# CONSTRUCTION QUALITY ASSURANCE / CONSTRUCTION QUALITY CONTROL PLAN

## Part 360 Series Permit Renewal/Modification Application

### LOCKWOOD ASH DISPOSAL SITE

**Prepared on behalf of:**

**Lockwood Hills LLC**
590 Plant Road
P.O. Box 187
Dresden, New York 14441

**Prepared by:**

DAIGLER ENGINEERING, P.C.
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2620 Grand Island Blvd.
Grand Island, New York 14072-2131

**August 2020**

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# 1 INTRODUCTION

## 1.1 BACKGROUND

The Lockwood Ash Disposal Site (Landfill) is located on Swarthout Road near NYS Route 14, in the Town of Torrey, Yates County, New York. The Landfill is owned and operated by Lockwood Hills LLC (Lockwood). The operation of the Landfill is carried out in accordance with the requirements of 6 NYCRR Part 360 Solid Waste Management Facility Permit No. 8-5736-00005-00003-0, which permits the Landfill to accept ash and wastewater treatment plant sludge from various sources. Stormwater and leachate discharge from the Landfill are managed in accordance with the requirements of State Pollutant Discharge Elimination System (SPDES) Permit No. NY-0107069.

## 1.2 CONSTRUCTION QUALITY CONTROL AND CONSTRUCTION QUALITY ASSURANCE

The purpose of this CQA/CQC Plan is to develop systematic procedures to assure and document that project requirements are properly implemented during construction.

Construction Quality Assurance and Construction Quality Control are defined as follows:

- Construction quality assurance (CQA) means a planned system of activities that provides assurance that the facility was constructed as specified in the design. CQA includes inspections, verifications, audits, and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility. CQA refers to measures taken by the CQA organization to assess if the contractor's complete work is in compliance with the plans, specifications and regulatory approvals for the project. This can also include quality control for those actions taken before construction to ensure that the materials chosen, and workmanship comply with the Department approved engineering plans, reports, and specifications.
- Construction quality control (CQC) means a planned system of inspections that are used to directly monitor and control the quality of a construction project. CQC refers to measures, typically taken by the contractors, to determine compliance with the

requirements for materials and workmanship as stated in the plans and specifications for the project. CQC actions help achieve the highest quality in the constructed or installed system.

- Conformance Testing refers to testing completed by the QA Engineer.

The CQA/CQC Plan presents the management organization, personnel and laboratory requirements, testing protocols, and requirements for documentation and record keeping.

# 2 MANAGEMENT ORGANIZATION

## 2.1 GENERAL

Lockwood will retain an engineering consulting firm to serve as the Project Engineer. The Project Engineer must be licensed to practice engineering in the State of New York and will be responsible for certifying, without influence from the Contractors or the facility owner, that activities related to quality assurance of the construction conform with the approved construction plans and specifications. The organization of all the involved parties is shown on Figure 2-1.

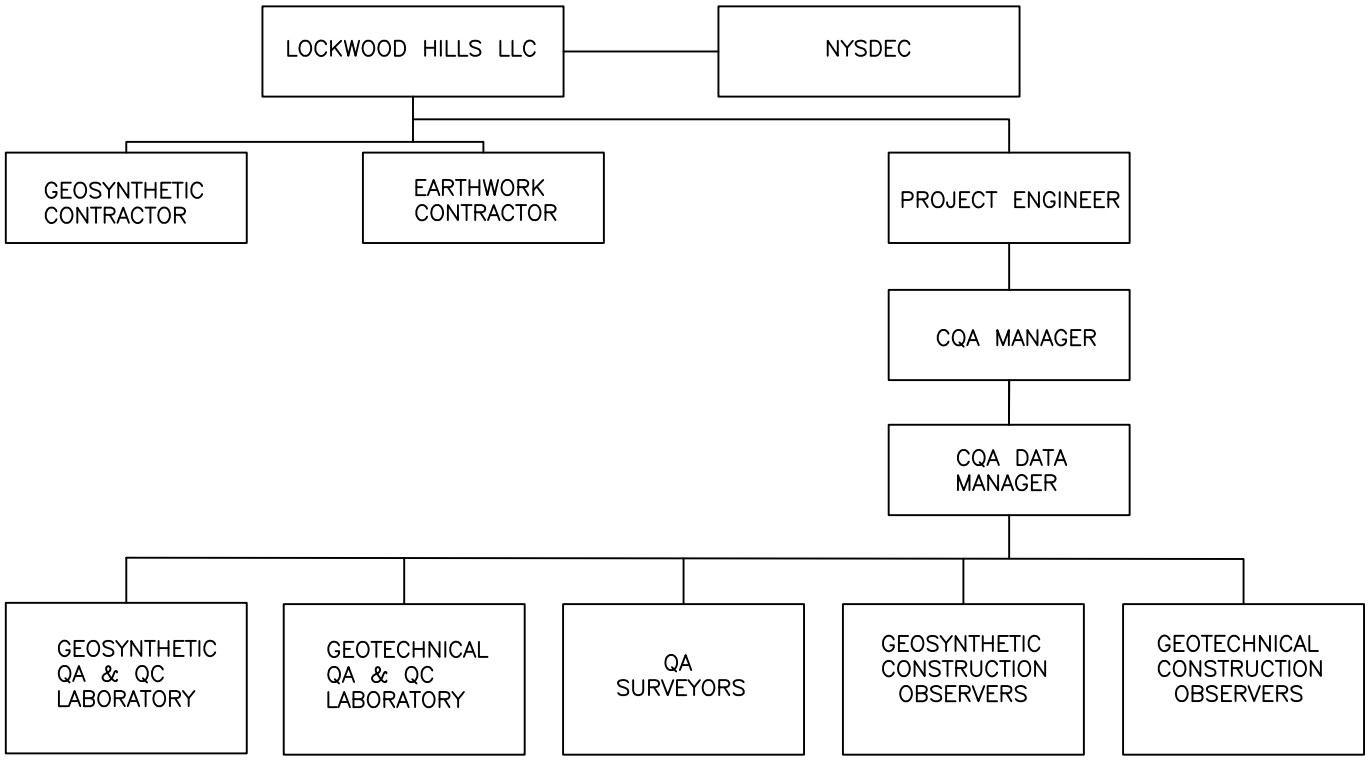
## 2.2 CQA PRE-CONSTRUCTION CONFERENCE

A CQA pre-construction conference will be held with the designated representative of the Owner, the Project Engineer, the General Contractor, and the geosynthetic subcontractors. Region 8 NYSDEC staff will be made aware of the time and place for the pre-construction meeting in advance.

The following will be presented and discussed at the pre-construction conference:

- Provide each involved entity with all relevant CQA/CQC documents and supporting information and address their role relative to the construction tasks and the CQA/CQC Program, especially highlighting the sequence of the works, the construction drawings, and the technical specifications;
- Review the responsibilities, authorities, and line of communication for each of the involved entities;
- Review the established procedures for observation and testing, including sampling strategies;
- Review the acceptance and rejection criteria as well as the anticipated methods and means for decision making and/or resolution of issues;
- Review methods for documenting and reporting inspection data and findings;
- Discuss the procedures for storage and protection of construction materials on the site; and

# LOCKWOOD HILLS LLC
# CONSTRUCTION CQA/CQC MANAGEMENT ORGANIZATION CHART

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| | | | | |
|---|---|---|---|---|
| LOCKWOOD HILLS LLC | | CQA/CQC MANAGEMENT ORGANIZATION CHART<br>CQA/CQC PLAN | | FIGURE 2-1 |
| SCALE: NOT TO SCALE | REVISION # 0 | | | |
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- Conduct a site tour to review the project site layout and construction material and equipment storage locations.

Before earthwork, pipeline installation, or installation of the geosynthetics begins, and routinely until the work is completed, project coordination meetings will be held with the designated representative of the General Contractor, Project Engineer, CQA Manager, and Owner in attendance. NYSDEC staff will be made aware of the time and place for routine project meetings in advance in the event Department staff wish to attend.

The following topics, at a minimum, will be discussed during the routine meetings:

- Progress of the work, problems encountered, and corrective measures undertaken;
- Adherence to the Specifications;
- Summary of QA and QC test results and construction observations;
- Adherence to the QA Program, including the timeliness of the pertinent forms and submittals; and
- Planned work and methods for the ensuing week, including estimate of time remaining to complete the work.

Minutes describing the discussions will be recorded by the CQA Manager and will be distributed to the attendees within one week after the meeting.

In the event a postconstruction meeting is determined to be appropriate, one will be convened. NYSDEC staff will be made aware of the time and place for any postconstruction meeting in advance, in the event Department staff wishes to attend.

## 2.3 CQA/CQC Staff

### 2.3.1 Project Engineer

The Project Engineer will be employed independently from Lockwood (the Owner) and will have overall responsibility for the implementation of the CQA/CQC Plan. The Project Engineer is responsible for independently certifying that, in his or her professional judgment and belief, based

on the information acquired by the CQA/CQC staff and inspections performed, the work has been completed in accordance with the plans and specifications.

### 2.3.2 CQA Manager

The CQA Manager will be employed independently from Lockwood and will report directly to the Project Engineer. The CQA Manager or a qualified designate of the Project Engineer, will be present on site at all times during construction activities. The CQA Manager will be responsible for auditing the activities of, and the supervision and management of the Construction Observers and the, Geotechnical and Geosynthetic QA Laboratories.

### 2.3.3 Construction Observers

The Construction Observers may be employed or retained directly by the Project Engineer or may be retained independently from the Project Engineer as a subcontractor by Lockwood and will report directly to the CQA Manager. The Construction Observers will be responsible for observing, testing, and documenting construction activities on a daily basis in accordance with this CQA/CQC Plan.

### 2.3.4 QA Surveyor

The QA Surveyor may be subcontracted by the Project Engineer or may be retained or provided independently by Lockwood and will report directly to the CQA Manager. Before any record survey work begins, the General or Geosynthetic Contractor must confirm that the prepared work is ready for the record survey and must formally request in writing that record survey measurements be obtained.

The QA Surveyor will be responsible for measuring the constructed dimensions of the facility components as described in this CQA/CQC Plan and as directed by the CQA Manager. The Project Engineer will be responsible to ensure that the measurements are checked against the project requirements and will be responsible for the accurate preparation of the Record Drawings. Given the nature of layered soil and geosynthetic containment system construction; specifically, the difficulty of predicting the timeframes that elements required to be located for the purpose of Record Drawing preparation will be covered and unavailable for location purposes, the Project

Engineer may review and utilize as appropriate QC survey data obtained by the construction survey crew in preparing the Record Drawings. The Project Engineer will be responsible to evaluate the QC survey data, verify its accuracy and the integrity of all data used in the preparation of the Record Drawings. The Project Engineer will be responsible to sign and stamp the Record Drawings for inclusion with the Certification Report.

## 2.4 CQA/CQC LABORATORIES

### 2.4.1 Geotechnical Quality Control Laboratory

The Geotechnical QC laboratory will be responsible for performing all soil related QC testing, as required by this plan or as directed by the General Contractor or the Project Engineer. The services of the Geotechnical QC Laboratory, which must meet the requirements set forth in this CQA/CQC Plan, may be secured by the General Contractor or the Project Engineer to complete the testing requirements presented in this plan.

### 2.4.2 Geosynthetic Quality Control Laboratory

The Geosynthetic QC laboratory will be responsible for performing all geosynthetic related QC testing, as required by this plan or as directed by the Geosynthetics Contractor or the Project Engineer. The services of the Geosynthetic CQC Laboratory, which must meet the requirements set forth in this CQA/CQC plan, will be secured by the geosynthetic material manufacturers or the Geosynthetics Contractor to complete the testing requirements presented in this plan. The Geosynthetic QC laboratories may be affiliated with the Geosynthetics Contractor or the material supplier; alternatively, the laboratory may be secured by the Project Engineer to complete the testing requirements presented in this plan.

### 2.4.3 Geotechnical and Geosynthetic Quality Assurance Laboratories

The services of Geotechnical and Geosynthetic Construction Quality Assurance Laboratories will be secured by the Project Engineer to complete the QA testing requirements presented in this CQA/CQC Plan. The selection of the QA Laboratories shall be based on a review of the laboratory's quality assurance manual that describes operating procedures, training requirements, calibration and maintenance procedures, corrective measure protocols and personnel resumes.

The QA Laboratories may be affiliated with the Project Engineer or may be subcontracted by the Project Engineer. If the services of the Geotechnical QA Laboratory are subcontracted, the laboratory will be independent of Lockwood, the General Contractor, Subcontractor, or material suppliers. If the services of the Geosynthetic QA Laboratory are subcontracted, the laboratory will be independent of Lockwood, the manufacturer, fabricator, or installer of geosynthetics at the site.

The Geotechnical and Geosynthetic QA Laboratories will complete the required testing as directed by the Project Engineer.

# 3 PERSONNEL QUALIFICATIONS AND RESPONSIBILITIES

The pertinent qualifications, experience requirements and responsibilities of each member of the CQA/CQC group are presented below. All QA and QC laboratories must provide evidence of the required certifications and equipment calibrations to the Project Engineer for review and approval.

## 3.1 PROJECT ENGINEER

### 3.1.1 Qualifications and Experience

The Project Engineer must be a Professional Engineer registered in the State of New York. The Project Engineer must demonstrate past experience in a position of significant responsibility for at least five landfill construction projects of similar or greater complexity to the Lockwood project. The Project Engineer must be knowledgeable of the project requirements and objectives, and must be familiar with the Construction Drawings, the CQA/CQC Plan, and the Technical Specifications. The Project Engineer will be capable of operating independently and without influence from the Contractors and the facility owner.

### 3.1.2 Responsibilities

The Project Engineer will have the following responsibilities in the implementation of the CQA/CQC Plan:

- Ultimate responsibility for the implementation of the CQA/CQC Plan;
- Ensure that appropriate technical review is completed by qualified representatives of the Project Engineer for the Construction Drawings, Technical Specifications, any modifications to the Drawings and Specifications, and the Construction Certification Report;
- Review all design documentation, including the Construction Drawings and Technical Specifications;
- Assist the CQA Manager in the review and interpretation of shop drawings and other submittals, field sampling and test results, and laboratory test results on a routine basis;

- Complete periodic site visits to review job quality, progress, and CQA/CQC activities; and
- Together with the CQA Manager, prepare the Construction Certification Report, and endorse it by affixing his/her NYS Professional Engineer stamp or seal to the document.

## 3.2 CQA MANAGER

### 3.2.1 Qualifications and Experience

The CQA Manager shall be employed or retained by the Project Engineer and must have previous experience on at least three landfill construction projects of similar or greater complexity to the Lockwood project or previous experience on at least one similar construction project combined with experience in managing other quality assurance programs for civil construction projects as approved by the NYSDEC. The CQA Manager must have a working knowledge of the quality assurance and quality control testing procedures included in this CQA/CQC Plan. The CQA Manager must have a thorough familiarity with the project, the Construction Drawings, the CQA/CQC Plan, and the Technical Specifications.

### 3.2.2 Responsibilities

The CQA Manager will have the following responsibilities in the implementation of the CQA/CQC Plan:

- Serve as the primary contact person for the Project Engineer. Maintain contact with Lockwood, the Contractors, and Subcontractors regarding conformance with the requirements of this Plan;
- Review of shop drawings and other submittals from the Contractors and Subcontractors for conformance with the Construction Drawings and the Technical Specifications, taking appropriate actions based on that review;
- Forward requests for any proposed modifications of the Construction Drawings, Technical Specifications, and/or CQA/CQC Plan requirements to the Project Engineer;

- Provide coordination of the activities of the Construction Observers and overall supervision of construction observers at all times;
- Monitor delivery of appropriate samples to the CQA laboratories for quality assurance testing;
- Coordinate with the Project Engineer to establish sampling procedures including proper sample location, sample size, sample collection protocol and sample numbering system;
- Provide assistance to the Construction Observers in the review and interpretation of field and CQA/CQC laboratory testing results on a routine basis. Receive and organize all quality assurance and quality control sampling and test results and check for compliance with specifications. Review test results with the Project Engineer to make determination of areas to be reworked or repaired and notify the Contractor involved and Construction Observers of results;
- Ensure the Construction Observers are informed of any noted deficiencies in quality assurance testing results or procedures so that corrective actions can be taken;
- Review all Daily Construction Reports prepared by the Construction Observers;
- Forward requests for any proposed design modifications to the Project Engineer;
- Organize all field quality assurance and quality control data for the purposes of preparing a weekly data summary as described in this CQA/CQC Plan; and
- Compile the Construction Certification Report with the assistance of the Geotechnical and Geosynthetic Construction Observers.

## 3.3 CONSTRUCTION OBSERVER

### 3.3.1 Qualifications and Experience

The Construction Observers may be subcontractors retained by Lockwood directly, or may be employed by the Project Engineer, and will report directly to the CQA Manager. The experience levels of the Construction Observers must be approved by the Project Engineer. Through a combination of formal education and experience, the Construction Observer must have at a

minimum; demonstrated knowledge of environmental construction projects including manufacturing, installation, and testing methods for geosynthetics.

### 3.3.2 Responsibilities

The Construction Observers will have the following responsibilities in the implementation of the CQA/CQC Plan:

- Observe and record procedures used for site preparation, clearing and grubbing;
- Observe and record procedures used for excavating and filling of subgrade to required elevations;
- Visually observe construction materials such as geomembranes, geotextiles, and geocomposite drainage layer delivered to the site to determine and document conformance with the material specifications;
- Visually observe construction materials such as soils and piping delivered to the site to determine and document conformance with material specifications;
- Observe and record condition of subgrade prior to placement of all geomembranes;
- Observe and record procedures for stockpiling, storage, and handling of geosynthetic materials, soil, and piping materials delivered to the site;
- Observe and record procedures used for installation of geomembranes;
- Visually observe all geosynthetics after installation for compliance with the requirements of this CQA/CQC Plan;
- Observe and record procedures used for the installation of manholes and appurtenances;
- Observe and record procedures used for installation of all piping systems;
- Observe and record procedures used for installation of all liner penetrations;
- Conduct final inspection of subgrade before any geosynthetics are placed;
- Observe and record procedures used for proof-rolling subgrade;

- Conduct final inspection of geomembranes immediately prior to placement of cover materials;
- Observe that panel placement is in accordance with the approved panel plan;
- Observe that permanent and temporary anchoring procedures are followed;
- Observe and record procedures used for seaming. Observe and record that the area of seam is clean, supported, and overlap and seam widths are in accordance with this CQA/CQC Plan;
- Observe and record that all required field-seaming tests are performed. Observe and record that all areas with deficient seams are marked for repair;
- Observe and record procedures used for all repairs;
- Assign locations and obtain samples for quality assurance testing;
- Provide for delivery of quality assurance samples to the CQA Laboratory or the CQA Manager;
- Record any onsite activities that could result in damage to geomembranes or other geosynthetics, and report these activities to the Contractors, Subcontractor, and the CQA Manager;
- Record any onsite activities that could result in damage to any earthwork or site improvements, such as compacted subgrade, low permeability soils, or geosynthetic reinforcement, and report these activities to the Contractors, Subcontractors and the CQA Manager, and
- Prepare Daily Construction Reports as described in this CQA/CQC Plan.

## 3.4 GENERAL CONTRACTOR

### 3.4.1 Qualifications and Experience

The General Contractor must have previous experience in the preparation of subgrade, placement of soil above geosynthetic materials on a 3:1 slope, placement of low permeability soil liners,

structural fills and drainage systems. The field supervisor must have as a minimum, successful experience on at least 50 acres of similar types of construction.

### 3.4.2 Responsibilities

The General Contractor will have the following responsibilities in the implementation of the CQA/CQC Plan:

- Receive and stockpile all materials required for the project prior to construction;
- Site preparation including but not limited to; excavation, grubbing and clearing, grading, compaction of soils and proof-rolling;
- Managing stormwater; trenching, installing piping and pumping systems as well as manholes; and
- Communicating closely with the CQA Manager to ensure that construction is in accordance with this CQA/CQC Manual and all technical specifications.

## 3.5 GEOSYNTHETICS CONTRACTOR

### 3.5.1 Qualifications and Experience

The General Contractor will subcontract the Geosynthetics Contractor. The Geosynthetics Contractor must have previous experience in the installation of geosynthetic liner systems. The field crew foreman must have a documented minimum qualification of successful installation experience on at least 50 acres of comparable geosynthetic system construction from a minimum of five different projects. Geomembrane seaming personnel must have a documented minimum qualification of successful installation experience on at least 30 acres of landfill or comparable geomembrane liner system construction.

# 4 CQA/CQC LABORATORIES

## 4.1 GEOTECHNICAL CQA/CQC LABORATORIES

The Geotechnical CQA/CQC Laboratories must have experience in testing low permeability soil, granular fills and aggregates, and be familiar with ASTM test standards, as required in this CQA/CQC Plan. The Geotechnical CQA/CQC laboratories must submit an acceptable Quality Assurance Plan to the Project Engineer to demonstrate that the laboratory has the capability to complete the quality control testing required in this CQA/CQC Plan. The Quality Assurance Plan shall include certification and calibration information pertaining to equipment to be utilized in the testing.

The Geotechnical CQA/CQC Laboratories are responsible for performing all tests and formally submitting results to the Project Engineer as required in this CQA/CQC Plan.

## 4.2 GEOSYNTHETIC CQA/CQC LABORATORIES

The Geosynthetic CQA/CQC Laboratories must have experience in testing geosynthetics, and must conform to ASTM, GRI and other applicable test standards. The Geosynthetic CQA/CQC laboratories must submit an acceptable Quality Assurance Plan to the Project Engineer to demonstrate that the laboratory has the capability to complete the testing required in this CQA/CQC Plan. The Quality Assurance Plan shall include certification and calibration information pertaining to equipment to be utilized in the testing.

The Geosynthetic CQA/CQC Laboratories are responsible for performing all test procedures in accordance with this CQA/CQC Plan and formally submitting results to the Project Engineer.

# 5 CQA/CQC PROTOCOLS

## 5.1 GENERAL

The testing protocols to be used during construction are presented on the following pages. The protocols address the following elements of construction:

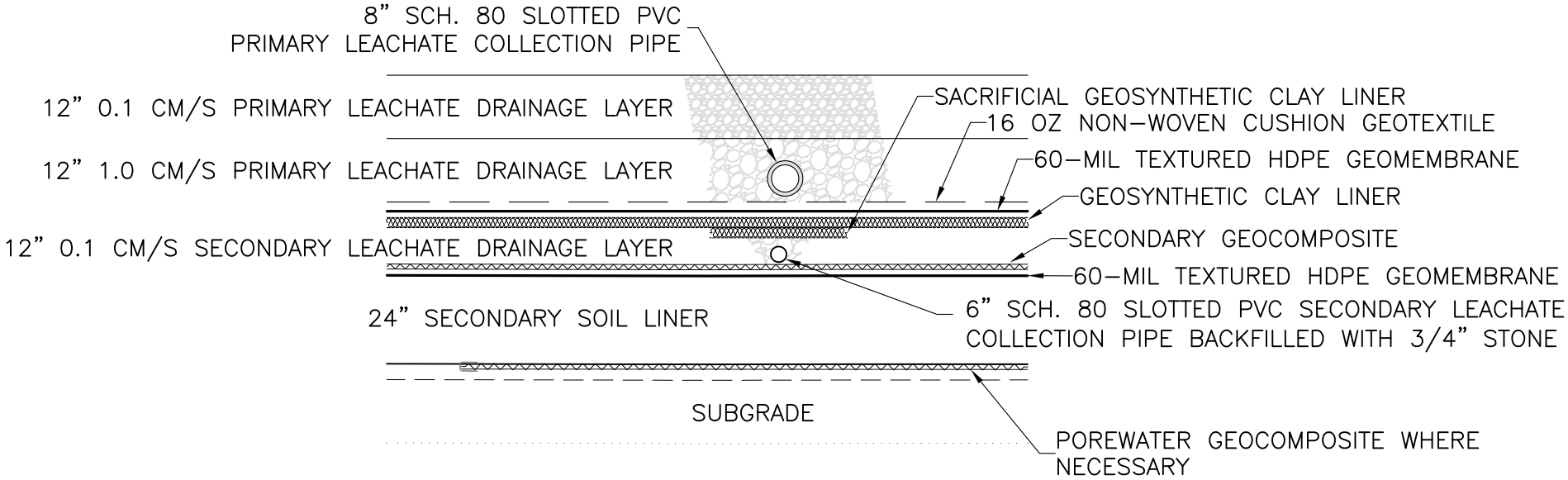
- Earthwork;
- Geosynthetics; and
- Piping.

When applicable, the protocols describe the following testing requirements for each of the elements of construction:

- Field testing procedures to be used;
- Field testing equipment to be used;
- Frequency of field testing;
- Sampling procedures to be used;
- Sampling equipment to be used;
- Frequency of sampling for laboratory testing;
- Acceptable limits for field and laboratory testing results; and
- Calibration of field-testing equipment.

A majority of the requirements presented herein address the construction of the baseliner and final cover systems. The baseliner system, as shown on Figure 5-1, consists of the following components in ascending order:

- A porewater geocomposite where necessary (Stage IV) above the subgrade;
- A two-foot thick compacted secondary soil liner;
- A 60-mil secondary textured high-density polyethylene (HDPE) geomembrane liner;

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| LOCKWOOD HILLS LLC | | BASELINER SYSTEM | | | FIGURE 5-1 |
|---|---|---|---|---|---|
| SCALE: NTS | REVISION # 0 | CQA/CQC PLAN | | | |
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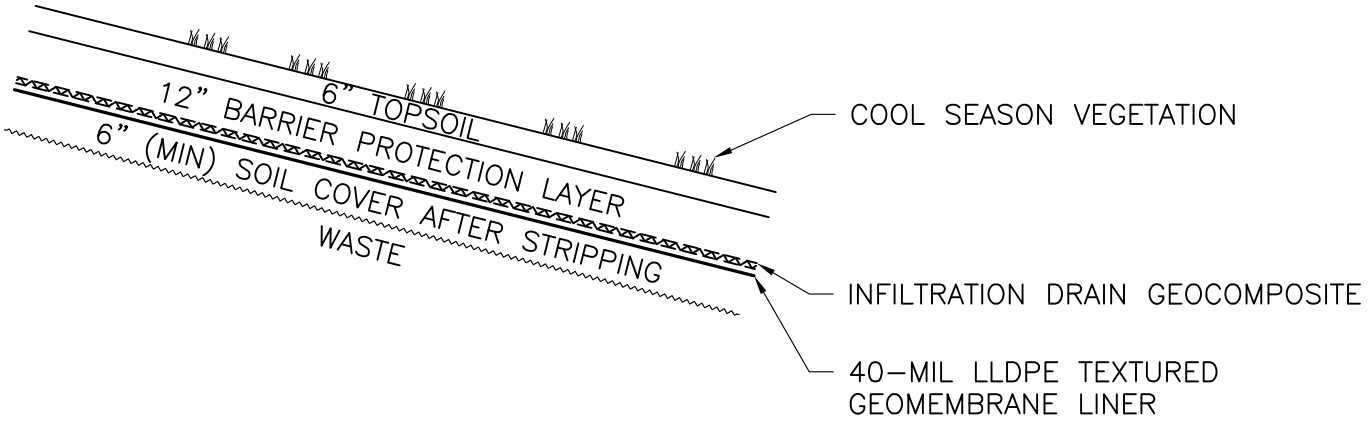
- A secondary geocomposite;
- A one-foot thick secondary soil leachate drainage layer including a leachate collection pipe network;
- A geosynthetic clay liner (GCL);
- A 60-mil primary textured HDPE geomembrane liner;
- A 16-oz non-woven cushion geotextile;
- A one-foot thick primary leachate drainage layer with a minimum hydraulic conductivity of 1.0 cm/s, including a primary leachate collection pipe network; and
- A one-foot thick primary leachate drainage layer with a minimum hydraulic conductivity of 0.1 cm/s.

The final cover system, as shown on Figure 5-2 consists of the following components in ascending order:

- 6-inch thick minimum prepared soil layer after stripping existing Intermediate Soil Cover;
- GCL for slopes less than 25%;
- Nominal 40-mil textured Linear Low-Density Polyethylene (LLDPE) Geomembrane;
- Geocomposite Infiltration Drainage Layer;
- 12-inch thick (minimum) Barrier Protection Soil Layer; and
- 6-inch thick (minimum) Topsoil Layer, seeded with Cool Season Vegetation.

The exposed geomembrane cover system, as shown on Figure 5-3 consists of the following components in ascending order:

- 6-inch thick minimum prepared soil layer after stripping Intermediate Soil Cover;
- Geosynthetic Clay Liner for slopes less than 25% (optional); and
- Reinforced LLDPE Geomembrane.




