Guidance for Liner Construction and Testing for a Municipal Solid Waste Landfill

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Chapter 1: Liner Quality Control Plan (LQCP)

1.1 Introduction

The Texas Commission on Environmental Quality (TCEQ) has developed this document for assistance in fulfilling the requirements of Title 30 Texas Administrative Code (30 TAC) Chapter 330, Subchapter H, relating to Liner System Design and Operation. The intent of this document is to provide reasonable technical guidance and a suggested minimum level of construction control and testing for various types of liner systems and to provide guidance for the analysis, design, and construction of liners placed below the seasonal high water table. It is not intended to be rules or policy and does not include all acceptable practices. It is also recognized that on-going research and experience in the design and construction of liners may eventually prove superior to suggestions detailed herein.

1.2 LQCP Preparation

A landfill must have an approved LQCP prepared under the direction of a licensed professional engineer, and it shall be the basis for the type and rate of quality control testing performance and reported in the SLER as required in 30 TAC Section (§)330.341 and §330.339(a).

The construction and testing of all liners must be in accordance with an approved LQCP as required by 30 TAC §330.339(a). A copy of the current LQCP must be maintained on site or an alternate location approved by the executive director (ED), as required by 30 TAC §330.125(a) and be available for inspections and for the construction and testing of the liner.

This document is intended for assistance to the regulated community for LQCP preparation. For ease in LQCP preparation, it is recommended that this document be adopted, in whole or in part, as the LQCP for the facility.

In accordance with 30 TAC §330.339, the applicant is required to provide the following information as an attachment to this document: a discussion regarding each component (e.g., soil liner, geomembrane, leachate collection system, protective cover, etc.) of the proposed liner system, and a drawing which depicts a cross-sectional view of the construction details of each proposed liner system. Please ensure that the drawing is signed and sealed in accordance with the Texas Engineering Practice Act.

1.3 Liner System Requirements for Type I Disposal Units

New permits for Type I landfill units, lateral expansions of Type I landfill units, vertical expansions of Type I landfills over landfills that do not meet the design criteria under paragraph (1) or (2) of this subsection and expansions of existing Type I Arid Exempt (AE) landfills that subsequently no longer satisfy the conditions specified in 30 TAC §330.5(b)(1), must be constructed in accordance with one of the following provisions approved by the ED:

1. A design that ensures that the concentration values listed in 30 TAC §330.331(a)(1), will not be exceeded in the uppermost aquifer at the point of compliance, as determined in 30 TAC §330.403; or

2. A composite liner, as defined in 30 TAC §330.331(b), and a leachate collection system that is designed and constructed to maintain less than a 30-cm depth of leachate over the liner.

In accordance with 30 TAC §330.331(b), "composite liner" means a system consisting of two components; the upper component must consist of a minimum 30-mil geomembrane liner and the lower component must consist of at least a two-foot layer of re-compacted soil with a hydraulic conductivity of no more than $1 \times 10^{-7}$ centimeters per second (cm/sec). Geomembrane liner components consisting of high density polyethylene (HDPE) must be at least 60-mil thick. The geomembrane liner component must be installed in direct and uniform contact with the compacted soil component.
1.4 Liner System Requirements for Type IV Disposal Units

1. There must exist at least four feet of in-situ soil between the deposited waste and groundwater. This in-situ soil must constitute an in-situ liner and must meet all the physical properties for a constructed liner as detailed in 30 TAC §330.339(c)(5). In-situ liners must not exhibit primary or secondary physical features such as jointing, fractures, bedding planes, solution cavities, root holes, desiccation shrinkage cracks etc., that have a coefficient of permeability greater than $1 \times 10^{-7}$ cm/sec; 

2. There must be at least a three-foot thick re-compacted clay liner between the deposited waste and groundwater. The constructed liner must meet all the criteria detailed in 30 TAC §330.339 and must at a minimum have one foot of protective cover overlying the re-compacted liner after all quality control testing and final thickness determinations are complete; or

3. An alternative liner design, in accordance with 30 TAC §330.335.

1.5 Full Time Quality Assurance

The construction and testing of all elements of the liner system must be in accordance with the LQCP. Quality control of construction and quality assurance of sampling and testing procedures should follow the latest technical guidelines of the ED. All field sampling and testing, both during construction and after completion, shall be performed by a person acting in compliance with the provisions of the Texas Engineering Practice Act and other applicable state laws and regulations.

In accordance with 30 TAC §330.339(a)(2), the Professional of Record (POR) who signs the Soil Liner Evaluation Report or his representative should be on site during all liner construction and testing. It is recommended that the POR be onsite as often as necessary depending on the experience of his representative and for all extraordinary construction events during all liner system construction.
Chapter 2: Soil Liner Systems

2.1 Soil Liner Material Requirements

Borrow source material and soil liner systems are required to meet the properties listed in Table 2-1.

Table 2-1: Soil Liner Requirements

<table>
<thead>
<tr>
<th>Soil Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasticity Index (PI)</td>
<td>≥ 15</td>
</tr>
<tr>
<td>Liquid Limit (LL)</td>
<td>≥ 30</td>
</tr>
<tr>
<td>Percent Passing No. 200 Mesh Sieve</td>
<td>≥ 30%</td>
</tr>
<tr>
<td>Percent Passing one-inch Sieve</td>
<td>= 100%</td>
</tr>
<tr>
<td>Permeability</td>
<td>≤ 1 x 10^{-7} cm/sec.</td>
</tr>
</tbody>
</table>

1 All borrow source material and constructed soil liners must have the referenced values verified by testing in a soils laboratory.

2.2 In-Situ Soils

In-situ soils (soils in place and not disturbed through excavation and recompaction) are rarely acceptable as low-permeability liners due to the frequent occurrence of either primary depositional physical features such as bedding planes, desiccation cracks caused by drying at the time of deposition, or sediment distribution. In addition, secondary features that occur subsequent to disposition such as jointing, fracturing due to stress relief, solution weathering, etc., are common. In-situ soils are not a component of the standard composite liner consisting of a constructed soil liner overlain by a geomembrane, but in those cases where primary and/or secondary features which could adversely affect liner quality do not exist or where the ED has approved corrective measures, the in-situ soils may be considered as an alternative liner design. In accordance with 30 TAC §305.62(j)(2)(C), authorization to use these in-situ soils in a Type I landfill will require a permit amendment which includes a demonstration using the specific on-site soil and groundwater characteristics and computer modeling showing that the in-situ soils will meet all of the requirements for groundwater protection. Discovery of adverse primary and/or secondary features, or an adverse change in lithology during landfill development may void the use of in-situ soils even after the landfill has received approval of a permit amendment for an alternative liner.

2.3 Soil Liner Construction Requirements

2.3.1 General

Constructed soil liners include those of over-excavated and recompacted in-situ soils and soils from a borrow source.

2.3.2 Installation

Liners on side slopes of greater than a 3H:1V slope angle (3 horizontal to 1 vertical) should not be constructed in parallel lifts due to both the inherent lack of stability of the compaction equipment on these steep slopes as well as the compaction inefficiency.

Placement of constructed liners should be in accordance with the following:

- All liner subgrade areas should be properly scarified a minimum of two inches and prepared to receive the liner.
- The top of each lift should be roughened to a shallow depth prior to the placement of the next lift of soil for compaction.
- No loose lift should be thicker than the pads of the compactor so that complete bonding with the top of the previous lift is achieved.
• Equipment and safety limitations prohibit finish grades with slopes greater than 3H:1V if the liner is constructed parallel to the surface. For an excavated wall with steeper than 3H:1V side slopes, the sidewall liner must be constructed in successive horizontal lifts.

• The top surface of the completed soil liner must be proof rolled with a smooth-wheel roller prior to final liner thickness surveying when placement of a geomembrane liner is required.

• It is recommended that the surface of a soil liner be proof rolled when construction is shut down for more than 24 hours and also be done on a routine basis during the summer months at the end of each day’s liner construction to mitigate the effects of desiccation cracking.

• The maximum clod size of the compacted liner soils shall be approximately one inch in diameter. In all cases soil clods shall be reduced to the smallest size necessary to achieve the coefficient of permeability reported by the testing laboratory (or the maximum value of $1 \times 10^{-7}$ cm/sec) and to destroy any macrostructure evidenced after the compaction of the clods under density-controlled conditions (30 TAC §330.339(g)).

• The liner soil material shall contain no rocks or stones larger than one inch in diameter or that total more than 10% by weight. The final lift for composite liners should not contain any rocks or any other materials that can cause damage to the geomembrane (30 TAC §330.339(h)). It is recommended that the soil liner surface that comes into contact with the geomembrane contain no rocks larger than 3/8-inch.

• Soil liners shall not be compacted with a bulldozer or any track-mobilized equipment unless it is used to pull a pad-footed roller. All soil liners shall be compacted with a pad-footed or prong-footed roller only (30 TAC §330.339(g)). When using American Society for Testing and Materials (ASTM) Test Method D 698 (Standard Proctor) density, the minimum weight of the compacter should be 1,500 pounds per linear foot of drum length, and multiple passes as needed should be used for the compaction process. Compaction equipment that develops a compactive effort equal to ASTM D 1557 (Modified Proctor) will result in greater compaction, lower coefficient of permeability due to decreased void space, and a lower optimum moisture content necessary to achieve the maximum dry density. This lower optimum moisture content may help in controlling the desiccation cracking of high plastic clays frequently used for liner soil. Recognizing the soil variability, the POR or his representative may adjust the compaction effort based on the site-specific soil conditions and the compaction experience with the specific soil type.

