$$Q = \frac{kA_g}{\nu L} \Delta h$$

$Q$ = rate of leakage through the GCL
k = permeability of GCL, $1 \times 10^{-9}$ m/s assumed

A = area evaluated, cross-sectional area of GCL along edge of connection per acre, assuming 1 square acre has 208 feet (63.4 m) of liner transition and GCL is 10 mm in thickness $A = 0.634$ m$^2$

g = gravitational constant, 9.81 m/s$^2$

v = viscosity of fluid, assume leachate approximately equal to water, 1.0 mPas

L = thickness of GCL, 10 ft (3.048 m)

$\Delta h$ = difference in hydraulic head on the flow path between the entrance and the highest point of the GCL, assuming the transition is completely flat the hydraulic head is 0.179 inches (0.0045 m) based on the HELP model for Permanent Closure, 3.5% [bottom] Slope

Assuming the overlap is completely flat is very conservative, this situation could only occur on a small floor area in the front portion of Stage 2A.

Therefore, the liquid flow rate on a per acre basis of liner transition through the GCL is:

$$Q = \frac{1 \times 10^{-9} \times 0.634 \times 9.81}{1 \times 3.048} \times 0.0045$$

$$Q = 9.182 \times 10^{-12}$$

Comparing the leakage rate through one acre of geomembrane to the leakage rate through the GCL of the transition at the most conservative possible location, it appears the transition is mathematically more permeable than the geomembrane.

**Conclusion**

As the length of the GCL flow path and the hydraulic head of the flow path are the controlling factors of the leakage rate, to adjust the design to a mathematical equivalency would require increasing the GCL flow path length or reducing the hydraulic head of the flow path.

Though miniscule the mathematical transition leakage rate is approximately 10 times the leakage rate of the geomembrane. As the GCL flow path length is inversely proportional to the leakage rate, increasing the length of the GCL flow path to mathematical equivalency would be impractical.

However, the hydraulic head on the liner transition area is relatively small and can be reduced to zero by adjusting the elevation of the upgradient side of the overlap to an elevation above the downdgradient side of the overlap, where the elevation difference is greater than the hydraulic head. The hydraulic head on the liner transition is 0.179 inches per the HELP model, and as required by Virginia Solid Waste Regulations, the hydraulic head on the liner must be less than 12 inches; therefore, designing the upgradient side of the overlap connection to be a minimum of 12 inches higher in elevation than the
downgradient side will reduce the hydraulic head on the transition to zero. Without hydraulic head on the transition, there is no leakage through the transition.

The only area of transition section that does not already have this elevation difference is the floor transition overlap. The design detail will be altered so that the floor transition will require a minimum of 12 inches difference in elevation between the beginning or bottom of the overlap and the end of PVC geomembrane.
OBJECTIVE:

Evaluate the puncture strength of the cushion geotextile that protects the geomembrane from the on-site crushed sandstone proposed for use as the leachate collection aggregate in Stage 2A and Stage 3A of the Curley Hollow Solid Waste Management Facility.

REFERENCES:


3. GAI Drawing C060702-00-005-00-E-F207, Permit Part B Drawing 22A.


BACKGROUND:

Although CHSWMF Stage 2A and Stage 3A was previously permitted for PVC liner, the liner is being changed to LLDPE because PVC geomembrane material meeting the project requirements is no longer available. To protect the LLDPE geomembrane, a cushion geotextile will be placed between the leachate collection aggregate and the geomembrane.

This calculation will determine if the previously proposed 16 oz/sy non-woven cushion geotextile will meet the minimum puncture resistance required for the cushion geotextile to prevent damage to the geomembrane resulting from anticipated site operations and loading conditions.
ANALYSIS:

The proposed landfill will be constructed with a liner system per Part B Drawing 22A (10/29/2019) consisting of (from top to bottom):

For Stage 2A liner deployed above the LCL Transition:

- **Fossil Fuel Products**
  - 10 oz/sq yard nonwoven filter geotextile
  - 18-inch thick layer on-site crushed sandstone (protective cover and leachate collection layer)
  - Geocomposite drainage net
  - 60-mil textured LLDPE geomembrane
  - 16 oz/sq yard nonwoven cushion geotextile
  - Compacted soil subbase

For Stage 2A liner deployed below the LCL Transition:

- **FFP**
  - 10 oz/sq yard nonwoven filter geotextile
  - 18-inch thick layer on-site crushed sandstone (protective cover and leachate collection layer)
  - 16 oz/sq yard nonwoven cushion geotextile
  - 60-mil textured LLDPE geomembrane
  - 16 oz/sq yard nonwoven cushion geotextile
  - Compacted soil subbase

For Stage 3A liner deployed above the LCL Transition:

- **Fossil Fuel Products**
  - 10 oz/sq yard nonwoven filter geotextile
  - 12-inch thick layer on-site crushed sandstone (protective cover and leachate collection layer)
  - Geocomposite drainage net
  - 60-mil textured LLDPE geomembrane
  - Geosynthetic clay liner
  - Compacted soil subbase

For Stage 3A liner deployed below the LCL Transition:

- **Fossil Fuel Products**
  - 10 oz/sq yard nonwoven filter geotextile
  - 18-inch thick layer on-site crushed sandstone (protective cover and leachate collection layer)
  - 16 oz/sq yard nonwoven cushion geotextile
  - 60-mil textured LLDPE geomembrane
  - Geosynthetic clay liner
  - Compacted soil subbase
For geotextile to function properly as a resistance to puncture, the cushion geotextile must have sufficient strength to survive installation and operations-related conditions. For the proposed landfill liner system, the cushion geotextile placed between the leachate collection layer and the geomembrane will be subjected to installation and operations-related stresses. Installation conditions were previously addressed in Part B Permit Application, “Equipment Traffic Evaluation Analyses”, March 27, 2008, Section 3 Module V Design Report Attachment 2, Miscellaneous Calculations. This 2019 analysis evaluates the puncture resistance of the cushion geotextile due to the presence of large, angular particles in the leachate collection layer under final conditions (maximum fill height).

Puncture of the liner could occur due to the presence of large, angular particles in the leachate collection layer once overburden stresses are imposed on the proposed liner system. Per the liner system described above the 16 oz/sy geotextile will be placed between the LLDPE geomembrane and leachate collection layer. In the liner sections where geocomposite drainage net replaces the 16 oz/sy non-woven geotextile it is assumed the 8 oz/sy non-woven geotextile on each side of the geocomposite drainage net combine to represent the same cushioning affect as the 16 oz/sy non-woven geotextile. Under these conditions, potential puncture of the cushion geotextile is based on the maximum particle size of the leachate collection layer and the resistance to puncture of the non-woven geotextile.

The methods for determining puncture resistance are empirical and based on protecting HDPE geomembrane with geotextile or protecting PVC geomembrane with geotextile. However, there is not a published method for LLDPE. LLDPE is a flexible membrane and is similar to PVC in elongation and puncture resistance. The following calculation uses the PVC method.

The PVC method:

Per Reference 4, the allowable overburden pressure on a 0.75 mm PVC geomembrane covering an object is:

\[
P'_\text{allow} = \left[ \frac{450 \ M}{H^2} \right] \left[ \frac{1}{(M_F)_S \cdot (M_F)_PD \cdot (M_F)_A \cdot (M_F)_CCH) \cdot \frac{1}{(F_S)_CR \cdot (F_S)_CBD}} \right]
\]

Where,
- \(P'_\text{allow}\) = Allowable overburden pressure (kPa)
- 450 = Empirical constant
- \(M\) = Mass per unit area of non-woven geotextile (g/m²)
- \(H\) = Effective height of protrusion (mm)
- \((M_F)_S\) = Modification Factor for shape
- \((M_F)_PD\) = Modification Factor for packing density
- \((M_F)_A\) = Modification Factor for soil arching
- \((M_F)_CCH\) = Modification Factor for critical cone height
- \((F_S)_CR\) = Factor of Safety for creep
- \((F_S)_CBD\) = Factor of Safety for chemical and biological degradation
Based on the site conditions the following was determined:

The 16 oz non-woven geotextile has an $M = 540 \text{ g/m}^2$.
Per reference 5, the waste has a unit weight of $\gamma = 82.3 \text{ lbs/ft}^3$
Per the Part B Permit Drawings, the height of waste $h = 377 \text{ ft}$
The on-site crushed aggregate (sandstone) has 27.6 percent by weight particles between 1 inch and 1 ½ inch in size. Therefore, $H = 0.5 \times 1\frac{1}{2} \text{ inch} = 0.75 \text{ inch}$, or $H = 19 \text{ mm}$
Per reference 1, figure 2.3 the crushed sandstone is subangular; therefore, subrounded for $MFS$. Per table 3 in reference 4:
- $MFS_x$, Subrounded = 0.5
- $MFPD$, Dense $19 \text{ mm} = 0.585$
- $MF_A$, Geostatic, Deep = 0.25
- $FS_{CR}$, Geomembrane 550, Protrusion $19 \text{ mm} = 1.4$
- $FS_{CBD}$, Mild Leachate = 1.1
Per reference 6, the critical cone height of LLDPE is 7.5 cm (2.75 inches)
Per reference 4, when critical cone height is larger than the maximum particle size is $MF_{CCH} = 0.1$; however, since a cushion geotextile is used, the value of $MF_{CCH}$ is set to unity; $MF_{CCH} = 1.0$

The current design provides a $P'_{\text{allow}}$ of:

$$P'_{\text{allow}} = \left[ \frac{450 \cdot 540 \text{ g/m}^2}{(19 \text{ mm})^2} \right] \left[ \frac{1}{0.5 \cdot 0.585 \cdot 0.25 \cdot 1.0} \right] \left[ \frac{1}{1.1 \cdot 1.4} \right]$$

$$P'_{\text{allow}} = 5,977 \text{ kPa}$$

Per site specific conditions, the required overburden pressure on the geomembrane is:

$$P'_{\text{req'd}} = \gamma \cdot h$$

Where,
- $P'_{\text{req'd}}$ = Site specific overburden pressure (lbs/ft$^2$)
- $\gamma$ = Unit weight of soil (waste), (lbs/ft$^3$)
- $h$ = Height of soil (waste) above geomembrane, (ft)

As, allowable overburden pressure is in kPa and has an empirical constant in SI units $P'_{\text{req'd}}$ must be factored from English units to SI units.

$$1 \text{ kPa} = 20.89 \text{ lbs/ft}^2$$

Based on site conditions we solve for $P'_{\text{req'd}}$:

$$P'_{\text{req'd}} = 82.3 \text{ lbs/ft}^3 \cdot 377 \text{ ft} \cdot 1 \text{ kPa} / 20.89 \text{ lbs/ft}^2$$

$$P'_{\text{req'd}} = 1,483 \text{ kPa}$$
Global Factor of Safety against puncture of a geomembrane is defined by the equation:

\[ FS = \frac{P_{\text{allow}}}{P_{\text{req'd}}} \]

Where, \( P_{\text{allow}} \) = Allowable overburden pressure (kPa)
\( P_{\text{req'd}} \) = Site specific overburden pressure (kPa)

For puncture resistance a greater than 3.0 Factor of Safety is desired. For the proposed conditions the Factor of Safety is:

\[ FS = \frac{5,977 \text{ kPa}}{1,483 \text{ kPa}} \]

\[ FS = 4.0 \]

**SUMMARY:**

A 16 oz/sq ft nonwoven geotextile (or equivalent geosynthetic drainage net) will be placed above the textured LLDPE geomembrane to reduce the risk of damage to the geomembrane resulting from anticipated site operations and loading conditions. Based on the above calculations the 16 oz/sq ft nonwoven geotextile provided a Factor of Safety for resisting puncture of 4.0 which is greater than the desired Factor of Safety of 3.0.
Purpose/Statement of Problem:

Conformance laboratory testing on the geosynthetics for the Stage 2A disposal site at the Curley Hollow Solid Waste Management Facility has resulted in some of the geosynthetics not meeting the requirements of the project specifications. In addition, under construction loading conditions shortly after placement of the geosynthetics, a large rain event occurred that caused the geosynthetics to slide downslope. This Permit Modification addendum is to request the use of textured linear low-density polyethylene (LLDPE) geomembrane in lieu of polyvinyl chloride (PVC) and to revise the required shear strength values.

Current Permitted Values:

<table>
<thead>
<tr>
<th>Normal Force</th>
<th>Material</th>
<th>HDPE/GDN</th>
<th>LLDPE</th>
<th>PVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>HDPE/GDN</td>
<td>92</td>
<td>Not Currently Permitted</td>
<td>Peak Shear Strength Shall Be Greater Than or Equal To 20 degrees Phi Angle.</td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td>306</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4000</td>
<td></td>
<td>1223</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11,500</td>
<td></td>
<td>1859</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2019 Analysis:

GAI Consultants, Ing. (GAI) used GeoStudio 2018 Version 9.0.4.15639 to model the current conditions of Stage 2A and 3A for this stability analysis. Stages 2A and 3A were analyzed using two critical cross-sections to develop the stability model. The plan view and cross-sections are shown in Attachments 1 and 2. The critical sections are described below.

Section 1 – Protective Cover Section – Attachment 1

The Protective Cover Section was selected to analyze the 100 and 300 pounds per square foot (psf) normal loads of the Protective Cover/Leachate Collection layer on the liner system during construction. Therefore, this section will model loading on the liner system prior to Fossil Fuel Product (FFP) disposal. The longest and steepest section in Stages 2A or 3A was modeled. Due to recent stability issues with the Stage 2A protective cover (as previously described), a 100 psf normal load test point is being included to more closely model the protective cover load. This section evaluated static conditions. It was determined using the HELP Model presented in the permit Design Report that a maximum of two inches of head would build up on the liner system. Therefore, the piezometric surface was modeled 0.2 feet above the liner system in the protective cover layer. Even though the section represents a temporary condition a seismic analysis was completed to be conservative. A rain cover will be installed over the protective cover. A revised peak ground acceleration (PGA) of 0.14g was used with this evaluation (see Attachment 3). This revised PGA was obtained from current United States Geological Survey (USGS) models that have since changed from the original permit analysis and includes the 2011 Mineral, Virginia earthquake. The revised PGA was obtained from USGS Unified Hazard Tool for 2 percent probability risk.
of exceedance in 50 years. This return period is equivalent to the 10 percent probability of exceedance in 250 years, which is required by the Virginia Solid Waste Management Regulations. Target factors of safety of 1.5 and 1.0 for static and seismic condition, respectively were selected based on the factors used in the permit Design Report. The results for the Protective Cover Section are below:

<table>
<thead>
<tr>
<th>Case</th>
<th>Condition</th>
<th>Calculated Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 1- Low Loads (Veneer)</td>
<td>Static-wet</td>
<td>1.52</td>
</tr>
<tr>
<td>Section 1 - Low Loads (Veneer)</td>
<td>Seismic-dry</td>
<td>1.11</td>
</tr>
</tbody>
</table>

**Section 2 – Valley Floor Section – Attachment 2**

The Valley Floor Section was selected to model the highest potential FFP overburden load on the liner system by accounting for the final FFP embankment configuration within the development stages of the landfill. This section was used to determine the minimum required shear strength for normal loads greater than 300 psf. This section was selected along the 2A/2B tie-in (see plan view in Attachment 2.)

Based on the Valley Floor Section, Stage 2A would have approximately 330-feet of FFP placed over the liner system. The normal loads being selected for this Permit Modification are based on varying fill heights up to the maximum fill depth (see table below). A 27,500 psf normal load was included in order to account for the maximum FFP cover of approximately 330 -feet.

One section was evaluated based on the five loading cases (see table below), each selected to correspond to varying fill heights: 0-300 psf; 300-1,000 psf; 1,000-4,000 psf; 4,000-11,500 psf; and 11,500 -27,500 psf. Each loading Case was evaluated under static and seismic conditions to determine the required minimum shear strengths per loading Case. Target factors of safety of 1.5 and 1.1 for static and seismic condition, respectively were selected based on the factors used in the permit Design Report for the full development stability analysis.

The analysis results for the Valley Floor Section are below:

<table>
<thead>
<tr>
<th>Case</th>
<th>Condition</th>
<th>Calculated Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-300 psf</td>
<td>Static-wet</td>
<td>2.58</td>
</tr>
<tr>
<td>300 - 1,000 psf</td>
<td>Static-wet</td>
<td>2.17</td>
</tr>
<tr>
<td>1,000 – 4,000 psf</td>
<td>Static-wet</td>
<td>2.14</td>
</tr>
<tr>
<td>4,000 – 11,500 psf</td>
<td>Static-wet</td>
<td>2.40</td>
</tr>
<tr>
<td>11,500 – 27,500 psf</td>
<td>Static-wet</td>
<td>2.11</td>
</tr>
<tr>
<td>0-300 psf</td>
<td>Seismic-wet</td>
<td>1.48</td>
</tr>
<tr>
<td>300 - 1,000 psf</td>
<td>Seismic-wet</td>
<td>1.26</td>
</tr>
<tr>
<td>1,000 – 4,000 psf</td>
<td>Seismic-wet</td>
<td>1.26</td>
</tr>
<tr>
<td>4,000 – 11,500 psf</td>
<td>Seismic-wet</td>
<td>1.33</td>
</tr>
<tr>
<td>11,500 – 27,500 psf</td>
<td>Seismic-wet</td>
<td>1.20</td>
</tr>
</tbody>
</table>
The material properties were adjusted for this analysis to better reflect current, properties of onsite construction materials. The materials are as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Weight (pcf)</th>
<th>Strength Function</th>
<th>Cohesion (psf)</th>
<th>Phi (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFP</td>
<td>82.2</td>
<td>Mohr-Coulomb</td>
<td>0</td>
<td>28</td>
</tr>
<tr>
<td>Liner Interface</td>
<td>20</td>
<td>Shear/Normal</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Protective Cover</td>
<td>130</td>
<td>Mohr-Coulomb</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>Stone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td></td>
<td>Bedrock (Impenetrable)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GAI did not have any site-specific conformance testing for LLDPE products but had several sets of test data from other landfill projects for LLDPE to GTX and LLDPE to GDN. This data was reviewed to ascertain that the required Shear/Normal values were potentially achievable.

The final cover system analysis for the landfill cap presented in the permit design report was not reanalyzed as part of this calculation because the shear strength requirements used for this calculation are equal to or greater than the friction angle used in the original analysis for the low loads (100 and 300 psf).

**Conclusion:**

This stability analysis was conducted to determine the minimum required interface shear strength requirements for the Permit Modification. Material selected for this project will be based on the performance requirements listed in the table below. It is GAI’s recommendation that this analysis be re-created when interface friction data from conformance testing becomes available to the project in the event that the required shear strengths are not met, as different shear strength values may result in acceptable factors of safety.

<table>
<thead>
<tr>
<th>Normal Force (PSF)</th>
<th>100</th>
<th>300</th>
<th>1,000</th>
<th>4,000</th>
<th>11,500</th>
<th>27,500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Required Shear Strengths (PSF)</td>
<td>65</td>
<td>116</td>
<td>380</td>
<td>1,550</td>
<td>4,250</td>
<td>7,750</td>
</tr>
</tbody>
</table>

Using the design input normal loads and the corresponding shear strength values, the model (Geostudio) created a regression line from the table above. Based on the regression line (see Attachment 3), GAI calculated the following minimum required shear strengths for use in the Project Specifications.
<table>
<thead>
<tr>
<th>Normal Force (PSF)</th>
<th>100</th>
<th>300</th>
<th>2,000</th>
<th>11,500</th>
<th>25,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Required Shear Strengths (PSF)</td>
<td>65</td>
<td>116</td>
<td>814</td>
<td>4,250</td>
<td>7,325</td>
</tr>
</tbody>
</table>
Attachment 1 – Protective Cover Section
### Curley Hollow Stage 2A/3A Permit Modification
#### Section 1 - Protective Cover Section
Static

<table>
<thead>
<tr>
<th>Color</th>
<th>Name</th>
<th>Model</th>
<th>Unit Weight (pcf)</th>
<th>Cohesion' (psf)</th>
<th>Phi' (°)</th>
<th>Strength Function</th>
<th>Piezometric Line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Liner Interface 1</td>
<td>Shear/Normal Fn.</td>
<td>20</td>
<td></td>
<td></td>
<td>Veneer Low Load Case - Target FS 1.5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Liner Interface 2</td>
<td>Shear/Normal Fn.</td>
<td>20</td>
<td></td>
<td></td>
<td>Veneer Low Load Case - Target FS 1.5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>PC Stone</td>
<td>Mohr-Coulomb</td>
<td>130</td>
<td>0</td>
<td>32</td>
<td>PC Stone Mohr-Coulomb</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Subgrade</td>
<td>Bedrock (Impenetrable)</td>
<td></td>
<td></td>
<td></td>
<td>Subgrade Bedrock (Impenetrable)</td>
<td></td>
</tr>
</tbody>
</table>

The diagram shows the elevation and distance data for the protective cover section, with colors indicating different materials and properties such as Liner Interface 1, Liner Interface 2, PC Stone, and Subgrade Bedrock (Impenetrable). The data includes unit weights, cohesion, angles, strength functions, and piezometric lines.

The data is organized in a table format with columns for color, name, model, unit weight, cohesion, phi, strength function, and piezometric line. The diagram visually represents the elevation and distance data across the section.
Curley Hollow Stage 2A/3A Permit Modification
Section 1 - Protective Cover Section
Seismic
Horz Seismic Coef.: 0.14

<table>
<thead>
<tr>
<th>Color</th>
<th>Name</th>
<th>Model</th>
<th>Unit Weight (pcf)</th>
<th>Cohesion' (psf)</th>
<th>Phi' (°)</th>
<th>Strength Function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Liner Interface 1</td>
<td>Shear/Normal Fn.</td>
<td>20</td>
<td></td>
<td></td>
<td>Veneer Low Load Case - Target FS 1.0</td>
</tr>
<tr>
<td></td>
<td>Liner Interface 2</td>
<td>Shear/Normal Fn.</td>
<td>20</td>
<td></td>
<td></td>
<td>Veneer Low Load Case - Target FS 1.0</td>
</tr>
<tr>
<td></td>
<td>PC Stone</td>
<td>Mohr-Coulomb</td>
<td>130</td>
<td>0</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subgrade</td>
<td>Bedrock (Impenetrable)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Distance

Elevation
Attachment 2 – Valley Floor Section
## Curley Hollow Stage 2A/3A Permit Modification
### Section 2 - Valley Floor Section
#### Static

<table>
<thead>
<tr>
<th>Color</th>
<th>Name</th>
<th>Model</th>
<th>Unit Weight (pcf)</th>
<th>Strength Function</th>
<th>Cohesion' (psf)</th>
<th>Phi' (°)</th>
<th>Piezometric Line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fossil Fuel Products</td>
<td>Mohr-Coulomb</td>
<td>82.2</td>
<td></td>
<td>0</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Liner Interface</td>
<td>Shear/Normal Fn.</td>
<td>20</td>
<td>Valley Floor Section - Target FS 1.5</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protective Cover Stone</td>
<td>Mohr-Coulomb</td>
<td>130</td>
<td></td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Subgrade</td>
<td>Bedrock (Impenetrable)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

0 to 300 PSF
### Curley Hollow Stage 2A/3A Permit Modification
#### Section 2 - Valley Floor Section

<table>
<thead>
<tr>
<th>Color</th>
<th>Name</th>
<th>Model</th>
<th>Unit Weight (pcf)</th>
<th>Strength Function</th>
<th>Cohesion' (psf)</th>
<th>Phi' (°)</th>
<th>Piezometric Line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fossil Fuel Products Mohr-Coulomb</td>
<td>82.2</td>
<td>0</td>
<td>Valley Floor Section - Target FS 1.5</td>
<td>1</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Liner Interface Shear/Normal Fn.</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protective Cover Stone Mohr-Coulomb</td>
<td>130</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subgrade Bedrock (Impenetrable)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

300 to 1,000 PSF
### Curley Hollow Stage 2A/3A Permit Modification
Section 2 - Valley Floor Section
Static

<table>
<thead>
<tr>
<th>Color</th>
<th>Name</th>
<th>Model</th>
<th>Unit Weight (pcf)</th>
<th>Strength Function</th>
<th>Cohesion' (psf)</th>
<th>Phi' (°)</th>
<th>Piezometric Line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fossil Fuel Products</td>
<td>Mohr-Coulomb</td>
<td>82.2</td>
<td>0</td>
<td>28</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Liner Interface</td>
<td>Shear/Normal Fn.</td>
<td>20</td>
<td>Valley Floor Section - Target FS 1.5</td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Protective Cover Stone</td>
<td>Mohr-Coulomb</td>
<td>130</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subgrade</td>
<td>Bedrock (Impenetrable)</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1,000 to 4,000 PSF
Curley Hollow Stage 2A/3A Permit Modification
Section 2 - Valley Floor Section
Static

<table>
<thead>
<tr>
<th>Color</th>
<th>Name</th>
<th>Model</th>
<th>Unit Weight (pcf)</th>
<th>Strength Function</th>
<th>Cohesion' (psf)</th>
<th>Phi' (°)</th>
<th>Piezometric Line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fossil Fuel Products</td>
<td>Mohr-Coulomb</td>
<td>82.2</td>
<td></td>
<td>0</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Liner Interface</td>
<td>Shear/Normal Fn.</td>
<td>20</td>
<td>Valley Floor Section - Target FS 1.5</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Protective Cover Stone</td>
<td>Mohr-Coulomb</td>
<td>130</td>
<td></td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Subgrade</td>
<td>Bedrock (Impenetrable)</td>
<td></td>
<td></td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4,000 to 11,500 PSF
Curley Hollow Stage 2A/3A Permit Modification
Section 2 - Valley Floor Section
Static

<table>
<thead>
<tr>
<th>Color</th>
<th>Name</th>
<th>Model</th>
<th>Unit Weight (pcf)</th>
<th>Strength Function</th>
<th>Cohesion' (psf)</th>
<th>Phi' (°)</th>
<th>Piezometric Line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fossil Fuel Products</td>
<td>Mohr-Coulomb</td>
<td>82.2</td>
<td></td>
<td>0</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Liner Interface</td>
<td>Shear/Normal Fr.</td>
<td>20</td>
<td>Valley Floor Section - Target FS 1.5</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Protective Cover Stone</td>
<td>Mohr-Coulomb</td>
<td>130</td>
<td></td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Subgrade</td>
<td>Bedrock (Impenetrable)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

11,500 to 27,500 PSF
### Curley Hollow Stage 2A/3A Permit Modification
### Section 2 - Valley Floor Section
### Seismic

<table>
<thead>
<tr>
<th>Color</th>
<th>Name</th>
<th>Model</th>
<th>Unit Weight (pcf)</th>
<th>Strength Function</th>
<th>Cohesion' (psf)</th>
<th>Phi' (°)</th>
<th>Piezometric Line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fossil Fuel Products</td>
<td>Mohr-Coulomb</td>
<td>82.2</td>
<td>0</td>
<td>0</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Liner Interface</td>
<td>Shear/Normal Fn.</td>
<td>20</td>
<td>Valley Floor Section - Target FS 1.1</td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Protective Cover Stone</td>
<td>Mohr-Coulomb</td>
<td>130</td>
<td></td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Subgrade</td>
<td>Bedrock (Impenetrable)</td>
<td>130</td>
<td></td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
</tbody>
</table>

0 to 300 PSF
Curley Hollow Stage 2A/3A Permit Modification
Section 2 - Valley Floor Section
Seismic
Horz Seismic Coef.: 0.14

<table>
<thead>
<tr>
<th>Color</th>
<th>Name</th>
<th>Model</th>
<th>Unit Weight (pcf)</th>
<th>Strength Function</th>
<th>Cohesion (psf)</th>
<th>Phi' (°)</th>
<th>Piezometric Line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fossil Fuel Products</td>
<td>Mohr-Coulomb</td>
<td>82.2</td>
<td>Valley Floor Section - Target FS 1.1</td>
<td>0</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Liner Interface</td>
<td>Shear/Normal Fn.</td>
<td>20</td>
<td>Valley Floor Section - Target FS 1.1</td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Protective Cover Stone</td>
<td>Mohr-Coulomb</td>
<td>130</td>
<td>Valley Floor Section - Target FS 1.1</td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Subgrade</td>
<td>Bedrock (Impenetrable)</td>
<td>130</td>
<td>Valley Floor Section - Target FS 1.1</td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
</tbody>
</table>

300 to 1,000 PSF
### Curley Hollow Stage 2A/3A Permit Modification

**Section 2 - Valley Floor Section**

**Seismic**

Horz Seismic Coef.: 0.14

<table>
<thead>
<tr>
<th>Color</th>
<th>Name</th>
<th>Model</th>
<th>Unit Weight (pcf)</th>
<th>Strength Function</th>
<th>Cohesion' (psf)</th>
<th>Phi' (°)</th>
<th>Piezometric Line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fossil Fuel Products</td>
<td>Mohr-Coulomb</td>
<td>82.2</td>
<td>0</td>
<td>28</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Liner Interface</td>
<td>Shear/Normal Fr.</td>
<td>20</td>
<td>Valley Floor Section - Target FS 1.1</td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Protective Cover Stone</td>
<td>Mohr-Coulomb</td>
<td>130</td>
<td>0</td>
<td>32</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subgrade</td>
<td>Bedrock (Impenetrable)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Elevation**

- 1,690
- 1,710
- 1,730
- 1,750
- 1,770
- 1,790
- 1,810
- 1,830
- 1,850
- 1,870
- 1,890
- 1,910
- 1,930
- 1,950
- 1,970
- 1,990
- 2,010
- 2,030
- 2,050
- 2,070
- 2,090
- 2,110
- 2,130
- 2,150
- 2,170
- 2,190

**Distance**

- 0
- 50
- 100
- 150
- 200
- 250
- 300
- 350
- 400
- 450
- 500
- 550
- 600
- 650
- 700
- 750
- 800
- 850
- 900
- 950
- 1,000
- 1,050
- 1,100
- 1,150
- 1,200
- 1,250
- 1,300
- 1,350
- 1,400
- 1,450
- 1,500
- 1,550
- 1,600
- 1,650
- 1,700
- 1,750
- 1,800
- 1,850
- 1,900
- 1,950
- 2,000
- 2,050
- 2,100
- 2,150
- 2,200
- 2,250
- 2,300
- 2,350
- 2,400
- 2,450
- 2,500

1,000 to 4,000 PSF
Curley Hollow Stage 2A/3A Permit Modification
Section 2 - Valley Floor Section
Seismic
Horz Seismic Coef.: 0.14

<table>
<thead>
<tr>
<th>Color</th>
<th>Name</th>
<th>Model</th>
<th>Unit Weight (pcf)</th>
<th>Strength Function</th>
<th>Cohesion' (psf)</th>
<th>Phi' (°)</th>
<th>Piezometric Line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fossil Fuel Products Mohr-Coulomb</td>
<td>82.2</td>
<td></td>
<td>0</td>
<td>28</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Liner Interface</td>
<td>Shear/Normal Fn.</td>
<td>20</td>
<td>Valley Floor Section - Target FS 1.1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protective Cover Stone Mohr-Coulomb</td>
<td>130</td>
<td></td>
<td>0</td>
<td>32</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subgrade</td>
<td>Bedrock (Impenetrable)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4,000 to 11,500 PSF
### Curley Hollow Stage 2A/3A Permit Modification
### Section 2 - Valley Floor Section

Seismic
Horz Seismic Coef.: 0.14

<table>
<thead>
<tr>
<th>Color</th>
<th>Name</th>
<th>Model</th>
<th>Unit Weight (pcf)</th>
<th>Strength Function</th>
<th>Cohesion' (psf)</th>
<th>Phi' (°)</th>
<th>Piezometric Line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fossil Fuel Products</td>
<td>Mohr-Coulomb</td>
<td>82.2</td>
<td>20</td>
<td>0</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Liner Interface</td>
<td>Shear/Normal Fn.</td>
<td>20</td>
<td>Valley Floor Section - Target FS 1.1</td>
<td>0</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Protective Cover Stone</td>
<td>Mohr-Coulomb</td>
<td>130</td>
<td></td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Subgrade</td>
<td>Bedrock (Impenetrable)</td>
<td></td>
<td></td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
</tbody>
</table>

11,500 to 27,500 PSF
Attachment 3 – Reference Materials
Unified Hazard Tool

Please do not use this tool to obtain ground motion parameter values for the design code reference documents covered by the U.S. Seismic Design Maps web tools (e.g., the International Building Code and the ASCE 7 or 41 Standard). The values returned by the two applications are not identical.

Input

<table>
<thead>
<tr>
<th>Edition</th>
<th>Spectral Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conterminous U.S. 2014 (v4.0.x)</td>
<td>Peak Ground Acceleration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Latitude</th>
<th>Time Horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decimal degrees</td>
<td>Return period in years</td>
</tr>
<tr>
<td>36.927</td>
<td>2475</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Longitude</th>
<th>Site Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decimal degrees, negative values for western longitudes</td>
<td>760 m/s (B/C boundary)</td>
</tr>
</tbody>
</table>
Hazard Curve

View Raw Data
Curley Hollow Permit Modification Design Curve - Determination of 2,000 psf Normal Load
Curley Hollow Permit Modification Design Curve -
Determination of 25,000 psf Normal Load
OBJECTIVE:

Determine the adequacy of the proposed anchor trench design for the Stage 2A bottom liner.

METHODOLOGY:

Use force equilibrium to estimate the factor of safety against liner pullout or tearing from the anchor trench.

REFERENCES:

2. GAI Construction Drawings C060702-52-000-00-E-F018, Drawing Sheet 42 of 50.
3. GAI Drawing C060702-00-005-00-E-F207, Permit Part B Drawing 22A.
5. Product Data Sheet, GSE UltraFlex Textured 60 mil LLDPE
6. Product Data Sheet, LLDPE MicroSpike® Geomembrane, 60 mils, Agru America

BACKGROUND:

The following bottom liner/protective cover system is proposed for Stages 2A (top to bottom) (Part B Drawing 22A, 10/29/19):

For liner deployed above the LCL Transition:

Fossil Fuel Products
10 oz/sq yd nonwoven filter geotextile
12-inch thick layer on-site crushed sandstone (protective cover and leachate collection layer)
Geocomposite drainage net (GDN)
60-mil textured LLDPE geomembrane
16 oz/sq yd nonwoven cushion geotextile
Compacted soil subbase

For liner deployed below the LCL Transition:

Fossil Fuel Products
10 oz/sq yd nonwoven filter geotextile
18-inch thick layer on-site crushed sandstone (protective cover and leachate collection layer)
16 oz/sq yd nonwoven cushion geotextile
60-mil textured LLDPE geomembrane
16 oz/sq yd nonwoven cushion geotextile
Compacted soil subbase
ANALYSIS:

Anchor Trench Design – To resist lateral movement and prohibit surface water from migrating under the geomembrane, an anchor trench with a frictional capacity less than the liner peak tensile strength was developed. A “L” shaped anchor trench was proposed. It is assumed that the geosynthetics will slide as a unit. The backfill soil in the anchor trench and above the runout length will be clayey soil. Assume the interface friction between the geosynthetics is slightly lower than the shear strength of the clay.

From Reference 1, the following equation was used for design:

\[ T = \frac{q_B L_{RO} \tan \delta + 2 \left[K_0 (\sigma_v)_{ave} d_{AT} + \sigma_v B L_{AT}\right] \tan \delta}{\cos \beta - \sin \beta \tan \delta} \]

Where
- \( T \) = anchor resistance = geomembrane tensile force per unit width, lb/ft
- \( \gamma_s \) = Unit weight of cover and backfill soil, pcf
- \( d_{cs} \) = depth of cover soil, ft
- \( d_{AT} \) = depth of anchor trench, ft
- \( L_{RO} \) = runout length, ft
- \( L_{AT} \) = length of anchor trench, ft
- \( \delta_c \) = interface between geomembrane and underlying soil, deg
- \( \delta_f \) = interface between geomembrane and backfill soil, deg
- \( \phi \) = friction angle between geomembrane and soil, deg
- \( \beta \) = side slope angle, deg
- \( (\sigma_v)_{ave} \) = average vertical stress in the anchor trench, psf

and

\[ q_B = \gamma_s d_{cs} \]
\[ K_0 = 1 - \sin \phi \]
\[ (\sigma_v)_{ave} = \gamma_s (d_{cs} + 0.5 d_{AT}) \]
\[ \sigma_v B = \gamma_s (d_{cs} + d_{AT}) \]

The proposed anchor trench dimensions are presented in Reference 2.

CASES:

Anchor resistance was determined for 3H:1V slopes. Reference 2 shows the following dimensions:
1. Cover Soil Depth = 0.0 ft
2. Liner Runout Length = 4.5 ft (approximate)
3. Trench Depth = 2.0 ft
4. Length of Anchor Trench = 2.0 ft
Anchor trench’s are typically designed for the geosynthetics to pull out of the trench prior to failure by tearing. Therefore, tensile force (T) should be less than $T_{ult}$ (tearing failure) but greater than $T_{allow}$. Per GRI GM 17 (Reference 4) and GSE UltraFlex Textured 60 mil LLDPE Liner (Reference 5) has a tensile strength at break is 90 lb/in but AGRU literature for 60-mil LLDPE Microspike Liner (Reference 6) has a tensile strength at break of 168 lb/in, so both cases were evaluated.

Interface friction between geosynthetics and soil above (anchor trench backfill) was assumed to be equal to interface friction and soil below (subbase soil). The interface friction angle is unknown, therefore the range of acceptable angles was determined.

As shown on the summary sheet, for a 60-mil LLDPE with a $T_{ult}$ of 90 lb/in, an interface friction angle between 15.9 degrees and 34.1 degrees would mobilize liner strength but not exceed ultimate strength. Since interface friction between 15.9 and 34.1 is likely, the anchor trench dimensions are acceptable.

For a 60-mil LLDPE with a $T_{ult}$ of 168 lb/in, an interface friction angle between 27.5 degrees and 48 degrees would mobilize liner strength but not exceed ultimate strength. Since interface friction between 27.5 and 48 is unlikely range, the anchor trench dimensions were modified. Modifying the trench depth to 2.5 feet provides an interface friction range of 21.7 to 42.5, which may not be likely, but an anchor trench depth of 3 ft required a range of 17.4 degrees to 37.3 degrees, which is likely.

If a different LLDPE product is selected with a $T_{ult}$ other than 90 or 168 lb/in, then the calculation shall be re-run to confirm anchor trench dimensions.

**CONCLUSION:**
For a 60-mil LLDPE with a $T_{\text{ult}}$ of 90 lb/in, the following anchor trench dimensions are acceptable.

1. Cover Soil Depth = 0.0 ft  
2. Liner Runout Length = 4.5 ft (approximate)  
3. Trench Depth = 2.0 ft  
4. Length of Anchor Trench = 2.0 ft

For a 60-mil LLDPE with a $T_{\text{ult}}$ of 168 lb/in, the following anchor trench dimensions are needed to mobilize liner strength.

1. Cover Soil Depth = 0.0 ft  
2. Liner Runout Length = 4.5 ft (approximate)  
3. Trench Depth = 3.0 ft  
4. Length of Anchor Trench = 2.0 ft
ATTACHMENT 1
CALCULATION SPREADSHEETS
LANDFILL LINER Rectangular Shaped Anchor Trench

Determine whether anchor resistance capacity falls between yield stress and allowable stress for the geosynthetic layers in the Liner Anchor Trench. These layers include GDN or cushion geotextile, geomembrane, and cushion geotextile for Stage 2A.

Unit weight of Protective Cover, $\gamma_s = 120$ lb/ft$^3$
Depth of cover soil, $d_{CS} = 0$ ft
Anchor trench depth, $d_{AT} = 2$ ft
Runout length, $L_{RO} = 4.5$ ft
Anchor trench length, $L_{AT} = 2$ ft

For a $3$ H:1V slope:
- Side slope angle, $\beta = 0.322$ rad = 18.43 degrees
- Friction angle of backfill soil in anchor trench, $\phi = 0.595$ rad = 34.1 degrees

When $\delta_c = \delta_p$ (when friction angle between geosynthetic and underlying soil = friction angle between geosynthetic and backfill soil)

$$ T = \frac{q_B*L_{RO}*\tan\delta + 2*[K_o*(\sigma_p)ave * d_{AT} + \sigma_{oB}*L_{AT}]*\tan\delta}{\cos\beta - \sin\beta*\tan\delta} $$

where
- $q_B = \gamma_s * d_{CS} = 0$ lb/ft$^3$
- $K_o = 1 - \sin\phi = 0.4$ high phi
- $0.726$ low phi
- $(\sigma_p)ave = \gamma_s * (d_{CS} + 0.5 * d_{AT}) = 120$ lb/ft$^2$
- $\sigma_{oB} = \gamma_s * (d_{CS} + d_{AT}) = 240$ lb/ft$^2$

$T_{ult} = 90$ lb/in (GRI GM 17 and GSE UltraFlex Textured 60 mil LLDPE Liner tensile strength at break)
for a factor of safety of 2.5, allowable stress = $90/2.5 = 36$ lb/in

For GSE UltraFlex:
- If interface between geomembrane and soil, $\delta = 34.1$ degrees
  - tensile force per unit width, $T = 1079.2$ lb/ft = 89.9 lb/in for 3H:1V slope
- If interface between geomembrane and soil, $\delta = 0.278$ rad = 15.9 degrees
  - tensile force per unit width, $T = 434.1$ lb/ft = 36.2 lb/in for 3H:1V slope

Conclusion: For this configuration, interface phi between geomembrane and soil should be between 34.1 and 15.9 degrees.
LANDFILL LINER Rectangular Shaped Anchor Trench

Anchor trench Detail 5, Sheet 42 of 50

Determine whether anchor resistance capacity falls between yield stress and allowable stress for the geosynthetics layers in the Liner Anchor Trench. These layers include GDN or cushion geotextile, geomembrane, and cushion geotextile for Stage 2A.

Unit weight of Protective Cover, $\gamma_s = 120 \text{ lb/ft}^3$
Depth of cover soil, $d_{CS} = 0 \text{ ft}$
Anchor trench depth, $d_{AT} = 2 \text{ ft}$
Runout length, $L_{RO} = 4.5 \text{ ft}$
Anchor trench length, $L_{AT} = 2 \text{ ft}$

For a 3 H:1V slope:
- Side slope angle, $\beta = 0.322 \text{ rad} = 18.43 \text{ degrees}$
- Friction angle of backfill soil in anchor trench, $\phi = 0.838 \text{ rad} = 48 \text{ degrees}$

When $\phi_C = \phi_F$ (when friction angle between geosynthetic and underlying soil = friction angle between geosynthetic and backfill soil)

$$T = \frac{q_B L_{RO} \tan \beta + 2 \cdot [K_o (\sigma_p) \text{ave} \cdot d_{AT} + \sigma_{pB} (d_{CS} + d_{AT})] \tan \delta}{\cos \beta - \sin \beta \cdot \tan \delta}$$

where
- $q_B = \gamma_s \cdot d_{CS} = 0 \text{ lb/ft}^2$
- $K_o = 1 - \sin \phi = 0.3 \text{ high phi}$
- $\sigma_p \text{ave} = \gamma_s \cdot (d_{CS} + 0.5 \cdot d_{AT}) = 120 \text{ lb/ft}^2$
- $\sigma_{pB} = \gamma_s \cdot (d_{CS} + d_{AT}) = 240 \text{ lb/ft}^2$

$T_{ult} = 168 \text{ lb/in}$ (AGRU literature for 60-mil LLDPE Microspike Liner tensile strength at break)

For a factor of safety of 2.5, allowable stress = $168/2.5 = 67.2 \text{ lb/in}$

Tensile force per unit width, $T = 2013.7 \text{ lb/ft}$ for 3H:1V slope

If interface between geomembrane and soil, $\delta = 48.0 \text{ degrees}$
- tensile force per unit width, $T = 167.8 \text{ lb/in}$

If interface between geomembrane and soil, $\delta = 0.480 \text{ rad} = 27.5 \text{ degrees}$
- tensile force per unit width, $T = 808.9 \text{ lb/ft}$

Conclusion: For this configuration, interface phi between geomembrane and soil should be between 48 and 27.5 degrees.

If interface friction between geomembrane and soil is less than 27.5 degrees for AGRU LLDPE, strength of the geomembrane will not be mobilized.
LANDFILL LINER Rectangular Shaped Anchor Trench

Determine whether anchor resistance capacity falls between yield stress and allowable stress for the geosynthetics layers in the Liner Anchor Trench. These layers include GDN or cushion geotextile, geomembrane, and cushion geotextile for Stage 2A.

Unit weight of Protective Cover, \( \gamma_s = 120 \) lb/ft\(^2\)

Depth of cover soil, \( d_{CS} = 0 \) ft

Anchor trench depth, \( d_{AT} = 3 \) ft

Runout length, \( L_{RO} = 4.5 \) ft

Anchor trench length, \( L_{AT} = 2 \) ft

For a 3 H:1V slope:

- Side slope angle, \( \beta = 0.322 \) rad = 18.43 degrees
- Friction angle of backfill soil in anchor trench, \( \phi = 0.651 \) rad = 37.3 degrees

When \( \phi_c = \phi_f \) (when friction angle between geosynthetic and underlying soil = friction angle between geosynthetic and backfill soil)

\[
T = \frac{q_B + L_{RO} \tan \beta + 2 \left( \sigma_v \left( \frac{d_{CS}}{2} + d_{AT} \right) \right) \tan \delta \tan \beta}{\cos \beta - \sin \beta \tan \delta}
\]

where

\[
q_B = \gamma_s \cdot d_{CS} = 0 \text{ lb/ft}^2
\]

\[
K_o = 1 - \sin \phi = 0.4 \text{ high phi}
\]

\[
\sigma_v = \gamma_s \cdot (d_{CS} + 0.5 \cdot d_{AT}) = 180 \text{ lb/ft}^2
\]

\[
\sigma_{vB} = \gamma_s \cdot (d_{CS} + d_{AT}) = 360 \text{ lb/ft}^2
\]

Tult = 168 lb/in (AGRU literature for 60-mil LLDPE Microspike Liner tensile strength at break)

For a factor of safety of 2.5, allowable stress = 168/2.5 = 67.2 lb/in

For AGRU Microspike:

- If interface between geomembrane and soil, \( \delta = 37.3 \) degrees
  - Tensile force per unit width, \( T = 2007.9 \text{ lb/ft} = 167.3 \text{ lb/in} \) for 3H:1V slope

- If interface between geomembrane and soil, \( \delta = 0.304 \) rad = 17.4 degrees
  - Tensile force per unit width, \( T = 810.4 \text{ lb/ft} = 67.5 \text{ lb/in} \) for 3H:1V slope

Conclusion: For this configuration, interface phi between geomembrane and soil should be between 37.3 and 17.4 degrees.
LANDFILL LINER Rectangular Shaped Anchor Trench

Anchor trench Detail 5, Sheet 42 of 50

Determine whether anchor resistance capacity falls between yield stress and allowable stress for the geosynthetics layers in the Liner Anchor Trench. These layers include GDN or cushion geotextile, geomembrane, and cushion geotextile for Stage 2A.

Unit weight of Protective Cover, $\gamma_s = 120$ lb/ft$^3$
Depth of cover soil, $d_{CS} = 0$ ft
Anchor trench depth, $d_{AT} = 2.5$ ft
Runout length, $L_{RO} = 4.5$ ft
Anchor trench length, $L_{AT} = 2$ ft

For a 3 H:1V slope:
Side slope angle, $\beta = 0.322$ rad = 18.43 degrees
Friction angle of backfill soil in anchor trench, $\phi = 0.742$ rad = 42.5 degrees

When $\delta_c = \delta_r$ (when friction angle between geosynthetic and underlying soil = friction angle between geosynthetic and backfill soil)

$$T = \frac{q_B L_{RO} \tan \delta + 2 \sigma_v \ave \times (d_{AT} + \sigma \ave \times d_{AT})}{\cos \beta - \sin \beta \tan \delta}$$

where

$$q_B = \gamma_s \times d_{CS} = 0 \text{ lb/ft}^2$$
$$K_\sigma = 1 - \sin \phi = 0.3 \text{ high phi} \quad 0.630 \text{ low phi}$$
$$\sigma_v \ave = \gamma_s \times (d_{CS} + 0.5 \times d_{AT}) = 150 \text{ lb/ft}^2$$
$$\sigma_B = \gamma_s \times (d_{CS} + d_{AT}) = 300 \text{ lb/ft}^2$$

$T_{ult} = 168$ lb/in (AGRU literature for 60-mil LLDPE Microspike Liner tensile strength at break)

For a factor of safety of 2.5, allowable stress = $168/2.5 = 67.2$ lb/in

For AGRU Microspike:

- If interface between geomembrane and soil, $\bar{\beta} = 42.5$ degrees
tensile force per unit width, $T = 2007.2$ lb/ft = $167.3$ lb/in for 3H:1V slope

- If interface between geomembrane and soil, $\bar{\beta} = 0.379$ rad = 21.7 degrees
  tensile force per unit width, $T = 809.0$ lb/ft = $67.4$ lb/in for 3H:1V slope

Conclusion: For this configuration, interface phi between geomembrane and soil should be between

42.5 degrees and 21.7 degrees

If interface friction between geomembrane and soil is less than 21.7 degrees for AGRU LLDPE, strength of the geomembrane will not be mobilized.
Try various combinations of $d_{AT}$ (depth of anchor trench) to determine acceptable $T$ at likely interface friction. Keep depth of cover soil constant.

<table>
<thead>
<tr>
<th>Case</th>
<th>$d_{CS}$</th>
<th>$d_{AT}$</th>
<th>$L_{RO}$</th>
<th>$L_{AT}$</th>
<th>60 MIL LLDPE</th>
<th>$T_{ult}$</th>
<th>PHI</th>
<th>$T$</th>
<th>$T_{allow}$</th>
<th>$T_{ult} &gt; T$?</th>
<th>$T &gt; T_{allow}$?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>2</td>
<td>4.5</td>
<td>2</td>
<td>GSE</td>
<td>90</td>
<td>34.1</td>
<td>15.9</td>
<td>89.9</td>
<td>36</td>
<td>YES</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>2</td>
<td>4.5</td>
<td>2</td>
<td>AGRU</td>
<td>168</td>
<td>48</td>
<td>27.5</td>
<td>167.8</td>
<td>67.2</td>
<td>YES</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>3</td>
<td>4.5</td>
<td>2</td>
<td>AGRU</td>
<td>168</td>
<td>37.3</td>
<td>17.4</td>
<td>167.3</td>
<td>67.2</td>
<td>YES</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>2.5</td>
<td>4.5</td>
<td>2</td>
<td>AGRU</td>
<td>168</td>
<td>42.5</td>
<td>21.7</td>
<td>167.3</td>
<td>67.2</td>
<td>YES</td>
</tr>
</tbody>
</table>

Tensile force ($T$) should be less than $T_{ult}$ but greater than $T_{allow}$.
Table 2(a) – Linear Low Density Polyethylene (LLDPE) Geomembrane (TEXTURED)

<table>
<thead>
<tr>
<th>Properties</th>
<th>Test Method</th>
<th>20 mils</th>
<th>30 mils</th>
<th>40 mils</th>
<th>50 mils</th>
<th>60 mils</th>
<th>80 mils</th>
<th>100 mils</th>
<th>120 mils</th>
<th>Testing Frequency (minimum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (min. ave.) - mils</td>
<td>D 5994</td>
<td>nom. -5%</td>
<td>nom. -5%</td>
<td>nom. -5%</td>
<td>nom. -5%</td>
<td>nom. -5%</td>
<td>nom. -5%</td>
<td>nom. -5%</td>
<td>nom. -5%</td>
<td>per roll</td>
</tr>
<tr>
<td>Asperity Height (min. ave.) - mils</td>
<td>D 7466</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>Every 2nd roll</td>
</tr>
<tr>
<td>Formulated Density (max.) - g/cc</td>
<td>D 1505/D 792</td>
<td>0.939</td>
<td>0.939</td>
<td>0.939</td>
<td>0.939</td>
<td>0.939</td>
<td>0.939</td>
<td>0.939</td>
<td>0.939</td>
<td>200,000 lb</td>
</tr>
<tr>
<td>Tensile Properties (2) (min. ave.)</td>
<td>D 6693</td>
<td>30</td>
<td>45</td>
<td>60</td>
<td>75</td>
<td>90</td>
<td>120</td>
<td>150</td>
<td>180</td>
<td>20,000 lb</td>
</tr>
<tr>
<td>Tear Resistance (min. ave.) - lb</td>
<td>D 1004</td>
<td>11</td>
<td>16</td>
<td>22</td>
<td>27</td>
<td>33</td>
<td>44</td>
<td>55</td>
<td>66</td>
<td>per formulation</td>
</tr>
<tr>
<td>Puncture Resistance (min. ave.) - lb</td>
<td>D 4833</td>
<td>22</td>
<td>33</td>
<td>44</td>
<td>55</td>
<td>66</td>
<td>88</td>
<td>110</td>
<td>132</td>
<td>45,000 lb</td>
</tr>
<tr>
<td>Axi-Symmetric Break Strain (min.) - %</td>
<td>D 5617</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>per formulation</td>
</tr>
<tr>
<td>Carbon Black Content - %</td>
<td>D 4218 (3)</td>
<td>2.0-3.0</td>
<td>2.0-3.0</td>
<td>2.0-3.0</td>
<td>2.0-3.0</td>
<td>2.0-3.0</td>
<td>2.0-3.0</td>
<td>2.0-3.0</td>
<td>2.0-3.0</td>
<td>45,000 lb</td>
</tr>
<tr>
<td>Carbon Black Dispersion</td>
<td>D 5596</td>
<td>note (4)</td>
<td>note (4)</td>
<td>note (4)</td>
<td>note (4)</td>
<td>note (4)</td>
<td>note (4)</td>
<td>note (4)</td>
<td>note (4)</td>
<td>45,000 lb</td>
</tr>
<tr>
<td>Oxidative Induction Time (OIT) (min. ave.) (5)</td>
<td>D 3895</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>200,000 lb</td>
</tr>
<tr>
<td>(e) Standard OIT - min.</td>
<td>D 5885</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>per formulation</td>
</tr>
<tr>
<td>(f) High Pressure OIT - min.</td>
<td>D 5721</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>per formulation</td>
</tr>
<tr>
<td>Oven Aiming at 85°C (6)</td>
<td>D 3895</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>per formulation</td>
</tr>
<tr>
<td>(a) Standard OIT (min. ave.) - % retained after 90 days</td>
<td>D 5885</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>per formulation</td>
</tr>
<tr>
<td>UV Resistance (7)</td>
<td>D 3895</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>per formulation</td>
</tr>
<tr>
<td>(a) Standard OIT (min. ave.)</td>
<td>D 5885</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>per formulation</td>
</tr>
<tr>
<td>(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (9)</td>
<td>D 5885</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>per formulation</td>
</tr>
</tbody>
</table>

(1) Alternate the measurement side for double sided textured sheet.
(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
(3) Break elongation is calculated using a gage length of 2.0 in. at 2.0 in./min.
(4) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.
(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

GM17 - 10 of 12

Rev. 13: 9/9/19
GSE UltraFlex Textured Geomembrane

GSE UltraFlex Textured is a co-extruded textured linear low density polyethylene (LLDPE) geomembrane available on one or both sides. It is manufactured from the highest quality resin specifically formulated for flexible geomembranes. This product is used in applications that require increased frictional resistance, flexibility and elongation properties where differential or localized subgrade settlements may occur such as in a landfill closure application.

Product Specifications

<table>
<thead>
<tr>
<th>Tested Property</th>
<th>Test Method</th>
<th>Frequency</th>
<th>Minimum Average Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness, mil</td>
<td>ASTM D 5994</td>
<td>every roll</td>
<td>40</td>
</tr>
<tr>
<td>Lowest individual reading</td>
<td></td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>Density, g/cm³ (max.)</td>
<td>ASTM D 1505</td>
<td>200,000 lb</td>
<td>0.939</td>
</tr>
<tr>
<td>Tensile Properties (each direction)</td>
<td>ASTM D 6693, Type IV</td>
<td>20,000 lb</td>
<td>60</td>
</tr>
<tr>
<td>Strength at Break, lb/in-width</td>
<td></td>
<td>90</td>
<td>250</td>
</tr>
<tr>
<td>Elongation at Break, %</td>
<td>G.L. 2.0 in</td>
<td>120</td>
<td>250</td>
</tr>
<tr>
<td>Tear Resistance, lb</td>
<td>ASTM D 1004</td>
<td>45,000 lb</td>
<td>22</td>
</tr>
<tr>
<td>Puncture Resistance, lb</td>
<td>ASTM D 4833</td>
<td>45,000 lb</td>
<td>44</td>
</tr>
<tr>
<td>Carbon Black Content, % (Range)</td>
<td>ASTM D 1603*/4218</td>
<td>20,000 lb</td>
<td>2.0 - 3.0</td>
</tr>
<tr>
<td>Carbon Black Dispersion</td>
<td>ASTM D 5596</td>
<td>45,000 lb</td>
<td>Note(1)</td>
</tr>
<tr>
<td>Asperity Height, mil</td>
<td>ASTM D 7466</td>
<td>second roll</td>
<td>18</td>
</tr>
<tr>
<td>Oxidative Induction Time, mins</td>
<td>ASTM D 3895, 200°C, O₂, 1 atm</td>
<td>200,000 lb</td>
<td>&gt;100</td>
</tr>
</tbody>
</table>

TYPICAL ROLL DIMENSIONS

<table>
<thead>
<tr>
<th>Roll Length(2), ft</th>
<th>Double-Sided Textured</th>
<th>Single-Sided Textured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roll Width(2), ft</td>
<td>Double-Sided Textured</td>
<td>Single-Sided Textured</td>
</tr>
<tr>
<td>Roll Area, ft²</td>
<td>Double-Sided Textured</td>
<td>Single-Sided Textured</td>
</tr>
</tbody>
</table>

NOTES:
- (1)Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- (2)Roll lengths and widths have a tolerance of ±1%.
- GSE UltraFlex Textured is available in rolls weighing approximately 4,000 lb.
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of < -77°C when tested according to ASTM D 746.
- *Modified.

For more information on this product and others, please visit us at GSEworld.com, call 800.435.2008 or contact your local sales office.
### PRODUCT DATA

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Frequency</th>
<th>Minimum Average Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (nominal), mil (mm)</td>
<td>ASTM D5994</td>
<td>Per Roll</td>
<td>40 (1.0) 60 (1.5) 80 (2.0) 100 (2.5)</td>
</tr>
<tr>
<td>Thickness (min avg), mil (mm)</td>
<td></td>
<td></td>
<td>38 (0.95) 57 (1.43) 76 (1.9) 95 (2.38)</td>
</tr>
<tr>
<td>Thickness (min 8 of 10), mil (mm)</td>
<td></td>
<td>2nd Roll</td>
<td>34 (0.85) 51 (1.28) 68 (1.7) 85 (2.13)</td>
</tr>
<tr>
<td>Thickness (lowest individual), mil (mm)</td>
<td></td>
<td>Per Roll</td>
<td>36 (0.90) 54 (1.35) 72 (1.8) 90 (2.25)</td>
</tr>
<tr>
<td>Asperity Height mils, (mm)</td>
<td>ASTM D7466</td>
<td>2nd Roll</td>
<td>20 (0.51) 20 (0.51) 18 (0.46) 18 (0.46)</td>
</tr>
<tr>
<td>Density, g/cc, maximum</td>
<td>ASTM D792, Method B</td>
<td>200,000 lb</td>
<td>0.939 0.939 0.939 0.939</td>
</tr>
<tr>
<td>Tensile Properties (both directions)</td>
<td></td>
<td>2 in/minute</td>
<td>20,000 lb 112 (19.6) 168 (29.4) 224 (39.2)</td>
</tr>
<tr>
<td>Strength @ Break, lb/in width (N/mm)</td>
<td>ASTM D6693, Type IV</td>
<td>2 in/minute</td>
<td>400 400 400 400</td>
</tr>
<tr>
<td>Elongation @ Break, % (GL=2.0in)</td>
<td></td>
<td>2 in/minute</td>
<td>400 400 400 400</td>
</tr>
<tr>
<td>Tear Resistance, lb,s. (N)</td>
<td>ASTM D1004</td>
<td>45,000 lb</td>
<td>25 (111) 36 (160) 50 (222) 60 (267)</td>
</tr>
<tr>
<td>Puncture Resistance, lbs. (N)</td>
<td>ASTM D4833</td>
<td>45,000 lb</td>
<td>50 (222) 70 (310) 90 (400) 115 (512)</td>
</tr>
<tr>
<td>Carbon Black Content, % (range)</td>
<td>ASTM D4218</td>
<td>20,000 lb</td>
<td>2-3 2-3 2-3 2-3</td>
</tr>
<tr>
<td>Carbon Black Dispersion (Category)</td>
<td>ASTM D5596</td>
<td>45,000 lb</td>
<td>Only near spherical agglomerates: 10 views Cat.1 or 2</td>
</tr>
<tr>
<td>Oxidative Induction Time, minutes</td>
<td>ASTM D3895, 200°C, 1 atm O₂</td>
<td>200,000 lb</td>
<td>≥140 ≥140 ≥140 ≥140</td>
</tr>
</tbody>
</table>

AGRU America’s geomembranes are certified to pass Low Temp. Brittleness via ASTM D746 (-80°C), Dimensional Stability via ASTM D1204 (±2% @ 100°C). Oven Aging and UV Resistance are tested per GRI GM 17. These product specifications meet or exceed GRI’s GM17.

### SUPPLY INFORMATION (STANDARD ROLL DIMENSIONS)

<table>
<thead>
<tr>
<th>THICKNESS</th>
<th>WIDTH</th>
<th>LENGTH</th>
<th>AREA (APPROX.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mil</td>
<td>ft</td>
<td>ft</td>
<td>ft²</td>
</tr>
<tr>
<td>mm</td>
<td>m</td>
<td>m</td>
<td>m²</td>
</tr>
<tr>
<td>40</td>
<td>23</td>
<td>7</td>
<td>1 Double-Sided</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>800</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>229</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>244</td>
</tr>
<tr>
<td>60</td>
<td>23</td>
<td>7</td>
<td>1 Double-Sided</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>540</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>165</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>171</td>
</tr>
<tr>
<td>80</td>
<td>23</td>
<td>7</td>
<td>1 Double-Sided</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>410</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>125</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>130</td>
</tr>
<tr>
<td>100</td>
<td>23</td>
<td>7</td>
<td>1 Double-Sided</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>335</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>102</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>104</td>
</tr>
</tbody>
</table>

Note:
- Average roll weight is 3,900 lbs (1,770 kg). All rolls are supplied with two slings. Rolls are wound on a 6” core. Special length available upon request. Roll length and width have a tolerance of ±1%. The weight values may change due to project specifications (i.e. average or absolute minimum thickness) or shipping requirements (i.e. international containerized shipments).

All information, recommendations and suggestions appearing in this literature concerning the use of our products are based upon tests and data believed to be reliable; however, it is the users responsibility to determine the suitability for their own use of the products described herein. Since the actual use by others is beyond our control, no guarantee or warranty of any kind, expressed or implied, is made by AGRU America as to the effects of such use or the results to be obtained, nor does AGRU America assume any liability in connection herewith. Any statement made herein may not be absolutely complete since additional information may be necessary or desirable when particular or exceptional conditions or circumstances exist or because of applicable laws or government regulations. Nothing herein is to be construed as permission or as a recommendation to infringe any patent.
OBJECTIVE:

Determine the adequacy of the proposed anchor trench design for the Stage 3A bottom liner.

METHODOLOGY:

Use force equilibrium to estimate the factor of safety against liner pullout or tearing from the anchor trench.

REFERENCES:

2. GAI Construction Drawings C060702-52-000-00-E-F018, Drawing Sheet 42 of 50.
3. GAI Drawing C060702-00-005-00-E-F207, Permit Part B Drawing 22A.
5. Product Data Sheet, GSE UltraFlex Textured 60 mil LLDPE
6. Product Data Sheet, LLDPE MicroSpike® Geomembrane, 60 mils, Agru America
8. Product Data Sheet, Bentomat® CL
9. Product Data Sheet, Bentomat® DN

BACKGROUND:

The following bottom liner/protective cover system is proposed for Stage 3A (top to bottom) (Part B Drawing 22A, 10/29/19):

For liner deployed above the LCL Transition:

Fossil Fuel Products
10 oz/sq yd nonwoven filter geotextile
12-inch thick layer on-site crushed sandstone (protective cover and leachate collection layer)
Geocomposite drainage net
60-mil textured LLDPE geomembrane
Geosynthetic clay liner
Compacted soil subbase

For liner deployed below the LCL Transition:

Fossil Fuel Products
10 oz/sq yd nonwoven filter geotextile
18-inch thick layer on-site crushed sandstone (protective cover and leachate collection layer)
16 oz/sq yd nonwoven cushion geotextile
60-mil textured LLDPE geomembrane
Geosynthetic clay liner
Compacted soil subbase
ANALYSIS:

Anchor Trench Design – To resist lateral movement and prohibit surface water from migrating under the geomembrane, an anchor trench with a frictional capacity less than the liner peak tensile strength was developed. A “L” shaped anchor trench was proposed. It is assumed that the geosynthetics will slide as a unit. The backfill soil in the anchor trench and above the runout length will be clayey soil. Assume the interface friction between the geosynthetics is slightly lower than the shear strength of the clay.

From Reference 1, the following equation was used for design:

\[ T = \frac{q_B \times L_{RO} \times \tan \delta + 2 \times [K_0 \times (\sigma_v)_{ave} \times d_{AT} + \sigma_{VB} \times L_{AT}] \times \tan \delta}{\cos \beta - \sin \beta \times \tan \delta} \]

Where

- \( T \) = anchor resistance = geomembrane tensile force per unit width, lb/ft
- \( \gamma_s \) = Unit weight of cover and backfill soil, pcf
- \( d_{CS} \) = depth of cover soil, ft
- \( d_{AT} \) = depth of anchor trench, ft
- \( L_{RO} \) = runout length, ft
- \( L_{AT} \) = length of anchor trench, ft
- \( \delta_c \) = interface between geomembrane and underlying soil, deg
- \( \delta_f \) = interface between geomembrane and backfill soil, deg
- \( \phi \) = friction angle between geomembrane and soil, deg
- \( \beta \) = side slope angle, deg
- \( (\sigma_v)_{ave} \) = average vertical stress in the anchor trench, psf

and

\[ q_B = \gamma_s \times d_{CS} \]
\[ K_0 = 1 - \sin \phi \]
\[ (\sigma_v)_{ave} = \gamma_s \times (d_{CS} + 0.5 \times d_{AT}) \]
\[ \sigma_{VB} = \gamma_s \times (d_{CS} + d_{AT}) \]

The proposed anchor trench dimensions are presented in Reference 2.

CASES:

Anchor resistance was determined for 3H:1V slopes

Reference 2 shows the following dimensions:

1. Cover Soil Depth = 0.0 ft
2. Liner Runout Length = 4.5 ft (approximate)
3. Trench Depth = 2.0 ft
4. Length of Anchor Trench = 2.0 ft
Anchor trenches are typically designed for the geosynthetics to pull out of the trench prior to failure by tearing. Therefore, tensile force ($T$) should be less than $T_{ult}$ (tearing failure) but greater than $T_{allow}$. Per GRI GM 17 (Reference 4) and GSE UltraFlex Textured 60 mil LLDPE Liner (Reference 5) has a tensile strength at break is 90 lb/in but AGRU literature for 60-mil LLDPE Microspike Liner (Reference 6) has a tensile strength at break of 168 lb/in, so both cases were evaluated.

Stage 3A anchor trench will also contain GCL, so GCL must be evaluated. Reference 7 shows Bentomat CL ultimate strength at 780 lb/ft (65 lb/in) allowable tension as 312 lb/ft (26 lb/in). Per References 8 & 9, ASTM D6768 strength is slightly greater for Bentomat DN than Bentomat CL. Assume Bentomat DN $T_{ult} = 65$ lb/in and $T_{allow} = 26$ lb/in. Because tensile strengths for GCL is less than for LLDPE, design anchor trench based on GCL strength.

Interface friction between geosynthetics and soil above (anchor trench backfill) was assumed to be equal to interface friction and soil below (subbase soil). The interface friction angle is unknown; therefore, the range of acceptable angles was determined.

As shown on the summary sheet, for a GCL with a $T_{ult}$ of 65 lb/in, an interface friction angle between 11.7 degrees and 26.6 degrees would mobilize liner strength but not exceed ultimate strength. Since the interface friction may be higher than 26.6 degrees, the anchor trench dimensions were modified. Modifying the trench depth to 1.5 feet provides a range of 34.2 degrees to 16.3 degrees, which is likely.

**CONCLUSION:**

For a GCL with a $T_{ult}$ of 65 lb/in, the following anchor trench dimensions are needed to mobilize liner strength.

1. Cover Soil Depth = 0.0 ft
2. Liner Runout Length = 4.5 ft (approximate)
3. Trench Depth = 1.5 ft
4. Length of Anchor Trench = 2.0 ft
ATTACHMENT 1
CALCULATION SPREADSHEETS
LANDFILL LINER Rectangular Shaped Anchor Trench

Anchor trench Detail 5, Sheet 42 of 50

Determine whether anchor resistance capacity falls between yield stress and allowable stress for the geosynthetics layers in the Liner Anchor Trench. These layers include GDN or cushion geotextile, geomembrane, and GCL for Stage 3A.

Unit weight of Protective Cover, $\gamma_s = 120$ lb/ft$^3$

Depth of cover soil, $d_{CS} = 0$ ft

Anchor trench depth, $d_{AT} = 2$ ft

Runout length, $L_{RO} = 4.5$ ft

Anchor trench length, $L_{AT} = 2$ ft

For a 3H:1V slope:

\[
\tan \beta = 0.322 \text{ rad} = 18.43 \text{ degrees} \\
\sin \beta = 0.333 \text{ rad} = 19.11 \text{ degrees} \\
\cos \beta = 0.949
\]

Friction angle of backfill soil in anchor trench, $\phi = 0.464$ rad = 26.6 degrees

\[
\sigma_{VB} = \gamma_s \times (d_{CS} + 0.5 \times d_{AT}) = 120 \text{ lb/ft}^2 \\
\sigma_{VB} = 240 \text{ lb/ft}^2
\]

$T_{ult} = 65 \text{ lb/in (Bentomat)}$

For a factor of safety of 2.5, allowable stress = 26 lb/in

For GCL:

If interface between geosynthetics and soil, $\delta = 26.6$ degrees

tensile force per unit width, $T = 776.2$ lb/ft = 64.7 lb/in for 3H:1V slope

If interface between geosynthetics and soil, $\delta = 0.204$ rad = 11.7 degrees

tensile force per unit width, $T = 314.8$ lb/ft = 26.2 lb/in for 3H:1V slope

Conclusion: For this configuration, interface phi between geomembrane and soil should be between

26.6 and 11.7 degrees
LANDFILL LINER Rectangular Shaped Anchor Trench

Anchor trench Detail 5, Sheet 42 of 50

Determine whether anchor resistance capacity falls between yield stress and allowable stress for the geosynthetics layers in the Liner Anchor Trench. These layers include GDN or cushion geotextile, geomembrane, and GCL for Stage 3A.

- Unit weight of Protective Cover, $\gamma_s = 120$ lb/ft$^3$
- Depth of cover soil, $d_{CS} = 0$ ft
- Anchor trench depth, $d_{AT} = 1.5$ ft
- Runout length, $L_{RO} = 4.5$ ft
- Anchor trench length, $L_{AT} = 2$ ft

For a 3 H:1V slope:

- Side slope angle, $\beta = 0.322$ rad = 18.43 degrees
- Friction angle of backfill soil in anchor trench, $\varphi = 0.597$ rad = 34.2 degrees

When $\delta_c = \delta_v$ (when friction angle between geosynthetic and underlying soil = friction angle between geosynthetic and backfill soil)

\[
t = \frac{q_B \cdot L_{RO} \cdot \tan \delta + 2 \cdot [K_0 \cdot (\sigma_v)_{ave} \cdot d_{AT} + \sigma_vB \cdot L_{AT}] \cdot \tan \delta}{\cos \beta \cdot \sin \beta \cdot \tan \delta}
\]

where

- $q_B = \gamma_s \cdot d_{CS} = 0$ lb/ft$^3$
- $K_0 = 1 - \sin \varphi = 0.4$ high phi
- $(\sigma_v)_{ave} = \gamma_s \cdot (d_{CS} + 0.5 \cdot d_{AT}) = 90$ lb/ft$^2$
- $\sigma_vB = \gamma_s \cdot (d_{CS} + d_{AT}) = 180$ lb/ft$^2$

- Tult = 65 lb/in (Bentomat)
  - for a factor of safety of 2.5, allowable stress = 26 lb/in

For GCL:

- If interface between geosynthetics and soil, $\delta = 34.2$ degrees
  - tensile force per unit width, $T = 776.3$ lb/ft = 64.7 lb/in for 3H:1V slope

- If interface between geosynthetics and soil, $\delta = 0.284$ rad = 16.3 degrees
  - tensile force per unit width, $T = 312.2$ lb/ft = 26.0 lb/in for 3H:1V slope

Conclusion: For this configuration, interface phi between geomembrane and soil should be between 34.2 and 16.3 degrees
Try various combinations of $d_{AT}$ (depth of anchor trench) to determine acceptable $T$ for GCL at likely interface friction. Keep depth of cover soil constant.