## FINAL COVER SYSTEM (SLOPES >25%)

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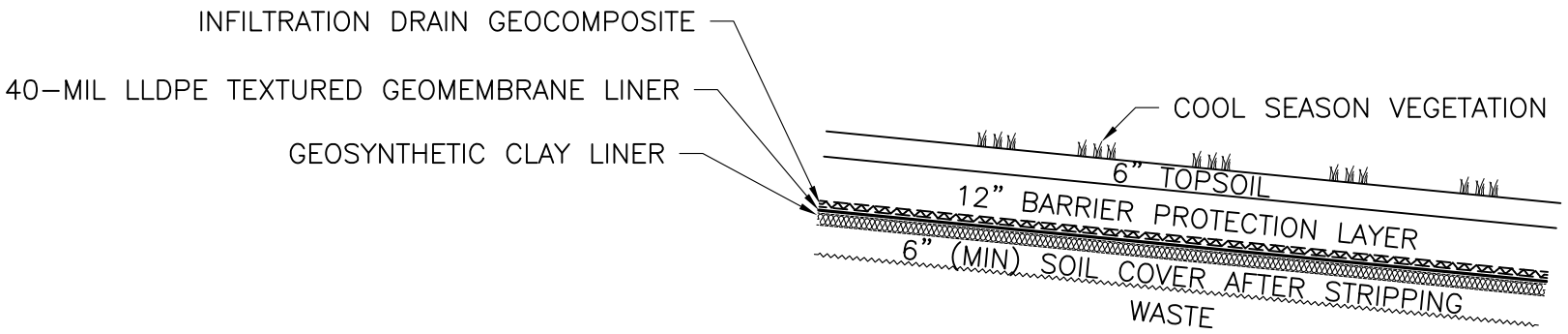


## FINAL COVER SYSTEM (SLOPES <25%)

NOT TO SCALE

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| LOCKWOOD HILLS LLC | | FINAL COVER SYSTEM CQA/CQC PLAN | | | FIGURE 5-2 |
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| SCALE: NTS | REVISION # 0 | | | | |
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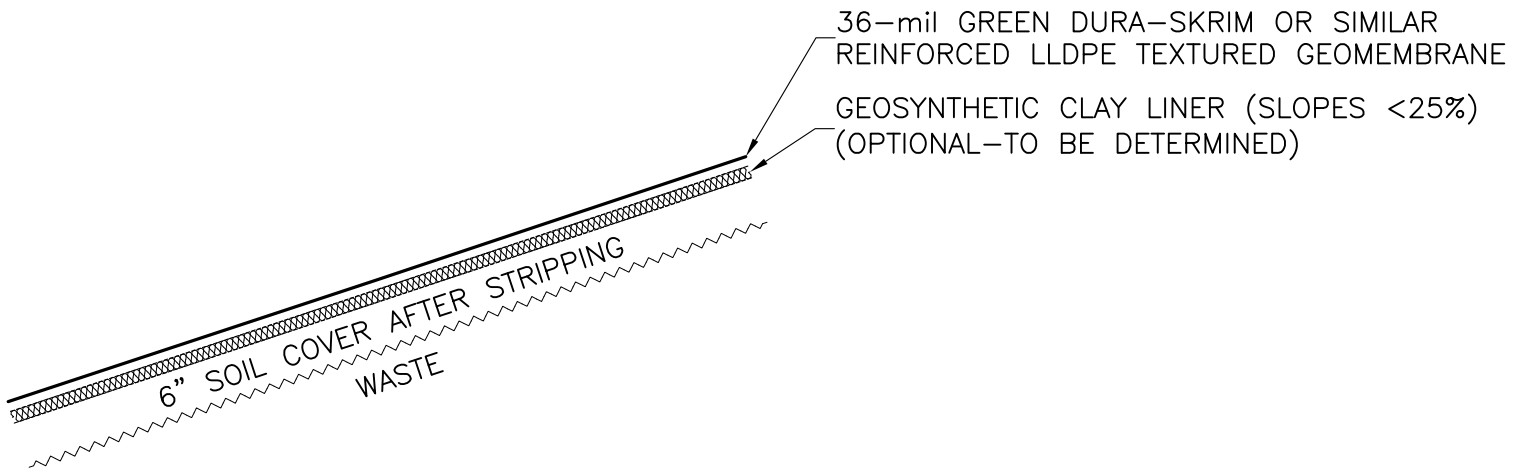


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| LOCKWOOD HILLS LLC | | EXPOSED GEOMEMBRANE SYSTEM | | FIGURE 5-3 |
|---|---|---|---|---|
| SCALE: NTS | REVISION # 0 | CQA/CQC PLAN | | |
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## 5.2 RECORD SURVEY REQUIREMENTS

Certain slope, elevation, and thickness tolerances will be adhered to during construction to help ensure the performance requirements of the containment systems are met. These tolerances are described in the Construction Stakeout, Tolerance and Record Survey Requirements summary included as Appendix C. This information will be plotted on a continuous basis as time allows during the course of the work. Due to the nature of the record survey task (i.e., construction progress, dependent scheduling, and data reduction time allowance), it is not appropriate to specify exact timeframes for final plotting of data points. The primary goal for the record survey effort is to obtain an optimum number of measurements and to ensure the design grades of the facility are obtained and plotted on a continuing basis

## 5.3 CHANGES TO APPROVED DOCUMENTS

A Field Change Log shall be maintained onsite during construction to record proposed field changes. Substantive changes from the approved documents must be approved by the Project Engineer. and will be incorporated into the Field Change Log. Upon completion of the project the Field Change Log will become part of the Construction Certification Report.

## 5.4 PERFORMANCE TESTING

### 5.4.1 Interface Shear

Prior to geosynthetic material shipment to the site, geosynthetic and soil samples must have been selected and sent out to the approved Geosynthetic Quality Assurance Laboratory for interface shear strength testing. An example of the interface shear testing protocol for the liner materials is provided in Appendix D. The interface shear strength requirements shall be determined during the design of each construction phase. The CQA Manager will examine all results from laboratory testing. No non-conforming material will be used in the work unless it is demonstrated to the NYSDEC that any non-compliant test result will not affect the long-term performance of the liner system.

### 5.4.2 Transmissivity

A single geocomposite transmissivity test must be conducted for each geocomposite material to confirm the required design transmissivity is met. An example of the transmissivity testing protocol is provided in Appendix D. The CQA Manager will examine all results from laboratory testing. No non-conforming material will be used in the work unless it is demonstrated to the NYSDEC that any non-compliant test result will not affect the long-term performance of the final cover or baseliner system.

## 5.5 Soil QA/QC

### 5.5.1 Test Method Reference

Test methods for all soil materials are in accordance with procedures developed by the American Society of Testing and Materials (ASTM). Table 5-1 lists those tests that may be required in the course of this project and the accepted test method reference. Substitution of a method other than that specified in Table 5-1 for a particular test is subject to the approval of the Project Engineer. Also, the use of test methods for those tests not listed in Table 5-1 that are deemed necessary for the work are subject to the approval of the Project Engineer.

**TABLE 5-1: ACCEPTED REFERENCES FOR TESTING OF SOILS**

| Test | Reference |
|---|---|
| Standard Test Method for Particle-Size Analysis of Soils | ASTM D-422 |
| Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis | ASTM D-6913 |
| Standard Test Methods for Amount of Material in Soils Finer than the No. 200 (75-m) Sieve | ASTM D-1140 |
| Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft$^3$ (2,700 kN-m/m$^3$)) | ASTM D-1557 |
| Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock By Mass | ASTM D-2216 |
| Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter | ASTM D-5084 |
| Standard Test Method for Permeability of Granular Soils | ASTM D2434 |

| | |
|---|---|
| Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) | ASTM D-2487 |
| Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth) | ASTM D-6938 |
| Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index of Soils | ASTM D-4318 |
| Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils | ASTM D2974 |
| Standard Test Methods for Pore Water Extraction and Determination of the Soluble Salt Content of Soils by Refractometer | ASTM D4542 |
| Standard Test Methods for pH of Soils | ASTM D4972 |
| Standard Test Method for Total Nitrogen in Organic Materials by Modified Kjeldahl Method | ASTM E258 |
| Constant Head Permeability Test (in Triaxial Cell with Back Pressure Saturation – Low Permeability Soils) | EM-1110-2-1906 |

### 5.5.2 Inspection of Work

Evaluation of soil placement consists primarily of observation of the quality of workmanship and soil materials used in performance of the work, observation of lift thickness, investigations into the adequacy of layer bonding as well as field sampling and testing.

All field and laboratory tests will be conducted on soils included in the actual construction product. The soil fills will be placed to the final thickness indicated on the Construction Drawings, as a minimum.

Evaluation of geosynthetic installation consists of observing the quality of workmanship and materials used, and field sampling and testing of the geomembrane liner, as well as the quality and workmanship and materials used of the geocomposite porewater drain. All field and laboratory tests will be conducted on geosynthetic materials included in the construction of the containment liner systems.

Any preconstruction testing data will be obtained by testing soils from stockpiles or sources to be utilized in the construction. The preconstruction testing data will be reviewed and approved by

the Project Engineer. When obvious changes in soil character are observed, the variation in soil properties may be determined by additional testing as required by the Project Engineer.

Inspection of the work will include some or all of the following depending on the level of testing required for each specific soil layer.

- Measurement of the moisture content and dry density of the Structural Fill compacted soil by nuclear density/moisture gauge per the requirements Section 02224 of the Technical Specifications;
- Observation of the effects of the compaction and heavy hauling equipment on the previously placed lifts (sheepsfoot penetration, pumping, cracking, etc.);
- Randomly observing the number of passes by compaction equipment used to compact soil lifts;
- Obtaining measurements of slope and finish grades to ensure tolerance and design requirements are met;
- Observing the subgrade to ensure that waste materials, organic and other undesirable soils are removed prior to final cover soil placement;
- Noting any changes in color or texture of soils along with the relative moisture content;
- Conducting routine in-place Shelby tube sampling;
- Sampling for constant head laboratory permeability tests;
- Inspecting the soils for the presence of roots, stumps, and large rocks; and
- Observation and documentation of the Contractor's operation.

### 5.5.3 Subgrade Preparation

The subgrade field QA/QC requirements are described in Section 02222 located in Appendix A. The General Contractor is responsible for subgrade preparation which consists of grading and proof-rolling the subgrade surface, and removing any unsuitable material as required. Once the General Contractor has prepared the subgrade to within the elevation and slope tolerance limits, a

Construction Observer will inspect and record the soil conditions. For baseliner subgrade nuclear moisture density measurements will be made at a minimum frequency of nine per acre.

A Construction Observer will observe and document proof rolling of the subgrade surface, using a smooth drum compactor in static mode, for the purpose of detecting unsuitable materials. Unsuitable materials are defined as excessively wet or soft soils that inhibit successful compaction of the overlying soil lifts or placement of geosynthetics. The reaction of the proof rolled surface will be observed as the compactor passes over the subgrade at walking speed. Permanent ruts or indentations that result in a breaking apart or significant cracking of the soil surface, or, that based on the judgment of the Construction Observer, may prevent the proper placement of overlying layers, will identify a failing area. The Construction Observer will establish the aerial extent of any unsuitable material and will determine the probable cause of the failing proof rolling results. The appropriate remedial actions will be taken; including but not necessarily limited to:

- Moisture adjustment (drying);
- Additional compaction;
- Surface water drainage or relief of excessive pore pressure by the extension of the subgrade surface drain system; or
- Removal and replacement of unsuitable soils.

In the event unsuitable materials are removed, they will be excavated and replaced with Structural Fill placed in accordance with Section 02224 of the Technical Specifications.

### 5.5.4 *Structural Fill*

Plain Embankment Structural fill shall be placed within baseliner embankments and subgrade over excavation areas. The Structural Fill material properties, installation, and field QA/QC are included in Specification 02224 located in Appendix A.

Initial sampling of the Structural Fill sources will include procurement of bulk samples for testing in accordance with Table 5-2. These samples will be subject to grain size distribution, as-received moisture content, Atterberg limits, and modified Proctor. The portion of the sample targeted for moisture content determination will be shipped in a moisture tight container. All preconstruction

testing data will be obtained by testing soils from stockpiles or sources to be utilized in the construction of the project at hand. The data will be reviewed by the Project Engineer prior to the commencement of Structural Fill construction activities.

**TABLE 5-2: STRUCTURAL FILL TESTING FREQUENCIES**

| Test | Frequency |
|---|---|
| 1. Moisture Content | 1 per 15,000 ccy of material or every change in source |
| 2. Grain Size Distribution | 1 per 15,000 ccy of material or every change in source |
| 3. Atterberg Limits | 1 per 15,000 ccy of material or every change in source |
| 4. Modified Proctor | 1 per 15,000 ccy of material or every change in source |

### 5.5.5 Secondary Soil Liner

The Secondary Soil Liner (SSL) consists of a 24-inch thick low permeability soil liner with an in-place permeability of 1 x $10^{-7}$ cm/sec or less placed above the baseliner subgrade. The SSL material properties, installation, and field QA/QC are included in Specification 02276, located in Appendix A. The SSL installation shall first be evaluated by constructing a test pad as required by Specification 02277, located in Appendix A.

Initial sampling of the SSL sources will include procurement of bulk samples for testing in accordance with Table 5-3. These samples will be subject to grain size distribution, as-received moisture content, Atterberg limits, modified Proctor, and recompacted permeability. The portion of the sample targeted for moisture content determination will be shipped in a moisture tight container. All pre-construction testing data will be obtained by testing soils from stockpiles or sources to be utilized in the construction of the project at hand. The data will be reviewed by the Project Engineer prior to the commencement of SSL construction activities and will be used to draft a moisture density/permeability window.

**TABLE 5-3: MINIMUM CONSTRUCTION TESTING FREQUENCY FOR SSL**

| Test | Frequency | |
|---|---|---|
| | Pre-Use | During Construction |
| Grain Size Distribution | 1 per 10,000 ccy | As required for 1 per 2,500 ccy total |
| Atterberg Limits | 1 per 4,000 ccy | As required for 1 per 1,000 ccy total |
| Laboratory Recompacted Permeability | 1 per 5,000 ccy | When material change occurs |
| Moisture-Density Relationship | 1 per 5,000 ccy | When material change occurs |
| Moisture Content | 1 per 4,000 ccy | As required for 1 per 1,000 ccy total |
| Moisture-Density with Nuclear Densometer | ---- | 9 per acre per lift |
| Laboratory Permeability on undisturbed sample from liner system | ---- | 1 per acre per lift |

During construction sampling and testing of the in-place SSL will be conducted in accordance with Table 5-3. Undisturbed Shelby tube samples will be collected and be tested for grain size distribution, as-received moisture content, Atterberg limits, and undisturbed permeability. In addition, in-place nuclear moisture density measurements will be conducted at a frequency of nine per acre per lift and be compared to the moisture density/permeability window to confirm the required permeability is met.

## 5.5.6 Leachate Collection and Removal System Drainage Layers

### 5.5.6.1 Secondary Drainage Layer

The secondary soil drainage layer is placed between the primary and secondary geomembrane liners on slopes less than 10 percent. The drainage layer is one foot thick with a minimum hydraulic conductivity of 0.1 cm/sec. The secondary drainage layer material properties, installation, and field QA/QC are included in Specification 02241 located in Appendix A.

The QA/QC testing will be performed as detailed in Table 5-4. The Secondary soil drainage layer will be sampled and tested for grain size and permeability.

**TABLE 5-4: MINIMUM CONSTRUCTION TESTING FREQUENCY FOR THE SECONDARY SOIL DRAINAGE LAYER**

| Test | Frequency | |
|---|---|---|
| | Pre-Use | During Construction |
| 1. Particle-Size Analysis | 1 per source | 1 per 1,000 cy total |
| 2. Laboratory Permeability | 1 per 2,500 cy | 1 per 2,500 cy total |

#### 5.5.6.2 Primary Drainage Layer

The primary drainage layer is the uppermost layer of the baseliner system and has a total thickness of 24 inches. The upper 12-inches of the primary layer may have a minimum permeability of 0.1 cm/sec if the lower 12-inches has a permeability of at least 1.0 cm/sec. On slopes greater than 10 percent, the entire layer will have a minimum hydraulic conductivity of 0.1 cm/sec. The primary layer material properties, installation, and field QA/QC are included in Specification 02240 located in Appendix A

The QA/QC testing for the primary drainage layer will be conducting at the frequencies indicated in Table 5-5. The primary drainage layer will be sampled and tested for grain size and permeability.

**TABLE 5-5: MINIMUM CONSTRUCTION TESTING FREQUENCY FOR THE PRIMARY DRAINAGE LAYER**

| Test | Frequency | |
|---|---|---|
| | Pre-Use | During Construction |
| 1. Particle-Size Analysis | 1 per source cy | 1 per 1,000 cy total |
| 2. Laboratory Permeability | 1 per 2,500 cy | 1 per 2,500 cy total |

### 5.5.7 Barrier Protection Soil Layer and Low Permeability Backfill

The Barrier Protection Soil Layer, including any drainage layer, must consist of a minimum of 12 inches of soil where cool season vegetation is specified. The Barrier Protection Soil Layer must protect the geomembrane barrier layer from root penetration, be stable for the specified slopes and

resist erosion. The Barrier Protection Soil Layer material properties, installation, and field QA/QC are included in Specification 02228 located in Appendix A.

Low Permeability Backfill is placed near the limit of waste above the final cover and baseliner geosynthetics termination. Any geosynthetic anchor trenches used in the construction will be backfilled or covered with Low Permeability Backfill. The Low Permeability Backfill material properties, installation, and field QA/QC are included in Specification 02226 located in Appendix A.

Initial sampling of the Barrier Protection and Low Permeability Backfill soil sources will include procurement of bulk samples for testing in accordance with the methods in Table 5-1. Each sample of the prospective material collected for laboratory analysis will be approximately 50 pounds. These samples will be subject to Atterberg limit determination, grain size distribution, and as-received moisture content. The portion of the sample targeted for moisture content determination will be shipped in a moisture tight container. All preconstruction testing data will be obtained by testing soils from stockpiles or sources to be utilized in the construction of the project at hand. The data will be reviewed by the Project Engineer prior to the commencement of Barrier Protection Soil Layer and Low Permeability Backfill construction activities. The QA/QC testing for the Barrier Protection Soil Layer and Low Permeability Backfill will be conducted at the frequencies indicated in Table 5-6.

**TABLE 5-6: MINIMUM BARRIER PROTECTION SOIL LAYER AND LOW PERMEABILITY BACKFILL CONSTRUCTION TESTING FREQUENCY**

| Test | Frequency |
|---|---|
| 1. Moisture Content | 1 per 15,000 ccy of material or every change in source |
| 2. Grain Size Distribution | 1 per 15,000 ccy of material or every change in source |
| 3. Atterberg Limits | 1 per 15,000 ccy of material or every change in source |

### 5.5.8 *Topsoil and Seeding*

A minimum six-inch Topsoil layer shall be placed above the Barrier Protection Soil Layer. The Topsoil layer must be suitable to maintain cool season vegetative growth. The Topsoil layer

material properties, installation, and field QA/QC are included in Specification 02235 (Soil Suitable for Vegetative Growth) located in Appendix A.

Initial sampling of the Topsoil sources will include procurement of bulk samples for testing in accordance with the methods listed in Table 5-1. These samples will be subject to grain size distribution, as-received moisture content, and one sample per source shall be tested for pH, and the percentage of nitrogen and phosphorus, potash soluble salt content, and organic matter content. The portion of the sample targeted for moisture content determination will be shipped in a moisture tight container. All preconstruction testing data will be obtained by testing soils from stockpiles or sources to be utilized in the construction of the project at hand. The data will be reviewed by the Project Engineer prior to the commencement of Topsoil layer construction activities. The QA/QC testing for the Topsoil layer will be conducted at the frequencies indicated in Table 5-7.

**TABLE 5-7: MINIMUM TOPSOIL LAYER CONSTRUCTION TESTING FREQUENCY**

| Test | Frequency |
|---|---|
| 1. Moisture Content | 1 per 15,000 ccy of material or every change in source |
| 2. Grain Size Distribution | 1 per 15,000 ccy of material or every change in source |
| 3. pH, conductivity, and organic matter content | 1 per source |

The Topsoil layer shall be seeded with cool season vegetation which is defined as vegetation that grows well in areas of the USA that experience extreme temperature fluctuations characterized by cold, freezing winters and hot, dry summers. The seeding material properties, installation, and field QA/QC are included in Specification 02936 located in Appendix A. Seed Mixture Type 2 and Type 3 are specified for permanent slope vegetation, while Type 4 is specified for the drainage swales and channels. These seed mixtures are comprised of appropriate cool season grasses which germinate and grow in cooler climates.

## 5.6 GEOSYNTHETIC QA/QC

### 5.6.1 Geomembrane Liners

The geomembrane liner will be installed to the lines and grades, as indicated on the Construction Drawings. Pass/fail criteria for geomembrane seam destructive test results will be in accordance with ASTM D6392 - Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods, and GRI GM19 - Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes. Copies of both standards are provided in Appendix B.

#### 5.6.1.1 Baseliner

The primary and secondary textured HDPE geomembrane in the baseliner system shall have a nominal thickness of 60 mil. The requirements for QA/QC of the manufacturing, transport, and installation of the HDPE geomembrane is included are Specification 02597, located in Appendix A. An Electrical Leak Location Survey shall be conducted on both the primary and secondary geomembrane per ASTM 7007 included in Appendix E.

#### 5.6.1.2 Final Cover and Exposed Geomembrane System

A textured 40-mil (nominal) LLDPE geomembrane liner shall be installed as part of the final cover system. A textured reinforced LLDPE geomembrane liner shall be installed for the exposed geomembrane cover system. The requirements for QA/QC of the manufacturing, transport, and installation of the LLDPE geomembrane are included in Specification 02781, located in Appendix A.

### 5.6.2 Geocomposites

The geocomposite will consist of an HDPE geonet with non-woven geotextiles heat-bonded to each side of the geonet. The material properties of the geocomposite will meet the requirements for QA/QC of the manufacturing, transport, and installation of the geocomposite are included in Specification 02599, located in Appendix A.

#### 5.6.2.1 Baseliner

A geocomposite drainage layer is included in the porewater collection system, and in the secondary leachate collection and removal system.

#### 5.6.2.2 Final Cover

A geocomposite shall be installed for the infiltration drainage layer in the final cover system. The geocomposite will be installed to the lines and grades, as indicated on the approved construction drawings.

### 5.6.3 Geotextiles

Geotextile shall consist of non-woven needle punched geotextile, and be installed, as indicated on the approved construction drawings. The requirements for QA/QC of the manufacturing, transport, and installation of the geotextile are included in Specification 02595, located in Appendix A.

#### 5.6.3.1 Baseliner

A 16-oz cushion geotextile will be used to protect the HDPE primary geomembrane liner from the primary drainage layer material. A 10-oz separation geotextile is specified for portions of the baseliner system to provide separation between fine grained soils and aggregate/geosynthetic drainage materials.

### 5.6.4 Geosynthetic Clay Liner

The GCL consists of a factory manufactured clay liner of a low permeability soil material supported by geotextiles which are held together by gluing, needling, or stitching. The requirements for QA/QC of the manufacturing, transport, and installation of the GCL are included in Specification 02278 located in Appendix A.

#### 5.6.4.1 Baseliner

A GCL will be installed below the primary geomembrane on slopes less than 10%. Additionally, a sacrificial strip of GCL is placed immediately below the GCL layer in alignment with the leachate collection pipe network.

#### 5.6.4.2 Final Cover and Exposed Geomembrane System

A GCL will be installed below the 40-mil LLDPE geomembrane liner on slopes less than 25%. A GCL may be installed below the reinforced LLDPE geomembrane on slopes less than 25%, as well.

## 5.7 PIPING SYSTEMS, MANHOLES, AND APPURTENANCES

The piping will be installed in accordance with the approved Construction Drawings and the Technical Specifications. All piping will be installed to the lines and grades specified on the Construction Drawings.

The piping and piping systems will be installed according to the procedures and requirements included in Section 02660 of the Technical Specifications for Polyethylene Pipes and Section 02650 of the Technical Specifications for PVC Pipes, located in Appendix A. The pipe will be placed on the minimum select stone bedding type and thickness and backfilled as required by the Construction Drawings. For piping outside the liner system, the technical specifications for the Bedding and Backfill, Coarse Sand and Common Trench Backfill are Section 02233, Section 02232, and Section 02223 respectively, located in Appendix A. Rock lined outlet protection for the stormwater system culverts and pipe down chutes shall be installed according to the approved construction drawings.

## 5.8 GROUNDWATER MONITORING WELL SPECIFICATIONS

The groundwater monitoring wells will be decommissioned, installed, and developed according to the specifications listed in Appendix F.

# 6 DOCUMENTATION AND RECORDKEEPING

Records of construction progress and quality assurance/quality control activities will be maintained throughout the construction of the landfill and related facilities. The following reports will be prepared:

- Daily Construction Report;
- Weekly Construction Data Summary Report, and
- Construction Certification Report.

## 6.1 DAILY CONSTRUCTION REPORT

Daily Construction Reports will be prepared by the Geotechnical Construction Observer and Geosynthetic Construction Observers at the conclusion of every day construction activities occur at the site.

The Daily Construction Reports will include the following:

- Date;
- Weather conditions, including daily high and low temperature, wind conditions, and precipitation, if any;
- General description of work activities at the site;
- List of personnel and equipment operating onsite, number of hours worked, number of hours on standby, and work activities completed. Include names of key CQA/CQC and construction personnel;
- Description of work completed for the day, referencing stationing and grid coordinates;
- Identification of areas worked including lift number, panel number, and seam number, etc.;
- Drawings, sketches, and maps showing work completed;
- Summary of CQA/CQC procedures used for the day;
- Results of all field testing performed;

- Drawings, sketches, and maps showing all field testing areas. Passing and failing areas of the soil liner, geomembrane panels and seams will be recorded;
- Reworked and repair areas will be recorded with all testing results;
- Identification of all samples collected for testing at the CQA/CQC laboratories, including sample number, location, and testing to be performed;
- Identify any field modifications; and
- Documentation of discussions, decisions or recommendations involving the Contractor (General or Geosynthetic), Subcontractors, Lockwood, NYSDEC, the Project Engineer and/or representatives thereof.

The Daily Construction Report will be submitted to the Project Engineer for review and inclusion in the project file.

## 6.2 WEEKLY CONSTRUCTION DATA SUMMARY REPORT

Weekly Construction Data Summary Reports will be prepared by the CQA Manager at the end of every working week. The weekly reports will summarize construction progress and testing based on the following:

- Daily Construction Reports for the work;
- Results from the geotechnical and geosynthetic CQA/CQC laboratories; and
- Shop drawings, and other submittals from the Contractor (General or Geosynthetic) and Subcontractors.

The Weekly Construction Data Summary Reports will include the following:

- General description of work activities completed at the site for the week;
- Specific description of work completed for the week, referencing stationing, and grid coordinates;
- Identification of areas worked for the week, including panel number and seam number;
- Drawings, sketches, and maps showing work completed for the week;

- Summary of CQA/CQC procedures used for the week;
- Summary of testing results for the week;
- Summary of reworked areas and repairs completed for the week;
- Identification of problems and corrective measures undertaken;
- Summary of shop drawings and submittals received from the Contractor (General or Geosynthetic) during the week, and disposition of same;
- Summary of results received from the Geotechnical and Geosynthetic CQA/CQC Laboratories during the week;
- Summary of field modifications; and
- A copy of the minutes of routine construction meetings for the week documenting the discussions and decisions; including any decisions and recommendations as a result of discussions with the Contractors, Subcontractors, Lockwood, NYSDEC, the Project Engineer, and/or representatives thereof.

The Weekly Construction Data Summary Report will be included in the project file.

## 6.3 CONSTRUCTION CERTIFICATION REPORTS

Upon completion of baseliner system and final cover construction activities and a final site inspection, a Construction Certification Report will be prepared under the direction of, and will be endorsed by, the Project Engineer who will be licensed to practice engineering in the State of New York. The report will be submitted to NYSDEC within 45 days after the completion of construction.

The Certification Report will document that construction was completed in accordance with Construction Drawings and Technical Specifications, with any exceptions noted. The Certification Report will include the following:

- Narrative description of the construction completed at the site;

- Description of any deviations from Construction Drawings and Technical Specifications and reasons for such changes;
- Description of testing procedures;
- Summary of test data;
- Drawings showing test locations;
- Descriptions of procedures used to correct deficiencies;
- As appropriate, raw data sheets and worksheets related to testing;
- Daily Construction Reports prepared by the CQA/CQC personnel;
- Record Drawings of the completed construction;
- Certification statement of completion of construction in accordance with the intent of the Construction Plans and Specifications, and
- A representative set of color photographs of the major project stages and features.

As part of the Construction Certification Report, record survey measurements will be obtained as identified in Section 5.2.

# APPENDIX A

# Technical Specifications

**Lockwood Hills LLC Construction**
**Technical Specifications**

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## Division 2 – Site Work

# SECTION 02222

# SUBGRADE

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools and appurtenances required to complete the work of subgrade preparation, including grading, proof-rolling, removal of unsuitable material (see Article 3.3 below for the definition of unsuitable material) as required and replacement with Structural Fill as specified in this Section and Section 02224.

B. The CONTRACTOR shall complete other related and incidental work within the designated area as required for the construction of work placed above the subgrade as shown, specified or required by other related Sections.

### 1.2 RELATED SECTIONS

A. Section 02224 - Structural Fill

B. Section 02276 – Soil Liner

C. Section 02595 - Geotextiles

D. Section 02597 – HDPE Geomembrane

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM)

1. ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

2. ASTM D6938 Standard Test Method for In-Place Density and Water Content of Soil And Soil-Aggregate by Nuclear Methods (Shallow Depth)

B. The most current version of the specified test method shall be followed by the EARTHWORK CONTRACTOR or authorized testing laboratory.

## 1.4 DEFINITIONS

A. Subgrade preparation shall consist of grading the surface as shown on the Drawings, proof-rolling the subgrade surface and removing any unsuitable material as required by the Specifications.

B. Structural fill placement shall consist of furnishing material and placing and compacting material where designated on the Drawings or as required by the Specifications.

## 1.5 PROTECTION OF PEOPLE AND PROPERTY

A. The Contractor shall ensure protection of people and property during construction activities.

# PART 2 PRODUCTS

## 2.1 MATERIALS GENERAL

A. Subgrade soils may consist of in-situ soils at the limit of excavation or structural fill as appropriate.

B. All structural fill materials shall conform to Section 02224 - Structural Fill. The structural fill material shall meet the approval of the PROJECT ENGINEER.

C. The maximum particle (stone) size shall be no larger than nine inches, or as restricted by Section 02597 in the case of geomembrane installation, or Section 02595 in the case of geotextile installation.

D. All subgrade and structural fill soil materials shall be substantially free from organic matter, wood, trash, and other objectionable materials which may be compressible or which cannot be properly compacted. It shall not contain blocks, broken concrete, masonry rubble, or other similar materials. It shall have physical properties such that it can be readily spread and compacted to the density required for the specified item. Snow, ice, and frozen soil shall not be permitted.

## 2.2 TESTING

A. The PROJECT ENGINEER shall obtain information on in-situ subgrade soils as required by Articles 3.2 and 3.3 of this Section.