2.3.3 Liner Tie-in

When a continuous trench (area fill) method of landfill development is in use, the leading twenty (20) feet of the floor liner shall not receive waste to facilitate tie-in with the next liner segment. Continuous floor liners shall not be constructed by “butting” the entire thickness of a new liner segment next to the previously constructed section of liner. It is recommended that liner tie-ins are done using one of the following methods:

• Stair-step method: The edge of the old section of liner is cut back on off-set layers (stair-step) so that each unit thickness of the existing liner edge is tied to new construction without superimposed construction joints. The length of the tie-in area should be at least 5 feet per foot thickness of liner (Figure 1).

• Sloped transition method: The edge of the previously installed section of liner is cut back on a 5H:1V slope, and is scarified as each successive lift is placed against the 5H:1V slope. Compaction extends from the new liner onto the transition zone with placement of each successive lift, thereby adequately blending the new and old liners together (Figure 2).
2.3.4 Construction Timing

Soil liner construction and testing should be conducted in a systematic and timely fashion. Delays should be avoided in liner completion. Construction and testing of soil liners should generally not exceed 60 working days from beginning to completion. There should not be more than a 14-day interruption in construction unless adverse weather prevents construction progress. Reasons for any liner construction project taking more than 60 working days to complete should be fully explained in the SLER submittal.

2.3.5 Liner Protection

Constructed and tested liners for which a SLER has been submitted shall have sufficient surface-drainage controls to prevent the accumulation of both contaminated and non-contaminated water. Any ponded water that accumulates on newly constructed liner surfaces shall be promptly and appropriately removed. The surface of the completed soil liner must be kept moist prior to placement of geomembrane or other overlying materials to reduce shrinkage cracking, but saturation of these soils by ponding water is not an acceptable practice. Complete saturation of any portion of the liner and its protective cover compromises their structural integrity and increases the degree of shrinkage cracking in the event of drying.

2.4 Testing Requirements for Soil Liners

2.4.1 Borrow Source Materials

Quality assurance and quality control (QA/QC) testing for all borrow source material used to construct the clay component of the liner system is required to be performed in accordance with the tests, test methods, and testing frequencies as indicated in Table 1. Borrow source
material must be retested for the requirements listed in Table 1, if there is a change in borrow source material.

A soil classification system, such as the United States Department of Agriculture Soil Classification System, American Association of State Highway and Transportation Officials system, and the Unified Soil Classification System may be used to determine whether there is a change in borrow source material.

The liquid limit (LL) and plasticity index (PI) of the soil may also be used to determine if there is a change in borrow source material. If either the LL or the PI varies by 10 or more points when compared against the appropriate moisture/density curve used for that soil borrow source, the soil is considered as a separate soil borrow source. Due to the high shrink/swell and desiccation cracking characteristics of high plasticity clays it is suggested that, where possible, the PI of clay liner soils be limited to be between 15 – 30.

2.4.2 Testing Frequency for Soil Liners

Each in-situ or constructed liner sidewall and floor area developed as a separate segment (non-monolithically) must be considered as separately evaluated areas independent of each other for the purpose of calculating dimensions to determine the required number of samples. Those sidewall and floor areas constructed or excavated as a bowl (monolithically) may be added together for the determination of their testing frequency and locations.

All holes dug or created during any sampling and/or testing shall be backfilled with a mixture of at least 20% bentonite-enriched liner soil and compacted by hand tamping or filled with an approved bentonite grout.

2.4.3 In-Situ Soils Testing Requirements

QA/QC testing for in-situ soils are required to be performed in accordance with the tests, test methods, and testing frequencies as indicated in Table 1.

For in-situ liners that are protected by one foot of protective cover added to the top, the entire series of quality assurance testing must be conducted and completed for all three feet (or approved alternate thickness) of liner soils prior to adding the protective cover.

For in-situ liners that are not to be protected by the placement of one foot of protective cover, the top one foot of the in-situ liner must serve as protective cover and the entire series of quality assurance testing must be conducted for the first four feet (or approved alternate thickness) of in-situ soil beginning with the surface of the protective cover.

2.4.4 Constructed Soil Liner Testing Requirements

QA/QC testing for constructed soil liners are required to be performed in accordance with the tests, test methods, and testing frequencies as indicated in Table 1.

Sidewall liner evaluations for lifts constructed parallel to the surface of the excavation will be evaluated by using the same criteria and rate of testing as for the bottom.

Sidewall evaluations for lifts constructed horizontally may be evaluated at a frequency not to exceed 12 inches in thickness (i.e. 2 lifts). Sample locations for field density testing should not exceed 100 linear feet and should be located within the 4 feet closest to the protected wall.

The usual sampling practice for quality assurance laboratory testing of the constructed liner is to retrieve representative samples from the same sampling tube and/or conduct field permeability tests. The location of the sampling/testing is adjacent to a field density/moisture test for comparing field and laboratory results.

2.4.4.1 Field Densities and Moisture Content

All field densities and moisture contents must compare with the limits specified below and to the proper ASTM D 698 or ASTM D 1557 moisture/density curve for the corresponding soil
borrow source in order to be considered passing. Passing field specifications for the ASTM D 698 moisture/density compaction relationship are at least 95% of maximum dry density and at or above the optimum moisture content. Passing specifications for the ASTM D 1557 moisture/density compaction relationship are at least 90% of the maximum dry density and at or above a moisture content 1% dryer than optimum. For both ASTM D 698 and D 1557, the moisture content should not exceed a maximum value which is governed by shear strength requirements and the need to minimize the possibility of rutting under construction equipment or desiccation cracking upon drying.

As an alternative to the above as the acceptance criteria, the “line of optimums” (described by Benson et al [1991]) may be used as the basis in field control. Under this alternative procedure, 80% of the field densities must lie on or above the line optimums. The line of optimums as described by Benson et al is essentially a line drawn through the points corresponding to the optimum moisture content/maximum dry density on the moisture/density relationship curves for the modified proctor test, the standard proctor test, and a third compaction test using a reduced energy from the standard proctor test. (It has been shown by Benson et al that compacted soil liners that have approximately 80% or more of the field density data points above, or wet, of the line of optimums have a significantly higher probability of achieving the 1 x 10^{-7} cm/sec permeability standard than liners constructed using the conventional percent compaction basis). If this procedure is used, those field density points that do not lie above the line of optimums must not be concentrated in any specific lift or section of fill.

Sections of compacted soils liner do not pass both the density and moisture requirements must be reworked and retested until the section in question does pass. All field density test results must be reported in the SLER, whether they indicate passing or failing values. The frequency of testing differ for the two lift placement methods below:

- Parallel Lifts-one test for each 8,000 ft² of surface area per lift (but no less than 3 density tests per 6 inch lift).
- Horizontal Lifts-one for each 100 linear feet for each 12 inches of thickness.

**2.4.5 Thickness Verification**

Thickness of constructed soil liners will be determined by instrument survey methods only. There should be a minimum of one verification point per 5,000 ft² of surface area. If the area under evaluation is less than 5,000 ft², a minimum of two reference points are required for verification. Reference location will be noted on a drawing of the area evaluated. All elevation calculations necessary for the thickness determination will be attached as part of the supporting documentation to the SLER including any necessary corrections for the true thickness measured perpendicularly to sidewalls. Cross-sections at approximately 100 foot spacing showing true liner thickness for sidewall liners that are constructed in horizontal lifts should be provided if appropriate.

Thickness of in-situ soil liners should be determined by augering to a depth equal to the required liner thickness plus one foot if top foot is to be used as protective cover. The rate of verification should be at a minimum of one location for each 5,000 ft² of surface area. Each augered hole shall be backfilled with a mixture of at least 20% bentonite by volume and parent soil material and, at a minimum, compacted by hand-tamping.

**2.5 Protective Cover Requirements**

Protective cover is required to be placed over the liner system and the installation and design requirements are summarized in the Table below. Full-time observation by the POR or his representative is required during protective cover installation.
Table 2-2: Protective Cover Requirements