<table>
<thead>
<tr>
<th>Case</th>
<th>$d_{CS}$ (ft)</th>
<th>$d_{AT}$ (ft)</th>
<th>$L_{RO}$ (ft)</th>
<th>$L_{AT}$ (ft)</th>
<th>$T_{ult}$ (ft)</th>
<th>$T_{allow}$ (ft)</th>
<th>$T_{ult} &gt; T$?</th>
<th>$T &gt; T_{allow}$?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>2</td>
<td>4.5</td>
<td>2</td>
<td>65</td>
<td>26</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>26.6</td>
<td>64.7</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11.7</td>
<td>26.2</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>1.5</td>
<td>4.5</td>
<td>2</td>
<td>65</td>
<td>34.2</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>26</td>
<td>64.7</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16.3</td>
<td>26.0</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

Tensile force ($T$) should be less than $T_{ult}$ but greater than $T_{allow}$.
ATTACHMENT 2
REFERENCE SHEETS
This procedure demonstrates how a mathematical model can be used to assess slope stability for a Bentomat CL-lined pond in cases where a simple sliding block analysis is inconclusive. It is not intended to derive or explain the model. Readers are referred to the full text of the source paper for detailed explanations.

The Giroud and Beech stability calculation differs from the simplified “sliding block” model presented in Section 2.2, because it includes consideration of toe buttressing and liner anchorage, both of which contribute to stability. The method does not include pore water (seepage) forces, which can contribute to instability. In a water containment application, seepage forces can occur during rapid drawdown of the water such as might occur in a fire pond application. In ordinary use, however, rapid drawdown is not likely and is not considered herein.

\[
\alpha = \frac{\gamma_c T_c^2}{\sin 2\beta} \left[ \left( \frac{2H \cos \beta}{T_c} - 1 \right) \left( \frac{\sin (\beta - \phi_i)}{\cos \phi_i} \right) - \left( \frac{\sin \phi_e}{\cos (\beta + \phi_e)} \right) \right]
\]

Where:
- \(\alpha\) = Liner tension per unit width
- \(\gamma_c\) = Unit weight of cover material
- \(T_c\) = Thickness of cover material
- \(\beta\) = Slope angle, degrees
- \(H\) = Slope height
- \(\phi_i\) = Minimum interface friction angle, degrees
- \(\phi_e\) = Internal friction angle of cover material, degrees

And:
\[
\tan \phi_m = \frac{\tan \phi_e}{FS}
\]

Where:
- \(\tan \phi_m\) = mobilized friction angles, with factor of safety included
- \(FS\) = factor of safety (engineer-determined)


Using this calculation, if the result \(\alpha\) is negative, then the liner system is not in tension and can be considered stable. If positive, then the geosynthetic component of the lining system above the critical interface will be in tension. This is because the driving force cannot be transferred through frictional resistance. If the tension exceeds the allowable amount for this component, failure could occur.

The value for allowable tension is determined by the ultimate tensile strength of the liner, which is reduced by an appropriate percentage to ensure that the liner is not excessively stressed. Assuming Bentomat CL is used, existing data indicates that its ultimate strength is 780 lbs/ft (11.4 kN/m). Assuming that the liner will still remain functional in the long term with 40% of this load applied, the “allowable” tensile stress is 312 lbs/ft (4.6 kN/m). If the designer opts to eliminate all tension on the liner, then the analysis is performed to ensure that \(\alpha=0\). An example calculation is provided below.
BENTOMAT® CL
CERTIFIED PROPERTIES

<table>
<thead>
<tr>
<th>MATERIAL PROPERTY</th>
<th>TEST METHOD</th>
<th>TEST FREQUENCY</th>
<th>REQUIRED VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentonite Swell Index¹</td>
<td>ASTM D 5890</td>
<td>1 per 50 tonnes</td>
<td>24 mL/2g min.</td>
</tr>
<tr>
<td>Bentonite Fluid Loss¹</td>
<td>ASTM D 5891</td>
<td>1 per 50 tonnes</td>
<td>18 mL max.</td>
</tr>
<tr>
<td>Bentonite Mass/Area²</td>
<td>ASTM D 5993</td>
<td>40,000 ft² (4,000 m²)</td>
<td>0.75 lb/ft² (3.6 kg/m²) min.</td>
</tr>
<tr>
<td>GCL Tensile Strength³</td>
<td>ASTM D 6768</td>
<td>200,000 ft² (20,000 m²)</td>
<td>45 lbs/in (78 N/cm) MARV</td>
</tr>
<tr>
<td>GCL Peel Strength³</td>
<td>ASTM D 6496</td>
<td>40,000 ft² (4,000 m²)</td>
<td>3.5 lbs/in (6.1 N/cm) min.</td>
</tr>
<tr>
<td>GCL Index Flux⁴</td>
<td>ASTM D 5887</td>
<td>Periodic</td>
<td>1 X 10⁻⁹ m³/m²/sec max.</td>
</tr>
<tr>
<td>GCL Hydraulic Conductivity⁴</td>
<td>ASTM D 5887</td>
<td>Periodic</td>
<td>5 X 10⁻¹⁰ cm/sec max.</td>
</tr>
<tr>
<td>GCL Hydrated Internal Shear Strength⁵</td>
<td>ASTM D 5321</td>
<td>Periodic</td>
<td>500 psf (24 kPa) typical</td>
</tr>
<tr>
<td></td>
<td>ASTM D 6243</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes**

1. Bentonite property tests performed at a bentonite processing facility before shipment to CETCO’s GCL production facilities.
2. Bentonite mass/area reported at 0 percent moisture content.
3. All tensile strength testing is performed in the machine direction using ASTM D 6768. All peel strength testing is performed using ASTM D 6496. Upon request, tensile and peel results can be reported per modified ASTM D 4632 using 4 inch grips.
4. ASTM D5887 index flux and hydraulic conductivity testing with deaerated distilled/deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. Reported value is equivalent to 92 gal/acre/day. This flux value is equivalent to a permeability of 5x10⁻¹⁰ cm/sec for typical GCL thickness. ASTM D 5887 testing is performed only on a periodic basis because the membrane is essentially impermeable.
5. Peak value measured at 200 psf (10 kPa) normal stress for a specimen hydrated for 48 hours. Site-specific materials, GCL products, and test conditions must be used to verify internal and interface strength of the proposed design.

Distributed by: Bowman Construction Supply, 10801 E. 54th Avenue, Denver, CO 80239; Phone: (303) 696-8960
# BENTOMAT® DN

## GEOSYNTHETIC CLAY LINER

<table>
<thead>
<tr>
<th>MATERIAL PROPERTY</th>
<th>TEST METHOD</th>
<th>TEST FREQUENCY ft²(m²)</th>
<th>REQUIRED VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentonite Swell Index¹</td>
<td>ASTM D 5890</td>
<td>1 per 50 tonnes</td>
<td>24 mL/2g min.</td>
</tr>
<tr>
<td>Bentonite Fluid Loss¹</td>
<td>ASTM D 5891</td>
<td>1 per 50 tonnes</td>
<td>18 mL max.</td>
</tr>
<tr>
<td>Bentonite Mass/Area²</td>
<td>ASTM D 5993</td>
<td>40,000 ft² (4,000 m²)</td>
<td>0.75 lb/ft² (3.6 kg/m²) min</td>
</tr>
<tr>
<td>GCL Grab Strength³</td>
<td>ASTM D 6768</td>
<td>200,000 ft² (20,000 m²)</td>
<td>50 lbs/in (88 N/cm) MARV</td>
</tr>
<tr>
<td>GCL Peel Strength³</td>
<td>ASTM D 6496</td>
<td>40,000 ft² (4,000 m²)</td>
<td>3.5 lbs/in (6.1 N/cm) min</td>
</tr>
<tr>
<td>GCL Index Flux⁴</td>
<td>ASTM D 5887</td>
<td>Weekly</td>
<td>1 x 10⁻⁸ m³/m²/sec max</td>
</tr>
<tr>
<td>GCL Hydraulic Conductivity⁴</td>
<td>ASTM D 5887</td>
<td>Weekly</td>
<td>5 x 10⁻⁹ cm/sec max</td>
</tr>
<tr>
<td>GCL Hydrated Internal Shear Strength⁵</td>
<td>ASTM D 5321</td>
<td>Periodic</td>
<td>500 psf (24 kPa) typ @ 200 psf</td>
</tr>
</tbody>
</table>

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

**Notes**

1. Bentonite property tests performed at a bentonite processing facility before shipment to CETCO’s GCL production facilities.
2. Bentonite mass/area reported at 0 percent moisture content.
3. All tensile strength testing is performed in the machine direction using ASTM D 6768. All peel strength testing is performed using ASTM D 6496. Upon request, tensile and peel results can be reported per modified ASTM D 4632 using 4 inch grips.
4. Index flux and permeability testing with deaired distilled/deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. Reported value is equivalent to 925 gal/acre/day. This flux value is equivalent to a permeability of 5 x 10⁻⁹ cm/sec for typical GCL thickness. Actual flux values vary with field condition pressures. The last 20 weekly values prior to the end of the production date of the supplied GCL may be provided.
5. Peak values measured at 200 psf (10 kPa) normal stress for a specimen hydrated for 48 hours. Site-specific materials, GCL products, and test conditions must be used to verify internal and interface strength of the proposed design.

CETCO has developed an edge enhancement system that eliminates the need to use additional granular sodium bentonite within the overlap area of the seams. We call this edge enhancement, SuperGroove™, and it comes standard on both longitudinal edges of Bentomat® DN. It should be noted that SuperGroove™ does not appear on the end-of-roll overlaps and recommend the continued use of supplemental bentonite for all end-of-roll seams.
MODULE V
ATTACHMENT 3 - PART A APPROVAL WITH MAPS
Once received, a copy of the Part A approval and maps will be inserted here.
The material to be placed in the CHSWMF will consist of FFPs and related material generated at the VCHEC. This material will be relatively inert and will not decompose and emit gas. Therefore, a Gas Management Plan is not required.
Module V, Attachment 5 – Technical Specifications
Virginia Department of Environmental Quality

Part B Permit Application
Curley Hollow Solid Waste Management Facility
To Support The Virginia City Hybrid Energy Center
Wise County, Virginia

GAI Project Number: C060702.00.005

March 2008
Revised June 2008, July 2008, September 2008,
November 2008, February 2009, June 2009,
August 2011, February 2017, October 2017, and December 2019

Prepared for: Dominion
5000 Dominion Boulevard
Glen Allen, Virginia 23060

Prepared by: GAI Consultants, Inc.
Pittsburgh Office
385 East Waterfront Drive
Homestead, Pennsylvania 15120-5005
# Table of Contents

## SECTION 1  EARTHWORK, BASE GRADE, AND SUBBASE .............................................. 1-1

1.01 GENERAL .............................................................................................................. 1-1
1.02 REFERENCES ......................................................................................................... 1-1
1.03 MATERIAL REQUIREMENTS .................................................................................. 1-1
1.04 CLEARING AND GRUBBING ................................................................................. 1-2
1.05 STRIPPING AND STOCKPILING OF TOP SOIL ...................................................... 1-3
1.06 LINES AND GRADES ............................................................................................ 1-3
1.07 EXCAVATION ......................................................................................................... 1-3
1.08 CONTROLLED BLASTING ...................................................................................... 1-4
1.09 FILL PLACEMENT ................................................................................................. 1-9
1.10 EARTHWORK, BASE GRADE AND SUBBASE PREPARATION ............................. 1-11
1.11 SUBMITTALS ....................................................................................................... 1-12

## SECTION 2  PVC GEOMEMBRANE ......................................................................... 2-1

2.01 GENERAL .............................................................................................................. 2-1
2.02 REFERENCES ......................................................................................................... 2-1
2.03 DEFINITIONS ......................................................................................................... 2-2
2.04 SUBMITTALS ........................................................................................................ 2-2
2.05 CONSTRUCTION QUALITY CONTROL AND QUALITY ASSURANCE .......... 2-4
2.06 MATERIALS REQUIREMENTS .............................................................................. 2-4
2.07 INSTALLATION ...................................................................................................... 2-7

## SECTION 3  HDPE GEOMEMBRANE ....................................................................... 3-1

3.01 GENERAL .............................................................................................................. 3-1
3.02 REFERENCES ......................................................................................................... 3-1
3.03 DEFINITIONS ......................................................................................................... 3-2
3.04 SUBMITTALS ........................................................................................................ 3-2
3.05 CONSTRUCTION QUALITY CONTROL AND QUALITY ASSURANCE .......... 3-5
3.06 MATERIAL REQUIREMENTS .............................................................................. 3-5
3.07 INSTALLATION ...................................................................................................... 3-7

## SECTION 4  GEOCOMPOSITE DRAINAGE NET ...................................................... 4-1

4.01 GENERAL .............................................................................................................. 4-1
4.02 REFERENCES ......................................................................................................... 4-1
4.03 DEFINITIONS ......................................................................................................... 4-2
4.04 SUBMITTALS ........................................................................................................ 4-2
4.05 CONSTRUCTION QUALITY CONTROL AND QUALITY ASSURANCE .......... 4-4
4.06 MATERIAL REQUIREMENTS .............................................................................. 4-5
4.07 INSTALLATION ...................................................................................................... 4-7
4.08 REPAIRS .............................................................................................................. 4-12
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.09</td>
<td>Acceptance and Covering</td>
<td>4-12</td>
</tr>
<tr>
<td>4.10</td>
<td>Warranties</td>
<td>4-12</td>
</tr>
<tr>
<td>5</td>
<td>Piping Systems and Leachate Collection and Groundwater Drainage</td>
<td>5-1</td>
</tr>
<tr>
<td>5.01</td>
<td>General</td>
<td>5-1</td>
</tr>
<tr>
<td>5.02</td>
<td>References</td>
<td>5-1</td>
</tr>
<tr>
<td>5.03</td>
<td>Material Requirements</td>
<td>5-2</td>
</tr>
<tr>
<td>5.04</td>
<td>Installation Requirements</td>
<td>5-4</td>
</tr>
<tr>
<td>6</td>
<td>Geotextiles</td>
<td>6-1</td>
</tr>
<tr>
<td>6.01</td>
<td>General</td>
<td>6-1</td>
</tr>
<tr>
<td>6.02</td>
<td>References</td>
<td>6-1</td>
</tr>
<tr>
<td>6.03</td>
<td>Definitions</td>
<td>6-2</td>
</tr>
<tr>
<td>6.04</td>
<td>Submittals</td>
<td>6-2</td>
</tr>
<tr>
<td>6.05</td>
<td>Construction Quality Assurance and Quality Control</td>
<td>6-4</td>
</tr>
<tr>
<td>6.06</td>
<td>Materials</td>
<td>6-4</td>
</tr>
<tr>
<td>6.07</td>
<td>Installation</td>
<td>6-6</td>
</tr>
<tr>
<td>7</td>
<td>Landfill Liner Protective Cover</td>
<td>7-1</td>
</tr>
<tr>
<td>7.01</td>
<td>General</td>
<td>7-1</td>
</tr>
<tr>
<td>7.02</td>
<td>References</td>
<td>7-1</td>
</tr>
<tr>
<td>7.03</td>
<td>Material Requirements</td>
<td>7-2</td>
</tr>
<tr>
<td>7.04</td>
<td>Placement Requirements</td>
<td>7-2</td>
</tr>
<tr>
<td>8</td>
<td>Fabricform Lining</td>
<td>8-1</td>
</tr>
<tr>
<td>8.01</td>
<td>General</td>
<td>8-1</td>
</tr>
<tr>
<td>8.02</td>
<td>References</td>
<td>8-1</td>
</tr>
<tr>
<td>8.03</td>
<td>Material Requirements</td>
<td>8-2</td>
</tr>
<tr>
<td>8.04</td>
<td>Installation</td>
<td>8-5</td>
</tr>
<tr>
<td>9</td>
<td>Furnishing, Delivery, and Placement of Concrete</td>
<td>9-1</td>
</tr>
<tr>
<td>9.01</td>
<td>General</td>
<td>9-1</td>
</tr>
<tr>
<td>9.02</td>
<td>References</td>
<td>9-1</td>
</tr>
<tr>
<td>9.03</td>
<td>Material Requirements</td>
<td>9-1</td>
</tr>
<tr>
<td>9.04</td>
<td>Installation</td>
<td>9-1</td>
</tr>
<tr>
<td>9.05</td>
<td>Submittals</td>
<td>9-2</td>
</tr>
<tr>
<td>10</td>
<td>Channel Lining</td>
<td>10-1</td>
</tr>
<tr>
<td>10.01</td>
<td>General</td>
<td>10-1</td>
</tr>
<tr>
<td>10.02</td>
<td>References</td>
<td>10-1</td>
</tr>
<tr>
<td>10.03</td>
<td>Material Requirements</td>
<td>10-1</td>
</tr>
<tr>
<td>10.04</td>
<td>Installation Requirements</td>
<td>10-2</td>
</tr>
</tbody>
</table>

December 2019
Module V - Specifications – VDEQ, Part B Permit Application - CHSWMF

SECTION 11 PRECAST CONCRETE MANHOLES AND BOXES, AND APPURTEYNANCES..................................................11-1
  11.01 GENERAL..................................................................................................................11-1
  11.02 REFERENCES...........................................................................................................11-1
  11.03 PRECAST CIRCULAR CONCRETE MANHOLES.......................................................11-1
  11.04 RECTANGULAR PRECAST CONCRETE BOXES OR MANHOLES..............11-1

SECTION 12 REVEGETATION ............................................................................................12-1
  12.01 GENERAL................................................................................................................12-1
  12.02 REFERENCES...........................................................................................................12-1
  12.03 MATERIAL REQUIREMENTS....................................................................................12-1
  12.04 EXECUTION .............................................................................................................12-3
  12.05 MAINTENANCE .......................................................................................................12-5

SECTION 13 EROSION AND SEDIMENT CONTROL............................................................13-1
  13.01 GENERAL................................................................................................................13-1
  13.02 E&S MEASURES AND SILT BARRIERS .................................................................13-2
  13.03 GRASS LINED CHANNELS ..................................................................................13-3
  13.04 TURF REINFORCEMENT MAT (TRM) LINED CHANNELS .................................13-4
  13.05 SEDIMENT TRAPS ..............................................................................................13-4
  13.06 SEDIMENT BASINS ............................................................................................13-4
  13.07 ROCK FILTERS ....................................................................................................13-5
  13.08 RIPRAP OUTLET PROTECTION ........................................................................13-5
  13.09 PUMPED WATER FILTER BAG ........................................................................13-5
  13.10 TEMPORARY BAFFLES (IF NEEDED) ...............................................................13-6
  13.11 TEMPORARY SEEDING AND MULCHING.........................................................13-6

SECTION 14 ROADS ..........................................................................................................14-1
  14.01 GENERAL................................................................................................................14-1
  14.02 REFERENCES...........................................................................................................14-1
  14.03 MATERIAL REQUIREMENTS....................................................................................14-1

SECTION 15 GROUT STABILIZATION OF ABANDONED UNDERGROUND MINE WORKINGS..............................................................................................................................................15-1
  15.01 GENERAL................................................................................................................15-1
  15.02 REFERENCES...........................................................................................................15-2
  15.03 DEFINITIONS..........................................................................................................15-2
  15.04 MATERIALS...........................................................................................................15-3
  15.05 GROUT AND CONCRETE MIXES........................................................................15-4
  15.06 EQUIPMENT..........................................................................................................15-5
  15.07 SURVEY LAYOUT .................................................................................................15-6
  15.08 INJECTION HOLE DRILLING ..............................................................................15-6
  15.09 PROCEDURES........................................................................................................15-8
15.10 TESTING .............................................................................................................. 15-9
15.11 SECONDARY DRILLING ..................................................................................... 15-9
15.12 BOREHOLE PHOTOGRAPHY ............................................................................. 15-9
15.13 RECORDS AND FORMS ................................................................................... 15-10

SECTION 16 SOIL COVER ......................................................................................... 16-1

16.01 GENERAL ......................................................................................................... 16-1
16.02 REFERENCES ..................................................................................................... 16-1
16.03 MATERIAL REQUIREMENTS ............................................................................ 16-1
16.04 COVER SOIL PLACEMENT ............................................................................... 16-2
16.05 MAINTENANCE .................................................................................................. 16-2

SECTION 17 GEOGRID REINFORCEMENT .............................................................. 17-1

17.01 GENERAL ......................................................................................................... 17-1
17.02 REFERENCES ..................................................................................................... 17-1
17.03 DEFINITIONS .................................................................................................... 17-2
17.04 SUBMITTALS .................................................................................................... 17-2
17.05 CONSTRUCTION QUALITY CONTROL AND QUALITY ASSURANCE .... 17-3
17.06 DELIVERY, STORAGE, AND HANDLING ...................................................... 17-3
17.07 MATERIAL REQUIREMENTS ............................................................................ 17-3
17.08 INSTALLATION ................................................................................................. 17-4
17.09 INSPECTION ..................................................................................................... 17-6
17.10 REPAIR ............................................................................................................. 17-6
17.11 PROTECTION ..................................................................................................... 17-6
17.12 WARRANTIES ...................................................................................................... 17-6

SECTION 18 GEOSYNTHETIC CLAY LINER ............................................................ 18-1

18.01 GENERAL ......................................................................................................... 18-1
18.02 REFERENCES ..................................................................................................... 18-1
18.03 DEFINITIONS .................................................................................................... 18-2
18.04 SUBMITTALS .................................................................................................... 18-2
18.05 CONSTRUCTION QUALITY CONTROL AND QUALITY ASSURANCE ... 18-4
18.06 PRODUCTS ........................................................................................................ 18-4
18.07 EXECUTION ....................................................................................................... 18-7

SECTION 19 LLDPE GEOMEMBRANE ..................................................................... 19-1

19.01 GENERAL ......................................................................................................... 19-1
19.02 REFERENCES ..................................................................................................... 19-1
19.03 DEFINITIONS .................................................................................................... 19-2
19.04 SUBMITTALS .................................................................................................... 19-2
19.05 CONSTRUCTION QUALITY CONTROL AND QUALITY ASSURANCE ... 19-5
19.06 MATERIAL REQUIREMENTS ........................................................................... 19-5
19.07 INSTALLATION ................................................................................................ 19-7
SECTION 1
EARTHWORK, BASE GRADE, AND SUBBASE

1.01 GENERAL
1.01.1 DESCRIPTION OF WORK
This section includes technical requirements for excavation and structural fills, preparing the base grade, and subbase, and procedures for stockpiling excavated material.

1.01.2 RELATED WORK SPECIFIED ELSEWHERE
A. Soil Erosion and Sedimentation Control (Section 14).
B. Geotextiles (Section 6).
C. Construction Quality Assurance (CQA) Plan.
   1. The Construction Quality Assurance (CQA) Consultant for the work in this Specification is the same entity as The CQA Officer, CQA monitor(s) and CQA personnel of the CQA Plan.

1.02 REFERENCES
1.02.1 CODES AND STANDARDS
The following codes and standards are referenced in this Section:
A. American Society for Testing and Materials (ASTM) Standards:
   3. D 2487, "Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)".
B. VDOT Road and Bridge Specifications - 2007

1.03 MATERIAL REQUIREMENTS
1.03.1 GENERAL FILL
General fill may be cohesive soil, durable or non-durable rock with a grading typically GW-GC as per ASTM D 2487 and shall be used in fill areas where structural stability is not an issue. General fill material is expected to be produced by site excavations and the Contractor shall sequence the fill operations to use up this material in deeper fills since it shall not be placed in the cover soil stockpile.
1.03.2 COMMON SOIL
Common soil shall consist of excavated soil and non-durable rock, with the maximum particle size not exceeding four inches and no more than 50 percent by weight of particles larger than one inch. It shall not contain coal, organic matter, ice, frozen materials, or other deleterious materials. Excess common soil meeting cover soil requirements shall be placed in the cover soil stockpile area.

1.03.3 SUBBASE AND SELECT FILL MATERIAL
Subbase material shall be on-site soil or non-durable rock within the USCS classification range from VDOT Grading A Fine Aggregate and gravel to clayey VDOT Grading A Fine Aggregate and gravel and shall be segregated for use in subbase construction. It shall not be used in the fill or base grade of the Perimeter Access Roads. It may, however, be used in other fills. The maximum particle size shall be less than ½ inch and clod size shall not exceed 3 inches. It shall not contain coal, organic matter, ice, frozen materials, or other deleterious materials.

1.03.4 STRUCTURAL FILL
Structural fill material shall be cohesive soil of the ML, CL and CL-ML type, or durable or non-durable rock of USCS classification GW-GC as per ASTM D 2487, and shall be used in fill applications where structural stability is an issue, such as embankments. It shall not contain coal, organic matter, ice, frozen materials, or other deleterious materials.

1.03.5 COVER SOIL
Cover soil shall be soil with physical and chemical characteristics conductive to the establishment of vegetation and shall be free of wood fragments, coal, ice, rocks larger than 3 inches and clods not larger than 6 inches.

1.04 CLEARING AND GRUBBING
1.04.1 Designated areas shall be cleared of objectionable material, rubbish, fencing, structures, trees, stumps, brush roots, down timber, and other vegetation or organic matter to the limits necessary to perform the construction as shown on the Drawings.

1.04.2 All embedded root mats or stumps shall be removed to a depth of not less than 2 feet below existing grade. Depressions shall be graded to drain.

1.04.3 Materials removed in the clearing and grubbing operations shall be either disposed of at an Owner approved location on site or burned at the direction of the Owner.

1.04.4 Burning shall be in accordance with Federal, State and local laws and regulations. Any and all costs associated with obtaining permits or filing of plans for burning shall be at the Contractor’s expense. Burning shall not be located on areas where waste has been deposited, areas being used for active disposal or areas of existing liner system. Burning shall be performed in a manner and in locations so not to cause a fire or safety hazard. Fire-fighting equipment shall be available during burning operations. Materials burned shall be reduced to ashes. Incompletely burned materials shall be placed in a location designated by the Owner. The Contractor shall maintain a 24-hour fire watch during all burning operations.
1.05 STRIPPING AND STOCKPILING OF TOP SOIL

1.05.1 Topsoil within the excavation and earth fill work areas and the top twelve (12) inches of cover soil in areas requiring clearing and grubbing shall be stripped and placed in the cover stockpile area at the location designated on the Drawings.

1.05.2 The surface of the soil cover stockpile and unsuitable material disposal area shall be graded to provide positive drainage at all times. Upon completion, the soil cover stockpile and unsuitable material disposal area shall be vegetated with the seed mixture as specified herein.

1.06 LINES AND GRADES

1.06.1 The Drawings indicate existing and proposed contours defining the lines and grades of the site, as well as typical sections. The Contractor shall be responsible for the land surveying defining all excavations and fills required to complete the Work.

1.06.2 The Drawings indicate reference survey control, which has been established by the Owner. The Work shall be located from this control by the Contractor.

1.07 EXCAVATION

1.07.1 Excavation shall conform to the lines and grades shown on the Drawings. Any deviation shall require prior approval of the Owner. Material shall be selectively excavated such that the excavated materials are segregated in accordance with the characteristics defined in Section 1.03.1 to 1.03.5. Excavated areas shall be shaped and fine graded to provide a uniform surface free from windrows, bumps, and hollows.

1.07.2 In excavations in liner installation areas, a minimum of six inches of approved subbase material shall be maintained between the liner assembly and the base grade, whether base grade surface is soil or rock. After finish grading excavation and subbase placement is complete, the Contractor shall check the six-inch minimum cover requirement. Test locations will be selected by the Owner. Where, in the opinion of the Owner, the minimum cover is not achieved, corrective measures must be made to satisfy the six-inch minimum cover requirement.

1.07.3 The Contractor shall grade excavations to provide positive drainage at all times. Any material which in the opinion of the Owner is rendered unsuitable due to the failure of the Contractor to maintain proper drainage shall be removed and disposed of as unsuitable material and replaced, all at the Contractor’s expense.

1.07.4 All excavation materials satisfying the requirements of cohesive soil or common soil and those considered satisfactory for fill by the Owner shall be considered suitable. All other materials shall be considered unsuitable and shall be removed and placed in the location designated by the Owner.

1.07.5 Excavation operations shall be conducted so that material outside the excavation limits is not disturbed or loosened. Material disturbed or loosened shall be restored to at least its original condition.
1.07.6 Any over excavation beyond the lines and grades shown on the Drawings that was not directed by the Owner shall be brought back to the designated grade(s) with approved material and compacted at the Contractor’s expense.

1.07.7 The Contractor shall maintain all Contractor used haul roads which shall include the application of any dust suppressant to minimize fugitive dust. All dust control and haul road maintenance required due to the Contractor’s operation shall be at the Contractor’s expense.

1.07.8 Unsuitable, soft or organic areas, previous landslide areas, and excavation below base grade not identified as bulk excavation encountered during base grade preparation shall be “over excavated” until material acceptable to the Owner is encountered, and backfilled with suitable structural fill.

1.08 CONTROLLED BLASTING

1.08.1 INTRODUCTION

Blasting will be required to provide stable slopes within the CHSWMF and along the haul road leading from the plant to the CHSWMF.

1.08.2 PROJECT ON-SITE PERSONNEL AND ORGANIZATION

The Contractor will be responsible for general blasting procedures and safety. The Contractor will employ a Licensed Blaster registered in Virginia. The Licensed Blaster will conform to the Department’s rules regulating blasting operations in Virginia. The Contractor will employ a consultant to conduct seismic surveys.

1.08.3 DESCRIPTION OF FIELD ACTIVITIES

Seismic Surveys are planned along US Alternate Route 58 and on the properties adjacent the site on both the north and south sides of the planned area of development.

1.08.4 PREBLAST SURVEY

At least 30 days before initiation of blasting, the Owner shall notify, in writing, residents or owners of dwellings or other structures located within ½ mile of the permit area where blasting will occur of the right to a preblasting survey, the right to receive a copy of the preblasting survey and how to request a preblasting survey. On the request to the Department or Owner by a resident or owner of a dwelling or structure that is located within ½ mile of any part of the permit area where blasting will occur, the Owner shall promptly conduct a preblasting survey of the dwelling or structure. If a dwelling or structure is renovated or added to subsequent to a preblasting survey, then, upon request by the resident or owner to the Department or Owner, a survey of the additions and renovations shall be performed by the Owner under this section. The Owner shall provide the Department with a copy of the request.

The survey shall determine the condition of the dwelling or structure and document any preblasting damage and other physical factors that could reasonably be affected by the blasting. Assessments of structures such as pipes, cables, transmission lines, and wells and other water systems shall be limited to surface condition and readily available data. Preblasting conditions of wells and other water systems used for human, animal, or agricultural purposes shall be ascertained to the extent possible regarding the quantity and quality of the water.

A written report of the survey shall be prepared and signed by the person who conducted the survey. The report may include recommendations of any special conditions or proposed adjustments to the blasting procedure which should be incorporated into the blasting plan to prevent damage. Copies of the report shall be promptly provided to the person requesting the survey and to the Department. If the person requesting the survey disagrees with the results of the survey, the person may notify, in writing, both the permittee and the Department of the specific areas of disagreement.
A preblasting survey requested more than 10 days before planned initiation of blasting shall be completed by the Owner before the initiation of blasting.

1.08.5 BLASTING

1.08.5.1 Blasting Schedule Publication

The Owner shall publish a blasting schedule in a newspaper of general circulation in the locality of the proposed site, at least 10 days, but not more than 30 days, before beginning the blasting program.

Copies of the schedule shall be distributed by mail to local governments and public utilities and by mail or delivered to each resident within ½ mile of the blasting area. Copies sent to residents shall be accompanied by information advising the owner or resident how to request a preblasting survey.

The person who conducts the blasting activities shall republish and redistribute the schedule by mail at least every 12 months.

1.08.5.2 Blasting Schedule

The blasting schedule shall contain at a minimum the following:

- Identification of the specific areas in which blasting will take place.
- Dates and time periods (not to exceed four hours) when explosives are to be detonated.
- Methods to be used to control access to the blasting area.
- Audible warnings and all-clear signals shall be used before and after blasting.
- Emergency situations that might prevent blasting at times announced in the blasting schedule, such as rain, lightning, other atmospheric conditions or operator or public safety which may require unscheduled detonation shall be stated in the blasting schedule.

1.08.5.3 Public Notice of Changes to Blasting Schedules

The Owner shall prepare a revised blasting schedule before blasting in areas or at times not in a previous schedule.

The blasting schedule shall be revised, published and distributed in accordance with this action.

Blasting shall be conducted between sunrise and sunset, at times announced in the blasting schedule.

Warning and all-clear signals shall be different in pattern, audible with a range of ½ mile from the point of the blast, sounded before and after each blast. Persons who work within the ½ mile of the blasting area shall be notified of the meaning of the signals through appropriate instructions. These instructions shall be periodically delivered or otherwise communicated in a manner which can be reasonably expected to inform these persons of the meaning of the signals. The Contractor who conducts blasting incident to earth moving activities shall:

- Give sufficient warning that persons approaching the area where a blast is about to be detonated may be warned of the danger and be given ample time to retreat a safe distance from the blast area.
• Erect signs at least 500 feet from the blast area reading: BLAST AREA-SHUT OFF ALL TWO-WAY RADIOS. The letters of these signs shall be at least four inches in height on a contrasting background.

• Place at the entrances to the permit area from public roads or highways conspicuous signs which state “Warning. Explosives in Use” which clearly explain the blast warning and all clear signals that are in use and which explain the marking of blasting areas and charged holes within the permit area.

Access to an area possibly subject to flyrock from blasting shall be controlled to protect the public and livestock. Access to the area shall be controlled to prevent the presence of livestock or unauthorized personnel during blasting and until the Contractor has reasonably determined:

• That no unusual circumstances, such as imminent slides or undetonated charges, exist.

• That access to and travel in or through the area can be safely resumed.

• An airblast shall be controlled so that it does not exceed the noise level specified at a dwelling, public building, school, church or commercial or institutional structure, unless the structure is owned by the person who conducts the surface mining activities and is not leased to another person. The lessee may sign a waiver relieving the Owner and Contractor from meeting the airblast limitations of this subsection.

Maximum allowable noise levels: Lower frequency limit of measuring system in Hz (+3dB)
Maximum level (dB) 0.1 Hz or lower flat response 134, peak 2 Hz or lower flat response 133, peak 6 Hz or lower flat response 129, peak c-weighted, slow response 105 peak dBC.

If necessary to prevent damage, the Department may specify lower maximum allowable airblast levels than those of this subsection for use in the vicinity of a specific blasting operation. The measuring systems used shall have a flat response of at least 200 Hz at the upper end. The Type 1 sound level meter shall use the slow response C – weighted network and shall meet American National Standards Institute (ANSI) S1.4-1971 specifications.

The Owner shall conduct periodic monitoring to ensure compliance with the airblast standards. The Department may require an airblast measurement of blasts, and may specify the location of the measurements.

1.08.5.4 Requirements for blasting are as follows:

• Public highways and entrances to the operation shall be barricaded and guarded by the Contractor if the highways and entrances to the operations are located within 1,000 feet of a point where a blast is about to be fired.

• When a blast is about to be fired within 200 feet of a pipeline, the Contractor shall exercise necessary caution as needed for the protection of the pipeline. The Contractor shall notify the owner of the pipeline of the Contractor’s intention to blast, giving a description of the precautionary measures that will be taken.

• When blasting is to be done within 1,000 feet of schools or public buildings, it shall be done only during the time approved by the Department. Prior to the blasts, the Contractor or foreman in charge of the blasting operation shall, within 24 hours prior to the blast, notify persons within this area that a blast is to be detonated. Approval of
the method of notification shall be obtained from the Department prior to commencing blasting.

- Blasting may not be done within the confines of an area of 300 feet of an occupied dwelling unless prior written consent of the property owner has been obtained.
- Flyrock may not be cast from the blasting vicinity more than one-half the distance to the nearest dwelling or occupied structure and in no case beyond the permit boundary, or beyond the area or regulated access.
- No blasting, whether of overburden or of coal, may be done or performed in a manner and under circumstances or conditions to eject debris into the air, to constitute a hazard or danger or do harm or damage to person or property in the area of the blasting.

Blasting shall be conducted to prevent injury to person, damage to public or private property outside the permit area, adverse impacts on an underground-mine, or availability of groundwaters or surface waters; and shall be prohibited in cases when the effect of the blasting is liable to change the course or channel of a stream.

1.08.5.5 Blast Monitoring (vibrations and air blast limitation)

The maximum peak particle velocity may not exceed the values approved in the blast plan at the location of a dwelling, public building, school, church, commercial or institutional building or other structure. Peak particle velocities shall be recorded in three mutually perpendicular directions. The maximum peak particle velocity shall be the largest of any three measurements. The Department may reduce the maximum peak particle velocity allowed, if it determines that a lower standard is required because of density of population or land use, age or type of structure, geology or hydrology of the area, frequency of the vibration or other factors.

The maximum peak particle velocity limitation does not apply at structures located on the permit area when the owner and lessee, if leased to another party, of the structure have each signed a waiver releasing the vibration limit. This waiver shall be submitted to the Department prior to the firing of a blast which exceeds the current vibration limit, as stated in the blast plan.

When seismographs are not used to monitor peak particle velocity, the maximum weight of explosives to be detonated within an 8 millisecond period may be determined by the formula $W = (D/Ds)^2$ where $W$ equals the maximum weight of explosives, in pounds, that can be detonated in any 8 millisecond period or greater, $D$ equals the distance, in feet, from the blast to the nearest dwelling, school, church, commercial or institutional building and $Ds$ equals the scaled distance factor. The development of a modified scaled-distance factor may be authorized by the Department on receipt of a written request by the Owner, supported by seismographic records of blasting at the site. The modified scaled distance factor shall be determined so that the particle velocity of the predicted ground vibration will not exceed the prescribed maximum allowable peak particle velocity at a 95 percent confidence level.

When a seismograph is used to monitor the peak particle velocity, a seismograph record shall be obtained for each blast and within 30 calendar days become part of the blast record. The seismograph record shall be analyzed by an independent party qualified in the analysis of seismic data.
The use of a formula to determine maximum weight of explosives per delay for blasting operations at a particular site may be approved by the Department if the peak particle velocity of 1 inch per second would not be exceeded.

The Department may require a seismograph record of blasts and may specify the location at which such measurements are taken.

The maximum ground vibration may not exceed the following limits at the location of a dwelling, public building, school, church or community or institutional building:

<table>
<thead>
<tr>
<th>Distance (D) from Blast Site (ft.)</th>
<th>Maximum allowable peak particle velocity (Vmax) (inches/second)</th>
<th>Scaled-distance to be applied without seismic monitoring (Ds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 300</td>
<td>1.25</td>
<td>50</td>
</tr>
<tr>
<td>301 – 5,000</td>
<td>1.00</td>
<td>55</td>
</tr>
<tr>
<td>5,001 and beyond</td>
<td>0.75</td>
<td>65</td>
</tr>
</tbody>
</table>

Notes:

1. Ground vibration shall be measured as the particle velocity. Particle velocity shall be recorded in three mutually perpendicular directions. The maximum allowable peak particle velocity shall apply to each of the three measurements.

2. Applicable to the scaled-distance equation of subsection (j).

1.08.5.6 Additional Requirements

Blasting shall not be conducted until:

- Blasting plans are approved by the Department and the approved blasting plan is returned to the Owner.
- Notification of completion of requested preblasting surveys is received by the Department.
- Copy of the proof of publication of each blasting schedule is received by the Department.

The Contractor shall provide a seismograph recording including both the particle velocity time-history (wave form) and the particle velocity and vibration frequency levels for each blast.

- The vibration frequency shall be displayed and analyzed over the frequency range of 1 Hz through 100 Hz.
- The permittee shall obtain Department approval of the analytical method used to determine the predominant frequency before applying this alternative criterion.

1.08.5.7 Use of explosives: records of blasting operations

A record of each blast shall be retained for at least 3 years and shall be available for inspection by the Department and the public on request. Seismographic reports, if applicable, shall be made a part of that record. The record shall contain the following data:

- The name of the operator conducting the blast.
- The location, date and time of blast.
- The name, signature and license number of blaster-in-charge.
The direction and distance, in feet, to the nearest dwelling, public building, school, church, commercial or institutional building or other structure.

Weather conditions, including temperatures, wind direction and approximate velocity.

The type of material blasted.

The number of holes, burden, and spacing.

The diameter and depth of holes.

The types of explosive used.

The total weight of explosives used.

The maximum weight of explosives detonated per delay interval.

The maximum number of holes detonated per delay interval.

The initiation system.

The type and length of stemming.

The mats or other protections used.

The type of delay detonator and delay periods used.

A sketch of the blast pattern, including number of holes, burden, spacing, decks and delay pattern.

The number of persons in the blasting crew.

Seismographic and airblast records, when required, including the type of instrument, sensitivity and calibration signal of the gain setting or certification of annual calibration and the following:

i. The seismographic or airblast level, or both, reading, including the exact location of seismograph and its distance from the blast.

ii. The name of the person taking the seismograph reading.

iii. The name of the person and firm analyzing the seismographic record.

The reasons and conditions for each unscheduled blast.

1.09 FILL PLACEMENT

1.09.1 Structural fill to develop the base grade shall be placed in nearly horizontal lifts (unless shown otherwise on the Drawings) during construction. Surfaces shall be provided with sufficient longitudinal and transverse slope to provide positive drainage of surface water.

1.09.2 Hauling equipment shall not be permitted to repeatedly follow a single track, but shall use different tracks each run in order to provide uniform compaction of the fill.

1.09.3 All fills shall be benched into existing ground, at junctions between fill and existing grade. Minimum bench width shall be a dozer width. The existing grade shall be cut back, if necessary, to expose compact stable material.
1.09.4 No fill shall be placed while rain is falling unless approved by the Owner. Prior to resuming fill operations after rain; all muddy material shall be bladed off the surface to a depth necessary to expose firm compacted material.

1.09.5 No fill shall be placed on frozen ground, and no frozen material shall be used for fill.

1.09.6 At the end of the day’s operation and/or when rain is threatening, the fill shall be sloped to provide positive drainage and shall be compacted over the entire cross-section and length with a smooth wheel roller to seal it against the entry of water.

1.09.7 When the top of the fill or base grade has dried out, become excessively wet, or been damaged by construction equipment, the surface on which additional fill or a structure is to be placed shall be scarified to a minimum depth of six inches, brought to the specified moisture content, and recompacted to the specified density prior to the placement of additional fill or a structure.

1.09.8 Fill which does not meet the requirements for moisture content at the time of compaction shall be dried or wetted to meet the specified requirements. If the fill material requires drying, this may be accomplished by reworking it under warm and dry atmospheric conditions. Water, if required, shall be added carefully by sprinkling and care should be taken that no more than the amount needed is applied. Ponding or flooding shall not be permitted.

1.09.9 Sheepfoot, segmented, or rubber-tired rollers shall be used to compact cohesive soils and vibratory drum rollers shall be used to compact granular materials unless otherwise approved.

1.09.10 General fill to be used in fill areas shall be intermixed with soil under the liner areas to the satisfaction of the Owner, but in no case within one foot of the final base grade elevation.

1.09.11 The term "non-durable rock fill," when used herein, includes all fill material which can be broken down and disintegrated during normal compaction with mechanical equipment, and includes soft to medium-soft weathered rocks such as claystones and some shales.

Non-durable rock should be crushed and broken by appropriate construction equipment and techniques. After the non-durable rock has been satisfactorily disintegrated to a common fill material, it shall be compacted to the requirements of general fill as stated herein. The Contractor shall be responsible for achieving and maintaining the designated moisture content. Controlled sprinkling or drying may be required to obtain the correct moisture content.

1.09.12 The term "durable rock fill," when used herein, includes all fill material which is of such size and hardness as cannot practically be broken down and disintegrated during normal compaction, and which is resistant to weathering and decomposition. This includes, but is not limited to, medium hard and hard sandy shale, sandstone, siltstone, and limestone. Durable rock may be used when there is more than four feet of fill required. The rock fill shall be placed in accordance with Section 303.04(h), page 310 of VDOT Road and Bridge Specifications - 2007 requirements. No durable rock fill shall be used within two-feet of the liner assembly or within the sedimentation pond embankment.
1.10 EARTHWORK, BASE GRADE AND SUBBASE PREPARATION

1.10.1 The base grade shall be developed from excavation and site soil structural fill. The base grade and the structural fill below base grade shall consist of excavated soil and/or durable and non-durable rock in accordance with these specifications.

1.10.2 The base grade and structural fill below base grade shall be compacted to a minimum density equal to 95 percent of the maximum dry density as determined by the Standard Proctor Test (ASTM D 698). The moisture content at the time of compaction shall not vary from the optimum moisture content by more than two percent. The rock correction procedure shall be applied.

1.10.3 Base grade areas shall be proofrolled with at least two passes of a large (greater than 10 tons) rubber tire roller or other approved heavy compaction equipment. Confined areas inaccessible to heavy compaction equipment shall be compacted with a minimum of four passes with the largest practicable impact plate-compactor or roller. Unsuitable, soft or organic areas, or previous landslides detected during base grade preparation shall be over excavated until material acceptable to the Owner is encountered, and backfilled with suitable compacted soil.

1.10.4 All proofrolling shall be performed in the presence of the Owner. At least 48 hours notice to the Owner shall be required prior to performing base grade proofrolling.

1.10.5 The Contractor shall protect the completed base grade and subbase from damage by equipment, trucks, or weather. Any damage to the base grade or subbase shall be repaired at the Contractor’s expense.

1.10.6 Within the limits of the liner installation, as shown on the Drawings, the Contractor shall remove all surface stones larger than four inches and then proofroll the base grade to detect any soft or unsuitable areas, rock outcrops, zones of granular or relatively permeable soils, springs, seeps, and wet areas. The proofrolling shall take place after all cuts, fills and fine grading are complete in the area.

1.10.7 Steep slopes which pose an unsafe situation for rollers may be proofrolled with tracked equipment and an approved towed roller capable of attaining the specified compaction requirements.

1.10.8 The base grade layer shall be placed within plus or minus 0.5-foot of the grades shown on the Drawings. Any deviation in line and grade from that shown on the Drawings shall require prior approval of the Owner.

1.10.9 If springs, seeps, or wet areas are found, drains shall be installed in accordance with the details shown on the Drawings. Soft areas shall be over excavated and replaced with suitable compacted soil and graded to drain, as directed by the Owner.

1.10.10 Base grade surfaces within the limits of the proposed liner shown on the Drawings shall be covered by a minimum of six inches of approved subbase material.

1.10.11 For drainage channel excavation and finished excavation, materials within one foot of basegrade shall be compacted to at least 95% of the maximum dry density as determined by the Standard Proctor Test (ASTM D 698).
1.10.12 For structural fill, approved soil material shall be placed in eight inch loose lifts and compacted with sheepsfoot rollers or other rollers acceptable to the Owner.

Structural fill within one foot of the basegrade shall be compacted to at least 95 percent of the maximum dry density as determined by the Standard Proctor Test (ASTM D 698). Durable rock shall be placed in accordance with Section 303.04(h), page 310, of the VDOT Road and Bridge Specifications - 2007.

1.10.13 Subbase is the bottom six inches of the liner assembly and must meet all requirements of base grade soils along with the following additional requirements:

A. Hard, uniform, smooth and free of debris, plant materials, and other foreign material.

B. Have no surface rocks larger than three eighths of an inch.

C. A minimum of six inches of subbase material shall be placed on top of the base grade surface throughout the entire limits of liner.

1.10.14 Perimeter liner termination area backfill and cover must be placed in a timely manner after the installation of the liner system and prior to the placement of the drainage layer on the liner system. Perimeter liner termination area backfill is to be placed or spread at a maximum lift thickness of six inches and compacted using equipment of the type and size required to produce 95 percent of Standard Proctor density. Compaction shall be performed in such a manner that no damage of the liner system occurs.

After backfilling or cover placement, the disturbed areas shall be fine graded to blend in with existing contours or to elevations as indicated on the Drawings. The finished areas will be left with puddle-free drainage.

1.11 SUBMITTALS

1.11.1 Submittals by the successful bidder prior to placement of earthwork, base grade and subbase shall include:

A. Identification of excavated soils to be used and the test method to identify soil types.

B. Submit the roller specifications for type of roller to be used.

C. Have laboratory facilities in place and all required testing completed and approved prior to beginning placement of the base grade structural fill and subbase.

1.11.2 At the completion of the installation of the base grade structural fill and subbase:

A. Submit test records as detailed in the accompanying CQA Plan.

B. At the completion of laboratory tests, submit copy to the Owner.
SECTION 2
PVC GEOMEMBRANE

2.01 GENERAL

2.01.1 DESCRIPTION OF WORK

A. Contractor shall furnish all supervision, labor, products, equipment, and tools, including all necessary and incidental items as detailed or required, to install geomembrane in accordance with the Contract Drawings, Technical Specifications, and project Construction Quality Assurance (CQA) Plan.

2.01.2 RELATED WORK SPECIFIED ELSEWHERE

A. Earthwork, base grade and Subbase - Section 1
B. Piping Systems and Leachate Collection and Subsurface Drainage - Section 5
C. Geocomposite Drainage Net – Section 4
D. Construction Quality Assurance Plan.

2.02 REFERENCES

2.02.1 CODES AND STANDARDS

A. American Society for Testing and Materials (ASTM) Standards:
   5. D 1004, “Standard Test Method for Tear Resistance (Graves Tear) of Plastics Film and Sheeting”.
   7. D 1204, “Standard Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature”.


2.03 DEFINITIONS

2.03.1 Formulation: The mixture of a unique combination of ingredients identified by type, properties, and quantity. For polyvinyl chloride (PVC) geomembrane, a formulation is defined as the exact percentages and types of resin(s), and additives.

2.04 SUBMITTALS

2.04.1 Contractor shall be responsible for timely submittals to the Owner.

2.04.2 The following submittals shall be provided with Contractor’s Bid:

A. The geomembrane and Geomembrane Manufacturer must be approved by the Owner prior to Contract award. Submittals for approval include:

1. Geomembrane Manufacturer’s specification sheet(s) demonstrating compliance with the requirements of Table 2-1.

2. Written certification that the Geomembrane Manufacturer has produced a minimum of 5,000,000 square feet of PVC geomembrane that has been installed for hydraulic containment purposes in the last two years, including a list of the relevant completed facilities. Each entry in this list should include the name, location, and purpose of the facility; geomembrane thickness, total square footage, and date of installation; names of the Owner, Designer, Fabricator (if any), and Geomembrane Installer; and the name and telephone number of a contact at the facility who can discuss the project.

3. A copy of the Geomembrane Manufacturer’s manufacturing quality control (MQC) manual. This manual should describe the quality control program(s) for formulation ingredients (raw materials), and finished geomembrane sheet and indicate the properties, test methods, and testing frequencies used for each. Geomembrane Manufacturer shall modify the MQC manual to comply with the requirements of these Specifications, with any variations, deviations, or exceptions clearly noted in an attached letter.

B. The geomembrane shall meet the interface shear strength requirements of Table 2-2. Interface shear strength testing to verify compliance with the requirements of Table 2-2 shall be performed by the Owner as noted in Section 2.07.3.C. However, the Geomembrane Manufacturer shall review the interface shear strength requirements and test procedures outlined in Table 2-2 to avoid proposing the use of a geomembrane product(s) that will not meet these requirements. The interfaces that exist for this project include:
1. Geomembrane against geotextile; and
2. Geomembrane against GDN (double-bonded).

C. The Geomembrane Installer must be approved by the Owner prior to Contract award. Submittals for approval include:

1. Written certification that the Geomembrane Installer has installed a minimum of 1,000,000 square feet of PVC geomembrane for hydraulic containment purposes in the last four years, including a list of the relevant completed facilities. Each entry in this list should include the name, location, and purpose of the facility; geomembrane thickness, total square footage, and date of installation; names of the Owner, Designer, Contractor, and CQA Consultant; and the name and telephone number of a contact at the facility who can discuss the project.

2. A copy of the Geomembrane Installer’s construction quality control (CQC) manual. This manual should describe the quality control programs for handling, deploying, placing, anchoring, seaming, repairing, and testing geomembrane. Geomembrane Installer shall modify the CQC manual to comply with the requirements of these Technical Specifications and the project CQA Plan, with any variations, deviations, or exceptions clearly noted in an attached letter.

2.04.3 The following submittals shall be provided after award of Contract:

A. Geomembrane Manufacturer:

1. Prior to or coincident with shipment of geomembrane to the project site, submit written certification and supporting test data documenting that all resin used for geomembrane production complies with the requirements of Section 2.06.1.C. This certification shall state the producer, product designation, lot or batch number, and production date of all resin used in the manufacture of geomembrane shipped to the project site and shall include copies of all quality control certificates issued by the resin producer.

2. Prior to or coincident with shipment of geomembrane to the project site, submit written certification and supporting test data, in the form of Quality Control Certificates, documenting that all geomembrane shipped to the project site complies with the requirements of Section2.06.1.D. Geomembrane Quality Control Certificates must be reviewed and signed by a responsible representative of the Geomembrane Manufacturer.

B. Geomembrane Installer:

1. Four weeks prior to shipment of geomembrane to the project site, submit six full sets of field installation drawings for the Quality Assurance Officer’s (QAO’s) approval. Installation drawings shall show the proposed length, width, and position of all geomembrane panels and the location of all field seams. Geomembrane panels and field seams shall have distinct identification systems. Installation drawings shall also show complete details for field seaming and repairs, anchoring geomembrane at the perimeter of the installation area, and attachments to structures and other penetrations, as required.
2. Two weeks prior to arrival at the project site, submit personnel resumes demonstrating compliance with the following:
   a. A minimum of one field superintendent per shift shall be designated by the Geomembrane Installer and approved by the Owner. Each field superintendent shall have a minimum of five years of field experience installing PVC geomembrane. Any change or replacement of superintendents during the project must be approved in advance by the Owner.
   b. Each seaming crew shall have a designated foreman. Said foreman must have a minimum of two years of PVC geomembrane installation experience and must work continuously with the seaming crew.
   c. Each welding technician shall have a minimum of 1,000,000 square feet of PVC geomembrane welding experience.

3. Within four weeks after completion of geomembrane installation, submit a written report containing the following:
   a. Written certification stating that the geomembrane has been installed in accordance with the Contract Drawings, Technical Specifications, and project CQA Plan.
   b. Product and installation warranties as required by Section 2.07.9.
   c. Copies of daily field records and all testing documentation (trial seam testing, non-destructive testing, etc.).
   d. As-built drawings depicting actual geomembrane panel placement and all associated details. As-built geomembrane plans ("panel diagrams") shall be prepared at a reasonable Engineer’s scale using Contractor’s surveyed edge of geomembrane limits (anchor trenches, runouts, etc.), and shall accurately depict panel orientations and dimensions; all repair locations (patches, cap strips, etc.); and shall clearly identify all panel numbers, seam identification numbers, and destructive testing sample locations.

2.05 CONSTRUCTION QUALITY CONTROL AND QUALITY ASSURANCE

2.05.1 Geomembrane CQC will be performed by the Geomembrane Installer in accordance with the CQC manual approved by the Owner.

2.05.2 Geomembrane CQA will be performed by the QAO and paid for by the Owner. Geomembrane CQA will be performed in accordance with these Technical Specifications and the project CQA Plan.

2.06 MATERIALS REQUIREMENTS

2.06.1 PVC GEOMEMBRANE
   A. The geomembrane and Geomembrane Manufacturer must be approved by the Owner prior to Contract award, as required by Section 2.04.2.A and B.
   B. Geomembrane shall be 50 mil polyvinyl chloride (PVC) for the facility liner. The physical, mechanical, and chemical properties of the geomembranes shall comply with the requirements of Table 2-1.
C. Resin used in the manufacture of geomembrane is to be made from virgin, uncontaminated ingredients and shall be designed and manufactured specifically for producing geomembrane. Incoming resin shall be sampled and tested in accordance with the Geomembrane Manufacturer’s approved MQC manual. Testing frequencies, test procedures, and resin properties shall comply with the requirements of Table 2-1. Results from the resin sampling and testing program are to be submitted to the Owner in accordance with Section 2.04.2.A.3.

D. During production, finished geomembrane sheet shall be sampled and tested in accordance with the Geomembrane Manufacturer’s approved MQC manual. Testing frequencies, test procedures, and finished sheet properties shall comply with the requirements of Table 2-1. Results from the finished sheet sampling and testing program, in the form of Quality Control Certificates, are to be submitted to the CQA Consultant in accordance with Section 2.04.2.A.3.

E. Geomembrane shall be produced free of holes, blisters, undispersed raw materials, contamination by foreign matter, dimensional abnormalities, or other defects. The CQA consultants may reject all or portions of units of geomembrane shipped to the project site if significant production flaws are observed.

F. Geomembrane shall be prefabricated into panels prior to delivery to the project site in order to reduce the amount of field seaming required during installation. The Geomembrane Fabricator, if different from the Geomembrane Manufacturer, shall have previously demonstrated ability to fabricate PVC geomembrane by having successfully fabricated a minimum of five million square feet of PVC geomembrane for hydraulic containment purposes in the last four years. PVC geomembrane not meeting the requirements of Table 2-1 shall not be incorporated into fabricated panels.

G. Geomembrane panels shall be fabricated using fusion methods such as hot air, hot wedge, or ultrasonic equipment in accordance with the Geomembrane Manufacturer’s requirements and approved by the Owner. Single or double fusion seams are acceptable. Fabricated seams may also be completed by means of solvent or bodied solvent adhesive in accordance with the Geomembrane Manufacturer’s requirements and approved by the Owner.

H. Geomembrane factory seams shall be nondestructively and destructively tested by the Geomembrane Fabricator prior to shipment. Nondestructive testing may include pressure testing, spark testing, or other method approved by the Owner. Destructive testing of factory seams shall be in
accordance with Table 2-3A and Table 2-3B. Results of the destructive
testing program shall be submitted to the CQA Consultant for review before
shipping geomembrane to the project site. The Geomembrane Fabricator
shall also prepare and submit panel identification drawings for each panel
that include overall panel dimensions, source roll numbers, locations of
factory seams and repairs, and the date of fabrication.

I. Each geomembrane panel shall be marked or labeled to identify the
Geomembrane Manufacturer, product designation, manufacturer's lot
number, manufacturer's roll number(s), sheet thickness, length and width
of each panel, and panel number (if applicable). Roll identification
numbers shall conform to the numbering system established on the
Geomembrane Manufacturer's Quality Control Certificates. Labels or
markings shall be legible and located so that each panel can be identified
by examining the outside of the packaged panel. Markings or labels shall
be weather proof.

J. The Geomembrane Fabricator shall protect all fabricated panels from
"blocking", excessive folding, and other damage during fabrication, storage,
and shipment. All panels prepared for shipment shall be packaged for
protection from weather and handling damage in accordance with
Geomembrane Manufacturer's requirements. Any panels delivered to the
site without adequate protection may be rejected by the CQA Consultant.
Any such rejected material shall be replaced by the Contractor at no cost to
the Owner.

K. All raw material and finished geomembrane properties, including testing
frequencies and test procedures used, shall meet the requirements of this
Section. No geomembrane shall be installed until the CQA Consultant has
reviewed all certifications and supporting test data and determined that the
geomembrane delivered to the project site is acceptable for use. Factory
seaming shall be tested at the same frequency as field seaming as
described in Section 2.07.5. Manufacturing records, including test data,
shall be maintained by the Geomembrane Manufacturer for two years after
acceptance of the geomembrane, and shall be made available upon
request.

2.06.2 PIPE PENETRATION SEALS

A. Boots (sleeves and skirts) to be used for sealing all pipe penetrations in the
geomembrane shall be 50 mil PVC meeting the physical, mechanical, and chemical
properties of Table 2-1.

B. Gaskets to be used for sealing boots to pipes penetrating the geomembrane shall be
neoprene and have a width of two inches and thickness of 0.25-inch. Neoprene
adhesive shall be in accordance with the Geomembrane Manufacturer's
requirements.

C. Banding Straps to be used to attach boots to pipes penetrating the geomembrane
shall be stainless steel and meet the dimensional requirements shown on the
Contract Drawings.
2.07 INSTALLATION

2.07.1 PRE-INSTALLATION MEETING
A. Prior to scheduled geomembrane installation, the Owner, CQA Consultant, Contractor, and Geomembrane Installer shall attend a pre-installation meeting at the project site. This meeting shall be scheduled by the Owner after receipt of Geomembrane Installer’s field installation drawings.
B. Geomembrane Installer shall be represented by both the project field superintendent and the project manager.
C. At the pre-installation meeting, site safety and rules of operation, scheduling, methods of installation, and construction quality control and quality assurance shall be discussed. The Geomembrane Installer and CQA Consultant shall at this time agree to the required geomembrane placement, seaming, sampling, testing and repair procedures for the project.

2.07.2 SHIPPING, HANDLING, AND STORAGE
A. Contractor is responsible for proper shipping, unloading, and storage of the geomembrane. Geomembrane damaged during shipping, unloading, or storage shall be repaired or replaced at no cost to Owner.
B. During unloading at the project site, Contractor shall conduct a surface inspection of all geomembrane for defects and damage. Contractor shall immediately notify the CQA Consultant of any defects or damage observed. 
C. Extreme care shall be taken by all personnel while unloading and handling geomembrane. Equipment used to unload and handle geomembrane shall have sufficient capacity to manage the roll/panel weight without damaging the geomembrane.
D. Geomembrane shall be stored at the project site in an area(s) designated by the CQA Consultant. Contractor shall grade the storage area so that it is reasonably level and well-drained, and shall prepare the ground surface so that it is firm, smooth, and free of stones, sticks, or other materials that may damage the geomembrane.
E. Stacking of geomembrane for storage is not allowed.
F. During storage, geomembrane shall be protected from excessive dust and mud by covering the rolls/panels with a plastic sheet or waterproof tarpaulin. Labels shall remain intact and legible. Any geomembrane that has no label or where the label is damaged or otherwise illegible may be rejected by the CQA Consultant.

2.07.3 QUALITY ASSURANCE CONFORMANCE TESTING
A. Quality assurance conformance testing of the geomembrane shall be performed by the CQA Consultant and paid for by the Owner. Conformance testing lab results shall be provided directly to Owner and CQA Consultant for review upon receipt of testing data from lab. Conformance sampling and testing shall be completed in accordance with the project CQA Plan; per Table III-1, or as directed by the CQA Consultant. Owner has the option to increase the frequency of conformance testing or to sample and test any questionable roll or lot.
B. Owner may revise the test methods used for determination of conformance properties to allow for use of new or revised methods.

C. All geomembrane conformance test results shall comply with the requirements of Tables 2-1 and 2-2 prior to installation. Any geomembrane that does not conform to these requirements shall be retested or rejected in accordance with the CQA Plan.

D. Geomembrane shall only be approved for use with the GDN and/or geotextile products used for interface shear strength testing. Changes in GDN and/or geotextile products during construction will require retesting and reapproval of the geomembrane at no cost to the Owner.

E. Geomembrane that is rejected shall be removed from the project site and replaced at no cost to Owner. Sampling and conformance testing of geomembrane supplied as replacement for rejected material shall be performed by the CQA Consultant at Contractor’s cost.

2.07.4 DEPLOYMENT AND PLACEMENT

A. Geomembrane shall be deployed and placed in general accordance with the Geomembrane Installer’s approved field installation drawings. Depending on field conditions, it may be necessary to alter the geomembrane panel arrangement from that shown on the approved field installation drawings. These alterations shall be approved by the CQA Consultant prior to geomembrane deployment.

B. Geomembrane Installer shall maintain a daily field record of actual placement of each geomembrane panel, noting base grade conditions, weather, seaming parameters, panel numbers placed, seams completed, samples taken, and tests run. A copy of each day’s field record shall be furnished to the CQA Consultant no later than the following work day.

C. Geomembrane shall only be placed on surfaces (geotextile or subbase) that have been installed in accordance with the Contract Drawings and Technical Specifications, and have been accepted in writing by the Contractor, Geomembrane Installer, and CQA Consultant. Once a surface has been accepted by the CQA Consultant, any additional surface preparation that the Contractor or Geomembrane Installer feels necessary to meet the requirements of the Technical Specifications shall be the responsibility of the Contractor.

D. Geomembrane shall only be placed on subbase that is free from standing water, excessive moisture, rutting, or other damage caused by vehicular traffic, erosion, or other causes. Surface requirements, including allowances for desiccation cracking, shall be as outlined in Section 1 – Earthwork, Base Grade and Subbase, of the Specifications. Areas exhibiting deficient surface shall be reported to the CQA Consultants and Owner for repair.

E. It is imperative to keep surface water runoff from beneath the geomembrane at all times during installation. Geomembrane Installer’s panel placement and seaming techniques and schedule shall minimize or eliminate the potential for accumulation of water beneath the geomembrane. Any water found ponded beneath the geomembrane after it has been installed shall be removed by the Contractor, as directed by the CQA Consultant, at no cost to Owner. Any soil beneath installed
geomembrane (subbase or base grade) that has become excessively moist, soft, or unsuitable to perform its intended function, shall be removed and replaced by the Contractor, as directed by the CQA Consultant, at no cost to Owner.

F. Equipment and tools used to deploy and place geomembrane shall not stretch, tear, puncture, or otherwise damage the geomembrane, and shall not damage the underlying geotextile, subbase or base grade.

G. Under no circumstances shall any construction or vehicular traffic be allowed to drive over exposed geomembrane. Geomembrane showing evidence of trafficking shall be inspected by the Geomembrane Installer, Contractor, and CQA Consultant to evaluate damage, if any. At the direction of the CQA Consultant, any damaged geomembrane shall be tested, rejected, or repaired at no cost to Owner. The CQA Consultant may allow limited use of four-wheeled ATVs or other low ground pressure equipment (having 6 psi or less contact pressure) by the Geomembrane Installer during installation, but use shall be prohibited if excessive trafficking or any geomembrane damage is observed.

H. Geomembrane shall be placed in such a manner as to minimize dragging of panels into position (“spotting”). Geomembrane Installer shall immediately provide temporary anchorage of the geomembrane to prevent wind uplift, panel movement during field seaming, and bridging (refer to Section 2.07.4.1 for bridging requirements). Temporary anchorage methods shall be approved by the CQA Consultant. If bags are used for temporary anchorage, they shall be filled with fine-grained VDOT Grading A Fine Aggregate that has been approved for use by the CQA Consultant. Any geomembrane exhibiting damage due to insufficient or improper temporary anchorage shall be repaired or replaced, as directed by the CQA Consultant, at no cost to Owner.

I. Geomembrane shall be installed so as to minimize or eliminate bridging (“trampolining”) at the toe of slopes down to temperatures as low as 32°F. Bridging control measures may include providing slack, using and maintaining additional temporary anchorage (e.g., sandbagging), or other methods approved by the CQA Consultant. If bridging is observed, Geomembrane Installer shall repair affected areas, as directed by the CQA Consultant, at no cost to Owner.

J. Panel seams shall be oriented in a direction parallel to the line of maximum base grade slope (i.e., down, not across the slope) and shall be placed in a manner that minimizes the number and length of field seams. In corners and odd-shaped geometric locations, the number of field seams shall be minimized and moved to locations outside the corners as appropriate.

K. For geomembrane placed on slopes, panels shall be shingled such that the “upstream” panel overlaps the “downstream” panel in order to minimize infiltration potential.

L. All panel seams parallel to the toe of a slope (“longitudinal seams”) shall be located at least 10 feet from the toe of the slope, except where explicitly approved by the CQA Consultant. Longitudinal seams are to be avoided on sideslopes. If a longitudinal seam is necessary, it shall be 45° to the slope contours. Adjacent sideslope seams shall be staggered a minimum of the panel width.
M. All geomembrane panels shall be permanently seamed on the same day they are placed except where explicitly approved by the CQA Consultant.

N. Contractor shall be responsible for excavation, maintenance, ballasting and backfilling of the geomembrane anchor trench. Backfilling of the anchor trench shall commence only after the geotextile or geocomposite drainage net (covering the geomembrane) has been approved by the CQA Consultant. Backfilling materials and compaction methods shall be as outlined in the Technical Specifications.

O. Loose soil shall not be permitted to underlie the geosynthetics in the anchor trenches or perimeter liner termination area. These features shall be graded to prevent ponding or run-on of water while the area is exposed. Contractor shall be responsible for preventing surface water runoff from accumulating beneath or atop the geosynthetics while the anchor trenches perimeter liner termination area is exposed.

P. Backfilling of the perimeter liner termination area shall commence only after the leachate collection system geotextile or GDN has been approved by the CQA Consultant. Backfilling materials and compaction methods shall be as outlined in Section 1 – Earthwork, Base Grade and Subbase, of the Specifications.

2.07.5 SEAMING

A. Lap joints and thermo-fusion or bodied solvent adhesive seaming methods shall be used to join geomembrane panels in the field. A minimum overlap of four inches shall be used for thermo-fusion welded seams and a minimum overlap of six inches shall be used for solvent welded seams. For joining geomembrane panels, dual hot wedge is the preferred seaming method. Bodied solvent adhesive welding can be used primarily for repairs, detailing, and tie-in areas (joining new geomembrane to geomembrane placed during previous construction projects).

B. Geomembrane Installer shall provide the following equipment, and any required accessories, to complete geomembrane seaming. Equipment shall be provided and maintained in sufficient numbers to avoid delaying Work.

1. Seaming equipment: Hot wedge (single and dual track), and hot air ("leister") welding machines. All seaming equipment shall be equipped with gauges that clearly display wedge temperature, rate of travel, and nozzle temperature, as applicable.

2. Destructive testing equipment: Punch press and field tensiometer for field destructive testing of geomembrane seams. Punch press shall be capable of producing die-cut geomembrane specimens in accordance with ASTM D 6392. Tensiometer shall be built to applicable ASTM specifications, be in good working order, and shall be accompanied by evidence of calibration within the last year.

3. Non-destructive testing equipment: Air pump(s) and gauges, air lance, and voltage applicator(s) for non-destructive testing of geomembrane seams and repairs. All testing equipment shall be built to applicable ASTM specifications and be in good working order.

4. Portable electric generators: Capable of providing constant voltage under a combined-line load. Generators must have rubber tires or be placed on a layer of cushioning material that does not damage the geomembrane.
5. **Miscellaneous equipment:** Any other equipment or tools (e.g., hook blades, scissors, markers, etc.) necessary to complete geomembrane seaming, testing, and labeling in accordance with these Technical Specifications and the Geomembrane Installer’s approved CQC manual.

C. No production seaming shall commence until trial seaming, as outlined in **Section 2.07.5.G,** is successfully completed and accepted by the CQA Consultant.

D. The Owner, in conjunction with the Geomembrane Installer and Contractor, shall establish site-specific limits of weather conditions, including, but not limited to, temperature, humidity, precipitation, and wind speed and direction, within which geomembrane panel placement and seaming can be conducted. In the absence of site-specific criteria, the following limitations shall apply:

1. No placement or seaming shall be conducted in the presence of precipitation, such as rain, snow, sleet, dew or fog.

2. No placement or seaming shall be conducted in the presence of winds in excess of 20 miles per hour, when dirt or debris is blown into seaming areas, or when seaming temperatures cannot be adequately monitored and controlled.

3. Seaming shall not be conducted when geomembrane sheet temperature falls below **40°F** unless approved by the CQA Consultant. In order for seaming to be approved, Geomembrane Installer shall be required, at a minimum, to prepare additional trial seams to demonstrate conformance with these Specifications. Owner reserves the right to require additional destructive seam testing when seaming is conducted at geomembrane sheet temperatures below **40°F.** Geomembrane Installer shall be prepared to pre-heat seaming areas prior to production seaming in accordance with Geomembrane Manufacturer recommendations.

4. Seaming shall not be conducted when geomembrane sheet temperature exceeds **104°F** unless approved by the CQA Consultant. Criteria for demonstration of conformance shall be outlined by the Owner.

E. For purposes of monitoring production seaming, geomembrane sheet temperature shall be measured and recorded by the CQA Consultant at multiple locations along seam overlap areas.

F. Storage of fuel, oils, and other petroleum products shall be restricted to off-geomembrane areas. Similarly, fueling of equipment (e.g., generators) and changing of oil and oil filters shall be restricted to off-geomembrane areas. If any fuel, oils, or other petroleum products are leaked or accidentally spilled on the geomembrane, they shall be immediately removed. The spill area shall be inspected for damage by the Contractor, Geomembrane Installer, and CQA Consultant, and any damaged geomembrane shall be repaired or replaced as directed by the CQA Consultant.

G. **Trial Seaming**

1. Geomembrane Installer shall be responsible for field destructive testing of all trial seams.

2. Trial seams shall be prepared for each piece of seaming equipment whenever any of the following conditions occur:
Module V - Specifications – VDEQ, Part B Permit Application - CHSWMF

a. Shift start-up.
b. Every six hours of continuous seaming within a shift.
c. “Cold” restart of seaming equipment.
d. Change in welding technician.
e. Significant change in geomembrane sheet temperatures.
f. As required by the CQA Consultant.

3. Trial seams shall be prepared in the presence of the CQA Consultant using the same personnel, equipment, and seaming conditions that will be used during production seaming. Field destructive test results acceptable to the CQA Consultant shall be obtained prior to performing any production seaming. This may require resampling of completed trial seams or repeating the trial seam process, as directed by the CQA Consultant.