B. The CONTRACTOR shall not proceed with placement of structural fill within subgrade over excavations until the PROJECT ENGINEER has approved the proposed material in accordance with Section 02224.

# PART 3 EXECUTION

## 3.1 PRECAUTIONS

A. Structural Fill placement shall not:

1. Be performed with or placed on frozen materials.

2. Be placed on snow that has a thickness greater than one tenth of an inch.

3. Be placed on ice. Ice shall be defined as frozen water on the surface of in situ soils or previously placed material.

B. Where the subgrade surface is to be covered by a geosynthetic layer, the subgrade must have a smooth surface to minimize the potential for damage to the adjacent geosynthetic layer, as described in the Section of the Technical Specifications addressing the subject geosynthetic (e.g. Section 02597 – HDPE Geomembrane).

## 3.2 FILLING AND COMPACTION OF SUBGRADE OVER EXCAVATIONS

**A.** Prior to placement of overlying soil or geosynthetic materials, the subgrade shall be proof-rolled to confirm the subgrade is suitable. Once the CQA Manager confirms that the Earthwork Contractor has graded the Subgrade surface to within the tolerance limits (Appendix D), a Geotechnical Construction Observer will inspect and record the soil conditions at the limit of the design. A Geotechnical Construction Observer will observe and document proof rolling of the Subgrade surface, using a compactor in static mode, for the purpose of detecting unsuitable materials. Excessively wet or soft soils will be determined present when permanent ruts or indentations in excess of one inch are observed, and the soils in that area will be considered unsuitable. Unsuitable soils that cannot be repaired to meet the project requirements shall be over-excavated and replaced with structural fill not to exceed two feet.

In the event softer soils are left in-place based on the judgment of the CQA Manager or Project Engineer, wheeled vehicle traffic and proof rolling will be excluded. It is recommended that the excavation be far enough in advance of porewater drain system construction such that a stiff crust can be developed through weathering/drying and adequate compaction of the secondary soil liner can be achievable.

Structural fill shall be brought uniformly to grade throughout the over-excavation area and compacted. The compacted thickness of each structural fill lift shall not exceed 1 foot, unless otherwise approved by the PROJECT ENGINEER. The moisture content of the structural fill material shall be such that proper compaction as defined by Section 02224 is readily obtained. The soils shall be placed and compacted in a manner that eliminates lift interfaces and prevents the formation of observable voids in the completed lifts as determined by the PROJECT ENGINEER.

B. Hand-operated plate type vibratory tampers or other suitable equipment as proposed by the CONTRACTOR and approved by the PROJECT ENGINEER must be used in areas not accessible to larger compactors. Structural fill shall be placed in maximum three-inch compacted lifts where hand-tamper equipment is used.

## 3.3 FIELD QUALITY ASSURANCE/QUALITY CONTROL

A. The CONTRACTOR shall complete, and the PROJECT ENGINEER shall observe and document, proof-rolling of the subgrade for the purpose of detecting unsuitable material. Unsuitable materials are defined as: ASTM D2487 classification PT, OH, OL; or excessively wet or soft soils which inhibit compaction. Excessively wet or soft soils will be determined present when permanent ruts or indentations in excess of one inch are observed, All unsuitable materials in the subgrade that cannot be repaired to meet the project requirements shall be removed and replaced with structural fill materials as required by Section 02224 of the Technical Specifications.

B. The slope of the subgrade shall be no less than the minimum and no greater than the maximum slope requirements as specified in the CQA Plan, and as measured on a 50-foot grid.

C. The PROJECT ENGINEER shall perform on-site field moisture and density testing at an overall frequency of nine tests per acre per lift over the entire subgrade area, including in-situ soils, and all areas of structural fill placement. The soil moisture and density measurements shall be performed using a nuclear densometer at a probe depth of 12 inches, unless otherwise approved by the PROJECT ENGINEER.

D. No minimum/maximum density or moisture content will be established for the in-place soil moisture and density testing of the in-situ subgrade soils. This data will be recorded and reviewed together with the results of proof rolling to assist the PROJECT ENGINEER in evaluating the suitability of the subgrade.

E. In-place soil moisture and density testing within structural fill will be compared to the moisture-density relationship for the soil at a frequency determined by the PROJECT ENGINEER, but not less than nine tests per acre lift of soil placed. The CONTRACTOR shall rework, or remove and replace as directed by the PROJECT ENGINEER, any structural fill material that does not meet the requirements of Section 02224.

F. On trench subgrade, field density and field moisture testing shall be performed at a frequency determined by the PROJECT ENGINEER.

G. In areas where the degree of compaction is questionable, or the uniformity of materials is not maintained, additional tests will be made as directed by the PROJECT ENGINEER.

END OF SECTION

# SECTION 02223

# COMMON TRENCH BACKFILL

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools and appurtenances required to complete the work of placing and consolidating common trench backfill as shown, specified or required.

### 1.2 RELATED SECTIONS

A. Section 02226 – Low Permeability Backfill

B. Section 02233 - Bedding and Backfill

### 1.3 DEFINITIONS

A. Common trench backfill shall consist of furnishing material, if necessary, and placing and consolidating material within excavated trenches. If the trenches are for pipes, the common trench backfill is placed above the select granular backfill.

## PART 2 PRODUCTS

### 2.1 MATERIALS GENERAL

A. All common trench backfill materials shall consist of approved fill material from a suitable source. The CONTRACTOR shall not place common trench backfill only after approval of the soil source by the PROJEC ENGINEER.

B. The common trench backfill shall be consolidated in 12 to 18-inch-thick lifts. The maximum particle (stone) size shall be no larger than nine inches.

C. All required fill materials shall be substantially free from organic materials, wood, trash, and other objectionable materials which may be compressible, or which cannot be properly densified by common earthwork equipment. It shall not contain granite blocks, broken concrete, masonry rubble, or other similar materials. It shall have physical properties such that it can be readily spread and consolidated. Snow, ice, and frozen soil shall not be permitted.

# PART 3 EXECUTION

## 3.1 PRECAUTIONS

A. Common trench backfill placement shall not:

1. Be performed with or placed on frozen materials;

2. Be placed on snow that has a thickness greater than one tenth of an inch; or,

3. Be placed on ice. Ice shall be defined as frozen water on the surface of in situ soils or previously placed material.

## 3.2 BACKFILLING

A. Common trench backfill shall not be placed until the pipeline or other construction component has been inspected in-place and approved by the PROJECT ENGINEER. If the trench contains pipes, the common trench backfill is placed after the select granular backfill has been placed and approved by the PROJECT ENGINEER. The extent of trench left open shall be kept to a minimum.

B. Unless otherwise directed, excavations shall be backfilled as soon as possible after pipes are laid and the work is inspected, tested as required and accepted by the PROJECT ENGINEER. Immediately prior to backfilling, all rubbish, debris, forms and similar materials shall be removed from the excavations.

C. Where sheeting is withdrawn, all cavities left thereby shall be filled with common trench backfill, tamped in place so as to fill all voids thoroughly.

D. Common trench backfill shall be brought to grade uniformly throughout the area. The thickness of each layer shall not exceed 18 inches or unless otherwise specified by the PROJECT ENGINEER.

E. All common trench backfill is to be consolidated to the satisfaction of the PROJECT ENGINEER. After the material is placed in a lift, it is consolidated to eliminate excessive voids through use of hand-operated plate type vibratory tampers or other suitable equipment.

## 3.3 FIELD QUALITY CONTROL

A. The PROJECT ENGINEER shall perform on-site visual inspection of the CONTRACTOR'S compaction efforts on common trench backfill outside the limits of the landfill liner system to determine if it is satisfactory.

B. All common trench backfill placed inside the limits of the landfill liner system shall be subject to inspections and soil moisture and density testing as required for structural fill and defined in Section 02224.

END OF SECTION

# SECTION 02224

# STRUCTURAL FILL

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The CONTRACTOR shall furnish all labor, equipment, tools and appurtenances required to complete the work of structural fill placement, grading, and other related and incidental work within the work area and as required for the construction of Liner System Structural Fill, Plain Embankment Structural Fill, MSE Embankment Structural Fill and subgrade as shown, specified or required by the Drawings and Specifications.

### 1.2 RELATED SECTIONS

A. Section 02223 – Common Trench Backfill

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM)

1. D422-63 Standard Test Method for Particle-Size Analysis of Soils

2. D1557 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft$^3$ (2,700 kN-m/m$^3$))

3. D2216 Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

4. D3080 Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions

5. D4318 Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index Of Soils

6. D4767 Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils

7. D6938 Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

B. The most current version of the specified test method shall be followed by the CONTRACTOR or authorized testing laboratory

## 1.4 DEFINITIONS

A. Structural fill for liner system and embankments shall consist of placing and compacting material where designated on the Drawings, by these specifications or by the PROJECT ENGINEER.

B. Plain embankments are those embankments without geosynthetic or other reinforcement materials.

## 1.5 PROTECTION OF PEOPLE AND PROPERTY

A. The CONTRACTOR shall ensure protection of people and property during construction activities.

# PART 2 PRODUCTS

## 2.1 MATERIALS GENERAL

A. All structural fill materials shall be substantially free from organic materials, wood, trash, and other objectionable materials which may be compressible, or which cannot be properly compacted. It shall have physical properties such that it can be readily spread and compacted to the specified density. Snow, ice, and frozen soil shall not be permitted.

B. The maximum particle (stone) size shall be no larger than nine inches for Plain Embankment Structural Fill and Liner System Structural Fill. The maximum particle (stone) size shall be no larger than six-inches for MSE Embankment Structural Fill.

## 2.2 STRUCTURAL FILL MATERIALS

A. Materials used as structural fill shall be obtained from a suitable source. The CONTRACTOR shall not place structural fill prior to the availability of geotechnical testing, and only after approval of the soil source by the PROJECT ENGINEER. Soil from a new source location shall not be included in the work prior to the written acceptance of testing by the PROJECT ENGINEER. Should unstable soils be encountered in the work, no further material shall be placed in the area in question without the approval of the PROJECT ENGINEER.

B. The soil material used for structural fill as shown in the Drawings shall be placed at a minimum dry density and maximum moisture content as determined by the pre-construction testing to achieve the minimum shear strength specified by the design.

C. The OWNER may complete initial testing of the soil types that may be used for structural fill and submit the results to the PROJECT ENGINEER for review. This information would consist of the following:

| | |
|---|---|
| 1. Moisture Content | ASTM D2216 |
| 2. Grain Size | ASTM D422 |
| 3. Atterberg Limits | ASTM D4318 |
| 4. Modified Proctor | ASTM D1557 |
| 5. Consolidated Undrained Triaxial Shear | ASTM D4767 |
| 6. Direct Shear | ASTM D3080 |

# PART 3 EXECUTION

## 3.1 PRECAUTIONS

A. Structural fill placement and compaction shall not:

1. Be performed with or placed on materials that are frozen;

2. Be performed on snow that has a thickness greater than one tenth of an inch; or,

3. Be performed on ice. Ice shall be defined as frozen water on the surface of in situ soils or previously placed material.

## 3.2 PLACEMENT AND COMPACTION OF STRUCTURAL FILL

A. The subgrade area for structural fill placement shall be cleared of any topsoil, roots, garbage, or other deleterious materials. The subgrade for Plain Embankment Structural Fill and Liner Structural Fill shall be inspected by the PROJECT ENGINEER and be proof rolled as required by Section 02222 of the Technical Specifications. The subgrade for MSE Embankment Structural Fill shall not be proof rolled. Unsuitable soils in the subgrade shall be excavated as directed by the PROJECT ENGINEER. For plain embankments and liner systems, any over excavation of the subgrade shall be backfilled with structural fill in accordance with the requirements of Plain Embankment Structural Fill and Liner Structural Fill. For the MSE Embankment, any over excavation of the subgrade shall be backfilled in accordance with the requirements for MSE Embankment Structural Fill.

B. Prior to placement of the initial lift of structural fill, the prepared subgrade shall be scarified to a depth of two (2) inches.

C. The CONTRACTOR is encouraged to excavate and deliver the structural fill soils to the point of use in such a manner as to minimize the mixing of the various strata within the source area. Soil stratum are typically sampled as unmixed sources for the purpose of compaction control and testing. In the event the CONTRACTOR wishes to employ active soil stratum mixing to address site conditions, the CONTRACTOR shall propose a method of soil mixing to the PROJECT ENGINEER such that representative sampling strategies can be employed.

D. The CONTRACTOR shall place and compact structural fill in lifts to form a uniform upper surface to the lines and grades as shown on the Drawings. In the case of Plain Embankment Structural Fill and MSE Embankment Structural Fill, the upper surface of each lift shall be scarified in order to provide proper adhesion to subsequently placed lifts of structural fill. Each lift shall be cleared of any roots, garbage or other deleterious materials prior to compaction. For Plain Embankment Structural Fill and Liner Structural Fill, each lift shall be a maximum of twelve (12) inches thick after the lift is compacted, unless otherwise approved by the PROJECT ENGINEER based on the results of a test pad program. For MSE Embankment Structural Fill, each lift shall be a maximum of nine (9) inches thick after the lift is compacted

E. At the discretion of the CONTRACTOR prior to commencement of structural fill construction that may differ from any requirements of this Specification, the CONTRACTOR may complete a test pad utilizing the soils, equipment and placement techniques proposed for use in the project. The PROJECT ENGINEER shall observe, measure, sample and evaluate the test pad construction as required to establish the appropriate means and methods, including lift thickness, that are required to obtain the proper engineering properties of the structural fill soils.

F. Structural fill shall be placed in well-drained "horizontal" lifts. The contractor is responsible for maintaining the surface of the structural fill to prevent ponding or other conditions that will lead to degradation of materials. The CONTRACTOR shall drain areas of completed lifts that accumulate standing water, scarify, and dry as necessary for re-compaction. Fill materials that become soft or overly moist will not be incorporated within the final embankment, liner system or subgrade.

G. All structural fill is to be compacted. The density and moisture content of all structural fill shall be consistent with the requirements established by the PROJECT ENGINEER based on his review of the pre-construction geotechnical test results. Unless otherwise approved by the PROJECT ENGINEER, the minimum dry density for Plain Embankment Structural Fill and Liner System Structural Fill shall be 90% of the modified Proctor maximum dry density. For MSE Embankment Structural Fill the soil shall be placed at a moisture content between plus 1% and minus 3% of the modified Proctor optimum moisture content, and the dry density shall be at least 90% of the modified Proctor maximum dry density.

H. Hand-operated plate type vibratory tampers or other suitable equipment must be used in areas not accessible to larger compactors, using a smaller lift thickness approved by the PROJECT

ENGINEER. The PROJECT ENGINEER shall complete in-place soil moisture and density testing on areas where hand-operated plate type vibratory tampers or other manual compaction efforts have been performed, to ensure adequate compaction.

I. The CONTRACTOR is responsible for achieving the appropriate in-situ dry density and moisture content. The CONTRACTOR is responsible for staging and/or manipulation of the excavation and structural fill placement that will allow the soils to reach the moisture content required to meet the specifications.

## 3.3 FIELD QUALITY CONTROL/QUALITY ASSURANCE

A. The engineering properties for the structural fill shall be established and confirmed throughout the project work by laboratory testing. Quality assurance laboratory testing for Plain Embankment Structural Fill and Liner System Structural Fill shall be performed at a minimum frequency of 1 moisture density relationship, 1 grain size distribution (without hydrometer) and 1 Atterberg (liquid and plastic) limits test per 15,000 compacted cubic yards (ccy) of material placed in the work. Quality assurance laboratory testing for MSE Embankment Structural Fill shall be performed at a minimum frequency of 1 moisture density relationship, 1 grain size distribution (without hydrometer), 1 Atterberg (liquid and plastic) limits test and 1 direct shear test per 15,000 ccy. Additional tests may be performed at the discretion of the PROJECT ENGINEER. The specified test program must be completed on any soils that are not representative of the available test results.

B. The PROJECT ENGINEER is to perform on-site field moisture and density testing at a minimum frequency of at least nine tests per acre per 12-inch lift over the entire area of Liner System Structural Fill placement. The field density and field moisture test coverage shall include at a minimum, at least one test for every 75 linear feet of embankment for every lift of Plain Embankment Structural Fill and MSE Embankment Structural Fill. The field density and moisture test shall be D6938. The field test will be performed using a probe depth of 12 inches for Plain Embankment Structural Fill and nine-inches for Liner System Structural Fill and MSE Embankment Structural Fill, unless otherwise stated or approved by the PROJECT ENGINEER.

C. Structural fill moisture and density tests are required to exhibit a minimum dry density and moisture content range as specified in Paragraph 3.2 G of this Section.

D. Any areas not meeting the specified moisture content and dry density will receive additional compaction; or be reworked and re-compacted; or be removed, replaced and re-compacted; and retested until a passing determination is achieved. All retests will be performed in as close a position to the original failed test location as can be reasonably ascertained by the Geotechnical Construction Observer.

END OF SECTION

# SECTION 02226

# LOW PERMEABILITY BACKFILL

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools and appurtenances required to complete the work of low permeability backfill placement, grading and consolidation.

### 1.2 RELATED SECTIONS

A. Section 02223 - Common Trench Backfill

B. Section 02781– LLDPE Geomembrane

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM)

1. D422 Standard Test Method for Particle-Size Analysis of Soils

2. D4318 Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index Of Soils

B. The most current version of the specified test method shall be followed by the EARTHWORK CONTRACTOR or authorized testing laboratory.

### 1.4 DEFINITIONS

A. Low permeability backfill shall consist of furnishing source material, placing and compacting the material where designated on the Drawings, or by the ENGINEER.

B. Low permeability backfill is to be used at the limit of waste above the geosynthetics, or at the edge of waste placed near the temporary liner terminations, as shown in the Construction Drawings. In particular, any geosynthetic anchor trenches used in the construction will typically be shown to be backfilled or covered with low permeability backfill.

# PART 2 PRODUCTS

## 2.1 MATERIALS GENERAL

A. All low permeability backfill materials shall consist of fine-grained soils. The material shall be substantially free from organic matter, wood, trash, and other objectionable substances which may be compressible, or which cannot be properly consolidated. It shall have physical properties such that it can be readily spread and consolidated. Snow, ice, and frozen soil shall not be permitted.

B. The maximum particle (stone and/or soil clod) size shall be no larger than four inches, or no larger than 75% of the lift thickness, whichever is less.

## 2.2 SOIL

A. Soil to be used for low permeability backfill shall be approved for such use by the PROJECT ENGINEER. Available test data shall be supplied by the CONTRACTOR to the PROJECT ENGINEER for the following tests: grain size distribution and liquid and plastic limits. The plasticity index shall be at least 6.

B. The CONTRACTOR shall not place low permeability backfill prior to the PROJECT ENGINEERS review and approval of the available test data. Depending on the test results, the PROJECT ENGINEER shall accept or reject the soil, or require further testing.

## 2.3 TESTING

A. The CONTRACTOR shall submit to the PROJECT ENGINEER for approval suitable evidence that the soils proposed for low permeability backfill are appropriate. This information is to be provided for each individual low permeability backfill source, or when in the opinion of the PROJECT ENGINEER, the material is different in any way from the originally tested and approved material. This evidence shall include, but not necessarily be limited to, the following testing.

1. Grain Size ASTM D422

2. Atterberg (liquid and plastic) Limits ASTM D4318

A. If in the opinion of the PROJECT ENGINEER based on his review of the available data, the CONTRACTOR'S soil is unsuitable for the proposed application, the CONTRACTOR shall submit the above evidence for soil of another type or from another source for consideration by the PROJECT ENGINEER.

# PART 3 EXECUTION

## 3.1 PRECAUTIONS

A. Low permeability backfill placement shall not:

1. Be performed with or placed on frozen materials.

2. Be placed on snow that has a thickness greater than a tenth of an inch.

3. Be placed on ice or in standing water. Ice shall be defined as frozen water on the surface of in situ soils or previously placed material.

## 3.2 PLACEMENT OF LOW PERMEABILITY BACKFILL

A. Low permeability backfill shall be brought to grade uniformly throughout the area and consolidated using a smooth drum roller to achieve the quality of low permeability soil described in 3.2 C. Hand-operated plate type vibratory tampers or other suitable equipment must be used in areas not accessible to larger compactors.

B. The thickness of each consolidated lift shall not exceed 1 foot, unless otherwise specified by the PROJECT ENGINEER.

C. The low permeability backfill shall be placed in a manner that isolates soil clods, eliminates lift interfaces and prevents the formation of observable voids in the completed lifts as determined by the PROJECT ENGINEER.

## 3.3 FIELD QUALITY ASSURANCE/QUALITYCONTROL

A. The PROJECT ENGINEER shall observe and document the placement procedures to be utilized by the CONTRACTOR in construction of the low permeability backfill. The PROJECT ENGINEER shall perform in-place shovel testing on select lifts at a rate sufficient to document that proper consolidation procedures are being employed to achieve the requirements of Paragraph 3.2 C. All shovel tests shall be performed throughout the full thickness of the lift(s).

B. The PROJECT ENGINEER shall observe that the soil has been consolidated such that soil clods in excess of four inches have been eliminated, and that the consolidated soil includes no observable lift interfaces or voids.

C. Any areas not meeting the specified consolidation or uniformity requirements will receive additional consolidation; or be reworked and reconsolidated; or be removed, replaced and reconsolidated; and retested until acceptable results are achieved throughout the backfill. All retests will be performed within two feet of the original failed test location.

END OF SECTION

# SECTION 02228

# BARRIER PROTECTION SOIL LAYER

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The CONTRACTOR shall furnish all labor, materials, equipment, and tools required to complete the work of barrier protection layer soil placement, grading and consolidation.

### 1.2 RELATED SECTIONS

A. Section 02235 - Topsoil

B. Section 02599 – Geocomposite Drainage Layer

C. Section 02781 – LLDPE Geomembrane Liner

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM)

1. D422 Standard Test Method for Particle-Size Analysis of Soils

2. D4318 Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index Of Soils

B. The most current version of the specified test method shall be followed by the EARTHWORK CONTRACTOR or authorized testing laboratory.

### 1.4 DEFINITIONS

A. Barrier Protection Layer Soil shall consist of furnishing source material, placing and consolidating the material where designated on the Drawings, or by the PROJECT ENGINEER.

B. Barrier Protection Layer Soil is to be used above the geocomposite drainage layer on slopes greater than or equal to 25%, LLDPE geomembrane liner on slopes less than 25% in the final cover system, as shown in the Construction Drawings.

# PART 2 PRODUCTS

## 2.1 MATERIALS GENERAL

A. All Barrier Protection Layer Soil materials shall consist of fine-grained soils. The material shall be substantially free of organic matter, wood, trash, and other objectionable substances which may be compressible, or which cannot be properly consolidated. It shall have physical properties such that it can be readily spread and consolidated. Snow, ice, and frozen soil shall not be permitted.

B. The maximum particle (stone and/or soil clod) size shall be no larger than four inches, or no larger than 75% of the lift thickness, whichever is less.

C. One hundred percent of the soil used to construct the lower six inches of the Barrier Protection Soil Layer must pass a two-inch sieve.

## 2.2 SOIL

A. Soil to be used for Barrier Protection Layer Soil shall be approved for such use by the PROJECT ENGINEER. Available test data shall be supplied by the CONTRACTOR to the PROJECT ENGINEER for the following tests: grain size distribution and liquid and plastic limits. The plasticity index shall be at least 6.

B. The CONTRACTOR shall not place Barrier Protection Layer Soil prior to the PROJECT ENGINEER'S review and approval of the available test data. Depending on the test results, the PROJECT ENGINEER shall accept or reject the soil, or require further testing.

## 2.3 TESTING

A. The CONTRACTOR shall submit to the PROJECT ENGINEER for approval suitable evidence that the soils proposed for Barrier Protection Layer Soil are appropriate. This information is to be provided for each individual Barrier Protection Layer Soil source, or when in the opinion of the PROJECT ENGINEER, the material is different in any way from the originally tested and approved material. This evidence shall include, but not necessarily be limited to, the following testing.

| | |
|---|---|
| 1. Grain Size | ASTM D422 |
| 2. Atterberg (liquid and plastic) Limits | ASTM D4318 |

B. If in the opinion of the PROJECT ENGINEER based on his review of the available data, the CONTRACTOR'S soil is unsuitable for the proposed application, the CONTRACTOR shall submit the above evidence for soil of another type or from another source for consideration by the PROJECT ENGINEER.

# PART 3 EXECUTION

## 3.1 PRECAUTIONS

A. Barrier Protection Layer Soil placement shall not:

1. Be performed with or placed on frozen materials.

2. Be placed on snow that has a thickness greater than a tenth of an inch.

3. Be placed on ice or in standing water. Ice shall be defined as frozen water on the surface of in situ soils or previously placed material.

## 3.2 PLACEMENT OF BARRIER PROTECTION LAYER SOIL

A. Barrier Protection Layer soil shall be scraped/shaved from the excavation face in a manner that controls particle size to within the specifications

B. Barrier Protection Layer Soil shall be brought to grade uniformly throughout the area and moderately consolidated using a smooth drum compactor to achieve the quality described in 3.2.C. Hand-operated plate type vibratory tampers or other suitable equipment must be used in areas not accessible to larger compactors.

C. The first lift over any geosynthetic material will be placed such that the consolidated thickness will be no less than one-foot (plus 0.2 feet, minus 0.1 feet). All other lifts shall not exceed nine-inches thickness of the consolidated lift shall not be less than or exceed 1-foot, unless otherwise specified by the PROJECT ENGINEER.

D. The Barrier Protection Layer Soil shall be placed in a manner that isolates soil clods, eliminates lift interfaces and prevents the formation of observable voids in the completed lifts as determined by the PROJECT ENGINEER, all without damaging the underlying geosynthetics. Laborers shall be staged to assist in the identification and removal of oversize cobbles and boulders or hardened till clods.

E. The Barrier Protection Layer Soil shall be placed in a manner so that it minimizes the traffic cycling and use of heavy equipment on the slope. No unnecessary or repeated travel shall be permitted on the slope. For soil needed in longer slopes consider placing soil from the top and bottom of the slope.

F. Only low ground pressure bulldozers with a low-profile straight dozer blade, or with a curved blade shall be used for Barrier Protection Layer soil placement. Haul truck travel shall not be permitted on the slope.

G. Bulldozer speed shall be controlled and minimized to avoid abrupt acceleration and breaking while not spinning the tracks. Turning/tipping the machine in a manner that increases ground pressure imposed by the tracks shall be avoided.

H. Fill placement shall be done in a manner that prevents buildup of wrinkles and/or slippage of the geosynthetics. Extra control and restraint shall be practiced in areas where wrinkling of the GCD is concentrated.

I. While using heavy equipment with a blade to push material, limit the down force on the blade and do not heavily load the blade with material causing the equipment to exert extra force. Let the soil "fall" onto the GCD rather than grading in a manner that scrapes soil across the surface of the GCD. The blade shall not be heavily loaded when pushing soil up or down the slope

J. Trucks or other heavy equipment shall not be operated over pipelines until a minimum of twenty-four (24) inches of backfill above the crown of the trenched pipe has been placed and properly compacted by the tampers or other approved method.

K. Movements of the heavy equipment on the geosynthetic slope shall only be parallel with the slope direction.

## 3.3 FIELD QUALITY ASSURANCE/QUALITYCONTROL

L. The PROJECT ENGINEER shall observe and document the placement procedures to be utilized by the CONTRACTOR in construction of the Barrier Protection Layer Soil. The PROJECT ENGINEER may perform in-place shovel testing on select lifts at his or her discretion to document that proper consolidation procedures are being employed to achieve the requirements of Paragraph 3.2.C. All shovel tests shall be performed throughout the full thickness of the lift(s).

M. The PROJECT ENGINEER shall observe that the soil has been consolidated such that soil clods in excess of four inches have been eliminated, and that the consolidated soil includes no observable lift interfaces or voids.

N. Any areas not meeting the specified consolidation or uniformity requirements will receive additional consolidation; or be reworked and reconsolidated; or be removed, replaced, and reconsolidated; and retested until acceptable results are achieved throughout the layer. All retesting observations will be performed within two feet of the original failed test location.

END OF SECTION

# SECTION 02232

# COARSE SAND

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools, and appurtenances required to complete the placement of coarse sand to backfill the leachate transfer pipes below the final cover geomembrane, as shown, specified, or elsewhere required.

### 1.2 RELATED SECTIONS

A. Section 02781 – LLDPE Geomembrane

B. Section 02599 – Geocomposite Drainage Layer

C. Section 02650 – Polyvinyl Chloride (PVC) Pipe

### 1.3 DEFINITIONS

A. Coarse sand placement shall consist of furnishing and placing material where designated in the Drawings, or as directed by the PROJECT ENGINEER.

## PART 2 PRODUCTS

### 2.1 MATERIALS GENERAL

A. All coarse sand materials, unless otherwise specified, shall come from off-site sources, and shall be approved by the PROJECT ENGINEER prior to placement.

B. All coarse sand materials shall be free from organic matter, wood, trash, and other objectionable materials which may be compressible, or which may result in damage to any adjacent geosynthetics, to the satisfaction of the PROJECT ENGINEER. Snow, ice, and frozen material shall not be permitted.

C. The typical gradation requirements for coarse sand are as follows:

| Sieve Size Designation | Percent Passing by Weight |
|---|---|
| No. 4 | 80-100 |
| No. 16 | 30-70 |
| No. 100 | 0-10 |

### 2.2 TESTING

A. The CONTRACTOR shall submit to the PROJECT ENGINEER for approval, evidence the proposed materials are appropriate, including but not necessarily limited to grain size analysis (ASTM D422). This information is to be provided for each individual source of coarse sand, or when in the opinion of the PROJECT ENGINEER, the material is different in any way from the originally tested and approved material.

B. The CONTRACTOR shall not proceed with placement of coarse sand until the PROJECT ENGINEER has approved the proposed material.