<table>
<thead>
<tr>
<th>Material</th>
<th>Earthen material not previously mixed with garbage, rubbish, or other solid waste.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permeability</td>
<td>Protective cover overlying a leachate collection and removal system (LCRS) in general must have permeabilities $\geq 1 \times 10^{-4}$ cm/sec, or be provided with appropriate passageways for moisture, such as chimney drains, in order to allow leachate to readily drain to the LCRS.</td>
</tr>
<tr>
<td>Thickness</td>
<td>Thickness $\geq 24$ inches for liner system that includes a GCL and/or a geomembrane. There must be 12 inches or more of cover between leachate collection pipes and waste. There must be 12 inches or more of cover between clay liners and waste.</td>
</tr>
<tr>
<td>Installation General</td>
<td>The protective cover does not require compaction under density-controlled construction procedures. Protective cover must be placed as soon as possible, typically after installation of the soil liner, GCL, geomembrane, and any overlying geosynthetics.</td>
</tr>
<tr>
<td>Installation over Geomembrane</td>
<td>All soil materials placed over a geomembrane should be placed during the coolest part of the day and deployed in “fingers” along the surface so as to control the amount of slack and minimize wrinkles and folds in the geomembrane. These materials must be deployed only up-slope on side slopes so that stress imparted to the geomembrane is minimized. Protective cover should contain no rock greater than 3/8 inch, vegetation, or other material that may damage the geomembrane. If the protective cover contains material greater than 3/8-inch in size, a layer of protective geotextile must be placed over the geomembrane’s surface. Protective cover must be placed with light equipment (such as dozers with less than 5 psi contact pressure) while maintaining at least 12-inches of material between the dozer and the geomembrane.</td>
</tr>
<tr>
<td>Installation over GCL</td>
<td>The operation of any equipment over the GCL liner while placing the protective cover or for any subsequent need should be minimized to mitigate the possibility of tearing the GCL. The minimum thickness of any protective cover necessary to overcome stresses imposed by equipment upon the GCL should be analyzed carefully. As a rule of thumb, the protective cover thickness should be on the order of at least 1.5 to 2 times the minimum equipment track or tire width. Soil cover material placed over GCL should be non-calcareous and should contain no rocks greater than 3/4-inch in size (or as recommended by the manufacturer) or other material which may damage the GCL or cause subsequent localized thinning of the bentonite component. The cover must be placed with low-ground-pressure dozers or other light equipment in such a way that the GCL is not damaged. Filling must be in the direction of downgradient shingling of the GCL overlaps. Placement on sideslopes must be from the bottom of the slope upward.</td>
</tr>
<tr>
<td>Maintenance</td>
<td>The surface of the protective cover should be wetted during dry periods to keep the liner moist to prevent desiccation cracking.</td>
</tr>
</tbody>
</table>
Chapter 3: Geomembrane Liners

3.1 General

Geomembrane is used as a component in a standard composite liner system per 30 TAC §330.331. Geomembrane material may include high-density polyethylene (HDPE) or other materials approved by the TCEQ. The information provided in this document will primarily address the use of HDPE geomembranes. Materials, construction, and QA/QC standards for other geomembrane materials should follow industry standards and the manufacturer's guidelines.

Geomembrane must have a minimum thickness of at least 30 mils, or 60 mils if consisting of HDPE. If heat bonding is used for seaming, the geomembrane should have a minimum thickness of 30 mils. Any acceptable geomembrane material used must overlie and be in direct contact with the compacted clay liner or an approved alternative liner (30 TAC §330.331(b)).

3.2 Manufacturing

Geomembrane material must be produced from virgin raw materials. Reground, reworked, or trim material from the same lot may be acceptable but recycled or reclaimed materials must not be used in the manufacturing process. HDPE material and required welding rods shall contain between 2% and 3% carbon black and may contain no more than 1% other additives.

3.3 Shipping, Handling, and Storage

All HDPE liner material shall be shipped in rolls. Folded or creased sections of panels are not acceptable and shall not be used unless they are a normal part of the manufacturing process.

- The POR or his representative should inspect the delivered materials for damage and defects. Geomembrane sheets must be free from pinholes, surface blemishes, scratches, or other defects (e.g. non-uniform color, streaking, roughness, agglomerates of carbon black or other additives or fillers, visibly discernible regrind or rework, etc.).
- Offloading at the job site should be performed with cranes or fork lifts in a workmanlike manner such that damage does not occur to any part of the geomembrane.
- Unloading of rolls or pallets at the job site’s temporary storage location should be such that no damage to the geomembrane occurs.
- Pushing, sliding or dragging of rolls or pallets of geomembranes should not be permitted.
- Temporary storage at the job site should be in an area where standing water cannot accumulate at any time.
- Geomembrane material must be protected from soft, wet, rocky, and rough ground.
- The ground surface should be suitably prepared such that no stones or other rough objects which could damage the geomembranes are present.
- Temporary storage of rolls of HDPE or VLDPE geomembranes in the field should not be so high that crushing of the core or flattening of the rolls occur. This limit is typically 5 rolls high, or as recommended by the manufacture.
- Temporary storage of pallets of PVC or CSPE-R geomembranes by stacking should not be permitted.
- Suitable means of securing the rolls or pallets should be used such that shifting, abrasion, or other adverse movement does not occur.
- If storage of rolls or pallets of geomembranes at the job site is longer than 6 months, a sacrificial covering or temporary shelter should be provided for protection against precipitation, ultraviolet exposure, and accidental damage.
### 3.4 Geomembrane Installation and Testing

Geomembrane installation and testing requirements have been summarized in the tables provided below.

#### Table 3-1: Geomembrane Installation Requirements

<table>
<thead>
<tr>
<th>Installation</th>
<th>Follow all manufacturer’s recommendations. Install in direct and uniform contact with the compacted soil component or approved alternate liner.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subgrade Preparation</td>
<td>Surface of the subgrade soil must be free of sharp stones, stones larger than 3/8-inch, sticks, or other debris. Soil subgrade surface must be finished by rolling with a flat wheel roller until a smooth uniform surface is achieved. Soil subgrade must be protected from desiccation cracking, rutting, erosion, and ponding prior to and during placement of the geomembrane. Subgrade must be preserved by regular watering and proof rolling or by placing a minimum 12-inches of temporary soil cover which must be removed prior to geomembrane placement and the soil subgrade surface resurveyed.</td>
</tr>
<tr>
<td>Geomembrane Deployment</td>
<td>Deployment must not damage the subgrade. If geomembrane is placed over geosynthetic, construction equipment must not ride directly on the lower geosynthetic material.</td>
</tr>
<tr>
<td>Weather</td>
<td>Geomembrane should not be placed during inclement weather such as rain, high winds, or freezing temperatures.</td>
</tr>
<tr>
<td>Equipment on Geomembrane</td>
<td>Vehicular traffic on the liner shall be limited to low-ground-pressure supporting equipment only (e.g. golf carts, ATV’s or other small rubber tired equipment with a ground pressure ≤ 5 psi and a total weight &lt; 750 lbs). Any damaged areas of the geomembrane due to vehicular traffic must be repaired. Personnel working on the geomembrane shall not smoke, wear damaging shoes, or engage in any other activity likely to damage the geomembrane.</td>
</tr>
<tr>
<td>Placement</td>
<td>Only those geomembrane sheets that are to be placed and seamed in one day should be unrolled. Position geomembrane with overlap recommended by manufacturer, but not less than 3-inches for HDPE. Placement and overlap should be visually inspected by POR or his representative.</td>
</tr>
<tr>
<td>Folds, Large Wrinkles, &amp; Fish Mouths</td>
<td>Wrinkles shall be walked-out or removed prior to field seaming. No folds, large wrinkles, or fish mouths shall be allowed in the seam. Only normal factory-induced creasing may be acceptable. Where wrinkles or folds occur, the material shall be cut, overlapped, and welded. This process should be accomplished in such a manner that constructed seams are not required to carry significant tensile loads. During wrinkle or fold repairs, adjacent geomembrane may not necessarily be required to meet the 3-inch minimum overlap if approved by the POR or his representative. Dirt, water, oil, etc. shall be removed from the area to be bonded. All completed seams shall be tightly bonded and sealed.</td>
</tr>
<tr>
<td>Tack Welds</td>
<td>Tack welds (if used) with HDPE geomembrane shall use heat only.</td>
</tr>
</tbody>
</table>
No double-sided tape, glue, or other method will be permitted when extrusion or fusion welding is used for bonding.

<table>
<thead>
<tr>
<th>Geomembrane Seaming</th>
<th>Follow manufacturer recommendations for field seaming and repairs. For HDPE fusion or extrusion welding is acceptable.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seam Joints</td>
<td>Seams on side slopes (e.g. slopes steeper than 6H:1V) must be oriented parallel to the side slope direction. Seams that join the side slopes and bottom sections should be located at least 5 feet from the side slope and along the floor. In corners and odd-shaped geometric locations, the number of field seams should be minimized.</td>
</tr>
<tr>
<td>Temperature</td>
<td>No seaming should be attempted above 104 °F. Follow Geosynthetic Research Institute (GRI) Test Method GM-9 (GRI GM-9) for seaming geomembrane at temperatures below 32 °F.</td>
</tr>
<tr>
<td>End of Each Work Day</td>
<td>At the end of each day or installation segment, all unseamed edges should be anchored by sand bags or other approved devices. Staples, U-shaped rods, or other penetrating anchors shall not be used.</td>
</tr>
</tbody>
</table>

### Table 3-2: Geomembrane Testing Requirements

<table>
<thead>
<tr>
<th>QA/QC Testing</th>
<th>Manufacturing and conformance testing requirements for geomembrane liners are specified in Table 2. All geomembrane material properties must meet the manufacturer’s standards and (for HDPE) the values in the GRI Test Method GM13 (GRI GM-13). For other types of geomembranes, manufacturer’s recommendations and acceptable industry practice should be followed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conformance Testing</td>
<td>Prior to acceptance of the geomembrane from the manufacturer, the POR should verify that it meets the required specifications. Conformance testing is required to be performed at an independent third party laboratory. Depending on the geomembrane type, other tests not listed in Table 2 may apply.</td>
</tr>
<tr>
<td>Seam Testing</td>
<td>The POR or his representative should observe all test seam procedures and all seam testing. All seam testing of the geomembrane liner should follow current ASTM standards and GRI Test Method GM-19 (GRI GM-19).</td>
</tr>
</tbody>
</table>
### Table 3-3: Trial Seam Testing Requirements