4. Trial seams shall have a minimum length of six feet and minimum width of one-foot, with the seam centered across the width. Geomembrane Installer shall cut the trial seam into two equal length samples suitable for testing. One sample shall be kept by the Geomembrane Installer for destructive testing at the project site in the presence of the CQA Consultant. The duplicate sample shall be furnished to the CQA Consultant for the project record and possible future testing. Geomembrane Installer shall mark the duplicate sample with the date, time, ambient temperature, seaming machine identification, seaming technician initials, and seaming parameters (set temperature, rate of travel, etc.) used to prepare the trial seam.

5. Trial seam samples shall be destructively tested in peel and shear in accordance with the Geomembrane Installer’s approved CQC manual. A minimum of three specimens shall be tested in peel and two in shear for each trial seam. For dual hot wedge seams, specimens must be tested in peel for each external seam track. Test specimens shall be die cut by the Geomembrane Installer using a die and punch press capable of producing specimens in accordance with ASTM D 6392. Specimens shall be cut from the center two-thirds of the trial seam sample once it has cooled to ambient temperature.

6. Qualification criteria for all trial seam destructive testing are summarized in Table 2-3. Acceptable failure of seam specimens shall be in the geomembrane sheet, not within the seam itself. A partial seam separation (“peel incursion”) during testing will be accepted as indicated in Table 2-3. Excessive peel incursion within the seam area shall constitute disqualification even if strength criteria are met. If any specimens fail to meet qualification criteria, the CQA Consultant may have additional specimens from the sample tested in order to determine trial seam acceptance.

7. If a trial seam fails to meet all qualification criteria, a new trial seam must be prepared. If this second trial seam also fails, the seaming equipment and/or seaming technician preparing the trial seams shall not be allowed to perform production seaming until any deficiencies are corrected and two consecutive trial seams meeting all qualification criteria are prepared and accepted by the CQA Consultant.
8. Trial seam test results shall be recorded in the Geomembrane Installer’s “preweld” test log or daily field record and a copy furnished to the CQA Consultant no later than the following work day. Specimens tested by the Geomembrane Installer shall be marked and stored on the project site for inspection by the Owner’s Representative or Owner.

H. Production Seaming

1. No production seaming shall commence until trial seaming, as outlined in Section 2.07.5.G, is successfully completed and accepted by the CQA Consultant.

2. All geomembrane panels shall be permanently seamed on the same day they are placed except where explicitly approved by the CQA Consultant.

3. Geomembrane that is to be hot wedge seamed shall be prepared as follows:
   a. Position geomembrane sheets to create a minimum overlap of four inches. If the overlap is excessive, excess geomembrane shall be trimmed from the lower sheet where possible. If excess geomembrane is trimmed from the upper sheet, Geomembrane Installer shall not damage the lower sheet. Geomembrane damaged during trimming may be removed and the panel overlap reset, as directed by the CQA Consultant.
   b. Temporarily anchor sheets in a manner approved by the CQA Consultant to prevent movement during seaming and to maintain a “flat” lap of sheets. No glue or tape shall be used to temporarily hold sheets together before seaming.
   c. Prepare overlap area to provide a suitable welding surface. Overlap area shall be free of dirt, dust, moisture, or other foreign material. No solvents shall be used to clean geomembrane sheets prior to seaming.
   d. Seaming shall be completed as soon as is practical after preparation and cleaning is completed.

4. No folds, wrinkles, or “fish-mouths” shall be allowed within any seam areas. Where wrinkles or folds occur, the material shall be cut, overlapped, and a patch applied. During wrinkle or fold repairs, adjacent geomembrane may not be required to meet the four-inch minimum overlap, if approved by the CQA Consultant.

I. Non-Destructive Testing

1. Geomembrane Installer shall be responsible for non-destructive testing of the entire length (100 percent) of all production seams and repairs to verify their continuity. Non-destructive testing shall be conducted as geomembrane seaming and repair work progresses and shall be performed in the presence of the CQA Consultant.
2. Non-destructive test methods shall include the air lance, air-pressure test, spark test, or other methods approved by the Owner. Non-destructive testing procedures shall be described in the Geomembrane Installer’s approved CQC manual and shall comply with all requirements of these Technical Specifications and the project CQA Plan.

3. Seams or portions of seams that cannot be non-destructively tested due to access constraints or other reasons may be covered with a cap-strip as required by the CQA Consultant.

4. Geomembrane Installer shall submit copies of all non-destructive testing documentation to the CQA Consultant in accordance with Section 2.04.3.B.3.

J. Destructive Testing

1. Laboratory destructive testing of production seams is the responsibility of the CQA Consultant and will be paid for by the Owner. Field destructive testing of production seams is the responsibility of the Geomembrane Installer. Geomembrane Installer is also responsible for obtaining samples and repairing sampling locations for all laboratory and field destructive testing.

2. Destructive testing sample locations shall be repaired in accordance with Section 2.07.6.

3. Production seam samples suitable for laboratory destructive testing shall be obtained by the Geomembrane Installer at locations established by the CQA Consultant as production seaming progresses. All seaming equipment and welding technicians will be representatively sampled at a rate of one sample per 500 linear feet of production seam. Additional samples shall be obtained by the Geomembrane Installer from areas of questionable integrity, as directed by the CQA Consultant.

4. Laboratory destructive testing samples shall have a minimum length of three feet and minimum width of one-foot, with the seam centered across the width. Geomembrane Installer shall cut the destructive sample into two equal length samples suitable for testing. Both samples shall be furnished to the CQA Consultant, who will forward one sample to a geosynthetic testing laboratory where it shall be destructively tested in peel and shear in accordance with ASTM D 6392. The duplicate sample shall be retained by the CQA Consultant for the project record and possible future testing. An additional duplicate destructive sample may be obtained and retained for testing by the Geomembrane Installer at the Installer’s discretion. This additional sampling and testing, if performed, shall be completed at no cost to Owner.

5. Qualification criteria for all production seam destructive testing are summarized in Tables 2-3A and 2-3B. Acceptable failure of seam specimens shall be in the geomembrane sheet, not within the seam itself. A partial seam separation ("peel incursion") during testing will be accepted as indicated in Tables 2-3A and B. Excessive peel incursion within the seam area shall constitute disqualification even if strength criteria are met. If any specimens fail to meet qualification criteria, CQA Consultant may
have additional specimens from the sample tested in order to determine production seam acceptance.

6. If a destructive test sample fails to meet all qualification criteria, Geomembrane Installer shall obtain additional production seam samples for laboratory destructive testing as required by the project QA Plan. Testing of these samples shall be performed by the CQA Consultant at the Geomembrane Installer’s expense. Resampling and associated repairs shall be the responsibility of the Geomembrane Installer and shall be performed at no cost to Owner.

7. In order for a production seam to be accepted, a failed destructive test sample shall be bounded by two passing destructive test samples, and the seam between the two passing test locations shall be reconstructed. Alternatively, the entire length of the seam in question may be repaired by placement of a cap strip, or by another repair procedure, as directed by the CQA Consultant.

8. The CQA Consultant or Owner may require that additional destructive test samples be taken at random locations from production seams completed during the same work shift as a failing destructive test sample or in areas that visually appear defective or not in accordance with these Technical Specifications. Testing of these samples shall be performed by the QAO, but obtaining the samples and repairing the sampling locations shall be the responsibility of the Geomembrane Installer and shall be performed at no cost to Owner.

2.07.6 REPAIRS

A. During installation, Geomembrane Installer and CQA Consultant shall visually inspect all geomembrane panels and seams for damage, defects, or non-compliance with the Contract Drawings and Technical Specifications, and shall mark any such areas for repair. Geomembrane Installer shall repair marked areas as soon as possible. Any defects that could allow surface water runoff beneath the geomembrane shall be repaired on the same day they are marked.

B. Acceptable geomembrane repair methods include:

1. Patching: For repair of surface defects, small tears, punctures, destructive sampling locations, etc. Patches shall have a minimum size of 12 inches by 12 inches, extend at least six inches beyond the edge(s) of a defect, and have rounded corners.

2. Reconstruction: For repair of lengths (segments) of unacceptable seams. Performed by cutting and removing the unacceptable seam segment and replacing it with new geomembrane that is seamed into place.

3. Cap stripping: For repair of lengths (segments) of unacceptable seams in lieu of reconstruction. Cap strips shall extend at least 12 inches beyond the edge(s) of a seam, and have rounded corners.

C. Intersections of field made seams (“tees”) shall be covered with a patch meeting the requirements of Section 2.07.6.B.1.
D. The CQA Consultant may require repair or replacement of any area where overheating or unacceptable preparation, seaming or testing techniques are observed. Such repair or replacement may be required even if samples removed from affected areas pass destructive testing.

E. All repairs shall be non-destructively tested by the Geomembrane Installer in accordance with Section 2.07.5.1.

2.07.7 PIPE PENETRATION SEALS
A. Pipe penetrations in the geomembrane shall be sealed using PVC pipe boots (sleeves and skirts), neoprene gaskets, and stainless steel banding straps, as shown on the Contract Drawings and specified in Section 2.06.2.
B. Surfaces where pipe boots are to be attached (including HDPE pipe) shall be cleaned to remove dirt, oil, debris, or other deleterious materials.
C. Prior to attaching and/or seaming pipe boots, the CQA Consultant shall visually inspect all prepared surfaces to verify that proper preparation techniques have been followed. The CQA Consultant may require repair of areas exhibiting improper preparation techniques or damage, which may include removal and replacement of affected geomembrane or pipe.
D. Geomembrane Installer shall be responsible for non-destructive testing of the entire length (100 percent) of all pipe boot seams to verify their continuity. Non-destructive testing shall be performed in the presence of the CQA Consultant and in accordance with Section 2.07.5.1.

2.07.8 FINAL INSPECTION, ACCEPTANCE, AND COVERING
A. A final visual examination of all geomembrane panels, seams, repairs, and pipe penetration seals shall be completed by the CQA Consultant prior to accepting geomembrane. The CQA Consultant's inspection shall only be performed following a complete inspection and approval by the Geomembrane Installer's field superintendent or designated quality control technician. Contractor shall be responsible for cleaning, sweeping, or other measures necessary to provide a thoroughly visible geomembrane surface for the CQA Consultant's inspection.
B. Geomembrane Installer shall repair and test any areas identified during the CQA Consultant's final inspection as not being in accordance with the Contract Drawings and Technical Specifications. Any such repairs and testing shall be performed at no cost to Owner.
C. No geomembrane shall be covered until it has been accepted by the CQA Consultant in writing. Once accepted, geomembrane shall be covered as soon as possible in accordance with the Contract Drawings and Technical Specifications.

2.07.9 Warranties
A. Contractor shall be responsible for obtaining any necessary guarantees or certifications from the Geomembrane Manufacturer and Geomembrane Installer and submitting them to the Owner prior to acceptance of installed geomembrane.
B. Contractor shall guarantee the integrity, within the realm of limitations of Contractor's responsibility, of the installed geomembrane for its intended use, from installation defects for a period of two years from the date of geomembrane installation, and from manufacturing defects for a period of 20 years from the date of geomembrane installation. Such written warranties shall provide for the total and complete repair
and/or replacement of any defect or defective areas of geomembrane upon written notification and demonstration by the Owner of the specific non-conformance of the geomembrane or installation with the Contract Drawings and Technical Specifications. Such defects or non-conformance shall be repaired and/or replaced expeditiously, at no cost to Owner.
### Table 2-1
**REQUIRED PROPERTIES OF PVC GEOMEMBRANE**

<table>
<thead>
<tr>
<th>Property (Units)</th>
<th>MQC Testing Frequency (Minimum)</th>
<th>Test Method(2)</th>
<th>50-Mil Required Value</th>
<th>40-Mil Required Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Certified Properties</strong>(3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness (mils)</td>
<td>Each roll</td>
<td>ASTM D 5199</td>
<td>50 ± 2.5</td>
<td>40 ± 2.0</td>
</tr>
<tr>
<td>Tensile Properties (each direction)</td>
<td>Every 40,000 lb</td>
<td>ASTM D 882 Test in machine direction and cross-machine direction.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Break Strength (lb/in)</td>
<td></td>
<td>116 (min ave)</td>
<td>97 (min ave)</td>
<td></td>
</tr>
<tr>
<td>2. Break Elongation (%)</td>
<td></td>
<td>430 (min ave)</td>
<td>430 (min ave)</td>
<td></td>
</tr>
<tr>
<td>3. Modulus @ 100% (lb/in)</td>
<td></td>
<td>50 (min ave)</td>
<td>40 (min ave)</td>
<td></td>
</tr>
<tr>
<td>Tear Resistance (lb)</td>
<td>Every 40,000 lb</td>
<td>ASTM D 1004</td>
<td>13 (min ave)</td>
<td>10 (min ave)</td>
</tr>
<tr>
<td>Dimensional Stability (%)</td>
<td>Every 40,000 lb</td>
<td>ASTM D 1204</td>
<td>3 (max change)</td>
<td>3 (max change)</td>
</tr>
<tr>
<td>Low Temperature Impact</td>
<td>Every 40,000 lb</td>
<td>ASTM D 1790</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td><strong>Index Properties</strong>(4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific Gravity (g/cc)</td>
<td>Each formulation</td>
<td>ASTM D 792</td>
<td>1.2 (min ave)</td>
<td>1.2 (min ave)</td>
</tr>
<tr>
<td>Water Extraction (%)</td>
<td>Each formulation</td>
<td>ASTM D 1239</td>
<td>0.20 (max loss)</td>
<td>0.20 (max loss)</td>
</tr>
<tr>
<td>Plasticizer Molecular Weight</td>
<td>Each formulation</td>
<td>ASTM D 2124</td>
<td>400 (average)</td>
<td>400 (average)</td>
</tr>
<tr>
<td>Volatile Loss</td>
<td>Each formulation</td>
<td>ASTM D 1203</td>
<td>0.5 (max loss)</td>
<td>0.5 (max loss)</td>
</tr>
<tr>
<td>Soil Burial</td>
<td>Each formulation</td>
<td>ASTM G 160</td>
<td>5 (max)</td>
<td>5 (max)</td>
</tr>
<tr>
<td>1. Break Strength (% change)</td>
<td></td>
<td>20 (max)</td>
<td>20 (max)</td>
<td></td>
</tr>
<tr>
<td>2. Break Elongation(% change)</td>
<td></td>
<td>20 (max)</td>
<td>20 (max)</td>
<td></td>
</tr>
<tr>
<td>3. Modulus @ 100% (% change)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrostatic Resistance (lb/in²)</td>
<td>Each formulation</td>
<td>ASTM D 751</td>
<td>150 (min ave)</td>
<td></td>
</tr>
<tr>
<td>Interface Shear Strength(1)</td>
<td>Every 500,000 ft²</td>
<td>ASTM D 5321</td>
<td>See Table 2-2</td>
<td>See Table 2-2</td>
</tr>
</tbody>
</table>

**Notes:**

1. The required properties specified herein may be revised by the Owner to reflect new or revised test methods or to conform with improvements to the state-of-the-practice. **Interface Shear Strength testing is not an MQC test but part of CQA Conformance Testing.**

2. Number of specimens per test established in applicable test method unless otherwise noted. Modifications of test methods are described in PVC Geomembrane Institute Standard PGI 1104, Appendix B.

3. Certified properties are tested by lot as specified in PVC Geomembrane Institute Standard PGI 1104, Appendix A.

4. Index properties are tested as specified in PVC Geomembrane Institute Standard PGI 1104, Appendix A.
### Table 2-2

**MINIMUM INTERFACE SHEAR STRENGTH REQUIREMENTS FOR PVC GEOMEMBRANE**(1)(2)(3)

<table>
<thead>
<tr>
<th>Normal Load (psf)</th>
<th><strong>Standard Test</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak Shear Strength (psf)<strong>(3)</strong></td>
</tr>
<tr>
<td>100</td>
<td>65</td>
</tr>
<tr>
<td>300</td>
<td>116</td>
</tr>
<tr>
<td>2,000</td>
<td>814</td>
</tr>
<tr>
<td>11,500</td>
<td>4,250</td>
</tr>
<tr>
<td>25,000</td>
<td>7,325</td>
</tr>
</tbody>
</table>

**ASTM D 5321**

- **Conditioning:**
  - Set up each test to match field placement orientation.
  - Run all tests under wet conditions.

- **Procedure A:**
  - Geomembrane against GDN
  - Substrate: Steel Rasp Platen
  - Superstratum: Steel Rasp Platen
  - Displacement Rate: 0.04 ipm (max.)
  - Total Displacement: 2.25 in (min.)

- **Procedure B:**
  - Geomembrane against Geotextile
  - Substrate: Steel Rasp Platen
  - Superstratum: Steel Rasp Platen
  - Displacement Rate: 0.04 ipm (max.)
  - Total Displacement: 2.25 in (min.)

- **Special Instructions:**
  - None.

**Note:**

1. In lieu of testing individual interfaces, a system test may be performed using a configuration that allows failure to occur through the weakest shearing plane. System test configuration, conditions, and procedures must be accepted by the Owner prior to submitting test results for review and approval.

2. **Lower interface shear strength requirements may be acceptable if additional slope stability analysis is completed by the Design Engineer** verifying a long-term static factor of safety greater than 1.5 and a long-term seismic factor of safety greater than 1.1.

3. **If the test data is below the stated peak shear strength, the results may be deemed acceptable by the Design Engineer after reviewing a slope stability analysis of the test data.**
Table 2-3A
FIELD SEAM QUALIFICATION CRITERIA
FOR 50 MIL PVC GEOMEMBRANE<sup>(1)</sup>

<table>
<thead>
<tr>
<th></th>
<th>Trial Seaming&lt;sup&gt;(2)(3)&lt;/sup&gt;</th>
<th>Production Seaming&lt;sup&gt;(3)(4)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peel Strength (lbs.)</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Peel Incursion (%)</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Shear Strength (lbs.)</td>
<td>96</td>
<td>96</td>
</tr>
</tbody>
</table>

Notes:

<sup>(1)</sup> Peel strengths and shear strengths listed are minimum required values. Peel incursion percentages listed are maximum allowable values. In order to be considered qualified, all trial seam test specimens must meet all strength and incursion requirements, and four out of five production seam test specimens must meet all strength and incursion requirements. The fifth production seam test specification must meet or exceed 80% of the values for all strength and incursion requirements.

<sup>(2)</sup> Field test in accordance with project Technical Specifications and CQA Plan.

<sup>(3)</sup> Laboratory test in accordance with ASTM D 7408.

<sup>(4)</sup> Only the following break types will be acceptable for thermofusion welds: SE1, SE2, and AD-BRK.
SECTION 3
HDPE GEOMEMBRANE

3.01 GENERAL
3.01.1 DESCRIPTION OF WORK
A. The Contractor shall furnish all supervision, labor, products, equipment, and tools, including all necessary and incidental items as detailed or required, to install geomembrane in accordance with the Contract Drawings, Technical Specifications, and project Construction Quality Assurance (CQA) Plan.

3.01.2 RELATED WORK SPECIFIED ELSEWHERE
A. Earthwork, Base Grade and Subbase - Section 1.
B. Geotextiles - Section 6.
C. Quality Assurance Plan.

3.02 REFERENCES
3.02.1 CODES AND STANDARDS
A. American Society for Testing and Materials (ASTM) Standards:
   2. D 1004, “Standard Test Method for Tear Resistance (Graves Tear) of Plastics Film and Sheeting”.

December 2019

B. Geosynthetic Research Institute (GRI) Standards:

3.03 DEFINITIONS
3.03.1 Formulation: The mixture of a unique combination of ingredients identified by type, properties, and quantity. For high density polyethylene (HDPE) geomembrane, a formulation is defined as the exact percentages and types of resin(s), additives, and carbon black.

3.04 SUBMITTALS
3.04.1 Contractor shall be responsible for timely submittals to the Owner.
3.04.2 The following submittals shall be provided with Contractor’s Bid:
A. The geomembrane and Geomembrane Manufacturer must be approved by the Owner prior to Contract award. Submittals for approval include:
   1. Geomembrane Manufacturer’s specification sheet(s) demonstrating compliance with the requirements of Table 3-1.
   2. Written certification that the Geomembrane Manufacturer has produced a minimum of 5,000,000 square feet of HDPE geomembrane that has been installed for hydraulic containment purposes in the last two years, including a list of the relevant completed facilities. Each entry in this list should include
the name, location, and purpose of the facility; geomembrane thickness, total square footage, and date of installation; names of the Owner, Designer, Fabricator (if any), and Geomembrane Installer; and the name and telephone number of a contact at the facility who can discuss the project.

3. A copy of the Geomembrane Manufacturer’s MQC manual. This manual should describe the quality control program(s) for formulation ingredients (raw materials), and finished geomembrane sheet and indicate the properties, test methods, and testing frequencies used for each. Geomembrane Manufacturer shall modify the MQC manual to comply with the requirements of these Specifications, with any variations, deviations, or exceptions clearly noted in an attached letter.

B. The geomembrane shall meet the interface shear strength requirements of Table 3-2. Interface shear strength testing to verify compliance with the requirements of Table 3-2 shall be performed by the Owner as noted in Section 3.07.3.C. However, the Geomembrane Manufacturer shall review the interface shear strength requirements and test procedures outlined in Table 3-2 to avoid proposing the use of a geomembrane product(s) that will not meet these requirements. The interfaces that exist for this project include:

1. Geomembrane against geotextile; and
2. Geomembrane against GDN (double-bonded).

C. The Geomembrane Installer must be approved by the Owner prior to Contract award. Submittals for approval include:

1. Written certification that the Geomembrane Installer has installed a minimum of 1,000,000 square feet of HDPE geomembrane for hydraulic containment purposes in the last four years, including a list of the relevant completed facilities. Each entry in this list should include the name, location, and purpose of the facility; geomembrane thickness, total square footage, and date of installation; names of the Owner, Designer, Primary Contractor, and CQA Consultant; and the name and telephone number of a contact at the facility who can discuss the project.

2. A copy of the Geomembrane Installer’s CQC manual. This manual should describe the quality control programs for handling, deploying, placing, anchoring, seaming, repairing, and testing geomembrane. Geomembrane Installer shall modify the CQC manual to comply with the requirements of these Technical Specifications and the project CQA Plan, with any variations, deviations, or exceptions clearly noted in an attached letter.

3.04.3 The following submittals shall be provided after award of Contract:

A. Geomembrane Manufacturer:

1. Prior to or coincident with shipment of geomembrane to the project site, submit written certification and supporting test data documenting that all resin used for geomembrane production complies with the requirements of Section 3.06.1.C. This certification shall state the producer, product designation, lot or batch number, and production date of all resin used in the manufacture of geomembrane shipped to the project site and
shall include copies of all quality control certificates issued by the resin producer.

2. Prior to or coincident with shipment of geomembrane to the project site, submit written certification and supporting test data, in the form of Quality Control Certificates, documenting that all geomembrane shipped to the project site complies with the requirements of Section 3.06.1.D. Geomembrane Quality Control Certificates must be reviewed and signed by a responsible representative of the Geomembrane Manufacturer.

B. Geomembrane Installer:

1. Four weeks prior to shipment of geomembrane to the project site, submit six full sets of field installation drawings for the Quality Assurance Officer’s (QAO’s) approval. Installation drawings shall show the proposed length, width, and position of all geomembrane panels and the location of all field seams. Geomembrane panels and field seams shall have distinct identification systems. Installation drawings shall also show complete details for field seaming and repairs, anchoring geomembrane at the perimeter of the installation area, and attachments to structures and other penetrations, as required.

2. Two weeks prior to arrival at the project site, submit personnel resumes demonstrating compliance with the following:
   a. A minimum of one field superintendent per shift shall be designated by the Geomembrane Installer and approved by the Owner. Each field superintendent shall have a minimum of five years of field experience installing HDPE geomembrane. Any change or replacement of superintendents during the project must be approved in advance by the Owner.
   b. Each seaming crew shall have a designated foreman. Said foreman must have a minimum of two years of HDPE geomembrane installation experience and must work continuously with the seaming crew.
   c. Each welding technician shall have a minimum of 1,000,000 square feet of HDPE geomembrane welding experience.

3. Within four weeks after completion of geomembrane installation, submit a written report containing the following:
   a. Written certification stating that the geomembrane has been installed in accordance with the Contract Drawings, Technical Specifications, and project CQA Plan.
   b. Product and installation warranties as required by Section 3.07.9.
   c. Copies of daily field records and all testing documentation (trial seam testing, non-destructive testing, etc.).
   d. As-built drawings depicting actual geomembrane panel placement and all associated details. As-built geomembrane plans (“panel diagrams”) shall be prepared at a reasonable Engineer’s scale using Contractor’s surveyed edge of geomembrane limits (anchor trenches,
runouts, etc.), and shall accurately depict panel orientations and dimensions; all repair locations (patches, cap strips, etc.); and shall clearly identify all panel numbers, seam identification numbers, and destructive testing sample locations.

3.05 CONSTRUCTION QUALITY CONTROL AND QUALITY ASSURANCE

3.05.1 Geomembrane CQC will be performed by the Geomembrane Installer in accordance with the CQC manual approved by the Owner.

3.05.2 Geomembrane CQA will be performed by the CQA Consultant and paid for by the Owner. Geomembrane CQA will be performed in accordance with these Specifications and the project CQA Plan.

3.06 MATERIAL REQUIREMENTS

3.06.1 HDPE GEOMEMBRANE

A. The geomembrane and Geomembrane Manufacturer must be approved by the Owner prior to Contract award, as required by Sections 3.04.2.B and C.

B. Geomembrane shall be 60 mil high density polyethylene (HDPE) having textured upper and lower sheet surfaces. The physical, mechanical, and chemical properties of the geomembrane shall comply with the requirements of Tables 3-1 and 3-2a. Textured geomembrane having smooth edge strips six to eight inches in width (to facilitate field seaming) may be acceptable if the base geomembrane complies with the requirements of Table 3-4 and the texturing material is of the same type of polymer and formulation as the base geomembrane. A co-extruded geomembrane having a light reflective surface (for reducing heat-related wrinkles) will be acceptable if the Geomembrane Manufacturer provides complete documentation demonstrating conformance with project criteria.

C. Geomembrane formulation shall consist of at least 97 percent (by weight) polyethylene resin, two percent to three percent (by weight) of carbon black (added for ultraviolet radiation resistance), and a maximum of one percent (by weight) of other additives. No plasticizers, fillers, extenders, post-consumer resin (PCR), or other materials shall be mixed into the formulation. Rerind, rework, or trim materials may be added to the formulation if they are produced by the Geomembrane Manufacturer and are of the same formulation as the geomembrane being produced. Rerind, rework, and trim materials shall not exceed 10 percent (by weight) of the geomembrane formulation.

D. Polyethylene resin used in the manufacture of geomembrane is to be made from virgin, uncontaminated ingredients and shall be designed and manufactured specifically for producing geomembrane. Incoming resin shall be sampled and tested in accordance with the Geomembrane Manufacturer’s approved MQC manual. Testing frequencies, test procedures, and resin properties shall comply with the requirements of Table 3-1. Results from the resin sampling and testing program are to be submitted to the Owner in accordance with Section 3.04.3.A.2.

E. During production, finished geomembrane sheet shall be sampled and tested in accordance with the Geomembrane Manufacturer’s approved MQC manual. Testing frequencies, test procedures, and finished sheet properties shall comply with the requirements of Table 3-1. Results from the finished sheet sampling and testing
program, in the form of Quality Control Certificates, are to be submitted to the Owner in accordance with Section 3.04.3.A.2.

F. Geomembrane shall be produced free of holes, bubbles, blisters, scratches, undispersed raw materials, contamination by foreign matter, dimensional abnormalities, or other defects. Textured geomembrane shall generally have a uniform texturing appearance and be free from agglomerated texturing material. The Owner may reject all or portions of units (rolls) of geomembrane shipped to the project site if significant production flaws are observed.

G. Geomembrane shall be manufactured as a continuous sheet having a minimum width of 20 feet and minimum length of 500 feet in order to reduce the amount of field seaming required during installation. No factory seaming of HDPE geomembrane panels shall be accepted.

H. Geomembrane shall be rolled onto hollow cores having a minimum outside diameter of six inches and an inside diameter large enough to allow the use of a spreader bar assembly or fork lift stinger for handling and deployment. Cores shall be of stable construction such that they support the roll without excessively deflecting, buckling, or otherwise failing during handling, transportation, and storage. Rolled geomembrane shall be secured using dedicated straps, slings, or other suitable means to facilitate handling.

I. Each geomembrane roll shall be marked or labeled to identify the Geomembrane Manufacturer, product designation, manufacturer's lot number, manufacturer's roll number, sheet thickness, length and width of each roll, and panel number (if applicable). Roll identification numbers shall conform to the numbering system established on the Geomembrane Manufacturer’s Quality Control Certificates. Labels or markings shall be legible and located so that each roll of geomembrane can be identified by examining the outside of the roll or the core ends. Markings or labels shall be weather proof.

J. At the option of the Owner, an Owner’s Representative may inspect the geomembrane manufacturing process on a full-time basis. This inspection program would include conformance sampling as required. If requested, the Geomembrane Manufacturer shall submit a production schedule to the Owner and cooperate with the Owner’s Representative during plant inspection.

K. All raw material and finished geomembrane properties, including testing frequencies and test procedures used, shall meet the requirements of this Section. No geomembrane shall be installed until the Owner has reviewed all certifications and supporting test data and determined that the geomembrane delivered to the project site is acceptable for use. Manufacturing records, including test data, shall be maintained by the Geomembrane Manufacturer for two years after acceptance of the geomembrane, and shall be made available upon request.

3.06.2 HDPE EXTRUDATE ROD

A. Extrudate rod to be used for all extrusion seaming of the geomembrane shall be made from the same resin as the geomembrane and shall be free of contamination by moisture or other materials. Carbon black and additives shall be thoroughly dispersed throughout the extrudate rod.
B. Extrudate rod resin and finished rod shall be sampled and tested in accordance with the Geomembrane Manufacturer's approved QC manual. Extrudate rod resin shall meet the HDPE geomembrane resin requirements of Table 3-1. Finished extrudate rod shall meet the HDPE geomembrane carbon black content and carbon black dispersion requirements of Table 3-1. Testing frequencies and test procedures shall comply with the requirements of Table 3-1, as applicable. Results from the extrudate rod sampling and testing program are to be submitted to the Owner in accordance with Section 3.04.3.A.2.

3.06.3 PIPE PENETRATION SEALS

A. Boots (sleeves and skirts) to be used for sealing all pipe penetrations in the geomembrane shall be smooth 60-mil HDPE meeting the physical, mechanical, and chemical properties of Table 3-4 and the formulation and resin requirements of Section 3.06.1.C and 3.06.1.D. Factory pre-fabricated boots, produced by either the Geomembrane Manufacturer or Geomembrane Installer, are preferred for this project.

B. Gaskets to be used for sealing boots to pipes penetrating the geomembrane shall be neoprene and have a width of two inches and thickness of 0.25-inch. Neoprene adhesive shall be in accordance with the Geomembrane Manufacturer’s requirements.

C. Banding Straps to be used to attach boots to pipes penetrating the geomembrane shall be stainless steel and meet the requirements shown on the Contract Drawings.

3.07 INSTALLATION

3.07.1 PRE-INSTALLATION MEETING

A. Prior to scheduled geomembrane installation, the Owner, Owner’s Representative, CQA Consultant, Contractor, and Geomembrane Installer shall attend a pre-installation meeting at the project site. This meeting shall be scheduled by the Owner after receipt of Geomembrane Installer’s field installation drawings.

B. Geomembrane Installer shall be represented by both the project field superintendent and the project manager.

C. At the pre-installation meeting, site safety and rules of operation, scheduling, methods of installation, and construction quality control and quality assurance shall be discussed. The Geomembrane Installer, Owner’s Representative, and CQA Consultant shall at this time agree to the required geomembrane placement, seaming, sampling, testing and repair procedures for the project.

3.07.2 SHIPPING, HANDLING, AND STORAGE

A. Contractor is responsible for proper shipping, unloading, and storage of the geomembrane. Geomembrane damaged during shipping, unloading, or storage shall be repaired or replaced at no cost to the Owner.

B. Geomembrane rolls shall be packaged and shipped so that no damage is caused during delivery to the project site. Geomembrane shipping shall be by open trailer so rolls can be readily unloaded at the project site by lifting directly from the trailer using slings/straps, a stinger, or a spreader bar assembly.
C. During unloading at the project site, Seller shall conduct a surface inspection of all geomembrane rolls for defects and damage. Seller shall immediately notify CQA Consultant and Owner of any defects or damage observed.

D. Extreme care shall be taken by all personnel while unloading and handling geomembrane. Equipment used to unload and handle geomembrane shall have sufficient capacity to manage the roll weight without damaging the geomembrane. Geomembrane shall only be unloaded and handled using a stinger, spreader bar assembly, or the straps/slings provided by the Geomembrane Manufacturer. Pushing, sliding, or dragging of geomembrane rolls is not permitted. CQA Consultant shall have the option of inspecting all geomembrane panels, prior to final placement, to verify that all defects or damage are identified for repair.

E. Geomembrane shall be stored at the project site in an area(s) designated by the Owner and accepted by the CQA Consultant. Seller shall grade the storage area so that it is reasonably level and well-drained, and shall prepare the ground surface so that it is firm, smooth, and free of stones, sticks, or other materials that may damage the geomembrane.

F. Stacking of geomembrane rolls for storage is allowed but should not be so high that crushing of cores or flattening of rolls occurs. In general, the maximum stacking limit is 3 rolls high. A suitable means of securing the rolls shall be used so that shifting, abrasion, or other adverse movement does not occur. Geomembrane with folds or creases of any kind shall be rejected and removed from the project site.

G. During storage, geomembrane shall be protected from excessive dust and mud by covering the rolls with a plastic sheet or waterproof tarpaulin. Roll labels shall remain intact and legible. Any roll of geomembrane that has no label or where the label is damaged or otherwise illegible may be rejected by the CQA Consultant.

3.07.3 QUALITY ASSURANCE CONFORMANCE TESTING

A. Quality assurance conformance testing of the geomembrane shall be performed by the CQA Consultant and paid for by the Owner. Conformance testing lab results shall be provided directly to Owner and CQA Consultant for review upon receipt of testing data from lab. Conformance sampling and testing shall be completed in accordance with the project CQA Plan; per Table III-2, or as directed by the Owner’s Representative. Owner has the option to increase the frequency of conformance testing or to sample and test any questionable roll or lot.
B. Owner may revise the test methods used for determination of conformance properties to allow for use of new or revised methods.

C. All geomembrane conformance test results shall comply with the requirements of Tables 3-1 and 3-2a prior to installation. Any geomembrane that does not conform to these requirements shall be retested or rejected in accordance with the CQA Plan.

D. Geomembrane that is rejected shall be removed from the project site and replaced at no cost to Owner. Sampling and conformance testing of geomembrane supplied as replacement for rejected material shall be performed by the CQA Consultant at Seller’s cost.

3.07.4 CONTRACTOR’S DEPLOYMENT AND PLACEMENT

A. Geomembrane shall be deployed and placed in general accordance with the Geomembrane Installer’s approved field installation drawings. Depending on field conditions, it may be necessary to alter the geomembrane panel arrangement from that shown on the approved field installation drawings. These alterations shall be approved by the CQA Consultant prior to geomembrane deployment.

B. Geomembrane Installer shall maintain a daily field record of actual placement of each geomembrane panel, noting base grade conditions, weather, seaming parameters, panel numbers placed, seams completed, samples taken, and tests run. A copy of each day’s field record shall be furnished to the CQA Consultant no later than the following work day.

C. Geomembrane shall only be placed on surfaces (subbase) that have been installed in accordance with the Contract Drawings and Specifications, and have been accepted in writing by the Seller, Geomembrane Installer, and CQA Consultant. Once a surface has been accepted by the CQA Consultant, any additional surface preparation that the Seller or Geomembrane Installer feels necessary to meet the requirements of the Specifications shall be the responsibility of the Contractor.

D. Geomembrane shall only be placed on subbase that is free from standing water, excessive moisture, rutting, or other damage caused by vehicular traffic, erosion, or other causes. Surface requirements, including allowances for desiccation cracking, shall be as outlined in Section 1 – Earthwork, Base Grade and Subbase, of the Specifications. Areas exhibiting deficient surface shall be reported to the CQA Consultant and Owner for repair.

E. It is imperative to keep surface water runoff from beneath the geomembrane at all times during installation. Geomembrane Installer’s panel placement and seaming techniques and schedule shall minimize or eliminate the potential for accumulation of water beneath the geomembrane. Any water found ponded beneath the geomembrane after it has been installed shall be removed by the Seller, as directed by the CQA Consultant, at no cost to Owner. Any soil beneath installed geomembrane (subbase or base grade) that has become excessively moist, soft, or unsuitable to perform its intended function, shall be removed and replaced by the Contractor, as directed by the CQA Consultant, at no cost to Owner.

F. Equipment and tools used to deploy and place geomembrane shall not stretch, score, scratch, crease, or otherwise damage the geomembrane, and shall not damage any underlying geosynthetic or soil.
G. Under no circumstances shall any construction or vehicular traffic be allowed to drive over exposed geomembrane. Geomembrane showing evidence of trafficking shall be inspected by the Geomembrane Installer, Owner, and CQA Consultant to evaluate damage, if any. At the direction of the CQA Consultant, any damaged geomembrane shall be tested, rejected, or repaired at no cost to Owner. CQA Consultant may allow limited use of four-wheeled ATVs or other low ground pressure equipment (having 6 psi or less contact pressure) by the Geomembrane Installer during installation, but use shall be prohibited if excessive trafficking or any geomembrane damage, including scratches, is observed.

H. Geomembrane shall be placed in such a manner as to minimize dragging of panels into position (“spotting”). Geomembrane Installer shall immediately provide temporary anchorage of the geomembrane to prevent wind uplift, panel movement during field seaming, and bridging (refer to Section 3.03.4.J for bridging requirements). Temporary anchorage methods shall be approved by the Owner and CQA Consultant. If bags are used for temporary anchorage, they shall be filled with fine-grained VDOT Grading A Fine Aggregate that has been approved for use by the CQA Consultant. Any geomembrane exhibiting damage due to insufficient or improper temporary anchorage shall be repaired or replaced, as directed by the CQA Consultant, at no cost to Owner.

I. Geomembrane Installer shall place and seam geomembrane panels to provide adequate, well distributed slack to account for thermal expansion or contraction of the geomembrane. For this purpose, the Geomembrane Installer may use a working range of geomembrane sheet temperatures from 0° to 150°F to determine required techniques. In critical areas such as sumps, leachate pipe trenches, and corners, the Geomembrane Installer may propose slack control techniques for approval by the Owner.

J. Geomembrane shall be installed so as to minimize or eliminate bridging ("trampolining") at the toe of slopes or within leachate pipe trenches at temperatures as low as 32°F. Bridging control measures may include providing slack, using and maintaining additional temporary anchorage (e.g., VDOT Grading A Fine Aggregate bagging), or other methods approved by the Owner. If bridging is observed, Geomembrane Installer shall repair affected areas, as directed by the CQA Consultant, at no cost to Owner.

K. Scratches on the geomembrane surface caused during geomembrane handling, deployment, or by placement or transport of geomembrane or overlying materials, shall be evaluated for repair by the CQA Consultant. Excessive scratches may result in removal and replacement of the entire affected panel.

L. Panel seams shall be oriented in a direction parallel to the line of maximum base grade slope (i.e., down, not across the slope) and shall be placed in a manner that minimizes the number and length of field seams. In corners and odd-shaped geometric locations, the number of field seams shall be minimized and moved to locations outside the corners as appropriate.

M. For geomembrane placed on slopes, panels shall be shingled such that the "upstream" panel overlaps the "downstream" panel in order to minimize infiltration potential.
Module V - Specifications – VDEQ, Part B Permit Application - CHSWMF

N. All panel seams parallel to the toe of a slope ("longitudinal seams") shall be located at least 10 feet from the toe of the slope, except where explicitly approved by the CQA Consultant. Longitudinal seams are to be avoided on sideslopes. If a longitudinal seam is required, it shall be 45° to the slope contours. Adjacent sideslope seams shall be staggered a minimum of the panel width.

O. All geomembrane panels shall be permanently seamed on the same day they are placed except where explicitly approved by the CQA Consultant.

P. The Contractor shall be responsible for excavation, maintenance, ballasting, and backfilling of the geomembrane anchor trench. Backfilling of the anchor trench shall commence only after the geomembrane and geotextile installations have been approved by the CQA Consultant. Backfilling materials and compaction methods shall be as outlines in the Technical Specifications.

Q. Loose soil shall not be permitted to underlie the geosynthetics in the anchor trench or perimeter liner termination area. These features shall be graded to prevent ponding or run-on of water while the area is exposed. Contractor shall be responsible for preventing surface water runoff from accumulating beneath or atop the geosynthetics while the anchor trenches or perimeter liner termination area is exposed.

R. Backfilling of the perimeter liner termination area shall commence only after the leachate collection system GDN has been approved by the CQA Consultant. Backfilling materials and compaction methods shall be as outlined in Section 1 – Earthwork, Base Grade and Subbase, of the Specifications.

3.07.5 SEAMING

A. Lap joints and thermo-fusion seaming methods shall be used to join geomembrane panels in the field. A minimum overlap of four inches shall be used. Seams shall be hot wedge or extrusion welded as prescribed by the Geomembrane Manufacturer and approved by the Owner. For joining geomembrane panels, dual hot wedge is the preferred seaming method. For tie-in areas (joining new geomembrane to geomembrane placed during previous construction projects), single hot wedge is the preferred seaming method, as approved by the Owner’s Representative and CQA Consultant. Extrusion seaming shall be used primarily for repairs and detailing.

B. Geomembrane Installer shall provide the following equipment, and any required accessories, to complete geomembrane seaming. Equipment shall be provided and maintained in sufficient numbers to avoid delaying work.

1. Seaming equipment: Hot wedge (single-track and dual-track), extrusion, and hot air ("leister") welding machines. All seaming equipment shall be equipped with gauges that clearly display wedge temperature, rate of travel, barrel temperature, and nozzle ("pre-heat") temperature, as applicable.

2. Destructive testing equipment: Punch press and field tensiometer for field destructive testing of geomembrane seams. Punch press shall be capable of producing die-cut geomembrane specimens in accordance with ASTM D 6392. Tensiometer shall be built to applicable ASTM specifications, be in good working order, and shall be accompanied by evidence of calibration within the last year.
3. Non-destructive testing equipment: Vacuum box, air pump(s) and gauges, and voltage applicator(s) for non-destructive testing of geomembrane seams and repairs. All testing equipment shall be built to applicable ASTM specifications and be in good working order.

4. Portable electric generators: Capable of providing constant voltage under a combined-line load. Generators must have rubber tires or be placed on a layer of cushioning material that does not damage the geomembrane.

5. Miscellaneous equipment: Any other equipment or tools (e.g., hook blades, scissors, markers, etc.) necessary to complete geomembrane seaming, testing, and labeling in accordance with these Specifications and the Geomembrane Installer’s approved CQC manual.

C. No production seaming shall commence until trial seaming, as outlined in Section 3.07.5.1, is successfully completed and accepted by the CQA Consultant.

D. The Owner’s Representative and Owner, in conjunction with the Geomembrane Installer and Seller, shall establish site-specific limits of weather conditions, including, but not limited to, temperature, humidity, precipitation, and wind speed and direction, within which geomembrane panel placement and seaming can be conducted. In the absence of site-specific criteria, the following limitations shall apply:

1. No placement or seaming shall be conducted in the presence of precipitation, such as rain, snow, sleet, dew or fog.

2. No placement or seaming shall be conducted in the presence of winds in excess of 20 miles per hour, when dirt or debris is blown into seaming areas, or when seaming temperatures cannot be adequately monitored and controlled.

3. Seaming shall not be conducted when geomembrane sheet temperature falls below 40°F unless approved by the CQA Consultant. In order for seaming to be approved, Geomembrane Installer shall be required, at a minimum, to prepare additional trial seams to demonstrate conformance with these Specifications. Owner’s Representative reserves the right to require additional destructive seam testing when seaming is conducted at geomembrane sheet temperatures below 40°F. Geomembrane Installer shall be prepared to pre-heat seaming areas prior to production seaming in accordance with Geomembrane Manufacturer recommendations.

4. Seaming shall not be conducted when geomembrane sheet temperature exceeds 104 degrees F unless approved by the CQA Consultant. Criteria for demonstration of conformance shall be outlined by the Owner’s Representative.

E. For purposes of monitoring production seaming, geomembrane sheet temperature shall be measured and recorded by the CQA Consultant at multiple locations along seam overlap areas.

F. Geomembrane Installer shall not cause excessive overheating of the geomembrane during trial or production seaming. Excessive overheating is defined as any of the following:
1. Application of seaming temperatures or seaming rates that result in visible warping, deformation, or discoloration of the bottom surface of the lower geomembrane in the seam area.

2. Seaming over an existing seam ("piggybacking"), except for repairs (patches, cap strips, etc.) which cross over existing seams.

3. Seaming using temperatures in excess of the Geomembrane Manufacturer’s recommended seaming temperatures as defined at the pre-installation meeting.

G. All extrusion seaming material shall be of a type or types recommended by the Geomembrane Manufacturer and shall be delivered to the project site in original sealed containers or packaging, each with an indelible label bearing the manufacturer’s name, manufacturer’s batch or lot number, and complete directions as to proper storage and use.

H. Storage of fuel, oils, and other petroleum products shall be restricted to off-geomembrane areas. Similarly, fueling of equipment (e.g., generators) and changing of oil and oil filters shall be restricted to off-geomembrane areas. If any fuel, oils, or other petroleum products are leaked or accidentally spilled on the geomembrane, they shall be immediately removed. The spill area shall be inspected for damage by the Contractor, Geomembrane Installer, and CQA Consultant, and any damaged geomembrane shall be repaired or replaced as directed by the CQA Consultant.

I. Trial Seaming

1. Geomembrane Installer shall be responsible for field destructive testing of all trial seams.

2. Trial seams shall be prepared for each piece of seaming equipment whenever any of the following conditions occur:
   a. Shift start-up.
   b. Every **six** hours of continuous seaming within a shift.
   c. “Cold” restart of seaming equipment.
   d. Change in welding technician.
   e. Significant change in geomembrane sheet temperatures.
   f. As required by the CQA Consultant.

3. Trial seams shall be prepared in the presence of the CQA Consultant using the same personnel, equipment, and seaming conditions that will be used during production seaming. Field destructive test results acceptable to the CQA Consultant shall be obtained prior to performing any production seaming. This may require resampling of completed trial seams or repeating the trial seam process, as directed by the CQA Consultant.

4. Trial seams shall have a minimum length of six feet and minimum width of one-foot, with the seam centered across the width. Geomembrane Installer shall cut the trial seam into two equal length samples suitable for testing. One sample shall be kept by the Geomembrane Installer for destructive
testing at the project site in the presence of the CQA Consultant. The duplicate sample shall be furnished to the CQA Consultant for the project record and possible future testing. Geomembrane Installer shall mark the duplicate sample with the date, time, ambient temperature, seaming machine identification, seaming technician initials, and seaming parameters (set temperature, rate of travel, etc.) used to prepare the trial seam.

5. Trial seam samples shall be destructively tested in peel and shear in accordance with the Geomembrane Installer’s approved CQC manual. A minimum of five specimens shall be tested for each trial seam. For dual hot wedge seams, five specimens must be tested for each external seam track. Test specimens shall be die cut by the Geomembrane Installer using a die and punch press capable of producing specimens in accordance with ASTM D 6392. Specimens shall be cut from the center two-thirds of the trial seam sample once it has cooled to ambient temperature.

6. Qualification criteria for all trial seam destructive testing are summarized in Table 3-3. Acceptable failure of seam specimens shall be in the geomembrane sheet, not within the seam itself. A partial seam separation (“peel incursion”) during testing will be accepted as indicated in Table 3-3. Excessive peel incursion within the seam area shall constitute disqualification even if strength criteria are met. If any specimens fail to meet qualification criteria, CQA Consultant may have additional specimens from the sample tested in order to determine trial seam acceptance. Failures attributed to excessive grinding beyond weld bead areas for extrusion seams may require retesting or preparation of a new trial seam, as directed by the CQA Consultant.

7. If a trial seam fails to meet all qualification criteria, a new trial seam must be prepared. If this second trial seam also fails, the seaming equipment and/or seaming technician preparing the trial seams shall not be allowed to perform production seaming until any deficiencies are corrected and two consecutive trial seams meeting all qualification criteria are prepared and accepted by the CQA Consultant.

8. Trial seam test results shall be recorded in the Geomembrane Installer’s "preweld" test log or daily field record and a copy furnished to the CQA Consultant no later than the following work day. Specimens tested by the Geomembrane Installer shall be marked and stored on the project site for inspection by the Owner’s Representative or Owner.

J. Production Seaming

1. No production seaming shall commence until trial seaming, as outlined in Section 3.07.5.1, is successfully completed and accepted by the CQA Consultant.

2. All geomembrane panels shall be permanently seamed on the same day they are placed except where explicitly approved by the CQA Consultant.

3. Geomembrane that is to be hot wedge seamed shall be prepared as follows:
   a. Position geomembrane sheets to create a minimum overlap of four inches. If the overlap is excessive, excess geomembrane shall
be trimmed from the lower sheet where possible. If excess geomembrane is trimmed from the upper sheet, Geomembrane Installer shall not scratch or score the lower sheet. Geomembrane damaged during trimming may be removed and the panel overlap reset, as directed by the CQA Consultant.

b. Temporarily anchor sheets in a manner approved by the CQA Consultant to prevent movement during seaming and to maintain a “flat” lap of sheets. No glue or tape shall be used to temporarily hold sheets together before seaming.

c. Prepare overlap area to provide a suitable welding surface. Overlap area shall be free of dirt, dust, moisture, or other foreign material. No solvents shall be used to clean geomembrane sheets prior to seaming.

d. Seaming shall be completed as soon as is practical after preparation and cleaning is completed.

4. Geomembrane that is to be extrusion seamed shall be prepared as follows:

a. Position geomembrane sheets to create a minimum overlap of four inches.

b. Grind the edge of the upper geomembrane sheet to a 45 degree bevel using a disc grinder or equivalent tool. Lift the upper geomembrane sheet away from the lower sheet during beveling to prevent gouging of the lower sheet.

c. Temporarily bond geomembrane sheets, using hot air (“leister”) equipment, to prevent movement during seaming and to maintain a “flat” lap of sheets. No glue or tape shall be used to temporarily hold sheets together before seaming. Overheating of the geomembrane during temporary bonding shall result in rejection of the seam or repair in question and shall be repaired as directed by the CQA Consultant.

d. Grind geomembrane surfaces that are to receive the extrusion weld bead, using a disc grinder or equivalent tool, no more than 15 minutes prior to seaming. Grinding area shall extend no more than one-quarter-inch beyond the extrusion weld bead area and the grinding depth shall not exceed 10 percent of the geomembrane sheet thickness. Extrusion seam ends that are more than five minutes old shall be ground prior to joining or extending the seam. All geomembrane residue generated during grinding shall be cleared from the seaming area.

e. Prior to extrusion seaming, CQA Consultant shall visually inspect all prepared geomembrane surfaces to verify that excessive grinding has not occurred and that the upper geomembrane sheet is properly beveled. CQA Consultant may require repair of areas exhibiting excessive grinding or improper beveling, which may include removal and replacement of affected geomembrane.
5. Extrusion welding machines are to be purged of all heat-degraded extrudate prior to seaming. During seaming operations, extrudate purging will be required whenever the welding machine is idle for more than two minutes, or as directed by the CQA Consultant.

6. No folds, wrinkles, or “fish-mouths” shall be allowed within any seam areas. Where wrinkles or folds occur, the material shall be cut, overlapped, and a patch applied. During wrinkle or fold repairs, adjacent geomembrane may not be required to meet the four-inch minimum overlap, if approved by the CQA Consultant.

K. Non-Destructive Testing

1. Geomembrane Installer shall be responsible for non-destructive testing of the entire length (100 percent) of all production seams and repairs to verify their continuity. Non-destructive testing shall be conducted as geomembrane seaming and repair work progresses and shall be performed in the presence of the CQA Consultant.

2. Non-destructive test methods shall include the vacuum test, air-pressure test, spark test, or other methods approved by the Owner’s Representative. Non-destructive testing procedures shall be described in the Geomembrane Installer’s approved CQC manual and shall comply with all requirements of these Specifications and the project CQA Plan.

3. Seams or portions of seams that cannot be non-destructively tested due to access constraints or other reasons may be covered with a cap-strip as required by the CQA Consultant.

4. Geomembrane Installer shall submit copies of all non-destructive testing documentation to the Owner’s Representative in accordance with Section 3.04.3.B.c.

L. Destructive Testing

1. Laboratory destructive testing of production seams is the responsibility of the CQA Consultant and will be paid for by the Owner. Field destructive testing of production seams is the responsibility of the Geomembrane Installer. Geomembrane Installer is also responsible for obtaining samples and repairing sampling locations for all laboratory and field destructive testing.

2. Destructive testing sample locations shall be repaired in accordance with Section 3.07.6.

3. Production seam samples suitable for laboratory destructive testing shall be obtained by the Geomembrane Installer at locations established by the CQA Consultant as production seaming progresses. All seaming equipment and welding technicians will be representatively sampled at a rate of one sample per 500 linear feet of production seam. Additional samples shall be obtained by the Geomembrane Installer from areas of questionable integrity, as directed by the CQA Consultant.

4. Laboratory destructive testing samples shall have a minimum length of three feet and minimum width of one-foot, with the seam centered across the width. Geomembrane Installer shall cut the destructive sample into two
equal length samples suitable for testing. Both samples shall be furnished to the CQA Consultant, who will forward one sample to a geosynthetic testing laboratory where it shall be destructively tested in peel and shear in accordance with ASTM D 6392. The duplicate sample shall be retained by the CQA Consultant for the project record and possible future testing. An additional duplicate destructive sample may be obtained and retained for testing by the Geomembrane Installer at the Installer's discretion. This additional sampling and testing, if performed, shall be completed at no cost to Owner.

5. Qualification criteria for all production seam destructive testing are summarized in Table 3-3. Acceptable failure of seam specimens shall be in the geomembrane sheet, not within the seam itself. A partial seam separation (“peel incursion”) during testing will be accepted as indicated in Table 3-3. Excessive peel incursion within the seam area shall constitute disqualification even if strength criteria are met. If any specimens fail to meet qualification criteria, CQA Consultant may have additional specimens from the sample tested in order to determine production seam acceptance. Failures attributed to excessive grinding beyond weld bead areas for extrusion seams may require resampling and retesting, as directed by the CQA Consultant. CQA Consultant shall determine acceptance of any destructive testing in cases of dispute.

6. If a destructive test sample fails to meet all qualification criteria, Geomembrane Installer shall obtain two additional production seam samples, each a distance of approximately 10 feet in opposite directions from the original sample, for laboratory destructive testing. Testing of these samples shall be performed by the CQA Consultant at the Geomembrane Installer's expense. Resampling and associated repairs shall be the responsibility of the Geomembrane Installer and shall be performed at no cost to Owner.

7. In order for a production seam to be accepted, a failed destructive test sample shall be bounded by two passing destructive test samples, and the seam between the two passing test locations shall be reconstructed. Alternatively, the entire length of the seam in question may be repaired by placement of a cap strip, or by another repair procedure, as directed by the CQA Consultant.

8. The CQA Consultant, Owner's Representative, or Owner may require that additional destructive test samples be taken at random locations from production seams completed during the same work shift as a failing destructive test sample or in areas that visually appear defective or not in accordance with these Specifications. Testing of these samples shall be performed by the CQA Consultant, but obtaining the samples and repairing the sampling locations shall be the responsibility of the Geomembrane Installer and shall be performed at no cost to Owner.
3.07.6 REPAIRS

A. During installation, Geomembrane Installer and CQA Consultant shall visually inspect all geomembrane panels and seams for damage, defects, or non-compliance with the Contract Drawings and Specifications, and shall mark any such areas for repair. Geomembrane Installer shall repair marked areas as soon as possible. Any defects that could allow surface water runoff beneath the geomembrane shall be repaired on the same day they are marked.

B. Acceptable geomembrane repair methods include:

1. Patching: For repair of surface defects, small tears, punctures, destructive sampling locations, etc. Patches shall have a minimum size of 12 inches by 12 inches, extend at least six inches beyond the edge(s) of a defect, and have rounded corners so that the repair may be completed with a continuous extrusion seam. In some cases, the CQA Consultant may direct the Geomembrane Installer to cut out and remove a defect prior to patching in order to minimize the risk of crack propagation.

2. Spot welding ("bead repairs"): For repair of pinholes or other minor, localized defects. Spot welding shall only be permitted where explicitly approved by the CQA Consultant prior to performing the repair.

3. Reconstruction: For repair of lengths (segments) of unacceptable seams. Performed by cutting and removing the unacceptable seam segment and replacing it with new geomembrane that is seamed into place.

4. Cap stripping: For repair of lengths (segments) of unacceptable seams in lieu of reconstruction. Cap strips shall extend at least 12 inches beyond the edge(s) of a seam, and have rounded corners so that the repair may be completed with a continuous extrusion seam.

5. Flap seaming: For repair of small lengths of unacceptable hot wedge seams in lieu of cap stripping. Performed by extrusion seaming the excess upper geomembrane flap of a hot wedge seam to the lower geomembrane sheet. Flap seaming shall only be permitted when the affected area is less than 10 feet in length and is explicitly approved by the CQA Consultant prior to performing the repair.

6. Grinding and reseaming: For repair of small lengths of unacceptable extrusion seams in lieu of cap stripping. Grinding and reseaming shall only be permitted when the affected area is less than three feet in length and is explicitly approved by the CQA Consultant prior to performing the repair.

C. Under no circumstances shall seams be repaired by placing extrusion seams directly atop previously seamed areas ("piggybacking").

D. Seam intersections ("tees") shall be covered with a patch meeting the requirements of Section 3.07.6.B.1, except where explicitly approved by the CQA Consultant prior to performing the repair.

E. CQA Consultant may require repair or replacement of any area where excessive grinding, overheating, or unacceptable preparation, seaming or testing techniques are observed. Such repair or replacement may be required even if samples removed from affected areas pass destructive testing.
F. All repairs shall be non-destructively tested by the Geomembrane Installer in accordance with Section 3.07.5.K.

3.07.7 PIPE PENETRATION SEALS

A. Pipe penetrations in the geomembrane shall be sealed using HDPE pipe boots (sleeves and skirts), neoprene gaskets, and stainless steel banding straps, as shown on the Contract Drawings and specified in Section 3.06.3.

B. Surfaces where pipe boots are to be attached (including HDPE pipe) shall be cleaned to remove dirt, oil, debris, or other deleterious materials. Geomembrane and HDPE pipe surfaces that will be extrusion seamed to a pipe boot are to be prepared in accordance with Section 3.07.5.J.4.

C. Prior to attaching and/or seaming pipe boots, CQA Consultant shall visually inspect all prepared surfaces to verify that proper preparation techniques have been followed. The CQA Consultant may require repair of areas exhibiting improper preparation techniques or damage, which may include removal and replacement of affected geomembrane or pipe.

D. Geomembrane Installer shall be responsible for non-destructive testing of the entire length (100 percent) of all pipe boot extrusion seams to verify their continuity. Non-destructive testing shall be performed in the presence of the CQA Consultant and in accordance with Section 3.07.5.K.

3.07.8 FINAL INSPECTION, ACCEPTANCE, AND COVERING

A. A final visual examination of all geomembrane panels, seams, repairs, and pipe penetration seals shall be completed by the CQA Consultant prior to accepting geomembrane. CQA Consultant’s inspection shall only be performed following a complete inspection and approval by the Geomembrane Installer’s field superintendent or designated quality control technician. Contractor shall be responsible for cleaning, sweeping, or other measures necessary to provide a thoroughly visible geomembrane surface for the CQA Consultant’s inspection.

B. Geomembrane Installer shall repair and test any areas identified during the CQA Consultant’s final inspection as not being in accordance with the Contract Drawings and Specifications. Any such repairs and testing shall be performed at no cost to Owner.

C. No geomembrane shall be covered until it has been accepted by the CQA Consultant in writing. Once accepted, geomembrane shall be covered as soon as possible in accordance with the Contract Drawings and Specifications.

D. If textured geomembrane is to be covered with other geosynthetics (e.g., GDN), a smooth temporary geosynthetic covering ("slip sheet") shall be used to protect both the geomembrane and overlying geosynthetic from damage until the overlying geosynthetic is in its final position for seaming.

3.07.9 WARRANTIES

A. Seller shall be responsible for obtaining any necessary guarantees or certifications from the Geomembrane Manufacturer and Geomembrane Installer and submitting them to the Owner’s Representative and Owner prior to acceptance of installed geomembrane.
B. Contractor shall guarantee the integrity, within the realm of limitations of Contractor's responsibility, of the installed geomembrane for its intended use, from installation defects for a period of two years from the date of geomembrane installation, and from manufacturing defects for a period of 20 years from the date of geomembrane installation. Such written warranties shall provide for the total and complete repair and/or replacement of any defect or defective areas of geomembrane upon written notification and demonstration by the Owner of the specific non-conformance of the geomembrane or installation with the Contract Drawings and Specifications. Such defects or non-conformance shall be repaired and/or replaced expeditiously, at no cost to Owner.
Table 3-1

REQUIRED PROPERTIES OF TEXTURED 60 MIL HDPE GEOMEMBRANE\(^{(1)}\)

<table>
<thead>
<tr>
<th>Property (Units)</th>
<th>MQC Testing Frequency (Minimum)</th>
<th>Test Method(^{(2)})</th>
<th>Required Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resin</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density (g/cc)</td>
<td>1 per Resin Batch</td>
<td>ASTM D 1505 or D 792</td>
<td>0.932 (min)</td>
</tr>
<tr>
<td>Melt Flow Index (g/10 mins)</td>
<td>1 per Resin Batch</td>
<td>ASTM D 1238, Condition 190/2.16</td>
<td>1.0 (max)</td>
</tr>
<tr>
<td><strong>Finished Sheet</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core Thickness (mil)</td>
<td>Each roll</td>
<td>ASTM D 5994</td>
<td>57 (min ave)(^{(3)})</td>
</tr>
<tr>
<td>Asperity Height (mil)</td>
<td>Every 2(^{nd}) roll</td>
<td>ASTM D 7466</td>
<td>10 (min ave)(^{(4)})</td>
</tr>
<tr>
<td>Density (g/cc)</td>
<td>Every 200,000 lb</td>
<td>ASTM D 1505 or D 792</td>
<td>0.940 (min ave)</td>
</tr>
<tr>
<td>Carbon Black Content (%)</td>
<td>Every 20,000 lb</td>
<td>ASTM D 1603(^{(5)})</td>
<td>2.0 - 3.0</td>
</tr>
<tr>
<td>Carbon Black Dispersion</td>
<td>Every 45,000 lb</td>
<td>ASTM D 5596</td>
<td>Categories 1 or 2(^{(6)})</td>
</tr>
<tr>
<td>Tensile Properties (each direction)</td>
<td>Every 20,000 lb</td>
<td>ASTM D 6693, Test in machine direction and cross-machine direction.</td>
<td>126 (min ave)</td>
</tr>
<tr>
<td>1. Yield Strength (lb/in)</td>
<td></td>
<td></td>
<td>90 (min ave)</td>
</tr>
<tr>
<td>2. Break Strength (lb/in)</td>
<td></td>
<td></td>
<td>12 (min ave)</td>
</tr>
<tr>
<td>3. Yield Elongation (%)</td>
<td></td>
<td></td>
<td>100 (min ave)</td>
</tr>
<tr>
<td>4. Break Elongation (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tear Resistance (lb)</td>
<td>Every 45,000 lb</td>
<td>ASTM D 1004, Die C</td>
<td>42 (min ave)</td>
</tr>
<tr>
<td>Puncture Resistance (lb)</td>
<td>Every 45,000 lb</td>
<td>ASTM D 4833</td>
<td>90 (min ave)</td>
</tr>
<tr>
<td>Stress Crack Resistance(^{(7)})</td>
<td>Per GRI GM 10</td>
<td>ASTM D 5397 (Appendix)</td>
<td>Transition time &gt; 200 hours</td>
</tr>
<tr>
<td>Oxidative Induction Time (mins)(^{(8)})</td>
<td>Every 200,000 lb</td>
<td>ASTM D 3895, ASTM D 5885</td>
<td>100 (min ave), 400 (min ave)</td>
</tr>
<tr>
<td>1. Standard OIT; or</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. High Pressure OIT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oven Aging at 85°C(^{(8)})</td>
<td>Per each formulation</td>
<td>ASTM D 5721, ASTM D 3895, ASTM D 5885</td>
<td>55 (min ave), 80 (min ave)</td>
</tr>
<tr>
<td>1. Standard OIT (% retained after 90 days); or</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. High Pressure OIT (% retained after 90 days)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UV Resistance(^{(9)})</td>
<td>Per each formulation</td>
<td>GRI GM 11, ASTM D 5885</td>
<td>50 (min ave)</td>
</tr>
<tr>
<td>1. High Pressure OIT (% retained after 1,600 hours)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Interface Shear Strength</strong>(^{(1)})</td>
<td>Every 500,000 ft(^{2})</td>
<td>ASTM D 5321</td>
<td>See Table 3-2a</td>
</tr>
</tbody>
</table>

Notes:
1. The required properties specified herein may be revised by the Owner's Representative to reflect new or revised test methods or to conform with improvements to the state-of-the practice. Interface Shear Strength testing is not an MQC test but part of CQA Conformance Testing.
2. Number of specimens per test established in applicable test method unless otherwise noted.
3. Lowest individual value for 8 out of 10 readings = 54 mil; Lowest individual value for all readings = 51 mil.
4. Alternate side of sheet measured each time a roll is tested. 8 out of 10 readings must be ≥ 7 mil; Lowest individual reading = 5 mil.
5. ASTM Method D 4218 is acceptable if an appropriate correlation to D 1603 can be established.
6. For 10 different views: 9 in Categories 1 or 2 and 1 in Category 3. Only near spherical agglomerates are to be considered.
7. For textured geomembrane, tests should be conducted on smooth sheet made from the same formulation as the textured sheet. Yield stress used to calculate test load should be Geomembrane Manufacturer’s mean value via MQC testing.
8. Geomembrane Manufacturer may select either of the OIT methods listed to evaluate antioxidant content.
9. Condition of test should be 20-hour UV cycle at 75°C followed by four-hour condensation at 60°C.

---

\(^{(1)}\) Module V - Specifications – VDEQ, Part B Permit Application - CHSWMF

December 2019
### Table 3-2a

**MINIMUM INTERFACE SHEAR STRENGTH REQUIREMENTS FOR TEXTURED 60 MIL HDPE GEOMEMBRANE**

<table>
<thead>
<tr>
<th>Normal Load (psf)</th>
<th>Standard Test Peak Shear Strength (psf) $(^3)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>65</td>
</tr>
<tr>
<td>300</td>
<td>116</td>
</tr>
<tr>
<td>2,000</td>
<td>814</td>
</tr>
</tbody>
</table>

**Notes:**

1. Testing to be performed in accordance with ASTM D 5321 utilizing the test conditions and procedures outlined in Table 3-2b.

2. Lower interface shear strength requirements may be acceptable if additional slope stability analysis is completed by the Design Engineer verifying a long-term static factor of safety greater than 1.5 and a long-term seismic factor of safety greater than 1.1.

3. If the test data is below the stated peak shear strength, the results may be deemed acceptable by the Design Engineer after reviewing a slope stability analysis of the test data.
### Table 3-2b

**INTERFACE SHEAR STRENGTH TESTING REQUIREMENTS FOR TEXTURED 60 MIL HDPE GEOMEMBRANE**

<table>
<thead>
<tr>
<th>Standard Test</th>
<th>Conditioning &amp; Set-up: Set up each test to match field placement orientation. Run all tests under wet conditions.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Procedure A:</strong> Geomembrane against Geotextile</td>
</tr>
<tr>
<td></td>
<td>Substrate: Steel rasp platen</td>
</tr>
<tr>
<td></td>
<td>Superstratum: Steel rasp platen</td>
</tr>
<tr>
<td></td>
<td>Displacement Rate: 0.04 ipm (maximum)</td>
</tr>
<tr>
<td></td>
<td>Total Displacement: 2.5 in (minimum)</td>
</tr>
<tr>
<td></td>
<td><strong>Procedure B:</strong> Geomembrane against Subbase</td>
</tr>
<tr>
<td></td>
<td>Substrate: Subbase soil at a minimum of 95% Standard Proctor and at optimum plus 2%</td>
</tr>
<tr>
<td></td>
<td>Superstratum: Steel rasp platen</td>
</tr>
<tr>
<td></td>
<td>Displacement Rate: 0.04 ipm (maximum)</td>
</tr>
<tr>
<td></td>
<td>Total Displacement: 2.5 in (minimum)</td>
</tr>
<tr>
<td></td>
<td><strong>Special Instructions:</strong> None.</td>
</tr>
</tbody>
</table>

**Note:**

(1) In lieu of testing individual interfaces, a system test may be performed using a configuration that allows failure to occur through the weakest shearing plane. System test configuration, conditions, and procedures must be accepted by the **Design** Engineer prior to submitting test results for review and approval.
### Table 3-3

**FIELD SEAM QUALIFICATION CRITERIA FOR TEXTURED 60 MIL HDPE GEOMEMBRANE**

<table>
<thead>
<tr>
<th></th>
<th>Trial Seaming$^{(2)}$</th>
<th>Production Seaming$^{(3)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hot Wedge Seams</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peel Strength (lbs)</td>
<td>91</td>
<td>91</td>
</tr>
<tr>
<td>Peel Incursion (%)</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Shear Strength (lbs)</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Shear Elongation at Break (%)</td>
<td>--</td>
<td>50</td>
</tr>
<tr>
<td><strong>Extrusion Fillet Seams</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peel Strength (lbs)</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>Peel Incursion (%)</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Shear Strength (lbs)</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Shear Elongation at Break (%)</td>
<td>--</td>
<td>50</td>
</tr>
</tbody>
</table>

**Notes:**

1. Peel strengths, shear strengths, and shear elongations listed are minimum required values. Peel incursion percentages listed are maximum allowable values. In order to be considered qualified, all five trial seam test specimens must meet all strength and incursion requirements, and *five* out of five production seam test specimens must meet all strength, elongation, and incursion requirements. **Requirements may be modified by the Design Engineer per the latest version of Geosynthetic Institute’s GRI-GM19a Standard Specification.**

2. Field test in accordance with project Specifications and CQA Plan.

3. Laboratory test in accordance with ASTM D 6392.
# Module V - Specifications – VDEQ, Part B Permit Application - CHSWMF

## Table 3-4

**REQUIRED PROPERTIES OF SMOOTH 60 MIL HDPE GEOMEMBRANE**

<table>
<thead>
<tr>
<th>Property (Units)</th>
<th>MQC Testing Frequency (Minimum)</th>
<th>Test Method(2)</th>
<th>Required Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resin</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density (g/cc)</td>
<td>1 per Resin Batch</td>
<td>ASTM D 1505 or D 792</td>
<td>0.932 (min)</td>
</tr>
<tr>
<td>Melt Flow Index (g/10 mins)</td>
<td>1 per Resin Batch</td>
<td>ASTM D 1238, Condition 190/2.16</td>
<td>1.0 (max)</td>
</tr>
<tr>
<td><strong>Finished Sheet</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness (mil)</td>
<td>Each roll</td>
<td>ASTM D 5199</td>
<td>60 (min ave)(3)</td>
</tr>
<tr>
<td>Density (g/cc)</td>
<td>Every 200,000 lb</td>
<td>ASTM D 1505 or D 792</td>
<td>0.940 (min ave)</td>
</tr>
<tr>
<td>Carbon Black Content (%)</td>
<td>Every 20,000 lb</td>
<td>ASTM D 1603(4)</td>
<td>2.0 - 3.0</td>
</tr>
<tr>
<td>Carbon Black Dispersion</td>
<td>Every 45,000 lb</td>
<td>ASTM D 5596</td>
<td>Categories 1 or 2(5)</td>
</tr>
<tr>
<td>Tensile Properties (each direction)</td>
<td>Every 20,000 lb</td>
<td>ASTM D 6693</td>
<td>Test in machine direction and cross-machine direction.</td>
</tr>
<tr>
<td>1. Yield Strength (lb/in)</td>
<td></td>
<td></td>
<td>126 (min ave)</td>
</tr>
<tr>
<td>2. Break Strength (lb/in)</td>
<td></td>
<td></td>
<td>228 (min ave)</td>
</tr>
<tr>
<td>3. Yield Elongation (%)</td>
<td></td>
<td></td>
<td>12 (min ave)</td>
</tr>
<tr>
<td>4. Break Elongation (%)</td>
<td></td>
<td></td>
<td>100 (min ave)</td>
</tr>
<tr>
<td>Tear Resistance (lb)</td>
<td>Every 45,000 lb</td>
<td>ASTM D 1004, Die C</td>
<td>42 (min ave)</td>
</tr>
<tr>
<td>Puncture Resistance (lb)</td>
<td>Every 45,000 lb</td>
<td>ASTM D 4833</td>
<td>108 (min ave)</td>
</tr>
<tr>
<td>Stress Crack Resistance(6)</td>
<td>Per GRI GM 10</td>
<td>ASTM D 5397(Appendix)</td>
<td>Transition time &gt; 200 hours</td>
</tr>
<tr>
<td>Oxidative Induction Time (mins)(7)</td>
<td>Every 200,000 lb</td>
<td>ASTM D 3895</td>
<td>100 (min ave)</td>
</tr>
<tr>
<td>1. Standard OIT; or</td>
<td></td>
<td>ASTM D 5885</td>
<td>400 (min ave)</td>
</tr>
<tr>
<td>2. High Pressure OIT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oven Aging at 85°C(7)</td>
<td>Per each formulation</td>
<td>ASTM D 5721</td>
<td>55 (min ave)</td>
</tr>
<tr>
<td>1. Standard OIT (% retained after 90 days); or</td>
<td></td>
<td>ASTM D 3895</td>
<td></td>
</tr>
<tr>
<td>2. High Pressure OIT (% retained after 90 days)</td>
<td></td>
<td>ASTM D 5885</td>
<td>80 (min ave)</td>
</tr>
<tr>
<td>UV Resistance(8)</td>
<td>Per each formulation</td>
<td>GRI GM 11</td>
<td>50 (min ave)</td>
</tr>
<tr>
<td>1. High Pressure OIT (% retained after 1,600 hours)</td>
<td></td>
<td>ASTM D 5885</td>
<td></td>
</tr>
</tbody>
</table>

**Interface Shear Strength**(3) | Every 500,000 ft² | ASTM D 5321 | See Table 3-2a |

**Notes:**

1. The required properties specified herein may be revised by the Owner’s Representative to reflect new or revised test methods or to conform with improvements to the state-of-the-practice. *Interface Shear Strength testing is not an MQC test but part of CQA Conformance Testing.*

2. Number of specimens per test established in applicable test method unless otherwise noted.

3. Lowest individual value for all readings = 54 mil.

4. ASTM Method D 4218 is acceptable if an appropriate correlation to D 1603 can be established.

5. For 10 different views: 9 in Categories 1 or 2 and 1 in Category 3. Only near spherical agglomerates are to be considered.