C. If in the opinion of the PROJECT ENGINEER the CONTRACTOR'S proposed material is unsuitable for the proposed application, the CONTRACTOR shall submit the above evidence for material of another type or from another source for consideration by the PROJECT ENGINEER.

## PART 3 EXECUTION

### 3.1 PLACEMENT

A. Coarse sand shall not be placed until the PROJECT ENGINEER has approved the installation of the underlying geosynthetics/subgrade.

B. The CONTRACTOR shall use extreme care in placing the coarse sand.

END OF SECTION

# SECTION 02233

# BEDDING AND BACKFILL

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools, and appurtenances required to complete the placement of bedding and backfill, including grading, as shown, specified, or required.

### 1.2 RELATED SECTIONS

A. Section 02223 - Common Trench Backfill

B. Section 02650 - Polyvinyl Chloride (PVC) Pipe

C. Section 02660 – Polyethylene Pipe

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM)

1. D422 Standard Test Method for Particle-Size Analysis of Soils

B. The most current version of the specified test method shall be followed by the EARTHWORK CONTRACTOR or authorized testing laboratory.

### 1.4 DEFINITIONS

A. Bedding and backfill placement shall consist of furnishing, placing and compacting material as designated in the Drawings or as indicated by these specifications.

## PART 2 PRODUCTS

### 2.1 MATERIALS GENERAL

A. All bedding and backfill materials, unless otherwise specified, shall consist of clean, sound, durable granular material from approved off-site sources and shall meet the approval of the PROJECT ENGINEER. All materials shall meet New York State Department of Transportation (NYSDOT) specifications for soundness and hardness in accordance with NYSDOT Standard Specification and the proper ASTM procedures, as demonstrated by the supplier's standard QC test data.

B. All bedding and backfill materials shall be substantially free from organic materials, wood, trash, slag, and other objectionable materials which may be compressible, or which cannot be properly compacted. It shall not contain blocks, broken concrete, masonry rubble, or other similar materials. It shall have physical properties such that it can be readily spread and compacted to the required density. Snow, ice, and frozen material shall not be permitted.

## 2.2 TYPE 2 (NYSDOT 304 – 2.02 TYPE 2 STONE BACKFILL)

A. Type 2 granular material shall be used as shown on the Drawings for select soil bedding and backfill, for bedding and backfilling structures, and for pipe bedding and backfill unless otherwise stated in the Drawings or as directed by the PROJECT ENGINEER.

B. Soils used as Type 2 material shall be provided by the CONTRACTOR from an approved off-site source. Materials shall be a well-graded, clean, sound, durable, stone and shall not contain slag, organics, or other deleterious materials.

C. The CONTRACTOR shall not place Type 2 material without the approval of the PROJECT ENGINEER.

D. The material shall generally exhibit the following gradation requirements:

| Sieve Size Designation | Percent Passing by Weight |
|---|---|
| 2 inch | 100 |
| 1/4-inch | 25-60 |
| No. 40 | 5-40 |
| No. 200 | 0-10 |

## 2.3 TYPE 1 (NYSDOT 304 – 2.02 TYPE 1 STONE BEDDING)

A. Type 1 material shall be used as shown on the Drawings as select soil bedding and backfill for bedding and backfilling structures, and for pipe bedding and backfill unless otherwise stated in the Drawings or as directed by the PROJECT ENGINEER.

B. Soils used as Type 1 material shall be provided by the CONTRACTOR from an approved source. Materials shall be a well-graded, clean, sound, durable, stone and shall not contain slag, organics, or other deleterious materials.

C. The CONTRACTOR shall not place Type 1 material without the approval of the PROJECT ENGINEER.

D. The material shall generally exhibit the following gradation requirements:

| Sieve Size Designation | Percent Passing by Weight |
|---|---|
| 2 inch | 90-100 |

| | |
|---|---|
| 1/4-inch | 30-65 |
| No. 40 | 5-40 |
| No. 200 | 0-10 |

## 2.4 NUMBER 4 STONE (NYSDOT 703 – 02SIZE 4 CRUSHED STONE)

A. Number 4 stone shall be used as shown on the Drawings as backfill.

B. Materials used as Number 4 stone shall be provided by the CONTRACTOR from an approved off-site source. Materials shall be clean, sound, durable stone and shall not contain slag, organics, or other deleterious materials.

C. The CONTRACTOR shall not place Number 4 stone without the approval of the PROJECT ENGINEER.

D. The material shall generally exhibit the following gradation requirements:

| Sieve Size Designation | Percent Passing by Weight |
|---|---|
| 4-inch | 100 |
| 3-inch | 90-100 |
| 2-inch | 0-15 |

## 2.5 NUMBER 2 STONE (NYSDOT 703- 02SIZE 2 CRUSHED STONE)

A. Number 2 stone shall be used as shown on the Drawings as selected soil bedding and backfill, for bedding and backfilling structures, and for pipe bedding and backfill unless otherwise stated in the Drawings or as directed by the PROJECT ENGINEER.

B. Materials used as Number 2 stone shall be provided by the CONTRACTOR from an approved off-site source. Materials shall be clean, sound, durable stone and shall not contain slag, organics, or other deleterious materials.

C. The CONTRACTOR shall not place Number 2 stone without the approval of the PROJECT ENGINEER.

D. The material shall generally exhibit the following gradation requirements:

| Sieve Size Designation | Percent Passing by Weight |
|---|---|
| 1 1/2-inch | 100 |
| 1-inch | 90-100 |
| 1/2-inch | 0-25 |
| No. 200 | 0-5.0 |

## 2.6 NUMBER 1 STONE (NYSDOT 703-02 SIZE 1 CRUSHED STONE)

A. Number 1 stone shall be used as shown on the Drawings as selected soil bedding and backfill, for bedding and backfilling structures, for pipe bedding and backfill unless otherwise stated in the Drawings or as directed by the PROJECT ENGINEER. A washed Number 1 stone shall be used for tank bedding and backfill.

B. Materials used as Number 1 stone shall be provided by the CONTRACTOR from an approved off-site source. Materials shall be clean, sound, durable stone and shall not contain slag, organics, or other deleterious materials.

C. The CONTRACTOR shall not place Number 1 stone without the approval of the PROJECT ENGINEER.

D. The material shall generally exhibit the following gradation requirements:

| Sieve Size Designation | Percent Passing by Weight |
|---|---|
| 1-inch | 100 |
| 1/2-inch | 90-100 |
| 1/4-inch | 0-15 |
| No. 200 | 0-1.0 |

## 2.7 TESTING

A. The CONTRACTOR shall submit to the PROJECT ENGINEER for approval suitable evidence that any materials proposed for bedding and backfill are appropriate. This information is to be provided for each individual type and source of material or when in the opinion of the PROJECT ENGINEER the material is different in any way from the originally tested and approved material. This evidence shall include, but not necessarily be limited to a grain size analysis (ASTM D422). The CONTRACTOR shall furnish a 50-pound sample of each proposed soil type (i.e. Type 2, Type 1, Number 4 stone, Number 2 stone or Number 1 stone) to the PROJECT ENGINEER.

B. The CONTRACTOR shall not proceed with placement of bedding and backfill until the PROJECT ENGINEER has approved the proposed material.

C. Sampling and testing of the bedding and backfill materials for determination of minimum and maximum density values may be performed at the PROJECT ENGINEER's discretion.

D. If in the opinion of the PROJECT ENGINEER the CONTRACTOR'S proposed material is unsuitable for the intended application, the CONTRACTOR shall submit the above evidence for material of another type or from another source for consideration by the PROJECT ENGINEER.

# PART 3 EXECUTION

## 3.1 PRECAUTIONS

A. Bedding and backfill placement shall not:

1. Be performed with or placed on frozen materials;

2. Be placed on snow that has a thickness greater than one tenth of an inch; or,

3. Be placed on ice. Ice shall be defined as frozen water on the surface of in situ soils or previously placed material.

## 3.2 BEDDING AND BACKFILLING

A. All excavations shall be made to such depth as required and of the width shown on the Drawings to provide suitable room for building the structure or laying the pipe(s) they are to contain and for sheeting, shoring, pumping, and draining as necessary, and for removing peat, silt, or any other materials the PROJECT ENGINEER deems unsuitable.

B. The bottom of trenches and excavations shall be accurately graded to provide a uniform layer of bedding material as required for the structure or each section of pipe. The CONTRACTOR shall trim and shape the bottom of trenches or excavations and leave them free of irregularities, lumps, and projections.

C. If, in the opinion of the PROJECT ENGINEER, existing material below the excavation or trench grade is unsuitable for properly placing bedding material and installing the structure or pipe, the CONTRACTOR shall excavate and remove the unsuitable material and replace the same with an approved material properly compacted in place.

D. The side slopes of excavations shall comply with all applicable codes and regulations. The CONTRACTOR shall shore, brace, or slope the excavation or trench as required to maintain the excavation or trench in a safe condition until the completion of backfilling.

E. Removal of materials beyond the indicated elevations, without authorization by the PROJECT ENGINEER, shall be remedied by replacing the same with an approved material properly compacted in place. This work shall be performed by the CONTRACTOR at no additional cost to the OWNER.

F. The CONTRACTOR shall remove all excess water from the excavation or trench promptly throughout the progress of the work and shall keep the excavation or trench stable at all times until the structure or pipe to be constructed therein is completed and backfilled or have sufficient weight to resist uplift pressures. No structure or pipe is to be laid on loose or softened soils or in water, and water shall not be allowed to rise or flow over any pipe or

structure until such time as approved by the PROJECT ENGINEER. Precautions shall be taken to protect uncompleted work from flooding during storms or other causes. All pipe lines or structures not stable against uplift during construction prior to completion shall be thoroughly braced or otherwise protected.

G. Bedding and backfill shall not be placed until the excavation or trench have been inspected in place and approved. The extent of any excavation or trench left open shall be kept to a minimum. Immediately prior to material placement, all rubbish, debris, forms, and similar materials shall be removed from the excavations.

H. Bedding and backfilling shall be accomplished in three stages unless otherwise proposed by the CONTRACTOR and approved by the PROJECT ENGINEER. The first stage shall involve the placement of the bedding material as a layer of select material as shown on the Drawings or as approved by the PROJECT ENGINEER to support the pipe or structure. This material shall be compacted as required by the PROJECT ENGINEER or as specified on the Drawings. In the case of pipe installations, the second stage shall consist of "haunching" which shall be placed to the springline of the pipe and consolidated in-place as directed by the PROJECT ENGINEER. In the case of other structures, the second stage shall consist of the first lift of backfill placed in a lift not to exceed 12 inches and shall be consolidated in-place as approved by the PROJECT ENGINEER. The third stage involves the placement of select backfill lifts not to exceed 12 inches in thickness that shall be placed and consolidated in-place as approved by the PROJECT ENGINEER. The remainder of the trench or excavation shall be brought to grade using materials as shown on the Drawings using methods to be approved by the PROJECT ENGINEER.

I. Any pipe or structure that is damaged or moved out of alignment shall be replaced or realigned at no additional cost to the OWNER.

J. Tank bedding and backfill shall be performed as per the tank manufacturer's recommendations.

## 3.3 FIELD QUALITY ASSURANCE/QUALITY CONTROL

A. The CONTRACTOR shall notify the PROJECT ENGINEER at least one working day in advance of all phases of excavation and backfilling operations.

B. The PROJECT ENGINEER shall typically perform on-site visual inspection of the CONTRACTOR'S placement effort to determine if it is satisfactory.

C. The PROJECT ENGINEER may direct additional tests to establish gradation, maximum density and in-place density as required by the Drawings or field conditions.

END OF SECTION

# SECTION 02235

# SOIL SUITABLE FOR VEGETATIVE GROWTH

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The CONTRACTOR shall furnish all labor, equipment, and incidentals necessary to perform all fill and grading required to complete the placement of soil suitable for vegetative growth in all areas shown on the Drawings or as directed by the PROJECT ENGINEER. The work shall include, but not necessarily be limited to, the earthwork required for placement of soil suitable for vegetative growth and all related work.

### 1.2 RELATED SECTIONS

A. Section 02228 – Barrier Protection Layer Soil

B. Section 02936 – Seeding

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM):

1. D422 Standard Test Method for Particle-Size Analysis of Soils
2. D2974 Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils
3. D4542 Standard Test Methods for Pore Water Extraction and Determination of the Soluble Salt Content of Soils by Refractometer
4. D4972 Standard Test Methods for pH of Soils

## PART 2 PRODUCTS

### 2.1 SOIL SUITABLE FOR VEGETATIVE GROWTH

A. Soil suitable for vegetative growth used for surface restoration can be provided by the from on-site or off-site sources.

B. Soil suitable for vegetative growth shall have at least two percent by weight of fine textured stable organic material, and no greater than six percent, or as approved by the PROJECT ENGINEER.

C. Soil suitable for vegetative growth shall have not less than 20 percent fine textured material (passing the No. 200 sieve) and not more than 15 percent clay, or as approved by the PROJECT ENGINEER.

D. Soil suitable for vegetative growth that was treated with soil sterilant or herbicides shall be so identified by the CONTRACTOR.

E. Soil suitable for vegetative growth shall have a pH between 6.0 and 8.0, or as approved by the PROJECT ENGINEER.

F. Soil suitable for vegetative growth shall be relatively free of stones over 1 & 1/2 inches in diameter, trash, noxious weeds such as nut sedge and quackgrass, and will have less than 10 percent gravel by volume, or as approved by the PROJECT ENGINEER.

G. Soil suitable for vegetative growth that contains soluble salts greater than 500 ppm shall not be used, or as approved by the PROJECT ENGINEER.

### 2.2 TESTING

A. The CONTRACTOR may submit, to the PROJECT ENGINEER for approval, evidence that the material proposed for use as soil suitable for vegetative growth is adequate for the proposed application. Available test data shall be supplied by the CONTRACTOR to the PROJECT ENGINEER for the following tests: grain size distribution and moisture content.

B. The soil suitable for vegetative growth shall be analyzed by the PROJECT ENGINEER's designated laboratory to determine the conductivity, organic matter content and pH.

C. No material shall be placed unless approved by the PROJECT ENGINEER.

D. If in the opinion of the PROJECT ENGINEER, the soil is unsuitable for the proposed application then the CONTRACTOR may submit to the PROJECT ENGINEER the required information specified in (A) and (B) above for soil from a different source.

## PART 3 EXECUTION

### 3.1 INSTALLATION

A. This item shall consist of the placement of soil suitable for vegetative growth in all areas shown on the Drawings or as directed by the PROJECT ENGINEER. The CONTRACTOR shall provide all the required labor, and equipment to perform the work in accordance with these Specifications.

B. The CONTRACTOR shall install and maintain erosion control devices such as diversions, channels, sediment traps, and stabilizing measures as needed to preserve the soil layer until vegetation is established.

C. After PROJECT ENGINEER has approved the grades and subsoil, CONTRACTOR shall scarify all compact subsoil areas. The CONTRACTOR shall scarify at approximately right angles to the slope direction in areas that are steeper than five percent.

D. Soil suitable for vegetative growth shall be installed in a single, minimum 4-inch lift in all areas except the final cover system. Soil shall not be placed when it is partly frozen, muddy, or on frozen slopes or over ice, snow, or standing water. Minimum final thickness shall be 6 inches when used on the landfill final cover system.

E. The CONTRACTOR shall take care to ensure that underlying soil remains intact and does not become mixed with the soil suitable for vegetative growth during installation.

END OF SECTION

# SECTION 02240

# PRIMARY DRAINAGE LAYER

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. CONTRACTOR shall furnish all labor, materials, equipment, tools and appurtenances required to complete the work of furnishing, placing, and grading the primary drainage layer material as shown, specified or required.

### 1.2 RELATED SECTIONS

A. Section 02233 – Bedding and Backfill

B. Section 02595 - Geotextile

C. Section 02597 – HDPE Geomembrane

D. Section 02650 - Polyvinyl Chloride (PVC) Pipe

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM)

1. C136 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates

2. D422 Standard Test Method for Particle-Size Analysis of Soils

3. D2434 Standard Test Method for Permeability of Granular Soils (Constant Head)

B. New York State Department of Transportation (NYSDOT)

1. GCP-19 Revision #6 April 2007 Geotechnical Control Procedure: Sampling and Testing of Tire Shreds

C. The most current version of the specified test method shall be followed by the EARTHWORK CONTRACTOR or authorized testing laboratory

## 1.4 TOLERANCES

A. The total thickness of the primary drainage layers shall be no less than the minimum thickness shown on the Drawings.

# PART 2 PRODUCTS

## 2.1 MATERIALS

A. The upper 12-inches of the primary drainage layer shall have a minimum permeability of 0.1 cm/sec. The lower 12-inches of the primary drainage layer shall have a minimum permeability of 1.0 cm/sec or greater.

B. On slopes greater than 10 percent, the entire 24-inch primary layer shall have a minimum permeability of at least 0.1 cm/sec.

C. The upper 12 inches of the primary drainage layer design shall consists of a minimum 15-inch thick tire shred layer overlying a lower minimum 12-inch thick ¾ inch nominal stone primary drainage layer. In the event a thicker primary drainage stone layer is placed, the tire shred layer thickness can be reduced to a lesser thickness as approved by the PROJECT ENGINEER.

C. The ¾ inch nominal stone portion of the primary drainage layer shall be free of organic material and comprised of clean, sound, durable stone and shall be free of slag or any other materials capable of damaging the geomembrane liner. The ¾ inch nominal stone material used for the lower 12-inch thick portion of the primary drainage layer shall be in general conformance with the following gradation:

| | **Percent Passing** |
|---|---|
| **Sieve Size** | **By Weight** |
| 1 1/2-inch | 100 |
| 1-inch | 85-100 |
| 1/2-inch | 0-30 |
| No. 200 | 0-5 |

The upper 15 inches of the primary drainage layer by design shall be comprised of tire shreds with the gradation specified below, and with no whole or sectioned tires.

D. The material used for the tire shred portion of the primary drainage layer shall be in conformance with the following shred gradation:

| Length (inches maximum) | Percent Passing by Weight |
|---|---|
| 16 | 92 to100 |
| 12 | 90 to 100 |
| 8 | 75 - 100 |
| 1 1/2 | 0 - 25 |
| 3/16 | 0 - 1 |

E. Along a 1-foot wide strip centered along the collection pipes, the primary drainage blanket shall consist entirely of a minimum 24-inch thick ¾ inch nominal stone layer.

### 2.2 TESTING

A. The CONTRACTOR will be responsible for all initial testing of the primary drainage layer materials. The testing required shall be completed on at least one sample of the material, and will include:

1. Grain Size (Stone) ASTM D422
2. Grain Size (Tire Shreds) ASTM C136 or per gradation testing as described in NYSDOT GCP-19, or as approved by PROJECT ENGINEER)
3. Permeability (ASTM D2434 or as approved by the PROJECT ENGINEER)

B. The initial test information shall be submitted, reviewed, and approved by the PROJECT ENGINEER before the material is used in the construction. No material shall be placed unless approved by the PROJECT ENGINEER.

C. The ¾ inch nominal stone supplier shall provide one grain size analysis (ASTM D 422) for each 1,000 cubic yard block of material delivered and installed, for review by the PROJECT ENGINEER. Additional sampling and testing shall be taken from delivered, stockpiled and installed materials as required by the project CQA/CQC Plan.

## PART 3 EXECUTION

### 3.1 INSTALLATION - LEACHATE COLLECTION SYSTEM BLANKET DRAIN

A. This item shall consist of the placement of the primary drainage layer over the cushion geotextile and geomembrane liner. The CONTRACTOR shall provide all the required materials, labor, and equipment to perform the work in accordance with these Specifications.

B. The primary drainage layer shall be installed as shown by the details in the Drawings. The primary drainage layer shall cover the base of the lined area as illustrated in the Drawings.

C. No material shall be placed until the PROJECT ENGINEER has approved the installation of the underlying cushion geotextile and geomembrane liner materials.

D. The primary drainage layer shall be placed directly above the cushion geotextile covering the geomembrane liner in 12-inch minimum lifts.

E. The CONTRACTOR shall use extreme care in the placing of the primary drainage layer over the geotextile and geomembrane liner. The material shall be placed in a manner that will maintain a minimum thickness of 1 foot of material between the geomembrane liner and the spreading equipment. Only tracked equipment shall be allowed on the 1 foot thick aggregate layers. Access roads used to deliver aggregate materials over previously constructed liner shall have a minimum thickness of 3 feet. All equipment to be used in this operation shall be low ground pressure equipment and be approved by the PROJECT ENGINEER. All primary drainage layer placement operations on slopes greater than 10% will proceed from the bottom of the slope to the top.

F. The CONTRACTOR shall take care to ensure that:

1. The cushion geotextile and geomembrane liner remain intact during the installation of the primary drainage layer;

2. During installation of the stone portion of the primary drainage layer, the maximum geomembrane wrinkle size shall not exceed three-inches or a height to width ratio of 0.5, or as deemed acceptable by the PROJECT ENGINEER. The height of the wrinkle shall be measured from the base or subgrade to the peak of the wrinkle. The width of the wrinkle shall be as measured along its base. The geomembrane wrinkle must be trapped during stone installation to prevent spreading and enlargement. The geomembrane wrinkles should not be folded over during primary drainage layer stone installation.

3. No foreign objects or material is mixed into the primary drainage layer, in any significant amount as determined by the PROJECT ENGINEER, which may produce clogging or restrict the ability of the layer to transmit water or leachate.

4. No vehicles shall drive on the uncovered cushion geotextile and geomembrane liner, unless previously approved in writing by the PROJECT ENGINEER.

# PART 4 QUALITY ASSURANCE/QUALITY CONTROL

## 4.1 GENERAL

A. The PROJECT ENGINEER will develop and maintain a construction control grid. The control grid shall have defined positions across the area of the proposed overfill liner. All aspects of construction shall be referenced to the control grid including, but not limited to, tops and toes of slope, leachate collection headers, laterals and cleanout risers, berms,

manholes, roadways and culverts. The construction control grid shall be established in rectangular coordinates, and lie in the same orientation to, and with an established relationship to, the site grid.

B. The PROJECT ENGINEER shall have grain-size analyses performed on installed stone and tire shred samples as specified in the project CQA/CQC Plan.

C. The thickness of the primary drainage layer as measured perpendicular to the slope of the liner system shall be determined by random excavation of the stone layer and the tire shred layer individually, or by instrument survey. The locations of all hand excavations and/or survey points shall be determined and documented by the Geotechnical Construction Observers, and plotted on a plan area map of the landfill.

D. A laboratory permeability test shall be performed during construction at a frequency that results in a total of at least one test for every 2,500 cubic yards of stone and tire shred material delivered and placed, in accordance with the project CQA/CQC Plan.

END OF SECTION

# SECTION 02241

# SECONDARY SOIL DRAINAGE LAYER

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. CONTRACTOR shall furnish all labor, materials, equipment, tools and appurtenances required to complete the work of furnishing, placing, and grading the primary drainage layer material as shown, specified or required.

### 1.2 RELATED SECTIONS

A. Section 02233 – Bedding and Backfill

B. Section 02595 - Geotextile

C. Section 02597 – HDPE Geomembrane

D. Section 02650 - Polyvinyl Chloride (PVC) Pipe

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM)

1. C136 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates

2. D422 Standard Test Method for Particle-Size Analysis of Soils

3. D2434 Standard Test Method for Permeability of Granular Soils (Constant Head)

B. The most current version of the specified test method shall be followed by the EARTHWORK CONTRACTOR or authorized testing laboratory

### 1.4 TOLERANCES

A. The total thickness of the primary drainage layers shall be no less than the minimum thickness shown on the Drawings.

# PART 2 PRODUCTS

## 2.1 MATERIALS

A. The minimum permeability for the secondary drainage soil shall be 0.1 cm/sec on slopes less than or equal to 10 percent.

B. As illustrated on the Drawings, the secondary soil drainage layer design consists of a minimum 12-inch thick layer of soil drainage media.

C. The secondary soil drainage layer shall be free of organic material and comprised of clean, sound, coarse sand and shall be free of slag or any other materials capable of damaging the secondary geocomposite layer. The coarse sand material used for the secondary drainage layer shall be in general conformance with the following gradation:

| **Sieve Size** | **Percent Passing By Weight** |
|---|---|
| No. 4 | 80-100 |
| No. 16 | 30-70 |
| No. 100 | 0-10 |
| No. 200 | 0-5 |

D. Along a 1-foot wide strip centered along the collection pipes, the secondary drainage blanket shall consist entirely of a minimum 12-inch thick ¾ inch nominal stone layer.

## 2.2 TESTING

A. The CONTRACTOR will be responsible for all initial testing of the primary drainage layer materials. The testing required shall be completed on at least one sample of the material, and will include:

1. Grain Size (Stone) ASTM D422
2. Permeability (ASTM D2434 or as approved by the PROJECT ENGINEER)

B. The initial test information shall be submitted, reviewed, and approved by the PROJECT ENGINEER before the material is used in the construction. No material shall be placed unless approved by the PROJECT ENGINEER.

C. The sand supplier shall provide one grain size analysis (ASTM D 422) for each 1,000 cubic yard block of material delivered and installed, for review by the PROJECT ENGINEER.

Additional sampling and testing shall be taken from delivered, stockpiled and installed materials as required by the project CQA/CQC Plan.

# PART 3 EXECUTION

## 3.1 INSTALLATION - LEACHATE COLLECTION SYSTEM BLANKET DRAIN

A. This item shall consist of the placement of the secondary soil drainage layer over the secondary geocomposite drainage layer. The CONTRACTOR shall provide all the required materials, labor, and equipment to perform the work in accordance with these Specifications.

B. The secondary soil drainage layer shall be installed as shown by the details in the Drawings. The primary drainage layer shall cover the base of the lined area as illustrated in the Drawings.

C. No material shall be placed until the PROJECT ENGINEER has approved the installation of the underlying secondary geocomposite layer.

D. The secondary soil drainage layer shall be placed directly above the secondary geocomposite drainage layer in 12-inch minimum lifts.

E. The CONTRACTOR shall use extreme care in the placing of the secondary soil drainage layer over the secondary geocomposite layer. The material shall be placed in a manner that will maintain a minimum thickness of 1 foot of material between the secondary geocomposite and the spreading equipment. Only tracked equipment shall be allowed on the 1 foot thick aggregate layers. Access roads used to deliver aggregate materials over previously constructed liner shall have a minimum thickness of 3 feet. All equipment to be used in this operation shall be low ground pressure equipment and be approved by the PROJECT ENGINEER.

F. The CONTRACTOR shall take care to ensure that:

1. The secondary geocomposite remains intact during the installation of the secondary soil drainage layer;

2. During installation of the secondary soil drainage layer, the maximum geomembrane wrinkle size shall not exceed three-inches or a height to width ratio of 0.5, or as deemed acceptable by the PROJECT ENGINEER. The height of the wrinkle shall be measured from the base or subgrade to the peak of the wrinkle. The width of the wrinkle shall be as measured along its base. The geomembrane wrinkle must be trapped during stone installation to prevent spreading and enlargement. The geomembrane wrinkles should not be folded over during secondary soil drainage layer stone installation.

3. No foreign objects or material is mixed into the secondary soil drainage layer, in any significant amount as determined by the PROJECT ENGINEER, which may produce clogging or restrict the ability of the layer to transmit water or leachate.

4. No vehicles shall drive on the uncovered secondary geocomposite, unless previously approved in writing by the PROJECT ENGINEER.

# PART 4 QUALITY ASSURANCE/QUALITY CONTROL

## 4.1 GENERAL

A. The PROJECT ENGINEER will develop and maintain a construction control grid. The control grid shall have defined positions across the area of the proposed baseliner. All aspects of construction shall be referenced to the control grid including, but not limited to, tops and toes of slope, leachate collection headers, laterals and cleanout risers, berms, manholes, roadways and culverts. The construction control grid shall be established in rectangular coordinates, and lie in the same orientation to, and with an established relationship to, the site grid.

B. The PROJECT ENGINEER shall have grain-size analyses performed on installed secondary soil drainage layer samples as specified in the project CQA/CQC Plan.

C. The thickness of the secondary soil drainage layer as measured perpendicular to the slope of the liner system shall be determined by random excavation, or by instrument survey. The locations of all hand excavations and/or survey points shall be determined and documented by the Geotechnical Construction Observers, and plotted on a plan area map of the landfill.

D. A laboratory permeability test shall be performed during construction at a frequency that results in a total of at least one test for every 2,500 cubic yards of material delivered and placed, in accordance with the project CQA/CQC Plan.

END OF SECTION

# SECTION 02276

# SOIL LINER

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools and appurtenances required to complete the work of supplying, placing and compacting material for the low permeability soil liners as shown, specified or required.

### 1.2 RELATED SECTIONS

A. Section 02222 – Subgrade

B. Section 02277 – Test Pad

C. Section 02278 – Geosynthetic Clay Liner

D. Section 02597 – HDPE Geomembrane

E. Section 02595 - Geotextile

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM)

1. D422 Standard Test Method for Particle-Size Analysis of Soils

2. D1557 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft$^3$ (2,700 kN-m/m$^3$))

3. D2216 Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock By Mass

4. D4318 Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index Of Soils

5. D5084 Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

6. D6938 Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

B. United States Army Corps of Engineers (USACOE)

1. EM-1110-2-1906 Constant Head Permeability Test (in Triaxial Cell with Back Pressure Saturation – Low Permeability Soils)

C. The most current version of the specified test method shall be followed by the EARTHWORK CONTRACTOR or authorized testing laboratory

### 1.4 TOLERANCES

A. The minimum completed, compacted thickness of the secondary soil liner shall be 24 inches, and the minimum thickness of the primary soil liner, if used, shall be 6 inches. Thickness tolerances for both the primary and secondary soil liners are +3 inches, provided the minimum slope of the soil liner surface is maintained.

B. The slope of any soil liner shall be as specified in the Drawings and within the tolerance limits included in the project CQA/CQC Plan. This slope shall be as measured between any two points at least 50 feet distant.

C. The maximum acceptable compacted soil liner lift thickness shall be as determined by Test Pad construction as specified in Section 02277, with the exception of the first lift of any soil liner directly overlying liner system geosynthetics, in which case the default maximum lift thickness shall be 12 inches.