<table>
<thead>
<tr>
<th>Trial Seam Testing</th>
<th>Each day, prior to commencing field seaming, test seams shall be made on fragment pieces of geomembrane to verify that seaming conditions are adequate. Each individual seamer shall make at least one test seam each day they actually perform seaming. Both the welder and the machine must be tested for each new trial seam when extrusion welding. Only the machine needs to be tested for each new trial seam when fusion welding since the machine is not operator dependent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial Seam Test Criteria</td>
<td>Trial seams shall be at least 3-ft long by 1-ft wide. Four (6 when possible if using dual fusion welding) adjoining 1-inch wide specimens will be die-cut from the test seam sample. Two specimens will be tested in the field for shear and 2 for peel (4 when possible if testing both inner and outer welds for dual track fusion welding). The extensometer testing apparatus used for peel and shear tests must have an updated calibration certificate traceable to National Bureau of Standards (NBS).</td>
</tr>
<tr>
<td>Trial Seam Failure Criteria</td>
<td>Trial seam failure criteria is the same as for destructive seam testing. These test specimens must exhibit acceptable break codes and properties specified in the most current version of GRI GM-19. Elongation measurements are not required for trial seams. If one test seam fails, the trial seam will be repeated. If this trial seam also fails, then two more trial seams must be constructed and tested. This process should continue and no welding can begin for the machine or welder (if applicable) until all test seams are passing.</td>
</tr>
</tbody>
</table>
| Additional Trial Seams | Additional trial seams shall be made for all of the following:  
  - At the beginning of each seaming period for each seaming apparatus used that day (the beginning of each seaming period is considered to be the morning, and immediately after a break);  
  - Each occurrence of significantly different environmental conditions (such as temperature, humidity, dust, etc.);  
  - Any time the machine is turned off for more than 30 minutes; and  
  - When seaming different geomembrane (e.g. tie-ins and smooth to textured). |
Table 3-4: Destructive Testing Requirements

| Testing Frequency | Destructive test samples shall be taken at a minimum of one stratified location for every 500 linear feet of field seam or major fraction thereof. The total footage of individual repairs of leaks of more than 10 feet and individual repairs of more than 10 feet for failed seams must also be counted and destructively tested using the same frequency of testing described above.
|                  | At a minimum, a destructive test must be done for each welding machine used for seaming or repairs.
|                  | Additional destructive test samples may be taken if deemed necessary by the POR or his representative.

| Test Specimens   | A sufficient amount of the seam must be removed in order to conduct field testing, independent laboratory testing, and archiving of enough material in order to retest the seam when necessary.
|                  | Field testing shall include at least 2 peel test specimens (4 when possible for testing both tracks on dual-track fusion welded seams) and 2 shear test specimens.

| Repairs          | Destructive seam-testing locations shall be cap-stripped and the cap completely seamed by extrusion welding to the parent geomembrane. Capped sections shall be non-destructively tested.

| Passing Criteria | All laboratory-tested specimens from a destructive-test location must exhibit acceptable break codes, strength, elongation, and percent peel separation as described in GRI GM-19.
|                  | Field-tested specimens are determined as passing if the specimen exhibits acceptable break codes and strengths described in GM-19.

| Retesting        | If destructive tests fails, additional destructive tests must be conducted at least 10 feet on both sides of the failed destructive test. If either of these destructive tests fail, the sampling and testing process must be repeated until the failed seam is located by passing destructive tests.
|                  | The failed seam must then be capped between the passing tests.
|                  | Alternatively, all seams done by the welder/machine within the time period (between passing destructive tests or trial welds) represented by the failed destructive test may be capped.

Table 3-5: Non Destructive Testing Requirements

| Non Destructive Testing | Installer must perform continuous non-destructive testing on all factory and field seams.
|                         | The POR or his representative is required to observe all non-destructive testing.
|                         | Air-pressure testing required for dual-track fusion welds. Vacuum-box testing required for all extrusion welds. Other types of non-destructive testing must have prior written approval from the TCEQ.
|                         | All indicated leaks must be isolated and should be repaired by following the procedures described in Section 3.5.
Air Pressure Testing
The ends of the air channel of the dual-track fusion weld must be sealed and pressured to approximately 30 psi for HDPE geomembrane. The air pump must then be shut off and the air pressure observed after 5 minutes. A loss of less than 4 psi is acceptable if it is determined that the air channel is not blocked between the sealed ends. A loss equal to or greater than 4 psi indicates the presence of a seam leak which must then be isolated and repaired (see Section 3.5).

Vacuum Box Testing
A suction value of approximately 4 to 8 psi must be applied to all extrusion welded seams that can be tested in this manner. Examples of extrusion welded seams that do not easily lend themselves to vacuum testing would be around boots, appurtenances, etc. The seam must be observed for leaks for at least 10 seconds while subjected to this vacuum.

3.5 Repairs and Retesting
All seam leaks and destructive test locations shall be repaired for a distance of at least 6 inches on each side of the faulty spot or area detected. At a minimum, these repairs shall be non-destructively retested and possibly destructively tested (refer to destructive testing criteria for repaired seams as described in Table 3-4).

3.6 Anchor Trench and Backfilling
The anchor trench should be completed around all portions of the geomembrane where the leading edge(s) of the geomembrane will not be needed for a tie-in for expansion into the next area to be lined. The excavated anchor trench shall have rounded corners in order to help protect the geomembrane. No loose soil shall be allowed to underlie the geomembrane in the anchor trench. Excavations of the anchor trench should be closely time to the installation of the geomembrane.

The anchor trench should be backfilled and compacted to at least 90% of the density as determined by the moisture/density compaction values determined in the soils portion of this document. Care should be used when backfilling and compacting the trench to prevent damage to the geomembrane. The anchor trench shall be backfilled at the earliest practicable time following synthetics deployment. Results of the compaction testing need not be reported.
Chapter 4: Geosynthetic Clay Liners

4.1 General

A geosynthetic clay liner (GCL) may be used in alternative liners if it can be shown that a GCL material can be utilized as an equivalent substitute and meet all regulatory requirements of a liner. Such demonstrations should be made as part of the permit application, or as an amendment to an existing permit (30 TAC §305.62). For a GCL the provisions in 30 TAC §330.331 and §330.335 need to be met.

As used in this document, GCL refers to a factory-manufactured hydraulic barrier consisting of a bentonite layer supported by geotextiles or geomembrane. Depending on the GCL type and the manufacturer, the bentonite may be bonded to geomembrane or between layers of geotextile with chemical additives, held between layers of geotextile which are needle punched or stich bonded together, or encapsulated within a geomembrane/geotextile composite.

4.2 GCL Required Properties

The GCL and its component materials (bentonite, geotextile, and/or geomembrane) must be tested as described in Section 4.5 and have the following properties.

<table>
<thead>
<tr>
<th>Table 4-1: GCL Required Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentonite 1</td>
</tr>
<tr>
<td>Free swell</td>
</tr>
<tr>
<td>Fluid Loss</td>
</tr>
<tr>
<td>GCL Product 2</td>
</tr>
<tr>
<td>bentonite mass/unit area</td>
</tr>
<tr>
<td>permeability</td>
</tr>
</tbody>
</table>

1 bentonite must be sodium montmorillonite variety and have the following properties:
2 or as required by the permit)

4.3 Manufacturing, Shipping, Unloading, and Storage

Information regarding the manufacturing, unloading, and storage have been summarized in the table below.

<table>
<thead>
<tr>
<th>Table 4-2: GCL Manufacturing, Shipping, Unloading, and Storage Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
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<tr>
<td></td>
</tr>
</tbody>
</table>
### Damaged Product

If at any time from manufacture to storage, shipment, unloading, and on-site storage the weatherproof wrapping covering the GCL rolls is damaged and the outer portions of the GCL becomes wet or partially hydrated, the portion damaged should be removed and the remainder of the roll once again tightly covered.

### Unloading

A crane or front-end loader fitted with a sling and center rod which is pushed through the core around which the GCL is rolled, or a fork lift with a “stinger”, or other equipment which does not damage the GCL rolls may be used for off-loading and on-site delivery.

### Storage

GCL rolls must be stored on a platform or otherwise elevated off the ground and covered with a tarpaulin to preclude moisture intrusion while awaiting deployment. It is recommended that storage be in an enclosed building or closed shipping trailer if possible.

The rolls must not be stacked higher than recommended by the manufacturer to protect thinning of the bentonite at contact points.