6. Yield stress used to calculate test load should be Geomembrane Manufacturer’s mean value via MQC testing.

7. Geomembrane Manufacturer may select either of the OIT methods listed to evaluate antioxidant content.

8. Condition of test should be 20-hour UV cycle at 75°C followed by four-hour condensation at 60°C.
SECTION 4
GEOCOMPOSITE DRAINAGE NET

4.01 GENERAL
4.01.1 DESCRIPTION OF WORK
A. Contractor shall furnish all supervision, labor, products, equipment, and tools, including all necessary and incidental items as detailed or required, to install geocomposite drainage net (GDN) in accordance with the Contract Drawings, Specifications, and project Construction Quality Assurance (CQA) Plan.

B. The perimeter liner termination area shall be excavated, maintained and backfilled by the Contractor.

4.01.2 RELATED WORK SPECIFIED ELSEWHERE
A. Earthwork, Base Grade and Subbase - Section 1.
B. PVC Geomembrane - Section 2.
C. Piping Systems and Leachate Collection, Leak Detection, and Subsurface Drainage - Section 5.
D. Construction Quality Assurance Plan.

4.02 REFERENCES
4.02.1 CODES AND STANDARDS
A. American Society for Testing and Materials (ASTM) Standards:
10. D 4716, “Standard Test Method for Determining the (In-Plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head”.

December 2019

B. Geosynthetic Research Institute (GRI) Standards:
1. GC 7, “Test Method for Determination of Adhesion and Bond Strength of Geocomposites”.

4.03 DEFINITIONS
4.03.1 MARV: Minimum Average Roll Value. For geosynthetics, the mean value minus two standard deviations calculated from documented quality control test results for a defined population for one specific test method associated with one specific property.
4.03.2 MaxARV: Maximum Average Roll Value. For geosynthetics, the mean value plus two standard deviations calculated from documented quality control test results for a defined population for one specific test method associated with one specific property.

4.04 SUBMITTALS
4.04.1 Contractor shall be responsible for timely submittals to the Owner.
4.04.2 The following submittals shall be provided with Contractor’s Bid:
A. The GDN and GDN Manufacturer must be approved by the Owner prior to Contract award. Submittals for approval include:
1. GDN Manufacturer’s specification sheet(s) demonstrating compliance with the requirements of Table 4-1a.
2. GDN Manufacturer’s transmissivity test results. GDN transmissivity test procedures and results shall comply with the requirements of Table 4-1a. Include two samples of finished GDN, 1 s.y. each, for possible transmissivity confirmation testing by the Owner.
3. Written certification that the GDN Manufacturer has produced a minimum of 5,000,000 square feet of GDN that has been installed for hydraulic containment purposes in the last two years, including a list of the relevant completed facilities. Each entry in this list should include the name, location, and purpose of the facility; GDN product designation, total square footage, and date of installation; names of the Owner, Designer, and Contractor; and the name and telephone number of a contact at the facility who can discuss the project.
4. A copy of the GDN Manufacturer’s manufacturing quality control (MQC) manual. This manual should describe the quality control program(s) for GDN
components (geonet, nonwoven geotextile, etc.) and finished GDN, and indicate the properties, test methods, and testing frequencies used for each. GDN Manufacturer shall modify the MQC manual to comply with the requirements of these Specifications, with any variations, deviations, or exceptions clearly noted in an attached letter.

B. The GDN shall meet the interface shear strength requirements of Table 4-2a. Submittals for approval include:

1. Interface shear strength test results for GDN against geomembrane. Test procedures for this interface are outlined in Table 4-2b.
2. Interface shear strength test results for GDN against fine aggregate. Test procedures for this interface are outlined in Table 4-2b.
3. GDN shall only be approved for use with the tested geomembrane and leachate collection layer products. Changes in geomembrane and/or leachate collection layer product will require retesting and reapproval of the GDN at no cost to Owner.

C. The GDN Installer must be approved by the Owner prior to Contract award. Submittals for approval include:

1. Written certification that the GDN Installer has installed a minimum of 1,000,000 square feet of GDN for hydraulic containment purposes in the last two years, including a list of the relevant completed facilities. Each entry in this list should include the name, location, and purpose of the facility; GDN product designation, total square footage, and date of installation; names of the Owner, Designer, Primary Contractor, and CQA Consultant; and the name and telephone number of a contact at the facility who can discuss the project.
2. A copy of the GDN Installer’s QC manual. This manual should describe the quality control program(s) for handling, deploying, anchoring, seaming, and repairing GDN. GDN Installer shall modify the QC manual to comply with the requirements of these Specifications and the project CQA Plan, with any variations, deviations, or exceptions clearly noted in an attached letter.

4.04.3 The following submittals shall be provided after award of Contract:

A. GDN Manufacturer:

1. Prior to or coincident with shipment of GDN to the project site, submit written certification and supporting test data documenting that all GDN components and finished GDN shipped to the project site comply with the requirements of Section 4.06. This shall include:

a. HDPE geonet and nonwoven polypropylene (PP) geotextile resins (Sections 4.06.1.C and 4.06.2.C). Certifications shall state the producers, product designations, lot or batch numbers, and production dates of all resins used in the manufacture of GDN components shipped to the project site and shall include copies of all quality control certificates issued by the resin producer.

b. HDPE geonet and nonwoven PP geotextile formulations (Sections 4.06.1.B and 4.06.2.B). Certifications shall state that all formulations used to produce GDN components shipped to the
project site comply with the requirements of Sections 4.06.1.B and 4.06.2.B.

c. Finished HDPE geonet and nonwoven PP geotextiles (Section 4.06.1.D and 4.06.2.D). Certifications shall include copies of all quality control certificates issued by the Geonet and Geotextile Manufacturers. Include two samples of finished geonet and finished geotextile, 1 yd² each, for the project records of the Owner and CQA Consultant. Each sample shall be labeled with the manufacturer’s name, product designation, lot number, roll number, and date of sampling.

d. Finished GDN shipped to the project site (Section 4.06.3.F). Certifications shall include GDN Quality Control Certificates that have been reviewed and signed by a responsible representative of the GDN Manufacturer.

B. Contractor:

1. Prior to shipment of GDN to the project site, submit six full sets of field installation drawings for approval to the Owner. Installation drawings shall show the proposed length, width, and position of all GDN panels and the location of all field seams. GDN panels shall have a distinct identification system. Installation drawings shall also show complete details for field seaming and repairs, anchoring GDN at the perimeter of the installation area, and attachments to structures and other penetrations, as required.

2. After completion of GDN installation, submit a written report containing the following:

   a. Written certification stating that the GDN has been installed in accordance with the Contract Drawings, Specifications, and project CQA Plan.

   b. Product and installation warranties as required by Section 4.07.8.

   c. Copies of daily field records.

4.05 CONSTRUCTION QUALITY CONTROL AND QUALITY ASSURANCE

4.05.1 GDN construction quality control (CQC) will be performed by the Contractor in accordance with the CQC manual approved by the Owner.

4.05.2 GDN CQA will be performed by the CQA Consultant and paid for by the Owner. GDN CQA will be performed in accordance with these Specifications and the project CQA Plan.
4.06 MATERIAL REQUIREMENTS

4.06.1 GEONET

A. Geonet used in the manufacture of GDN shall be solid rib, biplanar high density polyethylene (HDPE). The physical, mechanical, and chemical properties of the geonet shall comply with the requirements of Table 4-1a.

B. Geonet formulation shall consist of at least 97 percent (by weight) polyethylene resin, two percent to three percent (by weight) of carbon black (added for ultraviolet radiation resistance), and a maximum of one percent (by weight) of other additives. No plasticizers, fillers, extenders, post consumer resin (PCR), or other materials shall be mixed into the formulation. Rerind, rework, or trim materials may be added to the formulation if they are produced by the Geonet Manufacturer and are of the same formulation as the geonet being produced. Rerind, rework, and trim materials shall not exceed 10 percent (by weight) of the geonet formulation.

C. Polyethylene resin used in the manufacture of geonet is to be made from virgin, uncontaminated ingredients and shall be designed and manufactured specifically for producing geonet. Incoming resin shall be sampled and tested in accordance with the Geonet Manufacturer’s MQC program. Testing frequencies, test procedures, and resin properties shall comply with the requirements of Table 4-1a. Results from the resin sampling and testing program are to be submitted to the Owner in accordance with Section 4.04.3.A.1.a.

D. Geonet shall be sampled and tested, prior to incorporation into finished GDN, in accordance with the GDN Manufacturer’s approved MQC manual. Testing frequencies, test procedures, and HDPE geonet properties shall comply with the requirements of Table 4-1a. Results from the geonet sampling and testing program are to be submitted to the Owner in accordance with Section 4.04.3.A.1.c.

4.06.2 GEOTEXTILE

A. Geotextiles used in the manufacture of GDN shall be nonwoven needle punched polypropylene (PP). The physical, mechanical, and chemical properties of the geotextiles shall comply with the requirements of Table 4-1a. During production, geotextile shall be continuously inspected for the presence of broken needles, which shall be removed from the finished product.

B. Geotextile formulation shall consist of at least 95 percent (by weight) polypropylene resin, one percent to three percent (by weight) of carbon black (added for ultraviolet radiation resistance), and a maximum of two percent (by weight) of other additives. No plasticizers, fillers, extenders, post-consumer resin (PCR), or other materials shall be mixed into the formulation. Rework or trim materials may be added to the formulation if they are produced by the Geotextile Manufacturer and are of the same formulation as the geotextile being produced. Rework and trim materials shall not exceed 10 percent (by weight) of the geotextile formulation.

C. Polypropylene resin used in the manufacture of nonwoven geotextile is to be made from virgin, uncontaminated ingredients and shall be designed and manufactured specifically for producing geotextile. Incoming resin shall be sampled and tested in accordance with the Geotextile Manufacturer’s MQC program. Testing frequencies, test procedures, and resin properties shall comply with the requirements of
Table 4-1a. Results from the resin sampling and testing program are to be submitted to the Owner in accordance with Section 4.04.3.A.1.a.

D. Nonwoven geotextiles shall be sampled and tested, prior to incorporation into finished GDN, in accordance with the GDN Manufacturer’s approved MQC manual. Testing frequencies, test procedures, and PP nonwoven geotextile properties shall comply with the requirements of Table 4-1a. Results from the geotextile sampling and testing program are to be submitted to the Owner in accordance with Section 4.04.3.A.1.c.

4.06.3 GEOCOMPOSITE DRAINAGE NET

A. The GDN and GDN Manufacturer must be approved by the Owner prior to Contract award, as required by Section 4.04.2.A and B.

B. GDN shall consist of a high density polyethylene (HDPE) geonet with nonwoven geotextiles thermally-bonded to its upper and lower surfaces. The physical, mechanical, and chemical properties of the GDN shall comply with the requirements of Tables 4-1a, 4-2a, and 4-2b.

C. Geonet used in the manufacture of GDN shall be in accordance with the requirements of Section 4.06.1.

D. Geotextile used in the manufacture of GDN shall be in accordance with the requirements of Section 4.06.2.

E. Bonding of the nonwoven geotextiles to the geonet shall be completed in a uniform manner using thermal bonding techniques. Adhesive bonding is not acceptable. Minimum ply adhesion of the thermally bonded surfaces shall be as required in Tables 4-2a and 4-2b. GDN shall be produced with unbonded panel edges to facilitate field seaming. Unbonded panel edges are to have a minimum width of three inches and maximum width of six inches. Nonwoven geotextile shall extend a minimum of three inches beyond the edges of the geonet on both sides of the GDN.

F. During production, finished GDN shall be sampled and tested in accordance with the GDN Manufacturer’s approved MQC manual. Testing frequencies, test procedures, and finished GDN properties shall comply with the requirements of Tables 4-1a, 4-2a, and 4-2b. Results from the finished GDN sampling and testing program, in the form of Quality Control Certificates, are to be submitted to the Owner in accordance with Section 4.04.3.A.1.d.

G. GDN shall be produced free of holes, tears, overheated areas, unbonded areas (except for panel edges), contamination by foreign matter, dimensional abnormalities, or other defects. The Owner may reject all or portions of units (rolls) of GDN shipped to the project site if significant production flaws are observed.

H. GDN shall be manufactured as a continuous panel having a nominal width of 14 feet and minimum length of 200 feet in order to reduce the amount of field seaming required during installation. Rolls of GDN having lengths shorter than 200 feet may be shipped to the project site if the number of such rolls is approved by the Owner prior to shipment.
I. GDN shall be rolled onto hollow cores having a minimum inside diameter of four inches to allow the use of a stinger or spreader bar assembly for handling and deployment. Cores shall be of stable construction such that they support the roll without excessively deflecting, buckling, or otherwise failing during handling, transportation, and storage. Each roll of GDN shall be protected by wrapping it in packaging that is waterproof, resistant to photodegradation by ultraviolet light, and completely covers all exposed GDN surfaces and edges.

J. Each GDN roll shall be labeled to identify the GDN Manufacturer, product designation, manufacturer's lot number, manufacturer's roll number, and the length, width, and weight of each roll. Roll identification numbers shall conform to the numbering system established on the GDN Manufacturer's Quality Control Certificates. Labels shall be weather proof, legible, and located so that each roll of GDN can be identified by examining the outside of the roll or the core ends.

K. At the option of the Owner, Owner may inspect the GDN manufacturing process on a full-time basis. This inspection program would include conformance sampling as required. If requested, GDN Manufacturer shall submit a production schedule to the Owner and cooperate with the Owner during plant inspection.

L. All GDN components and finished GDN properties, including testing frequencies and test procedures used, shall meet the requirements of this Section. No GDN shall be installed until the Owner has reviewed all certifications and supporting test data and determined that the GDN delivered to the project site is acceptable for use. Manufacturing records, including test data, shall be maintained by the GDN Manufacturer for two years after acceptance of the GDN, and shall be made available upon request.

4.06.4 PLASTIC TIES
A. Plastic ties shall be used to join and make repairs to GDN panels in the field. Ties shall be colored white or yellow to facilitate CQA inspection. Metallic ties or fasteners are not acceptable.

4.07 INSTALLATION
4.07.1 PRE-INSTALLATION MEETING
A. Prior to scheduled GDN installation, the Owner, CQA Consultant, Contractor, and Contractor shall attend a pre-installation meeting at the project site. This meeting shall be scheduled by the Owner after receipt of Contractor’s field installation drawings.

B. Contractor shall be represented by both the project field superintendent and the project manager.

C. At the pre-installation meeting, site safety and rules of operation, scheduling, methods of installation, and construction quality control and quality assurance shall be discussed. The Contractor, Owner, and CQA Consultant shall at this time agree to the required GDN placement, seaming, and repair procedures for the project.
4.07.2 SHIPPING, HANDLING, AND STORAGE

A. Contractor is responsible for proper shipping, unloading, and storage of the GDN. GDN damaged during shipping, unloading, or storage shall be repaired or replaced at no cost to Owner.

B. GDN rolls shall be packaged and shipped so that no damage is caused during delivery to the project site. GDN shipping shall be by open or enclosed trailers loaded in such a manner that rolls can be readily unloaded at the project site using slings, a stinger, or a spreader bar assembly. GDN rolls shipped by open trailer shall be protected with a sacrificial or temporary cover during shipment.

C. During unloading at the project site, Contractor shall conduct a surface inspection of all GDN rolls for defects and damage, including damage to the original protective packaging. Contractor shall immediately notify CQA Consultant and Owner of any defects or damage observed.

D. Extreme care shall be taken by all personnel while unloading and handling GDN. Equipment used to unload and handle GDN shall have sufficient capacity to manage the roll weight without damaging the GDN. GDN shall only be unloaded and handled using slings, a stinger, or a spreader bar assembly recommended by the GDN Manufacturer or accepted by the CQA Consultant. Pushing, sliding, or dragging of GDN rolls is not permitted. CQA Consultant shall have the option of inspecting all GDN panels, prior to final placement, to verify that all defects or damage are identified for repair.

E. GDN shall be stored at the project site in an area(s) designated by the Owner and accepted by the CQA Consultant. Contractor shall grade the storage area so that it is reasonably level and well-drained, and shall prepare the ground surface so that it is firm, smooth, and free of stones, sticks, or other materials that may damage the GDN.

F. GDN rolls shall be stored off the ground and continuously supported along their length. Stacking of GDN rolls for storage is allowed but should not be so high that crushing of cores or flattening of rolls occurs. In general, the maximum stacking limit is 5 rolls high. A suitable means of securing the rolls shall be used so that shifting or other adverse movement does not occur.

G. During storage, GDN shall be protected from moisture, direct sunlight, mud, and excessive dust by covering the rolls with a plastic sheet or waterproof tarpaulin. Roll labels shall remain intact and legible. Any roll of GDN that has no label or where the label is damaged or otherwise illegible may be rejected by the CQA Consultant. GDN rolls shall be kept in their original protective packaging until immediately before they are to be deployed.

4.07.3 QUALITY ASSURANCE CONFORMANCE TESTING

A. Quality assurance conformance testing of the GDN shall be performed by the CQA Consultant and paid for by the Owner. Conformance testing lab results shall be provided directly to Owner and CQA Consultant for review upon receipt of testing data from lab. Conformance sampling and testing shall be completed in accordance with the project CQA Plan, with at least one sample per production lot as directed by the Owner. Owner has the option to increase the frequency of conformance testing or to sample and test any questionable roll or lot.
B. Owner may revise the test methods used for determination of conformance properties to allow for use of new or revised methods.

C. All GDN conformance test results shall comply with the requirements of Tables 4-1a, 4-2a and 4-2b prior to installation. Any GDN that does not conform to these requirements shall be retested or rejected in accordance with the CQA Plan.

D. GDN that is rejected shall be removed from the project site and replaced at no cost to Owner. Sampling and conformance testing of GDN supplied as replacement for rejected material shall be performed by the CQA Consultant at Contractor’s cost.

4.07.4 DEPLOYMENT AND PLACEMENT

A. GDN shall be deployed and placed in general accordance with the Contractor’s approved field installation drawings. Depending on field conditions, it may be necessary to alter the GDN panel arrangement from that shown on the approved field installation drawings. These alterations shall be approved by the CQA Consultant prior to GDN deployment.

B. The Owner, in conjunction with Contractor, shall establish site-specific limits of weather conditions, including, but not limited to, precipitation and wind speed and direction, within which GDN panel placement can be conducted. In the absence of site-specific criteria, the following limitations shall apply:
   1. No placement shall be conducted in the presence of precipitation, such as rain, snow, or sleet.
   2. No placement shall be conducted in the presence of winds in excess of 20 miles per hour or when dirt or debris is blown into working areas.

C. Contractor shall maintain a daily field record of actual placement of each GDN panel, noting base grade conditions, weather, panel numbers placed, and seaming methods. A copy of each day’s field record shall be furnished to the CQA Consultant no later than the following work day.

D. GDN shall only be placed on base grade (geomembrane) that has been installed in accordance with the Contract Drawings and Specifications, and has been accepted in writing by the Contractor and CQA Consultant. Once base grade has been accepted by the CQA Consultant, any additional surface preparation that the Contractor feels necessary to meet the requirements of the Specifications shall be the responsibility of the Contractor. Geomembrane (base grade) should have all folds, wrinkles, and other undulations removed and its surface shall be free of rocks, dirt, tools, or other debris before placing GDN. Areas the Contractor believes exhibit deficient base grade conditions shall be reported to the CQA Consultant and Owner for repair.

E. Contractor shall coordinate placement of the GDN with placement of the covering material. All GDN panels shall be appropriately covered within 30 days after they are placed to prevent deterioration of the upper geotextile. Any GDN that
deteriorates or is otherwise damaged prior to placement of covering material shall be removed and replaced by the Contractor, as directed by the CQA Consultant, at no cost to Owner.

F. It is imperative to keep surface water runoff containing sediment or other debris from contacting the GDN at all times during installation. Contractor’s panel placement techniques and covering schedule shall minimize or eliminate the potential for accumulation of sediment or other debris on the GDN. Contractor shall remove accumulated sediment or debris by sweeping, hosing, or other methods acceptable to the CQA Consultant, prior to covering the GDN. Any GDN that cannot be adequately cleaned shall be removed and replaced by the Contractor, as directed by the CQA Consultant, at no cost to Owner.

G. Extreme care shall be taken by all personnel while handling, unwrapping, deploying, and placing GDN. Equipment and tools used shall not stretch, tear, crimp, fold, or otherwise damage the GDN, and shall not cause damage to the underlying geomembrane (base grade). Equipment shall have sufficient capacity to manage the roll weight without damaging the GDN. GDN shall only be handled and deployed using a stinger or spreader bar assembly recommended by the GDN Manufacturer or acceptable to the CQA Consultant. Pushing, sliding, or dragging of GDN rolls is not permitted.

H. Under no circumstances shall any construction or vehicular traffic be allowed to drive over exposed GDN. GDN showing evidence of trafficking shall be inspected by the Contractor and CQA Consultant to evaluate damage, if any. At the direction of the CQA Consultant, any damaged GDN shall be repaired or replaced at no cost to Owner. CQA Consultant may allow limited use of four-wheeled ATVs or other low ground pressure equipment (having 7 psi or less contact pressure) by the Contractor during installation, but use shall be prohibited if excessive trafficking or any GDN damage is observed.

I. GDN rolls shall be transported from the storage area to the working area in their original protective packaging. After packaging is carefully removed, GDN shall be unrolled and placed in such a manner as to minimize dragging of panels into position (“spotting”). A temporary smooth geosynthetic base grade covering (“slip sheet”) shall be used to protect the bottom surface of the GDN from damage, as directed by the CQA Consultant.

J. Contractor shall immediately provide temporary anchorage of the GDN to prevent wind uplift, bridging (refer to Section 4.07.4.K for bridging requirements), and panel movement during placement of covering materials (geomembrane). No permanent bonding of GDN to geomembrane shall be permitted. Temporary anchorage methods shall be approved by the Owner and CQA Consultant. If bags are used for temporary anchorage, they shall be filled with fine-grained sand that has been approved for use by the CQA Consultant. Any GDN exhibiting damage due to insufficient or improper temporary anchorage shall be repaired or replaced, as directed by the CQA Consultant, at no cost to Owner.

K. GDN shall be installed so that is in continuous contact with the underlying geomembrane surface, without being tensioned, and with no wrinkles or folds. Bridging at the toe of slopes or within leachate pipe trenches shall not be permitted. If bridging is observed, Contractor shall repair affected areas, as directed by the CQA Consultant, at no cost to Owner.
L. GDN panel seams (edges) shall be oriented in a direction parallel to the line of maximum base grade slope (i.e., down, not across the slope) and shall be placed in a manner that minimizes the number and length of field seams. In corners and odd-shaped geometric locations where panel seams are staggered or butted, an extra layer of GDN shall be installed from the crest to the toe of the slope.

M. All GDN panel seams shall be shingled such that the "upstream" panel overlaps the "downstream" panel in order to minimize the possibility of lifting panel edges during placement of covering material.

N. All GDN panel seams parallel to the toe of a slope ("longitudinal seams") shall be located at least five feet from the toe of the slope, except where explicitly approved by the CQA Consultant. Longitudinal seams are permitted on sideslopes, but must be staggered in a manner approved by the Owner and CQA Consultant.

O. Contractor shall be responsible for excavation, maintenance, and backfilling of the perimeter liner termination area in accordance with the perimeter liner termination area requirements outlined in Sections 2 and 3 – PVC and HDPE Geomembrane of the Specifications. Backfilling of the perimeter liner termination area shall commence only after the leachate collection system GDN has been approved by the CQA Consultant. Backfilling materials and compaction methods shall be as outlined in Section 1 – Earthwork, Base Grade and Subbase, of the Specifications.

4.07.5 SEAMING

A. A combination of lap joints (geonet) and sewing (geotextile) shall be used to join GDN panels in the field. A minimum geonet overlap of three inches shall be used for panel edges and a minimum GDN overlap of 24 inches shall be used for panel ends. Overlap areas shall be kept free of rocks, loose soil, or other debris. All GDN panels should be seamed as soon as possible after they are placed and prior to being covered.

B. Geonet overlaps along panel edges shall be secured using a minimum of one plastic tie per five linear feet of seam except in perimeter liner termination areas, where spacing shall be a minimum of one plastic tie per six linear inches of seam. Geonet overlaps in corners or other odd-shaped geometric locations where panel seams are staggered or butted shall be secured using a minimum of one plastic tie per six linear inches of seam. GDN panel end seams shall be secured using a minimum of one plastic tie per six linear inches of seam.

C. GDN panel edge overlap areas shall be left open (i.e., upper geotextiles pulled back) after placing plastic ties to allow the CQA Consultant to verify that the overlap area and tie spacing meet the requirements of this Section. Geotextile overlaps shall not be closed and sewn until verbal acceptance of the geonet seam is given by the CQA Consultant.

D. Geotextile overlaps on GDN panel edges shall be joined with a flat ("prayer") seam using either one row of Type 401 stitching (for leachate detection zone GDN) or two rows of Type 401 stitching (for leachate collection system GDN). All sewn seams shall be continuous and completed using thread made from the same type of
polymer as the geotextiles being sewn together. Sewing thread should be a color that contrasts the geotextile color. Thermal seaming methods may be accepted if successfully demonstrated in the field and approved by the Owner and CQA Consultant.

E. Completed GDN seams shall lay flat and be free of any rocks, loose soil, or other debris. Where wrinkles or folds do occur, the material shall be cut, overlapped, and a patch applied in accordance with Section 4.08.

4.08 REPAIRS

4.08.1 During installation, Contractor and CQA Consultant shall visually inspect all GDN panels and seams for damage, defects, or non-compliance with the Contract Drawings and Specifications, and shall mark any such areas for repair. Contractor shall repair marked areas as soon as possible and prior to covering the GDN with geomembrane.

4.08.2 For repair of surface defects, small tears, punctures, etc. patches shall have a minimum size of 24 inches by 24 inches and extend at least 12 inches beyond the edge(s) of a defect. Patches shall be secured to original GDN using plastic ties placed at a minimum six-inch spacing around the patch.

4.08.3 If an area to be repaired is more than 50 percent of the width of a GDN panel, the damaged area shall be removed across the entire panel width and the two remaining portions of GDN shall be joined in accordance with Section 3.03.5. Such repair areas shall be explicitly approved by the CQA Consultant prior to making the repair.

4.09 ACCEPTANCE AND COVERING

4.09.1 No GDN shall be covered until it has been accepted by the CQA Consultant in writing.

4.09.2 Contractor shall repair any areas identified by the CQA Consultant as not being in accordance with the Contract Drawings and Specifications. Once all repairs are completed and accepted by the CQA Consultant, GDN shall immediately be covered with geomembrane or landfill liner protective cover in accordance with the Contract Drawings and Specifications.

4.09.3 All GDN panels shall be covered with protective cover material within 30 days after they are placed to prevent deterioration of the upper geotextile. Any GDN that deteriorates or is otherwise damaged prior to placement of covering material shall be removed and replaced by the Contractor, as directed by the CQA Consultant, at no cost to Owner.

4.09.4 If textured geomembrane is used to cover the GDN, a smooth temporary geosynthetic covering ("slip sheet") shall be used to protect the upper surface of the GDN from damage until the geomembrane is in its final position for seaming.

4.10 WARRANTIES

4.10.1 Contractor shall be responsible for obtaining any necessary guarantees or certifications from the GDN Manufacturer and Contractor and submitting them to the Owner prior to acceptance of installed GDN.

4.10.2 Contractor shall guarantee the integrity, within the realm of limitations of Contractor's responsibility, of the installed GDN for its intended use, from installation defects for a period of two years from the date of GDN installation, and from manufacturing defects for a period of 2 years from the date of GDN installation.
### Table 4-1a

**REQUIRED PROPERTIES OF LEACHATE COLLECTION SYSTEM GEOCOMPOSITE DRAINAGE NET\(^{(1)}\)**

<table>
<thead>
<tr>
<th>Property (Units)</th>
<th>MQC Testing Frequency (Minimum)</th>
<th>Test Method(^{(2)})</th>
<th>Required Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HDPE Geonet Resin</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density (g/cc)</td>
<td>1 per Resin Batch</td>
<td>ASTM D 1505 or D 792</td>
<td>0.932 (min)</td>
</tr>
<tr>
<td>Melt Flow Index (g/10 mins)</td>
<td>1 per Resin Batch</td>
<td>ASTM D 1238, Condition 190/2.16</td>
<td>1.0 (max)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Finished HDPE Geonet(^{(3)})</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density (g/cc)</td>
<td>Every 50,000 ft(^2)</td>
<td>ASTM D 1505 or D 792</td>
<td>0.940 (min ave)</td>
</tr>
<tr>
<td>Thickness (mil)</td>
<td>Every 50,000 ft(^2)</td>
<td>ASTM D 5199</td>
<td>250 (min ave)(^{(4)})</td>
</tr>
<tr>
<td>Carbon Black Content (%)</td>
<td>Every 50,000 ft(^2)</td>
<td>ASTM D 1603</td>
<td>2.0 - 3.0 (min ave)</td>
</tr>
<tr>
<td>Transmissivity (m(^2)/sec)</td>
<td>Every 200,000 ft(^2)</td>
<td>ASTM D 4716</td>
<td>3.0 x 10(^{-3}) (min ave)(^{(5)})</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nonwoven PP Geotextile Resin</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density (g/cc)</td>
<td>1 per Resin Batch</td>
<td>ASTM D 1505</td>
<td>0.909 (min)</td>
</tr>
<tr>
<td>Melt Flow Index (g/10 mins)</td>
<td>1 per Resin Batch</td>
<td>ASTM D 1238, Condition 230/2.16</td>
<td>3.5 (min)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Finished Nonwoven PP Geotextile(^{(3)})</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass per unit Area (oz/yd(^2))</td>
<td>Every 100,000 ft(^2)</td>
<td>ASTM D 5261</td>
<td>8.0 (MARV)</td>
</tr>
<tr>
<td>Grab Tensile Strength (lb)</td>
<td>Every 100,000 ft(^2)</td>
<td>ASTM D 4632</td>
<td>215 (MARV)</td>
</tr>
<tr>
<td>Tear Strength (lb)</td>
<td>Every 100,000 ft(^2)</td>
<td>ASTM D 4533</td>
<td>85 (MARV)</td>
</tr>
<tr>
<td>Puncture Strength (lb/in(^3))</td>
<td>Every 100,000 ft(^2)</td>
<td>ASTM D 4833</td>
<td>135 (MARV)</td>
</tr>
<tr>
<td>Burst Strength (lb/in(^3))</td>
<td>Every 100,000 ft(^2)</td>
<td>ASTM D 3786</td>
<td>375 (MARV)</td>
</tr>
<tr>
<td>Permittivity (sec(^{-1}))</td>
<td>Every 500,000 ft(^2)</td>
<td>ASTM D 4491</td>
<td>0.2 (MARV)</td>
</tr>
<tr>
<td>AOS (mm)</td>
<td>Every 500,000 ft(^2)</td>
<td>ASTM D 4751</td>
<td>0.18 (MaxARV)</td>
</tr>
<tr>
<td>UV Stability (% strength retained at 500 hours)</td>
<td>Per Formulation</td>
<td>ASTM D 4355</td>
<td>70 (min)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Finished GDN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmissivity (m(^2)/sec)</td>
<td>Every 200,000 ft(^2)</td>
<td>ASTM D 4716</td>
<td>3 x 10(^{-4}) (min ave)(^{(6)})</td>
</tr>
<tr>
<td>Ply Adhesion (lb/in)</td>
<td>Every 15,000 ft(^2)</td>
<td>GRI GC 7</td>
<td>1.0 (min ave)(^{(7)})</td>
</tr>
<tr>
<td><strong>Interface Shear Strength(^{(4)})</strong></td>
<td>Every 500,000 ft(^2)</td>
<td>ASTM D 5321</td>
<td>See Table 4-2a</td>
</tr>
</tbody>
</table>

**Notes:**

\(^{(1)}\) The required properties specified herein may be revised by the Owner to reflect new or revised test methods or to conform with improvements to the state-of-the-practice. *Interface Shear Strength testing is not an MQC test but part of CQA Conformance Testing.*

\(^{(2)}\) Number of specimens per test established in applicable test method unless otherwise noted.

\(^{(3)}\) Perform tests on material before incorporation into finished GDN.

\(^{(4)}\) Diameter of presser foot shall be 2.22 inches and pressure shall be 2.9 lb/in\(^2\). Lowest individual value = 230 mil.

\(^{(5)}\) Perform test using rigid platens for substrate and superstratum. Test conditions: Normal stress = 10,000 lb/ft\(^2\); Hydraulic gradient = 1.0; Seating period = 15 minutes.
(6) Perform test using deaired water, project geomembrane for substrate, and project protective cover material for superstratum. Test conditions: Normal stress = 11,500 lb/ft²; Hydraulic gradients = 0.1, 0.3, 1.0; Seating period = 48 hours. Transmissivity at a hydraulic gradient of 0.1 will be used to determine acceptance.

(7) Average of 5 equally spaced tests across the roll width. Lowest individual value = 1.0 lb/in.
### Table 4-2a

**MINIMUM INTERFACE SHEAR STRENGTH REQUIREMENTS FOR GEOCOMPOSITE DRAINAGE NET**(1)

<table>
<thead>
<tr>
<th>Normal Load (psf)</th>
<th>Standard Test Peak Shear Strength (psf)(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>65</td>
</tr>
<tr>
<td>300</td>
<td>116</td>
</tr>
<tr>
<td>2,000</td>
<td>814</td>
</tr>
<tr>
<td>11,500</td>
<td>4,250</td>
</tr>
<tr>
<td>25,000</td>
<td>7325</td>
</tr>
</tbody>
</table>

**Notes:**

(1) Testing to be performed in accordance with ASTM D 5321 utilizing the test conditions and procedures outlined in Table 4-2b. Geocomposite drainage net is not acceptable if geotextile delaminates from the geonet, even if required strengths are attained.

(2) Lower interface shear strength requirements may be acceptable if additional slope stability analysis is completed by the Design Engineer verifying a long-term static factor of safety greater than 1.5 and a long-term seismic factor of safety greater than 1.1.

(3) If the test data is below the stated peak shear strength, the results may be deemed acceptable by the Design Engineer after reviewing a slope stability analysis of the test data.
# Table 4-2b

INTERFACE SHEAR STRENGTH TESTING
REQUIREMENTS FOR GEOCOMPOSITE DRAINAGE NET\(^{(1)}\)

<table>
<thead>
<tr>
<th>Standard Test</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASTM D 5321</strong></td>
<td>• Conditioning &amp; Set-up: Set up each test to match field placement orientation. Run all tests under wet conditions.</td>
</tr>
<tr>
<td></td>
<td>• Procedure A: GDN against Geomembrane</td>
</tr>
<tr>
<td></td>
<td>Substrate: Steel rasp platen</td>
</tr>
<tr>
<td></td>
<td>Superstratum: Steel rasp platen</td>
</tr>
<tr>
<td></td>
<td>Displacement Rate: 0.04 ipm (maximum)</td>
</tr>
<tr>
<td></td>
<td>Total Displacement: 2.5 in (minimum)</td>
</tr>
<tr>
<td></td>
<td>• Procedure B: GDN against <strong>Leachate Collection Aggregate (Bottom Liner)</strong></td>
</tr>
<tr>
<td></td>
<td>Substrate: <strong>Leachate Collection Aggregate</strong> at 90% relative density and as-received water content percent</td>
</tr>
<tr>
<td></td>
<td>Superstratum: Steel rasp platen</td>
</tr>
<tr>
<td></td>
<td>Displacement Rate: 0.04 ipm (maximum)</td>
</tr>
<tr>
<td></td>
<td>Total Displacement: 2.5 in (minimum)</td>
</tr>
<tr>
<td></td>
<td>• Procedure C: GDN against <strong>Cover Soil (Final Cover Cap System)</strong></td>
</tr>
<tr>
<td></td>
<td>Substrate: Steel rasp platen</td>
</tr>
<tr>
<td></td>
<td>Superstratum: <strong>Cover Soil</strong> tamped to represent compaction expected after placement</td>
</tr>
<tr>
<td></td>
<td>Displacement Rate: 0.04 ipm (maximum)</td>
</tr>
<tr>
<td></td>
<td>Total Displacement: 2.5 in (minimum)</td>
</tr>
<tr>
<td></td>
<td>• Special Instructions: None.</td>
</tr>
</tbody>
</table>

**Note:**
\(^{(1)}\) In lieu of testing individual interfaces, a system test may be performed using a configuration that allows failure to occur through the weakest shearing plane. System test configuration, conditions, and procedures must be accepted by the **Design** Engineer prior to submitting test results for review and approval.
SECTION 5
PIPING SYSTEMS AND LEACHATE COLLECTION AND GROUNDWATER DRAINAGE

5.01 GENERAL
5.01.1 DESCRIPTION OF WORK
This section includes technical requirements for installing the groundwater underdrains and the leachate collection system. Also included are culvert pipes and pond discharge pipes.

5.01.2 ITEMS INCLUDED IN THIS SECTION
A. Furnishing and installing the leachate collection system, including the perforated and solid wall PVC pipes, geotextile, and leachate collection layer aggregate. The GDN is not included since it is specified in Section 3 herein.
B. Furnishing and installing the groundwater underdrains, including the perforated PVC pipes, geotextile, and pipe bedding and drainage aggregate.
C. Furnishing and installing leachate conveyance pipe and landfill culverts to the extent and details shown on the drawings.

5.01.3 RELATED WORK SPECIFIED ELSEWHERE
A. Earthwork, Base Grade and Subbase – Section 1.
B. PVC Geomembrane – Section 2.
C. Geocomposite Drainage Net – Section 4.
D. Geotextiles – Section 6.
E. Construction Quality Assurance Plan.

5.02 REFERENCES
5.02.1 CODES AND STANDARDS
A. American Society for Testing and Materials (ASTM) Standards:

5.02.2 VDOT Road and Bridge Specifications - 2007.
5.02.3 AASHTO M294, “Standard Specification for Corrugated Polyethylene Pipe”.
5.02.4 ASME B16.5.
5.02.5 ASME B31.1.
5.03 MATERIAL REQUIREMENTS

5.03.1 LEACHATE COLLECTION LAYER

A. Leachate collection layer (LCL) medium shall be a coarse material with a minimum hydraulic conductivity of $1 \times 10^{-3}$ cm/sec. A material with a gradation similar to AASHTO No. 57 or AASHTO/VDOT No. 8 aggregate gradation is acceptable. If filter compatibility with FFPs can be demonstrated, an overlying “filter” geotextile will not be required.

B. Other aggregate gradations that meet hydraulic conductivity may be used if filter compatibility can be demonstrated between the FFP, protective cover, and LCL. Alternative materials must be approved by the Owner’s Engineer, verifying the material has acceptable hydraulic conductivity and filter compatibility.

C. Aggregate shall be tested for gradation, permeability, and carbonate content in accordance with the CQA Plan.

D. If filter compatibility cannot be achieved with the Contractor’s proposed LCL aggregate, the Owner may accept the material with the incorporation of a “filter” geotextile within or above the leachate collection layer and protective cover matrix. The geotextile will typically be a non-woven, needle-punched geotextile meeting the requirements of a “filter geotextile” in Table 6-1. However, the type of geotextile and placement location shall be determined by the Owner’s Engineer, based on the aggregate characteristics.

E. Aggregate for the leachate collection pipe drainage envelope shall be AASHTO/VDOT No. 8 aggregate, or other Owner’s Engineer-approved material and having a similar gradation. The leachate collection pipe envelope shall be constructed to the dimensions shown on the Drawings. The pipe and aggregate envelope shall be wrapped with a non-woven, needle-punched geotextile meeting the requirements of a “filter geotextile” in Table 6-1.

F. The aggregate shall be manufactured from natural material and consist of angular, hard, tough, durable, uncoated particles; free of organic matter, coal, iron, shale, clay or weak, flat, elongated, argillaceous, or decomposed material. It shall not be made of acid forming or toxic forming rock or slag.

G. Rock and stone shall be of a quality that will withstand the action of water, frost, and other weathering. Fully rounded rocks or boulders shall not be used.

H. Limestone, dolomite, or other materials with a carbonate content exceeding 15% shall not be used (sandstone, basalt and gneiss are acceptable materials) in the LCL.

I. Bottom ash from the Virginia City Hybrid Energy Center may be used if it meets the minimum hydraulic conductivity requirement.

J. For purchased materials, the Contractor shall supply the Owner with the source of material, grain-size analysis, and material certification before any material is accepted.
5.03.2 CULVERT AND PIPE BEDDING AGGREGATE
A. Aggregate for culvert and leachate conveyance pipe bedding and backfill shall be of the type and gradation shown on the Drawings.
B. Portions of the discharge pipe from the leachate ponds through the embankment shall be bedded in a Portland Cement Concrete (3000 psi) cradle. Refer to the Drawings for locations and details.
C. Rock and stone shall be of a quality that will withstand the action of water, frost, and other weathering. Fully rounded rocks or boulders shall not be used.
D. A carbonate limit does not apply to aggregate used for pipe bedding and backfill.
E. The Contractor shall supply the Owner with the source of material, grain-size analysis, and material certification before any material is accepted.

5.03.3 GROUNDWATER UNDERDRAIN AGGREGATE
A. Aggregate for groundwater underdrain trenches and pipe backfill shall be a coarse material with a gradation similar to AASHTO/VDOT No. 57.
B. Aggregate for groundwater blanket drains shall be a coarse material with a gradation similar to AASHTO/VDOT No. 1.
C. A carbonate limit does not apply to aggregate used for pipe bedding.
D. The material shall consist of angular, hard, tough, durable, uncoated particles; free of organic matter, coal, iron, shale, clay or weak, flat, elongated, argillaceous, or decomposed material. It shall not be made of acid forming or toxic forming rock or slag.
E. Rock and stone shall be of a quality that will withstand the action of water, frost, and other weathering. Fully rounded rocks or boulders shall not be used.
F. Geotextile used in groundwater underdrains and blanket drains shall be a non-woven, needle-punched geotextile meeting the requirements of a “filter geotextile” in Table 6-1.
G. The Contractor shall supply the Owner with the source of material, grain-size analysis, and material certification before any material is accepted.

5.03.4 HDPE PIPE
A. The pipe and fittings for HDPE pipe shall be made of high density, high molecular weight polyethylene pipe material meeting the requirements of ASTM D 1248 and ASTM D 3350.
B. HDPE pipe joints shall be butt-fusion welded in accordance with ASTM D 2657 and ASTM D 3350, and the manufacturer's requirements or made using a collar fusion device.
C. All HDPE pipe bends equal to or greater than three degrees may be accomplished using factory fabricated fittings. Bends indicated on the Drawings depict horizontal bends only. The Contractor shall be responsible for furnishing and installing all bends required including bends required at changes in pipe slope. In lieu of
fabricated pipe bends, the Contractor may make gradual long radius pipe bends by deflecting the straight run of pipe. No pipe deflection shall be made with a radius of curve less than 40 pipe diameters.

D. Pipe boots for penetration of piping through the geomembranes shall be as specified in Sections 2 and 3, HDPE Geomembrane, and as shown on the Drawings.

5.03.5 LEACHATE COLLECTION AND GROUNDWATER UNDERDRAIN PIPE
A. The leachate collection and groundwater underdrain pipes within the footprint of the landfill liner shall be perforated and solid wall PVC pipe meeting the requirements of ASTM D 1785. The leachate collection pipes shall be perforated pipe with solid wall pipe for the cleanouts. Pipe schedules and diameters are shown on the Drawings. The perforations shall be sized and spaced as shown on the Drawings.

B. The leachate conveyance pipe outside the landfill liner shall be HDPE solid wall pipe, of the diameters and wall thickness shown on the Drawings.

C. Leachate Pond discharge pipes shall be HDPE solid wall pipe, as shown on the Drawings.

D. The landfill culvert pipes shall be SDR 26 solid wall HDPE or smooth interior, gasketed Hancor Hi Q Sure Lok, ADS N 12, or approved AASHTO M294, Type S equivalent, of the sizes shown on the Drawings.

E. Pond riser shall be solid wall HDPE pipe of the size and wall thickness shown on the Drawings.

F. Cleanouts for the leachate collection drain piping shall be as shown on the Drawings.

5.03.6 LEACHATE CONVEYANCE PIPE
A. Above ground pipe shall be as shown on the Drawings.

B. Buried pipe shall be HDPE of the sizes and pressure ratings shown on the Drawings.

5.03.7 VALVES
A. Valves shall be as shown on the Drawings. All valves shall be stainless steel, industrial grade, and selection shall be based on experience and reliability.

5.04 INSTALLATION REQUIREMENTS
5.04.1 COARSE AGGREGATE PLACEMENT
A. Coarse aggregate meeting the specifications of Section 5.03.3 will be placed around the groundwater under drain pipes and in pipeless trenches. Coarse aggregate for the leachate collection layer will be placed to a one-foot depth on the PVC liner protective geotextile to the limits shown on the Drawings.

B. Care shall be taken to avoid damage to pipes and geosynthetics as discussed in the CQA Plan.

C. No vehicular traffic will be allowed directly on the composite liner or other geosynthetics.

D. The minimum one-foot depth of leachate collection layer aggregate shall be placed with track mounted low ground pressure (6 psi or less) equipment. The placement shall be accomplished in a manner that minimizes turning of the equipment.
E. Aggregate backfill around groundwater underdrain pipes shall be compacted to a minimum of 70 percent relative density (ASTM D 4253 and D 4256).

F. Culverts and discharge pipes shall be bedded and backfilled as shown on the Drawings.

5.04.2 PIPING AND LEACHATE COLLECTION, LEAK DETECTION, AND SUBSURFACE DRAINAGE INSTALLATION

A. All pipe shall be installed so that the pipe shall be in uniform contact with the bedding for its entire length. Pipe shall not be placed directly on the liner or geotextile. The pipe shall be installed on the aggregate bedding.

B. Perforated pipe shall be installed with the perforations down unless indicated otherwise on the Drawings.

C. Trench construction for the groundwater underdrain, culverts, and leachate conveyance pipes shall be performed in accordance with the following requirements:

1. Trench excavation shall be performed to the lines and grades shown on the Drawings. Before commencing trench excavation, the Contractor shall verify the invert elevation and coordinates of any existing pipe “tie in” points.

2. Care shall be exercised to avoid damage to the liner, geotextile, structures, pipes, or utilities.

3. Sheeting, bracing, and shoring shall be installed as required to safely maintain excavations and protect existing structures, utilities, and personnel as required by federal, state, and local laws and ordinances, including OSHA Subpart P.

4. Trenches for leachate collection pipes will be depressions in the liner system as shown on the Drawings, and the pipes and stone shall typically be installed as part of the liner system installation. If pipes must be installed within existing protective cover, the trench shall then be excavated into the fill with EXTREME CARE, and the trench bottom shall be a minimum of three inches above the liner. The pipe shall then be installed as required. If the liner is damaged, the Contractor shall repair the liner to the satisfaction of the Owner.

5. The minimum width of the trench shall be as shown on the Drawings and shall not be greater than that necessary to permit the Work to proceed.

6. Soft or organic material encountered at the bottom of the trench shall be removed for the full width of the trench to the depths required by the Owner and replaced with bedding material required for the pipe or utility.

7. If stones larger than three inches in diameter are encountered in the bottom of the trench, they shall be removed and the void shall be backfilled with coarse aggregate as directed by the Owner.

8. Trenches shall not be backfilled until the pipe joints are made, required tests performed, pipe encased as necessary, as built survey information is obtained, and Owner approval is granted to proceed.

9. Bedding and backfill material shall meet the requirements of the pipe manufacturer and as shown on the Drawings.

10. The pipe will be in continuous and uniform contact with the bedding.
11. Care shall be taken so as not to cause vertical or lateral displacement of pipe during backfilling. The Owner shall be notified if any difficulties are encountered.

12. Backfill around pipes shall be placed so that the elevation of the fill is the same on both sides.

13. After backfilling, the disturbed areas shall be fine graded to blend in with existing contours.

14. In the landfill liner area, aggregate backfill around leachate collection, and under pipes shall be compacted to a minimum of 70 percent relative density.

15. Trenches for underdrain pipes, culverts, and pond discharge pipes shall be excavated through natural ground or as required within fills. For pipes to be installed within base grade fills, the fill shall first be constructed to the base grade elevation prior to trench excavation.

16. When in weathered rock, or in trench excavation in rock (with Owner approval), rock encountered shall be removed to a minimum depth of 10 inches below the bottom of the pipe for the full width of the trench, and replaced with six inches of compacted common soil and four inches of crushed stone pipe bedding. Trench rock excavation shall be defined as material which cannot be excavated by a 145 HP tracked hydraulic backhoe equipped with a 1.0 cubic yard rock bucket recommended by the backhoe manufacturer to dig rock. Some trench rock excavation may be required. Blasting in any form and for any purpose will not be permitted except with the prior written approval of the Owner. Any trench rock excavation shall be performed under the direction of the Owner.

D. All solid wall leachate collection and pond discharge pipes shall be hydrostatic pressure tested at a minimum of 1.5 times the maximum operating pressure. The pipes shall be tested with potable water only.

E. The leachate collection and pond discharge pipes to the sampling chamber or manhole connections shall be as shown on the Drawings.

F. The pond orifice pipe stubs in the concrete riser shall be as shown on the Drawings.

5.04.3 VALVES

A. Valve weight should not be carried by the pipe. Valves should be supported by a concrete or steel cradle or concrete block with anchors.
SECTION 6
GEOTEXTILES

6.01 GENERAL

6.01.1 SUMMARY
A. Contractor shall furnish all supervision, labor, products, equipment, and tools, including all necessary and incidental items as detailed or required, to install geotextiles in accordance with the Contract Drawings, Specifications, and project Construction Quality Assurance (CQA) Plan.

6.01.2 RELATED WORK SPECIFIED ELSEWHERE
A. Earthwork, Base Grade and Subbase - Section 1.
B. PVC Geomembrane - Section 2.
C. HDPE Geomembrane - Section 3.
D. Piping Systems and Leachate Collection, Leak Detection, and Subsurface Drainage - Section 4.
E. Landfill Liner Protective Cover - Section 7.
F. Fabricform Lining - Section 8.
G. Rock and Grouted Rock Channel Lining - Section 10.
H. Roads - Section 15.
I. Construction Quality Assurance Plan.

6.02 REFERENCES

6.02.1 CODES AND STANDARDS
A. ASTM International Standards:

December 2019
Module V - Specifications – VDEQ, Part B Permit Application - CHSWMF


B. VDOT Road and Bridge Specification-2007, Section 245.

6.03 DEFINITIONS

6.03.1 MARV: Minimum Average Roll Value. For geosynthetics, the mean value minus two (2) standard deviations calculated from documented quality control test results for a defined population for one specific test method associated with one specific property.

6.03.2 MaxARV: Maximum Average Roll Value. For geosynthetics, the mean value plus two (2) standard deviations calculated from documented quality control test results for a defined population for one specific test method associated with one specific property.

6.04 SUBMITTALS

6.04.1 Contractor shall be responsible for timely submittals to the Owner.

6.04.1 The following submittals shall be provided with Contractor’s Bid:

A. Geotextile and Geotextile Manufacturer(s) must be approved by the Owner prior to Contract award. Submittals for approval include:

1. Geotextile Manufacturer’s specification sheet(s) demonstrating compliance with the requirements of Table 6-1.

2. Written certification that the Geotextile Manufacturer(s) has produced a minimum of 5,000,000 square feet of geotextile that has been installed for solid waste landfill purposes in the last two years, including a list of the relevant completed facilities. Each entry in this list should include the name, location, and purpose of the facility; geotextile product designation, total square footage, and date of installation; names of the Owner, Designer, and Contractor; and the name and telephone number of a contact at the facility who can discuss the project.

3. A copy of the Geotextile Manufacturer’s manufacturing quality control (MQC) manual. This manual should describe the quality control program(s) for geotextile resins and finished geotextile, and indicate the properties, test methods, and testing frequencies used for each. Geotextile Manufacturer shall modify the MQC manual to comply with the requirements of these Specifications, with any variations, deviations, or exceptions clearly noted in an attached letter.

B. The Contractor must be approved by the Owner prior to Contract award. Submittals for approval include:

1. Written certification that the Contractor has installed a minimum of 1,000,000 square feet of geotextile for solid waste landfill purposes in the last two years, including a list of the relevant completed facilities. Each entry in this list should include the name, location, and purpose of the facility; geotextile product designation, total square footage, and date of installation; names of the Owner, Designer, Primary Contractor, and CQA Consultant; and the
name and telephone number of a contact at the facility who can discuss the project.

2. A copy of the Contractor's construction quality control (CQC) manual. This manual should describe the quality control program for handling, deploying, anchoring, seaming, and repairing geotextile. Contractor shall modify the CQC manual to comply with the requirements of these Specifications and the project CQA Plan, with any variations, deviations, or exceptions clearly noted in an attached letter.

6.04.3 The following submittals shall be provided after award of Contract:

A. Geotextile Manufacturer:

1. Prior to or coincident with shipment of geotextile to the project site, submit written certification and supporting test data documenting that all finished geotextile(s) shipped to the project site comply with the requirements of Section 6.02. This shall include:
   a. Nonwoven and woven polypropylene (PP) geotextile resin (Section 6.06.1.C and 6.06.2.C). Certifications shall state the producers, product designations, lot or batch numbers, and production dates of all resins used in the manufacture of geotextile(s) shipped to the project site and shall include copies of all quality control certificates issued by the resin producer.
   b. Nonwoven and woven PP geotextile formulations (Section 6.06.1.B and 6.06.2.B). Certifications shall state that all formulations used to produce geotextile(s) shipped to the project site comply with the requirements of Section 6.06.1.B and 6.06.2.B.
   c. Finished nonwoven and woven PP geotextile (Section 6.06.1.D and 6.06.2.D). Certifications shall include copies of all Quality Control Certificates that have been reviewed and signed by a responsible representative of the Geotextile Manufacturer(s). Include two samples of finished geotextile(s), 1 yd² each, for project records of the Owner and CQA Consultant. Each sample shall be labeled with the manufacturer's name, product designation, lot number, roll number, and date of sampling.

B. Contractor:

1. Within four weeks after completion of geotextile installation, submit a written report containing the following:
   a. Written certification stating that the geotextile has been installed in accordance with the Contract Drawings, Specifications, and project CQA Plan.
   b. Product and installation warranties as required by Section 6.03.8.
   c. Copies of daily field records.
6.05 CONSTRUCTION QUALITY ASSURANCE AND QUALITY CONTROL

6.05.1 Geotextile CQA will be performed by the CQA Consultant and paid for by the Owner. Geotextile CQA will be performed in accordance with these Specifications and the project CQA Plan.

6.05.2 Geotextile CQC will be performed by the Contractor in accordance with the CQC manual approved by the Owner.

6.06 MATERIALS

6.06.1 NONWOVEN GEOTEXTILE

A. The physical, mechanical, and chemical properties of the geotextiles shall comply with the requirements of Table 6-1. During production, geotextiles shall be continuously inspected for the presence of broken needles, which shall be removed from the finished product.

B. Geotextile formulations shall consist of at least 95 percent (by weight) polypropylene resin, one percent to three percent (by weight) of carbon black (added for ultraviolet radiation resistance), and a maximum of two percent (by weight) of other additives. No plasticizers, fillers, extenders, post-consumer resin (PCR), or other materials shall be mixed into the formulation. Rework or trim materials may be added to the formulation if they are produced by the Geotextile Manufacturer and are of the same formulation as the geotextile being produced. Rework and trim materials shall not exceed 10 percent (by weight) of the geotextile formulation.

C. Polypropylene resin used in the manufacture of nonwoven geotextile is to be made from virgin, uncontaminated ingredients and shall be designed and manufactured specifically for producing geotextile. Incoming resin shall be sampled and tested in accordance with the Geotextile Manufacturer’s MQC program. Testing frequencies, test procedures, and resin properties shall comply with the requirements of Table 6-1. Results from the resin sampling and testing program are to be submitted to the Owner in accordance with Section 6.04.3.A.1.b.

D. Nonwoven geotextile shall be sampled and tested in accordance with the Geotextile Manufacturer’s approved MQC manual. Testing frequencies, test procedures, and PP nonwoven geotextile properties shall comply with the requirements of Table 6-1. Results from the geotextile sampling and testing program are to be submitted to the Owner in accordance with Section 6.04.3.A.1.c.

E. See Section 6.06.3 for additional geotextile requirements.

6.06.2 WOVEN GEOTEXTILE

A. The physical, mechanical, and chemical properties of the woven monofilament polypropylene (PP) geotextile shall comply with the requirements of Table 6-1.

B. Geotextile formulations shall consist of at least 95 percent (by weight) polypropylene resin, one percent to three percent (by weight) of carbon black (added for ultraviolet radiation resistance), and a maximum of two percent (by weight) of other additives. No plasticizers, fillers, extenders, post-consumer resin (PCR), or other materials shall be mixed into the formulation. Rework or trim materials may be added to the formulation if they are produced by the Geotextile Manufacturer and are of the same formulation as the geotextile being produced. Rework and trim materials shall not exceed 10 percent (by weight) of the geotextile formulation.
C. Polypropylene resin used in the manufacture of woven geotextile is to be made from virgin, uncontaminated ingredients and shall be designed and manufactured specifically for producing geotextile. Incoming resin shall be sampled and tested in accordance with the Geotextile Manufacturer’s MQC program. Testing frequencies, test procedures, and resin properties shall comply with the requirements of Table 6-1. Results from the resin sampling and testing program are to be submitted to the Owner in accordance with Section 6.04.3.A.1.b.

D. Woven geotextile shall be sampled and tested in accordance with the Geotextile Manufacturer's approved MQC manual. Testing frequencies, test procedures, and PP woven geotextile properties shall comply with the requirements of Table 6-1 of this Section. Results from the geotextile sampling and testing program are to be submitted to the Owner in accordance with Section 6.04.3.A.1.d.

E. See Section 6.06.3 for additional geotextile requirements.

6.06.3 ADDITIONAL GEOTEXTILE REQUIREMENTS

A. All geotextiles shall be produced free of holes, tears, contamination by foreign matter, dimensional abnormalities, or other defects. The CQA Consultant may reject all or portions of units (rolls) of geotextile shipped to the project site if significant production flaws are observed.

B. Geotextile(s) shall be manufactured as a continuous panel having a nominal width of 14 feet and minimum length of 300 feet in order to reduce the amount of field seaming required during installation. Rolls of geotextile having lengths shorter than 300 feet may be shipped to the project site if the number of such rolls is approved by the Owner prior to shipment.

C. Geotextile shall be rolled onto hollow cores having a minimum inside diameter of four inches to allow the use of a stinger or spreader bar assembly for handling and deployment. Cores shall be of stable construction such that they support the roll without excessively deflecting, buckling, or otherwise failing during handling, transportation, and storage. Each roll of geotextile shall be protected by wrapping it in packaging that is waterproof, resistant to photodegradation by ultraviolet light, and completely covers all exposed geotextile surfaces and edges.

D. Each geotextile roll shall be labeled to identify the Geotextile Manufacturer, product designation, manufacturer’s lot number, manufacturer’s roll number, and the length, width, and weight of each roll. Roll identification numbers shall conform to the numbering system established on the Geotextile Manufacturer’s Quality Control Certificates. Labels shall be weather proof, legible, and located so that each roll of geotextile can be identified by examining the outside of the roll or the core ends.

E. At the option of the Owner may inspect the geotextile manufacturing process on a full-time basis. This inspection program would include conformance sampling as required. If requested, Geotextile Manufacturer(s) shall submit a production schedule to the Owner and cooperate with the Owner during plant inspection.

F. All finished geotextile properties, including testing frequencies and test procedures used, shall meet the requirements of this Section. No geotextile shall be installed until the Owner has reviewed all certifications and supporting test data and
determined that the geotextile(s) delivered to the project site is acceptable for use. Manufacturing records, including test data, shall be maintained by the Geotextile Manufacturer for two years after acceptance of the geotextile(s), and shall be made available upon request.

6.06.4 SEWING THREAD
A. Thread for sewing geotextiles together in the field shall be made from the same type of polymer as the geotextiles being sewn together. Sewing thread should be a color that contrasts the geotextile color to facilitate CQA inspection.

6.07 INSTALLATION
6.07.1 PRE-INSTALLATION MEETING
A. Prior to scheduled geotextile installation, the Owner, CQA Consultant, Contractor, and Contractor shall attend a pre-installation meeting at the project site. The Contractor shall be represented by both the project field superintendent and the project manager. At the pre-installation meeting, site safety and rules of operation, scheduling, methods of installation, and construction quality control and quality assurance shall be discussed. The Contractor, Owner, and CQA Consultant shall at this time agree to the required geotextile placement, seaming, and repair procedures for the project.

6.07.2 SHIPPING, HANDLING, AND STORAGE
A. Contractor is responsible for proper shipping, unloading, and storage of the geotextile. Geotextile damaged during shipping, unloading, or storage shall be repaired or replaced at no cost to the Owner.

B. Geotextile rolls shall be packaged and shipped so that no damage is caused during delivery to the project site. Geotextile shipping shall be by open or enclosed trailers loaded in such a manner that rolls can be readily unloaded at the project site using slings, a stinger, or a spreader bar assembly. Geotextile rolls shipped by open trailer shall be protected with a sacrificial or temporary cover during shipment.

C. During unloading at the project site, Contractor shall conduct a surface inspection of all geotextile rolls for defects and damage, including damage to the original protective packaging. Contractor shall immediately notify CQA Consultant and Owner of any defects or damage observed.

D. Extreme care shall be taken by all personnel while unloading and handling geotextile. Equipment used to unload and handle geotextile shall have sufficient capacity to manage the roll weight without damaging the geotextile. Geotextile shall only be unloaded and handled using slings, a stinger, or a spreader bar assembly recommended by the Geotextile Manufacturer or accepted by the CQA Consultant. Pushing, sliding, or dragging of geotextile rolls is not permitted. CQA Consultant shall have the option of inspecting all geotextile panels, prior to final placement, to verify that all defects or damage are identified for repair.

E. Geotextile shall be stored at the project site in an area(s) designated by the Owner and accepted by the CQA Consultant. Contractor shall grade the storage area so
that it is reasonably level and well-drained, and shall prepare the ground surface so that it is firm, smooth, and free of stones, sticks, or other materials that may damage the geotextile.

F. Geotextile rolls shall be stored off the ground and continuously supported along their length. Stacking of geotextile rolls for storage is allowed but should not be so high that crushing of cores or flattening of rolls occurs. In general, the maximum stacking limit is eight rolls high. A suitable means of securing the rolls shall be used so that shifting or other adverse movement does not occur.

G. During storage, geotextile shall be protected from moisture, direct sunlight, mud, and excessive dust by covering the rolls with a plastic sheet or waterproof tarpaulin. Roll labels shall remain intact and legible. Any roll of geotextile that has no label or where the label is damaged or otherwise illegible may be rejected by the CQA Consultant. Geotextile rolls shall be kept in their original protective packaging until immediately before they are to be deployed.

6.07.3 QUALITY ASSURANCE CONFORMANCE TESTING

A. Quality assurance conformance testing of the geotextile(s) shall be performed by the CQA Consultant and paid for by the Owner. Conformance testing lab results shall be provided directly to Owner and CQA Consultant for review upon receipt of testing data from lab. Conformance sampling and testing shall be completed in accordance with the project CQA Plan, with at least one sample per production 100,000 sq. ft. as directed by the Owner. Owner has the option to increase the frequency of conformance testing or to sample and test any questionable roll or lot.

B. The Owner may revise the test methods used for determination of conformance properties to allow for use of new or revised methods.

C. All geotextile conformance test results shall comply with the requirements of Table 6-1 prior to installation. Any geotextile that does not conform to these requirements shall be retested or rejected in accordance with the CQA Plan.

D. Geotextile that is rejected shall be removed from the project site and replaced at no cost to the Owner. Sampling and conformance testing of geotextile supplied as replacement for rejected material shall be performed by the CQA Consultant at Contractor’s cost.
6.07.4 DEPLOYMENT AND PLACEMENT

A. The Owner, in conjunction with the Contractor, shall establish site-specific limits of weather conditions, including, but not limited to, precipitation and wind speed and direction, within which geotextile panel placement can be conducted. In the absence of site specific criteria, the following limitations shall apply:

1. If thermal seaming methods are to be used, no placement shall be conducted in the presence of precipitation, such as rain, snow, or sleet.

2. No placement shall be conducted in the presence of winds in excess of 20 miles per hour or when dirt or debris is blown into working areas.

B. Contractor shall maintain a daily field record of actual placement of geotextile, noting base grade conditions, weather, roll numbers placed, and seaming methods. A copy of each day’s field record shall be furnished to the CQA Consultant no later than the following work day.

C. Geotextile shall only be placed on surfaces (soil, aggregate, or geomembrane) that have been installed in accordance with the Contract Drawings and Specifications, and have been accepted in writing by the Contractor and CQA Consultant. Once a surface has been accepted by the CQA Consultant, any additional surface preparation that the Contractor feels necessary to meet the requirements of the Specifications shall be the responsibility of the Contractor. Geosynthetic surfaces should have all folds, wrinkles, and other undulations removed and shall be free of rocks, dirt, tools, or other debris before placing geotextile. Areas the Contractor believes exhibit deficient surface conditions shall be reported to the CQA Consultant and Owner for repair.

D. Contractor shall coordinate placement of the geotextile with placement of the covering material (coarse aggregate, fabricform, etc.). All geotextiles shall be covered within 30 days after they are placed to prevent deterioration. Any geotextile that deteriorates or is otherwise damaged prior to placement of covering material shall be removed and replaced by the Contractor, as directed by the CQA Consultant, at no cost to Owner.

E. It is imperative to keep surface water runoff containing sediment or other debris from contacting the geotextile at all times during installation. Contractor’s panel placement techniques and covering schedule shall minimize or eliminate the potential for accumulation of sediment or other debris on the geotextile. Contractor shall remove accumulated sediment or debris by sweeping, hosing, or other methods accepted by the CQA Consultant, prior to covering the geotextile. Any geotextile that cannot be adequately cleaned shall be removed and replaced by the Contractor, as directed by the CQA Consultant, at no cost to Owner.

F. Extreme care shall be taken by all personnel while handling, unwrapping, deploying, and placing geotextile. Equipment and tools used shall not stretch, tear, or otherwise damage the geotextile, and shall not cause damage to the underlying base grade. Equipment shall have sufficient capacity to manage the roll weight without damaging the geotextile. Pushing, sliding, or dragging of geotextile rolls is not permitted.

G. Under no circumstances shall any construction or vehicular traffic be allowed to drive over exposed geotextile. Geotextile showing evidence of trafficking shall be
inspected by the Contractor and CQA Consultant to evaluate damage, if any. At the direction of the CQA Consultant, any damaged geotextile shall be repaired or replaced at no cost to Owner. CQA Consultant may allow limited use of four-wheeled ATVs or other low ground pressure equipment (having 6 psi or less contact pressure) by the Contractor during installation, but use shall be prohibited if excessive trafficking or any geotextile damage is observed.

H. Geotextile rolls shall be transported from the storage area to the working area in their original protective packaging. After packaging is carefully removed, geotextile shall be unrolled and placed in such a manner as to minimize dragging of panels into position (“spotting”).

I. Contractor shall immediately provide temporary anchorage of the geotextile to prevent wind uplift and panel movement during placement of covering materials (coarse aggregate, fabricform, etc.). Temporary anchorage methods shall be approved by the Owner and CQA Consultant. Any geotextile exhibiting damage due to insufficient or improper temporary anchorage shall be repaired or replaced, as directed by the CQA Consultant, at no cost to the Owner.

J. Geotextile shall be installed so that is in continuous contact with the base grade surface without being tensioned.

K. Geotextile panel seams (edges) shall be oriented in a direction parallel to the line of maximum base grade slope (i.e., down, not across the slope) and shall be placed in a manner that minimizes the number and length of field seams. Longitudinal seams are permitted on sideslopes, but must be staggered in a manner approved by the Owner and CQA Consultant.

L. All geotextile panel seams shall be shingled as required in order to minimize the possibility of lifting panel edges during placement of covering material (coarse aggregate, fabricform, etc.).

6.07.5 SEAMING

A. A combination of lap joints and sewing shall be used to join geotextile panels in the field. Thermal seaming methods may be accepted if successfully demonstrated in the field and approved by the Owner’s Agent and CQA Consultant. All geotextile panels should be seamed as soon as possible after they are placed and prior to being covered.

B. Lap joints shall be constructed using a minimum overlap of 18 inches for panel edges and panel ends. Overlap areas shall be kept free of rocks, loose soil, or other debris. For sewn seams, geotextile overlaps on panel edges shall be joined with a flat (“prayer”) seam using two rows of Type 401 stitching. All sewn seams shall be continuous and completed using thread made from the same type of polymer as the geotextiles being sewn together. Sewing thread should be a color that contrasts the geotextile color.

C. Completed geotextile seams shall lay flat and be free of any rocks, loose soil, or other debris. Where wrinkles or folds do occur, the material shall be cut, overlapped, and a patch applied in accordance with Section 6.07.6.
6.07.6 REPAIRS

A. During installation, Contractor and CQA Consultant shall visually inspect all geotextile panels and seams for damage, defects, or non-compliance with the Contract Drawings and Specifications, and shall mark any such areas for repair. Contractor shall repair marked areas as soon as possible and prior to covering the geotextile.

B. Acceptable geotextile repair methods include:

1. Patching: For repair of surface defects, small tears, punctures, etc. Patches shall have a minimum size of 24 inches by 24 inches and extend at least 12 inches beyond the edge(s) of a defect. Patches shall be secured to original geotextile using adhesive or by hot air bonding (“leistering”) around the patch.

C. If an area to be repaired is more than 50 percent of the width of a geotextile panel, the damaged area shall be removed across the entire panel width and the two remaining portions of geotextile shall be joined in accordance with Section 6.03.5. Such repair areas shall be explicitly approved by the CQA Consultant prior to making the repair.

6.07.7 ACCEPTANCE AND COVERING

A. No geotextile shall be covered until it has been accepted by the CQA Consultant in writing.

B. Contractor shall repair any areas identified by the CQA Consultant as not being in accordance with the Contract Drawings and Specifications. Once all repairs are completed and accepted by the CQA Consultant, geotextile shall immediately be covered in accordance with the Contract Drawings and Specifications.

C. All geotextiles shall be covered within 30 days after they are placed to prevent deterioration. Any geotextile that deteriorates or is otherwise damaged prior to placement of covering shall be removed and replaced by the Contractor, as directed by the CQA Consultant, at no cost to Owner.

D. If textured geomembrane is used to cover the geotextile, a smooth temporary geosynthetic covering (“slip sheet”) shall be used to protect the upper surface of the geotextile from damage until the geomembrane is in its final position for seaming.

6.07.8 WARRANTIES

A. Contractor shall be responsible for obtaining any necessary guarantees or certifications from the Geotextile Manufacturer and Contractor and submitting them to the Owner prior to acceptance of installed geotextile.