### 1.5 DELIVERY, STORAGE AND HANDLING

A. All soil designated for use as low permeability soil liner shall be delivered, stored, and handled in a manner that will prevent contamination by other soils or deleterious materials.

## PART 2 PRODUCTS

### 2.1 SOIL

A. The soil liner shall be constructed with natural clayey soils obtained on-site or from an off-site source. Natural clayey soil means a fine-grained soil containing sufficient plastic fines on the order of 20 percent or greater such that the soil acts as a clay and will readily achieve the specified maximum permeability requirements. The soil is typically classified as a CL or CH (Unified Soil Classification System), with a liquid limit between 25 to 50, placed above the

A-line on the plasticity chart and a minimum plastic index of 10; however, the governing characteristic shall be that the soil is capable of achieving and maintaining the required permeability.

B. All soil liner material shall be free from organic matter, wood, trash, and other objectionable substances which may be compressible or which cannot be properly compacted. It shall not contain blocks, broken concrete, masonry rubble or other similar materials. It shall have physical properties such that it can be readily spread and compacted to achieve the specified permeability. Snow, ice, and frozen soil shall not be permitted.

C. The maximum particle (stone) size for the lowermost portion of the secondary soil liner shall be three inches. The maximum particle size for soil in contact with the geomembrane shall be one-inch.

# PART 3 EXECUTION

## 3.1 SOIL PLACEMENT

A. The permeability of the in-place soil liner shall not exceed $1 \times 10^{-7}$ cm/sec.

B. Soil liners shall be graded and compacted to a uniform lift thickness no greater than the maximum lift thickness approved by the PROJECT ENGINEER based on the results of the test pad specified by Section 02277. All soil liner lifts shall be placed, and compaction shall be performed, in a manner that properly controls moisture content, lift thickness, compactive/kneading action to effectively control soil clod size and eliminate lift interfaces. Soil clods, if found, must not exceed either one-half the lift thickness or a maximum of four-inches, in maximum dimension, and must be isolated within the matrix of the soil liner so as not to create a void. Hauling and spreading equipment will not be considered as compaction equipment.

C. The CONTRACTOR shall continue to place and compact lifts of soil liner to form a uniform upper surface to the requirements of the grading plan. The upper surface of each lift shall be scarified, dried or hydrated as required to provide proper adhesion and bonding to subsequently placed lifts of soil liner as determined by the PROJECT ENGINEER.

D. The soil liner shall be placed so as to minimize ponding of rainfall and runoff. Where ponding has occurred, the CONTRACTOR shall remove the excess water prior to continuing operations in those areas. Any soil material that has become too wet for proper placement and compaction, as determined by a failure to meet the requirements of Article 3.2H, shall be removed or dried prior to placement of additional material.

E. The top lift of soil liner shall be placed and finished to a smooth, uniform appearance reasonably free of cracks or other openings that would promote drying of underlying layers.

Desiccation cracks with a depth or width in excess of one-half inch on any lower lifts shall be reworked and moisture/density field tests will be performed and/or Shelby tube/block samples obtained at the discretion of the PROJECT ENGINEER. Bentonite can be used to fill cracks only in the event of sporadic and isolated cracking. Desiccation cracks on the top lift that exceed one-half inch, shall be remediated. Excessive desiccation of an area of soil liner shall be prevented by covering the completed area of soil liner as soon as practical after acceptance of the soil liner area by the PROJECT ENGINEER.

F. The CONTRACTOR shall restrict vehicular traffic or equipment operation on finished soil liner areas except as required for redressing or placement of overlying liner system components. Those areas, which are completed and approved by the PROJECT ENGINEER, shall be identified and marked along the perimeters by suitable means. The PROJECT ENGINEER will maintain documentation identifying completed areas.

G. No soil liner material shall be placed in a frozen state, or on any material that has become frozen. All frozen material shall be completely removed prior to placement of additional soil liner.

H. In-place soil liner which fails to meet the specified thickness, density, moisture content or permeability requirements, or exhibits excessive cracking, drying, or other damage prior to covering by the overlying material shall be reworked, or removed and replaced by the CONTRACTOR according to the Specifications.

## 3.2 QUALITY CONTROL/QUALITY ASSURANCE

A. The PROJECT ENGINEER shall maintain a construction control grid having defined positions across the liner system construction area. All aspects of construction shall be referenced to the control grid, including but not limited to, moisture-density test locations, Shelby tube (or other) sample locations, soil placement areas and tops/toes of slope. The construction control grid shall be established in rectangular coordinates and lie in the same orientation as the site grid.

B. The CONTRACTOR shall submit to the PROJECT ENGINEER, for his approval, evidence that the proposed soil liner material meets the requirements of this Specification. This evidence shall include, but not necessarily be limited to, the following test results performed on at least one sample from the proposed borrow source:

| | |
|---|---|
| Atterberg Limits | ASTM D4318 |
| Grain Size Distribution | ASTM D422 |
| Moisture Content | ASTM D2216 |
| Modified Proctor | ASTM D1557 |
| Permeability | USACOE EM 1110-2-1906<br>or, ASTM D5084 |

If the test data indicates the proposed soil may not be suitable for use in constructing the low permeability soil liners, the CONTRACTOR shall submit information as noted above for soil from an alternative borrow source.

C. Upon approval of the CONTRACTOR's Quality Control soil test data, the PROJECT ENGINEER shall obtain additional samples for conformance testing. The number of conformance samples collected shall be specified by the project CQA/CQC Plan. Upon receipt of the initial conformance test data, the PROJECT ENGINEER shall prepare a moisture-density-permeability relationship and acceptance window to be used for moisture-density pass/fail criteria during soil liner construction.

D. If the PROJECT ENGINEER determines that soil delivered to the project varies significantly from the soil approved for use, or material is obtained from an alternate source, additional sampling and testing shall be performed on that source as defined above.

E. During the course of construction, the PROJECT ENGINEER shall modify the acceptance window as appropriate. The changes shall be based on the moisture, density and permeability QA data obtained during soil liner placement.

F. Prior to soil liner construction, test pad(s) shall be completed by the CONTRACTOR for the purpose of confirming acceptable construction procedures for soil source and equipment combinations that have not previously been used successfully on the project . The test pad(s) shall be completed in accordance with Section 02277, on a slope(s) representative of the average bottom slope of the soil liner. This could include slopes between approximately 2% and 10%, and slopes between 10% and 33% to simulate soil construction on an embankment slopes. The test pad(s) shall be constructed with the same equipment to be used to construct the soil liner. The thickness of the lifts shall be the maximum lift thickness to be placed and compacted during soil liner installation. The PROJECT ENGINEER shall observe test pad construction, obtain the required data, assess the acceptability of construction procedures and prepare a report to document the findings. To replicate design boundary conditions, the test pad will be installed over installed geosynthetic materials to simulate the final construction. Alternatively, a layer of the proposed boundary material shall be placed below the test pad to model design conditions.

G. Prior to the start of any soil liner construction operations, the PROJECT ENGINEER will review the subgrade QA information, including record survey data and/or drawing(s) showing the elevations and slopes of the underlying subgrade surface. The PROJECT ENGINEER shall check the subgrade for conformance with the requirements of Section 02222, and the grades as required by the design. Soil liner placement shall not begin prior to approval of the subgrade by the PROJECT ENGINEER. The CONTRACTOR shall note any discrepancies and shall plan his operations so that upon completion of the liner, the finish grades conform with the specified slope requirements.

H. Field moisture-density testing shall be performed at a rate of not less than one test for each day of soil liner placement, and at least 9 tests per acre per lift. Test locations must be proportionately distributed throughout the soil liner. Prior to leaving the test area, each test location shall be determined by the Construction Observer to within two feet of its actual

location and plotted on a plan of the work area illustrating the construction control grid. The Construction Observer shall also plot the dry density and moisture content values on the moisture-density-permeability acceptance window. Failing test results are those that plot outside the acceptance window, and shall not be accepted by the PROJECT ENGINEER.

I. The soil liner area determined to have unacceptable moisture or density test results shall be defined by the PROJECT ENGINEER based on a series of soil moisture-density tests designed to delineate the failing area. Once defined by the PROJECT ENGINEER, the failed area shall be reworked (further compact and/or hydrate), or removed and replaced by the CONTRACTOR.

J. Moisture-density tests shall be taken through the full depth of the lift, except where the soil liner is placed above a geosynthetic material. In no case shall a drive pin for the nuclear densometer be advanced closer than three inches above the geosynthetic. In cases where soil liner is placed above a geosynthetic material and moisture-density tests are not taken through the full depth of the lift soil moisture and density will be established by the undisturbed permeability test results. Permeability specimens tested in the lab shall be taken from the lowermost portion of the soil liner adjacent to the geosynthetic.

K. The Construction Observer shall measure the height of the dozer blade above the previous layer or lift to verify the setting on the GPS and the thickness of the layer to be placed that day. In addition, if there is a change in the lift thickness during the day, the Construction Observer shall remeasure the height of the dozer blade above the previous layer or lift. The thickness of each soil lift may be checked by the Construction Observer with random, manual auger holes through the lift. If auger holes are used to determine lift thickness, the location of the lift thickness measurements shall be plotted by the Construction Observer on a plan of the work area illustrating the construction control grid. The final thickness of the soil liner shall be checked by the Construction Observer with random, manual auger holes through the entire soil liner, at locations selected by the PROJECT ENGINEER and/or using surfaces generated in three-dimensional modeling software.

L. Routine in-place soil moisture and density testing will be confirmed by laboratory permeability tests on undisturbed Shelby tube samples or block samples, described further in Section 5.3.6 of the CQA/CQC Plan submitted to the NYSDEC. One constant head laboratory permeability test result shall be obtained per acre per lift of soil liner. The samples shall be taken in the locations selected by the PROJECT ENGINEER to ensure a representative and proportionate distribution of test results for the completed soil liner. The CONTRACTOR shall rework, or remove and replace as directed by the PROJECT ENGINEER, any material with a permeability greater than $1 \times 10^{-7}$ cm/sec, as determined by the PROJECT ENGINEER based on his review of the permeability test data, field observations and confirmation of soil liner conditions (that may include additional soil moisture-density measurements and/or undisturbed sampling and laboratory testing activities).

M. The CONTRACTOR shall provide the heavy equipment required for Shelby tube and/or block sampling; including but not limited to, a bulldozer and operator and shall assist and cooperate with the PROJECT ENGINEER for all sampling and testing activities. If required, the

CONTRACTOR shall restrict operations in designated areas to allow for additional sampling and testing (moisture-density and permeability).

N. All penetrations of the soil liner resulting from nuclear moisture-density testing and Shelby tube sampling shall be sealed using bentonite approved by the PROJECT ENGINEER. The bentonite shall be rodded into the open hole. The CONTRACTOR shall backfill block sample excavations with soil liner material, and compact the soil using the same procedures required during initial placement.

O. All soil liner that, after placement and prior to covering, is determined by the PROJECT ENGINEER to be unsuitable (i.e., too wet, too dry, excessive cracking or otherwise compromised), shall be repaired by the CONTRACTOR to the satisfaction of the PROJECT ENGINEER and in conformance with the provisions of these Specifications.

END OF SECTION

# SECTION 02277

# TEST PAD

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The CONTRACTOR shall furnish all labor, materials, equipment, tools and appurtenances required to complete the work of constructing pre-soil liner installation test pad(s).

B. The purpose of the test pad(s) is to evaluate the materials, methods and equipment proposed by the CONTRACTOR to install the soil liner, and to document that the materials, methods, and equipment proposed by the CONTRACTOR are adequate to meet the project requirements.

### 1.2 RELATED SECTIONS

A. Section 02222 – Subgrade

B. Section 02227 – Subgrade Soil Barrier

C. Section 02276 - Soil Liner

### 1.3 SUBMITTALS

A. The CONTRACTOR shall provide to the PROJECT ENGINEER the following items:

1. At least 3 days prior to test pad construction, the PROJECT ENGINEER shall be notified of when and where the test pad work will be conducted. The notification shall specify the soil source that will be used to construct the test pad(s) in accordance with the requirements of this Section.

2. At least 2 days prior to construction of the test pad(s), results of the pre-qualification material testing program required by Section 02276.

3. If the test pad is to be completed in an area of the landfill to be included in the certified construction, the PROJECT ENGINEER must prepare or be supplied with a survey showing the location and extent of the test pad subgrade such that any additional testing (e.g. proof rolling, moisture-density, etc.) and approval of the subgrade can be completed prior to test pad construction. The location shown on the drawing must be referenced to the survey control network developed for the project.

4. The NYSDEC shall be notified by the PROJECT ENGINEER of the time and place of test pad construction a minimum of 3 days in advance of the work.

## PART 2 MATERIALS

### 2.1 GENERAL

A. The CONTRACTOR shall construct the test pad(s) with the materials identified and approved by the PROJECT ENGINEER for construction of the soil liner, as specified in Section 02276.

## PART 3 EXECUTION

### 3.1 SITE PREPARATION

A. The CONTRACTOR shall construct the test pad(s) on subgrade conditions that mimic those of the actual soil liner construction, and in a location approved by the PROJECT ENGINEER. If a test pad is constructed in an area where it will become part of the soil liner, the subgrade shall be prepared, observed, evaluated and approved in accordance with the requirements of Section 02222.

### 3.2 INSTALLATION

A. The test pad(s) shall be constructed in a manner that is representative of the manner in which the soil liner will be installed for the project. One test pad shall be required for each soil source/construction methodology/equipment combination. The test pad process may be used to evaluate alternate sources, methods and equipment combinations; however, the PROJECT ENGINEER must obtain separate sets of data and record individual observations for each test pad. All procedures, equipment and soil materials that will be used in the construction of the test pad shall be consistent with the requirements of Section 02276.

B. The test pad(s) shall be completed on a slope(s) representative of the average bottom slope of the soil liner. This includes two ranges of grade; the first for slopes between approximately 2% and 10%, and the second for slopes between 10% and 33% to simulate soil construction on an embankment slope. The test pads shall be at least 30 feet wide and 80 feet long, or as required to allow placement and compaction equipment to reach normal operating speed before entering the area to be tested and sampled by the PROJECT ENGINEER.

C. The test pad shall demonstrate that the CONTRACTOR can meet the material, construction, and quality requirements of Section 02276. If there is a change in borrow soil, construction methodology, equipment or construction conditions, as determined by the PROJECT ENGINEER, a new test pad shall be required.

D. The CONTRACTOR shall assist and cooperate with the PROJECT ENGINEER during all sampling and testing activities.

E. The CONTRACTOR shall protect the test pad until the soil liner material, and the method of installation, have been approved by the PROJECT ENGINEER.

## PART 4 QUALITY CONTROL

### 4.1 GENERAL

A. The testing protocol described in Section 02276 for the Soil Liner, except as modified by this Section, shall be applied to the test pad to monitor and document the construction quality of the test pad.

### 4.2 OBSERVATIONS, SAMPLING AND TEST REQUIREMENTS

A. The following techniques shall be followed (unless modified by the CONTRACTOR and approved by the PROJECT ENGINEER) in the construction of each test pad:

1. The borrow area loading procedure shall be developed to produce a soil material with a manageable clod size such that remaining clods can readily be destroyed during the CONTRACTOR's proposed grading and compaction process.

2. The soils shall be hauled to the test pad location and graded by multiple passes of the bulldozer to grade the soil uniformly throughout the test pad area. The soil shall be compacted in a manner that destroys soil clods, eliminates lift interfaces and prevents the formation of observable voids in the completed lifts as determined by the PROJECT ENGINEER.

3. The soil shall be graded to a lift thickness that represents the maximum lift thickness to be allowed during soil liner installation, but in no case greater than 12 inches.

4. The test pad shall consist of at least 2 lifts. The second or subsequent lift(s) shall be placed, graded and compacted in the same manner as the initial lift.

5. The upper surface of the lower lift(s) shall be scarified, and hydrated/dried as required, prior to the placement of an overlying lift, in the same manner as will be carried out during soil liner installation.

B. The PROJECT ENGINEER shall obtain measurements and samples during test pad construction, as follows:

1. Measure and record the overall size of the test pad. Measure and record individual loose and compacted lift thickness.

2. A minimum of one bulk sample per soil type shall be obtained for laboratory testing of liquid and plastic limit, modified Proctor moisture-density relationship and grain-size distribution. Such samples and data will be used to help meet the sampling and testing frequencies required for the installed soil liner.

3. At least two soil moisture and density measurements shall be obtained from the test pad soils after each pass of the compactor. The PROJECT ENGINEER will use this information to help evaluate the effects of additional passes of the equipment on soil moisture and density. The number of passes shall be sufficient to allow the soil moisture and density measurements to plot within the initial acceptance window developed by the PROJECT ENGINEER.

4. Soil samples shall be obtained in accordance with the requirements of the gauge manufacturer for the purpose of calculating moisture corrections for the test equipment.

5. A minimum of one Shelby tube sample per lift per test pad shall be obtained for laboratory permeability testing. The PROJECT ENGINEER shall advance the Shelby tube sampler through the entire lift such that the lowermost portion of the lift will be included in the sample recovery. In the event unacceptable sample compression occurs in the sample while advancing the tube, the PROJECT ENGINEER shall modify the sampling technique (e.g. to remove the upper portion of the lift in the sample area) to obtain a reasonably undisturbed sample for laboratory testing. The PROJECT ENGINEER shall instruct the laboratory to obtain the laboratory permeability specimen from the lowermost portion of the tube sample.

6. Two test holes shall be excavated to the entire depth of each lift to evaluate and document the effectiveness of any kneading action in the soil matrix, and soil clod destruction. Photos shall be taken to document the absence and/or presences of voids or clods remaining in the constructed test pad.

C. The PROJECT ENGINEER shall observe and document the CONTRACTOR's test pad construction procedures, as follows:

1. Complete notes and obtain photographs documenting the soil type, equipment used, placement techniques, sampling and testing procedures;

2. Document the grading technique employed and results achieved by the bulldozer (e.g. distance of grading the end dumped material, number of passes to obtain lift thickness, effectiveness in reducing clod size, etc.);

3. Record compaction equipment specifications, including model, total static weight, drum type, drum width and foot length;

4. Document the number of passes made by the compactor to achieve the measured soil densities;

5. Observe and record borrow area soil loading method, mixing method (if any) and resulting maximum clod size;

6. Observe and record procedures for lift surface scarification and preparation, including the resulting scarification depth and distribution. Excavate exploratory holes in the pad to establish the presence or absence of seams between lifts; and,

7. Observe and record compaction equipment speed and mode (i.e. static or vibratory).

D. Information obtained from test pad construction will be assembled by the PROJECT ENGINEER into a manner suitable for submission to the NYSDEC, and shall confirm the materials, lift thickness and construction methods for soil liner placement are adequate to meet the requirements of Section 02276. The test pad information shall be made available to the NYSDEC prior to soil liner construction.

E. Additional sampling, testing and documentation will be performed as directed by the PROJECT ENGINEER. In the event the test pad is constructed within the liner area, the CONTRACTOR shall rework, or remove and replace any test pad material with a hydraulic conductivity greater than $1 \times 10^{-7}$ cm/sec.

END OF SECTION

# SECTION 02278

# GEOSYNTHETIC CLAY LINER

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The GEOSYNTHETICS CONTRACTOR shall furnish all labor, required materials, equipment, tools, and appurtenances required to complete the installation of all geosynthetic clay liner (GCL) layers as shown on the Drawings. The OWNER will purchase the GCL material and the powdered bentonite. Procurement and delivery of these materials will be at the direction of the PROJECT ENGINEER.

### 1.2 RELATED SECTIONS

A. Section 02595 – Geotextile

B. Section 02781 – LLDPE Geomembrane

C. Section 02599 - Geocomposite Drainage Layer

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM):

1. D4354 Standard Practice for Sampling of Geosynthetics and Rolled Erosion Products (RECPs) for Testing

2. D6768 Standard Test Method for Tensile Strength of Geosynthetic Clay Liners

3. D6496Standard Test Method for Determining Average Bonding Peel Strength Between the Top and Bottom Layers of Needle Punched Geosynthetic Clay Liners of Geosynthetic Clay Liners

4. D4643 Standard Test Method for Determination of Water (Moisture) Content of Soil by Microwave Oven Heating

5. D4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples

6. D5084 Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

7. D5262 Standard Test Method for Evaluating the Unconfined Tension Creep and Creep Rupture Behavior of Geosynthetics

8. D5321 Standard Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear

9. D5887 Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter

10. D5888 Standard Guide for Storage and Handling of Geosynthetic Clay Liners

11. D5889 Standard Practice for Quality Control of Geosynthetic Clay Liners

12. D5890 Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners

13. D5891 Standard Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners

14. D5993 Standard Test Method for Measuring Mass Per Unit of Geosynthetic Clay Liners

15. D6072 Standard Practice for Obtaining Samples of Geosynthetic Clay Liners

16. D6243 Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method

17. D6495 Standard Guide for Acceptance Testing Requirements for Geosynthetic Clay Liners

18. D6766 Standard Test Method for Evaluation of Hydraulic Properties of Geosynthetic Clay Liners Permeated with Potentially Incompatible Aqueous Solutions.

B. GRI Standards:

1. GRI-GCL3 Test Methods, Required Properties, and Testing Frequencies of Geosynthetic Clay Liners (GCLs)

2. GRI-GCL4 - Gripping of Reinforced GCLs to End Platens During Direct (Interface) Shear Testing

C. The most current version of the specified test method shall be followed by the MANUFACTURER, PROJECT ENGINEER, GEOSYNTHETICS CONTRACTOR and/or all authorized testing laboratories

## 1.4 DEFINITIONS

A. Minimum Value – Property value representing the lowest individual allowable value obtained when tested according to the specified test method. This applies to individual readings, such as thickness; or, where only one specimen is tested for the specified parameter.

B. Minimum Average Value – Property value representing the lowest allowable value for the average of results for the specimens tested.

C. Minimum Average Roll Value (MARV) – Property value calculated as the average test result minus two standard deviations. Statistically, this implies a 97.5 percent confidence that any specimen tested during quality assurance will exceed the value reported.

D. Nominal Value – Property value that is representative of a measurable property, determined under a set of prescribed test conditions, by which a product may be described.

E. Typical Roll Value – Property value calculated as the average or mean obtained from test data.

## 1.5 SUBMITTALS

A. The GEOSYNTHETICS CONTRACTOR shall submit to the PROJECT ENGINEER all items included in this Article. Submittals shall be provided as follows:

1. Submitted with the BID:

   a. A project reference list demonstrating the GEOSYNTHETICS CONTRACTOR'S experience on a minimum of 5 projects, totaling at least two million square feet of installed GCL.

   b. Minimum installation crew list including how many crew members in each job classification will be required to perform the work. Although the minimum crew size may be increased by the GEOSYNTHETICS CONTRACTOR, at no additional cost to the OWNER, the crew may not be decreased without prior approval by the PROJECT ENGINEER.

   c. Resumes summarizing prior experience in installing GCL for all key GCL installation crew members, including Supervisor, Foreman and QC Technician. GCL installation staff will be subject to approval by the PROJECT ENGINEER and OWNER. Include resumes of all potential key GCL installation crew members that might be anticipated to work on this project.

2. Fifteen days prior to mobilization to the site, unless stated otherwise below:

   a. Shop drawings including details of overlapping, seaming, and anchoring, if required by the contract documents or at the OWNERS request.

   b. Resumes summarizing prior experience in installing GCL of all GCL installation crew members that will be mobilized to the site. GCL installation staff will be subject to approval by the PROJECT ENGINEER and OWNER. Resumes of any additional crew members required during the course of work shall be submitted to the PROJECT ENGINEER for approval. The additional

crew member(s) will be restricted to general laborer duties until approved by the PROJECT ENGINEER

3. Upon Completion

   a. Summary and log of all field quality control data and information obtained by the GEOSYNTHETICS CONTRACTOR.

   b. Statement of installation warranties.

B. The MANUFACTURER shall submit to the PROJECT ENGINEER all items included in this Article. Submittals shall be provided as follows:

1. Submitted upon material selection and prior to delivery to the site:

   a. A statement of the GCL MANUFACTURER'S experience, including the manufacturing and supplying company's name, address, and employee contacts.

   b. A copy of the GCL MANUFACTURER'S Manufacturing Quality Assurance/Manufacturing Quality Control (MQA/MQC) Plan.

   c. Long term creep test (ASTM D5262) data demonstrating a maximum 4 mm displacement of the upper geotextile from lower geotextile when placed under a normal load of 500 psf, and a constant shear of 350 lbs over a 10,000-hour period.

   d. Samples of the proposed GCL shall be sent to the OWNER for interface shear testing within 5 days after such request is made by the OWNER. The GCL MANUFACTURER shall coordinate the quantity and dimensions of the samples with the OWNER.

2. Fifteen days prior to site delivery, unless stated otherwise below:

   a. Manufacturing Quality Control (MQC) Manufacturing Quality Assurance (MQA) test data for the material to be delivered to the site. The reports shall include the test results for samples obtained prior to and during the manufacture of the material to be delivered to the site. In the event that material is delivered prior to receipt of the manufacturer's quality control certificates, the GCL without quality control certificates will be stored separate from material with certificates. The GCL will be rejected if it does not meet the requirements of this Specification, or if it is found to have defects, rips, holes, flaws, deterioration, or other damage deemed unacceptable by the PROJECT ENGINEER.

   b. A certification from the manufacturer that the manufacturing process used to produce the GCL includes continuous needle detection and a mechanism for removal of detected needles. The certification must include tracking forms for

each roll, demonstrating that the continuous needle detection and removal process has been applied to all GCL supplied to this project.

c. Statement of manufacturing warranties.

d. No material shall be loaded for delivery to the site prior to approval by the PROJECT ENGINEER.

## 1.6 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. The MANUFACTURER shall be responsible for the protection of the GCL against damage during transportation to the site. The OWNER will be responsible for protection of the GCL during storage at the site until the GEOSYNTHETICS CONTRACTOR mobilizes to the site. Once mobilized the GEOSYNTHETICS CONTRACTOR shall be responsible for the protection of the GCL against damage prior to and during its installation until completion of the CONTRACT.

B. GCL labeling, shipment, and storage shall follow ASTM D4873 and D5888, as modified by this Specification.

C. Product labels shall be placed on the ends of the roll such that they can be seen when rolls are stacked, and shall clearly show the manufacturer or supplier name, style name, roll number, and roll dimensions.

D. If any special handling is required, it shall be so marked on the outside surface of the wrapping, i.e., "Do not stack more than three rolls high", etc.

E. The GCL shall be supplied dry (unhydrated, less than 40% moisture content) and be delivered to the site undamaged.

F. Each GCL roll shall be wrapped with a material that will protect the bentonite from moisture and the GCL from damage due to shipment, water, sunlight, and contaminants. The protective wrapping shall be maintained during periods of shipment and storage.

G. Storage areas shall be stable, dry, relatively flat, and well drained. During storage, the GCL rolls shall be adequately covered and protected from the following:

1. Site construction damage;

2. Exposure to ultraviolet (UV) radiation in excess of 14 days;

3. Precipitation;

4. Chemicals that are strong acids or strong bases;

5. Flames, sparks, temperatures in excess of 49 deg C (120 deg F); and,

6. Any environmental condition that might damage the GCL.

H. The GEOSYNTHETICS CONTRACTOR shall protect the work described in this Section before, during, and after installation, and shall protect the installed work specified in other Sections as well as work completed by the OWNER. Only non-damaged, sufficiently dry material (as determined by the PROJECT ENGINEER) shall be included within the construction.

I. Roll numbers on partially used rolls shall be maintained such that each GCL roll number can be readily identified just prior to deployment of the remaining portions of the roll.

J. If the PROJECT ENGINEER determines the GCL is damaged, the GEOSYNTHETICS CONTRACTOR shall make all repairs and replacements in a timely manner so as to prevent delays in the progress of the work. Any material damaged by the GEOSYNTHETICS CONTRACTOR or damaged by others due to improper installation or protection, shall be replaced by the GEOSYNTHETICS CONTRACTOR at no additional cost to the OWNER.

K. Upon delivery, the PROJECT ENGINEER will examine the rolls of GCL and obtain archive samples. Archive samples will be a minimum of three feet long by three feet wide.

## 1.7 QUALITY ASSURANCE SAMPLING, TESTING AND ACCEPTANCE

A. Interface and internal shear strength testing of the GCL is the responsibility of the OWNER. All shear strength testing must be completed prior to installation of the materials. Testing for interfaces involving GCL shall be conducted according to ASTM D6243. The results must comply with the criteria required by the OWNER, as specified on the Drawings.

# PART 2 MATERIALS

## 2.1 GENERAL

A. The GCL shall consist of a reinforced, needle punched composite of natural granular sodium bentonite clay encapsulated between two geotextiles. The bentonite and finished product requirements are described in the following Parts, including the minimum Manufacturing Quality Assurance (MQA) and Manufacturing Quality Control (MQC) testing.

B. The GCL MANUFACTURER shall provide the PROJECT ENGINEER with certified laboratory data sheets for MQA/MQC testing described in this Part.

C. Overlap lines should be printed on both edges of the geotextile surface of the manufactured GCL. The overlap lines are minimally 150mm (6.0in.) from the edges of the GCL.

## 2.2 BENTONITE

A. The bentonite used in the GCL shall be a natural granular (powdered bentonite shall not be used in the manufacture of the GCL) sodium bentonite. The table presented in 2.2B

represents the minimum required Manufacturing Quality Assurance (MQA) testing that must be conducted by the GCL MANUFACTURER on the bentonite portion of the GCL.