### 4.4 Installation and Repairs

Procedures for the installation and repairs of GCL have been summarized in the table below.

| Surface Preparation | GCL must not be placed directly over rough or uneven surfaces, surfaces with protrusions or ruts, or soil with particle sizes greater than ¾-inch (or as recommended by the manufacturer if less than ¾-inch)
|                     | The soil surface must be rolled with a flat wheel roller and maintained in a smooth, uniform, and compacted condition prior to GCL placement.
|                     | Adequate drainage of the soil surface must be maintained until GCL installation is complete.
| Installation        | GCL panels must be installed with the proper side up.
|                     | GCL placed over other geosynthetics must be placed by hand or using light equipment with low contact pressure rubber tires (e.g. smooth-tired ATVs or golf carts).
|                     | Dragging of the geotextile or bentonite facing of the GCL on the subgrade should be avoided.
|                     | Deployed GCL panels should contain no folds or excessive slack.
|                     | Each panel should be overlapped in the match lines on both edges of the GCL (at least 6 to 12 inches depending on the manufacturer).
|                     | There is no required physical bonding such as sewing or gluing of the panels edges during placement. The needle punched manufactured GCLs, however, do normally require dry granular bentonite placed in the lap-joints between the panel edges.
|                     | Where bentonite enrichment in the lap-joints is required, the minimum amount must be ¼-lb dry bentonite per linear foot of lap joint or as recommended by the manufacturer to produce a joint essentially as impermeable as the GCL itself. Bentonite placed in the lap-joint must be...
the same type used in the manufacture of the GCL. Other lapping
materials should be only used with the prior approval of the TCEQ.
Generators, gasoline, or solvent cans, tools, or supplies must not be
stored directly on GCL.
Installation personal must not smoke or wear damaging shoes when
working on GCL.
Deployed GCL must not be used as a work area unless a protective
tarpaulin, rub sheet, or sacrificial sheet is placed over the GCL.
Care must be taken during installation to avoid entrapment of stones,
trash, or other debris beneath or within the GCL which may cause
damage to the GCL or overlying geomembrane, if applicable.
GCLs which are single geomembrane-backed should be covered with a
second geomembrane on the bentonite side to prevent hydration of the
bentonite.
GCLs used on slopes steeper than 7H:1V should be reinforced (e.g. lock
stitched or needle punched) to provided adequate internal shear
resistance.
GCL on side slopes must be unrolled in the direction of the slope. GCLs
should be anchored at the top of the slope and then unrolled working
down so as to keep the material free of wrinkles and folds.
There should be no horizontal seams on slopes steeper than 7H:1V.
The installed GCL surface must be inspected to ensure that no stones,
cutting blades, tools, or other objects which may damage the GCL are
present prior to covering.

| Equipment on GCL | Equipment used to deploy GCL over soil must not cause rutting of the
|                  | subgrade.
|                  | Vehicular traffic other than low contact pressure vehicles such as
|                  | smooth-tired ATVs or golf carts must not be allowed on the deployed
|                  | GCL. |

| Weather | GCL should not be placed in the rain or at times of impending rain.
|         | If the bentonite material becomes partially hydrated prior to being
|         | covered, it must be removed and replaced with new GCL material.
|         | Deployed GCL should be anchored by sandbags or other appropriate
devices to prevent uplift by wind prior to covering.
|         | GCL (in particular non-woven GCL which requires that dry bentonite be
added in the overlaps) should not be placed during excessive winds.
|         | Deployed GCLs should be covered by geomembrane or other liner system
components as required by the design on the same day as deployment to
prevent hydration due to weather conditions. |

| Repairs | Torn or otherwise damaged geosynthetic facing (with no loss of
bentonite from the GCL) must be patched with the same type of
geosynthetic. The geosynthetic patch must extend at least 12 inches
beyond the damaged area and must be adhesive or heat bonded to the
main GCL to avoid shifting during backfilling. |
If the GCL damage includes loss of bentonite, the patch must consist of full GCL extending at least 12 inches beyond the damaged area. Lapping procedures must be the same as specified for original laps of GCL panels.

4.5 GCL Testing Requirements

The testing requirements for GCL have been summarized in the table below.

<table>
<thead>
<tr>
<th>QA/QC Testing</th>
<th>The tests, testing frequencies, and testing methods are described below and are summarized in Table 3. Quality control testing of GCL products are generally performed by the supplier of the various components (bentonite, geotextile, and geomembrane), the GCL manufacturer, and the third-party independent laboratory under the direction of the POR.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing Results</td>
<td>All test results must meet the GCL manufacturer's criteria and the values given in Section 4.2.</td>
</tr>
<tr>
<td>Lap Joint Permeability</td>
<td>Testing should demonstrate that the overlap procedure produces a lap joint essentially as impermeable as the GCL itself. The lap joint permeability must be re-verified through testing if any of the component materials change (it is recommended that the lap joint permeability be periodically retested to account for any small variations in the GCL materials which may occur over time). Alternatively, if lap joint permeability testing on the material used has not been done or is not valid, the lap joint testing must be done as part of the conformance testing (Section 4.5.3).</td>
</tr>
<tr>
<td>Direct Shear Testing</td>
<td>Direct shear testing must be conducted on hydrated GCL (for GCL which is not &quot;sandwiched&quot; between geomembranes) and must include internal shear as well as shear between GCL and underlying or overlying material (such as soil, geomembrane, geosynthetic material, etc.). The direct shear testing must be conducted with site-specific materials for the initial liner area and need not be repeated for subsequent areas unless any of the component materials (such as either GCL or adjacent soil or geosynthetic) change. If any of the component materials change, direct shear testing must be repeated with the new materials. The minimum strength parameters obtained in the direct shear testing must be sufficient to demonstrate adequate stability of the GCL on the constructed slopes.</td>
</tr>
</tbody>
</table>

4.6 Slope Stability Analysis

Regardless of the type of GCL used, a slope stability analysis must be conducted (as part of either the site development plan (SDP), LQCP, or liner evaluation reports) to verify the stability of the GCL and adjacent slope components on slopes steeper than 7H:1V under hydrated conditions (or non-hydrated conditions if hydration is prevented through double-siding the bentonite with geomembrane).
Chapter 5: Leachate Collection Layer

5.1 Granular Material

Soil materials used to construct leachate collection layers should consist of clean granular soil. Unless specified otherwise in the SDP, granular soils in leachate collection layers should have permeabilities no less than \(1 \times 10^{-2}\) cm/sec. Material placed in contact with the geomembrane or GCL material should have a maximum particle size as indicated in Table 2-2, respectively. Granular material placed around collection pipes must have grain size compatible with the size of the holes in the collection pipes.

5.1.1 Installation

Granular materials should be placed and spread using equipment and methods which minimize generation of fine material. Materials placed over geomembrane or GCL (or other geosynthetics) should be placed as described in Table 2-2. Granular materials should not receive any compaction other than that which is incidental to the placement and spreading process.

5.1.2 Granular Material Testing

Quality assurance testing on granular soils by the independent laboratory should consist of grain size (ASTM D 422) and permeability (ASTM D 2434) analyses conducted at a frequency of 1 per 3,000 yd\(^3\) of material placed. Permeability testing requirements can be waived if it can be shown through correlation with the grain size analysis that the material easily meets the permeability criteria. All tests should be conducted on material after it has been placed to allow for any grain size reduction which may have occurred during the placement process. It is also recommended that the granular material be tested at its source for grain size (and permeability, if necessary) to pre-qualify the material prior to use.

Granular material used in leachate collection layers must be tested for calcium carbonate content (using J&L Test Method S-105-89, ASTM D 3042, or other appropriate method) by either the supplier or independent laboratory. The measured calcium carbonate content must not exceed 15%.

If chimney drains are not provided through the protective cover to the leachate collection system permeability tests must also be conducted on the protective cover to verify a permeability no less than \(1 \times 10^{-4}\) cm/sec.

The thickness of granular leachate collection and protective cover layers should be verified at a frequency of one verification point per 5,000 ft\(^2\).

5.2 Gecomposite Material

In this document the term geocomposite material refers to a geonet with a geotextile bonded on one or both sides. Geonets are unitized sets of parallel ribs positioned in layers such that liquid can be transmitted within their open spaces. Open space exists both in the plane of the geonet (above or under the parallel sets of ribs) and cross plane to the geonet (within the apertures between adjacent sets of ribs). Geonets always function with either geomembranes and/or geotextiles on their two planar surfaces. Geotextiles are typically bonded to the geonet by heat fusing or by using an adhesive.

Geosynthetic material (i.e. geocomposite, geonet, and geotextiles) used in leachate collection layers must have the transmissivity and other properties as specified in the SDP.

5.2.1 Installation

Installation procedures for geocomposite material should be as described in Chapter 6 of the U.S. EPA Technical Guidance Document “Quality Assurance and Quality Control for Waste Containment Facilities” (EPA/600R-93/182, September 1993).
5.2.2 Geocomposite Testing Requirements

QA/QC testing required for geocomposite drainage material can be found in Table 4. It is recommended that the geonet, geotextiles, and geocomposite material be tested to ensure that they meet the design requirements provided by the facility. Quality control certificates from the manufacturer should include proper identification of the product, style, and results of quality control tests. The manufacturer’s test results for geocomposite materials should be checked and verified by the POR or his representative to meet the minimum requirements for these materials established by the SDP.
Chapter 6: Liners Constructed Below the Seasonal High Water Table

6.1 Seasonal High Water Table Determination

In accordance with 30 TAC §330.339(b)(2)(B), the applicant is required to provide a determination of the seasonal high groundwater table as an attachment to this document.

The seasonal high water table is the highest measured or calculated water level in an aquifer during investigation for a permit application and/or any groundwater characterization studies at a site. Groundwater level measurements used for the determination of the seasonal high water table should be performed through at least 1 cycle of seasonal change (usually a period of 8 months to 1 year) in order to insure that seasonal variations of the groundwater table are considered.

An assessment of the seasonal high water table is typically made as part of a permit application for a site. The initial assessment of the seasonal high water table should be the basis for the liner and ballast design specified in the approved SDP. However, if after the permit is granted, additional data becomes available which indicates the seasonal high water table is higher than originally determined, the seasonal high water table must be adjusted upward, in accordance with 30 TAC §330.337(i). The seasonal high water table may not be adjusted downward. Additional data which may result in the upward revision of the seasonal high water table could be obtained from water elevation readings from the groundwater monitoring wells, or from groundwater characterization studies performed as a basis of updating the groundwater monitoring system to Subtitle D standards. The re-evaluation of the seasonal high water table should be performed routinely as part of each liner evaluation.