B. Contractor shall guarantee the integrity, within the realm of limitations of Contractor’s responsibility, of the installed geotextile for its intended use, from installation defects for a period of two years from the date of geotextile installation, and from manufacturing defects for a period of 2 years from the date of geotextile installation.
### Table 6-1
**REQUIRED PROPERTIES OF GEOTEXTILES**

<table>
<thead>
<tr>
<th>Property (Units)</th>
<th>MQC Testing Frequency (minimum)</th>
<th>Test Method (2)</th>
<th>Required Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Woven</td>
<td>Nonwoven</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Retention</td>
<td>Filter/Retention</td>
</tr>
<tr>
<td>Resin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density (g/cc)</td>
<td>1 per Resin Batch</td>
<td>ASTM D 1505</td>
<td>.909 (min)</td>
</tr>
<tr>
<td>Melt Flow Index</td>
<td>1 per Resin Batch</td>
<td>ASTM D 1238,</td>
<td>3.5 (min)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Condition 230/2.16</td>
<td></td>
</tr>
<tr>
<td>Finished Geotextile(3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass per unit Area (oz/yd²)</td>
<td>Every 100,000 ft²</td>
<td>ASTM D 5261</td>
<td>14.5</td>
</tr>
<tr>
<td>Grab Tensile Strength (lb)</td>
<td>Every 100,000 ft²</td>
<td>ASTM D 4632</td>
<td>250</td>
</tr>
<tr>
<td>Grab Tensile Elongation (%)</td>
<td>Every 100,000 ft²</td>
<td>ASTM D 4632</td>
<td>50 (min)</td>
</tr>
<tr>
<td>Tear Strength (lb)</td>
<td>Every 100,000 ft²</td>
<td>ASTM D 4533</td>
<td>100</td>
</tr>
<tr>
<td>Puncture Strength (lb)</td>
<td>Every 100,000 ft²</td>
<td>ASTM D 6241</td>
<td>150</td>
</tr>
<tr>
<td>Burst Strength (lb/in²)</td>
<td>Every 100,000 ft²</td>
<td>ASTM D 6241</td>
<td>460</td>
</tr>
<tr>
<td>Permittivity (sec⁻¹)</td>
<td>Every 500,000 ft²</td>
<td>ASTM D 4491</td>
<td>0.4</td>
</tr>
<tr>
<td>AOS (mm)</td>
<td>Every 500,000 ft²</td>
<td>ASTM D 4751</td>
<td>0.15 (MaxARV)</td>
</tr>
<tr>
<td>UV Stability (% strength retained at 500 hours)</td>
<td>Per Formulation</td>
<td>ASTM D 4355</td>
<td>70</td>
</tr>
<tr>
<td>Tensile Strength (at ultimate)</td>
<td>Every 500,000 ft²</td>
<td>ASTM D 4595</td>
<td>4,800 (lbs/ft)</td>
</tr>
<tr>
<td>Tensile Strength (at 2% strength)</td>
<td>Every 500,000 ft²</td>
<td>ASTM D 4595</td>
<td>960 (lbs/ft)</td>
</tr>
<tr>
<td>Tensile Strength (at 5% strength)</td>
<td>Every 500,000 ft²</td>
<td>ASTM D 4595</td>
<td>2,400 (lbs/ft)</td>
</tr>
<tr>
<td>Tensile Strength (at 10% strength)</td>
<td>Every 500,000 ft²</td>
<td>ASTM D 4595</td>
<td>4,800 (lbs/ft)</td>
</tr>
</tbody>
</table>

**Notes:**

(1) The required properties specified herein may be revised by the Design Engineer to reflect new or revised test methods or to conform with improvements to the state-of-the-practice.

(2) Number of specimens per test established in applicable test method unless otherwise noted.

(3) Unless otherwise noted, required values are minimum average roll values (MARV).
SECTION 7
LANDFILL LINER PROTECTIVE COVER

7.01 GENERAL
7.01.1 DESCRIPTION OF WORK
This section includes technical requirements for the protective cover over the liner system in the landfill.

7.01.2 RELATED WORK SPECIFIED ELSEWHERE
A. Piping Systems and Leachate Collection Groundwater Drainage – Section 5.

7.02 REFERENCES
7.02.1 CODES AND STANDARDS
A. ASTM Standard D 422, "Standard Method for Particle Size Analysis of Soils".
B. VDOT, Road and Bridge Specifications - 2007.

7.03 MATERIAL REQUIREMENTS
7.03.1 AGGREGATE
A. Protective Cover medium shall be a coarse material with a minimum hydraulic conductivity of 1x10^-3 cm/sec. A material similar to VDOT Fine Aggregate A gradation is acceptable.

B. Other aggregate gradations that meet hydraulic conductivity may be used if filter compatibility can be demonstrated between the FFP, protective cover, and LCL. Materials other than VDOT Fine Aggregate A gradation must be approved by the Owner’s Engineer, verifying the material has acceptable hydraulic conductivity and filter compatibility.

C. Aggregate shall be tested for permeability, gradation, and carbonate content in accordance with the CQA/QC Plan.

D. If filter compatibility cannot be achieved with the Contractor’s proposed protective cover aggregate, the Owner may accept the material with the incorporation of a “filter” geotextile within the protective cover and leachate collection layer matrix. The geotextile will typically be a non-woven, needle-punched geotextile meeting the requirements of a “filter geotextile” in Table 6-1. However, the type of geotextile and placement location shall be determined by the Owner’s Engineer, based on the aggregate characteristics.

E. The aggregate shall be manufactured from natural material and consist of angular, hard, tough, durable, uncoated particles; free of organic matter, coal, iron, shale, clay or weak, flat, elongated, argillaceous, minacious or decomposed material. It shall not be made of acid forming or toxic forming rock or slag.

F. Rock and stone shall be of a quality that will withstand the action of water, frost, and other weathering. Fully rounded rocks or boulders shall not be used.

G. Limestone, dolomite, or other materials with a carbonate content exceeding 15% shall not be used (sandstone, basalt and gneiss are acceptable materials) in the LCL.
H. The Contractor shall supply the Owner with the source of material, grain-size analysis, and material certification before any material is accepted.

7.03.2 BOTTOM ASH

Bottom Ash from the Virginia City Hybrid Energy Center may be used if it meets the minimum hydraulic conductivity requirement and acceptable filter compatibility can be achieved.

7.04 PLACEMENT REQUIREMENTS

7.04.1 The perimeter liner termination area must be ballasted or covered as shown on the Drawings prior to placement of the leachate collection layer. The fine aggregate will be placed in one 12-inch lift above the leachate collection GDN and one 6-inch lift above the leachate collection coarse aggregate.

7.04.2 Protective cover shall be placed as soon as possible upon installation of the leachate collection system. No vehicular traffic of any kind will be allowed directly on the pipes or geosynthetics. Protective cover shall be end dumped and pushed into place using a track mounted buldozer with a ground pressure not to exceed 6 psi. On slopes, the protective cover shall be placed from the low side and pushed uphill. Vehicular traffic on the protective cover shall be kept to an absolute minimum. Repeated traffic over the protective may adversely affect the permeability of the layer. The Contractor shall remove any over trafficked protective cover to the satisfaction of the Owner. Protective cover compaction shall consist of one pass of the track area of the dozer used for placement over the entire work area.

7.04.3 No bottom ash protective cover shall be placed upgradient of any uncompleted or unapproved liner seam where runoff water could flow off of or under the edge of liner. Rubber tired equipment shall not be used until at least three feet of material has been placed over the liner.

7.04.4 When rubber tired equipment is used on steeply sloped areas, trafficability problems may be encountered. In the event that the rubber tired vehicle’s tires begin to spin, the vehicle should be pulled out with track equipment to avoid possible damage to the liner system. Any damage to the liner system caused by Contractor’s operations shall be repaired at Contractor’s expense.

7.04.5 The Owner reserves the right to direct the Contractor to uncover suspected damaged areas of the liner system and has the option to dictate removal of any equipment or equipment operator noted to create damage or distress to the liner system. Any necessary repair work and cost of exposing the liner for inspection shall be performed at the Contractor’s cost. The Owner shall be the sole judge as to determining the extent of damage or distress and the adequacy of the repair.

7.04.6 In no instance shall equipment with teeth on the bucket or blade be allowed to operate within three feet vertically of any geosynthetic material.

7.04.7 In no instance shall equipment travel directly on any geosynthetic material. Only track equipment with ground pressures not to exceed 6 psi shall be allowed to routinely cross liner or geotextile areas provided a minimum of 12 inches of cover is maintained. Lightweight rubber-tired vehicles (e.g., pickup trucks) may occasionally cross the area as long as 18 inches of cover is maintained, turning is minimal and the vehicle wheels do not slip. The Contractor shall build a liner crossing area for any temporary access roads that cross the liner edge. The liner crossing shall consist of a minimum of two feet of AASHTO No. 57 or No. 8 aggregate (or similar stone) placed atop the liner system, then a filter geotextile, and then a minimum two feet of approved cover material. Temporary access roads within the lined landfill
area shall consist of a minimum of four feet of approved cover material atop the liner system. The Contractor shall maintain all temporary liner crossing areas and access roads as required. At the completion of protective cover placement activities, the Contractor shall remove all temporary liner crossing areas as called out and shown on the Drawings for the liner edge in that area.

7.04.8 The Owner reserves the right to direct the Contractor to replace an equipment operator who displays reckless operation of equipment that threatens damage to the liner system. It is the Contractor's responsibility to see that only equipment operators with experience in liner installation will be utilized in the placement of the protective cover material over the liner system.

7.04.9 It is the Contractor's responsibility to control and repair rainfall washouts or runoff damage to drainage layers or liner components. The Contractor should avoid exposing large areas of liner, which promotes rapid runoff, and should plan an orderly progression of installation and protection of the drainage layers and liner components. All repairs to damaged components shall be completed to the satisfaction of the Owner at no additional expense.

7.04.10 Rain covers (polyethylene tarps) may be placed over newly constructed leachate collection and protective cover layers in order to protect the aggregates from rainfall washouts, runoff damage, or to limit infiltration into the LCL by diverting surface runoff. The type of rain cover, the area to be covered, and the installation method must be approved by the Owner's Engineer.
SECTION 8
FABRICFORM LINING

8.01 GENERAL
8.01.1 DESCRIPTION OF WORK
This section includes the technical requirements for furnishing and installing the Uniform Section Mat (USM) revetment and Filter Point (FP) lining. The Work shall consist of installing a concrete lining by positioning a specially woven double layer synthetic fabricform on the surface to be protected, and filling it up with a pumpable fine aggregate concrete (structural grout) in such a way as to form a stable mat of required thickness, weight, and configuration.

8.01.2 ITEMS INCLUDED IN THIS SECTION
A. Furnish and install a USM lining or revetment.
B. Furnish and install a FP lining.

8.01.3 RELATED WORK SPECIFIED ELSEWHERE
A. Earthwork, Base Grade and Subbase - Section 1.
B. Geotextiles - Section 6.

8.02 REFERENCES
8.02.1 CODES AND STANDARDS
A. American Society for Testing and Materials (ASTM) Standards:

1. C 31, "Standard Practice for Making and Curing Concrete Test Specimens in the Field".
2. C 33, "Standard Specification for Concrete Aggregates".
5. C 192, "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory".
8. C 618, "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan Use in Concrete".


8.03 MATERIAL REQUIREMENTS

8.03.1 GROUT OR FINE AGGREGATE CONCRETE

A. Grout shall consist of a mixture of Portland cement, fly ash, fine aggregate sand, and water so proportioned and mixed as to provide a pumpable grout. Grout fluidifier conforming to these Specifications may be used at the option of the Contractor. The mix shall exhibit a compressive strength of 3,000 psi at 28 days when made and tested in accordance with ASTM C 31 and ASTM C 39.

1. Portland cement shall conform to ASTM C 150, Type II.
2. Fine aggregate shall conform to ASTM C 33, except as to grading. Aggregate grading shall be reasonably consistent and shall be well graded from the maximum size which can be conveniently handled with available pumping equipment.
3. Water for mixing shall be clean and free from injurious amounts of oil, acid, salt, alkali, organic matter, or other deleterious substances.
4. Fly ash shall conform to ASTM C 618 and be Class C or Class F fly ash with the exception that LOI can be up to 12 percent. To aid in pumpability, a pozzolan grade fly ash may be used as a substitute for up to 20 percent of the cement.
5. Grout fluidifier, if used, shall be a super-plasticizer agent conforming to ASTM C 494. The grout fluidifier shall serve the purpose of causing more efficient hydration of cement with the resulting higher strength.
6. Air-entraining admixtures shall conform to the requirements of ASTM C 260. The air content shall be five to eight percent for improved pumpability and resistance to freeze thaw.
7. Calcium chloride or admixtures containing more than trace amounts of calcium chloride, chlorides, sulfides, or nitrates shall not be used.

8. Coarse aggregate used in the grout as trench backfill shall conform to ASTM C 33.

9. A retarding admixture may be used in hot weather.

10. The typical range of mix proportions is as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>Mix Proportions (lbs./cubic yard)</th>
<th>After Placement (lbs./cubic yard)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>750 - 850</td>
<td>815 - 920</td>
</tr>
<tr>
<td>Sand</td>
<td>2,030 - 2,120</td>
<td>2,195 - 2,275</td>
</tr>
<tr>
<td>Water</td>
<td>540 - 555</td>
<td>460 - 470</td>
</tr>
<tr>
<td>Air</td>
<td>As Required</td>
<td></td>
</tr>
</tbody>
</table>

11. Grout consistency should be in the 9 to 12 second range when passed through the three quarter inch orifice of the standard flow cone described in ASTM C 939. Tests utilizing a concrete slump cone are not appropriate.

8.03.2 FABRICFORM

A. The fabricforms shall be TEXICON three inch, four inch, six inch, and eight inch USM and four inch FP as shown on the Drawings, manufactured by Donnelly Fabricators, or approved equal. Each layer of fabric shall meet or exceed the statistical mean (average) results as shown below:

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Composition</td>
<td>ASTM D 5261</td>
<td>Nylon</td>
</tr>
<tr>
<td>Weight (double-layer)</td>
<td>ASTM D 5199</td>
<td>12 oz/yd²</td>
</tr>
<tr>
<td>Thickness</td>
<td></td>
<td>25 mil</td>
</tr>
<tr>
<td>Mill Width</td>
<td></td>
<td>76 inches</td>
</tr>
<tr>
<td>Mechanical Wide-Width Tensile Strength Machine Cross Elongation at Break Machine Cross Trapezoid Tear Strength Machine Cross</td>
<td>ASTM D 4595</td>
<td>140 lbs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>110 lbs</td>
</tr>
<tr>
<td></td>
<td>ASTM D 4595</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>ASTM D 4533</td>
<td>150 lbs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 lbs</td>
</tr>
<tr>
<td>Hydraulic Apparent Opening Size Flow Rate Flow Rate through FP Only</td>
<td>ASTM D 4751</td>
<td>40 Sieve</td>
</tr>
<tr>
<td></td>
<td>ASTM D 4491</td>
<td>90 gal/min/sf</td>
</tr>
<tr>
<td></td>
<td>ASTM D 4491</td>
<td>7 gal/min/sf</td>
</tr>
<tr>
<td>Spacer Cord Break Strength</td>
<td>ASTM D 2256</td>
<td>160 lb/cord</td>
</tr>
</tbody>
</table>
The Contractor shall furnish to the Owner, the manufacturer’s certified test results showing actual test values obtained when the above physical properties were tested for compliance with the Specifications.

B. Fabricform material for USM shall consist of a double-layer woven fabric joined together by spacer cords, of uniform length, to produce a mat with finished nominal thickness as specified on the Drawings. Points of connection shall be staggered to provide a bonded cobbled surface appearance.

C. Fabricform material for FP shall consist of double-layer woven fabric joined together by spaced interwoven FPs to form a lining with a nominal finished thickness as specified on the Drawings, and a deeply cobbled surface appearance. After the form has been filled with fine aggregate concrete, the FP shall be on approximate spacing specified by the manufacturer, when measured along the diagonal. FPs shall be formed by interweaving the double layer fabric to form water permeable drains and attachment points for the control of concrete lining thickness. The interweaving of the fabric layers shall form an area of double density, high strength, single layer fabric with an area and perimeter as specified by the manufacturer. All FPs shall be cross shaped and shall have twill weave centers designed to function as drains to relieve hydrostatic uplift pressure.

D. Individual mill width rolls of fabricform shall be a minimum width of 76 inches. Each salvage edge of the top and bottom layers of fabric shall be reinforced for a width of not less than 1.35 inches by adding a minimum of six yarns to the warp construction. Mill width rolls shall be cut to the length required, and the two layers of fabric separately joined bottom edge to bottom edge, and top edge to top edge, by means of sewing thread to form multiple mill width panels with sewn seams on not less than 72-inch centers. All factory sewn seams shall be downward facing and shall not be less than 90 pounds per inch when tested in accordance with ASTM D 4884.

E. Grout stops shall be installed at predetermined, mill width intervals to regulate the lateral flow of fine aggregate concrete. The grout stop material shall be nonwoven filter fabric. The grab tensile strength of the filter fabric shall not be less than 90 pounds when tested in accordance with ASTM D 4632.

F. The fabricforms shall be kept dry and wrapped such that they are protected from the elements during shipping and storage. If stored outdoors, they shall be elevated and protected with a waterproof cover that is opaque to ultraviolet light. The fabricforms shall be labeled as per ASTM D 4873.

G. The Contractor shall submit a manufacturer’s certificate that the supplied fabricforms meet the criteria of these Specifications, as measured in full accordance with the test methods and standards referenced herein. The certificates shall include the following information about each fabricform delivered:

1. manufacturer’s name and current address;
2. full product name;
3. style and product code number;
4. form number(s);
5. composition of yards; and
6. manufacturer’s certification statement.

8.03.3 GEOTEXTILE
A. Geotextile shall be as shown on the Drawings and as specified in Section 6 - Geotextiles.

8.03.4 SHOP DRAWINGS
A. Shop drawings of the materials, equipment, method of installation, installation details for the complete system, and manufacturer’s product literature and specifications for this installation shall be submitted prior to start of the installation for Owner review and acceptance.

8.04 INSTALLATION
8.04.1 SITE PREPARATION
A. Areas on which fabricforms are to be placed shall be constructed to the lines, grades, and dimensions shown on the Drawings.
B. All obstructions, such as roots and projecting stones, shall be removed and the fabricform shall be placed on filter geotextile that has been placed on a clean, smooth surface.
C. Excavation and preparation of perimeter liner termination areas, terminal trenches, and lap joint trenches shall be performed in accordance with the lines, grades, and dimensions shown on the Drawings.
D. Immediately prior to placing the fabricforms, the prepared area shall be inspected by the Owner and no forms shall be placed thereon, until the area has been approved.
E. No fabricforms shall be placed over the liner system until after the synthetic liner assembly installation has been approved by the Owner.

8.04.2 GEOTEXTILE
A. Geotextile shall be placed as shown on the Drawings and in accordance with Section 6 - Geotextiles.

8.04.3 FABRICFORM PLACEMENT
A. Fabricform panels shall be placed within the limits shown on the Drawings.
B. Adjacent fabricform panels shall be joined before fine aggregate concrete injection by field sewing or zippering the two bottom layers of fabric together and the two top layers of fabric together. All sewn seams shall be downward facing except with the approval of the Owner. All field seams shall be made using two lines of U.S. Federal Standard Type 101 stitches. All sewn stitches shall be downward facing, and shall be not less than 90 pounds per inch when tested in accordance with ASTM D 4884.
C. When conventional joining of panels is impractical, or where called for on the Drawings, adjacent panels may be overlapped a minimum of three feet pending approval by the Owner. In no case shall simple butt joints between panels be permitted.
D. Lap joints and expansion joints shall be provided as required.
E. Immediately prior to injection of fine aggregate concrete, the assembled fabricform panels shall be inspected by the Owner and no fine aggregate concrete shall be pumped therein until the fabric seams, panel connections, and anchor system have been approved. At no time shall the fabricforms be exposed to ultraviolet light (including sunlight) for a period exceeding five days prior to concrete injection.

F. No joints shall be placed within channel bends or within 15 feet upstream or downstream of channel bends, or at other locations where the joint may effect the water flow characteristics.

G. Channel joints shall not result in upstream ponding of water.

8.04.4 FINE AGGREGATE CONCRETE PLACEMENT

A. Following panel placement, small slits shall be cut in the top layer of the fabricform to allow for the insertion of the injection pipe. Fine aggregate concrete shall be injected between the top and bottom layers of fabric, filling the panel to the recommended thickness and configuration.

B. Fine aggregate concrete shall be injected in such a way that excessive pressure on the fabricform and cold joints are avoided. A cold joint is one in which the concrete injection into a fabricform is discontinued or interrupted for an interval of 45 or more minutes.

C. Holes in the fabric left by the removal of the injection pipe shall be temporarily closed by inserting a piece of nonwoven fabric or similar material. The material shall be removed when the concrete is no longer fluid and the concrete surface at the hole shall be cleaned and smoothed by hand. Foot traffic on the filled mat shall be restricted to an absolute minimum for one hour after pumping.

D. Upon completion of the fine aggregate concrete placement, all perimeter liner termination areas, terminal trenches, and toe trenches shall be backfilled with either grout or soil cover as shown on the Drawings. Soil cover shall be placed and compacted.
SECTION 9
FURNISHING, DELIVERY, AND PLACEMENT OF CONCRETE

9.01 GENERAL

9.01.1 DESCRIPTION OF WORK

This section includes technical requirements for producing and furnishing concrete to designated locations at the job site, and placing concrete as shown on the Drawings.

9.01.2 RELATED WORK SPECIFIED ELSEWHERE

A. Fabricform Lining - Section 8.
B. Rock and Grouted Rock Channel Lining - Section 10.
C. Pond Riser, Sampling Chambers, Manholes, and Appurtenances – Section 11.

9.02 REFERENCES

9.02.1 The following are referenced in this section:

A. VDOT, Road and Bridge specifications - 2007
   1. ACI 211.5R, "Guide for Submittal of Concrete Proportions".
   2. ACI 301, "Specifications for Structural Concrete".

9.03 MATERIAL REQUIREMENTS

9.03.1 All materials for concrete shall comply with and meet the requirements of the VDOT. Road and Bridge Specification Section 217 Hydraulic Cement Concrete with the following exception. Type II Portland cement shall be used in the production of all concrete that will be contacted by leachate or runoff from the active placement area.

9.04 INSTALLATION

9.04.1 All concrete, VDOT Grading A Fine Aggregate, cement, grout, reinforcing, formwork, etc. and other related items installed by the Contractor shall meet the applicable requirements of the VDOT, Road and Bridge Specifications with the following exception. Type II Portland cement shall be used in all cast in place features (including fabric form) and precast units that will be in contact with leachate or active placement area runoff.
9.05 **SUBMITTALS**

9.05.1 Submittals required by this section are, at a minimum, as follows:

<table>
<thead>
<tr>
<th>Submittal Requirements</th>
<th>Submittal Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland Cement: source of material and material certification</td>
<td></td>
</tr>
<tr>
<td>Aggregates: source of material, material certification, and grain-size analysis</td>
<td></td>
</tr>
<tr>
<td>Admixtures: material certification</td>
<td></td>
</tr>
<tr>
<td>Fly Ash: material certification</td>
<td></td>
</tr>
<tr>
<td>Concrete Design Mix</td>
<td></td>
</tr>
<tr>
<td>Concrete Batch Ticket</td>
<td></td>
</tr>
<tr>
<td>Qualification Tests of Materials: test results and certification</td>
<td></td>
</tr>
<tr>
<td>Curing Compound for Surfaces to Receive Special Coatings</td>
<td></td>
</tr>
<tr>
<td>Request for Approval of Rock Cuts for Forms</td>
<td></td>
</tr>
<tr>
<td>Form Release Agent: source of material and technical data</td>
<td></td>
</tr>
<tr>
<td>Request for Approval of Repair Procedure for Formwork</td>
<td>source of material and technical data</td>
</tr>
<tr>
<td>Additional Construction Joint Locations: source of material and technical data</td>
<td></td>
</tr>
<tr>
<td>Method of Sealing Porous Base Grades</td>
<td></td>
</tr>
<tr>
<td>Procedure for Placing Concrete Underwater, If Required</td>
<td></td>
</tr>
<tr>
<td>Request to Place Concrete by Pumping: source of material and technical data</td>
<td></td>
</tr>
</tbody>
</table>
### Table 9-1
REQUIRED QUALIFICATION TESTS

<table>
<thead>
<tr>
<th>Material</th>
<th>Test for Compliance With</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Concrete Aggregates</td>
<td>ASTM C 33(^{(1)})</td>
<td>As Referenced in ASTM C 33</td>
</tr>
<tr>
<td>2. Cement</td>
<td>ASTM 150(^{(1)})</td>
<td>As Referenced in ASTM C 150</td>
</tr>
<tr>
<td>3. Admixtures</td>
<td>ASTM C 260 and/or C494(^{(1)})</td>
<td>Manufacturer’s Certification</td>
</tr>
<tr>
<td>4. Fly Ash</td>
<td>ASTM C 618(^{(1)})</td>
<td>As Referenced in ASTM C 618</td>
</tr>
<tr>
<td>5. Water</td>
<td>Part 9.03.2 Herein</td>
<td>As Given in Part 9.03.2 Herein</td>
</tr>
</tbody>
</table>

**Note:**
\(^{(1)}\) As amended by this section.
SECTION 10
CHANNEL LINING

10.01 GENERAL
10.01.1 DESCRIPTION OF WORK
This section includes technical requirements for installing the rock and grouted rock drainage channels and the outlet protection for drainage channels and culverts.

10.01.2 RELATED WORK SPECIFIED ELSEWHERE
A. Earthwork, Base Grade And Subbase – Section 1.
B. Geotextiles - Section 6.
C. Furnishing Delivery and Placement of Concrete – Section 9.

10.02 REFERENCES
10.02.1 The following codes and standards are referenced in this section.
A. American Society for Testing and Materials (ASTM) Standards.
B. ACI 304, “Guide for Measuring, Mixing, Transporting and Placing Concrete”.
C. VDOT Road and Bridge Specifications – 2007.

10.03 MATERIAL REQUIREMENTS
10.03.1 ROCK RIPRAP
A. Rock used for channel linings, outlet protection, and other erosion control measures shall be in accordance with the Drawings, VDOT Road and Bridge Specifications Section 414 for size and weight, and shall meet the additional quality requirements as specified herein. It shall be angular and irregular in shape, without shale or weak seams, with neither width nor thickness less than one third its length, and shall have a minimum specific gravity of 2.6 when tested in accordance with ASTM C 127. Each load of rock shall be well graded from the smallest to largest size.
B. The aggregate shall be manufactured from natural material and consist of angular, hard, tough, durable, uncoated particles; free of organic matter, coal iron, shale, clay or weak, flat, elongated, argillaceous, minacious, or decomposed material. It shall not be made of acid forming or toxic forming rock or slag.
B. Rock shall be of a quality that will withstand the action of water, frost, and other weathering. Rounded rocks or boulders shall not be used.
C. Rock shall meet the size and gradation of the NSA or AASHTO designation shown on the Drawings.

10.03.2 GABION STONE
A. Gabion Stone shall be in accordance with the Drawings and VDOT Road and Bridge Specifications Section 204 for size and weight.
10.03.3 COARSE AGGREGATE
A. Coarse aggregate shall be of the type and size as specified in the Drawings.
B. The aggregate shall be manufactured from natural material and consist of angular, hard, tough, durable, uncoated particles; free of organic matter, coal, iron, shale, clay or weak, flat, elongated, argillaceous, minacious or decomposed material. It shall not be made of acid forming or toxic forming rock or slag.
C. Rock and stone shall be of a quality that will withstand the action of water, frost, and other weathering. Fully rounded rocks or boulders shall not be used.

10.03.4 GEOTEXTILE
A. Geotextile, where shown on the Drawings, geotextile shall be as specified in Section 6.

10.03.5 GROUT
A. The grout shall meet the applicable requirements of Section 9 herein and the following criteria:
   - Slump in inches: 8 ± 1
   - Entrained air content, percent by volume: 6 ± 1
   - Maximum water:cement ratio: 0.35
   - Compressive strength at 28 days (psi): 2,500
   - Mix proportion-cement: VDOT Grading A Fine Aggregate: 1.3 maximum
B. In no case shall lime be added to the grout mix.
C. The Contractor shall submit the grout mix design and material certifications to the Owner for record.
D. Grout shall be mixed to give a uniform fluid consistency without segregation of materials.

10.03.6 CONCRETE MAT CHANNEL LINING
A. Concrete mat channel lining Armorflex Cellular Concrete Mat as manufactured by Contech Construction Products, Inc., West Chester, Ohio or Owner-approved equivalent.

10.03.7 PVC COATED GABIONS
A. PVC Coated Gibions shall be in accordance with VDOT, Road and Bridgespecification Section 610.

10.03.8 TURF REINFORCEMENT MAT
A. Turf reinforcement mat shall be C 350, P300, P 550, or SC 250 as manufactured by North American Green, Evansville, Indiana, or Owner Approved Equivalent.

10.04 INSTALLATION REQUIREMENTS
10.04.1 ROCK RIPRAPH
A. Install the rock riprap in accordance with VDOT Road and Bridge, Section 414.03
and as shown on the Drawings.

10.04.2 COARSE AGGREGATE
A. Coarse aggregate, as called for on the Drawings, shall be placed as shown and in such a manner so that the underlying geotextile is not damaged.

10.04.3 GEOTEXTILE
A. Geotextile shall be placed in accordance with Section 6 - Geotextiles.

10.04.4 GROUT
A. Except as noted below, the requirements of ACI 304 shall apply:
   1. Grout shall be mixed a minimum of five minutes after all materials are placed in the mixer unless otherwise directed by the Owner.
   2. Grout shall be placed before initial set takes place. Retempering of grout will not be permitted.
   3. The rock shall be thoroughly wet immediately before the grout is applied. Grout shall be poured fluid enough to flow into all crevices and to fully penetrate the stone thickness such that the top layer of stone is embedded 70 percent in grout. Vibrating and/or light rodding shall be used to force grout into crevices.
   4. The stones shall be brushed, if necessary, so that the top surfaces are exposed.

10.04.5 CONCRETE MAT CHANNEL LINING
A. Install in accordance with the details on the Drawings and manufacturer's recommendations.

10.04.6 PVC COATED GABIONS
A. PVC coated Gabions shall be installed in accordance with VDOT, Road and Bridge specification Section 610.

10.04.7 TURF REINFORCEMENT MAT
A. Turf reinforcement mat shall be installed at the locations shown on the Drawings. The material applications are shown on the details of the Drawings. Installation shall be in accordance with the turf reinforcement mat manufacturers recommendations.
SECTION 11
PRECAST CONCRETE MANHOLES AND BOXES,
AND APPURTEYNANCES

11.01 GENERAL
11.01.1 DESCRIPTION OF WORK
This Section contains technical requirements necessary to construct precise concrete manholes and boxes at the locations shown on the Drawings.

11.01.2 ITEMS INCLUDED IN THIS SECTION
A. This Section includes the following items:
   1. Furnishing and installing rectangular and circular precast concrete structures, including steps.
   2. Furnishing and installing door frames and covers for the structures.
   3. Furnishing and installing appurtenances.

11.01.3 RELATED WORK SPECIFIED ELSEWHERE
A. Earthwork, Base Grades, and Subbase – Section 1.
B. Geotextiles – Section 6.
C. Furnishing, Delivery, and Placement of Concrete – Section 9.

11.02 REFERENCES
11.02.1 VDOT, Road and Bridge Specifications – 2007.

11.03 PRECAST CIRCULAR CONCRETE MANHOLES
11.03.1 Furnish precast circular concrete manhole sections with a nominal cylinder internal diameters as shown on the Drawings and install in accordance with the manufacturers recommendations.

11.03.2 The manhole sections shall comply with VDOT, Road and Bridge Specifications – 2007, section 302 Drainage Structures.

11.03.3 Furnish and install appurtenances as specified on the Drawings.

11.03.4 The manufacturer shall furnish conformance certification as the basis of acceptance of the material.

11.03.5 Manhole frames and covers shall comply with VDOT Road and Bridge specifications and be waterproof.

11.04 RECTANGULAR PRECAST CONCRETE BOXES OR MANHOLES
11.04.1 Rectangular precast boxes manholes and flat top sections shall be precast, reinforced concrete. Precast structures shall comply with VDOT, Road and Bridge Specifications.

11.04.2 Access doors and frames shall be manufactured by Pennsylvania Insert Corporation, or equivalent, subject to acceptance by the Owner. Doors shall be hinged, double leafed, standard duty aluminum with snap lock. Frame shall be six
inch deep aluminum extrusion with integral anchor flange, hinge, drain channel, and neoprene gasket.

11.04.3 The top of the concrete base section shall extend a minimum of six inches above the final ground elevation.

11.04.4 Lean concrete shall be poured in the structures to the required depth and formed to the configuration shown on the Drawings.

11.04.5 Incoming and exiting pipes shall enter the structure in the manner and elevations shown in the details and shall extend a minimum of six inches beyond the inside wall to facilitate flow monitoring operations.

11.04.6 Ladders shall be Guard Way fiberglass reinforced plastic (FRP) by IKG Borden, or equivalent, subject to acceptance by the Owner, attached to the inner face of the structure with stainless steel fasteners.

11.04.7 Vertical handrails shall be FRP by IKG Borden, or equivalent, subject to acceptance by the Owner, attached to the outer face of the structure with stainless steel fasteners and extending three feet above the top of the concrete roof slab.

11.04.8 Watertight seals shall be used around pipes entering and exiting structures and shall be neoprene rubber boot couplings by Press Seal Gasket Corporation, Kor-N-Seal or Contour Seal by NPC Inc., A-Lock Seal or Z-Lock Seal by A-Lock Products, or equivalent, subject to acceptance by the Owner.

11.04.9 Concrete and lean concrete shall meet the requirements of Section 9 herein.

11.04.10 The Contractor shall label the pipe inlets and outlets inside the structure.

11.04.11 All sampling chambers and manholes shall be installed level.
SECTION 12
REVEGETATION

12.01 GENERAL

12.01.1 SUMMARY

A. This Section includes technical requirements for soil preparation, seeding and mulching of stockpiles, disturbed areas, and areas where Work will temporarily cease. Any reference to seeding, temporary seeding, or seeding and mulching in this Specification shall be construed to mean soil preparation and the application of lime, fertilizer, seed, and mulch as contained in this section.

B. Items Included in this Section:
   1. Seeding and mulching the stockpiles.
   2. Seeding and mulching of all disturbed areas resulting from Contractor’s operation that are located outside of paved or stone surfaces.
   3. Seeding and mulching grass lined drainage facilities.
   4. Seeding and mulching areas where Work will temporarily cease for a period of greater 20 days.

12.02 REFERENCES

12.02.1 The following codes and standards are referenced in this section.

A. VDOT, Road and Bridge Specifications – 2007.


12.03 MATERIAL REQUIREMENTS

12.03.1 Commercial Fertilizer:

A. Commercial fertilizer shall conform to the requirements of the Virginia Fertilizer, Soil Conditioner and Plant Growth Substance Law, as amended.

B. Liquid formulations may be used in lieu of dry formulations provided that the following conditions are satisfied:
   1. The application rate shall be adjusted to apply the same quantities of nitrogen, phosphorus, and potassium per unit area.
   2. The nitrogen, phosphorus, and potassium ratio shall be the same as specified for the dry formulation.
   3. The liquid formulation shall be furnished and applied at no additional cost to the Owner.

C. The derivation of dry fertilizer elements shall be as follows:
   1. Nitrogen - ammonium sulfate, ammonium nitrate, diammonium phosphate, monoammonium phosphate, or urea.
   2. Phosphorus - phosphoric acid, triple superphosphate, calcium phosphate, diammonium phosphate, or monoammonium phosphate.
3. Potassium - muriate of potash or sulfate of potash.

D. The Contractor shall supply the Owner with material certification.

12.03.2 Seed:

A. All seed shall conform to the Virginia Seed Law of the Virginia Office of Product and Industry Standards and regulations of the Association of Official Seed Analysts. Purity and germination analyses will be conducted under the current Rules for Testing Seeds, Association of Official Seed Analysts. All seed shall have an inspection tag, stamped, and dated by the seed supplier. No seed shall be utilized which has a germination test date older than (9) months. No seed shall be used on any project unless it has been inspected as described and meets the specifications provided below.

B. Seed mixtures shall be composed of seed of the variety, purity, germination, percentage by weight, and rates specified as follows

1. Permanent Cover:

<table>
<thead>
<tr>
<th>Seed Mixture</th>
<th>Seed Quality</th>
<th>Seeding Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Species</td>
<td>Lbs./Acre</td>
</tr>
<tr>
<td>Johnstone or Festoria Tall Fescue</td>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>Spring Oats</td>
<td>30</td>
<td>85</td>
</tr>
<tr>
<td>Winter Rye</td>
<td>75</td>
<td>80</td>
</tr>
</tbody>
</table>

2. Temporary Cover:

<table>
<thead>
<tr>
<th>Seed Mixture</th>
<th>Seed Quality</th>
<th>Seeding Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Species</td>
<td>Lbs./Acre</td>
</tr>
<tr>
<td>Johnstone or Festoria Tall Fescue</td>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>plus Spring Oats or Winter Rye</td>
<td>30</td>
<td>85</td>
</tr>
<tr>
<td>or Winter Rye</td>
<td>75</td>
<td>80</td>
</tr>
</tbody>
</table>
C. The inoculant for treating leguminous seed shall be standard commercial product consisting of a suitable carrier containing a culture of nitrogen fixing bacteria specific for the seed to be inoculated. All containers must remain sealed until contents are used in their entirety. Inoculant shall not be used after the expiration date indicated on the container. Suitable storage in a moderate temperature shall be provided at all times.

D. The Contractor shall supply the Owner with the seed tags and material certification.

12.03.3 Mulch:
A. Mulching material shall be free from mature seed-bearing stalks or roots of prohibited or noxious weeds as defined in the Virginia Seed Law, as amended. Mulches for seeded areas shall be one or a combination of the following: grass hay or cereal straw. Other mulch material must have prior approval of the Owner. Hay and straw mulch shall be well cured to less than 20 percent moisture content by weight and shall contain no stems of tobacco, soybeans, or other coarse or woody materials.

1. Hay shall consist of timothy hay, mixed clover and timothy hay, or other approved native or forage grasses. Salt grass hay or other saline grasses are not acceptable.

2. Straw mulching shall be wheat, rye, barley, or oats straw.

B. Wood cellulose fiber shall be used as a tie-down for hay or straw mulch.

1. Wood cellulose shall consist of specially prepared wood cellulose fibers containing no growth of germination inhibiting factors and shall be dyed green, unless otherwise specified. Wood cellulose fiber shall be furnished air dry in packages not exceeding 100 pounds gross, with net weight indicated on the package.

12.04 EXECUTION

12.04.1 SEED APPLICATION
A. Seeding shall be performed within the following dates: Spring March 15 to May 15, Fall September 15 to November 15. Where local conditions justify, the Owner may modify these dates. Unless otherwise directed by the Owner, all seeding shall be performed within 20 days of completion of finished grading.

B. The seed mixtures shall be applied as specified in Section 13.03.3 and shall be used as follows:

1. Permanent - Areas at final grade and areas disturbed outside of paved or stone surfaces. Permanent seeding is also anticipated for the permanent stockpile areas and along in the grass portions of permanent drainage facilities.

2. Temporary - Temporary soil stockpiles, temporary material disposal areas, temporary grass lined drainage channels, and other areas where Work will temporarily cease for a period greater than 20 days.

C. On areas having grades less than three horizontal to one vertical, the soil shall be tilled and loosened. All soil irregularities, however caused, shall be satisfactorily corrected before liming, fertilizing, seeding, or mulching.
D. Agricultural pulverized limestone and fertilizer shall be applied uniformly to the soil areas to be seeded. Properly documented bulk delivery of supplements will be permitted, provided uniform application rates are assured. Where liquid fertilizers are utilized, the material shall be agitated during application and shall be protected from freezing.

E. On all areas flatter than three horizontal to one vertical, lime and initial fertilizer application shall be incorporated into the soil.

F. Application rates of lime and fertilizer shall meet the following requirements. (These quantities are for bidding purposes only. The Owner will obtain the results from Penn State soil tests to determine actual rates):
   1. Pulverized agricultural limestone - 825 pounds per 1,000 square yards (two tons per acre) on a calcium carbonate equivalent (CCE) basis.
   2. Commercial fertilizer - provide a guaranteed total elemental analysis of 10-20-20 nitrogen phosphate-potash (N-P_{2}O_{5}-K_{2}O) fertilizer shall be applied at a rate of 248 pounds per 1,000 square yards. A maximum of 16.5 pounds per 1,000 square yards (80 pounds per acre) of 10-20-20 fertilizer shall be placed with the seed. The balance shall be broadcast prior to the raking, discing, harrowing, scarifying, and seeding operation.

G. All leguminous seed shall be inoculated with the proper cultures in accordance with the manufacturer's directions. Inoculated seed shall be protected from prolonged exposure to sunlight prior to sowing, and all seed not sown within 24 hours following inoculation shall be reinoculated. When seed is applied by hydraulic seeders, four times the manufacturer's recommended rate shall be utilized and the manufacturer's recommended procedures for inoculating will not apply. Seed and inoculants shall not be held in a slurry with fertilizers for more than one hour. Application of seed and inoculants separate from fertilizer will be required where this stipulation cannot be complied with.

H. Seed shall be uniformly sown on the designated areas by hydraulic, broadcast, drill, or hand seeding methods. All seeding equipment shall be inspected and, if required, adjustments made to assure the specified application rates.

12.04.2 MULCH APPLICATION

A. Mulching shall be placed within 24 hours after seeding and before rain. Unless otherwise directed by the Owner, mulching shall be placed over all seeded areas. Mulching shall be placed uniformly in a continuous blanket at a minimum rate of 1,250 pounds per 1,000 square yards (three tons per acre). The rate of application may be increased at Owner's direction based upon the materials, season, soil conditions, and method of application. A mechanical blower may be used to apply mulch material, provided the machine has been specifically designed and approved for this purpose. Machines which cut mulch into short (less than six inch) pieces will not be permitted. Mulching shall be anchored by the use of either emulsified asphalt or wood cellulose fiber. Emulsified asphalt shall be applied uniformly to the mulch at a rate of not less than 31 gallons per 1,000 square yards. If wood cellulose fiber is used to tack straw/hay mulch in place, it should be hydraulically applied over the straw/hay mulch at a rate of 165 pounds per 1,000 square yards (800 pounds per acre).
12.05 MAINTENANCE

12.05.1 Where seeded areas have become damaged by erosion, slide or slip, or by acts, omissions or work activities of the Contractor, the affected areas shall be promptly regraded, limed, fertilized, and reseeded as originally required at no additional cost to the Owner.

12.05.2 The Contractor shall, for areas that have not established a satisfactory vegetative cover at the end of one growing season, re-seed, lime, fertilize, and mulch as originally specified at Contractor's expense.
SECTION 13
EROSION AND SEDIMENT CONTROL

13.01 GENERAL

13.01.1 SUMMARY

A. This section includes technical requirements for the installation and implementation of general erosion and sediment (E&S) control measures.

B. The E&S Pollution Control Plan consists primarily of minimizing sediment transport from the site through the use of: temporary diversion and collection channels, sediment traps/basins, rock filters, riprap outlet protection, pumped water filter bags and temporary baffles, if needed.

C. Also, as part of the E&S Pollution Control Plan, the Contractor shall perform site earthwork to provide positive drainage of site run-off to the E&S control structures. This method of grading will contain any sediment on-site and within the perimeter sediment controls. This work could include, if necessary, excavating temporary ditches to provide drainage from low areas.

D. Several basic concepts have been developed in this plan to prevent accelerated erosion. These include the following:

1. Installation of the required E&S control facilities prior to any soil disturbance, and in their proper sequence as construction progresses.

2. Interception of offsite runoff and runoff from stabilized areas and diversion of that runoff around the working areas.

3. Installation of outlet protection or outlet measures with non-erosive velocities.

4. Minimization of the extent of denuded areas and the time of exposure.

5. If the season is not proper for temporary or permanent seeding, provide mulch over the area and over seed during the proper season.

6. Proper maintenance of all E&S control facilities, and all vegetated surfaces, including the removal of excessive sediment accumulation and restoring the facilities to the original design condition.

7. Prompt repairing and revegetating of any eroded areas that develop.

13.01.2 REFERENCES


B. VDOT Road and Bridge Specifications – 2007.

13.01.3 ITEMS NOT INCLUDED IN THIS SECTION

A. Specifications for culverts, fabricform and grouted rock lined channels, concrete, grout, and revegetation. These Specifications are included in Sections 4, 8, 9, 10, and 13, respectively.
13.02 E&S MEASURES AND SILT BARRIERS

13.02.1 MATERIAL REQUIREMENTS

A. Silt Fence:
   1. Silt fence shall be the Envirofence Sediment Control System as manufactured by the Celanese Fibers Marketing Company, New York, New York, or an approved reinforced mesh backed equal.
   2. Silt fence reinforcing mesh and stakes shall be of the type and dimensions detailed on the Drawings.

B. Straw Bales:
   1. Straw bales shall be nylon or wire bound.

13.02.2 INSTALLATION REQUIREMENTS

A. E&S Control:
   1. Soil E&S control shall be implemented prior to the start of any construction activities. The E&S measures shown on the Drawings are not intended to be all inclusive. It shall be the Contractor’s responsibility to install and maintain whatever measures are necessary to make certain all sediments are contained within the site area.
   2. Earthmoving operations shall be conducted in such a manner as to minimize soil erosion, in accordance with the Virginia Department of Environmental Quality (VDEQ) Erosion and Sedimentation Pollution Control Handbook, as specified herein, and as shown on the Drawings.
   3. Silt fence or straw bales shall be installed downgrade of all stockpile areas and other Contractor work areas to confine sediment that may be washed from new fill or cut slopes.
   4. Silt fence shall be installed at level grade. Both ends of each fence section should be extended at least eight feet upslope at 45 degrees to the main fence alignment to allow for pooling of water.
   5. Silt fence alignment shall be at least eight feet from the toe of fill slopes.
   6. Ditches and silt fence or straw bales shall be inspected daily. Ditch erosion or silt fence or straw bale damage shall be repaired immediately. Sediment accumulations shall be removed and placed in the soil stockpile(s) at the Contractor’s expense.
   7. All E&S control measures shall be maintained so as to function properly or be replaced until final protective vegetation has been established, or other ground cover materials have been placed. All maintenance shall be at the Contractor’s expense.
   8. Existing silt fence or straw bales around the soil or unsuitable material stockpiles shall be maintained during the Contract period if the Contractor utilizes that particular stockpile.
   9. Any new or existing rock filters or sediment traps should be cleaned and maintained by the Contractor during this Contract period.
10. Upon revegetation of the area, all silt fence and straw bales shall be removed at the Contractor’s expense.

11. Any additional E&S control measures beyond what is identified on the Drawings, but which are required due to the Contractor’s construction methods, sequencing, or operations, or temporary diversion of water shall be completed at the Contractor’s expense.

12. The Contractor is responsible for all measures required to control dusting at the site. This effort includes watering, as required, and other means necessary.

B. Control of Water:

1. Ditches, berms, site grading, sumps, and/or automatic pumping facilities shall be constructed or provided to direct, collect, and remove water from the working area. All water shall be conducted to areas away from the Work in a manner to prevent erosion, damage to adjacent structures or facilities, or in accordance with other requirements of the Owner.

2. No ponding of surface runoff or groundwater shall be allowed in the excavation or low areas of the site.

3. Groundwater and surface runoff shall be controlled to preclude disturbance of foundation bearing materials, base grades, and adjacent structures or facilities. The Contractor should limit the amount of open or exposed work areas since washouts or runoff water damage are the responsibility of the Contractor.

4. All control of water, including any temporary stream diversion and bypass pumping required for construction, shall be at the Contractor’s expense.

5. The Contractor shall control runoff of all contaminated water from leaving lined areas unless discharging directly into a collection channel. Runoff which comes in contact with ash or CCB materials shall be prevented from flowing across unlined base grade areas.

6. The Contractor shall not divert any contaminated collection channel water or leachate drain water into the clean water diversion channels for any reason. The Owner may allow temporary diversion of a clean water diversion channel into a collection channel only with prior written approval.

13.03 GRASS LINED CHANNELS

13.03.1 MATERIAL REQUIREMENTS

A. Grass lined channels shall be seeded with a Kentucky Bluegrass, Tall Fescue seed mixture. See Part 14.11, Temporary Seeding and Mulching, of this Specification.

13.03.2 INSTALLATION REQUIREMENTS

A. Channels should be constructed to the dimensions shown on the Drawings.

B. Channels shall be seeded and mulched in accordance with Part 13.11 of this Specification.
13.03.3 MAINTENANCE REQUIREMENTS
A. Channels shall be maintained to ensure that the specified design dimensions and protective linings are available at all times.
B. Damaged channel linings should be repaired or replaced immediately.

13.04 TURF REINFORCEMENT MAT (TRM) LINED CHANNELS
13.04.1 MATERIAL REQUIREMENTS
A. TRM shall be as specified in part 10.03.7 of this specification.

13.04.2 INSTALLATION REQUIREMENTS
A. TRM shall be installed according to the manufacturer’s requirements.
B. Channels shall be seeded and mulched in accordance with Part 13.11 of this Specification.

13.05 SEDIMENT TRAPS
13.05.1 MATERIAL REQUIREMENTS
A. The principal spillway embankment shall be composed entirely of rock, with a main body of NSA R-3 rock (or larger), and an inside face of AASHTO #57 stone or smaller.
B. The rock energy dissipater shall be composed of NSA R-3 rock (or larger).
C. Geotextile used at the inside face shall meet the requirements of filter geotextile, in Section 6 of these Specifications.

13.05.2 INSTALLATION REQUIREMENTS
A. A clean out stake shall be placed near center of each trap.
B. Accumulated sediment shall be removed when it reaches the clean out elevation marked on the stake.

13.05.3 MAINTENANCE REQUIREMENTS
A. Sediment traps shall be inspected on a weekly basis and after each runoff event. Sediment must be removed from the trap when the storage volume has been reduced to 1,300 ft³/ac of contributing drainage area. This elevation should be clearly marked on a stake near the center of the trap.
B. Clogged or damaged spillways shall be immediately restored to the design Specifications.
C. Other required maintenance shall be completed within five working days of the inspection.

13.06 SEDIMENT BASINS
13.06.1 MATERIAL REQUIREMENTS
A. Rock surrounding the perforated riser and the Rock Outlet Protection shall be NSA R-3 rock or larger.
B. The perforated temporary riser and barrel through the embankment shall be smooth interior, SDR 26 or equivalent strength, HDPE pipe with diameters as shown on the Drawings.

13.06.2 INSTALLATION REQUIREMENTS
A. A clean out stake shall be placed near center of each trap.
B. Accumulated sediment shall be removed when it reaches the clean out elevation marked on the stake.

13.06.3 MAINTENANCE REQUIREMENTS
A. Clogged or damaged spillways shall be immediately restored to the design Specifications.

13.07 ROCK FILTERS
13.07.1 MATERIAL REQUIREMENTS
A. The rock filter shall be composed entirely of rock; main body NSA R-3 rock (or larger), and an upstream face of AASHTO #57 stone or smaller.

13.07.2 INSTALLATION REQUIREMENTS
A. Rock filters shall be installed in accordance with the dimensions shown on the Drawings.

13.07.3 MAINTENANCE REQUIREMENTS
A. Rock filters shall be inspected on a weekly basis and after each runoff event.
B. Clogged filter stone (AASHTO #57) should be replaced.
C. Needed repairs should be initiated immediately after the inspection.

13.08 RIPRAP OUTLET PROTECTION
13.08.1 MATERIAL REQUIREMENTS
A. The riprap outlet protection shall be composed entirely of the NSA size and thickness of rock as depicted on the Drawings.
B. Geotextile shall meet the requirements of filter geotextile, in Section 6, Table 6-1.
C. Grout shall conform to the grout mixture specified for grout in Section 10 of this Specification.

13.08.2 INSTALLATION REQUIREMENTS
A. Riprap outlet protection shall be installed according to the dimensions shown on the Drawings.

13.09 PUMPED WATER FILTER BAG
13.09.1 MATERIAL REQUIREMENTS
A. Filter bags shall be made from non-woven geotextile material sewn with high strength, double stitched “J” type seams.
B. Filter bags shall be manufactured of geotextile capable of trapping particles larger than 150 microns.
C. The pumping rate shall not exceed 750 gpm or one half the maximum specified by the manufacturer, whichever is less.
D. Pump intakes shall be floating and screened.

13.09.2 INSTALLATION REQUIREMENTS
A. Filter bags shall be located in well-vegetated (grassy) areas, and discharged onto stable, erosion resistant areas. Where this is not possible, a geotextile flow path shall be provided.
B. Suitable means of accessing the bag with machinery required for disposal purposes must be provided.
C. Filter bags shall not be placed on slopes greater than five percent.
D. The pump discharge hose shall be inserted into the bags in the manner specified by the manufacturer and securely clamped.
E. The pumping rate shall not exceed 750 gpm or one half the maximum specified by the manufacturer, whichever is less.

13.09.3 MAINTENANCE REQUIREMENTS
A. Filter bags shall be replaced when they become one half full.

13.10 TEMPORARY BAFFLES (IF NEEDED)
13.10.1 MATERIAL REQUIREMENTS
A. Posts shall be made of pressure treated wood.
B. Plywood sheets shall be Marine grade of the dimensions specified on the Drawings.

13.10.2 INSTALLATION REQUIREMENTS
A. Baffles shall be installed as shown on the plan view on the Drawings.

13.11 TEMPORARY SEEDING AND MULCHING
13.11.1 GENERAL
A. The Contractor shall comply with the requirements of Section 12 - Revegetation, herein. The Contractor shall seed all areas disturbed within the limits of the Contractor’s work area. The work covered by this Specification shall consist of preparation of the seedbed, furnishing and placing pulverized agricultural limestone, commercial fertilizer, seed and mulch, and maintaining the seeded areas. The time of seeding may be selected by the Contractor who shall be responsible for securing a satisfactory stand of grass. Seeding should be performed as soon as possible following the completion and approval of finished grading, and the incorporation of soil supplements.
B. If erosion occurs between the time of finished grading and time of seeding, the Contractor shall replace the fine soil materials, which were eroded away and regrade all eroded areas to reestablish the finished grade. The Contractor shall also reapply and reincorporate soil supplements in the eroded areas. The Contractor may, at his own expense, perform temporary seeding operations in order to maintain finished graded areas until the optimum time for performing permanent seeding.
C. The Contractor shall perform temporary seeding in areas where permanent seeding has not been performed within a period of 20 days after the grading operation has been suspended, or in other areas where the VDEQ requests a temporary vegetative cover.
SECTION 14
ROADS

14.01 GENERAL
14.01.1 DESCRIPTION OF WORK
This section includes the technical requirements necessary for construction of the paved entrance road, the site access roads and the pond perimeter road as shown on the Drawings. Also included are the requirements for construction of soil road berms, guiderail and steel pipe gates where shown on the Drawings.

14.01.2 ITEMS NOT INCLUDED IN THIS SECTION
A. Earthwork, Base Grade and Subbase - Section 1.
B. Geotextiles - Section 6.

14.02 REFERENCES
14.02.1 The following codes and standards are referenced in this section.
VDOT, Road and Bridge Specifications - 2007.

14.03 MATERIAL REQUIREMENTS
14.03.1 GEOTEXTILE
Where shown on the Drawings, shall be separation geotextile as specified in Section 6.

14.03.2 UNIFORMLY GRADED COARSE AGGREGATE, ROCK AND STONE
A. Rock and stone shall be of the size shown on the Drawings and in accordance with gradations in VDOT Road and Bridge Specifications - 2007, Sections 203 and 204, except as modified herein. It shall consist of angular, hard, tough, durable, uncoated particles; free of organic matter, coal, iron, shale, clay or weak, flat, elongated, argillaceous, minacious or decomposed material. It shall not be made of acid forming or toxic forming rock or slag.
B. Coarse aggregate meeting the VDOT gradation requirements shall be crushed rock or crushed river gravel.
C. Rock and stone shall be of a quality that will withstand the action of water, frost, and other weathering. Fully rounded rocks or boulders shall not be used.
D. Stone and rock shall meet the size and gradation of the VDOT, Road and Bridge Specifications, or AASHTO designation from VDOT, Road and Bridge Specifications.
E. The Contractor shall supply the Owner with the source of material, grain-size analysis, and material certification before any material is delivered to the site.

14.03.3 BASE COURSE
Base course materials for the construction of the haul road shall be as shown on Drawings. Base course shall be in accordance with (VDOT), Publication, Section 211.
14.03.4 FLEXIBLE PAVEMENT
The haul road construction shall be surface paved in accordance with VDOT, Road and Bridge Specifications, and as shown on the details on the Drawings.

14.03.5 BITUMINOUS TACK COAT
Bituminous tack coat shall be in accordance with VDOT, Road and Bridge Specifications - 2007.

14.03.6 GUIDERAIL INSTALLATION
Guiderail shall be carefully salvaged and reinstalled with end sections at termination points in accordance with VDOT, Road and Bridge Specifications, Standard RC-52 and Section 620 of VDOT, Road and Bridge Specifications in locations specified on the Drawings. If damaged or additional is needed, new VDOT, Road and Bridge Specifications, Type 2-S guiderail with rubrail and end sections shall be used as replacement at the Contractor’s cost.

14.03.7 STEEL PIPE GATES (If Required)

14.04 INSTALLATION REQUIREMENTS
14.04.1 ROAD FOUNDATION PREPARATION
A. See Section 1 herein for Technical Specification for excavation and fill placement.
B. Additional Requirements for Roadway base grades:
   1. Base grade areas shall be proofrolled with at least four passes with a large (greater than 10 tons) rubber tire roller or other approved heavy compaction equipment. Confined areas inaccessible to heavy compaction equipment shall be compacted with a minimum of four passes with the largest practicable plate-compactor or roller. Soft or organic areas detected during base grade preparation shall be excavated and backfilled with compacted fill.
   2. The base grade of paved road areas shall be compacted to a minimum density equal to 95 percent of the maximum dry density as determined by the Modified Proctor Test (ASTM D 1557).
   3. All proofrolling shall be performed in the presence of the Owner. At least 48 hours notice to the Owner shall be required prior to performing base grade preparation.
   4. The Contractor shall protect the completed base grade from damage by equipment or trucks. Any damage to the base grade shall be repaired at the Contractor’s expense.

14.04.2 GEOTEXTILE INSTALLATION
A. See Section 6 herein.
B. Additional Requirements for Roadway Geotextiles:
   1. A base grade geotextile shall be laid flat on the finished base grade the full width of the stone layer to be placed above.
2. Adjacent sheets of geotextile shall be joined together in accordance with the manufacturer’s requirements of overlapped eighteen (18) inches unless indicated otherwise on the Drawings. A two thread double locked sewn stitch is an approved method of joining fabrics in lieu of overlapping. If sewn, the seam shall have six stitches minimum per inch, and the stitches shall be a minimum of two inches from the fabric edge.

3. Geotextile damaged or displaced before or during installation or during placement of subbase, or bedding shall be replaced or repaired to the satisfaction of the Owner, at the Contractor’s expense.

14.04.3 COARSE AGGREGATE PLACEMENT

A. Stone shall be placed in accordance with VDOT, Road and Bridge Specifications - 2007, and as shown on the Drawings.

B. After the geotextile is placed and accepted by the Owner, each type of coarse aggregate shall be placed in maximum 6-inch loose lifts to the width shown on the Drawings. The aggregate shall be compacted with a minimum of six (6) passes of a 10-ton or larger smooth wheel vibratory compactor.

C. The final road surface shall be graded to have positive drainage.

14.04.4 ROAD PAVING INSTALLATION

A. The Contractor shall sawcut and remove any existing paved shoulder and excavate for the full depth paving as called for on the Drawings in accordance with Section 1 of this Specification.

B. The Contractor shall furnish and place base course, subbase, and aggregate shoulders. Aggregate subbase and shoulders shall be constructed in accordance with VDOT, Road and Bridge Specifications and shall not exceed a maximum lift thickness of six inches. Base course shall be constructed in accordance with VDOT, Road and Bridge Specifications and shall not exceed a maximum lift thickness of 4 inches.

C. The Contractor shall furnish and apply bituminous tack coat to all existing surfaces or to the bituminous base or binder course when, in the opinion of the Owner, the surface is not satisfactory for direct placement of paving. Bituminous tack coat shall be applied in accordance VDOT, Road and Bridge Specifications.

D. The Contractor shall furnish and place the Superpave wearing course, on the Superpave binder course, and in accordance with VDOT, Road and Bridge Specifications.

E. The wearing surface of the entrance road pavement shall be flush and at the same grade upon completion as the wearing course of the existing roadway.

14.04.5 AGGREGATE ROAD INSTALLATION

A. The base grade shall be compacted to 95 percent of ASTM D 1557 maximum dry density prior to placing aggregate subbase. The profile grade of the base grade shall be such that the specified thickness of the subbase will be obtained. No subbase shall be placed when the base grade is frozen or when it is sufficiently wet that its surface can be marred by construction equipment.
B. The aggregate shall be placed and shaped on the prepared base grade, or any other surface, in multiple layers not exceeding 6 inches loose measure to achieve the compacted thickness shown on the Contract Drawings. When more than one layer is required, each layer shall be shaped and compacted to the specified density before the succeeding layer is placed. If power graders are used for spreading, the material shall be placed in windrows, uniformly and thoroughly mixed, prior to final spreading and compaction.

C. Quality control and acceptance for compaction of aggregate shall be in accordance with Section 1 herein. Each layer of aggregate subbase shall be compacted to 95 percent ASTM D1557 maximum dry density. Water shall be uniformly applied over the subbase materials during compaction in the amount necessary for proper consolidation. The surface of each layer shall be maintained during the compaction operations in such a manner that a uniform texture is produced and the aggregate firmly keyed. The surface of the top layer of the subbase course shall be carefully trued by blading if necessary.

14.04.6 GUIDERAIL INSTALLATION

Guiderail shall be carefully salvaged and reinstalled with end sections at termination points in accordance with VDOT, Road and Bridge Specifications in locations specified on the Drawings. If damaged or additional is needed, new VDOT, Road and Bridge Specifications, guiderail with rubrail and end sections shall be used as replacement at the Contractor’s cost. If guiderail posts cannot be driven without possible damage to any culverts, pipes, or concrete lined channels, the Contractor shall auger post holes and backfill with compacted concrete.
SECTION 15
GROUT STABILIZATION OF ABANDONED UNDERGROUND MINE WORKINGS

15.01 GENERAL

15.01.1 DESCRIPTION OF WORK

The work to be performed by the Contractor consists of furnishing all supervision, labor, plant, power and equipment, and performing all operations in connection with the stabilization program including, but not limited to providing access to the holes, the drilling and casing of holes, providing, handling, transporting, storing, mixing, and injecting the materials. The work also includes downhole video explorations and secondary injection holes, as well as the proper handling and disposal of drill cuttings, wastewater and waste materials, the cleanup and restoration of the area upon completion of the work, and all other such operations as are incidental to the program as specified herein. The purchase and delivery of materials to the site and their storage is the responsibility of the Contractor unless otherwise specified.

15.01.2 SUBSURFACE INFORMATION

Test borings for engineering purposes have been drilled at the approximate locations shown on Drawings. The accuracy of the relationship of the mine workings to the ground surface is unknown. The Contractor may, at the bidder’s expense, make additional explorations deemed necessary in the planning for construction, after coordinating with the Owner.

15.01.3 UTILITIES AND OTHER OBSTRUCTIONS

Utility locations, if shown on the Drawings, are approximate and are based on available data obtained from the various utility companies and the Owner. Verify this information prior to the initiation of work. It is your responsibility alone to locate and avoid all underground and overhead utilities, facilities and other structures and obstructions. Therefore, employ all necessary precautions and methods to insure avoidance of and prevention of damage to such underground and above ground utilities and facilities. In the event of such damage, notify the affected utility owner and the Owner immediately. Make or have made all necessary repairs and bear the expense of repairs for the damage thereof and any resulting damage caused thereby.

15.01.4 SUPERVISION

Provide a competent superintendent, satisfactory to the Owner, on the work site at all times during working hours with full authority to act for the Contractor.

15.01.5 ENVIRONMENTAL CONTROL

Boreholes drilled to underground mine workings may encounter methane gas during drilling and grouting. Provide a methane and oxygen monitor while drilling any boring to underground mine workings. Maintain all monitors in operating condition and in calibration for the life of the project. Make the monitors available to the Owner for checking any current or previously drilled holes on the project. Repair or replace any monitors within 24 hours of a malfunction. Drill no boring if a monitor is not
present. If methane above one (1) percent is detected, install suitable standpipes, flame arrestors, and other required accessories to prevent an explosion. If methane above five (5) percent is detected and/or the oxygen percentage falls below 19.5 percent, stop work until the methane level decreases below five (5) percent and/or the oxygen percentage increases above 19.5 percent. Conduct all work to minimize the amount of dust, erosion, clogging of existing drains and damage to local flora and fauna. General site cleanup shall be performed upon the completion of work or on a daily basis as determined by the Owner’s representative.

15.01.6 INTERPRETATIONS

The Contractor shall make interpretations of surface and subsurface conditions that may affect the methods or costs to execute the work and make no claim for damages or extra compensation should conditions found during the progress of the work different from those calculated or anticipated.

15.02 REFERENCES

15.02.1 CODES AND STANDARDS

A. American Society for Testing and Materials (ASTM Standards):
   2. C33 “Standard Specification for Concrete Aggregates’
   5. C939 “Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)”
   6. C618 “Standard Specification for Coal Fly ash and Raw or Calcinated Natural Pozzolan For Use in Concrete”
   8. C31 “Standard Practice for Making and Curing Concrete Test Specimens in the Field”

15.03 DEFINITIONS

15.03.1 ZONE

A zone is the horizontal area influenced by injection into a hole.

15.03.2 VOID

A void is any subsurface opening resulting from the removal of coal from the coal seam.

15.03.3 GOB

Gob is a mixture of materials found at mine level which consists of roof shales and other rock materials which have fallen or have been placed in a void.
15.03.4 COAL PILLAR
Coal pillar is an unmined block of coal remaining in the coal seam.

15.03.5 STAGE
A stage is a vertical subsurface injection interval which may include all or part of the drill hole length.

15.03.6 GRAVITY INJECTION
Gravity injection is the method used to place grout or concrete into the injection hole without pressure packers being used. The necessary materials are placed through a pipe at the specified interval of depth under the action of gravity (gravity flow). Pumping will be required to place concrete and grout at mine level to overcome friction in the injection hoses and pipes.

15.03.7 OVERBURDEN
Overburden includes soil and rock overlying the mined coal seam.

15.03.8 TAKE
Take is the volume of material injected into a specified interval of an injection hole.

15.03.9 MINE WORKINGS
The vertical interval which corresponds to the mined portion of the coal. This interval starts at the base of the coal and extends to the mine roof.

15.03.10 CLOSURE
A closure (split spacing) method for secondary injection will be used in areas as determined by the Owner. Closure holes will normally be located midway between three or four holes injected previously.

15.04 MATERIALS
15.04.1 WATER
The water used in grout and concrete shall be clean and free from injurious amounts of sewage, oil, acid, alkali, salts, organic matter or any other foreign solids, and shall be furnished by the Contractor. The water used shall meet the requirements of ASTM C 94. Whenever the outside air temperature is below 20 degrees F, the Contractor shall heat all water for mixing, cleaning or flushing. The final mix temperature shall range from 40 degrees F to 80 degrees F, with the water temperature not exceeding 140 degrees F at the time of mixing.

15.04.2 CEMENT
Cement used in grout or concrete shall conform to the requirements of ASTM C 150, "Portland Cement," Type II. The Contractor shall furnish and store cement so that it will not deteriorate from moisture, weather or other causes. Cement which has been in storage more than two months shall not be used for concrete or grout. The use of bulk cement will be permitted provided the Contractor provides methods of handling, transporting, storage and measuring that are satisfactory to the Owner. If sacked cement is used on the project, it shall be used in the chronological order in which it was produced to prevent undue aging after delivery. Store each shipment of cement
so that it may readily be distinguished from other shipments. Use cement free from lumps due to warehouse set.

15.04.3 FINE AGGREGATE
Fine Aggregate shall be sand-sized and consist of hard, dense, durable rock fragments and shall meet all requirements of ASTM C 33.

15.04.4 COARSE AGGREGATE
Coarse aggregate shall consist of hard, dense, durable rock fragments and shall meet the gradation requirements of AASHTO Number 7 (¾ inch to #8) or AASHTO #8 (½ inch to #16) and conform to all requirements of ASTM C 33.

15.04.5 DELETED

15.04.5.1 LIMESTONE DUST
The limestone dust, or approved equal material, to be used in the grout mix shall be subject to approval by the owner. The contractor shall provide the source of material and material properties for owner approval prior to construction, and whenever the source or material properties change.

15.04.6 Accelerator
The use of an early set accelerator shall be added to the mixes when directed by the Owner. All accelerator products shall conform to ASTM C 494.

15.04.7 OPTIONAL HIGH RANGE WATER REDUCER
The use of a water reducer may be added to the concrete mix only with the approval of the Owner. All water reducing products shall conform to ASTM C 494.

15.04.8 OPTIONAL SET RETARDER
The use of a set retarder may be added to the mixes only with the approval of the Owner. All set retarding products shall conform to ASTM C 494.

15.05 GROUT AND CONCRETE MIXES

15.05.1 GROUT MIX
The water-cement-limestone ratio of the grout mix shall be determined by the Contractor. The grout must be flowable and shall have a minimum unconfined compressive strength of 200 psi at 3 days cure. The Contractor shall be responsible for insuring that the grout mix can be pumped through the injection pipe he intends to utilize for the work. The grout placed shall meet or exceed the required minimum unconfined compressive strength and shall not exceed the water/cement ratio of the design mix. The grout shall have a flow cone value ranging from 30 to 60 seconds as determined by ASTM C 939.

15.05.2 CONCRETE MIX
Concrete shall be composed of a mixture of coarse aggregate, fine aggregate, cement, limestone dust and water. Low slump concrete shall have a mix proportioned for a two- to four-inch slump. High slump concrete shall be proportioned for a four- to eight-inch slump. The Contractor shall be responsible for insuring that the design
mix for low and high slump concrete can be pumped through the injection pipes that he intends to use for the work. All concrete placed shall have a minimum unconfined compressive strength of 200 psi after 3 days of curing, and the water/cement ratios shall not exceed those of the design mix for each design slump.

15.05.3 MIX DESIGNS

All concrete and grout mix designs to be used by the Contractor will be subject to review and approval of the Owner. The Contractor shall submit to the Owner the proposed mix designs along with sufficient test data using the proposed sources of mix components to verify strength parameters prior to the initiation of injection operations. This design mix testing shall include the corresponding slump or fluidity test results for the design mixes. If during injection operations either the testing indicates that required strengths are not being achieved or the design mix proportions are not being achieved, then the Contractor shall modify the mix proportions to achieve satisfactory mix proportions and strengths.

15.05.4 STRENGTH REQUIREMENT

All unconfined compressive strength requirements of this Specification are based on testing according to ASTM C 39 of cylindrical samples prepared according to ASTM C 31. If the Contractor desires to mold and test cube samples of grout according to ASTM C 109 to assist in quality control during injection, he must also present the results of unconfined compressive strengths of cube samples of the design mixes prior to the initiation of grouting and concreting operations. These test results will be used by the Owner to determine if and how much the design strength measured for cube samples must be increased in order to determine that the specified unconfined compressive strength based on cylindrical samples is being achieved.

15.06 EQUIPMENT

15.06.1 All equipment used for mixing and injecting grout and concrete shall be furnished by the Contractor. The power supply and equipment and the layout thereof shall meet all applicable requirements of local, State, and Federal regulations and codes, including those related to safety.

15.06.2 The Contractor can use a premixed grout delivery service or an on-site batch mixing facility to produce the grout shall be approved in advance by the Owner. In either case, the grout shall be well mixed and shall be free of hardened grout or foreign materials larger than a No. 16 U.S. Standard screen. The Contractor shall provide all necessary pumps, mixers, compressors, tanks, meters, valves, hoses, pipes, fittings, tools and other miscellaneous items to provide a continuous supply of grout and to maintain accurate control and measurement. The grout plant must be capable of providing 50 cubic yards of grout per hour to each operating pump. The grout supply pipe shall be metal or plastic stiff enough to maintain the tip below the level of grout during placement. The type and diameter of the grout supply pipe to be used shall be determined by the Contractor. If, at any time, it is determined that the pipe is of insufficient diameter, then the Owner will direct the Contractor shall use a larger diameter pipe.

15.06.3 The equipment used to mix grout and concrete shall have suitable metering devices to accurately and continuously measure the proportions of all components of the mix including water at the time of injection. The water meter shall be a non-resetable, continuous flow water meter and must meet the approval of the Owner.
All flow measurement and mix proportioning equipment shall have a recent calibration and shall be field calibrated periodically during the project.

**SURVEY LAYOUT**

**DESCRIPTION**

This work consists of furnishing, placing and maintaining layout stakes or marks necessary for the proper performance of work under this contract.

**PROCEDURE**

A. Locate and identify all injection holes, as shown on the Mine Grouting Plan. Field reference control points will be provided by the Owner. Determine the elevations of the tops of all holes to the nearest half (0.5) foot with reference to a benchmark established by the Owner.

B. Locate each hole within one half (0.5) foot of the planned location. Each injection hole shall be marked with a 2-inch square by 6-inch long oak hub driven flush with the ground surface, or on existing pavement or concrete, be indicated with chisel marks, paint, and/or offset stakes. Place a witness stake or paint markings bearing the hole number and ground surface elevation at each hole location. Replace any stakes or markings destroyed prior to the completion of injection operations in any hole.