B. The bentonite shall be tested in accordance with ASTM D5889 for "Clay" as modified by the following table. Testing shall be conducted as listed in the following table and must meet the specified values:

| PROPERTY | TEST METHOD | VALUE |
|---|---|---|
| Swell Index, mL/2g (min). | ASTM D5890 | 24 |
| Fluid Loss, ml (max) | ASTM D5891 | 18 |

## 2.3 GEOSYNTHETIC CLAY LINER

A. The following table represents the minimum required MQC testing that must be conducted by the GCL MANUFACTURER on the GCL. The GCL shall be tested in accordance with ASTM D5889 as modified by the following table. Testing shall be conducted as listed in the following table and must meet the specified values:

| PROPERTY | TEST METHOD | VALUE |
|---|---|---|
| Bentonite Mass / Area, dried [(1)], $lb/ft^2$ (min. avg.) | ASTM D5993 | 0.75 |
| Clay Moisture Content, % (max) | ASTM D5993 | 35 |
| GCL Tensile Strength [(2)], lbs/in. (min. avg.) | ASTM D6768 | 30 |
| Index Flux, $cm^3/cm^2/sec$ (max) | ASTM D5887 | $1x10^{-6}$ |
| Permeability, cm/sec (max) | ASTM D5887 | $5x10^{-9}$ |
| GCL Peel Strength, lbs/in. (min. avg.) | ASTM D6496 | 3.5 |
| GCL Hydrated Internal Shear Strength (min) | ASTM D6243 | 500 psf |

1. Dried bentonite is defined as 0 % moisture content.
2. Tensile testing performed in machine direction.

B. The manufacturing process shall include a mechanism for needle detection and needle removal. This mechanism shall be in operation throughout the production of all GCL rolls to be delivered to this site. The GCL MANUFACTURER shall issue a certification including a tracking form for each roll, demonstrating that the continuous needle detection and removal process has been applied to all GCL supplied to this project.

## PART 3 EXECUTION

### 3.1 SITE PREPARATION

A. Prior to the placement of the GCL, representatives of the PROJECT ENGINEER, GEOSYNTHETICS CONTRACTOR and the EARTHWORK CONTRACTOR will inspect the surface to be covered by the GCL. The surface to be covered by the GCL shall be cleared of sharp objects, angular stones sticks, or any materials that may contribute to punctures, shearing, rupturing or tearing of the geosynthetic materials. The GCL subgrade shall have a smooth, finished surface, free from pockets, holes, soft spots, ruts greater than 1 inch in depth, discontinuities that will cause bridging and overstress the material, and substantially free of loose soil as determined by the PROJECT ENGINEER. The subgrade shall be inspected for unsuitable areas or soft spots before the GCL is placed. The GEOSYNTHETICS CONTRACTOR is cautioned that placement of the GCL over any subgrade approved by the PROJECT ENGINEER constitutes acceptance of the subgrade by the GEOSYNTHETICS CONTRACTOR. Acceptance of the GCL subgrade transfers responsibility for protecting that surface as well as the GCL surface itself to the GEOSYNTHETICS CONTRACTOR for the duration of the CONTRACT. Should the GEOSYNTHETICS CONTRACTOR place GCL over an area not approved by the PROJECT ENGINEER, the GEOSYNTHETICS CONTRACTOR assumes responsibility for all costs associated with removal and replacement of the GCL as well as the subgrade surface preparation including but not limited to labor and equipment.

B. All subgrade approved by the PROJECT ENGINEER and not covered with GCL by the GEOSYNTHETICS CONTRACTOR will be protected against damage by the GEOSYNTHETICS CONTRACTOR at no additional cost to OWNER.

### 3.2 INSTALLATION

A. The GEOSYNTHETICS CONTRACTOR shall furnish the GCL roll number to the PROJECT ENGINEER prior to the installation of each panel.

B. The GEOSYNTHETICS CONTRACTOR shall maintain the GCL in a dry state up to and including the time that the primary geomembrane is accepted by the OWNER. The GCL must have, at a minimum, the confining load of the leachate collection system blanket drain in place prior to hydration.

C. GCL shall not be placed on wet subgrade. Any GCL that becomes softened prior to covering with geomembrane shall be removed and replaced by the GEOSYNTHETICS CONTRACTOR at no additional cost to the OWNER. In the event softening occurs prior to placement of the leachate collection system blanket drain, all softened GCL must be removed and replaced with “dry” material.

D. When a textured geomembrane is installed over the GCL, a slip sheet shall be used to minimize raveling of the GCL, unless the GEOSYNTHETIC CONTRACTOR demonstrates fraying or damage will not occur to the GCL.

E. The GEOSYNTHETICS CONTRACTOR shall install only as much GCL as can be covered and protected by the overlying geomembrane. The GEOSYNTHETICS CONTRACTOR shall sequence placement of the geomembrane so as to prevent damage, hydration, or excessive drying of the GCL. GCL deployment shall be limited during periods of impending wet weather such that a minimum of GCL is uncovered at any given time.

F. The GCL panels shall be installed free of tension and without folds or creases. Panels shall be staggered such that cross seams between panels are not continuous throughout the lined area.

G. The GCL seams shall be constructed by overlapping adjacent edges of the panels and adding granular bentonite as described in Item H below. Care shall be taken to ensure that the overlap zone is not contaminated with loose soil or other debris. The minimum dimension of the longitudinal overlap shall be 6 inches. End-of-roll overlapped seams shall be similarly constructed, but the minimum overlap shall measure 24 inches. All overlap lengths shall be as required to ensure a continuous GCL system after potential dehydration of the GCL due to overlying geomembrane placement. The GEOSYNTHETICS CONTRACTOR is advised that the PROJECT ENGINEER will complete a field test using site specific materials to define an adequate overlap prior to installation. Seams at the ends of the panels shall be constructed such that they are shingled in the direction of the grade such that the down slope panel is overlapped by the panel immediately upslope.

H. Bentonite enhanced seams shall be constructed between the overlapping adjacent panels described above. This bentonite enhanced seam can consist of a manufactured slice in the edges of the GCL that allows for expansion of the bentonite in the composite if not the seam area between the panels. If a manufactured slice in the edges of the GCL is not available, then a continuous bead of granular sodium bentonite shall be applied along a zone defined by the edge of the underlying panel and the 6-inch line. A similar bead of granular sodium bentonite shall be applied at the end-of-roll overlap. The granular bentonite shall be applied at a minimum rate of one quarter pound per lineal foot.

I. The GEOSYNTHETICS CONTRACTOR shall be responsible for the protection of the GCL during the installation. In no way shall any tracked equipment, or any other equipment which may pose a risk of puncturing, tearing, or otherwise damaging the GCL, be permitted to operate on the GCL.

J. Should any tear exceed 10% of the width of the panel, that portion of the panel roll will be removed and replaced. Care will be taken to remove any soil or other material that may have penetrated the torn GCL.

K. Any use of ATV's or other similar vehicles on the site must be pre-approved by the PROJECT ENGINEER. The GEOSYNTHETICS CONTRACTOR shall submit an S.O.P. describing how vehicles are to be used, if at all, in the deployment of GCL at the site. As a minimum, the following shall apply:

1. Any damage resulting from the use of vehicles, as determined by the PROJECT ENGINEER, shall be repaired according to Article 3.3, at no additional cost to the OWNER. If repeated repairs are required as the result of the use of vehicles operating on geosynthetic material, further use of such vehicles will be prohibited.

2. Any and all vehicles proposed to be used in the deployment of geosynthetics will be inspected by the PROJECT ENGINEER. Vehicles which are found to be leaking oil or fuel, or which in any other way exhibit the potential to damage the lining system components, will not be permitted.

3. Any GCL on which oil or fuel has leaked shall be removed by the GEOSYNTHETICS CONTRACTOR, and the geosynthetic material shall be replaced, at no additional cost to the OWNER.

4. Re-fueling of vehicles on geosynthetic materials is prohibited.

5. Vehicles shall have tires with low ground pressure, typically less than 5 psi, and shall have shallow treads.

6. Vehicles shall be operated by a single operator at speeds less than 5 mph.

7. Quick starts, stops, spinning wheels and sharp turns will not be permitted above any geosynthetic material.

## 3.3 REPAIRS

A. Repairs are to be made as soon as possible after deployment.

B. Damage to the GCL shall be repaired in the following manner:

1. The damaged area shall be cleared of dirt and debris.

2. A patch of GCL shall be cut to extend a minimum of 12 inches beyond the damaged area.

3. Granular bentonite shall be placed around the perimeter of the damaged area at a rate of 0.5 pounds per linear foot.

4. The patch shall be placed over the damaged area and secured with an adhesive to keep the patch in position as the overlying geomembrane is installed. The adhesive shall be approved by the GCL MANUFACTURER and the PROJECT ENGINEER.

# PART 4 FIELD QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

## 4.1 GENERAL

A. Before installation begins, and weekly thereafter, (more often if determined necessary by the PROJECT ENGINEER) project coordination meetings shall be held with the

designated representative of the CONTRACTOR, GEOSYNTHETICS CONTRACTOR, PROJECT ENGINEER, and OWNER in attendance to review the following information:

1. Progress of the work;

2. Adherence to the Specifications;

3. Adherence to the Construction Quality Control Program described in this Section, including the timely submission of the pertinent forms;

4. Planned work and methods for the ensuing week, including estimate of time remaining to completion of the work; and,

5. Problem resolutions to be implemented during the upcoming week.

B. All information specified and required must be submitted to the PROJECT ENGINEER in a timely fashion. No material shall be installed before the interface and internal shear strength results show that the GCL meets the Specifications.

C. Any changes in the proposed method of work, subcontractors to be utilized, manufacturing or materials must be approved in advance by the PROJECT ENGINEER. The GEOSYNTHETICS CONTRACTOR assumes all responsibility relevant to providing an acceptable product.

D. The GEOSYNTHETICS CONTRACTOR, before installation begins, shall appoint an experienced individual who will be on-site at all times during the installation, to represent him in all matters relevant to this work. This individual must have the experience level outlined in Article 1.5.A.1.a of this Section.

E. Any changes in the proposed method of work, manufacturing or GCL material must be approved in advance by the PROJECT ENGINEER.

## 4.2 INSTALLATION QA/QC

A. The GEOSYNTHETICS CONTRACTOR and PROJECT ENGINEER shall inspect the subgrade for unsuitable areas or soft spots before the GCL is placed. Additional subgrade surface cleaning or preparation may be required to eliminate deleterious materials and any unsuitable areas as defined by this Section, or as determined by the PROJECT ENGINEER. The suitability of the subgrade shall be confirmed and documented by signature on a Subgrade Acceptance Form to be administered by the PROJECT ENGINEER."

B. Damage to GCL during installation shall be repaired according to Article 3.3 of this Section. If the PROJECT ENGINEER determines that the damage is un-repairable, the damaged area will be replaced.

C. The PROJECT ENGINEER and GEOSYNTHETICS CONTRACTOR shall visually inspect all material to be included in the work and compare roll identification numbers

with those on the certification provided by the manufacturer to assure delivery of the appropriate material.

D. The GCL shall be inspected continuously by the PROJECT ENGINEER and GEOSYNTHETICS CONTRACTOR for the presence of broken needles in the GCL.

E. All panel seams shall be inspected and approved by the PROJECT ENGINEER prior to covering. The PROJECT ENGINEER shall confirm the overlap length is sufficient to prevent gaps between adjacent GCL panels after potential dehydration due to placement of the overlying geomembrane liner.

F. The PROJECT ENGINEER shall inspect the installed GCL system to ensure the requirements of this Specification have been met. In the event the requirements have not been met, the GEOSYNTHETICS CONTRACTOR shall make appropriate corrections at no additional cost to the OWNER.

## 4.3 WARRANTY

A. The GEOSYNTHETICS CONTRACTOR shall issue a warranty on the installation of GCL for a minimum period of 1 year.

B. The GCL MANUFACTURER shall issue a warranty on the GCL material for a minimum period of 5 years.

END OF SECTION

# SECTION 02595

# GEOTEXTILE

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The GEOSYNTHETICS CONTRACTOR shall furnish all labor, required materials, equipment, tools and appurtenances required to complete the installation of all geotextile material, complete with appurtenances, as shown, specified or required. The OWNER will purchase the geotextile material. Procurement and delivery of these materials will be at the direction of the PROJECT ENGINEER.

### 1.2 RELATED SECTIONS

A. Section 02278 - Geosynthetic Clay Liner

B. Section 02781 – LLDPE Geomembrane

C. Section 02599 - Geocomposite Drainage Layer

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM):

1. D-1883 Test Method for CBR (California Bearing Ratio) of Laboratory Compacted Soils

2. D-4354 Practice for Sampling of Geosynthetics for Testing

3. D-4355 Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus

4. D-4491 Standard Test Methods for Water Permeability of Geotextiles by Permittivity

5. D-4533 Standard Test Method for Trapezoid Tearing Strength of Geotextiles.

6. D-4595 Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method.

7. D-4632 Standard Test Method for Grab Breaking Load and Elongation of Geotextiles

8. D-4751 Standard Test Method for Determining Apparent Opening Size of a Geotextile

9. D-4759 Practice for Determining the Specification Conformance of Geosynthetics

10. D-4873 Guide for Identification, Storage and Handling of Geotextiles

11. D-6241 Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe

12. D4884 Standard Test Method for Strength of Sewn or Bonded Seams of Geotextiles

13. D-5034 Standard Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)

14. D-5035 Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method)

15. D-5261 Standard Test Method for Measuring Mass per Unit Area of Geotextiles

16. D-5321 Standard Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear

B. Geosynthetic Research Institute (GRI):

1. GRI GT12(a) Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials

2. GRI GT13(a) Test Methods and Properties for Geotextiles Used as Separation Between Subgrade Soil and Aggregate.

## 1.4 SUBMITTALS

A. The GEOTEXTILE MANUFACTURER shall furnish a mill certificate to the PROJECT ENGINEER attesting that the cushion (Type C) and separation (Type S) geotextile meet the chemical, physical, and manufacturing requirements specified in Part 2 of this Section. This certification shall be supported by quality control test results of samples obtained during the manufacture of the material to be delivered to the site. The PROJECT ENGINEER will reject geotextile if it does not meet the minimum property requirements or if it is found to have defects, rips, holes, flaws, deterioration or other damage deemed unacceptable.

B. The GEOTEXTILE MANUFACTURER shall furnish the PROJECT ENGINEER with a list of the geotextile material identification requirements itemized in Part 2 of this Section.

C. The GEOSYNTHETICS CONTRACTOR shall furnish the PROJECT ENGINEER with documentation of the thread used to construct geotextile seams. The documentation shall

certify that the thread has chemical resistance properties equal to or exceeding those of the geotextile.

D. In the event the GEOSYNTHETICS CONTRACTOR proposes to use thermal bonding techniques for seaming geotextiles, the PROJECT ENGINEER will require documentation describing the GEOSYNTHETICS CONTRACTOR previous experience with this technique, the method (e.g. wedge welding, hot air, flame) to be used, specifications for the welding equipment and the specific locations where the thermal bonding technique is proposed.

## 1.5 PRODUCT HANDLING

A. The GEOTEXTILE MANUFACTURER shall be responsible for the protection of the geotextile against damage during transportation to the site. The OWNER will be responsible for protection of the GCL during storage at the site until the GEOSYNTHETICS CONTRACTOR mobilizes to the site. Once mobilized the GEOSYNTHETICS CONTRACTOR shall be responsible for the protection of the geotextile against damage prior to and during its installation up to completion of the CONTRACT.

B. Geotextile labeling, shipment, and storage shall follow ASTM D4873 and D5888, as modified by this Specification.

C. Product labels shall be placed on the ends of the roll such that they can be seen when rolls are stacked, and shall clearly show the manufacturer or supplier name, style name, roll number, and roll dimensions.

D. If any special handling is required, it shall be so marked on the outside surface of the wrapping, i.e., "Do not stack more than three rolls high", etc.

E. Each Geotextile roll shall be wrapped with a material that will protect the geotextile from damage due to shipment, water, sunlight and contaminants. The protective wrapping shall be maintained during periods of shipment and storage.

F. Storage areas shall be stable, dry, relatively flat and well drained. During storage the geotextile rolls shall be adequately covered and protected from the following:

1. Site construction damage;

2. Exposure to ultraviolet (UV) radiation in excess of 14 days;

3. Precipitation;

4. Chemicals that are strong acids or strong bases;

5. Flames, sparks, temperatures in excess of 49 deg C (120 deg F); and,

6. Any environmental condition that might damage the geotextile.

G. The GEOSYNTHETICS CONTRACTOR shall protect the work described in this Section before, during, and after installation, and shall protect the installed work specified in other Sections as well as work completed by the OWNER. Only non-damaged, sufficiently dry material (as determined by the PROJECT ENGINEER) shall be included within the construction.

H. Roll numbers on partially used rolls shall be maintained such that each Geotextile roll number can be readily identified just prior to deployment of the remaining portions of the roll.

**I.** If the PROJECT ENGINEER determines the geotextile is damaged, the GEOSYNTHETICS CONTRACTOR shall make all repairs and replacements in a timely manner to prevent delays in the progress of the work. Any material damaged by the GEOSYNTHETICS CONTRACTOR, or damaged by others due to improper installation or protection, shall be replaced by the GEOSYNTHETICS CONTRACTOR at no additional cost to the OWNER.

# PART 2 MATERIALS

## 2.1 GENERAL

A. The geotextile shall be manufactured from first quality virgin materials. The geotextile manufacturer shall identify all rolls of geotextile delivered to the site with a weatherproof label located on the outside end of the wrapping material. This label shall include the following information as a minimum:

- Manufacturer's name
- Product identification and Style number
- Chemical composition of filaments
- Date of Manufacture
- Lot number
- Batch number
- Roll number
- Roll dimensions

Each roll of product shall include any additional information required to allow the PROJECT ENGINEER to relate that roll with the manufacturing quality control and raw material quality control documentation.

The PROJECT ENGINEER shall have the manufacturer's quality control data prior to site delivery. Geotextile with acceptable manufacturer's quality control data shall be stored

separately on-site from geotextile without quality control data and geotextile with unacceptable data to prevent placement of unacceptable material. Mislabeling or misrepresentation of materials shall be reason to reject those geotextile products.

## 2.2 CUSHION (TYPE C) AND SEPARATION (TYPE S) GEOTEXTILES

A. Cushion and separation geotextiles to be used for this project shall be non-woven needle-punched geotextiles unless called out otherwise in the Construction Documents.

B. The GEOTEXTILE MANUFACTURER shall provide the PROJECT ENGINEER with the Manufacturers written certification that the geotextile delivered to the site meets or exceeds the minimum properties required for the project. A person having legal authority to bind the GEOTEXTILE MANUFACTURER shall sign the certificate. This certification shall be supported by quality control test documentation developed during the manufacture of the delivered material to certify conformance with the following properties:

| PROPERTY | TEST METHOD | VALUE | | | UNITS |
|---|---|---|---|---|---|
| | | TYPE C | TYPE S (Nonwoven) | TYPE S (Woven) | |
| Weight per Area (min. avg.) | ASTM D5261 | 16.0 | 10.0 | 6.0 | $oz/yd^2$ |
| Grab Tensile Strength(1) (min. avg.) | ASTM D4632 | 380 | 270 | 315 | lbs |
| Grab Elongation(1) (min. avg.) | ASTM D4632 | 50 | 50 | 15 | % |
| CBR Puncture Resistance (min. avg.) | ASTM D6241 | 1200 | 700 | 1,000 | lbs |
| Trapezoid Tear (min. avg.) | ASTM D4533 | 150 | 100 | 120 | lbs |
| UV Resistance(3) | ASTM D7238 | 70 | 70 | 70 | % at 500 hours |
| Minimum Friction with material above and below. | ASTM D5321 | see note 2 | NA | NA | degree |
| Apparent Opening Size | ASTM D4751 | 0.024 | 0.024 | 0.024 | in. |
| Permittivity (min. avg.) | ASTM D4491 | 0.02 | 0.02 | 0.02 | $Sec^{-1}$ |

Notes:
1. Weakest Principal Direction.
2. The interface shear strength with materials above and below the geotextile must be greater than that specified in the drawings. The testing must be performed with actual materials to be used in construction and under a normal stress range approved by the PROJECT ENGINEER.

3. Representative UV Resistance test data for the polymer used in the manufacture of the geotextile that is acceptable to the Project Engineer can be supplied in lieu of specific testing of the material delivered to the site.

### 2.3 WIDTH OF GEOTEXTILES

A. To keep the number of overlays to a minimum, the geotextile shall be provided in sections not less than 12 feet wide. Seams, if used in roll products, shall be made at the factory and shall be tested in accordance with ASTM D5034 or ASTM D5035 as directed by the Project Engineer. The strength shall not be less than the required tensile strength of the fabric in any principal direction. Results of the factory fabricated seam tests shall be provided with the information required by 2.2 above.

### 2.4 GEOTEXTILE JOINING METHODS

A. Geotextiles shall be joined by field sewing or thermal bonding. Geotextile joining materials and methods shall be as approved by the PROJECT ENGINEER.

## PART 3 EXECUTION

### 3.1 SITE PREPARATION

A. Prior to the placement of the geotextile, representatives of the PROJECT ENGINEER, GEOSYNTHETICS CONTRACTOR and the EARTHWORK CONTRACTOR will inspect the surface to be covered by the geotextile. The surface to be covered by the geotextile shall be cleared of sharp objects, angular stones sticks, or any materials that may contribute to punctures, shearing, rupturing or tearing of the geosynthetic materials. The geotextile subgrade shall have a smooth, finished surface, free from pockets, holes, soft spots, ruts greater than 1 inch in depth, discontinuities that will cause bridging and overstress the material, and substantially free of loose soil as determined by the PROJECT ENGINEER. The subgrade shall be inspected for unsuitable areas or soft spots before the GCL is placed. The GEOSYNTHETICS CONTRACTOR is cautioned that placement of the geotextile over any subgrade approved by the PROJECT ENGINEER constitutes acceptance of the subgrade by the GEOSYNTHETICS CONTRACTOR. Acceptance of the geotextile subgrade transfers responsibility for protecting that surface as well as the geotextile surface itself to the GEOSYNTHETICS CONTRACTOR for the duration of the CONTRACT. Should the GEOSYNTHETICS CONTRACTOR place geotextile over an area not approved by the PROJECT ENGINEER, the GEOSYNTHETICS CONTRACTOR assumes responsibility for all costs associated with removal and replacement of the geotextile as well as the subgrade surface preparation including but not limited to labor and equipment.

B. All subgrade approved by the PROJECT ENGINEER and not covered with geotextile by the GEOSYNTHETICS CONTRACTOR will be protected against damage by the GEOSYNTHETICS CONTRACTOR at no additional cost to OWNER.

## 3.2 INSTALLATION

A. The geotextile shall be placed in the manner and at the locations shown on the Drawings. When placing the geotextile, sections shall be joined by overlapping the fabric a minimum of four inches with field-sewn seams, or as recommended by the manufacturer and as approved by the PROJECT ENGINEER. No horizontal seams (i.e., seams perpendicular to the maximum slope) shall be placed on slopes greater than 25% unless the slope length exceeds the manufactured roll length. Geotextile shall be laid smooth and free of excess tension, stress, folds, wrinkles, or creases.

B. During back dumping and spreading of soil over the geotextile, a minimum depth of 12 inches of soil shall always be maintained over the geotextile between the geotextile and wheels, tracks or buckets of heavy equipment or trucks. No portion of any heavy equipment or trucks shall be in direct contact with the geotextile.

C. If geotextile on a slope less than 15 percent should be damaged during any step of installation, a piece of geotextile material shall be cut and placed over the damaged area subject to a 3-foot minimum overlap requirement or as directed by PROJECT ENGINEER. If any rip or defect occurs across more than one-third the width of the roll, that portion of the roll will be removed from the work.

D. If the geotextile on a slope greater than 15 percent develops any holes or tears, they shall be repaired by a geotextile patch sewn or thermally bonded into place. If sewn, the GEOSYNTHETICS CONTRACTOR shall use a double sewn stitch 1/4 to 3/4 inches apart and no closer than one inch from any edge. If thermal methods are used the entire overlap shall be completely bonded; that is, heat tacking will not be permitted. Should any tear exceed ten percent of the width of the roll, that portion of the roll shall be removed from the slope and replaced. Care shall be taken to remove any soil or other material that may have penetrated the torn geotextile.

E. Soil shall be spread in the direction of geotextile overlap, except on slopes greater than 15 percent, at which time soil shall be placed from the bottom of slope to the top.

F. Smoking is not permitted on or near the geotextile.

## 3.3 PROTECTION

A. Any geotextile damaged during its installation shall be repaired by the GEOSYNTHETICS CONTRACTOR.

B. The work shall be scheduled so that the covering of the geotextile with a layer of the cover material is accomplished within 30 days after placement of the geotextile. Failure to comply with this requirement shall require replacement of the geotextile.

END OF SECTION

# SECTION 02597

# HDPE GEOMEMBRANE

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The GEOSYNTHETICS CONTRACTOR shall furnish all labor, required materials, equipment, tools and appurtenances required to complete the installation of all geomembrane, complete with appurtenances, as shown, specified or required by the Drawings. The OWNER will purchase the HDPE geomembrane material and the HDPE welding rod. Procurement and delivery of these materials will be the responsibility of the PROJECT ENGINEER.

### 1.2 RELATED SECTIONS

A. Section 02278 – Geosynthetic Clay Liner

B. Section 02595 – Geotextile

C. Section 02599 – Geocomposite Drainage Layer

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM):

1. D792 Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

2. D1004 Standard Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting

3. D1505 Standard Test Method for Density of Plastics by the Density-Gradient Technique

4. D1603 Standard Test Method for Carbon Black in Olefin Plastics

5. D3895 Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry

6. D4218 Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique

7. D4354 Standard Practice for Sampling of Geosynthetics for Testing

8. D4833 Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products

9. D4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples

10. D5199 Standard Test Method for Measuring the Nominal Thickness of Geosynthetics

11. D5321 Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method

12. D5397 Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test

13. D5596 Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics

14. D5641 Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber

15. D5820 Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes

16. D5885 Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry

17. D5994 Standard Test Method for Measuring Core Thickness of Textured Geomembrane

18. D6243 Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method

19. D6365 Standard Practice for the Nondestructive Testing of Geomembrane Seams Using the Spark Test

20. D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods

21. D6497 Standard Guide for Mechanical Attachment of Geomembrane to Penetrations or Structures

22. D6693 Standard Test Method for Determining Tensile Properties of Non-reinforced Polyethylene and Non-reinforced Flexible Polypropylene Geomembranes

23. D7007 - Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials

24. D7466 Standard Test Method for Measuring the Asperity Height of Textured Geomembrane

B. Geosynthetic Research Institute (GRI):

1. GRI GM6 – Pressurized Air Channel Test for Dual Seamed Geomembranes

2. GRI GM9 – Cold Weather Seaming of Geomembranes

3. GRI GM13 – Test Methods, Test Properties, and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes

4. GRI GM14 – Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes

5. GRI GM19 – Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes

C. Other:

1. ANSI/ASQC Z1.4 (2008) Sampling Procedures and Tables for Inspection by Attributes

D. The most current version of the specified test method shall be followed by the Manufacturer, GEOSYNTHETIC CONTRACTOR or authorized testing laboratory.

## 1.4 DEFINITIONS

A. Minimum Value – Property value representing the lowest individual allowable value obtained when tested according to the specified test method. This applies to individual readings, such as thickness; or where only one specimen is tested for the specified parameter.

B. Minimum Average Value – Property value representing the lowest allowable value for the average of results for the specimens tested.

C. Minimum Average Roll Value (MARV) – Property value calculated as the average test result minus two standard deviations. Statistically, this implies a 97.5 percent confidence that any specimen tested during quality assurance will exceed the value reported.

D. Nominal Value – Property value that is representative of a measurable property, determined under a set of prescribed test conditions, by which a product may be described.

E. Typical Roll Value – Property value calculated as the average or mean obtained from test data.

F. Unit – For the purposes of this project, a "Unit" shall be a single roll of geo synthetic material.

G. Lot - For the purposes of this project, a "Lot" will be defined as a single run of geosynthetic material from the same production facility, where the tooling and raw materials of production have not changed during manufacturing.

## 1.5 SUBMITTALS

A. The GEOSYNTHETICS CONTRACTOR shall submit to the ENGINEER all items included in this Article. Submittals shall be provided as follows:

1. With the GEOSYNTHETICS CONTRACTOR'S BID:

a. A project reference list documenting the experience of the GEOSYNTHETICS CONTRACTOR on a minimum of 5 projects consisting of at least 10 million square feet of installed textured HDPE geomembrane.

b. Minimum installation crew list including how many crew members in each job classification will be required to perform the work. Although the minimum crew size may be increased by the GEOSYNTHETICS CONTRACTOR, at no additional cost to the OWNER, the crew may not be decreased without prior approval by the PROJECT ENGINEER.

c. Resumes summarizing prior experience in installing HDPE geomembrane for all key HDPE geomembrane installation crew members, including Supervisor Foreman and QC Technician. HDPE geomembrane installation staff will be subject to approval by the PROJECT ENGINEER and OWNER. Include resumes of all potential key HDPE geomembrane installation crew members that might be anticipated to work on this project.

d. A schedule of operations, including means and methods of installation.

e. The proposed method of joining adjacent geomembrane panels.

f. The documented historic pass/fail rate for HDPE geomembrane seam destructive tests performed on seams created by the proposed welding crew members.