The following information must be provided in the SLER for each new increment of liner construction:

- A description of the seasonal high water table established in the SDP or previous SLER, as applicable;
- A summary of the groundwater data collected since the permit application or previous SLER;
- An evaluation of whether the seasonal high water table must be adjusted upward on the basis of this data; and
- An analysis of the changes required in liner design or ballast requirements as a result of the higher water table.

If existing data are thought to be misleading or incomplete, then it would be appropriate to conduct additional field investigations at the site, with a scope coordinated with the TCEQ technical staff to develop a database that can be used to make an analysis of whether unbalanced hydrostatic forces could develop.

6.2 Demonstrating that the liner will not undergo uplift

For Type I landfills, and Type IV landfills (if applicable), one of the methods listed in Table 6.1 must be used to demonstrate that the liner system will not undergo uplift from hydrostatic forces during its construction. In accordance with 30 TAC §330.337(b), please provide a discussion regarding the method(s) that will be used and all associated information as an attachment to this document. Please ensure that the information will include the methods and tests to be used to verify that the liner will not undergo uplift during construction and until ballast placement (if required) is complete.
Table 6.1: Uplift Protection for Liner

<table>
<thead>
<tr>
<th>Method Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Providing calculations satisfactory to the ED that the weight of the liner systems, including any ballast, is sufficient to offset by a factor of 1.2 any otherwise unbalanced upward or inward hydrostatic forces on the liner.</td>
</tr>
<tr>
<td>Incorporating an active or passive dewatering system in the design to reduce upward or inward hydrostatic forces on the liner by a factor of 1.2 and by providing calculations satisfactory to the ED that the dewatering system will perform to adequately reduce those forces.</td>
</tr>
<tr>
<td>Providing evidence satisfactory to the ED that the soil surrounding the landfill is so poorly permeable that groundwater cannot move sufficiently to exert force that would damage the liner.</td>
</tr>
<tr>
<td>Providing evidence that the seasonal high water table is below the deepest planned excavation.</td>
</tr>
</tbody>
</table>

Any required leachate collection system shall be designed to handle both the leachate generated and the groundwater inflow from materials beneath and lateral to the liner system. The maximum volume of groundwater inflow shall be calculated based on determination of the permeability and potentiometric conditions of the liner system and of the materials surrounding the liner system.

6.3 Foundation Evaluation

**In accordance with 30 TAC §330.337(e), the applicant is required to provide a preliminary foundation evaluation as an attachment to this document, if applicable.** Prior to excavating any unit below the seasonal high water table, the owner or operator shall perform a preliminary foundation evaluation satisfactory to the ED. The foundation evaluation shall consider stability, settlement, and constructability.

6.4 Dewatering

Any dewatering systems used to ensure liner stability during construction and filling shall be operated until the ED determines that such systems are no longer required.

6.5 Ballast

If ballast will be used, please ensure that the information provided in the LQCP will include the measures and tests that will be used to verify that any required ballast meets the criteria established, including, but not limited to, inspections, compaction, weight and density of material, thickness, and top elevations.

**In accordance with 30 TAC §330.337(f)(2), if waste will be used as ballast, the applicant is required to include a discussion regarding the use of waste as ballast as an attachment to this document.** Please ensure that discussion will include the following information:

- The first five feet or the total thickness of the ballast, whichever is less, placed on the liner system shall be free of brush and large bulky items, which would damage the underlying parts of the liner system or which cannot be compacted to the required density.
- If waste is used for ballast, a wheeled compactor having a minimum weight of 40,000 pounds, or equivalent equipment, shall be properly utilized to reach a compaction density of at least 1,200 pounds per cubic yard. For purposes of determining the required ballast thickness, a density of compacted waste of 1,200 pounds per cubic yard shall be used. The weight of the liner system, including any ballast, must be sufficient to offset any unbalanced upward or inward hydrostatic forces on the liner by a factor of 1.5 when waste is used for ballast.
- The information provided shall also include the method(s) to be used to verify that compaction of waste used for ballast is to a density of not less than 1,200 pounds per
cubic yard. If a compactor having a minimum weight of 40,000 pounds is used, no compaction density verification will be required.

- If waste is used for ballast, the ballast evaluation report shall also include verification that a compactor having a minimum weight of 40,000 pounds was used or, if not, that compaction was at least 1,200 pounds per cubic yard.

If ballasting or dewatering is used, the owner or operator shall submit a ballast evaluation report in a format specified by the ED in duplicate to the ED when the owner or operator determines that ballasting or dewatering is no longer necessary. If the ED provides no response within 14 days of the date of receipt, the owner or operator may discontinue dewatering or ballasting operations. The ballast evaluation report shall include:

- verification that the liner did not undergo uplift during construction, using the method identified in the liner quality control plan;
- certification that ballast met the criteria established in this section and in the liner quality control plan; and
- signature and seal of an independent licensed professional engineer performing the evaluation and signature of the facility operator or his authorized representative.
Chapter 7: Documentation and Reporting

7.1 Liner Evaluation Report

All liner QA/QC testing must be performed in conformance with the LQCP as required by 30 TAC §330.339(a). The data must be submitted as a Liner Evaluation Report (LER), which may be a soil Liner Evaluation Report (SLER), Geosynthetic Clay Liner Evaluation Report (GCLER), or Geomembrane Liner Evaluation Report (GLER), depending on the type of liner construction.

The limits of all constructed liners, including the most recent covered by the current evaluation, must be clearly marked with the placement of red-colored markers. These markers must be readily discernible by site workers and site inspectors, and shall be maintained at all times during the active disposal operations within the area and may be removed as needed to facilitate operations upon approval of subsequent LER areas. The LER markers must be tied into the master site grid system for reference and shall not be placed through the constructed liner.

Each LER submitted must include a clearly legible site map which depicts the grid system on site, graphic scale, north arrow, sectorized fill layout plan, filled area, present active area, and area covered by the current submittal. The site map must show the area covered by all previous LER submittals with the dates of acceptance by the TCEQ. It may be a print from a master drawing which is annotated and updated with each new submittal. In addition, each LER submittal to the TCEQ must include all or parts of the following items as appropriate and depending on the constructed elements of the liner:

- All field and laboratory test documentation for liner soils and test and sample locations plotted on a location plan (SLER);
- All test documentation for leachate collection and protective cover layers (SLER/GCLER/GLER);
- If the liner includes a geomembrane, manufacture's certifications, documentation of all manufacturer's and independent testing, seaming and repair records, seam tests, and a site map showing locations and panels, repairs, and tests (GLER);
- If the liner includes a GCL, documentation of all manufacturer's and independent materials tests, manufacturer's certifications, stability analyses (if required), and a site map showing panel layout (GCLER);
- Manufacturer's certification and testing documentation for all geosynthetics (SLER/GCLER/GLER); and
- A survey documentation of the thickness of the soil liner, leachate collection, and protective cover layers (SLER/GCLER/GLER).

All field and laboratory sampling and testing of components of the liner and its construction must be under the direct supervision of the POR or his representative. Any completed lined area that fails to meet the minimum specified conditions of the required tests must be reworked or reconstructed to achieve the required results. Inability to achieve the required results through reworking shall be cause for rejection of the area in question. All reworked areas shall be retested to prove adequacy to meet all the applicable requirements.

In accordance with 30 TAC §330.341(b) and (c), no area may be used for the receipt of solid waste until the TCEQ has given confirmation of its acceptance of the LER or fourteen days from the date(s) of arrival of the LER at the TCEQ, MSW Permits Section, have lapsed. It is recommended that the permittee call the MSW Permits Section prior to use of the area in question if confirmation of acceptance has not been received and the permittee believes that the fourteen-day review period has lapsed.
7.2 Interim Status Report

An Interim Status Report (ISR) for all liners should be provided to the TCEQ for portions of the liner that remain uncovered with waste for more than six months from the date that the protective cover was applied, and the area shall be reevaluated by a geotechnical professional as stated in 30 TAC §330.341(d).

7.3 Ballast

Liners constructed below the groundwater table require several elements of evaluation and quality assurance beyond the basic requirements of the LER. Most of these additional documentation and evaluation activities are performed as part of the liner design before construction or during the same time as the monitoring for the clay liner construction. To avoid duplication in reporting requirements, these activities should logically be included in the LER. The documentation and evaluation include the following:

- Summary of soil stratigraphy and properties of soils exposed on the bottom and sidewalls of the area being lined.
- Adjusted seasonal high water table, based on the SDP data, groundwater monitoring well data, or other data.
- Calculation of ballast required, and type of ballast to be used (soil or waste).
- Discussion of whether subgrade required an underdrain system or other dewatering method, using criteria established in the SDP and LQCP.
- Method of controlling uplift forces during construction (low-permeability foundation soil, dewatering, or combination).
- Monitoring of dewatering system to demonstrate that hydrostatic forces did not develop during liner construction.
- Pre-construction and top-of-liner evaluations of the liner, and confirmation of liner weight. The survey elevations must be performed at the frequency required in the LQCP.

7.3.1 Soil as Ballast

If soil is to be used as ballast, it would be placed immediately after liner or leachate collection system construction. If soil ballast is placed directly on a clay liner (for sites where no geomembrane is required), the as-built ballast density and thickness should be included with the SLER. If soil ballast is to be placed on the composite liner system, the SLER should include a statement that the ballast will be documented in the GLER, which will document the as-built density and thickness of the soil ballast. The soil ballast thickness should be surveyed at the same frequency required in the LQCP for the liner.