C. Perform all surveys using a surveyor licensed or registered in the Commonwealth of Virginia.

D. The Owner reserves the right to review and approve all survey procedures.

**INJECTION HOLE DRILLING**

**DESCRIPTION**

This work consists of drilling injection holes from the ground surface to below the base of the mined coal seam and installing casing as directed by these Specifications. The anticipated sequence is to drill all injection holes prior to grouting, fill the perimeter injection holes with low slump concrete and then grout the interior injection holes with flowable grout. Secondary borings may be added by the Owner for confirmation of grout take and filling of additional borings or voids. Observations of encountered voids may be complemented with borehole video camera service when requested by the Owner to view conditions at mine level prior to injection.

**EQUIPMENT**

Standard rotary or downhole percussion type drilling equipment can be used. The drilling equipment must be capable of drilling the injection holes to the required diameter and depth. The drilling equipment must be equipped with dust control devices and pressure gauges which indicate the downhole drilling pressure.

**PROCEDURES**

A. Drill all injection boreholes to a depth of two feet below the base of the mined seam and of such diameter to permit the installation and removal of the required casing, the supply pipe, and other materials. Drill both vertical and inclined boreholes to a nominal diameter in rock of no less than six-inches. Drill
each borehole (boring) to intercept mine level at the plan location shown on the Drawings. These locations may be modified by the Owner. Drill so as to minimize mine-roof collapse by such means as reducing down pressure directly above the mine workings. Drill using bits and stabilizers or collars as required to achieve full-diameter, straight holes. Vertical holes shall have a maximum deviation from the vertical of two percent of the hole length. Inclined holes shall be started within 2 degrees of the specified angle. Anticipate no more than 30 percent of the total boring footage will be inclined borings.

B. The Owner must approve in advance of drilling any special provisions to avoid existing structures, utilities, and the like.

C. Remove and replace any structures damaged as a result of the drilling and injection work.

D. Contain and filter by the use of straw bales or silt fence any water encountered in the drilling process that is carried to the surface with cuttings. After drilling is completed and prior to grout injection into the hole, clear from around the hole any cuttings, dust, and sludge.

E. Protect all drilled and cleaned out holes from debris until the completion of the work at the hole. Debris contamination boreholes shall be cleared as directed by the Owner.

F. Cap and otherwise protect all boreholes to be injected from caving or becoming otherwise obstructed. Case injection boreholes through soil to the top of rock. Furnish, handle and install all pipe fittings required for casing holes. The casing must be strong enough to maintain an open hole. Metal or plastic casing may be used as approved by the Owner if strong enough to maintain an open hole and must extend a minimum of 1 foot above the ground surface. The casings in soil shall be of sufficient inside diameter to permit drilling the required diameter hole in rock. Casing to be left in any paved area shall be steel and shall be cut flush to pavement level and capped with a steel cap. Leave casing in the hole until the completion of grout injection in that hole. Remove all metal casing completely. Remove plastic casing to a minimum of one foot below finished base grade.

15.08.4 RECORDS OF BORINGS

A. Maintain drilling logs (records) that document the types of soil and rock encountered, the depth of changes in soil and rock types, and the locations of voids, fractures, and water bearing zones, with special attention being given to the conditions at mine level (e.g., the presence of coal, gob, roof falls, voids, mud and water), to locations of abnormal loss or gain of drill water or air, and to interconnections between holes as evidenced by dust or water discharge from hole(s) other than the hole being drilled or grouted. This requirement is not relieved by the Owner being present and keeping a separate record of the drilling.

B. Provide a copy of the Contractor’s drilling log to the Owner within one day of completion of a particular hole and prior to the injection of grout.
15.08.5 DIRECTIVES

Depending upon conditions at the time of construction, the Owner reserves the right to:

A. Specify the sequence of drilling;
B. Terminate the drilling of any hole at any depth;
C. Order the drilling of holes in addition to those specified herein or delete the drilling of holes specified herein; and
D. Change the proposed locations of any of the holes.
E. Add additional holes for grouting and/or confirmation

This work consists of purchasing, handling and delivering to the site all required materials for injection and injecting the materials as directed by these specifications.

15.09 PROCEDURES

15.09.1 The Contractor will perform periodic soundings during grout and concrete injection operations to determine the levels of injected materials in the holes, and maintain the discharge points of the injection pipes below the surface level of the grout or concrete. Should the Owner suspect or observe that the grout or concrete take is moving off-site, pumping shall be halted and alternative measures will be directed by the Owner.

15.09.2 Barrier holes are the outer two rows of boreholes located along the perimeter of the area to be stabilized. The outer two rows of boreholes adjacent to the existing building are not considered barrier holes. Interior holes are boreholes located within the area bounded by the barrier holes. In general, low slump concrete is to be injected in void stages of barrier holes and grout is to be injected in non-void stages of barrier holes and all stages of interior holes. High slump concrete may be injected into void stages of interior holes if directed by the Owner. Barrier holes shall be completed prior to starting injection in interior holes unless otherwise approved by the Owner.

15.09.3 Injection sequence and injection materials and procedures for each hole will be determined by the Owner. In general, no more than 50 cubic yards of concrete shall be injected into a single barrier borehole in any one day. In general, grout or concrete shall be injected continuously into an interior borehole until the borehole fills to the base of the casing or until the Owner directs the Contractor to terminate injection into that borehole. The Owner may terminate injection in any borehole at any time that he determines is appropriate to attempt to limit undesirable loss of injection materials outside the area of stabilization. A minimum period of 12 hours shall elapse between subsequent injection stages in a given borehole.

15.09.4 All injection shall be performed using the gravity injection technique described herein. The grout or concrete supply pipe shall be extended to the bottom of the hole, filled with grout or concrete and slowly withdrawn from the borehole, as the grout or concrete rises. Additional material shall be pumped into the pipe as it is withdrawn such that the pipe is always full and the bottom of the pipe is always maintained within the grout or concrete being placed. Free fall of grout or concrete through the injection stage is prohibited.
15.09.5 Grouting above the mine shall continue to the top of rock unless large takes are encountered, in which case the mix may be thickened. If directed by the Owner, fine or coarse aggregate shall be placed in the hole by shoveling or other methods approved by the Owner while grouting continues.

15.09.6 No flushing of water down the hole or into the mine will be allowed once injection has commenced in that borehole. The Contractor shall inject the grout in such a way as to not coat or foul the borehole until mine-level voids are filled and the grout backs up into the borehole.

15.09.7 Concrete shall be placed within the following time limits after the introduction of the cement:
   1. 90 minutes when the ambient air temperature is 80°F or less.
   2. 60 minutes when the ambient air temperature is over 80°F.

15.09.8 Once the injection holes have been grouted or concrete placed to the ground surface, the casing shall be removed. Concurrently with or immediately after removal of the casing, the remaining open hole in the overburden shall be filled with grout or concrete to the ground surface. If settlement of the filler occurs later, the hole shall be refilled to the ground surface.

15.10 TESTING

15.10.1 The Contractor shall prepare grout and concrete test cylinders in accordance with ASTM C 31 at a rate of four per 50 cubic yards placed in a single pour or four for each pour less than 50 cubic yards. The Owner reserves the right to require preparation of cylinders from any batch. The samples shall be obtained at the injection hole location or at the batch plant as directed by the Owner. The Contractor shall have the cylinders tested according to ASTM C 39 at (two samples) 3, 7, and 28 days cure and shall report the results to the Owner in writing within 48 hours of the completion of each test. Test cylinders shall also be prepared at each plant or field change of the water-cement-limestone ratio. The slump of each load or batch of concrete shall be determined using the procedures of ASTM C 143. The fluidity of each load or batch of grout shall be determined according to ASTM C 939. The slump or fluidity of the mix shall be tested by the Contractor when requested by the Owner. A record of all test results shall be made.

15.10.2 If the Contractor desires to test cubes of grout and has completed the previous testing discussed under "Mix Designs," then he can mold and test cube samples of grout at the frequency specified above for cylinders in accordance with ASTM C 109.

15.11 SECONDARY DRILLING

15.11.1 GENERAL

The Contractor shall perform secondary drilling as required by the Owner to determine the effectiveness of the injection operations or to determine subsurface conditions and potentially grout encountered voids. The borehole shall be backfilled with grout upon completion as based on these specifications.

15.12 BOREHOLE PHOTOGRAPHY

15.12.1 The Contractor shall have the capability to retain the services of a qualified borehole video camera service to make and record on VHS tape (or digital media) horizontal visual observations with combined audio records through boreholes of the
effectiveness of the filling of the mine voids or to view conditions at mine level prior to injection. Provide a borehole television camera system for video inspection of the overburden rock and mine voids with the following features:

A. Accessibility through a 6-inch diameter borehole to a depth of 100 feet.
B. Provide video with high resolution and sharpness on VHS or DVD format.
C. Remotely controlled focus and internal variable light source.
D. Reel mounted cable with depth increments.
E. On-screen indicator of depth.
F. Portable video monitor for field viewing.
G. Audio input capability.
H. Lens and light source suitable for inspecting the walls of the borehole in the overburden rock.
I. Right angle lens and light source suitable for inspecting mine voids to a minimum distance of 30 feet from the borehole.
J. Audio down hole compass bearing of the direction that the lens is facing.
K. Waterproof light source capable of being lowered through a 6-inch borehole to a depth of 110 feet, in addition to the camera’s light source.

These services shall be provided when requested by the Owner. The Owner will request these services when the Design Engineer deems verification of mine level conditions necessary. The name and qualifications of the company providing these services shall be provided with the bid documents.

15.13 RECORDS AND FORMS

15.13.1 The Contractor shall maintain daily labor and material records on forms suitable to the Owner. The records shall include the actual measured quantities of each component of injection materials, including water.

15.13.2 The Contractor shall record the quantities of concrete and grout injected into each injection hole, using forms subject to the approval of the Owner.

15.13.3 Daily records of labor, mix proportions, slump measurements, fluidity measurements, and injection quantities shall be submitted to the Owner within one day of injection.
SECTION 16
SOIL COVER

16.01 GENERAL
16.01.1 DESCRIPTION OF WORK
This section included technical requirements for the soil cover material to be placed over the completed facility.

16.01.2 RELATED WORK SPECIFIED ELSEWHERE
A. Earthwork, base grade, and subbase (Section 1)
B. Revegetation (Section 12)

16.02 REFERENCES
16.02.1 The following codes and standards are referenced in this section.
A. VDOT, Road and Bridge Specifications – 2007.

16.03 MATERIAL REQUIREMENTS
16.03.1 Final Cover Soil:
A. Final pile surfaces shall be covered with 24 inches of soil (6-inch erosion layer and 18-inch infiltration layer).
B. At least 40 percent by weight of the soil cover shall be capable of passing through a 2 mm (U.S. Standard) No. 10 mesh sieve.
C. Soil cover shall fall within the United States Department of Agriculture texture classes of sandy loam, loam, sandy clay loam, silty clay loam, loamy sand, and silt loam. Also included will be clayey loam, sandy clay, clay, and silty clay if no more than 45 percent by weight (passing the No. 10 sieve) are smaller than 0.002 mm (clay).
D. The soil cover shall not include rocks that are greater than six inches in diameter.
E. Soil used for final cover shall have a coefficient of permeability less than $1 \times 10^{-3} \text{ cm/sec}$.

16.03.2 Intermediate Cover Soil:
A. Pile surfaces shall be covered with 12 inches of soil.
B. At least 40 percent by weight of the soil cover shall be capable of passing through a 2 mm (U.S. Standard) No. 10 mesh sieve.
C. Soil cover shall fall within the United States Department of Agriculture texture classes of sandy loam, loam, sandy clay loam, silty clay loam, loamy sand, and silt loam. Also included will be clayey loam, sandy clay, clay, and silty clay if no more than 45 percent by weight (passing the No. 10 sieve) are smaller than 0.002 mm (clay).
D. The soil cover shall not include rocks that are greater than six inches in diameter.
16.04 COVER SOIL PLACEMENT
A. The final soil cover on the pile shall be placed in 6-inch lifts and tracked in by two passes of the track area of a 165 HP or larger dozer within 90 days on those areas of the landfill embankment as they are brought to final grade.
B. The soil cover shall not be placed while rain is falling,
C. Material shall not be placed on frozen ground, and frozen material shall not be used for the soil cover.
D. At the end of the day’s operation, the soil cover shall be sloped to provide drainage to reduce infiltration of excess moisture.
E. In steep sloped areas, soil cover shall be placed from the bottom of the slope upward.

16.05 MAINTENANCE
A. Where landfill embankment areas have become damaged by erosion, slide or slip, or by acts, omissions or work activities of the Contractor, the affected areas shall be promptly regraded, limed, fertilized, and reseeded as originally required at no additional cost to the Owner.
B. The Contractor shall, for areas that have not established a satisfactory vegetative cover at the end of one growing season, re-seed, lime, fertilize, and mulch as originally specified at Contractor's expense.
SECTION 17
GEOGRID REINFORCEMENT

17.01 GENERAL
A. Section Includes - Geogrid reinforcement of base grade. Design details for geogrid reinforcement, such as geogrid type, fill thickness, and associated details, are shown on the contract drawings. Work consists of:
   1. Providing supplier representative samples for pre-construction conference with the Contractor and the Design Engineer.
   2. Furnishing geogrids as specified herein and shown on the contract drawings.
   3. Storing, cutting, and placing geogrids in accordance with these specifications and in reasonably close conformity with the lines, grades, and dimensions shown on the contract drawings or as established by the Design Engineer.
B. Related Sections
   1. Section 1.10 Earthwork, Base Grade and Subbase

17.02 REFERENCES
A. American Society for Testing and Materials (ASTM)
   1. D1388-96 - Standard Test Method for Stiffness of Fabrics, Option A
   3. D4354-96 - Practice for Sampling of Geosynthetics for Testing
   5. D5818-95 - Practice for Obtaining Samples of Geosynthetics from a Test Section for Assessment of Installation Damage
B. Geosynthetic Research Institute (GRI)
   1. GRI-GG2-87 - Standard Test Method for Geogrid Junction Strength
C. U.S. Environmental Protection Agency (U.S. EPA)
   1. EPA 9090 - Compatibility Test for Wastes and Membrane Liners
D. U.S. Army Corps of Engineers (U.S. CoE)
   1. Draft Specification for Grid Aperture Stability by In-Plane Rotation
   2. CW-02215 Determination of Percent Open Area.
E. Thomas C. Kinney, P.E., PhD
17.03 DEFINITIONS

A. Geogrid - A biaxial polymeric grid formed by a regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock, or earth to function primarily as reinforcement.

B. Welded Strip Geogrid – A geogrid product formed by heat bonding (welding) discrete strips of polymer into a regular network.

C. Minimum Average Roll Value (MARV) - Value based on testing and determined in accordance with ASTM D4759-92.

D. True Initial Modulus in Use - The ratio of tensile strength to corresponding zero strain. The tensile strength is measured via ASTM D6637 at a strain rate of 10 percent per minute. Values shown are MARVs. For multi-layer geogrid products, rib tensile testing shall be performed on the multi-layer configurations, as prescribed by ASTM D6637.

E. Junction Strength - Breaking tensile strength of junctions when tested in accordance with GRI-GG2 as modified by AASHTO Standard Specification for Highway Bridges, 1997 Interim, using a single rib having the greater of 3 junctions or 8 inches and tested at a strain rate of 10 percent per minute based on this gauge length. Values shown are minimum average roll values. For multi-layer geogrid products, junction strength testing shall be performed across junctions from each layer of grid individually, and results shall not be assumed as additive from single layers to multiple layers.

F. Flexural Stiffness (also known as Flexural Rigidity) - Resistance to bending force measured via ASTM D1388-96, Option A, using specimen dimensions of 864 millimeters in length by 1 aperture in width. Values shown are MARVs. For multi-layer geogrid products, flexural stiffness testing shall be performed directly on the multi-layer configuration without using any connecting elements other than those used continuously throughout the actual product, and results shall not be assumed as additive from testing performed on a single layer of the multi-layer product.

G. Aperture Stability Modulus (also known as Torsional Rigidity or Torsional Stiffness) - Resistance to in-plane rotational movement measured by applying a 20 kg-cm (2.0 m-N) moment to the central junction of a 9-inch by 9-inch specimen restrained at its perimeter. Values shown are MARVs. For multi-layer geogrid products, torsional stiffness testing shall be performed on each layer of grid individually, and results shall not be assumed as additive from single layers to multiple layers.

H. Base Grade Improvement – Placement of a geogrid immediately over a base grade soil in order to limit potential adverse effects on the liner system from tension cracks that could develop in the base grade in association with subsidence of the underground mine workings.

17.04 SUBMITTALS

A. Submit geogrid product sample approximately 4 inches by 7 inches or larger.

B. Submit geogrid product data sheet and certification from the Manufacturer that the geogrid product supplied meets the requirements of Section 17.07.B.

C. Submit Manufacturer’s installation instructions and general recommendations.

D. For Alternate Geogrid Materials submit the following for review:
1. Independent certified test results stating that the alternate geogrid exhibits an aperture stability modulus at 20cm-kg (2.0 m-N), when testing in accordance with the “Grid Aperture Stability In-Plane Rotation” test of 0.65 m-N/deg.

2. A list of 5 comparable projects that are similar in terms of size and application, are located in the United States, and where the results of using the specific alternate geogrid material can be verified after a minimum of 1 year of service life.

3. A sample (meeting the requirements of Section 17.07B) of the alternate geogrid material and certified specification sheets.

4. Recommended installation instructions.

5. Additional information as requested by the Owner’s Engineer to fully evaluate the product.

17.05 CONSTRUCTION QUALITY CONTROL AND QUALITY ASSURANCE

A. Pre-Construction Conference - Prior to the installation of the geogrid, the Contractor shall arrange a meeting at the site with the geogrid material supplier and, where applicable, the geogrid installer. The Owner and the Owner’s Engineer shall be notified at least 3 days in advance of the time of the meeting. A representative of the geogrid supplier shall be available on an “as needed” basis during construction.

B. Geogrid CQC will be performed by the Geogrid Installer in accordance with the CQC manual approved by the Owner.

C. Geogrid CQA will be performed by the QAO and paid for by the Owner. Geogrid CQA will be performed in accordance with these Technical Specifications and the project CQA Plan.

17.06 DELIVERY, STORAGE, AND HANDLING

A. Storage and Protection

1. Prevent excessive mud, wet concrete, epoxy, or other deleterious materials from coming in contact with and affixing to the geogrid materials.

2. Store at temperatures above -20 degrees F.

3. Rolled materials may be laid flat or stood on end.

4. Geogrid materials should not be left directly exposed to sunlight for a period longer than the period recommended by the manufacturer.

17.07 MATERIAL REQUIREMENTS

A. An approved geogrid is the BX1200 biaxial geogrid or equivalent manufactured by The Tensar Corporation.

B. Structural Soil Reinforcement Geogrid – The geogrid shall be integrally formed and deployed as a single layer having the following characteristics (ALL VALUES ARE MINIMUM AVERAGE ROLL VALUES UNLESS A RANGE OR CHARACTERISTIC IS INDICATED):
### Property Specifications – VDEQ, Part B Permit Application - CHSWMF

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Units</th>
<th>BX Geogrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aperture Stability Modulus at 20 cm-kg (2.0 m-N)</td>
<td>Kinney (2001)</td>
<td>m-N/deg</td>
<td>0.65</td>
</tr>
<tr>
<td>Rib Shape</td>
<td>Observation</td>
<td>N/A</td>
<td>Rectangular or Square</td>
</tr>
<tr>
<td>Rib Thickness</td>
<td>Calipered</td>
<td>in</td>
<td>0.05</td>
</tr>
<tr>
<td>Nominal Aperture Size</td>
<td>I.D. Calipered</td>
<td>(mm)</td>
<td>1.0 to 1.5</td>
</tr>
<tr>
<td>Junction Efficiency</td>
<td>GRI-GG2-87</td>
<td>%</td>
<td>93</td>
</tr>
<tr>
<td>Flexural Rigidity</td>
<td>ASTM D1388-96</td>
<td>mg-cm</td>
<td>750,000</td>
</tr>
<tr>
<td>Minimum True Initial Modulus in Use</td>
<td>ASTM D6637-01</td>
<td>lb/ft, lb/ft</td>
<td>27,420</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(kN/m)</td>
<td>(410)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>lb/ft, lb/ft</td>
<td>44,550</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(kN/m)</td>
<td>(620)</td>
</tr>
</tbody>
</table>

C. Alternate Structural Soil Reinforcement Materials – Alternate structural soil reinforcement materials will be considered in accordance with the following conditions:

1. Geotextile materials shall not be considered as an alternate to geogrid materials for base grade improvement or base grade/subbase reinforcement applications. A geotextile may be used in the cross-section to provide separation, filtration or drainage; however, no structural contribution shall be attributed to the geotextile.

2. Alternate geogrid materials shall not be used unless submitted to the Design Engineer and pre-approved in writing by the Design Engineer. In order to be considered, submittal packages for alternate geogrid materials must be prepared and submitted in accordance with Section 17.04D.

17.08 INSTALLATION

17.08.1 DELIVERY CHECK

The Contractor shall check the geogrid upon delivery to verify that the proper material has been received. The geogrid shall be inspected by the Contractor to be free of flaws or damage occurring during manufacturing, shipping, or handling.
17.08.2 PREPARATION
A. The base grade soil shall be prepared in accordance with Section 1.10 of this specification and as indicated on the construction drawings or as directed by the Owner’s Engineer.
B. Clear, grub and excavate to the design base grade elevation, stripping topsoil, deleterious debris and unsuitable material from the site.

17.08.3 DEPLOYMENT AND PLACEMENT
A. The geogrid shall be laid at the proper elevation and alignment as shown on the construction drawings.
B. Place rolls of geogrid in position, cut the roll bands and manually unroll the material over the prepared surface. Unroll the geogrid in the direction of fill advancement.
C. Overlap adjacent rolls along their sides and ends a minimum of one-foot and in the direction of fill placement to avoid peeling of the geogrid at overlaps by the advancing fill. To expedite shingling, consider placing rolls at the far end of the coverage area first, and work toward the near end from where the fill will be advanced.
D. Before fully unrolling the geogrid, anchor the beginning of the roll in the center and at the corners to the underlying surface. Anchoring may be done using either washers and pins or large, heavy-gauge staples by driving them into the subsoil through the apertures of the geogrid. If during fill placement waves are created in the geogrid, remove the anchoring and pull the geogrid taut before continuing fill placement.
E. Align the geogrid and pull it taut to remove wrinkles and laydown slack with hand tension, then secure in place.
F. Standard, highway-legal, rubber-tired trucks (end dumps and belly dumps) may drive over the geogrid at very slow speeds (less than 5 mph) and dump fill as they advance, provided this construction traffic will not cause significant rutting of the base grade. Turns and sudden starts and stops should be avoided.
G. Do not drive tracked equipment directly on the geogrid. Ensure at least one-foot of fill is spread between the geogrid and tracked equipment.

17.08.4 GRANULAR FILL PLACEMENT OVER GEOGRID
A. Granular fill material shall be placed in lifts and compacted as directed under Section 1.10. Granular fill material shall be placed, spread, and compacted in such a manner that minimizes the development of wrinkles in the geogrid and/or movement of the geogrid.
B. A minimum loose fill thickness of one-foot is required prior to operation of tracked vehicles over the geogrid. Turning of tracked vehicles should be kept to a minimum to prevent tracks from displacing the fill and damaging the geogrid. When underlying substrate is trafficable with minimal rutting, rubber-tired equipment may pass over the geogrid reinforcement at slow speeds (less than 10 mph) when integrally-formed geogrids are used. When woven, multi-layer or welded-strip geogrids are used, rubber-tired equipment shall not be allowed to pass directly on the geogrid. Sudden braking and sharp turning movements shall be avoided.
17.09 INSPECTION
A. The Owner or Owner’s representative may randomly inspect geogrid before, during and after (using test pits) installation.
B. Any damaged or defective geogrid (i.e. frayed coating, separated junctions, separated layers, tears, etc.) will be repaired/replaced in accordance with Section 3.06.

17.10 REPAIR
A. Any roll of geogrid damaged before, during and after installation shall be replaced by the Contractor at no additional cost to the Owner.
B. Proper replacement shall consist of replacing the affected area and adding 3ft (1m) of geogrid to either side of the affected area.

17.11 PROTECTION
A. Follow the Manufacturer’s recommendations regarding protection from exposure to sunlight.

17.12 WARRANTIES
A. Contractor shall be responsible for obtaining any necessary guarantees or certifications from the Geogrid Manufacturer and Contractor and submitting them to the Owner prior to acceptance of installed geogrid.
B. Contractor shall guarantee the integrity, within the realm of limitations of Contractor’s responsibility, of the installed geogrid for its intended use, from installation defects for a period of two years from the date of geogrid installation, and from manufacturing defects for a period of 2 years from the date of geogrid installation.
SECTION 18
GEOSYNTHETIC CLAY LINER

18.01 GENERAL

A. Contractor shall furnish supervision, labor, products, equipment, and tools, including necessary and incidental items as detailed or required, to install reinforced geosynthetic clay liner (GCL) in accordance with the Contract Drawings, Specifications, and project Construction Quality Assurance/Quality Control Plan (CQA/QC Plan).

B. GCL perimeter liner termination area shall be excavated, maintained, ballasted, and backfilled by the Contractor.

18.02 REFERENCES

A. American Society for Testing and Materials (ASTM) Standards:


December 2019


18.03 DEFINITIONS

**MARV:** Minimum Average Roll Value. For geosynthetics, the value calculated as the typical value minus two (2) standard deviations from documented quality control test results for a defined population from one specific test method associated with one specific property.

18.04 SUBMITTALS

A. Contractor shall be responsible for timely submittals to the Owner.

B. The following submittals shall be provided:

1. The GCL and GCL Manufacturer must be approved by the Owner. Submittals for approval include:

   a. GCL Manufacturer’s specification sheet(s) demonstrating compliance with the requirements of Table 18-1.

   b. GCL Manufacturer’s historical data for 10,000 hour large-scale constant load (“creep”) shear testing. Creep testing shall have been performed on hydrated reinforced GCL at a normal stress of 500 psf and at a constant shear stress of 250 psf.

   c. Written certification that the GCL Manufacturer has produced a minimum of 10,000,000 square feet of GCL that has been installed for hydraulic containment purposes in the last four years, including a list of the relevant completed facilities.
Each entry in this list should include the name, location, and purpose of the facility; GCL product designation, total square footage, and date of installation; names of the Owner, Designer, and GCL Installer; and the name and telephone number of a contact at the facility who can discuss the project.

d. A copy of the GCL Manufacturer’s manufacturing quality control (MQC) manual. This manual should describe the quality control program(s) for GCL components (bentonite clay, geotextiles, etc.) and finished GCL, and indicate the properties, test methods, and testing frequencies used for each. GCL Manufacturer shall modify the MQC manual to comply with the requirements of these Specifications, with variations, deviations, or exceptions clearly noted in an attached letter.

e. Prior to or coincident with shipment of GCL to the project site, submit written certification and supporting test data, in the form of Quality Control Certificates, documenting that all GCL components (bentonite and non-woven geotextile) and finished GCL shipped to the project site comply with the requirements of Section 18.06.1. GCL Quality Control Certificates must be reviewed and signed by a responsible representative of the GCL Manufacturer and shall include copies of all quality control certificates issued by the sodium bentonite and non-woven geotextile manufacturers.

f. Prior to or coincident with shipment of GCL to the project site, submit written certification stating that the GCL and accessory bentonite shipped to the project site were produced using the same sodium bentonite. Include supporting test data documenting that accessory bentonite complies with the requirements of Section 18.06.2.

2. The GCL Installer must be approved by the Owner. Submittals for approval include:

a. Written certification that the GCL Installer has installed a minimum of 2,000,000 square feet of GCL for hydraulic containment purposes in the last two years, including a list of the relevant completed facilities. Each entry in this list should include the name, location, and purpose of the facility; GCL product designation, total square footage, and date of installation; names of the Owner, Designer, Primary Contractor, and CQA Consultant; and the name and telephone number of a contact at the facility who can discuss the project.
b. A copy of the GCL Installer’s construction quality control (CQC) manual. This manual should describe the quality control program(s) for handling, deploying, anchoring, seaming, and repairing GCL. GCL Installer shall modify the CQC manual to comply with the requirements of these Specifications and the project CQA/QC Plan with variations, deviations, or exceptions clearly noted in an attached letter.

c. Four weeks prior to shipment of GCL to the project site, submit field installation drawings for approval. Installation drawings shall show the proposed length, width, and position of GCL panels and the location of butt seams. Installation drawings shall also show complete details for any proposed alternative installation methods. If any proposed alternative installation details are not accepted by the Design Engineer, the details provided on the construction drawings will be used.

d. Within one week after completion of GCL installation, submit a written report containing:

1) Written certification stating that the GCL has been installed in accordance with the Contract Drawings, Specifications, and project CQA/QC Plan.

2) Product and installation warranties as required by Section 18.07.8.

3) Copies of daily field records.

18.05 CONSTRUCTION QUALITY CONTROL AND QUALITY ASSURANCE

A. GCL construction quality control (CQC) will be performed by the GCL Installer in accordance with the approved CQC manual.

B. GCL construction quality assurance (CQA) will be performed by the CQA Consultant and paid for by the Owner. GCL CQA will be performed in accordance with these Specifications and the project CQA/QC Plan.

18.06 PRODUCTS

18.06.1 GEOCOMPOSITE CLAY LINER

A. The GCL and GCL Manufacturer must be approved by the Owner, as required by Section 18.04.
B. GCL shall consist of a layer of bentonite clay encapsulated between two non-woven needle-punched polypropylene (PP) geotextiles, and shall be fully needle-punched throughout to provide internal shear reinforcement. The physical, mechanical, and chemical properties of the reinforced GCL shall comply with the requirements of Table 18-1.

C. Bentonite used in the manufacture of GCL is to be processed specifically for producing GCL and shall be chemically compatible with the anticipated leachate. Bentonite shall be sampled and tested in accordance with the GCL Manufacturer’s approved MQC manual. Testing frequencies, test procedures, and bentonite properties shall comply with the requirements of Table 18-1. Results from the bentonite sampling and testing program are to be submitted to the Owner in accordance with Section 18.04.

D. Geotextile used in the manufacture of GCL shall be non-woven needle-punched polypropylene (PP) meeting the physical, mechanical, and chemical property requirements of Table 18-1. Polypropylene resin used in the manufacture of geotextile is to be made from virgin, uncontaminated ingredients and shall be designed and manufactured specifically for producing geotextile. Geotextile formulations shall contain no plasticizers, fillers, extenders, or post-consumer resin (PCR). During production, geotextile shall be continuously inspected for the presence of broken needles, which shall be removed from the finished product. Geotextile shall be sampled and tested, prior to incorporation into finished GCL, in accordance with the GCL Manufacturer’s approved MQC manual. Testing frequencies, test procedures, and geotextile properties shall comply with the requirements of Table 18-1. Results from the geotextile sampling and testing program are to be submitted to the Owner in accordance with Section 18.04.

E. During production, finished GCL shall be sampled and tested in accordance with the GCL Manufacturer’s approved MQC manual. Testing frequencies, test procedures, and finished GCL properties shall comply with the requirements of Table 18-1. Results from the finished GCL sampling and testing program, in the form of Quality Control Certificates, are to be submitted to the Owner in accordance with Section 18.04.

F. GCL shall be produced free of holes, tears, contamination by foreign matter, dimensional abnormalities, or other defects. During production, GCL shall be continuously inspected for the presence of broken needles, which shall be removed from the finished product. The CQA Consultant may reject all or portions of units (rolls) of GCL shipped to the project site if significant production flaws are observed.
G. GCL shall be manufactured as a continuous panel having a nominal width of 14.5 feet and minimum length of 150 feet in order to reduce the amount of field seaming required during installation. Rolls of GCL having lengths shorter than 150 feet may be shipped to the project site if approved by the Owner prior to shipment.

H. A six-inch overlap guideline shall be imprinted on both edges of one side of finished GCL to facilitate field seaming. Guidelines shall be printed in easily visible, non-toxic ink.

I. GCL shall be rolled onto hollow cores having a minimum inside diameter of four inches to allow the use of a stinger or spreader bar assembly for handling and deployment. Cores shall be of stable construction such that they support the roll without excessively deflecting, buckling, or otherwise failing during handling, transportation, and storage. Each roll of GCL shall be protected by wrapping it in packaging that is waterproof, resistant to photodegradation by ultraviolet light, and completely covers exposed GCL surfaces and edges.

J. Each GCL roll shall be labeled to identify the GCL Manufacturer, product designation, manufacturer’s batch or lot number, manufacturer’s roll number, length, width, and weight of roll. Roll identification numbers shall conform to the numbering system established on the GCL Manufacturer’s Quality Control Certificates. Labels shall be weather proof, legible, and located so each GCL roll can be identified by examining the outside of the roll or the core ends.

K. The Owner may inspect the GCL manufacturing process on a full-time basis. This inspection program would include conformance sampling as required. If requested, GCL Manufacturer shall submit a production schedule to the Owner and cooperate with the Owner during plant inspection.

L. GCL components and finished GCL properties, including testing frequencies and test procedures used, shall meet the requirements of this Section. No GCL shall be installed until the Owner has reviewed certifications and supporting test data and determined that the GCL delivered to the project site is acceptable for use. Manufacturing records, including test data, shall be maintained by the GCL Manufacturer for two years after acceptance of the GCL, and shall be made available upon request.

18.06.2 ACCESSORY BENTONITE

A. Granular bentonite sealing clay or bentonite mastic to be used for overlap seaming, penetration sealing, and repairs shall be made from the same bentonite used in the GCL.
B. Accessory bentonite shall be sampled and tested in accordance with the GCL Manufacturer’s approved MQC manual. Accessory bentonite shall meet the bentonite requirements of Table 18-1. Results from the accessory bentonite sampling and testing program are to be submitted to the Owner in accordance with Section 18.04.

18.07 EXECUTION

18.07.1 PRE-INSTALLATION MEETING

A. Prior to scheduled GCL installation, the Owner, Owner’s Engineer, CQA Consultant, Contractor, and GCL Installer shall attend a pre-installation meeting at the project site. This meeting shall be scheduled by the Owner after receipt of GCL Installer’s field installation drawings.

B. GCL Installer shall be represented by both the project field superintendent and the project manager.

C. At the pre-installation meeting, site safety and rules of operation, scheduling, methods of installation, construction quality control, and construction quality assurance shall be discussed. The GCL Installer, Owner’s Engineer, and CQA Consultant shall agree to the required GCL placement, seaming, and repair procedures for the project.

18.07.2 SHIPPING, HANDLING, AND STORAGE

A. Contractor is responsible for proper shipping, unloading, and storage of the GCL. GCL damaged during shipping, unloading, or storage shall be repaired or replaced at no cost to Owner.

B. GCL rolls shall be packaged and shipped so that no damage, including hydration, is caused during delivery to the project site. GCL shipping shall be by open or enclosed trailers loaded in such a manner that rolls can be readily unloaded at the project site using a stinger or spreader bar assembly. GCL rolls shipped by open trailer shall be protected with a sacrificial or temporary cover during shipment.

C. During unloading at the project site, Contractor shall conduct a surface inspection of GCL rolls for defects and damage, including damage to the original protective packaging. Contractor shall immediately notify CQA Consultant and Owner of any defects or damage observed.

D. Care shall be taken by personnel while unloading and handling GCL. Equipment used to unload and handle GCL shall have sufficient capacity to manage the roll weight without damaging the GCL. GCL
shall only be unloaded and handled using a stinger or spreader bar assembly meeting the requirements of ASTM D 5888 or as recommended by the GCL Manufacturer. Pushing, sliding, or dragging of GCL rolls is not permitted. CQA Consultant shall have the option of inspecting GCL panels, prior to final placement, to verify that defects or damage are identified for repair.

E. GCL shall be stored at the project site in an area(s) designated by the Owner and accepted by the CQA Consultant. The storage area shall be reasonably level and well-drained, and shall prepared so that the ground surface is firm, smooth, and free of stones, sticks, or other materials that may damage the GCL.

F. GCL rolls shall be stored off the ground and continuously supported along their length. Stacking of GCL rolls for storage is allowed but should not be so high that crushing of cores, flattening of rolls, or thinning of the GCL occurs. In general, the maximum stacking limit is three rolls high. A suitable means of securing the rolls shall be used so that shifting or other adverse movement does not occur.

G. During storage, GCL rolls and accessory bentonite shall be protected from moisture, direct sunlight, mud, and excessive dust by covering them with a plastic sheet or waterproof tarpaulin. Roll labels shall remain intact and legible. Rolls of GCL that have no label or where the label is damaged or otherwise illegible may be rejected by the CQA Consultant. GCL rolls shall be kept in their original protective packaging before they are to be deployed.

18.07.3 QUALITY ASSURANCE CONFORMANCE TESTING

A. Quality assurance conformance testing of the GCL shall be performed by the CQA Consultant and paid for by the Owner. If in-plant sampling is requested by the Contractor due to schedule or material qualification concerns, the Contractor shall reimburse the Owner for the additional costs to perform the sampling. Conformance testing lab results shall be provided directly to Owner and CQA Consultant for review upon receipt of testing data from lab. Conformance sampling and testing shall be completed in accordance with the project CQA/QC Plan, with at least one sample per production lot as directed by the Owner’s Engineer. Owner has the option to increase the frequency of conformance testing or to sample and test any questionable roll or lot.

B. Conformance testing of the GCL shall include, but not be limited to, the following properties:

1. Swell Index, ASTM D 5890

2. Dried Bentonite Mass per Unit Area, ASTM D 5993
3. **Moisture Content, ASTM D 4643**

4. **Peel Strength, ASTM D 6496 or ASTM D 4632**

5. **Permeability, ASTM D 5887**

6. **Interface Friction Strength, ASTM D 6423**

C. The Design Engineer may revise the test methods used for determination of conformance properties to allow for use of new or revised methods.

D. GCL conformance test results shall comply with the requirements of Table 18-1, prior to installation. GCL that does not conform to these requirements shall be retested or rejected in accordance with the CQA/QC Plan.

E. GCL that is rejected shall be removed from the project site and replaced at no cost to Owner. Sampling and conformance testing of GCL supplied as replacement for rejected material shall be performed by the CQA Consultant at Contractor’s cost.

**18.07.4 DEPLOYMENT AND PLACEMENT**

A. GCL shall be deployed and placed in general accordance with the GCL Installer’s approved field installation drawings. Depending on field conditions, it may be necessary to alter the GCL panel arrangement from that shown on the approved field installation drawings. These alterations shall be approved by the CQA Consultant prior to GCL deployment.

B. The Owner’s Engineer and Owner, in conjunction with the GCL Installer and Contractor, shall establish site-specific limits of weather conditions, including, but not limited to, temperature, precipitation, wind speed, and wind direction, within which GCL panel placement can be conducted. Acceptable weather conditions will be governed by the geomembrane used to cover the GCL. These weather conditions are outlined in Section 2 – PVC Geomembrane and Section 19 - LLDPE Geomembrane.

C. GCL Installer shall maintain a daily field record of actual placement of each GCL panel, noting GCL subbase conditions, weather, panel numbers placed, and seaming methods. A copy of each day’s field record shall be furnished to the CQA Consultant no later than the following work day.

D. Surfaces (compacted soil subbase) that receive GCL shall be prepared in accordance with the Contract Drawings and
Specifications. Once the surface has been approved by the CQA Consultant, any additional surface preparation that the Contractor or Geomembrane Installer feels necessary to meet the requirements of the Specifications shall be the responsibility of the Contractor. GCL installer shall install GCL only on surfaces that have been approved in writing by the Contractor, GCL Installer, and CQA Consultant.

E. GCL shall only be placed on surfaces (compacted soil subbase) that have been installed in accordance with the Contract Drawings and Specifications, and have been accepted in writing by the Contractor, GCL Installer, and CQA Consultant. Once a surface has been accepted by the CQA Consultant, any additional surface preparation that the Contractor or GCL Installer feels necessary to meet the requirements of the Specifications shall be the responsibility of the Contractor. Subbase surface shall be free of rocks, dirt, wet spots, tools, or other debris before placing GCL. Areas the GCL Installer believes exhibit deficient subgrade conditions shall be reported to the CQA Consultant and Owner for repair.

F. GCL Installer shall coordinate placement of GCL with placement of the covering material (geomembrane). GCL panels shall be covered with geomembrane as soon as possible after they are placed. Only as much GCL shall be deployed as can be covered by geomembrane in the same work day. No GCL shall be allowed to remain exposed at the end of a work day. GCL that becomes hydrated prior to placement of covering geomembrane shall be removed and replaced by the GCL Installer, as directed by the CQA Consultant, at no cost to Owner.

G. It is imperative to keep surface water runoff from contacting the GCL during installation. GCL Installer's and Contractor's anchor trench construction, stormwater controls, panel placement techniques and schedule shall minimize or eliminate the potential for accumulation of water beneath or atop the GCL. Any water found ponded on or beneath the GCL after it has been installed shall be removed by the Contractor, as directed by the CQA Consultant, at no cost to Owner. Any surface beneath installed GCL that has become excessively moist, soft, or unsuitable to perform its intended function, shall be removed and replaced by the Contractor, as directed by the CQA Consultant, at no cost to the Owner. GCL that becomes hydrated due to surface water runoff shall be removed and replaced by the GCL Installer, as directed by the CQA Consultant, at no cost to Owner.

H. Care shall be taken by personnel while handling, unwrapping, deploying, and placing GCL. Equipment and tools used shall not stretch, tear, or otherwise damage the GCL, and shall not cause rutting or other damage to the underlying surface. Equipment shall have sufficient capacity to manage the roll weight without damaging the GCL. GCL shall only be handled and deployed using a stinger or
spreader bar assembly meeting the requirements of ASTM D 5888 or as recommended by the GCL Manufacturer. Pushing, sliding, or dragging of GCL rolls is not permitted.

I. Construction or vehicular traffic shall not be allowed to drive over exposed GCL. GCL showing evidence of trafficking shall be inspected by the GCL Installer, Contractor, and CQA Consultant to evaluate damage. At the direction of the CQA Consultant, damaged GCL shall be repaired or replaced at no cost to Owner. CQA Consultant may allow limited use of four-wheeled ATVs or other low ground pressure equipment (having six psi or less contact pressure) by the GCL Installer during installation, but use shall be prohibited if excessive trafficking or any GCL damage is observed.

J. GCL rolls shall be transported from the storage area to the working area in their original protective packaging. After packaging is removed, GCL shall be unrolled and placed in such a manner as to minimize dragging of panels into position (“spotting”). A temporary smooth geosynthetic covering (“slip sheet”) shall be used to protect the top or bottom surface of the GCL from damage, as directed by the CQA Consultant.

K. GCL Installer shall immediately provide temporary anchorage of the GCL to prevent panel movement during placement of covering materials (geomembrane). Temporary anchorage methods shall be approved by the Owner and CQA Consultant. If bags are used for ballasting or temporary anchorage, they shall be filled with fine-grained sand that has been approved for use by the CQA Consultant. The use of bottom ash, fly ash, or aggregate to fill the bags is not permitted. GCL exhibiting damage due to insufficient or improper temporary anchorage shall be repaired or replaced, as directed by the CQA Consultant, at no cost to Owner.

L. GCL shall be installed so that it is in continuous contact with the underlying subbase, without being tensioned, and with no wrinkles or folds. Bridging at the toe of slopes or within pipe trenches shall not be permitted. If bridging is observed, GCL Installer shall repair affected areas, as directed by the CQA Consultant, at no cost to Owner.

M. GCL panel seams (edges) shall be oriented in a direction parallel to the line of maximum subgrade slope (i.e., down, not across the slope) and shall be placed in a manner that minimizes the number and length of field seams. In corners and odd-shaped geometric locations, the number of field seams shall be minimized and moved to locations outside the corners as appropriate.
N. GCL panel seams shall be shingled such that the "upstream" panel overlaps the "downstream" panel in order to minimize infiltration potential.

O. GCL panel seams parallel to the toe of a slope ("longitudinal seams") shall be located at least five feet from the toe of the slope, except where explicitly approved by the CQA Consultant. Longitudinal seams are permitted on sideslopes, but must be staggered in a manner approved by the CQA Consultant.

P. Contractor shall be responsible for excavation, maintenance, ballasting, and backfilling of the perimeter liner termination area in accordance with the perimeter liner termination area requirements outlined in geomembrane Section 2 or Section 19. Backfilling of the perimeter liner termination area shall commence only after the top geosynthetic layer has been approved by the CQA Consultant.

18.07.5 SEAMING

A. Lap joints shall be used to join GCL panels in the field. A minimum overlap of six inches shall be used for panel edges and 24 inches for panel ends. Overlap areas shall be kept free of rocks, loose soil, or other debris. GCL panels should be seamed as soon as possible after they are placed and prior to being covered with geomembrane.

B. For the GCL seams, a continuous bead of accessory bentonite having a minimum width of six inches and applied at a minimum rate of one-quarter-pound per linear foot of seam shall be placed in seam overlap areas. Particular care shall be taken to prevent fugitive bentonite from accumulating on the upper surface of the GCL and affecting geomembrane seaming operations. This accessory bentonite shall be applied even if the GCL product has “supergroove” or other self-seaming enhancements.

C. Seam overlap areas shall be left exposed after placing the accessory bentonite bead to allow the CQA Consultant to verify that the overlap area and the accessory bentonite bead meet the requirements of this Section. Seam overlaps shall not be “closed” until verbal acceptance of the seam is given by the CQA Consultant.

D. Completed GCL seams shall lay flat and be free of any rocks, loose soil, or other debris. Where wrinkles or folds do occur, the material shall be cut, overlapped, and a patch applied in accordance with Section 18.07.6.

18.07.6 REPAIRS

A. During installation, GCL Installer and CQA Consultant shall visually inspect GCL panels and seams for damage, defects, or
non-compliance with the Contract Drawings and Specifications, and shall mark any such areas for repair. GCL Installer shall repair marked areas as soon as possible and prior to covering the GCL with geomembrane.

B. Acceptable GCL repair methods include:

1. Patching: For repair of surface defects, small tears, punctures, etc. Patches shall have a minimum size of 24 inches by 24 inches and extend at least 12 inches beyond the edge(s) of a defect. Accessory bentonite or bentonite mastic shall be placed around a defect prior to placement of a patch. Where practical, patches shall be placed beneath installed GCL panels. If placed on top of installed GCL panels, patches may be affixed in place using an adhesive, as directed by the CQA Consultant. Care shall be taken to prevent fugitive bentonite from accumulating on the upper surface of the GCL and affecting geomembrane seaming operations.

2. In cases where an object beneath the GCL is causing the GCL to protrude more than one-half-inch, the CQA Consultant may direct the GCL Installer to cut the GCL and remove the object prior to patching.

18.07.7 ACCEPTANCE AND COVERING

A. No GCL shall be covered until it has been accepted by the CQA Consultant.

B. GCL Installer shall repair any areas identified by the CQA Consultant as not being in accordance with the Contract Drawings and Specifications. Once repairs are completed and accepted by the CQA Consultant, GCL shall immediately be covered with geomembrane in accordance with the Contract Drawings and Specifications.

C. If textured geomembrane is used to cover the GCL, a smooth temporary geosynthetic covering (“slip sheet”) shall be used to protect the GCL from damage until the geomembrane is in its final position for seaming.

18.07.8 WARRANTIES

A. Contractor shall be responsible for obtaining any necessary guarantees or certifications from the GCL Manufacturer and GCL Installer and submitting them to the Design Engineer and Owner prior to acceptance of installed GCL.

B. Contractor shall guarantee the integrity, within the realm of limitations of Contractor’s responsibility, of the installed GCL for its intended use, from installation defects for a period of two years from the date of GCL installation, and from manufacturing defects for a
period of 5 years from the date of GCL installation. Such written warranties shall provide for the total and complete repair and/or replacement of any defect or defective areas of GCL upon written notification and demonstration by the Owner of the specific non-conformance of the GCL or installation with the Contract Drawings and Specifications. Such defects or non-conformance shall be repaired and/or replaced expeditiously, at no cost to Owner.
## Table 18-1

**REQUIRED PROPERTIES OF REINFORCED GEOSYNTHETIC CLAY LINER**

<table>
<thead>
<tr>
<th>Property (Units)</th>
<th>MQC Testing Frequency (Minimum)</th>
<th>Test Method(2)</th>
<th>Required Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentonite(3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swell Index (ml/2g)</td>
<td>1 per 50 tons</td>
<td>ASTM D 5890</td>
<td>24 (min ave)</td>
</tr>
<tr>
<td>Fluid Loss (ml)</td>
<td>1 per 50 tons</td>
<td>ASTM D 5891</td>
<td>18 (max)</td>
</tr>
<tr>
<td>Non-Woven PP Geotextile(3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass per unit Area (oz/yd²)</td>
<td>Every 200,000 ft²</td>
<td>ASTM D 5261</td>
<td>6.0 (MARV)</td>
</tr>
<tr>
<td>Finished GCL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dried Bentonite Mass per unit Area (lb/ft²)</td>
<td>Every 40,000 ft²</td>
<td>ASTM D 5993</td>
<td>0.75 (min)(5)</td>
</tr>
<tr>
<td>Moisture Content (%)</td>
<td>Every 40,000 ft²</td>
<td>ASTM D 4643</td>
<td>30 (typ)</td>
</tr>
<tr>
<td>Grab Tensile Strength (lb)</td>
<td>Every 200,000 ft²</td>
<td>ASTM D 6768</td>
<td>50 (MARV)(4)</td>
</tr>
<tr>
<td>Peel Strength (lb/in or lb)</td>
<td>Every 40,000 ft²</td>
<td>ASTM D 6496 or ASTM D 4632</td>
<td>2.5 (min ave)(6) or 15 (min ave)(6)</td>
</tr>
<tr>
<td>Index Flux (m³/ m²/sec)</td>
<td>Weekly(7)</td>
<td>ASTM D 5887</td>
<td>1 x 10⁻³ (max)(8)</td>
</tr>
<tr>
<td>Permeability (cm/sec)</td>
<td>Weekly(7)</td>
<td>ASTM D 5887</td>
<td>5 x 10⁻³ (max)(8)</td>
</tr>
<tr>
<td>Internal Shear Strength</td>
<td>Every 500,000 ft²</td>
<td>ASTM D 6243</td>
<td>See Table 3-2a</td>
</tr>
<tr>
<td>Interface Shear Strength(1)</td>
<td>Every 500,000 ft²</td>
<td>ASTM D 6243</td>
<td>See Table 3-2a</td>
</tr>
</tbody>
</table>

**Notes:**

1. The required properties specified herein may be revised by the Design Engineer to reflect new or revised test methods or to conform with improvements to the state-of-the practice. Interface Shear Strength testing is not an MQC test but part of CQA Conformance Testing. Leachate compatibility testing is required and will be performed in advance by the owner to prequalify the proposed GCL material for the project. This requirement is not applicable to GCL used in PVC to LLDPE liner tie-in.

2. Number of specimens per test established in applicable test method unless otherwise noted.

3. Perform tests on as-received material before incorporation into finished GCL.

4. Perform tests in the machine direction.

5. Report at 0 percent moisture content.

6. Perform tests in the machine direction. ASTM D 6496 is the preferred test method for this project.

7. Provide the last 20 weekly values reported prior to the production date of the GCL supplied for the project. If GCL Manufacturer has multiple production lines or facilities, 20 values must be provided for each line and/or facility.

8. Prequalification testing may be performed in advance of the project by using deaired distilled/deionized water at 80 lb/in² cell pressure, 77 lb/in² headwater pressure, and 75 lb/in² tailwater pressure.
### Table 18-2

**MINIMUM INTERNAL AND INTERFACE SHEAR STRENGTH REQUIREMENTS FOR GEOSYNTHETIC CLAY LINER**

<table>
<thead>
<tr>
<th>Normal Load (psf)</th>
<th>Standard Test Peak Shear Strength (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>65</td>
</tr>
<tr>
<td>300</td>
<td>116</td>
</tr>
<tr>
<td>2,000</td>
<td>814</td>
</tr>
<tr>
<td>11,500&lt;sup&gt;(4)&lt;/sup&gt;</td>
<td>4,250</td>
</tr>
<tr>
<td>25,000&lt;sup&gt;(4)&lt;/sup&gt;</td>
<td>7,325</td>
</tr>
</tbody>
</table>

**Notes:**

1. Testing to be performed in accordance with ASTM D 6243 using the test conditions and procedures outlined in Table 18-2b.

2. Lower interface shear strength requirements may be acceptable if additional slope stability analysis is completed by the Design Engineer verifying a long-term static factor of safety greater than 1.5 and a long-term seismic factor of safety greater than 1.1.

3. If the test data is below the stated peak shear strength, the results may be deemed acceptable by the Design Engineer after reviewing a slope stability analysis of the test data.

4. Due to reduced loading condition of Stage 3A, GCL used for Stage 3A liner may ignore testing requirements for normal loads of 11,500 psf and 25,000 psf.
# Table 18-2b

**INTERFACE SHEAR STRENGTH TESTING**

**REQUIREMENTS FOR GEOSYNTHETIC CLAY LINER (1)**

<table>
<thead>
<tr>
<th>Standard Test</th>
<th>ASTM D 6243</th>
</tr>
</thead>
</table>
| **Conditioning & Set-up:** | 1. Hydrate GCL samples by themselves for 7 days @ 0 psf normal stress using tap water, or as directed by Owner’s Engineer.  
2. Consolidate GCL samples using the loading sequence below until the required shear test normal load is reached. Maintain each consolidation load increment for 48 hours, or sequence load as directed by Owner’s Engineer.  
3. Set up each test to match field placement orientation. Run all tests under wet conditions. |
| **Procedure A:** | Geomembrane against GCL  
Substrate: Coarse emery platen  
Superstratum: Steel rasp platen  
Displacement Rate: 0.005 ipm (maximum)  
Total Displacement: 2.25 in (minimum) |
| **Procedure B:** | GCL against Subbase  
Substrate: Compacted subbase (VDOT type A fine aggregate)  
Superstratum: Steel rasp platen  
Displacement Rate: 0.005 ipm (maximum)  
Total Displacement: 2.25 in (minimum) |
| **Special Instructions:** | None. |

**Note:**

(1) In lieu of testing individual interfaces, a system test may be performed using a configuration that allows failure to occur through the weakest shearing plane. System test configuration, conditions, and procedures must be accepted by the Design Engineer prior to submitting test results for review and approval.
SECTION 19
LLDPE GEOMEMBRANE

19.01 GENERAL
19.01.1 DESCRIPTION OF WORK
A. The Contractor shall furnish all supervision, labor, products, equipment, and tools, including all necessary and incidental items as detailed or required, to install geomembrane in accordance with the Contract Drawings, Technical Specifications, and project Construction Quality Assurance (CQA) Plan.

19.01.2 RELATED WORK SPECIFIED ELSEWHERE
A. Earthwork, Base Grade and Subbase - Section 1.
B. Geocomposite Drainage Net - Section 4.
B. Geotextiles - Section 6.
C. Quality Assurance Plan.

19.02 REFERENCES
19.02.1 CODES AND STANDARDS
A. American Society for Testing and Materials (ASTM) Standards:
   2. D 1004, “Standard Test Method for Tear Resistance (Graves Tear) of Plastics Film and Sheeting”.


**B. Geosynthetic Research Institute (GRI) Standards:**

1. **GM 11**, “Accelerated Weathering of Geomembranes Using a Fluorescent UVA-Condensation Exposure Device”.

2. **GM17**, “Test Methods, Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes”

3. **GM19a**, “Seam Strength and Related Properties of Thermally Bonded Homogeneous Polyolefin Geomembranes/Barriers”

**19.03 DEFINITIONS**

**19.03.1** Formulation: The mixture of a unique combination of ingredients identified by type, properties, and quantity. For linear low-density polyethylene (LLDPE) geomembrane, a formulation is defined as the exact percentages and types of resin(s), additives, and carbon black.

**19.04 SUBMITTALS**

**19.04.1** Contractor shall be responsible for timely submittals to the Owner.

**19.04.2** The following submittals shall be provided with Contractor’s Bid:

A. The geomembrane and Geomembrane Manufacturer must be approved by the Owner prior to Contract award. Submittals for approval include:
1. Geomembrane Manufacturer’s specification sheet(s) demonstrating compliance with the requirements of Table 19-1.

2. Written certification that the Geomembrane Manufacturer has produced a minimum of 5,000,000 square feet of LLDPE geomembrane that has been installed for hydraulic containment purposes in the last two years, including a list of the relevant completed facilities. Each entry in this list should include the name, location, and purpose of the facility; geomembrane thickness, total square footage, and date of installation; names of the Owner, Designer, Fabricator (if any), and Geomembrane Installer; and the name and telephone number of a contact at the facility who can discuss the project.

3. A copy of the Geomembrane Manufacturer’s MQC manual. This manual should describe the quality control program(s) for formulation ingredients (raw materials), and finished geomembrane sheet and indicate the properties, test methods, and testing frequencies used for each. Geomembrane Manufacturer shall modify the MQC manual to comply with the requirements of these Specifications, with any variations, deviations, or exceptions clearly noted in an attached letter.

B. The geomembrane shall meet the interface shear strength requirements of Table 19-2. Interface shear strength testing to verify compliance with the requirements of Table 19-2 shall be performed by the Owner. However, the Geomembrane Manufacturer shall review the interface shear strength requirements and test procedures outlined in Table 19-2 to avoid proposing the use of a geomembrane product(s) that will not meet these requirements. The interfaces that exist for this project include:

1. Geomembrane against geotextile; and
2. Geomembrane against GDN (double-bonded).

C. The Geomembrane Installer must be approved by the Owner prior to Contract award. Submittals for approval include:

1. Written certification that the Geomembrane Installer has installed a minimum of 1,000,000 square feet of LLDPE geomembrane for hydraulic containment purposes in the last four years, including a list of the relevant completed facilities. Each entry in this list should include the name, location, and purpose of the facility; geomembrane thickness, total square footage, and date of installation; names of the Owner, Designer, Primary Contractor, and CQA Consultant; and the name and telephone number of a contact at the facility who can discuss the project.

2. A copy of the Geomembrane Installer’s CQC manual. This manual should describe the quality control programs for handling, deploying, placing, anchoring, seams, repairing, and testing geomembrane. Geomembrane Installer shall modify the CQC manual to comply with the requirements of these Technical Specifications and the project CQA Plan, with any variations, deviations, or exceptions clearly noted in an attached letter.
19.04.3 The following submittals shall be provided after award of Contract:

A. Geomembrane Manufacturer:
   1. Prior to or coincident with shipment of geomembrane to the project site, submit written certification and supporting test data documenting that all resin used for geomembrane production complies with the requirements of Section 19.06.1.C. This certification shall state the producer, product designation, lot or batch number, and production date of all resin used in the manufacture of geomembrane shipped to the project site and shall include copies of all quality control certificates issued by the resin producer.
   2. Prior to or coincident with shipment of geomembrane to the project site, submit written certification and supporting test data, in the form of Quality Control Certificates, documenting that all geomembrane shipped to the project site complies with the requirements of Section 19.06.1.D. Geomembrane Quality Control Certificates must be reviewed and signed by a responsible representative of the Geomembrane Manufacturer.

B. Geomembrane Installer:
   1. Four weeks prior to shipment of geomembrane to the project site, submit six full sets of field installation drawings for the Quality Assurance Officer’s (QAO’s) approval. Installation drawings shall show the proposed length, width, and position of all geomembrane panels and the location of all field seams. Geomembrane panels and field seams shall have distinct identification systems. Installation drawings shall also show complete details for field seaming and repairs, anchoring geomembrane at the perimeter of the installation area, and attachments to structures and other penetrations, as required.
   2. Two weeks prior to arrival at the project site, submit personnel resumes demonstrating compliance with the following:
      a. A minimum of one field superintendent per shift shall be designated by the Geomembrane Installer and approved by the Owner. Each field superintendent shall have a minimum of five years of field experience installing LLDPE geomembrane. Any change or replacement of superintendents during the project must be approved in advance by the Owner.
      b. Each seaming crew shall have a designated foreman. Said foreman must have a minimum of two years of LLDPE geomembrane installation experience and must work continuously with the seaming crew.
      c. Each welding technician shall have a minimum of 1,000,000 square feet of LLDPE geomembrane welding experience.
   3. Within four weeks after completion of geomembrane installation, submit a written report containing the following:
a. Written certification stating that the geomembrane has been installed in accordance with the Contract Drawings, Technical Specifications, and project CQA Plan.

b. Product and installation warranties as required by Section 19.07.9.

c. Copies of daily field records and all testing documentation (trial seam testing, non-destructive testing, etc.).

d. As-built drawings depicting actual geomembrane panel placement and all associated details. As-built geomembrane plans ("panel diagrams") shall be prepared at a reasonable Engineer’s scale using Contractor’s surveyed edge of geomembrane limits (anchor trenches, runouts, etc.), and shall accurately depict panel orientations and dimensions; all repair locations (patches, cap strips, etc.); and shall clearly identify all panel numbers, seam identification numbers, and destructive testing sample locations.

19.05 CONSTRUCTION QUALITY CONTROL AND QUALITY ASSURANCE

19.05.1 Geomembrane CQC will be performed by the Geomembrane Installer in accordance with the CQC manual approved by the Owner.

19.05.2 Geomembrane CQA will be performed by the CQA Consultant and paid for by the Owner. Geomembrane CQA will be performed in accordance with these Specifications and the project CQA Plan.

19.06 MATERIAL REQUIREMENTS

19.06.1 LLDPE GEOMEMBRANE

A. The geomembrane and Geomembrane Manufacturer must be approved by the Owner prior to Contract award, as required by Section 19.04.2.B and Section 19.04.2.C.

B. Geomembrane shall be 60 mil linear low-density polyethylene (LLDPE) having textured upper and lower sheet surfaces. The physical, mechanical, and chemical properties of the geomembrane shall comply with the requirements of Tables 19-1 and 19-2a. Textured geomembrane having smooth edge strips six to eight inches in width (to facilitate field seaming) is acceptable provided the smooth edge material is of the same type of polymer and formulation as the base geomembrane. A co-extruded geomembrane having a light reflective surface (for reducing heat-related wrinkles) will be acceptable if the Geomembrane Manufacturer provides complete documentation demonstrating conformance with project criteria.

C. Geomembrane formulation shall consist of at least 97 percent (by weight) polyethylene resin, two percent to three percent (by weight) of carbon black (added for ultraviolet radiation resistance), and a maximum of one percent (by weight) of other additives. No plasticizers, fillers, extenders, post-consumer resin (PCR), or other materials shall be mixed into the formulation. Regrind, rework, or trim materials may be added to the formulation if they are produced by the Geomembrane Manufacturer and are of the same formulation as the
geomembrane being produced. Regrind, rework, and trim materials shall not exceed 10 percent (by weight) of the geomembrane formulation.

D. Polyethylene resin used in the manufacture of geomembrane is to be made from virgin, uncontaminated ingredients and shall be designed and manufactured specifically for producing geomembrane. Incoming resin shall be sampled and tested in accordance with the Geomembrane Manufacturer’s approved MQC manual. Testing frequencies, test procedures, and resin properties shall comply with the requirements of Table 19-1. Results from the resin sampling and testing program are to be submitted to the Owner in accordance with Section 19.04.3.A.2.

E. During production, finished geomembrane sheet shall be sampled and tested in accordance with the Geomembrane Manufacturer’s approved MQC manual. Testing frequencies, test procedures, and finished sheet properties shall comply with the requirements of Table 19-1. Results from the finished sheet sampling and testing program, in the form of Quality Control Certificates, are to be submitted to the Owner in accordance with Section 19.04.3.A.2.

F. Geomembrane shall be produced free of holes, bubbles, blisters, scratches, undispersed raw materials, contamination by foreign matter, dimensional abnormalities, or other defects. Textured geomembrane shall generally have a uniform texturing appearance and be free from agglomerated texturing material. The Owner may reject all or portions of units (rolls) of geomembrane shipped to the project site if significant production flaws are observed.

G. Geomembrane shall be manufactured as a continuous sheet having a minimum width of 20 feet and minimum length of 500 feet in order to reduce the amount of field seaming required during installation. No factory seaming of LLDPE geomembrane panels shall be accepted.

H. Geomembrane shall be rolled onto hollow cores having a minimum outside diameter of six inches and an inside diameter large enough to allow the use of a spreader bar assembly or fork lift stinger for handling and deployment. Cores shall be of stable construction such that they support the roll without excessively deflecting, buckling, or otherwise failing during handling, transportation, and storage. Rolled geomembrane shall be secured using dedicated straps, slings, or other suitable means to facilitate handling.

I. Each geomembrane roll shall be marked or labeled to identify the Geomembrane Manufacturer, product designation, manufacturer’s lot number, manufacturer’s roll number, sheet thickness, length and width of each roll, and panel number (if applicable). Roll identification numbers shall conform to the numbering system established on the Geomembrane Manufacturer’s Quality Control Certificates. Labels or markings shall be legible and located so that each roll of geomembrane can be identified by examining the outside of the roll or the core ends. Markings or labels shall be weather proof.

J. At the option of the Owner, an Owner’s Representative may inspect the geomembrane manufacturing process on a full-time basis. This inspection program would include conformance sampling as required. If requested, the Geomembrane Manufacturer shall submit a production schedule to the Owner and cooperate with the Owner’s Representative during plant inspection.
K. All raw material and finished geomembrane properties, including testing frequencies and test procedures used, shall meet the requirements of this Section. No geomembrane shall be installed until the Owner has reviewed all certifications and supporting test data and determined that the geomembrane delivered to the project site is acceptable for use. Manufacturing records, including test data, shall be maintained by the Geomembrane Manufacturer for two years after acceptance of the geomembrane, and shall be made available upon request.

19.06.2 LLDPE EXTRUDATE ROD
A. Extrudate rod to be used for all extrusion seaming of the geomembrane shall be made from the same resin as the geomembrane and shall be free of contamination by moisture or other materials. Carbon black and additives shall be thoroughly dispersed throughout the extrudate rod.

B. Extrudate rod resin and finished rod shall be sampled and tested in accordance with the Geomembrane Manufacturer’s approved QC manual. Extrudate rod resin shall meet the LLDPE geomembrane resin requirements of Table 19-1. Finished extrudate rod shall meet the LLDPE geomembrane carbon black content and carbon black dispersion requirements of Table 19-1. Testing frequencies and test procedures shall comply with the requirements of Table 19-1, as applicable. Results from the extrudate rod sampling and testing program are to be submitted to the Owner in accordance with Section 19.04.3.A.2.

19.06.3 PIPE PENETRATION SEALS
A. Boots (sleeves and skirts) to be used for sealing all pipe penetrations in the geomembrane shall be 60-mil LLDPE meeting the physical, mechanical, and chemical properties of Table 19-1 and the formulation and resin requirements of Section 19.06.1.C and Section 19.06.1.D. Factory pre-fabricated boots, produced by either the Geomembrane Manufacturer or Geomembrane Installer, are preferred for this project.

B. Gaskets to be used for sealing boots to pipes penetrating the geomembrane shall be neoprene and have a width of two inches and thickness of 0.25-inch. Neoprene adhesive shall be in accordance with the Geomembrane Manufacturer’s requirements.

C. Banding Straps to be used to attach boots to pipes penetrating the geomembrane shall be stainless steel and meet the requirements shown on the Contract Drawings.

19.07 INSTALLATION
19.07.1 PRE-INSTALLATION MEETING
A. Prior to scheduled geomembrane installation, the Owner, Owner’s Representative, CQA Consultant, Contractor, and Geomembrane Installer shall attend a pre-installation meeting at the project site. This meeting shall be scheduled by the Owner after receipt of Geomembrane Installer’s field installation drawings.
B. Geomembrane Installer shall be represented by both the project field superintendent and the project manager.

C. At the pre-installation meeting, site safety and rules of operation, scheduling, methods of installation, and construction quality control and quality assurance shall be discussed. The Geomembrane Installer, Owner’s Representative, and CQA Consultant shall at this time agree to the required geomembrane placement, seaming, sampling, testing and repair procedures for the project.

19.07.2 SHIPPING, HANDLING, AND STORAGE

A. Contractor is responsible for proper shipping, unloading, and storage of the geomembrane. Geomembrane damaged during shipping, unloading, or storage shall be repaired or replaced at no cost to the Owner.

B. Geomembrane rolls shall be packaged and shipped so that no damage is caused during delivery to the project site. Geomembrane shipping shall be by open trailer so rolls can be readily unloaded at the project site by lifting directly from the trailer using slings/straps, a stinger, or a spreader bar assembly.

C. During unloading at the project site, Seller shall conduct a surface inspection of all geomembrane rolls for defects and damage. Seller shall immediately notify CQA Consultant and Owner of any defects or damage observed.

D. Extreme care shall be taken by all personnel while unloading and handling geomembrane. Equipment used to unload and handle geomembrane shall have sufficient capacity to manage the roll weight without damaging the geomembrane. Geomembrane shall only be unloaded and handled using a stinger, spreader bar assembly, or the straps/slings provided by the Geomembrane Manufacturer. Pushing, sliding, or dragging of geomembrane rolls is not permitted. CQA Consultant shall have the option of inspecting all geomembrane panels, prior to final placement, to verify that all defects or damage are identified for repair.

E. Geomembrane shall be stored at the project site in an area(s) designated by the Owner and accepted by the CQA Consultant. Seller shall grade the storage area so that it is reasonably level and well-drained and shall prepare the ground surface so that it is firm, smooth, and free of stones, sticks, or other materials that may damage the geomembrane.

F. Stacking of geomembrane rolls for storage is allowed but should not be so high that crushing of cores or flattening of rolls occurs. In general, the maximum stacking limit is 3 rolls high. A suitable means of securing the rolls shall be used so that shifting, abrasion, or other adverse movement does not occur. Geomembrane with folds or creases of any kind shall be rejected and removed from the project site.

G. During storage, geomembrane shall be protected from excessive dust and mud by covering the rolls with a plastic sheet or waterproof tarpaulin. Roll labels shall remain intact and legible. Any roll of geomembrane that has no label or where the label is damaged or otherwise illegible may be rejected by the CQA Consultant.
19.07.3 QUALITY ASSURANCE CONFORMANCE TESTING

A. Quality assurance conformance testing of the geomembrane shall be performed by the CQA Consultant and paid for by the Owner. Conformance testing lab results shall be provided directly to Owner and CQA Consultant for review upon receipt of testing data from lab. Conformance sampling and testing shall be completed in accordance with the project CQA Plan; one (1) sample per 100,000 sf of geomembrane, with at least one sample per production lot as directed by the Owner’s Representative. Owner has the option to increase the frequency of conformance testing or to sample and test any questionable roll or lot.

B. Owner may revise the test methods used for determination of conformance properties to allow for use of new or revised methods.

C. All geomembrane conformance test results shall comply with the requirements of Tables 19-1 and 19-2a prior to installation. Any geomembrane that does not conform to these requirements shall be retested or rejected in accordance with the CQA Plan.

D. Geomembrane that is rejected shall be removed from the project site and replaced at no cost to Owner. Sampling and conformance testing of geomembrane supplied as replacement for rejected material shall be performed by the CQA Consultant at Seller’s cost.

19.07.4 CONTRACTOR’S DEPLOYMENT AND PLACEMENT

A. Geomembrane shall be deployed and placed in general accordance with the Geomembrane Installer’s approved field installation drawings. Depending on field conditions, it may be necessary to alter the geomembrane panel arrangement from that shown on the approved field installation drawings. These alterations shall be approved by the CQA Consultant prior to geomembrane deployment.

B. Geomembrane Installer shall maintain a daily field record of actual placement of each geomembrane panel, noting base grade conditions, weather, seaming parameters, panel numbers placed, seams completed, samples taken, and tests run. A copy of each day’s field record shall be furnished to the CQA Consultant no later than the following work day.

C. Geomembrane shall only be placed on surfaces (geotextile or subbase) that have been installed in accordance with the Contract Drawings and Specifications, and have been accepted in writing by the Seller, Geomembrane Installer, and CQA Consultant. Once a surface has been accepted by the CQA Consultant, any additional surface preparation that the Seller or Geomembrane Installer feels necessary to meet the requirements of the Specifications shall be the responsibility of the Contractor.

D. Geomembrane shall only be placed above subbase that is free from standing water, excessive moisture, rutting, or other damage caused by vehicular traffic, erosion, or other causes. Surface requirements, including allowances for desiccation cracking, shall be as outlined in Section 1 – Earthwork, Base
Grade and Subbase, of the Specifications. Areas exhibiting deficient surface shall be reported to the CQA Consultant and Owner for repair.

E. It is imperative to keep surface water runoff from beneath the geomembrane during installation. Geomembrane Installer's panel placement and seaming techniques and schedule shall minimize or eliminate the potential for accumulation of water beneath the geomembrane. Any water found ponded beneath the geomembrane after it has been installed shall be removed by the Seller, as directed by the CQA Consultant, at no cost to Owner. Any soil beneath installed geomembrane (subbase or base grade) that has become excessively moist, soft, or unsuitable to perform its intended function, shall be removed and replaced by the Contractor, as directed by the CQA Consultant, at no cost to Owner.

F. Equipment and tools used to deploy and place geomembrane shall not stretch, score, scratch, crease, or otherwise damage the geomembrane, and shall not damage any underlying geosynthetic or soil.