2. Fifteen days prior to mobilization to the site, unless stated otherwise below:

a. Working drawings, including proposed panel diagram and details of proposed work, extrusion welds, pipe boots, and details of sealing around all necessary geomembrane penetrations, to be submitted at least 15 days prior to delivery of geomembrane to the site. The panel diagram must depict and/or note the planned number and orientation of panels, the minimum panel size, seam orientation and overlap direction, placement of seams in corners, treatment of tee seams and the GEOSYNTHETICS CONTRACTOR'S preferred sequence of panel placement. The HDPE panels shall be orientated in a manner that minimizes seams and shall not have cross seams placed on slopes greater than 25% unless the slope length exceeds the manufactured roll length. The PROJECT ENGINEER prior to geomembrane installation must approve the panel diagram. The PROJECT ENGINEER, in writing, prior to altering the installation, must approve proposed revisions to the panel diagram.

b. Resumes of HDPE geomembrane crew; that will be mobilized to the site, Supervisor, QC Manager, Master Seamers and all Welding Technicians. The resumes shall include prior experience in installing Textured HDPE geomembrane. All individuals who will perform welding on this project shall be certified by the welding equipment manufacturer as having been trained in the use of the equipment; or, in lieu of such certification, the GEOSYNTHETICS CONTRACTOR shall provide other suitable evidence that demonstrates the proposed welding personnel possess intimate knowledge of welding equipment design, set-up, operation and maintenance. Individual geomembrane crew members will be subject to the approval of the PROJECT ENGINEER. Resumes of any additional crew members required during the course of work shall be submitted to the PROJECT ENGINEER for approval. The additional crew member(s) will be restricted to general laborer duties until approved by the PROJECT ENGINEER.

c. A copy of the GEOSYNTHETICS CONTRACTOR'S standard operating procedure (SOP) for operating an ATV or other utility vehicle to be used on site, particularly with respect to specific uses of such vehicles and the prevention of damage to materials.

d. Field tensiometer calibration certificate showing that the equipment to be used for shear/peel testing in the field has been calibrated by a qualified individual within the previous 6 months.

3. During Installation Submitted Daily:

a. Completed Subgrade Acceptance Form, as endorsed by the PROJECT ENGINEER, prior to geomembrane deployment in any area.

b. Construction progress reports clearly showing geomembrane placed by date.

c. Passing and failing test results for trial seams.

d. Documentation of passing and failing destructive and non-destructive testing of installed seams.

4. Within 5 days after completion:

a. Summary and log of all field quality control work completed by the GEOSYNTHETICS CONTRACTOR.

b. Certification statement signed by the Supervisor that geomembrane installation is complete and in accordance with these Specifications, with details of any changes or exceptions noted.

c. Statement of installation warranties.

B. The GEOMEMBRANE MANUFACTURER shall submit to the PROJECT ENGINEER all items included in this Article. Submittals shall be provided as follows:

1. Submitted upon material selection and prior to delivery to the site:

a. A statement of the HDPE GEOMEMBRANE MANUFACTURER'S experience, including the manufacturing and supplying company's name, address and employee contact.

b. A copy of the GEOMEMBRANE MANUFACTURER'S Manufacturing Quality Assurance/Manufacturing Quality Control (MQA/MQC) Plan for the complete geomembrane manufacturing process.

c. Geomembrane Sample - Samples of the proposed HDPE geomembrane shall be sent to the PROJECT ENGINEER for interface shear testing within 5 days after the PROJECT ENGINEER makes such request. The GEOMEMBRANE MANUFACTURER shall coordinate the quantity and dimensions of the samples with the PROJECT ENGINEER.

d. Statement of manufacturing warranties.

2. At least 15 days prior to delivery of geomembrane to the site, unless otherwise noted below:

a. Welding Rod - Manufacturing Quality Assurance (MQA) test data from the GEOMEMBRANE MANUFACTUER demonstrating that the resin utilized in the production of the geomembrane and welding rod and/or pellets meets the requirements specified in Article 2.2. The packages containing the welding rod and/or pellets must contain a label identifying the resin lot utilized in their manufacture.

b. HDPE Geomembrane - Manufacturing Quality Control (MQC) data certificates for the geomembrane to be delivered to the site. The reports shall reference the resin lot used in the manufacture of the sheet, and shall include the quality control test results obtained during the manufacture of the material. In the event material is delivered to the site prior to the receipt of the MQC certificates, the material without certificates will be stored separately from the material with certificates. Material with unacceptable MQC data will be segregated from approved material and shall be marked for rejection. The geomembrane will be rejected or if it is found to have defects, rips, holes, flaws, deterioration or other damage deemed unacceptable by the PROJECT ENGINEER.

c. Resin - Resin Manufacturer's certificate for each resin lot utilized by the GEOMEMBRANE MANUFACTUER in the production of the geomembrane and welding rod/pellets to be delivered to the site.

d. No material shall be loaded for delivery to the site prior to approval by the PROJECT ENGINEER.

C. The above-noted requirements shall apply to all shop-fabricated materials and those items specified for fabrication in the field

## 1.6 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. The GEOMEMBRANE MANUFACTURER shall be responsible for the protection of the HDPE geomembrane against damage during transportation to the site. The OWNER will be responsible for protection of the HDPE geomembrane during storage at the site until the GEOSYNTHETICS CONTRACTOR mobilizes to the site. Once mobilized the GEOSYNTHETICS CONTRACTOR shall be responsible for the protection of the HDPE geomembrane against damage prior to and during its installation up to completion of the CONTRACT.

B. Geomembrane labeling, shipment and storage shall follow ASTM D4873 as modified according to this Specification.

C. Product labels shall be placed on the ends of rolls such that they can be seen when rolls are stacked, clearly showing the manufacturer or supplier name, style name, roll number, and roll dimensions.

D. Each roll of product shall include any additional information required to allow the PROJECT ENGINEER to relate that roll with the manufacturing quality control and raw material quality assurance documentation. Additionally, if any special handling is required, it shall be so marked on the outside surface of the wrapping, i.e., "Do not stack more than five rolls high," etc.

E. During storage, the geomembrane shall be placed on a stable, relatively flat, dry, well-drained surface. The geomembrane shall not be placed on skids or other objects that may cause deformation of the geomembrane rolls. Adequate space shall be left between stacked rolls, such that roll labels can be examined. The geomembrane shall be protected from the following:

1. Mud and dust.

2. Site construction damage.

3. Chemicals that are strong acids or bases.

4. Flames, sparks, geomembrane temperatures in excess of 150° F.

5. Any environmental condition that might damage the geomembrane.

F. Roll numbers on partially used rolls must be maintained such that each roll number can be readily identified prior to deployment of the remaining portions of the roll. In the event roll numbers for partial rolls cannot be identified, such rolls will be marked for rejection.

G. If the PROJECT ENGINEER determines the geomembrane is damaged, the GEOSYNTHETICS CONTRACTOR shall make all repairs and replacements in a timely manner, so as to prevent delays in the progress of the work. As determined by the PROJECT ENGINEER, any material damaged by the GEOSYNTHETICS CONTRACTOR, shall be replaced by the GEOSYNTHETIC CONTRACTOR at no cost to the OWNER.

## PART 2 MATERIALS

### 2.1 GENERAL

A. The geomembrane shall be manufactured from first quality; virgin high-density polyethylene (HDPE) resin with no more than 10% rework. If rework is used it must be identical to the parent materials. The HDPE resin must be blended with carbon black. The resin and finished product requirements are described in this Part, including the minimum Manufacturing Quality Assurance (MQA) and Manufacturing Quality Control (MQC) sampling and testing requirements.

B. The HDPE sheet must be textured on both surfaces, and shall have a uniform texturing appearance. It shall be free from agglomerated texturing material and such defects that would affect the specified properties of the geomembrane.

C. The geomembrane may have a white surface to minimize geomembrane surface temperatures and reduce overall wrinkling in the panels during construction. Any non-black geomembrane must be suitable for exposure during the installation process without degradation to the physical and mechanical properties required by this Specification.

D. The GEOMEMBRANE MANUFACTURER shall be solely responsible for the quality of the material provided. Should any of the tests performed on the material yield unsatisfactory results, the GEOMEMBRANE MANUFACTURER will be responsible for replacing the material with satisfactory materials without delay to the project or cost to the OWNER.

## 2.2 RESIN

A. The textured HDPE geomembrane shall be manufactured from high quality HDPE resin with superior stress crack resistance. No post consumer resin of any type shall be added to the formulation. Once a resin has been accepted for use, all material for the project shall be manufactured from that resin unless approved by the PROJECT ENGINEER.

B. The following table represents the minimum required Manufacturing Quality Assurance (MQA) testing that must be conducted by the GEOMEMBRANE MANUFACTURER on the resin used to produce the geomembrane:

**RESIN MQA**
**MINIMUM TESTING**

| PROPERTY | TEST METHOD | REQUIRED VALUES |
|---|---|---|
| Density, g/cm$^3$ (allowable range) | ASTM D1505/D792 | 0.932 - 0.939 |
| Notched Constant Tensile Load (NCTL), hrs (Notes 1,2) | ASTM D5397, Single Point | 400 (minimum average) |

NOTES:

1. The NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces, therefore, in the case of textured geomembrane, the NCTL testing shall be conducted on representative smooth material produced from the same resin lots and formulations as the textured geomembrane supplied to this project.
2. Specimens for NCTL testing must contain carbon black. If samples used for testing are not taken from the finished product, they must be produced by a representative method, such as a lab-line or other acceptable method. Deviations from ASTM D5397 shall be noted by the GEOMEMBRANE MANUFACTURER and approved by the PROJECT ENGINEER.

## 2.3 GEOMEMBRANE

A. The sheet material shall be formulated from the appropriate polymers and compounding ingredients to form HDPE geomembrane that meets all requirements of this specification.

B. The GEOMEMBRANE MANUFACTURER shall complete Manufacturing Quality Control (MQC) testing on the geomembrane in accordance with the requirements summarized in the following table:

**GEOMEMBRANE MQA/MQC**
**MINIMUM TESTING**

| PROPERTY | TEST METHOD | TEXTURED SHEET VALUE |
|---|---|---|
| Core Thickness, mils (1) | ASTM D5994 | 60 nominal (-5%) |
| Asperity Height (min. avg.), mils (2,3) | ASTM D7466 | 16 |
| Density (min. avg.), g/cm$^3$ | ASTM D1505/D792 | 0.940 |
| Tensile Properties (min. avg.) both directions | ASTM D6693 | |
| • Yield strength, lb./in. | Note (4)<br>Notes (5,6) | 126 |
| • Break strength, lb./in. | | 90 |
| • Yield elongation, % | | 12 |
| • Break elongation, % | | 100 |
| Carbon Black Content (min. avg.), % (7,8) | ASTM D1603/D4218 | 2.0 - 3.0 |
| Carbon Black Dispersion | ASTM D5596 | Note (9) |
| Oxidative Induction Time (Standard) (minimum) | ASTM D3895 | 100 |
| Tear Resistance (min. avg.) (lb) | ASTM D1004 | 42 |
| Puncture Resistance (min. avg.) | ASTM D4833 | 90 |

NOTES:

1. The result obtained from D5994 will be an average of readings from 10 specimens per roll. The lowest allowable minimum average value shall be 57 mil, the lowest individual value for 8 out of the ten specimens shall be 54 mils, and the lowest individual value for any of the 10 specimens shall be 51 mil.
2. Of 10 readings, 8 out of 10 must be ≥16 mils, and the lowest individual reading must be ≥11 mils.
3. Both sides of the double-sided textured sheet shall be measured on each roll (reference Article 2.1B).
4. Yield elongation is calculated using a gauge length of 1.3 inches.
5. Break elongation is calculated using a gauge length of 2.0 inches.
6. Break elongation shall be determined based on the average of 5 specimens in the machine direction and the average of 5 specimens in the cross direction (reported separately).

7. Other methods, such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.

8. Carbon black content is only measured on the black backing of the white-surfaced geomembrane. Prior to measuring the carbon black content, the white surface shall be scrapped or ground off to avoid misrepresentative results in the final result.

9. Carbon black dispersion for 10 different views: At least nine in Categories 1 or 2, one (max.) in Category 3

C. Non-conforming material will not be used in the work. Additional sampling required to address non-conforming test results shall be performed in accordance with the project CQA/CQC Plan. The PROJECT ENGINEER may reject the entire lot containing non-conforming rolls at any stage of extended sampling and testing.

D. E. Interface Shear Testing - Interface shear strength testing of the geomembrane and related materials is the responsibility of the OWNER. The results must comply with the criteria determined by the PROJECT ENGINEER, as specified in the Construction Drawings. All testing must demonstrate the minimum required peak shear strength and minimum large strain shear strength as specified on the Drawings, and those results must be completed by the CQA/CQC LABORATORY and approved by the PROJECT ENGINEER prior to delivery of the materials to the site. Testing for geosynthetic to geosynthetic, or geosynthetic to soil interface, shall be conducted according to the current version of ASTM D5321. Testing for interfaces involving geosynthetic clay liner (GCL) shall be conducted according to the current version of ASTM D6243.

## 2.4 WELDING ROD AND/OR WELDING PELLETS

A. The GEOMEMBRANE MANUFACTURER shall certify that the welding rod and/or pellets used for extrusion welding shall be produced from the same resin type as that used to manufacture the geomembrane supplied for this Project.

B. The GEOMEMBRANE MANUFACTURER shall certify that the welding rod and/or pellets meet the following requirements:

| PROPERTY | TEST METHOD | REQUIRED VALUES |
|---|---|---|
| Density, g/cm$^3$ | ASTM D1505 | 0.940 (minimum avg.) |
| Carbon Black Content, % | ASTM D1603 or D4218 | 2.0 – 3.0 |

C. The PROJECT ENGINEER may perform conformance sampling and testing of the welding rod and/or pellets.

## 2.5 GEOMEMBRANE PENETRATION BOOTS

A. The GEOSYNTHETICS CONTRACTOR shall furnish any geomembrane penetration boots and other materials required for completion of the HDPE geomembrane installation. The HDPE geomembrane boots shall be of the same density and thickness as the HDPE geomembrane panels.

B. The HDPE GEOMEMBRANE MANUFACTURER shall provide a statement of hydraulic or pneumatic testing demonstrating that any shop-fabricated unit does not leak. A description of the method used for testing in the shop shall be submitted to the PROJECT ENGINEER for approval prior to shipping the shop-fabricated boots to the site.

C. HDPE geomembrane penetrations are to be constructed only at the locations shown on the Plans. The GEOSYNTHETIC CONTRACTOR is cautioned that no deviation in the quantity or configuration of HDPE geomembrane penetrations will be accepted without the advance written approval of the PROJECT ENGINEER.

D. The GEOSYNTHETICS CONTRACTOR shall construct penetrations in accordance with the procedures described in ASTM D6497, Standard Guide for Mechanical Attachment of Geomembrane to Penetrations or Structures, or as described by this Specification.

E. All penetrations through the HDPE geomembrane shall be thoroughly and securely sealed. The seal between the HDPE geomembrane and the pipe shall be without any detectable leakage.

F. In attaching the HDPE geomembrane penetration boot in the field, no field seams will be allowed in locations or configurations that do not allow for Construction Quality Control testing. Visual observation is not considered a sole acceptable method for in-field quality control.

G. Where clamps, fasteners, gasket seals or sealants are used, the GEOSYNTHETIC CONTRACTOR shall use only materials that are compatible with the geomembrane.

# PART 3 EXECUTION

## 3.1 SITE PREPARATION

A. All required grading, grooming and construction quality assurance (CQA) testing on any low permeability soil or GCL to be covered by the HDPE geomembrane shall be complete and accepted by the PROJECT ENGINEER prior to geomembrane placement.

B. The surface to be covered by the HDPE geomembrane shall be cleared of sharp objects, angular stones, sticks, or any materials that may contribute to punctures, shearing, rupturing or tearing of the geosynthetic materials. The HDPE geomembrane subgrade

surface shall be cleared of sharp objects, angular stones sticks, or any materials that may contribute to punctures, shearing, rupturing or tearing of the geosynthetic materials. The geomembrane subgrade shall have a smooth, finished surface, free from pockets, holes, soft spots, ruts greater than 1 inch in depth, discontinuities that will cause bridging and overstress the material, and free of substantial amounts of loose soil as determined by the PROJECT ENGINEER. The subgrade shall be inspected for unsuitable areas or soft spots before the HDPE geomembrane is placed, and additional surface preparation will be required to eliminate any unsuitable areas as determined by the PROJECT ENGINEER.

C. The GEOSYNTHETICS CONTRACTOR and PROJECT ENGINEER shall carefully and completely inspect the subgrade surface immediately prior to the deployment of each HDPE geomembrane panel. No HDPE geomembrane panel shall be placed without the PROJECT ENGINEER'S written approval or on an unsuitable subgrade surface as described in Part 3.1.B. The PROJECT ENGINEER and the GEOSYNTHETICS CONTRACTOR'S Superintendent or Quality Control (QC) inspector shall furnish their signatures on a Subgrade Acceptance Log prior to the installation of each panel or series of panels placed on a daily basis.

D. Under no condition shall the HDPE geomembrane be placed over standing water on the subgrade.

## 3.2 SEAMING METHODS

A. The HDPE geomembrane panels shall be joined utilizing approved seaming methods. Dual-track fusion welding shall be the required method on all seams where it is feasible. Extrusion welds shall be made only where approved by the PROJECT ENGINEER.

B. The GEOSYNTHETICS CONTRACTOR shall properly maintain and set-up the welding equipment prior to seaming operations on a regular as needed basis, in the manner specified by the Manufacturer. For wedge welding equipment this is expected to include as a minimum; checking the condition and adjusting the position of the nip rollers, hot wedge and contour rollers. As well, the GEOSYNTHETICS CONTRACTOR shall properly examine and check the cartridge heaters, thermocouples, drive chains and electronics for proper operation at the frequency recommended by the Manufacturer. The CQA Observers shall record and document the set-up, maintenance and adjustment process, as well as the settings/conditions each time acceptable seaming of the geomembrane has been confirmed by trial weld results.

C. All HDPE geomembrane surfaces that are to become a seam interface are to be free of dust, dirt, excess moisture or any other condition that may affect the quality of the seam.

D. Seaming will not be allowed during rain or snowfall, unless proper precautions are made to allow the seam to be made on dry subgrade and geomembrane materials. Seaming is also subject to wind and temperature restrictions as described in Article 3.3.M.

E. The seams shall be produced using one of the following methods:

1. Dual-Track Fusion (Wedge) Weld – A seam produced by melting the two intimate surfaces by running a hot metal wedge between the surfaces, followed immediately by pressure to form a homogeneous bond. This seam has a center air channel for non-destructive testing of the seam. Panels to be seamed shall be overlapped sufficiently to allow proper destructive testing of seams. No adjustments to the wedge settings during seaming operations will be allowed unless previously approved by the PROJECT ENGINEER. In situations where setting changes must be made (eg. material changes, grade changes or subgrade changes exist), the PROJECT ENGINEER will be informed prior to loading the wedge in the seam and trial welds for every scenario will be run by the wedge operator. The wedge operator and/or the technician assisting the wedge operator shall mark the liner where the wedge settings are adjusted (including speed, temperature, pressure, date and time). Any wedge setting adjustments made without prior approval of the PROJECT ENGINEER will result in the seam being rejected and the GEOSYNTHETICS CONTRACTOR will be required to reconstruct the seam at no additional cost to the OWNER. Measurable setting values, as well as Operator/Equipment ID, date and time shall be indicated on the liner where the wedge is loaded into the seam. If seaming is continuous through cross-seams at different panel interfaces, the time will be marked on the liner at every cross-seam.

2. Extrusion Weld – A seam produced by extruding molten HDPE at the edge of two overlapped panels. A bonded seam is completed when molten HDPE melts portions of the overlapping sheets to form a homogeneous weld. The center of the extrudate bead shall be located directly over the edge of the upper geomembrane. Panels to be seamed shall be overlapped a minimum of 4 inches. An electric rotary grinder and #80 grit paper, or finer, shall be used to remove the surface sheen in the area to be seamed. Grinding shall be completed no more than 10 minutes prior to seaming. Any grinding marks shall be oriented perpendicular to seam direction, and their depth shall be less than 5% of the sheet thickness. Grinding marks shall not appear beyond 0.25" of the extrudate after it is applied. The leading edge of the upper sheet shall be ground to a 45-degree bevel. Beveling shall be completed prior to tack welding to control damage to the lower sheet.

## 3.3 INSTALLATION

A. Based on the approved HDPE geomembrane panel diagram and material certifications, the individual panels will be numbered and seams will be identified by using the panel numbers that create the seam. The HDPE geomembrane panels shall be installed in a manner that minimizes seams. Seams shall be placed where normally applied stresses will be minimal. Longitudinal seams shall be oriented to be no greater than ten degrees from parallel with the direction of the slope. All panels placed on slopes greater than 25% shall extend down the full length of the slope unless the slope length is greater than the manufactured roll length. Any cross seams on slopes greater than 25% shall be staggered such that seams between adjacent panels are separated by a minimum of 10

feet. On slopes less than 25%, cross seams shall be placed no closer than five feet from the top of a steeper slope, or five feet from the toe of a steeper slope. All seam overlaps shall be shingled in a downslope direction. In no case shall parallel seams be placed within five feet of the centerline of any leachate collection pipe.

B. Piecework resulting in the placement and seaming of small panels not identified by the panel diagram shall not be permitted unless approved by the PROJECT ENGINEER. Any material variation from the approved panel diagram must be pre-approved by the PROJECT ENGINEER prior to altering the installation.

C. During installation, and any other period of exposure of HDPE geomembrane, pedestrian and equipment activity over the HDPE geomembrane shall be kept to a minimum, and restricted to only that which is necessary for HDPE geomembrane installation.

D. Smoking is not permitted on the HDPE geomembrane.

E. Construction workers shall take precautions not to damage the HDPE geomembrane surface. Construction workers shall wear smooth-soled footwear, and exercise care not to drag tools across the geomembrane surface. All large tools are to have smooth base plates or shoes. Construction and landfill staff shall be informed of the restricted access to areas of HDPE geomembrane placement by use of barriers and signs posted as necessary. Only hook blade knives shall be used to cut HDPE geomembrane.

F. The GEOSYNTHETICS CONTRACTOR shall perform all activities of geomembrane installation in such a way as to avoid damage to the HDPE geomembrane, including the prudent use of rub sheets. Any damage caused to the HDPE geomembrane by the GEOSYNTHETICS CONTRACTOR shall be repaired or the material replaced at the expense of the GEOSYNTHETICS CONTRACTOR.

   Generators and other stationary equipment that must be lubricated, fueled and/or oiled and that are staged on the geosynthetics must be placed within spill containment pads designed to prevent spillage of gasoline, diesel fuel or oil on the geosynthetics. If any such equipment is not placed in a spill containment structure, it must not be fueled on the geosynthetics. All equipment used on any geosynthetic surface shall be placed on a rub sheet.

G. No tracked or wheeled vehicles, other than low ground pressure ATVs or other similar vehicles as pre-approved by the PROJECT ENGINEER, shall be permitted on the HDPE geomembrane prior to placement of adequate soil cover, as determined by the PROJECT ENGINEER.

H. The GEOSYNTHETICS CONTRACTOR shall complete his work in a manner that will prevent water or wind from getting under the partially installed HDPE geomembrane. This could include, but is not limited to, installing sandbags along the leading edges. Should excessive moisture become trapped below the HDPE geomembrane, or should wind damage occur due to the negligence of the GEOSYNTHETICS CONTRACTOR, the GEOSYNTHETICS CONTRACTOR, at no extra cost to the OWNER, will be

required to perform all work, including removing and replacing as much of the in-place geosynthetic material as the PROJECT ENGINEER directs, to assure that the integrity of the HDPE geomembrane and the underlying sub base or geosynthetic clay liner (GCL) has not been compromised.

I. Seams shall be welded throughout the entire length of the panels during initial panel seaming.

J. Sandbags or other approved ballast shall be used to prevent bridging or material movement in areas such as toe of slope or near sumps. Ballast shall not be used to force the HDPE geomembrane into contact with the subgrade.

K. Special care shall be taken to prevent tensile stress in the HDPE geomembrane and HDPE geomembrane seams in all corners and grade changes.

L. The GEOSYNTHETICS CONTRACTOR shall exercise his best judgment and care to provide sufficient slack in the HDPE geomembrane to allow for thermal contraction without "trampolining", but to also avoid excessive slack such that wrinkling will be minimized during seaming and placement of overlying soil or geosynthetic materials.

M. The HDPE geomembrane shall not be seamed when ambient or sheet temperatures are below 32° F, when the sheet temperature exceeds 158° F, or when the air temperature is above 120° F unless the GEOSYNTHETICS CONTRACTOR demonstrates, to the satisfaction of the PROJECT ENGINEER, that procedures can be implemented which will result in the proper installation and seaming of the HDPE geomembrane.

For seaming activities below 32° F the GEOSYNTHETICS CONTRACTOR shall use procedures set forth in GRI GM 9. Maximum allowable time between trail welds shall be adjusted to 2 hours, decreasing one-half hour for each 10 deg F below 32 deg F.

N. Adjacent HDPE geomembrane panels shall be allowed to reach essentially equivalent temperatures prior to seaming to avoid development of fish mouths.

O. If fish mouths are created at the seam overlaps, they shall be cut to achieve a flat overlap. The cut shall be made with keyhole ends, and a patch shall be placed over the cut as required by Article 3.4.

P. Wrinkles shall not exceed a height to width ratio of 0.5, or as deemed acceptable by the PROJECT ENGINEER. The height of the wrinkle shall be measured from the base or subgrade to the peak of the wrinkle. The width of the wrinkle shall be measured along the base of the wrinkle.

Q. HDPE geomembrane covering operations shall be performed in a manner that does not damage the HDPE geomembrane lining system. HDPE geomembrane covering operations shall be performed only in the presence of the PROJECT ENGINEER such that the condition and cleanliness of the HDPE geomembrane is observed at the time the material is covered, and any effects of the covering operation on the HDPE geomembrane lining system can be observed.

R. In the event wrinkles develop during any covering operation that are capable of folding over, the excess material shall be cut out to achieve a flat overlap, or the covering operation shall be delayed until such time wrinkling subsides to acceptable levels. Any geomembrane cut shall be made with keyhole ends, and a patch shall be placed over the cut as required by Article 3.4. Wrinkles that do not lay flat and whose height to width ratio does not exceed 0.5 are susceptible to damage by soil placement equipment, and shall be carefully monitored by the PROJECT ENGINEER during cover operations.

S. Any use of ATV's or other similar vehicles on the site must be pre-approved by the PROJECT ENGINEER. The GEOSYNTHETICS CONTRACTOR shall submit an S.O.P. describing how vehicles are to be used, if at all, in the deployment of geomembrane at the site. As a minimum, the following shall apply:

1. Any damage resulting from the use of vehicles, as determined by the PROJECT ENGINEER, shall be repaired according to Article 3.4, at no additional cost to the OWNER. If repeated repairs are required as the result of the use of vehicles operating on geosynthetic material, further use of such vehicles will be prohibited.

2. Any and all vehicles proposed to be used in the deployment of geosynthetics will be inspected by the PROJECT ENGINEER. Vehicles which are found to be leaking oil or fuel, or which in any other way exhibit the potential to damage the lining system components, will not be permitted.

3. Any oil or fuel which leaks onto geosynthetic materials shall be thoroughly removed (cleaned) by the GEOSYNTHETICS CONTRACTOR, or the geosynthetic material shall be replaced at the discretion of the PROJECT ENGINEER, at no additional cost to the OWNER.

4. Re-fueling of vehicles on geosynthetic materials is prohibited.

5. Vehicles shall have tires with low ground pressure, typically less than 5 psi, and shall have shallow treads.

6. Vehicles shall be operated by a single operator at speeds less than 5 mph.

7. Quick starts, stops, spinning wheels and sharp turns will not be permitted above any geosynthetic material.

## 3.4 REPAIRS

A. All HDPE geomembrane panels and seams shall be examined by the PROJECT ENGINEER for uniform texturing, defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. The HDPE geomembrane surface shall be clean at the time of examination. Each suspect location shall be repaired and all repairs shall be non-destructively tested.

B. Damaged and/or unacceptable HDPE geomembrane shall be removed and replaced with acceptable HDPE geomembrane if damage cannot be repaired to the satisfaction of the PROJECT ENGINEER.

C. Any portion of the HDPE geomembrane, or any portion of a seam exhibiting a flaw or failing a destructive or non-destructive test, or an area where a wrinkle had been cut out shall be repaired, as follows:

1. HDPE geomembrane patches shall be used for holes over 1/8 of an inch in diameter, tears, and contamination by foreign matter. Patches shall be constructed of the same HDPE geomembrane, and will be joined to the panel using extrusion welding, or fusion welding where possible.

2. HDPE geomembrane patches or caps shall extend at least 6 inches beyond the edge of the defect or failed seam area, and all corners of material to be patched. The corners of the patch shall be rounded to a radius of at least 3 inches.

3. Spot extrusion welding (beads) shall be used to repair pinholes, or other minor localized flaws, only as approved by the PROJECT ENGINEER.

4. HDPE geomembrane caps shall be used to repair failed seams that are left in-place. Seams that fail destructive or non-destructive testing may also be removed and replaced if determined necessary by the PROJECT ENGINEER.

## PART 4 FIELD QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

### 4.1 GENERAL

A. Before installation begins, and weekly thereafter (more often if determined necessary by the PROJECT ENGINEER) a project coordination meeting shall be held with the designated representative of the NYSDEC, GEOSYNTHETICS CONTRACTOR, PROJECT ENGINEER and OWNER in attendance to review the following information:

B. Progress of the work.

C. Adherence to the Specifications.

D. Adherence to the Construction Quality Assurance Program described in this Section, including the timely submission of the pertinent forms.

E. Planned work and methods for the ensuing week, including estimate of time remaining to completion of the work.

F. Problem resolutions to be implemented during the upcoming week.

G. The NYSDEC shall be invited to each construction meeting.

H. All of the Forms specified and required must be submitted to the PROJECT ENGINEER in a timely fashion.

I. The OWNER and PROJECT ENGINEER must approve any changes in the proposed method of work, subcontractors to be utilized, geomembrane resin, or manufacturing in advance.

J. The GEOSYNTHETICS CONTRACTOR assumes all responsibility relevant to providing an acceptable product.

## 4.2 INSTALLATION QA/QC

A. The PROJECT ENGINEER and GEOSYNTHETICS CONTRACTOR shall visually inspect all material to be included in the work, and compare roll identification numbers with those on the certifications provided by the GEOMEMBRANE MANUFACTURER to assure delivery of the appropriate material.

B. Damage to HDPE geomembrane during installation shall be repaired according to Article 3.4. If the PROJECT ENGINEER determines that any damage cannot adequately be repaired, the damaged material will be replaced.