7.3.2 Waste as Ballast

If waste is used for ballast, the approval of the GLER must first be received from TCEQ. A follow-up report in the form of a Ballast Evaluation Report (BER) must then be prepared. A BER should be submitted after sufficient ballast is in place to demonstrate adequate uplift resistance against the long-term seasonal high groundwater level for a given waste cell, sector, or LER area. The BER must include the following documentation:

- The weight of the compactor being used to compact the waste is no less than 40,000 pounds, and a certification from the owner that this compactor was utilized during the entire period of placing the waste ballast.
- Certification from the owner of the type of waste placed in the lower 5 feet.
- If a 40,000 pound compactor was not used, calculations to show that the in-place density of waste is not less than 1,000 pounds per cubic yard. These calculations must include the following:
• Initial survey of the area to receive waste as ballast;
• Final survey and calculated volume of waste placed as ballast, and
• Weight of waste placed, based on actual measurements of truck weights at the scalehouse.

• Survey of the top of waste to document that the thickness calculated in the LER has been placed.

• Documentation that any dewatering system used to lower the groundwater level during liner construction was in effect throughout the completion of the ballast placement.

• Groundwater level measurement and pneumatic/vibrating wire piezometer measurements to demonstrate that hydrostatic heads did not exceed the allowable values.
Glossary

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) - One of the largest, professionally recognized voluntary standards development systems in the world.

ATTERBERG LIMITS - A series of six "limits of consistency" of fine-grained soils defined by Swedish soil scientist Albert Atterberg, two of which are frequently used today to establish a soil's physical boundaries dealing with its plasticity characteristics. These soil boundaries or limits used most frequently in geotechnical engineering are based upon the following:

Liquid Limit (LL) - The percentage of moisture in a soil, subjected to a prescribed test that defines the upper point at which the soil's consistency changes from the plastic to the liquid state.

Plastic Limit (PL) - The percentage of moisture in a soil, subjected to a prescribed test that defines the lower point at which the soil's consistency changes from the plastic to the semi-solid state.

Plasticity Index (PI) - The numerical difference between the LL and the PL of a fine-grained soil that denotes the soils plastic range. The larger the PI the greater a soil's plasticity range and the greater it's plasticity characteristics.

COEFFICIENT OF PERMEABILITY (a.k.a. Hydraulic Conductivity) - The amount of flow per unit of time through soil under unit hydraulic gradient at standard temperature.

COMPACTIVE EFFORT - The amount of compaction energy held constant, and usually transferred into a soil sample with a compaction hammer device, used on soil samples in various laboratory test procedures to establish a soil's density at various moisture contents.

CONSTRUCTED SOILS LINERS - Soils liners constructed from reworked in situ soils, soils from a borrow source, or bentonite-amended soils.

CONSTRUCTION QUALITY ASSURANCE (CQA) - A planned system of activities that provides the owner and permitting agency assurance that the facility was constructed as specified in the design (EPA, 1993).

CONSTRUCTION QUALITY CONTROL (CQC) - A planned system of inspections that is used to directly monitor and control the quality of a construction project (EPA, 1993).

FIELD PERMEABILITY TEST - A field test performed on a constructed liner or in situ soils to determine the in-place coefficient of permeability and usually performed as a Sealed Double Ring Infiltrometer Test (SDRI), or series of Boutwell field tests. This type of permeability test method is usually considered to have greater accuracy due to the area tested and the existing field conditions that may be obscured by a laboratory testing environment.

FILM TEAR BOND (FTB) - A failure in the geomembrane sheet material on either side of the seam and not within the seam itself.

FISH MOUTH - A semi-conical opening of the seam that is formed by an edge wrinkle in one sheet of the geomembrane.

GEOMEMBRANE LINER - An essentially impermeable geosynthetic composed of one or more synthetic sheets. See HDPE.

GEOMEMBRANE LINER EVALUATION REPORT (GLER) - A stand-alone as-built report prepared in accordance with the methods and procedures contained in the approved SLQCP that details the installation and testing of the geomembrane.

GEOMEMBRANE STRATIFIED SAMPLE - A randomly selected sample location within each 500-linear-foot interval.

GEOSYNTHETIC MATERIALS - Manufactured or man-made materials that include geomembranes, geogrids, geofilters, geocomposites, geonets, and geotextiles.
GRADATION - See SIEVE ANALYSIS

GEOSYNTHETIC RESEARCH INSTITUTE (GRI) - Located at Drexel University, the GRI conducts research with geosynthetic materials and develops industry testing standards for these materials. This institute is supported by many geosynthetic manufacturers, installers, and raw materials suppliers to the industry.

HIGH DENSITY POLYETHYLENE (HDPE) - A polymer prepared by low-pressure polymerization of ethylene as the principal monomer and having the characteristics of ASTM D1348, Type III and IV polyethylene. Such polymer resins have densities greater than or equal to 0.941 g/cc as noted in ASTM D 1248.

IN SITU LINERS - Soils liners consisting of undisturbed soils that do not exhibit primary or secondary physical features, and meet all physical and quality control testing requirements of the MSWR, and are found acceptable by the Commission.

IN SITU SOILS - Undisturbed soils; the term routinely used in describing an in-place soil liner.

INDEPENDENT TESTING LABORATORY - A laboratory that is independent of ownership or control by the permittee or any party to the construction of the liner or the manufacturer of the liner products used.

MANUFACTURING QUALITY ASSURANCE (MQA) - A planned system of activities that provides assurance that the raw materials were constructed (manufactured) as specified.

MANUFACTURING QUALITY CONTROL (MQC) - A planned system of inspection that is used to directly monitor and control the manufacture of a material.

MOISTURE/DENSITY RELATIONSHIP - A test in which soil samples are compacted in a known volumetric container at various moisture contents at a constant level of compactive effort and their corresponding densities are determined. The test procedures and compactive efforts used are those normally prescribed in ASTM D 698 and D1557. These tests are frequently designated the Standard Proctor and Modified Proctor compaction tests named after M. M. Proctor, the early developer of these test procedures for the determination of density control on compacted soil fills.

MUNICIPAL SOLID WASTE REGULATIONS (MSWR) - The TCEQ regulations that govern Municipal Solid Waste Management, as published in the Texas Register.

PERMEABILITY - See COEFFICIENT OF PERMEABILITY

PERMEANT FLUID - Fluid used in a laboratory coefficient of permeability test and limited to tap water or 0.05 Normal solution of CaSO4. Distilled water shall not be used in these test procedures.

PROFESSIONAL OF RECORD (POR) - A professional engineer registered in the state of Texas who possesses professional experience in geotechnical engineering, construction oversight, geosynthetics, and soil testing, or a graduate geologist who has a minimum of four years experience in engineering geology and is experienced in geotechnical testing and its interpretations. Note: All references to the Geotechnical Professional, Geotechnical Quality Control/Quality Assurance Professional, Professional of Record, etc., within the context of this document and the MSWR are interchangeable and are therefore synonymous.

QUALIFIED ENGINEERING TECHNICIAN - A representative of the POR who is NICET-certified in geotechnical technology at level 2 or higher and certified through the Geosynthetic Certification Institute’s Inspectors Certification Program (GCI-ICP), an engineering technician with a minimum of four years of directly related experience, or a graduate engineer or geologist with one year of directly related experience.

REPRESENTATIVE SAMPLE - A representative sample of geomembrane material consists of one or more specimens (commonly referred to as coupons) from the same rectangular portion of
geomembrane material, oriented along a seam, that is removed for field or laboratory testing purposes.

SIEVE ANALYSIS - A laboratory soil test consisting of placing a known weight of soil sample through a series of wire mesh sieves stacked upon each other in successively smaller mesh size and used to determine the percentage size gradation of the sample.

SOILS AND LINER EVALUATION REPORT (SLER) - A stand-alone, quality control test report prepared in accordance with the methods and procedures contained in the approved SLQCP that details the installation and testing of the soil liner.

SOILS AND LINER QUALITY CONTROL PLAN (SLQCP) - An approved plan that is prepared under the direction a registered professional engineer and is the basis for the construction/installation and testing of soils and/or flexible membranes materials for liners.

SOIL BORROW SOURCE - Soils in which the Liquid Limit (LL) and Plasticity Index (PI) do not vary by 10 points. A soil that varies by more than 10 or points from the originally established LL or PI is considered as a separate soil source for the purpose of this document and requires a separate soils test series.

SOIL TEST SERIES - Tests performed to determine a soil’s physical characteristics and to document its ability to satisfy the soil liner MSWR requirements. These tests include sieve analysis (gradation), Atterberg Limits, moisture/density, and coefficient of permeability.