G. Under no circumstances shall any construction or vehicular traffic be allowed to drive over exposed geomembrane. Geomembrane showing evidence of trafficking shall be inspected by the Geomembrane Installer, Owner, and CQA Consultant to evaluate damage, if any. At the direction of the CQA Consultant, any damaged geomembrane shall be tested, rejected, or repaired at no cost to Owner. CQA Consultant may allow limited use of four-wheeled ATVs or other low ground pressure equipment (having 6 psi or less contact pressure) by the Geomembrane Installer during installation, but use shall be prohibited if excessive trafficking or any geomembrane damage, including scratches, is observed.

H. Geomembrane shall be placed in such a manner as to minimize dragging of panels into position (“spotting”). Geomembrane Installer shall immediately provide temporary anchorage of the geomembrane to prevent wind uplift, panel movement during field seaming, and bridging (refer to Section 19.07.4.J for bridging requirements). Temporary anchorage methods shall be approved by the Owner and CQA Consultant. If bags are used for temporary anchorage, they shall be filled with fine-grained VDOT Grading A Fine Aggregate that has been approved for use by the CQA Consultant. Any geomembrane exhibiting damage due to insufficient or improper temporary anchorage shall be repaired or replaced, as directed by the CQA Consultant, at no cost to Owner.

I. Geomembrane Installer shall place and seam geomembrane panels to provide adequate, well distributed slack to account for thermal expansion or contraction of the geomembrane. For this purpose, the Geomembrane Installer may use a working range of geomembrane sheet temperatures from 0° to 150°F to determine required techniques. In critical areas such as sumps, leachate pipe trenches, and corners, the Geomembrane Installer may propose slack control techniques for approval by the Owner.

J. Geomembrane shall be installed to minimize or eliminate bridging (“trampolining”) at the toe of slopes or within leachate pipe trenches at temperatures as low as 32°F. Bridging control measures may include providing slack, using and maintaining additional temporary anchorage (e.g.,
VDOT Grading A Fine Aggregate bagging), or other methods approved by the Owner. If bridging is observed, Geomembrane Installer shall repair affected areas, as directed by the CQA Consultant, at no cost to Owner.

K. Scratches on the geomembrane surface caused during geomembrane handling, deployment, or by placement or transport of geomembrane or overlying materials, shall be evaluated for repair by the CQA Consultant. Excessive scratches may result in removal and replacement of the entire affected panel.

L. Panel seams shall be oriented in a direction parallel to the line of maximum base grade slope (i.e., down, not across the slope) and shall be placed in a manner that minimizes the number and length of field seams. In corners and odd-shaped geometric locations, the number of field seams shall be minimized and moved to locations outside the corners as appropriate.

M. For geomembrane placed on slopes, panels shall be shingled such that the "upstream" panel overlaps the "downstream" panel in order to minimize infiltration potential.

N. Panel seams parallel to the toe of a slope ("longitudinal seams") shall be located at least 10 feet from the toe of the slope, except where explicitly approved by the CQA Consultant. Longitudinal seams are to be avoided on side slopes. If a longitudinal seam is required, it shall be 45° to the slope contours. Adjacent side slope seams shall be staggered a minimum of the panel width.

O. Geomembrane panels shall be permanently seamed on the same day they are placed except where explicitly approved by the CQA Consultant.

P. The Contractor shall be responsible for excavation, maintenance, ballasting, and backfilling of the geomembrane anchor trench. Backfilling of the anchor trench shall commence only after the geomembrane and geotextile and/or GDN installations have been approved by the CQA Consultant. Backfilling materials and compaction methods shall be as outlined in the Technical Specifications.

Q. Loose soil shall not be permitted to underlie the geosynthetics in the anchor trench or perimeter liner termination area. These features shall be graded to prevent ponding or run-on of water while the area is exposed. Contractor shall be responsible for preventing surface water runoff from accumulating beneath or atop the geosynthetics while the anchor trenches or perimeter liner termination area is exposed.

R. Backfilling of the perimeter liner termination area shall commence only after the leachate collection system GDN or geotextile has been approved by the CQA Consultant. Backfilling materials and compaction methods shall be as outlined in Section 1 – Earthwork, Base Grade and Subbase, of the Specifications.

19.07.5 SEAMING

A. Lap joints and thermo-fusion seaming methods shall be used to join geomembrane panels in the field. A minimum overlap of four inches shall be used. Seams shall be hot wedge or extrusion welded as prescribed by the
Geomembrane Manufacturer and approved by the Owner. For joining geomembrane panels, dual hot wedge is the preferred seaming method. For tie-in areas (joining new geomembrane to geomembrane placed during previous construction projects), single hot wedge is the preferred seaming method, as approved by the Owner’s Representative and CQA Consultant. Extrusion seaming shall be used primarily for repairs and detailing.

B. Geomembrane Installer shall provide the following equipment, and any required accessories, to complete geomembrane seaming. Equipment shall be provided and maintained in sufficient numbers to avoid delaying work.

1. Seaming equipment: Hot wedge (single-track and dual-track), extrusion, and hot air (“leister”) welding machines. Seaming equipment shall be equipped with gauges that clearly display wedge temperature, rate of travel, barrel temperature, and nozzle (“pre-heat”) temperature, as applicable.

2. Destructive testing equipment: Punch press and field tensiometer for field destructive testing of geomembrane seams. Punch press shall be capable of producing die-cut geomembrane specimens in accordance with ASTM D 6392. Tensiometer shall be built to ASTM specifications, be in good working order, and shall be accompanied by evidence of calibration within the last year.

3. Non-destructive testing equipment: Vacuum box, air pump(s) and gauges, and voltage applicator(s) for non-destructive testing of geomembrane seams and repairs. Testing equipment shall be built to ASTM specifications and be in good working order.

4. Portable electric generators: Capable of providing constant voltage under a combined-line load. Generators must have rubber tires or be placed on a layer of cushioning material that does not damage the geomembrane.

5. Miscellaneous equipment: Any other equipment or tools (e.g., hook blades, scissors, markers) necessary to complete geomembrane seaming, testing, and labeling in accordance with these Specifications and the Geomembrane Installer’s approved CQC manual.

C. No production seaming shall commence until trial seaming, as outlined in Section 19.07.5.1, is successfully completed and accepted by the CQA Consultant.

D. The Owner’s Representative and Owner, in conjunction with the Geomembrane Installer and Seller, shall establish site-specific limits of weather conditions, including, but not limited to, temperature, humidity, precipitation, and wind speed and direction, within which geomembrane panel placement and seaming can be conducted. In the absence of site-specific criteria, the following limitations shall apply:

1. No placement or seaming shall be conducted in the presence of precipitation, such as rain, snow, sleet, dew or fog.

2. No placement or seaming shall be conducted in the presence of winds in excess of 20 miles per hour, when dirt or debris is blown into
seaming areas, or when seaming temperatures cannot be adequately monitored and controlled.

3. **Seaming shall not be conducted when geomembrane sheet temperature falls below 40°F unless approved by the CQA Consultant.** In order for seaming to be approved, Geomembrane Installer shall be required, at a minimum, to prepare additional trial seams to demonstrate conformance with these Specifications. Owner’s Representative reserves the right to require additional destructive seam testing when seaming is conducted at geomembrane sheet temperatures below 40°F. Geomembrane Installer shall be prepared to pre-heat seaming areas prior to production seaming in accordance with Geomembrane Manufacturer recommendations.

4. **Seaming shall not be conducted when geomembrane sheet temperature exceeds 104 degrees F unless approved by the CQA Consultant.** Criteria for demonstration of conformance shall be outlined by the Owner's Representative.

E. **For purposes of monitoring production seaming, geomembrane sheet temperature shall be measured and recorded by the CQA Consultant at multiple locations along seam overlap areas.**

F. **Geomembrane Installer shall not cause excessive overheating of the geomembrane during trial or production seaming.** Excessive overheating is defined as any of the following:

1. Application of seaming temperatures or seaming rates that result in visible warping, deformation, or discoloration of the bottom surface of the lower geomembrane in the seam area.

2. **Seaming over an existing seam ("piggybacking"), except for repairs (patches, cap strips, etc.) which cross over existing seams.**

3. **Seaming using temperatures in excess of the Geomembrane Manufacturer’s recommended seaming temperatures as defined at the pre-installation meeting.**

G. **Extrusion seaming material shall be of a type or types recommended by the Geomembrane Manufacturer and shall be delivered to the project site in original sealed containers or packaging, each with an indelible label bearing the manufacturer’s name, manufacturer’s batch or lot number, and complete directions as to proper storage and use.**

H. **Storage of fuel, oils, and other petroleum products shall be restricted to off-geomembrane areas.** Similarly, fueling of equipment (e.g. generators) and changing of oil and oil filters shall be restricted to off-geomembrane areas. If any fuel, oils, or other petroleum products are leaked or accidentally spilled on the geomembrane, they shall be immediately removed. The spill area shall be inspected for damage by the Contractor, Geomembrane Installer, and CQA Consultant, and any damaged geomembrane shall be repaired or replaced as directed by the CQA Consultant.

I. **Trial Seaming**
1. **Geomembrane Installer shall be responsible for field destructive testing of trial seams.**

2. **Trial seams shall be prepared for each piece of seaming equipment whenever any of the following conditions occur:**
   a. Shift start-up.
   b. Every six hours of continuous seaming within a shift.
   c. “Cold” restart of seaming equipment.
   d. Change in welding technician.
   e. Significant change in geomembrane sheet temperatures.
   f. As required by the CQA Consultant.

3. **Trial seams shall be prepared in the presence of the CQA Consultant using the same personnel, equipment, and seaming conditions that will be used during production seaming. Field destructive test results acceptable to the CQA Consultant shall be obtained prior to performing any production seaming. This may require resampling of completed trial seams or repeating the trial seam process, as directed by the CQA Consultant.**

4. **Trial seams shall have a minimum length of six feet and minimum width of one-foot, with the seam centered across the width. Geomembrane Installer shall cut the trial seam into two equal length samples suitable for testing. One sample shall be kept by the Geomembrane Installer for destructive testing at the project site in the presence of the CQA Consultant. The duplicate sample shall be furnished to the CQA Consultant for the project record and possible future testing. Geomembrane Installer shall mark the duplicate sample with the date, time, ambient temperature, seaming machine identification, seaming technician initials, and seaming parameters (set temperature, rate of travel, etc.) used to prepare the trial seam.**

5. **Trial seam samples shall be destructively tested in peel and shear in accordance with the Geomembrane Installer’s approved CQC manual. A minimum of three specimens shall be tested in peel and two in shear for each trial seam. For dual hot wedge seams, specimens must be tested in peel for each external seam track. Test specimens shall be die cut by the Geomembrane Installer using a die and punch press capable of producing specimens in accordance with ASTM D 6392. Specimens shall be cut from the center two-thirds of the trial seam sample once it has cooled to ambient temperature.**

6. **Qualification criteria for all trial seam destructive testing are summarized in Table 19-3. Acceptable failure of seam specimens shall be in the geomembrane sheet, not within the seam itself. A partial seam separation (“peel incursion”) during testing will be accepted as indicated in Table 19-3. Excessive peel incursion within the seam area shall constitute disqualification even if strength criteria are met. If any specimens fail to meet qualification criteria, CQA Consultant may have**
additional specimens from the sample tested in order to determine trial seam acceptance. Failures attributed to excessive grinding beyond weld bead areas for extrusion seams may require retesting or preparation of a new trial seam, as directed by the CQA Consultant.

7. If a trial seam fails to meet all qualification criteria, a new trial seam must be prepared. If this second trial seam also fails, the seaming equipment and/or seaming technician preparing the trial seams shall not be allowed to perform production seaming until any deficiencies are corrected and two consecutive trial seams meeting all qualification criteria are prepared and accepted by the CQA Consultant.

8. Trial seam test results shall be recorded in the Geomembrane Installer’s "preweld" test log or daily field record and a copy furnished to the CQA Consultant no later than the following work day. Specimens tested by the Geomembrane Installer shall be marked and stored on the project site for inspection by the Owner’s Representative or Owner.

J. Production Seaming

1. No production seaming shall commence until trial seaming, as outlined in Section 19.07.5.I, is successfully completed and accepted by the CQA Consultant.

2. Geomembrane panels shall be permanently seamed on the same day they are placed except where explicitly approved by the CQA Consultant.

3. Geomembrane that is to be hot wedge seamed shall be prepared as follows:
   a. Position geomembrane sheets to create a minimum overlap of four inches. If the overlap is excessive, excess geomembrane shall be trimmed from the lower sheet where possible. If excess geomembrane is trimmed from the upper sheet, Geomembrane Installer shall not scratch or score the lower sheet. Geomembrane damaged during trimming may be removed and the panel overlap reset, as directed by the CQA Consultant.
   b. Temporarily anchor sheets in a manner approved by the CQA Consultant to prevent movement during seaming and to maintain a “flat” lap of sheets. No glue or tape shall be used to temporarily hold sheets together before seaming.
   c. Prepare overlap area to provide a suitable welding surface. Overlap area shall be free of dirt, dust, moisture, or other foreign material. No solvents shall be used to clean geomembrane sheets prior to seaming.
   d. Seaming shall be completed as soon as is practical after preparation and cleaning is completed.

4. Geomembrane that is to be extrusion seamed shall be prepared as follows:
a. Position geomembrane sheets to create a minimum overlap of four inches.

b. Grind the edge of the upper geomembrane sheet to a 45-degree bevel using a disc grinder or equivalent tool. Lift the upper geomembrane sheet away from the lower sheet during beveling to prevent gouging of the lower sheet.

c. Temporarily bond geomembrane sheets, using hot air ("leister") equipment, to prevent movement during seaming and to maintain a "flat" lap of sheets. No glue or tape shall be used to temporarily hold sheets together before seaming. Overheating of the geomembrane during temporary bonding shall result in rejection of the seam or repair in question and shall be repaired as directed by the CQA Consultant.

d. Grind geomembrane surfaces that are to receive the extrusion weld bead, using a disc grinder or equivalent tool, no more than 15 minutes prior to seaming. Grinding area shall extend no more than one-quarter-inch beyond the extrusion weld bead area and the grinding depth shall not exceed 10 percent of the geomembrane sheet thickness. Extrusion seam ends that are more than five minutes old shall be ground prior to joining or extending the seam. Geomembrane residue generated during grinding shall be cleared from the seaming area.

e. Prior to extrusion seaming, CQA Consultant shall visually inspect all prepared geomembrane surfaces to verify that excessive grinding has not occurred, and that the upper geomembrane sheet is properly beveled. CQA Consultant may require repair of areas exhibiting excessive grinding or improper beveling, which may include removal and replacement of affected geomembrane. Extrusion welding machines are to be purged of all heat-degraded extrudate prior to seaming. During seaming operations, extrudate purging will be required whenever the welding machine is idle for more than two minutes, or as directed by the CQA Consultant.

5. No folds, wrinkles, or "fish-mouths" shall be allowed within any seam areas. Where wrinkles or folds occur, the material shall be cut, overlapped, and a patch applied. During wrinkle or fold repairs, adjacent geomembrane may not be required to meet the four-inch minimum overlap, if approved by the CQA Consultant.

K. Non-Destructive Testing

1. Geomembrane Installer shall be responsible for non-destructive testing of the entire length (100 percent) of all production seams and repairs to verify their continuity. Non-destructive testing shall be conducted as geomembrane seaming and repair work progresses and shall be performed in the presence of the CQA Consultant.

2. Non-destructive test methods shall include the vacuum test, air-pressure test, spark test, or other methods approved by the Owner's
Representative. Non-destructive testing procedures shall be described in the Geomembrane Installer’s approved CQC manual and shall comply with all requirements of these Specifications and the project CQA Plan.

3. Seams or portions of seams that cannot be non-destructively tested due to access constraints or other reasons may be covered with a cap-strip as required by the CQA Consultant.

4. Geomembrane Installer shall submit copies of all non-destructive testing documentation to the Owner’s Representative in accordance with Section 19.04.3.B.

L. Destructive Testing

1. Laboratory destructive testing of production seams is the responsibility of the CQA Consultant and will be paid for by the Owner. Field destructive testing of production seams is the responsibility of the Geomembrane Installer. Geomembrane Installer is also responsible for obtaining samples and repairing sampling locations for all laboratory and field destructive testing.

2. Destructive testing sample locations shall be repaired in accordance with Section 19.07.6.

3. Production seam samples suitable for laboratory destructive testing shall be obtained by the Geomembrane Installer at locations established by the CQA Consultant as production seaming progresses. All seaming equipment and welding technicians will be representatively sampled at a rate of one sample per 500 linear feet of production seam. Additional samples shall be obtained by the Geomembrane Installer from areas of questionable integrity, as directed by the CQA Consultant.

4. Laboratory destructive testing samples shall have a minimum length of three feet and minimum width of one-foot, with the seam centered across the width. Geomembrane Installer shall cut the destructive sample into two equal length samples suitable for testing. Both samples shall be furnished to the CQA Consultant, who will forward one sample to a geosynthetic testing laboratory where it shall be destructively tested in peel and shear in accordance with ASTM D 6392. The duplicate sample shall be retained by the CQA Consultant for the project record and possible future testing. An additional duplicate destructive sample may be obtained and retained for testing by the Geomembrane Installer at the Installer’s discretion. This additional sampling and testing, if performed, shall be completed at no cost to Owner.

5. Qualification criteria for all production seam destructive testing are summarized in Table 19-3. Acceptable failure of seam specimens shall be in the geomembrane sheet, not within the seam itself. A partial seam separation (“peel incursion”) during testing will be accepted as indicated in Table 19-3. Excessive peel incursion within the seam area shall constitute disqualification even if strength criteria are met. If any
specimens fail to meet qualification criteria, CQA Consultant may have additional specimens from the sample tested in order to determine production seam acceptance. Failures attributed to excessive grinding beyond weld bead areas for extrusion seams may require resampling and retesting, as directed by the CQA Consultant. CQA Consultant shall determine acceptance of any destructive testing in cases of dispute.

6. If a destructive test sample fails to meet all qualification criteria, Geomembrane Installer shall obtain two additional production seam samples, each approximately 10 feet in opposite directions from the original sample, for laboratory destructive testing. Testing of these samples shall be performed by the CQA Consultant at the Geomembrane Installer’s expense. Resampling and associated repairs shall be the responsibility of the Geomembrane Installer and shall be performed at no cost to Owner.

7. For a production seam to be accepted, a failed destructive test sample shall be bounded by two passing destructive test samples, and the seam between the two passing test locations shall be reconstructed. Alternatively, the entire length of the seam in question may be repaired by placement of a cap strip, or by another repair procedure, as directed by the CQA Consultant.

8. The CQA Consultant, Owner’s Representative, or Owner may require that additional destructive test samples be taken at random locations from production seams completed during the same work shift as a failing destructive test sample or in areas that visually appear defective or not in accordance with these Specifications. Testing of these samples shall be performed by the CQA Consultant but obtaining the samples and repairing the sampling locations shall be the responsibility of the Geomembrane Installer and shall be performed at no cost to Owner.

19.07.6 REPAIRS

A. During installation, Geomembrane Installer and CQA Consultant shall visually inspect all geomembrane panels and seams for damage, defects, or non-compliance with the Contract Drawings and Specifications, and shall mark any such areas for repair. Geomembrane Installer shall repair marked areas as soon as possible. Any defects that could allow surface water runoff beneath the geomembrane shall be repaired on the same day they are marked.

B. Acceptable geomembrane repair methods include:

1. Patching: For repair of surface defects, small tears, punctures, destructive sampling locations, etc. Patches shall have a minimum size of 12 inches by 12 inches, extend at least six inches beyond the edge(s) of a defect, and have rounded corners so that the repair may be completed with a continuous extrusion seam. In some cases, the CQA Consultant may direct the Geomembrane Installer to cut out and remove a defect prior to patching in order to minimize the risk of crack propagation.
2. **Spot welding ("bead repairs"):** For repair of pinholes or other minor, localized defects. Spot welding shall only be permitted where explicitly approved by the CQA Consultant prior to performing the repair.

3. **Reconstruction:** For repair of lengths (segments) of unacceptable seams. Performed by cutting and removing the unacceptable seam segment and replacing it with new geomembrane that is seamed into place.

4. **Cap stripping:** For repair of lengths (segments) of unacceptable seams in lieu of reconstruction. Cap strips shall extend at least 12 inches beyond the edge(s) of a seam and have rounded corners so that the repair may be completed with a continuous extrusion seam.

5. **Flap seaming:** For repair of small lengths of unacceptable hot wedge seams in lieu of cap stripping. Performed by extrusion seaming the excess upper geomembrane flap of a hot wedge seam to the lower geomembrane sheet. Flap seaming shall only be permitted when the affected area is less than 10 feet in length and is explicitly approved by the CQA Consultant prior to performing the repair.

6. **Grinding and reseaming:** For repair of small lengths of unacceptable extrusion seams in lieu of cap stripping. Grinding and reseaming shall only be permitted when the affected area is less than three feet in length and is explicitly approved by the CQA Consultant prior to performing the repair.

C. Under no circumstances shall seams be repaired by placing extrusion seams directly atop previously seamed areas ("piggybacking").

D. Seam intersections ("tees") shall be covered with a patch meeting the requirements of Section 19.07.6.B.1. except where explicitly approved by the CQA Consultant prior to performing the repair.

E. CQA Consultant may require repair or replacement of any area where excessive grinding, overheating, or unacceptable preparation, seaming or testing techniques are observed. Such repair or replacement may be required even if samples removed from affected areas pass destructive testing.

F. Repairs shall be non-destructively tested by the Geomembrane Installer in accordance with Section 19.07.5.K.

### 19.07.7 PIPE PENETRATION SEALS

A. **Pipe penetrations in the geomembrane shall be sealed using LLDPE pipe boots (sleeves and skirts), neoprene gaskets, and stainless steel banding straps, as shown on the Contract Drawings and specified in Section 19.06.3.**

B. **Surfaces where pipe boots are to be attached (including HDPE pipe) shall be cleaned to remove dirt, oil, debris, or other deleterious materials. Geomembrane and LLDPE pipe surfaces that will be extrusion seamed to a pipe boot are to be prepared in accordance with Section 19.07.5.J.4.**

C. **Prior to attaching and/or seaming pipe boots, CQA Consultant shall visually inspect prepared surfaces to verify that proper preparation techniques have been followed. The CQA Consultant may require repair of areas exhibiting**
improper preparation techniques or damage, which may include removal and replacement of affected geomembrane or pipe.

D. Geomembrane Installer shall be responsible for non-destructive testing of the entire length (100 percent) of all pipe boot extrusion seams to verify their continuity. Non-destructive testing shall be performed in the presence of the CQA Consultant and in accordance with Section 19.07.5.K.

19.07.8 FINAL INSPECTION, ACCEPTANCE, AND COVERING

A. A final visual examination of all geomembrane panels, seams, repairs, and pipe penetration seals shall be completed by the CQA Consultant prior to accepting geomembrane. CQA Consultant’s inspection shall only be performed following a complete inspection and approval by the Geomembrane Installer’s field superintendent or designated quality control technician. Contractor shall be responsible for cleaning, sweeping, or other measures necessary to provide a thoroughly visible geomembrane surface for the CQA Consultant’s inspection.

B. Geomembrane Installer shall repair and test any areas identified during the CQA Consultant’s final inspection as not being in accordance with the Contract Drawings and Specifications. Any such repairs and testing shall be performed at no cost to Owner.

C. No geomembrane shall be covered until it has been accepted by the CQA Consultant in writing. Once accepted, geomembrane shall be covered as soon as possible in accordance with the Contract Drawings and Specifications.

D. If textured geomembrane is to be covered with other geosynthetics (e.g. GDN), a smooth temporary geosynthetic covering (“slip sheet”) shall be used to protect both the geomembrane and overlying geosynthetic from damage until the overlying geosynthetic is in its final position for seaming.

19.07.9 WARRANTIES

A. Seller shall be responsible for obtaining any necessary guarantees or certifications from the Geomembrane Manufacturer and Geomembrane Installer and submitting them to the Owner's Representative and Owner prior to acceptance of installed geomembrane.

B. Contractor shall guarantee the integrity, within the realm of limitations of Contractor's responsibility, of the installed geomembrane for its intended use, from installation defects for a period of two years from the date of geomembrane installation, and from manufacturing defects for a period of 20 years from the date of geomembrane installation. Such written warranties shall provide for the total and complete repair and/or replacement of any defect or defective areas of geomembrane upon written notification and demonstration by the Owner of the specific non-conformance of the geomembrane or installation with the Contract Drawings and Specifications. Such defects or non-conformance shall be repaired and/or replaced expeditiously, at no cost to Owner.
### Table 19-1

**REQUIRED PROPERTIES OF TEXTURED 60 MIL LLDPE GEOMEMBRANE**

<table>
<thead>
<tr>
<th>Property (Units)</th>
<th>MQC Testing Frequency (Minimum)</th>
<th>Test Method&lt;sup&gt;(2)&lt;/sup&gt;</th>
<th>Required Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resin</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density (g/cc)</td>
<td>1 per Resin Batch</td>
<td>ASTM D 1505 or D 792</td>
<td>0.939 (max)</td>
</tr>
<tr>
<td>Melt Flow Index (g/10 mins)</td>
<td>1 per Resin Batch</td>
<td>ASTM D 1238, Condition 190/2.16</td>
<td>1.0 (max)</td>
</tr>
<tr>
<td><strong>Finished Sheet</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core Thickness (mil)</td>
<td>Each roll</td>
<td>ASTM D 5994</td>
<td>57 (min ave)&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>Asperity Height (mil)</td>
<td>Every 2&lt;sup&gt;nd&lt;/sup&gt; roll</td>
<td>ASTM D 7466</td>
<td>16 (min ave)&lt;sup&gt;(4)&lt;/sup&gt;</td>
</tr>
<tr>
<td>Density (g/cc)</td>
<td>Every 200,000 lb</td>
<td>ASTM D 1505 or D 792</td>
<td>0.939 (min ave)</td>
</tr>
<tr>
<td>Carbon Black Content (%)</td>
<td>Every 20,000 lb</td>
<td>ASTM D 1603&lt;sup&gt;(5)&lt;/sup&gt;</td>
<td>2.0 - 3.0</td>
</tr>
<tr>
<td>Carbon Black Dispersion</td>
<td>Every 45,000 lb</td>
<td>ASTM D 5596</td>
<td>Categories 1 or 2&lt;sup&gt;(6)&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Tensile Properties (each direction)</strong></td>
<td>Every 20,000 lb</td>
<td>ASTM D 6693</td>
<td>126 (min ave)</td>
</tr>
<tr>
<td>1. Yield Strength (lb/in)</td>
<td>-</td>
<td>Test in machine direction and cross-machine direction</td>
<td>90 (min ave)</td>
</tr>
<tr>
<td>2. Break Strength (lb/in)</td>
<td>-</td>
<td>-</td>
<td>12 (min ave)</td>
</tr>
<tr>
<td>3. Yield Elongation (%)</td>
<td>-</td>
<td>-</td>
<td>250 (min ave)</td>
</tr>
<tr>
<td>4. Break Elongation (%)</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Tear Resistance (lb)</strong></td>
<td>Every 45,000 lb</td>
<td>ASTM D 1004, Die C</td>
<td>33 (min ave)</td>
</tr>
<tr>
<td><strong>Puncture Resistance (lb)</strong></td>
<td>Every 45,000 lb</td>
<td>ASTM D 4833</td>
<td>66 (min ave)</td>
</tr>
<tr>
<td><strong>Oxidative Induction Time (mins)&lt;sup&gt;(8)&lt;/sup&gt;</strong></td>
<td>Every 200,000 lb</td>
<td>ASTM D 3895</td>
<td>100 (min ave)</td>
</tr>
<tr>
<td>1. Standard OIT; or</td>
<td>-</td>
<td>ASTM D 5885</td>
<td>400 (min ave)</td>
</tr>
<tr>
<td>2. High Pressure OIT</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Oven Aging at 85°C&lt;sup&gt;(8)&lt;/sup&gt;</strong></td>
<td>Per each formulation</td>
<td>ASTM D 5721</td>
<td>35 (min ave)</td>
</tr>
<tr>
<td>1. Standard OIT (% retained after 90 days); or</td>
<td>-</td>
<td>ASTM D 3895</td>
<td></td>
</tr>
<tr>
<td>2. High Pressure OIT (% retained after 90 days)</td>
<td>-</td>
<td>ASTM D 5885</td>
<td>60 (min ave)</td>
</tr>
<tr>
<td><strong>UV Resistance&lt;sup&gt;(9)&lt;/sup&gt;</strong></td>
<td>Per each formulation</td>
<td>GRI GM 11</td>
<td>35 (min ave)</td>
</tr>
<tr>
<td>1. High Pressure OIT (% retained after 1,600 hours)</td>
<td>-</td>
<td>ASTM D 5885</td>
<td></td>
</tr>
<tr>
<td><strong>Interface Shear Strength&lt;sup&gt;(10)&lt;/sup&gt;</strong></td>
<td>Every 500,000 ft&lt;sup&gt;2&lt;/sup&gt;</td>
<td>ASTM D 5321</td>
<td>See Table 19-2a</td>
</tr>
</tbody>
</table>

**Notes:**

<sup>(1)</sup> The required properties specified herein may be revised by the Owner’s Representative to reflect new or revised test methods or to conform with improvements to the state-of-the-practice.

<sup>(2)</sup> Number of specimens per test established in applicable test method unless otherwise noted.

<sup>(3)</sup> Lowest individual value for 8 out of 10 readings = 54 mil; Lowest individual value for all readings = 51 mil.

<sup>(4)</sup> Alternate side of sheet measured each time a roll is tested. 8 out of 10 readings must be ≥ 7 mil; Lowest individual reading = 5 mil.

<sup>(5)</sup> ASTM Method D 4218 is acceptable if an appropriate correlation to D 1603 can be established.

<sup>(6)</sup> For 10 different views: 9 in Categories 1 or 2 and 1 in Category 3. Only near spherical agglomerates are to be considered.
For textured geomembrane, tests should be conducted on smooth sheet made from the same formulation as the textured sheet. Yield stress used to calculate test load should be Geomembrane Manufacturer’s mean value via MQC testing.

Geomembrane Manufacturer may select either of the OIT methods listed to evaluate antioxidant content.

Condition of test should be 20-hour UV cycle at 75°C followed by four-hour condensation at 60°C.

Interface Shear Strength testing is not an MQC test but part of CQA Conformance Testing.
Table 19-2a

MINIMUM INTERFACE SHEAR STRENGTH REQUIREMENTS
FOR TEXTURED 60 MIL LLDPE GEOMEMBRANE\(^{(1)}\)

<table>
<thead>
<tr>
<th>Normal Load (psf)</th>
<th>Standard Test Peak Shear Strength (psf)(^{(3)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>65</td>
</tr>
<tr>
<td>300</td>
<td>116</td>
</tr>
<tr>
<td>2,000</td>
<td>814</td>
</tr>
<tr>
<td>11,500</td>
<td>4,250</td>
</tr>
<tr>
<td>25,000</td>
<td>7,325</td>
</tr>
</tbody>
</table>

**Notes:**

\(^{(1)}\) Testing to be performed in accordance with ASTM D 5321 utilizing the test conditions and procedures outlined in Table 19-2b.

\(^{(2)}\) Lower interface shear strength requirements may be acceptable if additional slope stability analysis is completed by the Design Engineer verifying a long-term static factor of safety greater than 1.5 and a long-term seismic factor of safety greater than 1.1.

\(^{(3)}\) If the test data is below the stated peak shear strength, the results may be deemed acceptable by the Design Engineer after reviewing a slope stability analysis of the test data.
### Table 19-2b

**INTERFACE SHEAR STRENGTH TESTING**  
**REQUIREMENTS FOR TEXTURED 60 MIL LLDPE GEOMEMBRANE**

<table>
<thead>
<tr>
<th>Standard Test</th>
<th>ASTM D 5321</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conditioning &amp; Set-up:</strong></td>
<td>Set up each test to match field placement orientation. Run all tests under wet conditions.</td>
</tr>
<tr>
<td><strong>Procedure A:</strong></td>
<td>Geomembrane against Geotextile</td>
</tr>
<tr>
<td>Substrate:</td>
<td>Steel rasp platen</td>
</tr>
<tr>
<td>Superstratum:</td>
<td>Steel rasp platen</td>
</tr>
<tr>
<td>Displacement Rate:</td>
<td>0.04 ipm (maximum)</td>
</tr>
<tr>
<td>Total Displacement:</td>
<td>2.5 in (minimum)</td>
</tr>
<tr>
<td><strong>Procedure B:</strong></td>
<td>Geomembrane against GDN</td>
</tr>
<tr>
<td>Substrate:</td>
<td>Steel rasp platen</td>
</tr>
<tr>
<td>Superstratum:</td>
<td>Steel rasp platen</td>
</tr>
<tr>
<td>Displacement Rate:</td>
<td>0.04 ipm (maximum)</td>
</tr>
<tr>
<td>Total Displacement:</td>
<td>2.5 in (minimum)</td>
</tr>
<tr>
<td><strong>Special Instructions:</strong></td>
<td>None.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standard Test</th>
<th>ASTM D 6243</th>
</tr>
</thead>
</table>
| **Conditioning & Set-up:** | 1. Hydrate GCL samples by themselves for 7 days @ 0 psf normal stress using tap water, or as directed by Owner’s Engineer.  
2. Consolidate GCL samples using the loading sequence below until the required shear test normal load is reached. Maintain each consolidation load increment for 48 hours, or as directed by the Owner’s Engineer.  
3. Set up each test to match field placement orientation. Run all tests under wet conditions. |
| **Procedure A:** | Geomembrane against GCL |
| Substrate: | Coarse emery platen or Steel rasp platen |
| Superstratum: | Steel rasp platen |
| Displacement Rate: | 0.005 ipm (maximum) |
| Total Displacement: | 2.25 in (minimum) |
| **Special Instructions:** | None. |

**Note:**

(1) In lieu of testing individual interfaces, a system test may be performed using a configuration that allows failure to occur through the weakest shearing plane. System test configuration, conditions, and procedures must be accepted by the Design Engineer prior to submitting test results for review and approval.
### Table 19-3

**FIELD SEAM QUALIFICATION CRITERIA**
**FOR TEXTURED 60 MIL LLDPE GEOMEMBRANE\(^{(1)}\)**

<table>
<thead>
<tr>
<th></th>
<th><strong>Trial Seaming(^{(2)})</strong></th>
<th><strong>Production Seaming(^{(3)})</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hot Wedge Seams</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peel Strength (lbs)</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Peel Incursion (%)</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Shear Strength (lbs)</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Shear Elongation at Break (%)</td>
<td>--</td>
<td>50</td>
</tr>
<tr>
<td><strong>Extrusion Fillet Seams</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peel Strength (lbs)</td>
<td>66</td>
<td>66</td>
</tr>
<tr>
<td>Peel Incursion (%)</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Shear Strength (lbs)</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Shear Elongation at Break (%)</td>
<td>--</td>
<td>50</td>
</tr>
</tbody>
</table>

**Notes:**

\(^{(1)}\) Peel strengths, shear strengths, and shear elongations listed are minimum required values. Peel incursion percentages listed are maximum allowable values. In order to be considered qualified, all five trial seam test specimens must meet all strength and incursion requirements, and five out of five production seam test specimens must meet all strength, elongation, and incursion requirements. Requirements may be modified by the Design Engineer per the latest version of Geosynthetic Institute’s GRI-GM19a Standard Specification.

\(^{(2)}\) Field test in accordance with project Specifications and CQA Plan.

\(^{(3)}\) Laboratory test in accordance with ASTM D 6392.
MODULE V
ATTACHMENT 6 - CONSTRUCTION QUALITY ASSURANCE PLAN
Module V, Attachment 6
Construction Quality Assurance Plan
Virginia Department of Environmental Quality
Part B Permit Application
Curley Hollow Solid Waste Management Facility
To Support The Virginia City Hybrid Energy Center
Wise County, Virginia

GAI Project Number: C060702.00.005

March 2008
Revised September 2008, February 2009, June 2009,
August 2011, October 2017, and December 2019

Prepared for: Dominion
5000 Dominion Boulevard
Glen Allen, Virginia  23060

Prepared by: GAI Consultants, Inc.
Pittsburgh Office
385 East Waterfront Drive
Homestead, Pennsylvania  15120-5005
Module V, Attachment 6 - Construction Quality Assurance Plan – VDEQ, Part B Permit Application

Table of Contents

SECTION I - GENERAL ......................................................................................................................... I-1
1.0 INTRODUCTION ............................................................................................................................ I-1
2.0 DEFINITIONS RELATING TO CONSTRUCTION QUALITY ASSURANCE .................... I-1
   2.1 Construction Quality Assurance and Construction Quality Control ......................... I-1
   2.2 Use of the Terms in This Plan ......................................................................................... I-1
3.0 PARTIES TO CONSTRUCTION QUALITY ASSURANCE ............................................... I-2
   3.1 Description of the Parties ............................................................................................... I-2
      3.1.1 Owner .................................................................................................................... I-2
      3.1.2 Owner’s Representative ......................................................................................... I-2
      3.1.3 Design Engineer .................................................................................................... I-2
      3.1.4 Construction Quality Assurance Officer ............................................................... I-2
      3.1.5 Construction Quality Assurance Monitors ............................................................ I-2
      3.1.6 Soils Construction Quality Assurance Laboratory ................................................ I-2
      3.1.7 Geosynthetics Construction Quality Assurance Laboratory ................................ I-3
      3.1.8 Contractor ............................................................................................................. I-3
      3.1.9 Supplier ................................................................................................................ I-3
      3.1.10 Manufacturer ...................................................................................................... I-3
      3.1.11 Fabricator .......................................................................................................... I-3
   3.2 Duties of Construction Quality Assurance Personnel ..................................................... I-3
      3.2.1 Introduction ............................................................................................................. I-3
      3.2.2 Owner’s Representative ......................................................................................... I-3
      3.2.3 Construction Quality Assurance Officer ............................................................... I-4
      3.2.4 Construction Quality Assurance Monitors ............................................................ I-5
      3.2.5 CQA Personnel .................................................................................................... I-6
4.0 SCOPE OF CONSTRUCTION QUALITY ASSURANCE ..................................................... I-6
5.0 UNITS ............................................................................................................................................ I-6
6.0 REFERENCES ................................................................................................................................. I-6
   6.1 Applicable Organization ................................................................................................. I-6
   6.2 Applicable Standards ....................................................................................................... I-6
7.0 SITE AND PROJECT CONTROL ........................................................................................... I-7
   7.1 Project Coordination Meetings ......................................................................................... I-7
      7.1.1 Pre-Construction Meeting ...................................................................................... I-7
      7.1.2 Progress Meetings ................................................................................................. I-8
      7.1.3 Problem or Work Deficiency Meeting ................................................................ I-8
   7.2 Project Control Visits ....................................................................................................... I-8

SECTION II - SOILS CONSTRUCTION QUALITY ASSURANCE ........................................... II-1
1.0 INTRODUCTION ........................................................................................................... II-1
2.0 SITE PREPARATION ................................................................................................. II-1
3.0 LANDFILL EXCAVATION AND REGRADING...................................................... II-1
4.0 FOUNDATION BASE GRADE ................................................................................ II-1
5.0 FILL MATERIALS ..................................................................................................... II-2
   5.1 Introduction ............................................................................................................. II-2
   5.2 Storage.................................................................................................................... II-2
   5.3 Conformance Evaluation ....................................................................................... II-2
   5.4 Placement and Compaction ................................................................................... II-2
   5.5 Construction Quality Control Evaluation ............................................................. II-3

SECTION III - GEOMEMBRANE CONSTRUCTION QUALITY ASSURANCE .......... III-1
1.0 GEOMEMBRANE MANUFACTURE AND DELIVERY ............................................. III-1
   1.1 Raw Material ....................................................................................................... III-1
   1.2 Geomembrane Manufacturing/Fabrication ............................................................ III-1
   1.3 Labeling .............................................................................................................. III-2
   1.4 Handling .............................................................................................................. III-2
   1.5 Storage ............................................................................................................... III-2
   1.6 Conformance Testing ......................................................................................... III-2
2.0 GEOMEMBRANE INSTALLATION .......................................................................... III-3
   2.1 Earthwork ............................................................................................................ III-3
      2.1.1 Surface Preparation ....................................................................................... III-3
   2.2 Geomembrane Deployment .................................................................................. III-4
      2.2.1 Layout Drawing ............................................................................................... III-4
      2.2.2 Field Panel Identification ............................................................................. III-4
      2.2.3 Field Panel Placement .................................................................................. III-5
   2.3 Field Seaming ...................................................................................................... III-6
      2.3.1 Seam Layout .................................................................................................. III-6
      2.3.2 Personnel ...................................................................................................... III-6
      2.3.3 Weather Conditions for Seaming ................................................................... III-6
      2.3.4 General Seaming Requirements .................................................................. III-7
      2.3.5 Nondestructive Seam Continuity Testing .................................................... III-7
      2.3.6 Destructive Seam Testing ............................................................................. III-8
         2.3.6.1 Concept ................................................................................................... III-8
         2.3.6.2 Location and Frequency ......................................................................... III-8
         2.3.6.3 Sampling Procedure ............................................................................... III-8
         2.3.6.4 Size of Samples ....................................................................................... III-9
         2.3.6.5 Field Testing ............................................................................................ III-9
         2.3.6.6 Construction Quality Assurance Laboratory Testing ......................... III-9
         2.3.6.7 Procedures for Destructive Test Failure ............................................... III-9
   2.4 Defects and Repairs............................................................................................... III-10
3.0 GEOSYNTHETIC CLAY LINER

3.1 General
3.2 Quality Control
3.3 Labeling
3.4 Handling and Storage
3.5 Conformance Testing
  3.5.1 Tests
  3.5.2 Sampling Procedure
  3.5.3 Test Results
  3.5.4 Conformance Test Failure
3.6 Protection from Moisture
3.7 Subbase Construction
  3.7.1 Surface Preparation
3.8 GCL Installation
  3.8.1 Field Panel Placement
  3.8.2 Location
  3.8.3 Anchorage System
  3.8.4 Anchoring and Placement
  3.8.5 Seams and Overlaps
  3.8.6 Patching and Repairs
  3.8.7 Cover Placement
  3.8.8 Sealing and Penetrations

SECTION IV - GEOTEXTILE CONSTRUCTION QUALITY ASSURANCE

1.0 GEOTEXTILES
  1.1 Manufacturing
  1.2 Labeling
  1.3 Handling and Storage
  1.4 Conformance Testing
  1.5 Handling and Placement
  1.6 Seams and Overlaps
  1.7 Repair
  1.8 Placement of Soil Materials

SECTION V - GEOCOMPOSITE DRAINAGE NET CONSTRUCTION QUALITY ASSURANCE

1.0 GEOCOMPOSITE DRAINAGE NET
  1.1 Manufacturing
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>PIPE MANUFACTURE AND DELIVERY</td>
<td>VI-1</td>
</tr>
<tr>
<td>1.1</td>
<td>Manufacturing</td>
<td>VI-1</td>
</tr>
<tr>
<td>1.2</td>
<td>Labeling</td>
<td>VI-1</td>
</tr>
<tr>
<td>1.3</td>
<td>Storage</td>
<td>VI-1</td>
</tr>
<tr>
<td>1.4</td>
<td>Conformance Testing</td>
<td>VI-1</td>
</tr>
<tr>
<td>2.0</td>
<td>AGGREGATE</td>
<td>VI-1</td>
</tr>
<tr>
<td>2.1</td>
<td>Material Requirements</td>
<td>VI-1</td>
</tr>
<tr>
<td>2.2</td>
<td>Certification</td>
<td>VI-2</td>
</tr>
<tr>
<td>2.3</td>
<td>Conformance Evaluation</td>
<td>VI-2</td>
</tr>
<tr>
<td>3.0</td>
<td>GEOCOMPOSITE DRAINAGE NET INSTALLATION</td>
<td>VI-2</td>
</tr>
<tr>
<td>4.0</td>
<td>PIPE INSTALLATION</td>
<td>VI-2</td>
</tr>
<tr>
<td>4.1</td>
<td>Handling and Laying</td>
<td>VI-2</td>
</tr>
<tr>
<td>4.2</td>
<td>Joints and Connections</td>
<td>VI-3</td>
</tr>
<tr>
<td>5.0</td>
<td>AGGREGATE PLACEMENT</td>
<td>VI-3</td>
</tr>
<tr>
<td>6.0</td>
<td>GEOCOMPOSITE DRAINAGE NET INSTALLATION</td>
<td>VI-3</td>
</tr>
<tr>
<td>VII-1</td>
<td>GEOGRID CONSTRUCTION QUALITY ASSURANCE</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>GEOGRIDS</td>
<td>VII-1</td>
</tr>
<tr>
<td>1.1</td>
<td>Manufacturing</td>
<td>VII-1</td>
</tr>
<tr>
<td>1.2</td>
<td>Labeling</td>
<td>VII-1</td>
</tr>
<tr>
<td>1.3</td>
<td>Handling and Storage</td>
<td>VII-1</td>
</tr>
<tr>
<td>1.4</td>
<td>Conformance Testing</td>
<td>VII-1</td>
</tr>
<tr>
<td>1.5</td>
<td>Handling and Placement</td>
<td>VII-2</td>
</tr>
<tr>
<td>1.6</td>
<td>Seams and Overlaps</td>
<td>VII-2</td>
</tr>
<tr>
<td>1.7</td>
<td>Repair</td>
<td>VII-2</td>
</tr>
<tr>
<td>1.8</td>
<td>Placement of Materials on Geogrid</td>
<td>VII-2</td>
</tr>
<tr>
<td>VIII-1</td>
<td>CONSTRUCTION QUALITY ASSURANCE DOCUMENTATION</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>DOCUMENTATION</td>
<td>VIII-1</td>
</tr>
</tbody>
</table>
SECTION I
GENERAL
1.0 INTRODUCTION

This Construction Quality Assurance (CQA) Plan for the Curley Hollow Solid Waste Management Facility (CHSWMF) has been prepared to meet the requirements of the Commonwealth of Virginia Solid Waste Management Regulations, specifically 9VAC20-80-270B.19. The CQA Plan is a supporting document for the Part B Application for the permitting of the CHSWMF to support the operations of the Virginia City Hybrid Energy Center (VCHEC).

The CQA Plan addresses construction quality assurance of the soils, geosynthetics, and related liner system and cover system components for the landfill expansion. The CQA Plan is divided into the following sections:

- Section I - General;
- Section II - Soils CQA;
- Section III - Geomembrane CQA;
- Section IV - Geotextile CQA;
- Section V - Geocomposite Drainage Net CQA;
- Section VI - Leachate Collection System Drainage Material CQA;
- Section VII – PVC Pipe and Fittings CQA; and
- Section VIII - HDPE Pipe and Fittings CQA.

2.0 DEFINITIONS RELATING TO CONSTRUCTION QUALITY ASSURANCE

2.1 Construction Quality Assurance and Construction Quality Control

The CQA Plan is a site-specific document which addresses the following: (i) CQA personnel responsibilities, authorities, and qualifications; (ii) inspection, monitoring, and testing activities necessary to ensure that the facility is constructed to meet or exceed design criteria, plans, and specifications; and (iii) CQA documentation requirements. This CQA Plan is devoted to Construction Quality Assurance and, regarding the soils components only, to Construction Quality Control. Construction Quality Assurance and Construction Quality Control are defined as follows:

- Construction Quality Assurance (CQA) - A planned and systematic pattern of all means and actions designed to provide adequate confidence that items or services meet contractual and regulatory requirements, and will perform satisfactorily in service.
- Construction Quality Control (CQC) - Those actions which provide a means to measure and control the characteristics of an item or service to contractual and regulatory requirements.

2.2 Use of the Terms in This Plan

In the context of this document:

- Construction Quality Assurance (CQA) refers to means and actions employed by the Owner to assure conformity of liner system and cover system preparation, production,
and installation with this CQA Plan, the Construction Drawings, and the Specifications. CQA is provided by a party independent from production and installation.

- Construction Quality Control (CQC) refers to those actions taken by Manufacturers, Suppliers, Contractors, or Owner, including their designated representatives, to ensure that the materials and the workmanship meet the requirements of the Construction Drawings and the Specifications. In the case of soils, CQC is typically combined with CQA and is provided by the Owner. In the case of geosynthetic and other non-soil components, CQC is provided by the Manufacturers and installers of the various geosynthetics or an independent laboratory.

## 3.0 PARTIES TO CONSTRUCTION QUALITY ASSURANCE

### 3.1 Description of the Parties

#### 3.1.1 Owner

The Owner owns and is responsible for the operation of the Curley Hollow Solid Waste Management Facility. In this CQA Plan, the term "Owner" refers specifically to Dominion and/or the Virginia City Hybrid Energy Center as may be appropriate.

#### 3.1.2 Owner’s Representative

The Owner’s Representative(s) is (are) Dominion’s on-site personnel that will observe all construction and CQA work. As representatives of Dominion they will have the authority to accept or reject work.

#### 3.1.3 Design Engineer

The Design Engineer is the engineer or an organization that designed the CHSWMF. During construction, the Design Engineer must approve any deviation from the design requirements of the Construction Drawings or Specifications in conjunction with the Commonwealth of Virginia Department of Environmental Quality (VDEQ). The Design Engineer may be an employee of the Owner. The Design Engineer must be registered as a Professional Engineer in the Commonwealth of Virginia.

#### 3.1.4 Construction Quality Assurance Officer

The CQA Officer is the party independent from the Owner and Contractor that observed tests and documents activities related to the CQA and CQC of the earthwork and observes tests and documents activities related to the CQA of the production and installation of the geosynthetic components of the liner system and liner cover system.

#### 3.1.5 Construction Quality Assurance Monitors

The CQA Monitors will assist the CQA Officer in monitoring, testing and documenting of all appropriate operations.

#### 3.1.6 Soils Construction Quality Assurance Laboratory

The Soils CQA Laboratory is independent from the soil Supplier and Contractor. The Soils CQA Laboratory conducts tests in the laboratory (which may be on-site or off-site) on samples of soil and drainage materials taken from stockpiles, the liner system, or cover system. The Soils CQA Laboratory will have experience in the physical testing of soils and drainage materials, meet all regulatory requirements, and be familiar with American Society for Testing
and Materials (ASTM) and other applicable test standards. The Soils CQA Laboratory will be capable of providing test results in accordance with the Specifications.

3.1.7 Geosynthetics Construction Quality Assurance Laboratory

The Geosynthetics CQA Laboratory conducts test on samples of geosynthetics taken from the site. The Geosynthetics CQA Laboratory service cannot be provided by any party involved with the manufacturing or installation of any of the geosynthetic components.

The Geosynthetics CQA Laboratory will have experience in testing geosynthetics and other liner system and cover system components and be familiar with ASTM and other applicable test standards.

3.1.8 Contractor

The individual, firm, or corporation undertaking the execution of the work under the terms of the bid documents, Construction Drawings, and Specifications. The Contractor may be responsible for constructing the entire liner system or cover system, or only selected components of the liner system or cover system.

3.1.9 Supplier

The Supplier procures and delivers materials to the Contractor or raw materials to the Manufacturer.

3.1.10 Manufacturer

The Manufacturer manufactures a specific component (e.g., geomembrane, geotextile, or pipe) of the proposed liner system or cover system and delivers the component to the Contractor at the site. In the Specifications, the term "Manufacturer" may refer to the geomembrane manufacturer, geotextile manufacturer, geocomposite drainage net manufacturer, or pipe manufacturer.

3.1.11 Fabricator

The Fabricator in this CQA Plan is the geomembrane fabricator. The Fabricator factory welds geomembrane panels into larger panels for field installation and supplies the Contractor with geomembrane.

3.2 Duties of Construction Quality Assurance Personnel

3.2.1 Introduction

The Owner’s Representative and Dominion Landfill Staff will be responsible for all CQA duties, including soils CQC/CQA, geosynthetics CQA, and pipe CQA. The personnel will include:

- The Owner’s Engineer;
- The CQA Officer, who is located at the site; and
- The CQA Monitors, who work under the direction of the CQA Officer.

The duties of the CQA personnel are described in the following subsections.

3.2.2 Owner's Representative

The Owner’s Representative will:

- Become familiar with all designs, plans, and specifications;
- Become familiar with all other site-specific documentation, including Construction Drawings, bid documents, soils and groundwater investigation reports, and for geosynthetics, the Manufacturer's and Contractor's literature (unless otherwise agreed, such reviews are for familiarization only, and the Owner's Representative will not make comments regarding the feasibility, appropriateness, or comprehensiveness of the design; similarly, the Owner's Representative will assume no responsibility for any aspect of the design);

- Attend the pre-construction meeting;
- Administer the CQA program (i.e., assign and manage all CQA personnel, review all field reports, and provide engineering review of all CQA-related issues);
- Provide quality control of the CQA personnel, including site visits;
- Become familiar with all changes to the design, plans, and specifications; and
- Prepare the final report with the CQA Officer and may also serve as the Certifying Engineer.

3.2.3 Construction Quality Assurance Officer

The CQA Officer will:

- Act as the on-site (resident) representative of the Owner's Engineer. The CQA Officer may also serve as the Certifying Engineer;
- Familiarize all CQA Monitors with the site and the CQA requirements for the project;
- Manage the daily activities of the CQA Monitors;
- Attend all CQA-related meetings discussed in Section 7 (i.e., pre-construction, weekly, etc.);
- Prepare or oversee the on-going preparation of the Record Drawings;
- Verify the calibration and condition of on-site CQA equipment;
- Assign locations for testing and sampling;
- Oversee collection and shipping of all laboratory test samples;
- Review and report results of laboratory testing;
- Review all CQA Monitors' logs;
- Prepare the daily field report that includes any relevant observations reported by the CQA Monitors;
- Provide reports to the Owner's Representative;
- Report any unresolved deviations from the CQA Plan to the Owner's Representative; and
- Prepare the final CQA report with the Owner's Representative.

Relative to soils and drainage materials, the CQA Officer will:

- Check sources periodically for variability of the soils and drainage materials, and ensure that conformance testing is carried out; and
Establish, with the Design Engineer and Owner’s Representative, additional test requirements beyond those in the specifications, when necessary.

Relative to geosynthetics, the CQA Officer will:

- Review all Supplier, Manufacturer, and Contractor certifications and documentation provided by the Owner, if required, and make appropriate recommendations to the Owner regarding the qualifications of each party; and
- Note any on-site activities that could result in damage to the geosynthetics and report them to the Owner.

3.2.4 Construction Quality Assurance Monitors

The duties of the CQA Monitors will be assigned by the CQA Officer and include monitoring, logging, and/or documenting all appropriate operations.

The duties to be performed and the operations to be monitored by the CQA Monitors specifically pertaining to soils and drainage materials will include:

- Monitoring soil excavation, stockpiling, and placement; and monitoring drainage material stockpiling and placement;
- Monitoring soil moisture content and, if required, moisture conditioning;
- Collection of soil and drainage material samples for laboratory testing;
- Monitoring of operations to protect completed areas before the overlying materials are placed;
- Examination of the soil surface for signs of excessive wetting, desiccation, or other disturbance prior to placement of any overlying materials; and
- Monitoring of scarification between lifts and before recompaction or proof rolling that is required to repair deteriorated areas.

The duties to be performed and the operations to be monitored by the CQA Monitors specifically pertaining to geosynthetics will include:

- Monitoring of material delivery and "spotting" to ensure material is not damaged by equipment;
- Monitoring of unloading and on-site transport and storage;
- Marking samples for conformance testing;
- Monitoring of sampling for conformance testing by the Geosynthetics CQA Laboratory;
- Monitoring of placement operations;
- Monitoring of the condition of panels as placed;
- Monitoring of joining and/or seaming operations; and
- Monitoring of repair operations.

Specifically, for geomembranes, the seaming operations to be monitored include:

- Seam preparation;
- Seaming;
• Nondestructive seam testing;
• Sampling for destructive seam testing;
• Field tensiometer testing; and
• Repair operations.

In addition to these specific duties, all CQA Monitors will take note of any on-site activities that could result in damage to the soils, geosynthetics, or other components of the liner system or cover system. Any observations so noted will be reported as soon as possible to the CQA Officer.

3.2.5 CQA Personnel

CQA Personnel as it appears in this refers to duties that can be covered by either the CQA Officer or CQA Monitor.

4.0 SCOPE OF CONSTRUCTION QUALITY ASSURANCE

The scope of this CQA Plan includes the CQA of the base grade, soil, drainage material, pipe, and geosynthetic components of the liner system and liner cover system. The CQA Plan includes the CQC of the selection, evaluation, and placement of the soils and drainage materials. The CQA Plan also includes the CQA of manufacturing, shipping, handling, and installing of all geosynthetics and pipe.

This CQA Plan does not address design guidelines, installation specifications, or selection of soils, drainage materials, geosynthetics, pipe or other liner system components, which are all described in the Specifications.

5.0 UNITS

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

6.0 REFERENCES

6.1 Applicable Organization

Organizations whose standards are referenced in the CQA Plan and the Specifications are as follows:

• AASHTO - American Association of State Highway and Transportation Officials;
• ASTM - American Society for Testing and Materials;
• OSHA - Occupational Safety and Health Administration; and
• USEPA - United States Environmental Protection Agency.

6.2 Applicable Standards

Any reference to standards of any society, institute, association, or governmental agency will pertain to the edition in effect as of the date of this CQA Plan, unless stated otherwise.
7.0 SITE AND PROJECT CONTROL

7.1 Project Coordination Meetings

7.1.1 Pre-Construction Meeting

The CQA Plan, the Specifications, and the Construction Drawings will be discussed at a Pre-Construction meeting. At a minimum, the meeting will be attended by the Contractor, the Design Engineer, Owner's Representative, the CQA Officer, and the Owner.

The purpose of this meeting is to begin planning for coordination of tasks, to present the schedule and sequence of work, to anticipate any problems which might cause difficulties and delays in construction, and, above all, present the CQA Plan to all of the parties involved. It is important that the specifications regarding testing, repair, etc., be understood by all.

At this meeting, the Owner may choose to delegate any or all of his project responsibilities to the Owner’s Representative. For this CQA Plan, assumptions were made as to how the Owner will delegate those responsibilities.

The first part of the pre-construction meeting may be devoted to a review of the CQA Plan, the Construction Drawings, and the Specifications for completeness and clarity.

This meeting should include all of the following activities:

- Communicate to all parties any relevant documents;
- Review critical design details of the project;
- Review the panel layout drawing provided by the Design Engineer or the Contractor;
- Review the project-specific CQA Plan;
- Make any appropriate modifications to the CQA Plan to ensure that it specifies all CQA activities that are necessary;
- Note any appropriate modifications to the Construction Drawings and the Technical Specifications so that the fulfillment of Design Specifications or performance standards which must be made can be achieved;
- Establish an understanding by all parties of the CQA Plan and QA and QC procedures, especially on methods of determining acceptability of the soils and geosynthetics comprising the liner system or cover system;
- Assign the responsibilities of each party;
- Establish work area security and safety protocol;
- Select testing equipment and review protocols for testing and placement of soil and drainage materials;
- Establish soil stockpiling locations (if any);
- Confirm the methods for documenting and reporting, and for distributing documents and reports;
- Confirm acceptance and approval process for task completion prior to schedule sequence advancement; and
- Confirm the lines of authority and communication.
The meeting will be documented by a person designated at the beginning of the meeting, and minutes will be transmitted to all parties.

7.1.2  Progress Meetings

Weekly progress meetings will be held between the CQA Officer, the Contractor, and the Owner’s Representative. Current progress, planned activities for the next week, and any new business or revisions to the work will be discussed at this meeting. The Owner’s Representative will log in the minutes of the meeting any problems, decisions, or questions arising at this meeting. Any matter requiring action which is raised in this meeting will be reported to the appropriate parties.

Other meetings as required may be called at any time by the Owner’s Representative at address concerns of the Owner or CQA Officer.

7.1.3  Problem or Work Deficiency Meeting

A special meeting will be held by the Owner when and if a problem or deficiency occurs or is likely to occur. At a minimum, the meeting will be attended by the Contractor, the Owner, and the CQA Officer. If the problem has the potential to require a design modification, the Design Engineer should also be present. The purpose of the meeting is to define and resolve the problem or work deficiency as follows:

- Define and discuss the problem or deficiency;
- Review alternative solutions; and
- Develop an action plan to resolve the problem or deficiency.

The meeting will be documented by a person designated at the meeting and minutes will be transmitted to affected parties.

7.2  Project Control Visits

Periodically, the construction site will be visited by the Design Engineer.
SECTION II

SOILS CONSTRUCTION QUALITY ASSURANCE
1.0 INTRODUCTION
This section of the CQA Plan addresses the soils and drainage material components of the liner systems or cover system and outlines the soils and drainage material CQA Requirements to be implemented with regard to materials selection and evaluation, laboratory test requirements, field test requirements, and treatment of problems.

This section of the CQA Plan addresses site preparation, excavation, soil stockpiling, and construction of structural fill, select base grade fill, bottom ash (or sand and gravel) layer, drainage and protective layers, pipe bedding aggregate, and topsoil.

2.0 SITE PREPARATION
The Contractor will be required to install erosion and sediment control devices as outlined in the Erosion and Sediment Control Plan prior to beginning work on the site. The Contractor will be required to maintain the erosion and sediment control devices for the duration of construction. The Contractor will be required to dispose of sediment accumulating behind or within the erosion and sediment control devices on-site in a manner approved by the Owner. The CQA Personnel will monitor the erosion and sediment control devices to ensure that they are maintained and functioning throughout the construction of the landfill.

The construction area will be required to be cleared of brush, vegetation, logs, rubbish, and other objectionable material by the Contractor in accordance with the Construction Drawings and the Specifications. All materials will be required to be disposed of off-site. Appropriate disposal of these materials will be monitored by CQA Personnel.

The Contractor will be required to construct permanent diversion ditches to divert run-on around the construction area. The ditches are shown on the Construction Drawings and described in the Specifications. CQA Personnel will monitor the construction of the permanent diversion ditches in accordance with approved plans.

3.0 LANDFILL EXCAVATION AND REGRADING
The Contractor will be required to carry out all excavation work in compliance with applicable OSHA regulations. Excavation and regrading of the existing FFP and soil may be required to attain the grades and elevations for the base grade shown on the Construction Drawings by the Contractor. FFP or FFP-contaminated soil excavated from existing landfill areas will be temporarily stockpiled on-site within the footprint of the existing landfill or placed in the lined landfill. Stockpile locations will be designated by the Owner if required. CQA Personnel will monitor excavation and stockpiling.

4.0 FOUNDATION BASE GRADE
When the excavation is completed, the CQA Officer will:

- Inspect the base grade on the side slopes and base of the landfill and note areas of soft or otherwise unacceptable base grade materials; and
- When deemed necessary by the CQA Personnel the Contractor will proofroll the base grade. CQA Personnel will observe the proofrolling and note any areas that exhibit excessive rutting, heaving, or softening.

The observations noted above will be reviewed with the Owner's Representative. With the approval of the Owner's Representative, the CQA Officer will direct the Contractor to excavate
weak, weathered, rutted, heaving, or soft areas and backfill the excavation. Material classified as structural fill will be required for backfill. CQA Personnel will observe any excavation and backfilling operations.

5.0 FILL MATERIALS

5.1 Introduction
In this CQA Plan, fill materials are as defined in Section 1 of the Technical Specifications. Thus, fill materials consist of general fill, common soil, structural fill, select and subbase fill, and cover soil.

5.2 Storage
The fill materials will be stockpiled in designated areas free of incompatible soil, clearing debris, or other objectionable materials. Fill may be placed on a protective sheet and covered to prevent contamination. Stockpile areas will be designated by the Owner. CQA Personnel will verify that the fill materials are stored appropriately and will report any potential contamination to the Owner’s Representative.

5.3 Conformance Evaluation
All testing used to evaluate the suitability or conformance of the fill materials will be carried out by CQA Personnel in accordance with the current versions of the corresponding ASTM test procedures except as noted herein. The test methods indicated in Table II-1 are those which will be used for the soils CQA.

The minimum frequency of testing for the fill materials will conform to the minimum frequencies presented in Table II-2. The actual frequency of testing required will be determined by the CQA Officer, based on material variability.

If a fill material fails to meet the requirements of the Specifications, the CQA Personnel will perform sufficient sampling and testing to identify the extent of the nonconforming material. Nonconforming material will be removed from the site.

The CQA Officer will report any problems or deviations from the above requirements to the Owner’s Representative.

5.4 Placement and Compaction
The Technical Specifications will be followed for the placement and compaction of fill materials. CQA Personnel will monitor the fill placement and compaction and verify the following if relevant to that type of fill (see the Specifications):

- Soil being placed meets the material requirements for the specific fill;
- Drainage materials are not dropped from a height greater than three feet;
- The lift thickness conforms to the Specifications and/or Drawings;
- Fill is constructed to the elevations, grades, and thicknesses shown on the Construction Drawings. Thickness is measured perpendicular to the plane of the slope at the measurement location. The drainage and protective layers shall be measured after installation is completed. Direct measurement shall be made with a rule or other gauging device (i.e., survey stake with blunt tip marked with required thickness) or by hand-excavating a small pit to the underlying layer. Care shall be taken to not damage any geotextile or geomembrane.
• Fill is moisture conditioned, as required;
• Fill is not frozen;
• The fill materials are placed at the proper moisture content and dry unit weight using the test methods and frequency;
• Perforations in the fill materials at testing locations are backfilled with material being tested and manually compacted;
• Underlying geosynthetics are free of holes, tears, wrinkles that may fold back on themselves, and foreign objects;
• If wrinkles begin to develop in underlying geosynthetics during material placement or spreading, the wrinkles are worked out prior to continued material placement operations;
• Extreme care is taken when placing materials directly over installed components of the liner system or final cover system; and
• All work on underlying layers is complete and accepted.

5.5 Construction Quality Control Evaluation

Nuclear density tests will be the primary method for field testing the dry unit weight and moisture content of the structural fill and select base grade fill. Sand cone tests and oven moisture content tests may also be used for field testing and, as necessary, to calibrate and verify the results of the nuclear density meter. Any conflict over the results will be resolved by the CQA Officer.

The minimum frequency of soils testing for CQA purposes will conform to the minimum frequencies presented in Table II-3. The actual frequency of testing required will be determined by the CQA Officer and Owner’s Representative, in light of the noted variability of materials.

During construction, the frequency of testing may also be increased during adverse weather conditions, if equipment breaks down, at the start and finish of grading, if the material fails to meet specifications, or if the work area is reduced.

All perforations in the fill at test locations will be backfilled with the same fill as being tested and compacted by manual tamping.

If a defective area is discovered in the fill material, the CQA Officer will determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Personnel will determine the extent of the defective area by additional tests, observations, a review of records, or other means that the CQA Officer deems appropriate. If the defect is related to adverse site conditions, such as excessively wet soils or surface desiccation, the CQA Personnel will define the limits and nature of the defect by testing or observation. After the extent and nature of a defect is determined, the CQA Officer will verify that the deficiency is corrected before any additional work is performed by the Contractor in the area of the deficiency.

Based on the requirements of the Specification, the Contractor will be required to use all means necessary to protect all prior work, as well as all materials and completed work of other Sections. In the event of damage, the Contractor will be required to make all repairs and replacements necessary. The CQA Officer will verify that all damage is repaired.
Table II-1
TEST PROCEDURES FOR THE CQA/CQC EVALUATION OF SOILS

<table>
<thead>
<tr>
<th>Test Method</th>
<th>To Determine</th>
<th>Standard Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Laboratory Test Procedures:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture Content</td>
<td>Moisture Content</td>
<td>ASTM D 2216</td>
</tr>
<tr>
<td>Standard Proctor</td>
<td>Moisture/Dry Unit Weight Relationship of Soil</td>
<td>ASTM D 698</td>
</tr>
<tr>
<td>Relative Density</td>
<td>Density of Coarse-Grained Soils</td>
<td>ASTM D 4253/4254</td>
</tr>
<tr>
<td>Atterberg Limits</td>
<td>Liquid Limit and Plastic Limit</td>
<td>ASTM D 4318</td>
</tr>
<tr>
<td>Sieve Analysis</td>
<td>Particle Size Distribution of Coarse Grained Soils</td>
<td>ASTM D 422</td>
</tr>
<tr>
<td>Permeability (Rigid Wall Permeameter)</td>
<td>Permeability of Drainage Soils</td>
<td>ASTM D 2434</td>
</tr>
<tr>
<td>Carbonate Content</td>
<td>Carbonate Content of Soils/Aggregates</td>
<td>ASTM D 4373</td>
</tr>
<tr>
<td>Soundness</td>
<td>Aggregate Soundness</td>
<td>AASHTO T104</td>
</tr>
<tr>
<td>Abrasion</td>
<td>Aggregate Abrasion</td>
<td>ASTM C 131</td>
</tr>
<tr>
<td>Consolidated Undrained Triaxial</td>
<td>Shear Strength of Cohesive Soils</td>
<td>ASTM D 4767</td>
</tr>
<tr>
<td><strong>Field Test Procedures:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear Density Meter</td>
<td>In Situ: Soil Dry Unit Weight Moisture Content</td>
<td>ASTM D 6938</td>
</tr>
<tr>
<td>Sand Cone (For Calibration and Verification Only)</td>
<td>In Situ: Soil Dry Unit Weight</td>
<td>ASTM D 1556</td>
</tr>
<tr>
<td><strong>Drive Cylinder Method (For Calibration and Verification Only)</strong></td>
<td>In Situ: Soil Dry unit Weight</td>
<td>ASTM D 2937</td>
</tr>
<tr>
<td>Oven Moisture Content (For Calibration and Verification Only)</td>
<td>Moisture Content</td>
<td>ASTM 2216</td>
</tr>
</tbody>
</table>
Table II-2  
MINIMUM FREQUENCY OF TESTING FOR CQC EVALUATION OF FILL MATERIALS

<table>
<thead>
<tr>
<th>Test</th>
<th>General, Structural, Select, and Subbase Fill Soil</th>
<th>Final Cover Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture Content</td>
<td>1 per 5,000 yd$^3$ (minimum 1 per source)</td>
<td>N/A</td>
</tr>
<tr>
<td>Sieve Analysis</td>
<td>1 per 10,000 yd$^3$ (minimum 1 per source)</td>
<td>1 per 10,000 yd$^3$ (minimum 1 per source)</td>
</tr>
<tr>
<td>Atterberg Limits</td>
<td>1 per 10,000 yd$^3$ (minimum 1 per source)</td>
<td>N/A</td>
</tr>
<tr>
<td>Standard Proctor</td>
<td>1 per 10,000 cy (minimum 1 per soil type and 1 per source)</td>
<td>N/A</td>
</tr>
<tr>
<td>Relative Density$^1$</td>
<td>1 per 10,000 yd$^3$ (minimum 1 per source)</td>
<td>N/A</td>
</tr>
<tr>
<td>Permeability</td>
<td>N/A</td>
<td>1 per 10,000 yd$^3$ (minimum 1 per source)</td>
</tr>
</tbody>
</table>

$^1$ – Perform relative density tests on aggregates and bottom ash.
Table II-3
MINIMUM FREQUENCY OF TESTING FOR CQA OF FILL MATERIALS

<table>
<thead>
<tr>
<th>Test</th>
<th>Structural Fill and Select Base Grade Fill</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nuclear Density Meter:</strong></td>
<td></td>
</tr>
<tr>
<td>In-Situ Moisture Content</td>
<td>4 per acre per lift</td>
</tr>
<tr>
<td>In-Situ Dry Unit Weight</td>
<td>4 per acre per lift</td>
</tr>
<tr>
<td><strong>Calibration and Verification:</strong></td>
<td></td>
</tr>
<tr>
<td>Sand Cone (In-Situ Density)</td>
<td>As necessary for calibration and verification.</td>
</tr>
<tr>
<td>Oven Moisture Content (In-Situ Moisture Content)</td>
<td>As necessary for calibration and verification.</td>
</tr>
</tbody>
</table>

**Note:** On the side slopes acreage is measured parallel to the slope (plane areas).
SECTION III

GEOMEMBRANE CONSTRUCTION QUALITY ASSURANCE
1.0 GEOMEMBRANE MANUFACTURE AND DELIVERY

1.1 Raw Material

The raw material used to manufacture the polyvinyl chloride (PVC), High-Density Polyethylene (HDPE), and Linear Low-Density Polyethylene (LLDPE) geomembrane for the liner system and cover system at the Disposal Facility will be new, first quality material meeting the requirements of the Specifications. The Contractor will require the geomembrane Manufacturer to perform conformance testing in accordance with the Specifications to demonstrate that the raw material meets the requirements of the Specifications.

Prior to the shipment of the geomembrane to the site, the Contractor will be required to provide the CQA Officer with the following information from the geomembrane Manufacturer:

- A copy of the quality control certificates issued by the raw material Supplier that includes the origin (Supplier’s name and production plant), identification (brand name, number), the production date of the raw material used in the manufacture of the geomembrane shipped to the site, and the results of tests conducted by the geomembrane Manufacturer to verify the quality of the raw material used to manufacture the geomembrane rolls assigned to the project.

The CQA Officer will review these documents and report any discrepancies with the above requirements to the Owner’s Representative.

1.2 Geomembrane Manufacturing/Fabrication

Prior to shipment of the geomembrane to the site, the Contractor will be required to provide the CQA Officer with the following information from the geomembrane Manufacturer/Fabricator:

- A list of geomembrane properties for the type of geomembrane to be delivered to the site which are guaranteed by the geomembrane Manufacturer to meet or exceed all specified properties measured using test methods indicated in this section of the CQA Plan and the Specifications;

- A certification signed by a responsible party employed by the geomembrane Manufacturer that the materials assigned and delivered to this project have properties which meet or exceed the guaranteed properties; and

- Manufacturing quality control certificates for geomembrane produced for this project, signed by a responsible party employed by the geomembrane Manufacturer (such as the production manager). The quality control certificates should include:
  - Roll numbers and identification
  - Sampling procedures and results of quality control tests including descriptions of the test methods used for geomembrane rolls assigned to the project.

The CQA Officer will verify that:

- The property values certified by the geomembrane Manufacturer meet all of the specified values listed in the Specifications and those values guaranteed by the geomembrane Manufacturer;

- The measurements of properties by the geomembrane Manufacturer are properly documented and the test methods used are acceptable; and
• The quality control certificates have been provided at the specified frequency for all rolls, and each certificate identifies the rolls related to it.

1.3 Labeling
The CQA Personnel will verify that the geomembrane Manufacturer has identified each roll of geomembrane with the following:
• Name of Manufacturer and Fabricator (if any);
• Product identification;
• Lot number;
• Roll or factory panel number; and
• Dimensions of roll or factory panel.

The CQA Personnel will examine geomembrane rolls and factory panels upon delivery and any deviation from the above requirements will be reported to the Owner’s Representative prior to installation of the geomembrane.

1.4 Handling
On-Site handling of the geomembrane will be the responsibility of the Contractor.

The CQA Officer will verify that:
• Handling equipment used on the site is adequate and does not pose any risk of damage to the geomembrane; and
• The Contractor’s personnel handle the geomembrane with care.

Upon delivery at the site, CQA Personnel will conduct a visual inspection of all rolls for defects and for damage. This examination will be conducted without unrolling rolls unless defects or damages are found or suspected. The CQA Officer will indicate to the Contractor:
• Any rolls that should be unrolled to allow for their inspection;
• Any rolls, or portions thereof, which should be rejected and removed from the site because they have severe flaws; and
• Any rolls which include minor repairable flaws.

1.5 Storage
The Contractor will be responsible for the storage of the geomembrane on-site. The Owner will be responsible for providing storage space in a location (or several locations) such that on-site transportation and handling are optimized, if possible. The geomembrane is required to be located in a storage space that provides protection from theft, vandalism, dirt, excessive heat or cold, puncture, cutting, or other damaging or deleterious conditions.

The CQA Personnel will verify that storage of the geomembrane ensures adequate protection against dirt, excessive heat or cold, and other deleterious conditions.

1.6 Conformance Testing
Upon delivery of the rolls or factory panels of geomembrane, the CQA Personnel may remove samples and forward them to the Geosynthetics CQA Laboratory for testing to ensure conformance with the Specifications and the geomembrane Manufacturer’s list of guaranteed properties.
These samples will be tested in accordance with the minimum sampling frequencies and test methods outlined in Table III-1, Table III-2, and Table III-2a of this CQA Plan.

The CQA Officer will examine all results from laboratory conformance testing and will report any nonconforming results to the Owner’s Representative as soon as they become available.

The following procedure will apply whenever conformance samples are to be obtained and tested. Conformance sampling and testing shall be completed at a minimum frequency of one sample per geomembrane production lot according to the following procedure:

- Cut a sample from the geomembrane that is three feet long by the full roll width wide. Mark the sample with arrows indicating the machine direction of the geomembrane.
- Affix an adhesive label to the sample that lists all pertinent project and geomembrane product information; and
- Complete chain-of-custody and testing request forms and forward conformance samples to a geosynthetics CQA laboratory for analysis.

The following procedure will apply whenever a sample fails a conformance test that is conducted by the Geosynthetics CQA Laboratory:

- If a random sample does not pass a conformance test, then the conformance test frequency is increased to one per 50,000 square feet or one per lot.
- The Contractor will be required to replace the roll or factory panel of geomembrane that is in nonconformance with the Specifications with a roll or factory panel that meets the Specifications.
- The CQA Officer will ensure that conformance samples are removed for testing by CQA Personnel from the closest numerical roll on both sides of the failed roll. These two samples must pass the above conformance tests. If either of these samples fails, samples will be collected from the five numerically closest untested rolls on both sides of the failed sample and tested by the Geosynthetics CQA Laboratory. These ten samples must pass the above conformance tests. If any of these samples fail, a sample from every roll of geomembrane on-site and every roll subsequently delivered from the same Manufacturer must be conformance tested by the Geosynthetics CQA Laboratory.

The CQA Officer will document actions taken in conjunction with conformance test failures and report all actions to the Owner’s Representative.

2.0 GEOMEMBRANE INSTALLATION

2.1 Earthwork

2.1.1 Surface Preparation

The Contractor will be responsible for preparing the supporting subbase according to the Specifications.
The CQA Officer will verify that:

- The supporting subbase to be lined is rolled and compacted so as to be free of irregularities, protrusions, loose soil, and abrupt changes in grade;

- The surface of the supporting soil or ash does not contain particles greater than ½-inch in diameter which may be damaging to the geomembrane. When the geomembrane is to be placed over the existing temporary soil covering, a protective cushion geotextile shall be placed between the geomembrane and the soil covering, as shown on the Drawings. Prior to placing the geomembrane over the soil cover layer, the surface is to be stripped of all vegetation, regraded, and be free of all stones and sharp objects greater than ½-inch in diameter; and

- There is no area on the supporting soil that is excessively softened by high moisture content or desiccated.

The Contractor will be required to certify in writing that the surface on which the geomembrane will be installed is acceptable. The certificate of acceptance will be required to be given by the Contractor to the Owner certifying that the subbase is accepted immediately prior to commencement of geomembrane installation in the area under consideration.

After the supporting soil has been accepted by the Contractor, it will be the CQA Officer’s responsibility to indicate to the Contractor any change in the soil condition that may require repair work and to direct the Contractor to repair the supporting soil.

2.2 Geomembrane Deployment

2.2.1 Layout Drawing

The Contractor/Fabricator will be required to produce layout drawings which show the geomembrane panel configuration, dimensions, details, seam locations, etc. The layout drawings must be approved by the Owner’s Representative prior to the installation of the geomembrane. The layout drawings, as modified and/or approved by the Owner’s Representative, will be part of the Specifications, and a copy will be furnished to the CQA Officer. The CQA Officer will become familiar with the layout drawings.

2.2.2 Field Panel Identification

A field panel is the unit area of geomembrane which is to be seamed in the field (i.e., a field panel is a roll, a factory panel, or a portion of roll or factory panel cut in the field).

CQA Personnel will ensure that each field panel is given an identification code (number or letter-number) consistent with the layout plan. This identification code will be agreed upon by the Owner’s Representative, Contractor, and CQA Officer. This field panel identification code should be as simple and logical as possible. (Note: manufacturing plant roll numbers are usually cumbersome and are not related to location in the field.) It will be the responsibility of the Contractor to ensure that each field panel placed is marked with the manufacturing plant roll number. The roll number will be marked in the center of the panel in a color to allow for easy inspection.

The CQA Officer will establish or obtain from vendor a table or chart showing correspondence between manufacturing plant roll numbers and field panel identification codes. The field panel identification code will be used for all CQA records.
2.2.3 Field Panel Placement

CQA Personnel will verify that field panels are installed at the locations and positions indicated in the Contractor’s layout plan, as approved or modified by the Owner’s Representative. The CQA Officer will record the identification code, location, and date of installation of each field panel.

The Specifications require that field panels be placed one at a time, and each field panel be seamed immediately after its placement (in order to minimize the number of unseamed field panels exposed to wind). It is usually beneficial to "shingle" overlaps in the downward direction to facilitate drainage in the event of precipitation. It is also beneficial to proceed in the direction of prevailing winds. Scheduling decisions must be made during installation, in accordance with varying conditions. In any event, the Contractor will be fully responsible for decisions regarding placement procedures.

The CQA Officer will evaluate every change in the schedule proposed by the Contractor and advise the Owner’s Representative on the acceptability of that change.

The CQA Personnel will verify that geomembrane is not placed during the following inclement weather conditions:

- An ambient temperature below 40ºF or above 104ºF (unless otherwise authorized by the Owner’s Representative);
- During any precipitation;
- In the presence of excessive moisture (e.g., fog, dew); and
- In the presence of excessive winds.

Additionally, CQA Personnel will verify that the underlying base grade has not been damaged by weather conditions.

CQA Personnel will verify that the Contractor employs placement methods which insure that:

- Vehicles do not traffic on the geomembrane;
- Any equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons, or other means;
- The base grade surface has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement;
- All personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane;
- The method used to unroll the panels does not scratch or crimp the geomembrane and does not damage the underlying soil;
- The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels);
- Adequate temporary loading and/or anchoring (e.g., sand bags), not likely to damage the geomembrane, has been placed to prevent uplift by wind (in case of high winds, continuous loading is provided along the panel edges to minimize the risk of wind flow under the panels);
- The geomembrane is protected in areas where excessive traffic may be expected; and
The geomembrane is temporarily anchored at the top of the side slopes to prevent unrestrained release of the geomembrane during deployment.

The Contractor’s panel placement techniques and schedule shall minimize or eliminate the potential for accumulation of surface water runoff beneath the geomembrane. If any water is found ponded beneath the geomembrane after it has been installed, it shall be removed by the Contractor as directed by the CQA Officer. Any subbase beneath installed geomembrane that has become excessively moist, soft, or unsuitable to perform its intended function, shall be removed and replaced by the Contractor as directed by the CQA Officer.

The CQA Officer will inform the Owner’s Representative if the above conditions are not fulfilled.

CQA Personnel will visually observe each panel after placement and prior to seaming for damage (e.g., holes, blisters, creases). The CQA Officer will advise the Contractor which panels, or portions of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels which have been rejected by CQA Personnel will be marked, and their removal from the work area will be recorded by the CQA Officer.

At a minimum, CQA Personnel will ensure that:

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

2.3 Field Seaming

2.3.1 Seam Layout

In general, as stated in the Specifications, seams should be oriented parallel to the line of maximum slope, i.e., oriented along, not across, the slope. In corners and odd-shaped geometric locations, the number of seams should be minimized. No horizontal seam should be less than ten feet from the toe of slopes, or areas of potential stress concentrations, unless otherwise authorized by the Design Engineer and the Owner’s Representative.

A seam numbering system compatible with the panel numbering system will be agreed upon by the Contractor, Owner’s Representative, and CQA Officer at the pre-construction meeting.

2.3.2 Personnel

All personnel performing seaming operations should have prior experience in field seaming with an understanding in general seaming requirements, non-destructive seam continuity testing, destructive testing, and defect procedures.

2.3.3 Weather Conditions for Seaming

To minimize geomembrane contraction stresses, seaming should be carried out in the morning, late evening, or during the day when the weather is overcast. If the panels are seamed in the middle of a sunny day, the Contractor will be required to ensure that the panels to be seamed are approximately the same temperature and that there is sufficient slack to prevent excessive stresses or “trampolining” when the geomembrane contracts. The slack should not be so much that significant wrinkling of the geomembrane occurs. If the CQA Officer observes trampolining or excessive wrinkles, the areas will be marked for repair.

The CQA Personnel will verify that geomembrane seaming is done under the specified weather conditions and sheet temperature conditions. The CQA Officer will advise the
Owner’s Representative if weather conditions are other than those required for seaming. The Owner’s Representative will then decide if the installation will be stopped or postponed.

2.3.4 General Seaming Requirements

Unless otherwise specified, the general seaming requirements used by the Contractor are provided in the Specifications. CQA Personnel will verify that:

- Trial seams are prepared for each seaming procedure in accordance with the frequencies and conditions required in the Specifications. If any specimens fail to meet qualification criteria, the CQA Officer may elect to have additional specimens from the sample tested in order to determine trial seam acceptance. If a trial seam fails to meet all qualification criteria, a new trial seam must be prepared and evaluated. If this second trial seam also fails, the seaming equipment and/or seaming technician preparing the trial seams shall not be allowed to perform production seaming until any deficiencies are corrected and two consecutive trial seams meeting all qualification criteria are prepared and accepted by the CQA Officer;
- All geomembrane overlaps are continuously seamed using approved procedures;
- Prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris, and foreign material;
- Seams are aligned with the fewest possible number of wrinkles and "fish mouths";
- Lap joints and bodied solvent adhesive or thermo-fusion seaming methods shall be used to join geomembrane panels in the field;
- Seaming extends to the outside edge of all panels;
- If seaming operations are carried out at night, adequate illumination is provided;
- The panels of geomembrane have a finished overlap of a minimum of six inches for chemically welded seams and four inches for thermo-fusion welded seams; and
- The procedure used to temporarily bond adjacent panels together does not damage the geomembrane or any other underlying materials.

The CQA Officer will inform the Owner’s Representative if the approved seaming procedures are not followed.

2.3.5 Nondestructive Seam Continuity Testing

The Contractor will be required to nondestructively test all field seams over their full length using either air pressure testing (thermo-fusion seams) in accordance with ASTM D 7177 or an air lance test (chemically welded seams) in accordance with ASTM D4437. Additionally, Extrusion welded HDPE and LLDPE field seams require nondestructive testing over their full length by Vacuum Chamber in accordance with ASTM D 5641. The testing will be performed by the Contractor in the presence of CQA Personnel. The purpose of nondestructive tests is to check the continuity of seams. Nondestructive tests do not provide any information on seam strength. Continuity testing will be carried out as the seaming work progresses, not at the completion of all field seaming. Nondestructive testing will not be permitted before sunrise or after sunset unless the Contractor demonstrates to the CQA Officer and the Owner’s Representative that the Contractor has the capabilities to do so.
CQA Personnel will:

- Observe all continuity testing;
- Mark any areas of the seam which fail the test;
- Record location, date, test unit number, name of tester, and outcome of all testing; and
- Inform the Contractor of any required repairs.

The Contractor will be required to complete any required repairs in accordance with Section 2.4.

The CQA Manager or his staff will:

- Observe the repair and re-testing of the repair;
- Mark on the geomembrane that the repair has been made; and
- Document the results.

**2.3.6 Destructive Seam Testing**

**2.3.6.1 Concept**

Destructive seam tests will be performed at selected locations. The purpose of these tests is to evaluate seam strength and integrity. Seam strength testing will be done as the seaming work progresses, not at the completion of all field seaming.

**2.3.6.2 Location and Frequency**

CQA Personnel will select locations where seam samples will be cut out for laboratory testing. The test frequency and locations will be established as follows:

- Samples will be collected at a minimum frequency of two test locations per the first 500 feet of seam length per seaming technician for each landfill phase and one per 500 feet of seam length thereafter (this minimum frequency is to be determined as an average taken throughout the entire facility).
- Test locations will be determined during seaming at the CQA Personnel's discretion; selection of such locations may be prompted by suspicion of inadequate bonding, contamination, offset seams, or any other potential cause of imperfect seaming.

The Contractor will not be informed in advance of the locations where the seam samples will be taken.

**2.3.6.3 Sampling Procedure**

The Contractor will be required to cut samples as directed by CQA Personnel as the seaming progresses in order to have laboratory test results before the geomembrane is covered by another material. CQA Personnel will:

- Observe sample cutting;
- Assign a number to each sample and mark it accordingly;
- Record the sample number and location on the panel layout drawing; and
- Record the reason for taking the sample at this location (e.g., routine testing, suspicious feature of the geomembrane).
All holes in the geomembrane resulting from destructive seam sampling will be required to be repaired immediately in accordance with repair procedures described in the Specifications and Section 2.4.4. The continuity of the new seams in the repaired area will be required to be tested according to the Specifications.

2.3.6.4 Size of Samples

The destructive sample for laboratory testing will be 12 inches wide by 42 inches long with the seam centered lengthwise. The sample will be cut into three parts and distributed as follows:

- One portion to the Contractor for on-site testing (if desired), 12 inches by 12 inches;
- One portion to the CQA Officer for archive storage, 12 inches by 12 inches; and
- One portion to the CQA Officer for Geosynthetic CQA Laboratory testing, 12 inches by 18 inches.

Final determination of the sample sizes will be made at the pre-construction meeting.

2.3.6.5 Field Testing

The CQA Officer may require the contractor to field test samples. The samples will be tested by tensiometer for peel and should meet the field seam requirements for peel adhesion as stated in the Specifications. If any field test sample fails to pass, then the procedures outlined in Section 2.3.6.7 will be required to be followed.

CQA Personnel will observe field tests and mark all samples and portions with their number, date, and time.

2.3.6.6 Construction Quality Assurance Laboratory Testing

Destructive test samples will be packaged and shipped by the CQA Personnel in a manner which will not damage the test sample. The CQA Personnel will store the archive samples until the completion of the project. This procedure will be fully outlined at the pre-construction meeting. Test samples will be tested by the Geosynthetics CQA Laboratory.

Testing will include "Seam Strength" and "Peel Adhesion" according to the ASTM procedures as listed in the Specifications. The minimum acceptable values to be obtained in these tests are those indicated in the Specifications. At least five specimens will be tested for each test method and at least four out of five of the specimens must pass.

The Geosynthetics CQA Laboratory will provide test results to the CQA Officer who will then review the results as soon as they become available and make appropriate recommendations to the Owner.

2.3.6.7 Procedures for Destructive Test Failure

Whenever a sample fails a destructive test, the Contractor shall reconstruct the seam between the failed location and adjacent passed test locations.

The Contractor can retrace the welding path to an intermediate location (at a minimum of 10 feet from the location of the failed test), at the CQA Personnel's discretion, and take a small sample for a field test. If this test passes, then the seam shall be reconstructed between that location and the original failed location. If the test fails, then the process is repeated.

All acceptable seams must be between two locations where samples passed the test procedures.
Over the length of seam failure, the Installer shall either cut out the old seam, reposition the panel and reseam, or add a cap strip, acceptable to the Owner's Representative.

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

2.4 Defects and Repairs

2.4.1 Identification

All seams and non-seam areas of the geomembrane will be inspected by CQA Personnel for evidence of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane will be required to be clean at the time of examination. The geomembrane surface will be required to be broomed or washed by the Contractor if the amount of dust or mud inhibits visual examination.

2.4.2 Evaluation

Each suspect location both in seam and non-seam areas will be required to be non-destructively tested using the methods described in Section 2.3.5 as appropriate. Each location which fails the non-destructive testing will be marked by the CQA Personnel and will be required to be repaired by the Contractor. Materials should not be placed over geomembrane locations that have been repaired until laboratory test results with passing values are available.

2.4.3 Large Wrinkles

When seaming of the geomembrane is completed (or when seaming of a large area of the geomembrane is completed) and prior to placing overlying materials, the CQA Personnel will observe the geomembrane for wrinkles. The CQA Personnel will indicate to the Contractor which wrinkles, if any, should be cut and reseamed. The seam thus produced will be tested like any other seam.

2.4.4 Repair Procedures

Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, will be required to be repaired by the Contractor. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure will be agreed upon between the Contractor, the CQA Officer, and the Owner’s Representative. The procedures available include:

- Patching, used to repair holes, tears, undispersed raw materials, contamination by foreign matter, or other areas where minor localized flaws exist;
- Capping, used to repair failed seams; and
- Removing a bad seam and replacing it with a strip of new material seamed into place (used with long lengths of seams).

The CQA Personnel will verify that the appropriate repair procedures are followed.

In addition, the CQA Personnel will verify that the following provisions are satisfied:

- All surfaces are clean and dry at the time of the repair;
- All seaming equipment used in repair procedures is approved by the Owner's Representative;
• The repair procedures, materials, and techniques are approved in advance of the specific repair by the Owner’s Representative;

• Patches or caps extend at least six inches beyond the edge of the defect, and all corners of patches are rounded with a radius of at least three inches; and

• The geomembrane below large caps is appropriately cut to avoid water collection between the two sheets.

2.4.5 Testing of Repairs

Each repair will be numbered and logged by CQA Personnel. Each repair will be non-destructively tested using the methods described in Section 2.3.5 as appropriate. Repairs which pass the non-destructive test will be considered to be adequate repairs. Large caps may be of sufficient extent to require destructive testing, at the discretion of the CQA Officer. Failed tests will require the repair to be redone and retested until a passing test results. CQA Personnel shall observe non-destructive testing of repairs and will record the date of the repair and test outcome.

2.5 Materials in Contact with the Geomembrane

The quality assurance procedures provided in this section are intended to assure that the installation of adjacent materials does not damage the geomembrane. Additional quality assurance procedures are provided in other sections of this CQA Plan to assure that systems built with these materials will be constructed in such a way to enable proper performance.

2.5.1 Soils

CQA Personnel will provide close monitoring of the placement and spreading of any soil materials over the geomembrane with earth moving equipment and verify that such placement is in accordance with the Specifications. The CQA Officer will inform the Owner if the above conditions are not fulfilled.

2.5.2 Appurtenances

A copy of the Specifications for appurtenances will be given to the CQA Officer for review. The CQA Officer will verify that:

• Installation of the geomembrane in appurtenance areas and connection of geomembrane to appurtenances have been made according to the Specifications and Drawings;

• Extreme care is taken while seaming around appurtenances since neither non-destructive nor destructive testing may be feasible in these areas; and

• The geomembrane has not been visibly damaged while being connected to appurtenances.

The CQA Officer will inform the Owner’s Representative if the above conditions are not fulfilled.
Table III-1
CQA CONFORMANCE SAMPLING AND TESTING REQUIREMENTS FOR PVC GEOMEMBRANE\(^{(1)}\)

<table>
<thead>
<tr>
<th>Property (Units)</th>
<th>CQA Sampling Frequency (Minimum)</th>
<th>Test Method(^{(2)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geomembrane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness (mils)</td>
<td>Every 100,000 ft(^2) (1 per Lot)</td>
<td>ASTM D 5199</td>
</tr>
<tr>
<td>Tensile Properties (each direction)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Break Strength (lb/in)</td>
<td>Every 100,000 ft(^2) (1 per Lot)</td>
<td>ASTM D 882 Test in machine direction and cross-machine direction.</td>
</tr>
<tr>
<td>2. Break Elongation (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Modulus @100% (lb/in)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tear Resistance (lb)</td>
<td>Every 100,000 ft(^2) (1 per Lot)</td>
<td>ASTM D 1004</td>
</tr>
<tr>
<td>Interface Shear Strength</td>
<td>Every 500,000 ft(^2)</td>
<td>ASTM D 5321</td>
</tr>
</tbody>
</table>

Notes:

\(^{(1)}\) The required properties specified herein may be revised by the Owner to reflect new or revised test methods or to conform with improvements to the state-of-the practice.

\(^{(2)}\) Number of specimens per test established in applicable test method unless otherwise noted.
Table III-2

CQA CONFORMANCE SAMPLING AND TESTING
REQUIREMENTS FOR 60-MIL HDPE GEOMEMBRANE (1)

<table>
<thead>
<tr>
<th>Property (Units)</th>
<th>CQA Sampling Frequency (Minimum)</th>
<th>Test Method (2)</th>
<th>Required Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Thickness (mil)</td>
<td>Every 100,000 ft² (per Lot)</td>
<td>ASTM D 5994</td>
<td>See Technical Specifications(3)</td>
</tr>
<tr>
<td>Asperity Height (mil)</td>
<td>Every 100,000 ft² (per Lot)</td>
<td>GRI GM 12</td>
<td>See Technical Specifications(4)</td>
</tr>
<tr>
<td>Density, (g/cc)</td>
<td>Every 100,000 ft² (per Lot)</td>
<td>ASTM D 1505 or D 792</td>
<td>See Technical Specifications</td>
</tr>
<tr>
<td>Tensile Properties (each direction)</td>
<td>Every 100,000 ft² (per Lot)</td>
<td>ASTM D 6693</td>
<td>See Technical Specifications</td>
</tr>
<tr>
<td>1. Yield Strength (lb/in)</td>
<td></td>
<td>Test in machine direction and cross-</td>
<td></td>
</tr>
<tr>
<td>2. Break Strength (lb/in)</td>
<td></td>
<td>machine direction.</td>
<td></td>
</tr>
<tr>
<td>3. Yield Elongations (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Break Elongation (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tear Resistance (lb)</td>
<td>Every 100,000 ft² (per Lot)</td>
<td>ASTM D 1004, Die C</td>
<td>See Technical Specifications</td>
</tr>
<tr>
<td>Puncture Resistance (lb)</td>
<td>Every 100,000 ft² (per Lot)</td>
<td>ASTM D 4833</td>
<td>See Technical Specifications</td>
</tr>
</tbody>
</table>

Notes:

(1) The required properties specified herein may be revised by the Engineers to reflect new or revised test methods or to conform with improvements to the state-of-the practice.

(2) Number of specimens per test established in applicable test method unless otherwise noted.

(3) Lowest individual value for 8 out of 10 readings - 54 mil; lowest individual vale for all reading = 52 mil.

(4) Test both sides of sheet. 8 out of 10 readings must be ≥ 7 mil; lowest individual reading = 5 mil.

(5) Perform tests incorporating the test conditions and procedures outlines in Table 4-2b.
Table III-2a
CQA CONFORMANCE SAMPLING AND TESTING REQUIREMENTS FOR 60-MIL LLDPE GEOMEMBRANE (1)

<table>
<thead>
<tr>
<th>Property (Units)</th>
<th>CQA Sampling Frequency (Minimum)</th>
<th>Test Method (2)</th>
<th>Required Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Thickness (mil)</td>
<td>Every 100,000 ft² (per Lot)</td>
<td>ASTM D 5994</td>
<td>See Technical Specifications (3)</td>
</tr>
<tr>
<td>Asperity Height (mil)</td>
<td>Every 100,000 ft² (per Lot)</td>
<td>GRI GM 12</td>
<td>See Technical Specifications (4)</td>
</tr>
<tr>
<td>Density, (g/cc)</td>
<td>Every 100,000 ft² (per Lot)</td>
<td>ASTM D 1505 or D 792</td>
<td>See Technical Specifications</td>
</tr>
<tr>
<td>Tensile Properties (each direction)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Yield Strength (lb/in)</td>
<td></td>
<td>ASTM D 6693</td>
<td>See Technical Specifications</td>
</tr>
<tr>
<td>7. Yield Elongations (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Break Elongation (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tear Resistance (lb)</td>
<td>Every 100,000 ft² (per Lot)</td>
<td>ASTM D 1004, Die C</td>
<td>See Technical Specifications</td>
</tr>
<tr>
<td>Puncture Resistance (lb)</td>
<td>Every 100,000 ft² (per Lot)</td>
<td>ASTM D 4833</td>
<td>See Technical Specifications</td>
</tr>
<tr>
<td>Interface Shear Strength</td>
<td>Every 500,000 ft²</td>
<td>ASTM D 5321</td>
<td>See Technical Specifications</td>
</tr>
</tbody>
</table>

Notes:
(1) The required properties specified herein may be revised by the Engineers to reflect new or revised test methods or to conform with improvements to the state-of-the practice.
(2) Number of specimens per test established in applicable test method unless otherwise noted.
(3) Lowest individual value for 8 out of 10 readings = 54 mil; lowest individual value for all reading = 52 mil.
(4) Test both sides of sheet. 8 out of 10 readings must be ≥ 11 mil; lowest individual reading = 8 mil.
(5) Perform tests incorporating the test conditions and procedures outlines in Table 4-2b
3.0 GEOSYNTHETIC CLAY LINER

3.1 General

The CQA Consultant will be responsible for documenting conformance with the testing frequency and requirements for geosynthetic clay liner materials and construction as identified in this section.

3.2 Quality Control

Bentonite and geotextiles will be certified by the manufacturer as described in Section 18 of the Technical Specifications.

3.3 Labeling

The GCL manufacturer will label all rolls with:

- Manufacturer’s name,
- Product designation,
- Batch or Lot number,
- Roll number,
- Roll Length,
- Roll width, and
- Roll weight

The CQA Consultant and Contractor will examine rolls upon delivery and any deviation from the above requirements will be reported to the Owner.

3.4 Handling and Storage

The rolls of the GCL shall be carefully unloaded by the Contractor upon arrival at the site. GCL shall only be unloaded and handled using a stinger or spreader bar assembly meeting the requirements of ASTM D 5888. If other methods of handling are to be used, consult the Manufacturer for recommendations.

Rolls of GCL shall be stored in their original, unopened, protective cover in a clean, dry area. The material shall be stored off the ground, be continuously supported along its length, and shall be covered with a heavy, protective tarpaulin or enclosed within a storage facility. Care shall be used to keep accessory bentonite clean and free from debris prior to installation.

3.5 Conformance Testing

3.5.1 Tests
Upon delivery of the rolls, the CQA Consultant will take samples and forward to the CQA Laboratory for conformance testing to the Specifications and the Manufacturer’s certified properties.

Conformance sampling and testing will be performed in accordance with Table III-3 of this Plan.

3.5.2 Sampling Procedure

Samples will be taken across the entire width of the roll and will not include the first 3-feet. The CQA Consultant will mark the machine direction on the samples with an arrow.

3.5.3 Test Results

The CQA Consultant will examine results from the laboratory conformance testing and will report non-conforming results to the Owner. The minimum standards and testing frequencies are given in Table III-3 and in the Specifications.

3.5.4 Conformance Test Failure

The following procedure will apply whenever a sample fails a conformance test.

The Installer will replace the roll that is in non-conformance with the Specifications with a roll that meets the Specifications.

The Installer will remove conformance samples for testing from the closest numerical roll on both sides of the failed roll. These two (2) samples must conform to the Specifications. If either of these samples fail, the five (5) numerically closest untested rolls on both sides of the failed sample will be tested. These 10 samples must conform to the Specifications. If any of these samples fail, every roll of material on-site and every subsequently delivered roll that is from the same supplier must be tested for conformance to the Specifications. This additional conformance testing will be at the expense of the Installer and General Contractor.

3.6 Protection from Moisture

The GCL shall be stored in a dry environment on firm, level ground. The rolls should be protected by an additional waterproof cover; i.e., canvas tarp, plastic sheet, etc. The GCL rolls shall not be stacked more than three (3) rolls high. Care shall be taken to keep vehicles from making direct contact with the bentonite portion of the GCL. The GCL is shipped in plastic wrapping which needs to remain on the GCL until it is ready to be installed. It is best to install the GCL so that it is covered directly after being laid down. A sudden rain may cause rework.

GCL placement should not take place during any precipitation, in the presence of excessive moisture, or in the presence of excessive wind.
3.7 Subbase Construction

3.7.1 Surface Preparation

The Contractor shall be responsible for preparing the subbase according to the Specifications.

The CQA Consultant will document that:

A qualified Land Surveyor has verified lines and grades.

The subbase requirements have been satisfied.

The CQA Consultant, Contractor, and installer shall certify in writing that the surface on which the GCL is to be installed is acceptable.

After the supporting subbase has been accepted, it shall be the Installer’s responsibility to indicate to the CQA Consultant any change in the supporting subbase condition that may require repair work. If the CQA Consultant concurs with the Installer, then the subbase will be repaired before proceeding with the installation.

3.8 GCL Installation

3.8.1 Field Panel Placement

The CQA Consultant shall document the field panel placement.

3.8.2 Location

The CQA Consultant will verify that field panels are installed at the location indicated in the Installer’s field installation drawings, as approved or modified.

3.8.3 Anchorage System

Anchor trenches shall be excavated by the Contractor to the lines and widths shown on the Drawings, prior to GCL placement. The CQA Consultant will verify that anchor trenches have been constructed according to the Drawings.

Slightly rounded corners shall be provided in trenches where the GCL adjoins the trench to avoid sharp bends in the GCL. No loose soil shall underlie the GCL in the trenches.

3.8.4 Anchoring and Placement

Anchoring will be done in accordance with the Drawings. The GCL panel shall extend to the back side of the anchor trench. The anchor trench shall be secured at all times with sandbags or other means until the overlying geomembrane is placed.

As each roll is moved from the storage area for placement, the labels shall be removed by the Installer and submitted to the CQA Consultant.
Dragging of the GCL panels over the subbase surface is prohibited. The GCL will be placed over the prepared surface in such a way to minimize handling. The anchor trench for the area to be lined shall be excavated before installation of the GCL begins. The cover materials will be placed over the GCL during the same day as the placement of the GCL. Only those GCL panels which can be anchored and covered that same day shall be unpackaged and placed in position. The GCL shall not be installed in standing water or during rain. The GCL must be dry when installed and must be dry when covered. In areas where wind is prevalent, GCL installation should be started at the upwind side of the project and proceed downwind. The leading edge of the GCL shall be secured with sandbags or other means sufficient to hold it down. The GCL shall be installed in a relaxed condition and shall be free of tension or stress upon completion of the installation. Stretching of the GCL is not permitted. The GCL shall be straightened to smooth out creases or irregularities in the runs.

3.8.5 Seams and Overlaps

Overlapping shall be 6-inches minimum.

Dirt, gravel, or other debris shall be removed from the overlap area. The overlap area shall have a bead of accessory bentonite applied at a minimum application rate of 1/4-pound per lineal foot of seam. Installer must be present during this operation.

Seams shall overlap such that the direction of flow is from the top sheet to the bottom sheet to form a shingle effect.

On slopes, runs shall be from crest to toe with the GCL machine direction running perpendicular to the base. The free end at the crest shall be locked into the anchor trench on the back side.

3.8.6 Patching and Repairs

Repair patches in installed GCL extend a minimum of 12-inches beyond the edge(s) of a defect. Horizontal patch seams shall be secured with accessory bentonite or bentonite mastic as approved by both the Manufacturer and the Engineer. With approval by the Engineer patches may be placed under the defective liner in order to prevent slippage of the patch.

3.8.7 Cover Placement

The GCL must be covered the same day with geomembrane. To prevent premature hydration or contraction in hot, arid conditions, only the amount of GCL that can be anchored, inspected, repaired and covered in the same day shall be installed.

Construction or vehicular traffic over exposed GCL is prohibited. GCL showing evidence of trafficking shall be inspected by the GCL Installer, Contractor, and CQA Consultant to evaluate damage. At the direction of
the CQA Consultant, any damaged GCL shall be repaired or replaced at no cost to Owner. CQA Consultant may allow limited use of four-wheeled ATVs or other low ground pressure equipment (having 6 psi or less contact pressure) by the GCL Installer during installation, but use shall be prohibited if excessive trafficking or any GCL damage is observed.

3.8.8 Sealing around Penetrations

The GCL shall be sealed around penetrations, pipes and structures, in accordance with the recommendations of the Manufacturers.

Pipe penetrations shall incorporate a collar of GCL wrapped around the pipe and securely fastened. Bentonite sealing compound shall be placed around the corners for additional protection.

An additional GCL skirt placed over the bentonite sealing compound shall be used to provide a third level of protection and prevent the bentonite sealing compound from being displaced.
## Table III-3

**CQA CONFORMANCE SAMPLING AND TESTING REQUIREMENTS FOR GEOSYNTHETIC CLAY LINER**

<table>
<thead>
<tr>
<th>Property (Units)</th>
<th>CQA Sampling Frequency (Minimum)</th>
<th>Test Method$^{(2)}$</th>
<th>Required Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Finished GCL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swell Index (ml/2g)</td>
<td>Every 200,000 ft$^2$</td>
<td>ASTM D 5890</td>
<td>See Technical Specifications</td>
</tr>
<tr>
<td>Dried Bentonite Mass per unit Area (lb./ft$^2$)</td>
<td>Every 40,000 ft$^2$</td>
<td>ASTM D 5993</td>
<td>See Technical Specifications$^{(3)}$</td>
</tr>
<tr>
<td>Moisture Content (%)</td>
<td>Every 40,000 ft$^2$</td>
<td>ASTM D 4643</td>
<td>See Technical Specification</td>
</tr>
<tr>
<td>Peel Strength (lb./in or lb.)</td>
<td>Every 40,000 ft$^2$</td>
<td>ASTM D 6496 or ASTM D 4632</td>
<td>See Technical Specifications$^{(4)}$</td>
</tr>
<tr>
<td>Permeability (cm/sec)</td>
<td>Every 200,000 ft$^2$</td>
<td>ASTM D 5887</td>
<td>See Technical Specifications$^{(5)}$</td>
</tr>
<tr>
<td>Interface/Internal Shear Strength</td>
<td>Every 500,000 ft$^2$</td>
<td>ASTM D 6243</td>
<td>See Technical Specifications</td>
</tr>
</tbody>
</table>

### Notes:

1. **The required properties specified herein may be revised by the Engineer to reflect new or revised test methods or to conform with improvements to the state-of-the practice.**

2. **Number of specimens per test established in applicable test method unless otherwise noted.**

3. **Report at zero percent moisture content.**

4. **Perform tests in the machine direction. ASTM D 6496 is the preferred test method for this project.**

5. **Perform tests using deaired distilled/deionized water at 80 lbs./in$^2$ cell pressure, 77 lbs./in$^2$ headwater pressure, and 75 lbs./in$^2$ tailwater pressure.**
SECTION IV
GEOTEXTILE CONSTRUCTION QUALITY ASSURANCE
1.0 GEOTEXTILES

1.1 Manufacturing
The Contractor will be required to provide the CQA Officer with the following information from the geotextile Manufacturer:

- A list of the geotextile Manufacturer’s certified "Minimum Average Roll Values" for the type of geotextile to be delivered, which meet or exceed the criteria specified for geotextiles in the Specifications; and
- A written certification signed by a responsible party employed by the geotextile Manufacturer that the materials assigned and delivered have "Minimum Average Roll Values" which meet or exceed the certified properties for that type of geotextile.

The CQA Officer will examine all geotextile Manufacturer’s certifications to ensure that the property values listed on the certifications meet or exceed those certified and that proper and complete documentation has been provided by the geotextile Manufacturer for all geotextile used at the site.

1.2 Labeling
The CQA Officer will verify that the geotextile Manufacturer has identified all rolls of geotextile with the following information:

- Name of Manufacturer;
- Product identification;
- Lot number;
- Roll number; and
- Roll dimensions.

CQA Personnel will examine rolls upon delivery and any deviation from the above requirements will be reported to the Owner’s Representative prior to installation of the geotextile.

1.3 Handling and Storage
All on-site handling of the geotextile is the responsibility of the Contractor.

During storage, the Contractor will be required to keep the geotextile off the ground and protect the geotextile from direct sunlight, precipitation or other inundation, excessive heat or cold, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions. To that effect, it is required that the geotextile rolls be shipped and stored in opaque and watertight wrappings.

CQA Personnel will observe rolls upon delivery to the site and any deviation from the above requirements will be reported to the Owner. Any damaged rolls will be rejected by the CQA Manager and required to be repaired or replaced by the Contractor.

1.4 Conformance Testing
Upon delivery of the materials, the CQA Personnel may remove samples and forward them to the Geosynthetics CQA Laboratory for testing to ensure conformance with the technical specifications and the Geotextile Manufacturer’s List of guaranteed properties.
1.5 Handling and Placement
The Contractor will be required to handle all geotextile in such a manner as to ensure that the geotextile is not damaged in any way. CQA Personnel will verify compliance with the following:

- Just prior to geotextile placement, the layer that underlies the geotextile, if it is a geosynthetic, is clean and free of dust, dirt, stones, rocks, or other obstructions that could potentially damage the liner system. As directed by CQA Personnel the Contractor may be required to clean the underlying layer with water.

- Geotextile is placed in accordance with the Technical Specifications, including shingling panels such that the "downstream" panel overlaps the "upstream" panel in order to minimize the possibility of lifting panel edges during placement of covering material; and offsetting all panel seams parallel to the toe of a slope ("longitudinal seams") at the specified distance from the toe of the slope;

- On side slopes, the geotextile is securely anchored at the top and then rolled down the slope in such a manner as to continually keep the geotextile in tension.

- In the presence of wind, all geotextile is weighted with sandbags (or equivalent weight approved by CQA Personnel). Sandbags are installed during placement and remain until replaced with an overlying layer.

- Geotextile is kept continually under tension to minimize the presence of wrinkles in the geotextile. If necessary, the geotextile is positioned by hand after being unrolled to minimize wrinkles.

- The Contractor takes any necessary precautions to prevent damage to the underlying layers during placement of the geotextile.

- During placement of geotextiles, care is taken not to entrap in the geotextile stones, excessive dust, or moisture that could damage the underlying layers, generate clogging of drains or filters, or hamper subsequent seaming.

- A visual examination of the geotextile is carried out over the entire surface, after installation, to ensure that no potentially harmful foreign objects, such as needles, are present.

- If white colored geotextile is used, precautions are taken against "snowblindness" of personnel.

- Tools are not left on the geotextile.

- Geotextile is not left exposed for a period in excess of 30-days after placement unless a longer exposure period is approved by the Design Engineer and Owner's Representative.

1.6 Seams and Overlaps
CQA Personnel will verify that all geotextiles are continuously sewn or overlapped as specified.

The Contractor will be required to pay close attention at seams to ensure that no protective soil layer material could be inadvertently placed between the geotextile and any geomembrane.
1.7 Repair
CQA Personnel will verify that any holes or tears in the geotextile are repaired in accordance with the Specifications. Care is taken to remove any soil or other material which may have penetrated the torn geotextile.

1.8 Placement of Soil Materials
The Contractor will be required to place all soil materials located on top of a geotextile in such a manner as to ensure the following:

- The geotextile and underlying materials are not damaged;
- Minimal slippage occurs between the geotextile and underlying layers; and
- Excess stresses are not produced in the geotextile.

Unless otherwise specified by the Design Engineer and the Owner’s Representative, a minimum thickness of one foot of cover will be required between low ground-pressure equipment (track pressure of six psi or less) and the geotextile. A minimum thickness of six feet of cover will be required between the geotextile and vehicular traffic with track pressures exceeding six psi and any tire mounted equipment. CQA Personnel will perform close inspection of the placement and spreading of any materials over the geotextile with earthmoving equipment.
SECTION V

GEOCOMPOSITE DRAINAGE NET
CONSTRUCTION QUALITY ASSURANCE
1.0 GEOCOMPOSITE DRAINAGE NET

1.1 Manufacturing
The Contractor will be required to provide the CQA Officer with the following information from the Geocomposite Drainage Net (GDN) Manufacturer:

- A list of the GDN Manufacturer’s certified material properties which meet or exceed the criteria specified for GDN in the Specifications; and
- A written certification signed by a responsible party employed by the GDN Manufacturer that the materials assigned and delivered have material properties which meet or exceed the certified properties for that type of GDN.

The CQA Officer will examine all of the GDN Manufacturer’s certifications to ensure that the property values listed on the certifications meet or exceed those specified and that proper and complete documentation has been provided by the GDN Manufacturer for all GDN used at the site. The CQA Officer will report any deviations from the above requirements to the Owner’s Representative prior to installation of the GDN.

1.2 Labeling
CQA Personnel will verify that the GDN Manufacturer has identified all rolls of GDN with the following:

- Name of Manufacturer;
- Product identification;
- Lot number;
- Roll number; and
- Roll dimensions.

Additionally, if any special handling of the GDN is required, it will be so marked on the top surface of the GDN (e.g., “This Side Up”).

CQA Personnel will examine rolls upon delivery and any deviation from the above requirements will be reported to the Owner’s Representative prior to installation of the GDN.

1.3 Handling and Storage
All on-site handling of the GDN is the responsibility of the Contractor.

During storage, the Contractor will be required to keep the GDN off the ground and protect it from direct sunlight, precipitation or other inundation, excessive heat or cold, mud, dirt, dust, cutting, or any other damaging or deleterious conditions.

CQA Personnel will observe rolls upon delivery to the site and any deviation from the above requirements will be reported to the Owner’s Representative. Any damaged rolls will be rejected by the CQA Officer and required to be repaired or replaced by the Contractor.

1.4 Conformance Testing
Conformance sampling and testing of the GDN shall be performed by CQA Personnel in accordance with the minimum sampling frequencies and test methods outlined in Table V-1 of this CQA Plan. Conformance sampling and testing shall be completed at a minimum frequency of one sample per GDN production lot according to the following procedure:
• Cut a sample from the GDN that is three feet long by the full roll width wide. Mark the sample with arrows indicating the machine direction of the GDN;

• Affix an adhesive label to the sample that lists all pertinent project and GDN product information; and

• Complete chain-of-custody and testing request forms and forward conformance samples to a geosynthetics CQA laboratory for analysis.

The CQA Manager shall review results from all conformance testing to verify compliance with the requirements of the Technical Specifications. If all requirements are met, the CQA Manager shall issue written acceptance of the GDN for installation. If the requirements are not met, the CQA Manager shall notify the Contractor and either resample/retest the failed roll or mark the failed roll as rejected. If the failed roll is rejected, CQA Personnel shall obtain conformance samples from the closest numerical roll on each side of the failed roll number. The two additional GDN samples must conform to the Technical Specifications. If either sample fails, the entire production lot will be marked as rejected and every roll in the GDN production lots remaining on-site shall undergo conformance testing.

1.5 Handling and Placement

The Contractor will be required to handle all GDN in such a manner as to ensure that it is not damaged in any way. CQA Personnel will verify compliance with the following:

• Just prior to GDN placement, the layer that will underlie the GDN is clean and free of dust, dirt, stones, rocks, or other obstructions that could potentially damage the underlying layers or clog the drainage system. As directed by the CQA Manager, the Contractor may be required to clean the underlying layer with water.

• All GDN panel seams shall be shingled such that the “upslope” panel overlaps the “donslope” panel in order to minimize the possibility of lifting panel edges during placement of covering material; and offsetting all panel seams parallel to the toe of a slope (“longitudinal seams”) at the specified distance from the toe of the slope;

• On side slopes, the GDN is securely anchored at the top and then placed down the slope in such a manner as to continually keep the panel in tension.

• In the presence of wind, all GDN will be weighed with sandbags (or equivalent weight approved by the CQA Personnel). Sandbags are installed during placement and will remain until replaced with an overlying layer.

• GDN is kept continually under tension to minimize the presence of wrinkles in the panels. If necessary, the GDN will be positioned by hand after being unrolled to minimize wrinkles.

• The Contractor takes all necessary precautions to prevent damage to the underlying layers during placement of the GDN.

• GDN will not be welded to geomembranes.

• During placement of clean GDN, care is taken not to entrap stones, excessive dust, or moisture that could damage an underlying geomembrane, generate clogging of drains or filters, or hamper subsequent seaming.

• Tools are not to be left on or in the GDN.
• A visual examination of the GDN is carried out over the entire surface, after installation, to ensure that no potentially harmful foreign objects are present.

• GDN is not left exposed for a period in excess of 30-days after placement unless a longer exposure period is approved by the Design Engineer and the Owner’s Representative.

1.6 Seams and Overlaps
GDN will be required to be seamed to the adjacent GDN material according to the manufacturer’s specifications.

1.7 Repair
CQA Personnel will verify that any holes or tears in the GDN are repaired in accordance with the Manufacturer’s recommendations.

1.8 Placement of Soil Materials
The Contractor will be required to place all soil materials located on top of the GDN in such a manner as to ensure the following:

• The GDN and overlying and underlying layers are not damaged.
• Minimal slippage occurs between the GDN and the overlying and underlying layers.
• Excess tensile stresses are not produced in the GDN.

Unless otherwise specified by the Design Engineer and Owner’s Representative, a minimum thickness of one foot of cover is specified between low ground-pressure equipment (six psi or less) and the GDN. A minimum thickness of six feet of cover will be required between the GDN and any tire mounted equipment or track mounted equipment with ground pressure exceeding six psi. CQA Personnel will observe the spreading or grading of any soils over the GDN with earthmoving equipment.
### Table V-1

**CQA CONFORMANCE SAMPLING AND TESTING REQUIREMENTS FOR GEOCOMPOSITE DRAINAGE NET**(1)

<table>
<thead>
<tr>
<th>Property (Units)</th>
<th>CQA Sampling Frequency (Minimum)</th>
<th>Test Method(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (mils) – Geonet Only</td>
<td>Every 100,000 ft² (1 per Lot)</td>
<td>ASTM D 5199(3)</td>
</tr>
<tr>
<td>Transmissivity (m²/sec)</td>
<td>Every 300,000 ft² (1 per Lot)</td>
<td>ASTM D 4716(4)</td>
</tr>
<tr>
<td>Ply Adhesion (lb/in)</td>
<td>Every 100,000 ft² (1 per Lot)</td>
<td>GRI GC-7(5)</td>
</tr>
<tr>
<td><strong>Interface Shear Strength</strong></td>
<td><strong>Every 500,000 ft²</strong></td>
<td><strong>ASTM D 5321</strong></td>
</tr>
</tbody>
</table>

**Notes:**

1. The required properties specified herein may be revised by the Owner to reflect new or revised test methods or to conform with improvements to the state-of-the practice.
2. Number of specimens per test established in applicable test method unless otherwise noted.
3. Diameter of presser foot shall be 2.22 inches and pressure shall be 2.9 lb/in².
4. Perform test using deaired water and project geomembrane for substrate and cover soil for superstratum. Test conditions: Normal stress = 1,000 lb/ft²; Hydraulic gradient = 0.04; Seating period = 1 hour.
5. Average of 5 equally spaced tests across the roll width.
SECTION VI

LEACHATE COLLECTION LAYER AND GROUNDWATER DRAIN MATERIAL CONSTRUCTION QUALITY ASSURANCE
1.0 PIPE MANUFACTURE AND DELIVERY

1.1 Manufacturing
Prior to the shipment of the pipe and fittings the Contractor will be required to provide the CQA Officer with the following information from the pipe Manufacturer:

- A list of properties for the pipe and fittings to be supplied which are certified by the pipe Manufacturer to meet or exceed the values given for properties required in the Specifications;
- A written certification signed by a responsible party employed by the pipe Manufacturer that no recycled resin was used in manufacturing the pipe and fittings; and
- A written certification signed by a responsible party employed by the pipe Manufacturer that the pipe and fittings assigned and delivered to this project have properties which meet or exceed the guaranteed properties.

The CQA Officer will verify that the property values certified by the pipe Manufacturer meet the requirements of the Specifications.

1.2 Labeling
The pipe Manufacturer will be required by the Contractor to continuously print on the pipe, at sufficient intervals, the following:

- Name and/or trademark of the pipe Manufacturer;
- Nominal pipe size;
- The letters PVC or PE followed by the grade per ASTM D 1248, followed by the hydrostatic design stress in 100’s of psi (i.e., PE 3408);
- Manufacturing standard reference (if applicable) (i.e., ASTM F 714-1 or AASHTO M252); and
- A production code from which the date and place of manufacture can be determined.

The CQA Officer will verify that the pipe is labeled with the above information, and will report any deviations to the Owner's Engineer prior to installation of the geonet.

1.3 Storage
On-site handling of the pipe is the responsibility of the Contractor. The Contractor will be required to ensure that the pipe and fittings are not cut, kinked, or otherwise damaged during transportation. The CQA Officer will also verify that the pipe and fittings are stored on clean level ground, and that stacking of the pipe is limited to a height that will not cause excessive deformation of pipe under the anticipated temperature conditions.

1.4 Conformance Testing
No conformance testing will be conducted on the materials delivered to the site.

2.0 AGGREGATE

2.1 Material Requirements
All aggregate shall comply with the appropriate section of the Technical Specifications.
2.2 Certification
Prior to the shipment of aggregate the Contractor will be required to provide the CQA Officer with written certification signed by a responsible party employed by the aggregate supplier that the aggregate meets or exceeds the properties and gradations of the Technical Specifications. The CQA Officer will verify the properties and gradations certified by the supplier meet the requirements of the Technical Specifications.

2.3 Conformance Evaluation
All testing used to evaluate the suitability of conformance of the aggregate will be carried out by CQA Personnel in accordance with the current versions of the corresponding ASTM procedures as noted therein. The test methods indicated in Table VI-1 are those that will be used for the aggregate CQA.

The minimum frequency of testing for the aggregate will conform to the minimum frequencies presented in Table VI-2.

3.0 GEOCOMPOSITE DRAINAGE NET INSTALLATION
See Section V.

4.0 PIPE INSTALLATION
4.1 Handling and Laying
The Contractor will be required to handle all pipes and fittings in such a manner as to ensure the materials are not damaged in any way. CQA Personnel will verify compliance with the following:

- Manufacturer’s certification of material properties for pipe;
- Test results from material supplier for permeability of drainage aggregate, per requirements for drainage blanket material;
- Pipe bedding and backfilling are placed per specification;
- Pipes, fittings, interconnections, etc., are located and configured as specified and designed;
- Installation and construction procedures are as specified or recommended by the Manufacturer;
- The handling of the joined pipe line is conducted in such a manner that the pipe is not cut, kinked, twisted, or otherwise damaged;
- Ropes, fabric, or rubber-protected slings and straps are used when handling pipe;
- Slings, straps, etc. are not positioned at joints;
- Chains, cables or hooks are not inserted into the pipe ends as a means of handling pipe;
- Pipe or fittings are not dropped onto rocky or unprepared ground or into trenches or dragged over sharp objects;
- Field-cutting of pipes is performed according to the Manufacturer’s recommendations.
• When pipe laying is not actively in progress, the open end of the pipe that has been placed is closed using a watertight plug;
• No pipe is brought into position until the preceding length has been bedded and secured in its final position;
• Blocking is not used under pipes unless specifically accepted by the Design Engineer; and
• Placement of backfill over the pipe is conducted in accordance with the requirements of the Manufacturer’s installation instructions and in a manner intended to prevent damage to the pipe.

The pipe and fittings will be carefully examined by the CQA Personnel for cracks, damage or defects before installation. CQA Personnel will also note the condition of the interior of pipes and fittings. Foreign materials are required to be removed from the pipe interior before it is moved into final position. No pipe will be permitted to be placed until the CQA Personnel have observed the condition of the pipe.

4.2 Joints and Connections
Lengths of pipe will be required to be assembled into suitable installation lengths by solvent or thermal welding or watertight couplings. It will be required that solvent and thermal welds be made by trained personnel authorized by the pipe Manufacturer to perform the work.

CQA Personnel will spot-monitor solvent and thermal welding operations to ensure that the Contractor follows the pipe Manufacturer’s recommendations. CQA Personnel will also confirm that the pipes are clean when installed and that any perforated sections of pipe are aligned properly prior to welding.

5.0 AGGREGATE PLACEMENT
CQA Personnel will monitor aggregate placement in accordance with the frequency/observation and acceptance criteria in Table VI-2.

6.0 GEOCOMPOSITE DRAINAGE NET INSTALLATION
See Section V.
<table>
<thead>
<tr>
<th>Test Method</th>
<th>To Determine</th>
<th>Test Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory Test Procedures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sieve Analysis (Gradation)</td>
<td>Particle Size Distribution of Coarse-Grained Soils</td>
<td>ASTM D 422 or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ASTM C136</td>
</tr>
<tr>
<td>Calcium Carbonate</td>
<td>To Determine Calcium Carbonate Content of Aggregate</td>
<td>ASTM D 3042</td>
</tr>
<tr>
<td>Permeability</td>
<td>To Determine Permeability of Aggregate</td>
<td>ASTM D 2434</td>
</tr>
<tr>
<td>Relative Density</td>
<td>Relative Density</td>
<td>ASTM D 4253</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ASTM D 4254</td>
</tr>
<tr>
<td>Item</td>
<td>Requirement</td>
<td>Minimum Test Frequency/Observation</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>--------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1. Leachate Collection Layer (LCL)</td>
<td>Gradation</td>
<td>1 per 10,000 cy of material placed, and whenever it appears a problem exists in the gradation of the material.</td>
</tr>
<tr>
<td></td>
<td>Non Carbonate.</td>
<td>1 per 10,000 cy of material placed, and whenever it appears that a problem exists in the calcium carbonate content of the material.</td>
</tr>
<tr>
<td></td>
<td>Permeability (under 40,000 psf load)</td>
<td>1 per 10,000 cy of material placed, and whenever it appears that a problem exists in the permeability of the material.</td>
</tr>
<tr>
<td></td>
<td>Lift Thickness</td>
<td>One test per acre</td>
</tr>
<tr>
<td></td>
<td>Type of Compaction Equip.</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Number of Passes</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Shall be placed after backfilling the perimeter liner termination area</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Shall be placed from the bottom by pushing the material upward</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Verify lines and grades</td>
<td>Survey – spot check necessary</td>
</tr>
<tr>
<td></td>
<td>Verification that undesirable materials are not in fill as stated in the specifications</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Placement shall not damage Geosynthetics</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Placement shall not cause wrinkles, folds, or bends in Geosynthetics</td>
<td>Visual Observation</td>
</tr>
<tr>
<td>Item</td>
<td>Requirement</td>
<td>Minimum Test Frequency/Observation</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>2. Protective Cover</td>
<td>Gradation</td>
<td>1 per 10,000 cy of material placed, and whenever it appears a problem exists in the gradation of the material.</td>
</tr>
<tr>
<td></td>
<td>Non Carbonate</td>
<td>1 per 10,000 cy of material placed, and whenever it appears that a problem exists in the calcium carbonate content of the material.</td>
</tr>
<tr>
<td></td>
<td>Permeability</td>
<td>1 per 10,000 cy of material placed, and whenever it appears that a problem exists in the permeability of the material.</td>
</tr>
<tr>
<td></td>
<td>Lift Thickness</td>
<td>One test per acre</td>
</tr>
<tr>
<td></td>
<td>Type of Compaction Equip.</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Number of Passes</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Shall be placed after backfilling the perimeter liner termination area</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Shall be placed from the bottom by pushing the material upward</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Verify lines and grades</td>
<td>Survey – spot check necessary</td>
</tr>
<tr>
<td></td>
<td>Verification that undesirable materials are not in fill as stated in the specifications</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Placement shall not damage Geosynthetics</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Placement shall not cause wrinkles, folds, or bends in Geosynthetics</td>
<td>Visual Observation</td>
</tr>
<tr>
<td>Item</td>
<td>Requirement</td>
<td>Minimum Test Frequency/Observation</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>3. Bottom Ash (for LCL and Protective Cover)</td>
<td>Gradation</td>
<td>1 per 10,000 cy of material placed, and whenever it appears a problem exists in the gradation of the material.</td>
</tr>
<tr>
<td></td>
<td>Permeability (under 40,000 psf load)</td>
<td>1 per 10,000 cy of material placed, and whenever it appears that a problem exists in the permeability of the material.</td>
</tr>
<tr>
<td></td>
<td>Lift Thickness</td>
<td>One test per acre</td>
</tr>
<tr>
<td></td>
<td>Type of Compaction Equip. Number of Passes</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Shall be placed after backfilling the perimeter liner termination area</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Shall be placed from the bottom by pushing the material upward</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Verify lines and grades</td>
<td>Survey – spot check necessary</td>
</tr>
<tr>
<td></td>
<td>Verification that undesirable materials are not in fill as stated in the specifications</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Placement shall not damage Geosynthetics</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Placement shall not cause wrinkles, folds, or bends in Geosynthetics</td>
<td>Visual Observation</td>
</tr>
<tr>
<td>Item</td>
<td>Requirement</td>
<td>Minimum Test Frequency/Observation</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>4. Aggregate for Pipe Installations</td>
<td>Cross-Section Dimensions</td>
<td>Visual Observation</td>
</tr>
<tr>
<td></td>
<td>Material Classification</td>
<td>Visual Observation</td>
</tr>
</tbody>
</table>

Note: Test Methods and Standards are listed in Table VI-1. Sample size and location are given in the Test Standards. Acceptance Criteria are listed in the Technical Specifications. Corrective action if test fails is specifically listed under sections entitled “Conformance Test Failure” or generally to remove or replace until acceptance.
SECTION VII

GEOGRID CONSTRUCTION QUALITY ASSURANCE
1.0 GEOGRIDS

1.1 Manufacturing
The Contractor will be required to provide the CQA Officer with the following information from the Geogrid Manufacturer:

- a list of the Geogrid Manufacturer’s guaranteed “Minimum Average Roll Values” (as defined by the Federal Highway Administration) for the type of Geogrid to be delivered, which meet or exceed the criteria specified for the geogrids in the Specifications; and

- a written certification signed by a responsible party employed by the Geogrid Manufacturer that the materials assigned and delivered have “Minimum Average Roll Values” which meet or exceed the guaranteed properties for that type of geogrid.

The CQA Officer will examine all of the Geogrid Manufacturer’s certifications to ensure that the property values listed on the certifications meet or exceed those guaranteed and that proper and complete documentation has been provided by the geogrid Manufacturer for all Geogrid used at the site. The CQA Officer will report any deviations from the above requirements to the Owner prior to installation of the geogrid.

1.2 Labeling
The CQA Personnel will verify that the geogrid Manufacturer has identified all rolls of geogrid delivered to the site with the following:

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

Additionally, if any special handling of the geogrid is required, it will be so marked on the top surface of the geogrid (e.g., “This Side Up”).

The CQA Personnel will examine rolls upon delivery and any deviation from the above requirements will be reported to the Owner’s Representative prior to installation of the geogrid.

1.3 Handling and Storage
All on-site handling of the geogrid is the responsibility of the Contractor.

During storage, the Contractor will be required to keep the geogrid off the ground and protect the geogrid from direct sunlight, precipitation or other inundation, excessive heat or cold, mud, dirt, dust, cutting, or any other damaging or deleterious conditions.

The CQA Personnel will observe rolls upon delivery to the site and any deviations from the above requirements will be reported to the Owner’s Representative. Any damaged rolls will be rejected by the CQA Officer and required to be repaired or replaced by the Contractor.

1.4 Conformance Testing
The CQA Officer shall obtain samples of the geogrid delivered to the project site and forward them to the Geosynthetics CQA Laboratory. If the conformance samples fail to meet project
requirements, the CQA Officer will immediately notify the Owner prior to installation of the geogrid.

1.5 Handling and Placement
The Contractor will be required to handle all geogrid in such a manner as to ensure that the geogrid is not damaged in any way. The CQA Personnel will verify compliance with the following:

- prior to shipment of the geogrid to the site, the Contractor will be required to provide the CQA officer with qualifications of previous geogrid installation. The CQA Officer will verify that the qualifications meet the requirements of the Specifications. The Owner may require an authorized Manufacturer’s representative to assist in technical guidance for the initial geogrid installation.
- just prior to geogrid placement, the base grade that will underlie the geogrid is clean and free of uncompacted soil, stones, rocks, or other obstructions that could potentially damage the geogrid; as requested by the CQA Officer, the Contractor will be required to remove any such debris prior to geogrid placement;
- on side slopes, the geogrid is securely anchored at the top and then rolled down the slope in such a manner as to continually keep the geogrid panel in tension;
- geogrid is kept continually under tension to minimize the presence of wrinkles in the geogrid; if necessary, the geogrid is repositioned by hand after being unrolled to minimize wrinkles;
- the Contractor takes all necessary precautions to prevent damage to the base grade during placement of the geogrid;
- tools are not to be left on or in the geogrid;
- after installation, a visual examination of the geogrid is carried out over the entire surface to ensure that no potentially harmful foreign objects are present; and
- geogrid is not left exposed for a period in excess of the exposure time recommended by the Manufacturer or 10 days after placement if no recommendation is given. A longer exposure period may be approved by the Owner.

1.6 Seams and Overlaps
Geogrid will be required to be overlapped to the adjacent geogrid material in accordance with Section 17 of the Specifications.

1.7 Repair
The CQA Personnel will verify that any tears in the geogrid are repaired in accordance with the Manufacturer’s recommendations.

1.8 Placement of Materials on Geogrid
The Contractor will be required to place all materials located on top of a geogrid in such a manner as to ensure the following:
- the geogrid and overlying and underlying layers are not damaged;
- minimal slippage occurs between the geogrid and the overlying and underlying layers; and
- excess tensile stresses are not produced in the geogrid.
Unless otherwise specified by the Design Engineer and/or Owner’s Representative, a minimum thickness of one foot of material is specified between low ground-pressure (six psi or less) equipment and the geogrid and overlying geotextile. The CQA Personnel will observe the spreading of geotextile over the geogrid to ensure that the geogrid remains in-place and is not damaged.
SECTION VIII
CONSTRUCTION QUALITY ASSURANCE DOCUMENTATION
1.0 DOCUMENTATION

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

The CQA Officer will provide the Owner's Representative with signed descriptive remarks, data sheets, and logs to verify that all monitoring activities have been carried out. The CQA Officer will maintain at the site a complete file of Construction Drawings, the CQA Plan, the Specifications, test procedures, daily reports, testing logs, and other pertinent documents.

1.2 Daily Recordkeeping

1.2.1 Overview
Daily records will be completed in the field documenting CQA project administration, soils CQA, geosynthetics CQA, and other required CQA activities.

1.2.2 Project Administration Records
Most project administration records are completed daily by the CQA Personnel. Typical records are as follows:

- **Daily Field Report** - The Daily Field Report will typically include: the date, project name, location, and other identification; a narrative of the events and activities, including meetings and observations which occurred during a given day; the weather conditions; the name of parties to any discussions; the relevant subject matter or issues; the activities planned and performed; the constraints or suggestions; the schedule; and the signature of the CQA Officer and/or CQA Personnel.

- **Daily Temperature Log** - Ambient temperatures and liner temperatures will be recorded on the Daily Temperature Log by the CQA Personnel at various times during the day.

- **Personnel Daily Log** - This log will list all the Contractor's and CQA Personnel involved with the project.

- All Daily Reports or Logs may be combined into one document.

1.2.3 Soils CQA Records
Records kept for soils-related activities will be completed by either the CQA Personnel. The information will be recorded as testing is done in the field or as results are received from the laboratory. At a minimum, the testing logs will include:

- Laboratory Density Test Log;
- Laboratory Sieve Analysis Test Log;
- Laboratory Atterburg Limits Test Log; and
- Field Density/Moisture Content Test Log.
1.2.4 Geosynthetics CQA Records

Records for the installation of geosynthetics will be completed by either the CQA Personnel. The information will be recorded as the work progresses. Typical records include:

- **Material Inventory** - The identifying roll number or panel number and pertinent information of each roll or panel of geosynthetic received at the site will be recorded on this form as the materials arrive at the site. This information will be used to track Manufacturer’s quality control information, conformance test samples, and other CQA documentation.

- **Nondestructive Test Log** - This form will be used to record the date, time, equipment operator, and results of air lance or air pressure testing of production geomembrane seaming operations.

- **Panel Placement Monitoring Log** - This form will be used to record geomembrane panel numbers as they are placed in the field and to cross-reference the assigned panel numbers with roll numbers. The weather conditions, time, and temperature at placement will be recorded on the log. Measured dimensions used to calculate the area of the geomembrane will be recorded on the log.

- **Repair Summary Log** - Information on repairs to geomembrane panels and seams will be recorded on this form. The information recorded will include a code to describe the type of repair, the name of the operator making the repair, the location (i.e., seam or panel location) of the repair, nondestructive testing results of the repair, and initials of the CQA Officer or CQA Monitor observing the repair.

- **Destructive Test Log** - This form will be used to record the results from testing performed on geomembrane seams at the Geosynthetics CQA Laboratory (an independent testing laboratory). The results for both peel and shear will be recorded. The form will be completed as data becomes available.

- **Seaming Log** - This form will be used to track production seaming activities. The time, temperature, name of seamer, and length of seam will be recorded.

- **Certificate of Acceptance Base Grade Surface** - The Certificate of Acceptance is required to be signed by the Contractor prior to the installation of the geomembrane. The area being accepted must be described on the certificate.

1.2.5 Grout Stabilization of Abandoned Mine Workings and Dry Seal of Abandoned Mine Entry Construction Quality Assurance, CQA Records

**GENERAL**

The grouting operation and the construction of abandoned mine entry dry seals will be monitored by Construction Quality Assurance, CQA personnel under the direction of a professional engineer licensed in the Commonwealth of Virginia.

CQA personnel will certify that mine stabilization and the construction of dry seals are installed in accordance with the plans, specifications and the CQA plan.

**DRY SEALS**

CQA personnel will document each exposed mine entry where a dry seal is to be constructed with photographs and a dimensioned sketch that includes the coordinates and elevation of the entry, the degree of collapse, the presence of any water discharge,
and other salient details. The documentation will include the quantities of stone placed on the entry, and how far back from the entry face the stone was placed and by what means.

CQA personnel will monitor the fill placement and verify that a dry seal is being constructed in a manner consistent with the specifications.

CQA personnel will photograph the finished backfilled entry.

**GROUTING**

CQA personnel, on a daily basis, will post the grout takes on a map of the site that includes an overlay of the mine workings.

On the basis of this ongoing review, CQA personnel will direct that confirmatory core borings be drilled at selected locations so that core samples of the emplaced grout can be examined and tested for unconfined compressive strength in the laboratory.

CQA personnel, on a daily basis, will evaluate the takes in the holes being grouted, compare the takes with those in previous holes and with mine level conditions shown on associated mine maps. CQA personnel will select the locations of auxiliary injection holes for grouting and/or inspection holes for downhole televiewing, as appropriate, and will direct the Contractor to perform these activities.

CQA personnel on a daily basis, will direct the Contractor to adjust the grout/concrete mix, adjust the injection hole locations, drill additional holes or take other such action as appropriate to achieve suitably stabilized mine workings.

CQA Personnel under the direction of the Engineer will verify that:

- The Contractor provides a competent superintendent at the site at all times during working hours.
- The Contractor furnishes and uses functioning methane and oxygen monitors when drilling all holes that intercept underground mine workings.
- Materials conform to the requirements of the Specification -- water quality and temperature (Section 15.04.1); cement (Section 15.04.2); fine and coarse aggregates (Sections 15.04.3 and 15.04.4); *limestone dust (Section 15.04.5.1)*; grout (Section 15.05.1); high and low slump concrete (Section 15.05.2).
- Mix designs for grout and concrete from the Contractor meet design requirements and are submitted to the Owner and approved prior to placement of those materials.
- The Contractor’s system of grout/concrete placement pumps, gages, meters and appurtenances meet project requirements and are acceptable to the Owner.
- A qualified surveyor shall layout the injection and confirmatory boreholes and elevations in advance of the grouting operation.
- Water, grout, and concrete from the drilling and mine stabilization processes is controlled and contained at ground surface.
Borehole video camera surveys are performed in selected boreholes where required per Section 15.12.1 of the Specifications to reveal mine level conditions.

The Contractor’s drilling and grouting logs for each hole are complete and up to date. This will be done on a daily basis.

The Contractor has prepared grout and concrete samples per Section 15.10.1 using cube or cylinder molds consistent with the manner of sampling for the mix design, that the tests are performed in a timely manner and that the design strengths are being attained.

The Contractor’s daily labor and material forms, with record of injected quantities of grout, concrete, and other materials, fluidity, slump of the injected material, are complete and up to date. This will be done on a daily basis.

Confirm that no work involves entering an unsupported entry.

TYPICAL RECORDS
Records for grout stabilization of the abandoned mine workings and the dry seal of abandoned mine entries will be completed by the CQA Personnel. The information will be recorded as the work progresses to ensure adherence to the Technical Specifications. Typical records include:

- Injection hole numbers and locations;
- Drilling logs;
- Number and footage of injection holes drilled;
- Locations of injection holes drilled into abandoned mine workings;
- Locations of injection holes drilled which did not penetrate abandoned mine workings;
- Volume of grout injected into abandoned mine workings;
- Mix proportions for the concrete and grout;
- Slump measurements for the concrete and grout;
- Borehole photography of abandoned mine workings where required;
- Secondary drilling footage and location of abandoned mine workings after grouting;
- Laboratory strength testing of concrete and grout test cylinders;
- Dry seal location;
- Quantity of materials used for dry seal; and
- Photographs of openings before and after dry seal construction.

1.3 Design and/or Specification Changes
Design and/or Specification changes may be required during construction. In such cases, the CQA Officer will notify the Owner’s Representative. The Owner’s Representative will notify the Design Engineer.
Design and/or Specification changes will be made only with the written agreement of the Design Engineer and Owner and will take the form of an addendum to the Specifications.

1.4 Signatures and Final Report

At the completion of the work, the CQA Officer will submit a final CQA report to the Owner. This report will document that the work has been performed in compliance with the Construction Drawings, the CQA Plan, and the Specifications, except as properly authorized and implemented, and that the summary document provides the necessary supporting information.

At a minimum, this report will include: (a) summaries of all construction activities; (b) observation logs and testing data sheets including sample location plans; (c) a discussion of any changes from design and material specifications; and (d) CQA Record Drawings. The CQA Record Drawings will include the following:

- geomembrane panel layout drawings; and
- verification of all material thicknesses and satisfaction of all lines and grades.
- As built drawings showing:
  1. base grade;
  2. linear panel layout;
  3. destructive testing sample locations;
  4. thickness map showing elevation and thickness of the leachate collection system; and
  5. final cover elevation.

1.5 Storage of Records

Records will be maintained in accordance with VDEQ requirement.
APPENDIX A

SHAW STONE & WEBSTER, INC.

LEACHATE TRANSFER SYSTEM
SYSTEM DESCRIPTION

LEACHATE POND SUMP PUMP
APPENDIX A

MINE SUBSIDENCE INVESTIGATION AND MITIGATION MEASURES
APPENDIX B
LABORATORY TESTING OF ON-SITE SOILS AND FFP
LABORATORY TESTING OF ON-SITE SOILS AND FFP

Laboratory testing of on-site soils and FFP is provided in this section by reference to the following documents; “Waste Characterization Study of Atmospheric Fluidized Bed Combustion Ash”, CHSWMF, GAI P.N. C060702.00.005, November 2007, and the “WDEQ Notice of Tent and Part A Permit Application, GAI P.N. C060702.00, August 2007 and Revised October 2007.”