SPECIMEN - (With respect to geomembrane destructive testing). - A specimen is the individual test strip (sometimes called coupon) from a sample location. A sample location usually consists of many specimens.
<table>
<thead>
<tr>
<th>Soil Test Category</th>
<th>Type of Test</th>
<th>Standard Test Methods</th>
<th>Frequency of Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Control</td>
<td>Unified Soil Classification</td>
<td>ASTM D 2487</td>
<td>Once per soil type</td>
</tr>
<tr>
<td>Testing of</td>
<td>Moisture/Density Relationship</td>
<td>ASTM D 698 or D 1557</td>
<td></td>
</tr>
<tr>
<td>Source Borrow</td>
<td>Sieve (Gradation)</td>
<td>ASTM D 422 or D 1140</td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>Atterberg Limits</td>
<td>ASTM D 4318</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coefficient of Permeability</td>
<td>ASTM D 5084 or CoE EM1110-2-1906</td>
<td>1/Moisture/Density Relationship</td>
</tr>
<tr>
<td>In-Situ Liners</td>
<td>Sieve (Gradation)</td>
<td>ASTM D 422 or D 1140</td>
<td>1/50,000 ft² per foot thickness of liner</td>
</tr>
<tr>
<td></td>
<td>Atterberg Limits</td>
<td>ASTM D 4318</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coefficient of Permeability (laboratory)</td>
<td>ASTM D 5084 or CoE EM1110-2-1906</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coefficient of Permeability (field)</td>
<td>ASTM D 5093 or D 6391</td>
<td>1 SDRI test or 1 Boutwell series® per 50,000 ft²A</td>
</tr>
<tr>
<td></td>
<td>Thickness</td>
<td>Auger</td>
<td>1/5,000 ft²A</td>
</tr>
<tr>
<td>Constructed</td>
<td>Field Density</td>
<td>ASTM D 1556, D 2167,</td>
<td>1/8,000 ft² per 6-inch parallel liftA; 1/100 lineal ft per 12 inches sidewall liner (horizontal lifts)B</td>
</tr>
<tr>
<td>Soil Liners</td>
<td></td>
<td>or D 6938</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sieve (Gradation)</td>
<td>ASTM D 422 or D 1140</td>
<td>1/100,000 ft² per 6-inch parallel liftA; 1/2,000 lineal ft per 12 inches sidewall liner (horizontal lifts)B</td>
</tr>
<tr>
<td></td>
<td>Atterberg Limits</td>
<td>ASTM D 4318</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Permeability</td>
<td>ASTM D 5084 or CoE EM1110-2-1906 (laboratory)</td>
<td>1/5,000 ft² (parallel lifts)A; 50-ft cross sections (horizontal-lift sidewall liners)A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air Entry Permeameter (field)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thickness</td>
<td>Registered Surveyor</td>
<td></td>
</tr>
</tbody>
</table>

Notes
A – A minimum of one of each of the designated tests must be conducted for each unit thickness of liner as indicated, regardless of liner area or length.
B – One Boutwell series includes 5 test holes.
C – Equivalent or better test methods may be provided by the POR.
<table>
<thead>
<tr>
<th>Test Category</th>
<th>Type of Test</th>
<th>Standard Test Methods</th>
<th>Frequency of Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin</td>
<td>Specific Gravity/Density</td>
<td>ASTM D 792 or D 1505</td>
<td>per 100,000 ft² and every resin lot</td>
</tr>
<tr>
<td></td>
<td>Melt Flow Index</td>
<td>ASTM D 1238</td>
<td></td>
</tr>
<tr>
<td>Geomembrane Manufacturer</td>
<td>MQC</td>
<td>Testing per GRI Test Method GM 13A</td>
<td></td>
</tr>
<tr>
<td>Conformance Testing by 3rd</td>
<td>Thickness</td>
<td>ASTM D 5199 (smooth), D 1593 (Textured), or D 5994 (Textured)</td>
<td>per 50,000 ft² and every resin lot</td>
</tr>
<tr>
<td>Party Independent Laboratory</td>
<td>Specific Gravity/Density</td>
<td>ASTM D 792 or D 1505</td>
<td>per 100,000 ft² and every resin lot</td>
</tr>
<tr>
<td></td>
<td>Carbon Black Content</td>
<td>ASTM D 1603</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carbon Black Dispersion</td>
<td>ASTM D 5596</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tensile Properties</td>
<td>ASTM D 638⁸ or D 6693</td>
<td></td>
</tr>
<tr>
<td>Destructive Seam Field Testing</td>
<td>Shear</td>
<td>ASTM D 4437 or D 6392</td>
<td>Varies for field, lab, and archive</td>
</tr>
<tr>
<td></td>
<td>Peal</td>
<td>ASTM D 4437</td>
<td></td>
</tr>
<tr>
<td>Non-destructive Seam Field Testing</td>
<td>Air Pressure</td>
<td>GRI GM-6 or ASTM D 5820</td>
<td>All dual-track fusion</td>
</tr>
<tr>
<td></td>
<td>Vacuum</td>
<td>ASTM D 4437 or D 5641</td>
<td>All non-air pressure tested seams when possible</td>
</tr>
</tbody>
</table>

Notes
A - UV resistance testing not required for HDPE which is to be immediately covered.
B - Break elongation calculated using 2 - inch initial gauge length.
C - Equivalent or better test methods may be provided by the POR
Table 3: Standard Tests on GCL Material

<table>
<thead>
<tr>
<th>Test Category</th>
<th>Test</th>
<th>Type of Test</th>
<th>Standard Test Methods</th>
<th>Frequency of Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier or GCL Manufacturer</td>
<td>Bentonite</td>
<td>Free Swell</td>
<td>GRI GCL-1 or ASTM D 5890</td>
<td>per 50 tons and every truck or railcar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fluid Loss</td>
<td>API 13B, or ASTM D 5891</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geotextile</td>
<td>Mass/Unit Area</td>
<td>ASTM D 5261</td>
<td>per 200,000 ft²</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grab Tensile Strength</td>
<td>ASTM D 4632</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mass/Unit Area</td>
<td>ASTM D 5261</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thickness (Smooth)</td>
<td>ASTM D 5199</td>
<td>per 200,000 ft²</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thickness (Textured)</td>
<td>ASTM D 5994</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tensile Properties</td>
<td>ASTM D 638 or D 6693</td>
<td></td>
</tr>
<tr>
<td>GCL Manufacturer</td>
<td>Bentonite Mass/Unit Area</td>
<td>ASTM D 5993</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bentonite Moisture Content</td>
<td>ASTM D 2216, D 4643, or D 5993</td>
<td>per 40,000 ft²</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tensile Strength</td>
<td>ASTM D 6768</td>
<td>per 200,000 ft²</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grab Tensile Strength</td>
<td>ASTM D 4632</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Permeability</td>
<td>GRI GCL-2, ASTM D 5084, D 5887, or D 6766</td>
<td>per week for each production line</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lap Joint Permeability</td>
<td>Flow box or other suitable device</td>
<td>per material and lap type</td>
<td></td>
</tr>
<tr>
<td>Independent Laboratory (Conformance Testing)</td>
<td>Clay Mass/Unit Area</td>
<td>ASTM D 5993</td>
<td>per 100,000 ft²</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Permeability</td>
<td>GRI GCL-2, ASTM D 5084, D 5887, or D 6766</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Direct Shear</td>
<td>ASTM D 5321 or D 6243</td>
<td>per GCL/adjoining material type</td>
<td></td>
</tr>
</tbody>
</table>

Notes
A - Test to be performed on bentonite before incorporation into GCL.
B - Not applicable for geomembrane-backed GCL. Manufacturer of geomembrane-backed GCL must, however, certify that product will meet required permeability standards based on prior testing.
C - Report last 20 permeability values, ending on production date of supplied GCL.
D - May also be done as conformance testing.
E - Test at confining/consolidating pressure simulating field conditions for ASTM D 5084. Permeability test not applicable for geomembrane-backed GCL which is installed geomembrane side down and covered with second geomembrane. Permeability test on geomembrane-backed GCL must be done with geomembrane backing removed and may be done at a reduced frequency (1 per 200,000 ft² to 300,000 ft²). Testing must be on material in hydrated state unless GCL is to include geomembrane on both sides of GCL, and must use strain rates, confining pressures, and other parameters which simulate field conditions.
F - Not applicable for slopes of 7H:1V or flatter. Testing must be on material in hydrated state unless GCL is to include geomembrane on both sides of GCL, and must use strain rates, confining pressures, and other parameters which simulate field conditions.
G - May be calculated using density and thickness of geomembrane.
H - Equivalent or better test methods may be provided by the POR.
Table 4: Tests on Geocomposite Material

<table>
<thead>
<tr>
<th>Test Category</th>
<th>Product</th>
<th>Test</th>
<th>Test Method</th>
<th>Testing Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>Resin (Geonet)</td>
<td>Density</td>
<td>ASTM D 792 or D 1505</td>
<td>per 100,000 ft² and every resin lot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Melt Flow Index</td>
<td>ASTM D 1238</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manufacturer</td>
<td>Density</td>
<td>ASTM D 792 or D 1505</td>
<td>per 100,000 ft² and every resin lot</td>
</tr>
<tr>
<td></td>
<td>Geonet</td>
<td>Mass/Area</td>
<td>ASTM D 5261</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thickness</td>
<td>ASTM D 5199</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compression</td>
<td>ASTM D 1621</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transmissivity</td>
<td>ASTM D 4716</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geotextile</td>
<td>Mass/Area</td>
<td>ASTM D 5261</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grab Tensile Strength</td>
<td>ASTM D 4632</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trapezoidal Tear Strength</td>
<td>ASTM D 4533</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Burst Strength</td>
<td>ASTM D 3786</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Puncture Strength</td>
<td>ASTM D 4833</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thickness</td>
<td>ASTM D 5199</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apparent Opening Size</td>
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Notes
B – Equivalent or better test methods may be provided by the POR
References