C. The GEOSYNTHETICS CONTRACTOR will be required to conduct both destructive and non-destructive testing on seams during the HDPE geomembrane installation, as part of the Construction Quality Control program. All trial and installed seam samples shall be tested according to ASTM D6392, as modified by this Specification.

D. The GEOSYNTHETICS CONTRACTOR will be required to complete trial seams throughout the project. The GEOSYNTHETICS CONTRACTOR will be required to utilize control charts to determine whether adjustments in the destructive sampling parameters are required during production seaming, per GRI GM14. The trial seams shall be provided in a timely fashion such that adequate time is available for field destructive testing, and preparation of the associated documentation by the PROJECT ENGINEER prior to production welding.

E. Trial Seams –

1. Trial seams shall be produced:

a. each day, at the start of each workday,

b. after every five hours of continuous operation,

c. after equipment maintenance, repair or replacement,

d. after lunch and/or dinner,

e. and if the geomembrane temperature changes by more than 45°F.

Trial seams shall be required each day for each piece of seaming equipment and each welding crew combination (including welding technician, seam cleaners and/or grinders). The trial seams will be performed on strips of geomembrane from approved rolls, and shall be produced at the work location such that the conditions mimic those under which production seams will be made.

2. A trial seam shall be a minimum of 5 feet in length for self-propelled seaming devices, and a minimum of 3 feet for hand-held seaming devices. The material for the trial seam and the test fixture for making the field tests shall be provided by the GEOSYNTHETICS CONTRACTOR at no additional cost. One-inch wide cutouts of the trial seams will be subject to shear and peel testing by the GEOSYNTHETICS CONTRACTOR'S QC technician at the site. A minimum of 5 cutouts will be tested for shear, and a minimum of 5 cutouts will be tested for peel. Only the upper weld area need be tested in peel. The PROJECT ENGINEER shall document the locus of break code for each specimen as shown in Figure 3 and Figure 4 of ASTM D6392, included at the end of this Section.

3. All trial seam specimens must be acceptable or the trial seam will be repeated until all results from a given trial seam are found acceptable. If any trial seam fails at any time during the workday, the reason for the failure shall be resolved before any production seaming of the geomembrane by the subject equipment and crew. All trial seam welding and testing must be observed by the PROJECT ENGINEER.

4. A trial seam specimen will be considered a failure if:

    a. For hot wedge seams:

        i. the bonded thickness of the seam fails before the adjacent sheet material; or, the shear strength of the specimen is less than 120 lb/in; or, the peel strength is less than 91 lb/in or greater than 25% of the originally bonded area separates as determined in accordance with Paragraph 6.1 of GRI GM 19.

    b. For extrusion fillet seams:

        i. the bonded thickness of the seam fails before the adjacent sheet material; or, the shear strength of the specimen is less than 120 lb/in; or, the peel strength is less than 78 lb/in or greater than 25% of the originally bonded area separates as determined in accordance with Paragraph 6.1 of GRI GM 19.

    c. In the shear or peel test, locus of break codes AD or AD-Brk >25% for hot wedge seams, AD1 or AD2 for extrusion fillet seams are reported by the PROJECT ENGINEER. AD-WLD and SIP are the exceptions.

    d. Upon visual inspection, the weld shows:

i. Excessive deformation or stepping of the bottom sheet when viewed in cross-section.

ii. Discoloration of the sheet such as that occurring from brittle failure.

iii. Inadequate or excessively narrow or flat weld bead (for extrusion seams).

iv. Water blisters in weld bead (for extrusion seams).

v. Misaligned weld bead, i.e., weld not reasonably centered with respect to overlap (for extrusion seams).

vi. Thinning of the sheet adjacent to the weld.

vii. Overgrinding marks outside of the extrudate bead (for extrusion seams).

F. The field tensiometer shall be strong enough to permit the operator to determine that the seam is at least as strong as either sheet, and shall permit accurate measurement of specimen elongation. The tensiometer shall have been calibrated within the 6-month period prior to its use on-site.

G. Should the PROJECT ENGINEER, at any time during the installation, believe the production seaming process may not be performing adequately, he may, to avoid destructive sampling of the installed HDPE geomembrane, request additional trial seams. The GEOSYNTHETICS CONTRACTOR shall do this at no additional cost.

H. The GEOSYNTHETICS CONTRACTOR shall complete non-destructive testing of all seams along their entire length, in the manner approved prior to installation, in the presence of the PROJECT ENGINEER. The recommended test methods are as follows:

1. Pressurized Air Channel

a. All field seams made by a dual-track fusion wedge welding device will be tested by applying air pressure within the air channel to a sealed length of seam, and monitoring the pressure over time. The testing shall be conducted in accordance with GRI GM6 or ASTM D5820.

b. For the 60 mil geomembrane, the initial inflation pressure shall be a minimum of 25.0 psi and a maximum of 30.0 psi. The maximum allowable pressure drop over a 5 minute period shall be 2.0 psi.

c. A pressure gauge shall be inserted into the far end of the air channel to check for continuity in the air channel. Alternately, the far end of the seam may be cut to relieve the air pressure. An audible rush of air shall serve as an indicator that the test represents the entire length of seam.

d. Air channels that do not hold the minimum specified air pressure shall be further inspected to identify the location and nature of any defects or unbonded sections of seam. The seam will then be repaired and retested. The PROJECT ENGINEER may, at his discretion, require the entire questionable seam area to be capped or replaced.

2. Vacuum Box Testing

a. Extrusion seams shall be inspected for unbonded areas or defects by applying a vacuum to a soaped section of seam. The vacuum shall be applied by a vacuum box equipped with a vacuum gauge, a clear glass view panel in the top, and a soft rubber gasket on the periphery of the open bottom. The testing shall be completed in accordance with ASTM D5641.

b. A section of the seam shall be soaped thoroughly and the inspection box shall be placed over the soaped seam section and the gasket sealed to the geomembrane. A vacuum of between 4 and 8 inches of Mercury (Hg) shall be applied to the box for a minimum of 10 seconds by use of a gasoline or electric driven power-vacuum pump apparatus. Adjacent placements of the vacuum box shall overlap the seam a minimum of 2 inches as viewed through the vacuum box-viewing window.

c. The PROJECT ENGINEER shall witness the testing, and the seam shall be clearly visible to the PROJECT ENGINEER and GEOSYNTHETICS CONTRACTOR during the test. Unbonded areas or defects shall be marked by the PROJECT ENGINEER for repair by the GEOSYNTHETICS CONTRACTOR.

3. Spark Testing

a. Spark testing may be used on short, detail (sump, penetration) extrusion welds that cannot be tested by vacuum box testing, and can use Alternating Current (AC) or Direct Current (DC) equipment. The DC equipment (using the latest version of ASTM D6365) is required for use on this project unless the GEOSYNTHETICS CONTRACTOR provides a detailed Workplan to the PROJECT ENGINEER regarding AC testing for approval, at least two weeks prior to beginning the testing.

b. The DC method typically uses a metal brush for the search electrode. For seams, a copper wire or tape is placed within the HDPE geomembrane/seam overlap, just to the inside of the center of the extruded bead. Prior to testing, a trial calibration seam must be made to confirm the minimum voltage required to discharge across a hole in the seam between the search electrode and the copper wire.

c. Spark testing must not be performed when the liner is wet. The test procedure for DC equipment can generally be describes as follows:

i. Connect the negative (ground) electrode of the testing equipment to the exposed end of the copper wire, or to a grounding rod if the copper wire is buried in the subgrade;

ii. Calibrate using a seam with a known leak path of the largest reached distance;

iii. Connect the positive electrode to the wire brush or other type of search electrode;

iv. Clean all debris and moisture from the seam area;

v. Apply a potential difference of between 20 and 55 kVDC, as determined in the calibration test, between the electrodes;

vi. Sweep the search electrode over the surface of the seam, maintaining contact with the extruded bead and the top of the lower HDPE geomembrane at the edge of the bead; and,

vii. Monitor for audible and/or visible spark discharges that are indicative of a defect. Mark defects for repair.

d. The exposed end of the wire must be cut short, and an extruded bead of molten polyethylene must be placed over the remaining wire exposure to ensure the wire is covered completely.

The OWNER will retain the services of a qualified ERT CONTRACTOR to conduct an electric leak location survey on the primary and secondary HDPE geomembrane liner after placement of the overlying respective soil drainage layers. The survey shall be performed using a proven process of locating potential leak paths in installed geomembrane through the use of electrical methods. The method will require access to the primary soil liner, and shall be capable of placing a voltage across the HDPE geomembrane liner, and locating areas where electric current flows through discontinuities in the HDPE geomembrane. The electric leak survey shall conform to the following requirements:

4. The survey shall be performed only by ERT CONTRACTORS experienced in performing electric leak surveys. The ERT CONTRACTOR shall have a minimum of three years experience in performing electric leak surveys, and shall have performed a minimum of 500,000 square feet of similar testing on three different projects. Qualifications and experience statements for the personnel assigned to the project shall be submitted by the ERT CONTRACTOR to the PROJECT ENGINEER for approval.

5. The electric leak survey will be performed on the primary HDPE geomembrane on the floor area only. The side slopes shall not be tested.

6. Testing shall be completed only after the soil drainage layers have been placed and graded over the primary HDPE geomembrane liner system.

7. The survey shall be capable of detecting and locating defects equal to a 6.4 mm diameter circular hole through the soil drainage layer.

8. The ERT CONTRACTOR shall submit to the PROJECT ENGINEER for approval a work plan outlining the specifications for the test, data analysis and reporting at least two weeks before commencing the survey. The work plan shall include test protocols such as probe spacing, etc., and other information regarding the requirements necessary for a successful survey such that the construction schedule will not adversely affect the survey.

9. The ERT CONTRACTOR shall complete a realistic test of the leak detection sensitivity as part of the leak location survey, using an artificial leak simulator for a 6.4 mm diameter leak. The leak location equipment and procedure shall be demonstrated to detect the artificial leak when the leak is midway between the measurement points on the surface of the nominal ¾-inch stone.

10. The leak location survey shall commence only after the PROJECT ENGINEER has confirmed the results of the leak detection sensitivity test. The leak location survey procedures shall be such that the measurements are made in the same manner as those employed in the leak detection sensitivity test.

11. The ERT CONTRACTOR shall submit to the PROJECT ENGINEER for approval an electric leak location survey test report to include the following:

    a. Brief description of the survey site;

    b. Description of the liner system design and materials;

    c. Climatic conditions during the test program;

    d. Description of electrical leak location system components and specifications;

    e. Sampling density of the measurements;

    f. Type, location and size of detected potential leak paths;

    g. Survey of repaired areas; and,

    h. Map of the surveyed area.

I. All inadequate seams or portions thereof that fail the non-destructive testing shall be repaired in accordance with this Specification and the method approved by the PROJECT ENGINEER. Should differences of opinion between the GEOSYNTHETICS CONTRACTOR and the PROJECT ENGINEER develop during the installation relevant

to seam integrity, the PROJECT ENGINEER may, at his discretion, obtain samples of the seams in dispute for field and/or laboratory testing. The GEOSYNTHETICS CONTRACTOR will be responsible for patching the resulting void in accordance with the previously approved procedures at no additional cost to the OWNER.

J. Destructive Sample Collection - Samples of the in-place seams shall be cut from the installed HDPE geomembrane at a frequency one per 1,000 feet of production seaming.

K. The destructive sample cutout sections shall be 12 inches wide by 40 inches long with the seam centered lengthwise. The sample size can be reduced to 30 inches if the GEOSYNTHETICS CONTRACTOR does not elect to have a cutout section for their use. A 1-inch wide specimen shall be cut from each end of the sample, and these two specimens shall be peel tested in the field in accordance with 4.2.E.4. The remaining sample shall be cut into two parts and distributed as follows:

1. One 12-inch by 18-inch sample to the PROJECT ENGINEER for independent laboratory testing; and,

2. One 12-inch by 18-inch sample to the OWNER for archive storage.

3. The remainder of the sample shall be available for the GEOSYNTHETICS CONTRACTOR if requested at the time of sample collection.

L. The 12-inch by 18-inch laboratory sample will provide 5 specimens for shear testing and 5 specimens for peel testing. Specimens that will be subject to peel and shear testing shall be selected alternately from the sample. All peel tests shall be performed on the outer track of wedge welds. The laboratory shall report the locus of break code for each specimen according to the definitions included in Figure 3 and Figure 4 of ASTM D6392, included at the end of this Section. The laboratory sample will be considered acceptable only if all 10 specimens meet the minimum requirements. The specimen will be considered a failure if:

1. For hot wedge seams - 1.) the bonded thickness of the seam fails before the adjacent sheet material; or, the shear strength of the specimen is less than 160 lb/in; or, the peel strength is less than 121 lb/in or greater than 25% of the originally bonded area separates as determined in accordance with Paragraph 6.1 of GRI GM 19; or, 2.) the shear percent elongation is less than 50% as determined in accordance with Paragraph 6.1 of GRI GM 19.

2. For extrusion fillet seams - 1.) the bonded thickness of the seam fails before the adjacent sheet material; or, the shear strength of the specimen is less than 160 lb/in; or, the peel strength is less than 104 lb/in or greater than 25% of the originally bonded area separates as determined in accordance with Paragraph 6.1 of GRI GM 19; or, 2.) the shear percent elongation is less than 50% as determined in accordance with Paragraph 6.1 of GRI GM 19.

3. In the shear or peel test, locus of break codes AD or AD-Brk >25% for hot wedge seams, AD1 or AD2 for extrusion fillet seams are reported by the PROJECT ENGINEER. AD-WLD and SIP are the exceptions.

4. Upon visual inspection, the weld shows:

   a. Excessive deformation or stepping of the bottom sheet when viewed in cross-section.

   b. Discoloration of the sheet such as that occurring from brittle failure.

   c. Inadequate or excessively narrow or flat weld bead (for extrusion seams).

   d. Water blisters in weld bead (for extrusion seams).

   e. Misaligned weld bead, i.e., weld not reasonably centered with respect to overlap (for extrusion seams).

   f. Thinning of the sheet adjacent to the weld.

   g. Overgrinding marks outside of the extrudate bead (for extrusion seams).

M. If a sample fails destructive testing, the welding path must be retraced to intermediate locations at least 10 feet in each direction from the location of the sample that failed the test, and a second sample shall be taken for an additional field test. If the tracking samples pass, the seam must be reconstructed between the location of the two tracking samples and the original sampled location. If the tracking sample fails, this process must be repeated. The seam between 2 passing test locations shall be capped, the cap seams shall be nondestructively tested, and shall include one field peel and shear test location along the reconstructed seam.

N. The PROJECT ENGINEER and GEOSYNTHETICS CONTRACTOR shall visually inspect all geomembrane seams. Extrusion welds shall be centered above the overlap, shall be free from blisters, and shall not include grinding marks that show more than 0.25 inches outside of the extrusion bead. If such grinding marks are found, the seam shall be repaired to the PROJECT ENGINEER'S satisfaction.

O. All welds shall be observed for traces of deformation to the HDPE geomembrane panels. Any seams, which in the opinion of the PROJECT ENGINEER, have caused excessive deformation of the sheet, show signs of discoloration, exhibit thinning or stepping of the sheet, or show visual signs of overheating of the HDPE geomembrane panels, shall be repaired at no additional cost to the OWNER regardless of the result of any destructive testing on the seam. The deficient seam or portion thereof shall be cut out, the HDPE geomembrane panels again overlapped and seamed, or the questionable seam length shall be capped, as approved by the PROJECT ENGINEER.

P. The GEOSYNTHETICS CONTRACTOR shall not place overlying materials on the installed HDPE geomembrane until the PROJECT ENGINEER has reviewed and

accepted the written test results for the HDPE geomembrane to be covered. At a minimum, the pre-delivery testing, the daily log of trial seam results, laboratory destructive sample results, non-destructive test results, record drawings of the completed area, and approval of the seams in place will be reviewed.

Q. The GEOSYNTHETICS CONTRACTOR shall provide a report to the OWNER and the PROJECT ENGINEER at the conclusion of the work which shall include the following:

1. The quality control tests used as specified and/or directed, including all requirements of the Report section of the specified test method.

2. Complete description of field sampling procedure, number of test specimens, size of test specimens.

3. Log of all Construction Quality Control work.

R. The GEOSYNTHETICS CONTRACTOR shall be responsible for all costs incurred by the OWNER including, but not limited to, additional field and laboratory CQA testing resulting from greater than 5 percent of the CQA testing not meeting or exceeding the Specifications.

S. All seams must be subjected to accepted Construction Quality Control or Construction Quality Assurance (CQA/CQC) testing.

## 4.3 WARRANTY

A. The GEOSYNTHETICS CONTRACTOR shall issue a warranty on the installation of geomembrane for a minimum period of 1 year.

B. The GEOMEMBRANE MANUFACTURER shall issue a warranty on the geomembrane material for a minimum period of 5 years.

END OF SECTION

# SECTION 02599

# GEOCOMPOSITE DRAINAGE LAYER

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The GEOSYNTHETICS CONTRACTOR shall furnish all labor, required materials, equipment, tools and appurtenances required to complete the installation of all geocomposite drainage (GCD) layers as shown, specified or required. The OWNER will purchase the GCD material and fasteners for the Drainage Net component of the GCD. Procurement and delivery of these materials will be the responsibility of the PROJECT ENGINEER. The GEOSYNTHETICS CONTRACTOR is responsible for supplying the thread for sewing of the Geotextile component of the GCD.

### 1.2 RELATED SECTIONS

A. Section 02278 - Geosynthetic Clay Liner

B. Section 02595 - Geotextile

C. Section 02781 - LLDPE Geomembrane

D. Section 02597 –HDPE Geomembrane

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM):

1. D413 Standard Test Methods for Rubber Property-Adhesion to Flexible Substrate

2. D792 Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

3. D1505 Standard Test Method for Density of Plastics by the Density-Gradient Technique

4. D1603 Standard Test Method for Carbon Black in Olefin Plastics

5. D4218 Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique

6. D4354 Standard Practice for Sampling of Geosynthetics and Rolled Erosion Products (RECPs) for Testing

7. D4491 Standard Test Methods for Water Permeability of Geotextiles by Permittivity

8. D4533 Standard Test Method for Trapezoid Tearing Strength of Geotextiles

9. D4595 Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method

10. D4632 Standard Test Method for Grab Breaking Load and Elongation of Geotextiles

11. D4716 Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head

12. D4751 Standard Test Method for Determining Apparent Opening Size of a Geotextile

13. D4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples

14. D6241 Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50 mm Probe.

15. D4884 Standard Test Method for Strength of Sewn or Bonded Seams of Geotextiles

16. D5199 Standard Test Method for Measuring the Nominal Thickness of Geosynthetics

17. D5261 Standard Test Method for Measuring Mass per Unit Area of Geotextiles

18. D5321 Standard Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear

19. D6243 Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method

20. D7005 Standard Test Method for Determining the Bond Strength (Ply Adhesion) of Geocomposites

21. F904 Standard Test Method for Comparison of Bond Strength or Ply Adhesion of Similar Laminates Made from Flexible Materials

B. Geosynthetic Research Institute (GRI):

1. GRI GC8 Determination of the Allowable Flow Rate of a Drainage Geocomposite

2. GRI GN2 and GRI GC13 Joining and Attaching Geonets and Drainage Composites

3. GRI GN4 Testing Methods, Required Properties and Testing Frequency for Biplanar Geonets and Biplanar Geonet Composites

C. The most current version of the specified test method shall be followed by the Manufacturer, GEOSYNTHETIC CONTRACTOR or authorized testing laboratory.

## 1.4 DEFINITIONS

A. Minimum Value – Property value representing the lowest individual allowable value obtained when tested according to the specified test method. This applies to individual readings, such as thickness; or where only one specimen is tested for the specified parameter.

B. Minimum Average Value – Property value representing the lowest allowable value for the average of results for the specimens tested.

C. Minimum Average Roll Value (MARV) – Property value calculated as the average test result minus two standard deviations. Statistically, this implies a 97.5 percent confidence that any sample tested during quality assurance will exceed the value reported.

D. Nominal Value – Property value that is representative of a measurable property, determined under a set of prescribed test conditions, by which a product may be described.

E. Typical Roll Value – Property value calculated as the average or mean obtained from test data.

## 1.5 SUBMITTALS

A. The GEOSYNTHETICS CONTRACTOR shall submit to the PROJECT ENGINEER all items included in this Article. Submittals shall be provided as follows:

1. Submitted with the BID:

   a. A project reference list demonstrating the GEOSYNTHETICS CONTRACTOR'S experience on a minimum of 5 projects, totaling at least two million square feet of installed GCD.

   b. Minimum installation crew list including how many crew members in each job classification will be required to perform the work. Although the minimum crew size may be increased by the GEOSYNTHETICS CONTRACTOR, at no additional cost to the OWNER, the crew may not be decreased without prior approval by the PROJECT ENGINEER.

   c. Resumes summarizing prior experience in installing GCD of all key GCD installation crew members, including Supervisor Foreman and Quality Control (QC) Technician, GCD installation staff will be subject to approval by the PROJECT ENGINEER and OWNER. Include resumes of all potential key GCD installation crew members that might be anticipated to work on this project.

2. Fifteen days prior to site mobilization to the site, unless stated otherwise below:

    a. Resumes summarizing prior experience in installing GCD for all GCD installation crew members to be mobilized to the site. GCD installation staff will be subject to approval by the PROJECT ENGINEER and OWNER. Resumes of any additional crew members required during the course of work shall be submitted to the PROJECT ENGINEER for approval. The additional crew member(s) will be restricted to general laborer duties until approved by the PROJECT ENGINEER.

    b. Shop drawings including details of overlap and method of joining adjacent panels, if required by the contract documents or at the OWNERS request. This shall include geonet tying detail; as well as, sewing thread type, stitch type, stitch density and number of rows, etc.

3. Upon Completion:

    a. Summary and log of all laboratory quality control and quality assurance data obtained by the GEOSYNTHETICS CONTRACTOR.

    b. Summary and log of all field quality control data and information obtained by the GEOSYNTHETICS CONTRACTOR.

    c. Statement of installation warranties.

B. The GCD MANUFACTURER shall submit to the PROJECT ENGINEER all items included in this Article. Submittals shall be provided as follows:

1. Submitted upon material selection and prior to delivery to the site:

    a. A statement of the GCD MANUFACTUER'S experience, including the manufacturing and supplying company's name, address and employee contact.

    b. A copy of the GCD MANUFACTUER'S Manufacturing Quality Assurance/Manufacturing Quality Control (MQA/MQC) Plan.

    c. In the event the GEOSYNTHETIC CONTRACTOR proposes to use thermal bonding techniques for seaming geotextiles, the PROJECT ENGINEER will require documentation describing the GEOSYNTHETICS CONTRACTORS previous experience with this technique, the method (e.g. wedge welding, hot air or flame) to be used, specifications for the welding equipment and the specific locations where the thermal bonding technique is proposed.

    d. Samples of the proposed GCD shall be obtained by the CQA/CQC LABORATORY for interface shear testing within 5 days after such request is made by the PROJECT ENGINEER. The CQA/CQC LABORATORY shall coordinate the quantity and dimensions of the samples with the PROJECT ENGINEER. Interface shear testing shall be conducted in accordance with the

CQA/CQC Plan by the PROJECT ENGINEER on materials to be used in the project.

e. Statement of material warranties.

2. Fifteen days prior to site delivery, unless stated otherwise below:

a. Manufacturing Quality Control (MQC) Manufacturing Quality Assurance (MQA) test data for the material to be delivered to the site. The reports shall include the test results for samples obtained prior to and during the manufacture of the GCD. In the event material is delivered prior to receipt of the manufacturer's data, the GCD without data will be stored separate from material with data. The GCD will be rejected if it does not meet the requirements of this Specification, or if it is found to have defects, rips, holes, flaws, deterioration or other damage deemed unacceptable by the PROJECT ENGINEER.

## 1.6 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. The GCD MANUFACTURER shall be responsible for the protection of the GCD against damage during transportation to the site. The OWNER will be responsible for protection of the GCD during storage at the site until the GEOSYNTHETIC CONTRACTOR mobilizes to the site. Once mobilized the GEOSYNTHETIC CONTRACTOR shall be responsible for the protection of the GCD against damage prior to and during its installation up to completion of the CONTRACT.

B. GCD labeling, shipment, and storage shall follow ASTM D4873, as modified by this Specification.

C. Product labels shall be placed on the ends of the roll such that they can be seen when rolls are stacked, and shall clearly show the manufacturer or supplier name, style name, date of manufacture, lot number, roll number and roll dimensions.

D. If any special handling is required, it shall be so marked on the outside surface of the wrapping (e.g. "Do not stack more than five rolls high," etc.).

E. Each GCD roll shall be wrapped with a material that will protect the material from damage due to shipment, water, sunlight and contaminants. The protective wrapping shall be maintained during periods of shipment and storage.

F. Storage areas shall be stable, dry, relatively flat and well drained. During storage the geocomposite rolls shall be adequately covered and protected from the following:

1. Exposure of the geotextile component to ultraviolet (UV) radiation in excess of 30 days, and as restricted by Section 02595, Article 3.3.B;

2. Site construction damage;

3. Precipitation;

4. Chemicals that are strong acids or strong bases;

5. Flames, sparks, temperatures in excess of 49 deg C (120 deg F); and,

6. Any environmental condition that might damage the geocomposite.

G. Roll numbers on partially used rolls shall be maintained such that each roll number can readily be identified prior to deployment of the remaining portions of the roll.

H. If the PROJECT ENGINEER determines the GCD material is damaged or has been subjected to excessive exposure, the GEOSYNTHETICS CONTRACTOR shall make all repairs and replacements in a timely manner to prevent delays in the progress of the work. Any material damaged by the GEOSYNTHETICS CONTRACTOR or damaged by others due to improper delivery or storage, as determined by the PROJECT ENGINEER, shall be replaced by the GEOSYNTHETICS CONTRACTOR at no additional cost to the OWNER.

I. Upon delivery, the PROJECT ENGINEER will examine the rolls and obtain archive samples. Archive samples will be a minimum of three feet long by three feet wide.

## PART 2 MATERIALS

### 2.1 GENERAL

A. The GCD layer shall consist of a high-density polyethylene (HDPE) geonet core between two layers of nonwoven, needle punched geotextile. The geotextiles shall be heat-bonded to the geonet core. The geonet core and the geotextiles, as well as the geocomposite itself, shall be subject to Manufacturing Quality Assurance (MQA) and Manufacturing Quality Control (MQC) testing as required by this Specification.

B. The GCD MANUFACTURER shall be solely responsible for the quality of the material provided. Should any of the tests performed on the material yield unsatisfactory results, the GEOSYNTHETIC MANUFACTURER will be responsible for replacing the material with satisfactory materials without delay to the project or cost to the OWNER.

C. The Interface shear strength testing of the geocomposite and related materials is the responsibility of the OWNER. The results must comply with the criteria determined by the PROJECT ENGINEER, as specified in the Construction Drawings. All testing must meet the minimum requirements, and the analysis of those results must be completed by the PROJECT ENGINEER prior to installation of the materials. Testing for geosynthetic to geosynthetic, or geosynthetic to soil interface, shall be conducted according to the current version of ASTM D5321. Testing for interfaces involving geosynthetic clay liner (GCL) shall be conducted according to the current version of ASTM D6243.

## 2.2 GEOTEXTILE

A. The geotextile component of the geocomposite shall be subject to MQA sampling and testing to verify the products meet or exceed the material specifications identified in this Section. Sampling shall take place prior to lamination to the geonet.

B. The geotextile shall meet the following requirements:

| PROPERTY | TEST METHOD | VALUE |
|---|---|---|
| Mass per Unit Area, oz/yd$^2$ (min. avg.) | ASTM D5261 | 6.0 |
| CBR Puncture lbs. (min. avg.) | ASTM D6241 | 450 |
| Trapezoidal Tear Strength - lbs. (min. avg.) | ASTM D4533 | 65 |
| Grab Tensile Strength(1), lbs. (min. avg.) | ASTM D4632 | 160 |
| Grab Elongation(1), % (min. avg.) | ASTM D4632 | 50 |
| A.O.S., U.S. Sieve (max) | ASTM D4751 | 70 |
| Permittivity, sec$^{-1}$ (min. avg.) | ASTM D4491 | 1.0 |

Note 1: Values required in weakest principal direction

Note 2: The Manufacturer shall provide evidence of any representative UV Resistance testing on the polymer used in the manufacture of the geotextile that is satisfactory to the Project Engineer

## 2.3 GEONET CORE

A. The geonet core of the geocomposite shall be subject to MQA/MQC sampling and testing to verify the product meets or exceeds the material specifications identified in this Section.

B. The resin shall be first; virgin material with no more than 25% rework. If rework is used it must be identical to the parent materials.

The geonet core shall meet the following requirements:

| PROPERTY | TEST METHOD | VALUE |
|---|---|---|
| Density, g/cc (min. avg.) | ASTM D1505/D792 | 0.95 |
| Carbon Black, % (min. avg.) | ASTM D1603/D4218 | 2.0 – 3.0 |

## 2.4 GEOCOMPOSITE DRAINAGE LAYER

A. The GCD shall be subject to Manufacturing Quality Control (MQC) testing for ply adhesion that must be conducted by the Manufacturer. Transmissivity testing shall be conducted by the CQA/CQC LABORATORY on material obtained at the plant by the CQA/CQC LABORATORY. The GCD shall meet the following minimum average values for the properties listed:

| PROPERTY | TEST METHOD | VALUE |
|---|---|---|
| Ply Adhesion, lb/in (min. avg.) | ASTM D7005 | 0.5 |
| Ply Adhesion, lb/in (max. avg.) | ASTM D7005 | 1.0 |
| Transmissivity(1), $m^2$/sec. (min.) | ASTM D4716 | (As specified per construction documents) |

Note 1: A single transmissivity test must be conducted by the OWNER on each Type of geocomposite prior to delivery of the material, under the following general conditions:

- Layering/Adjacent materials - as per design;
- Flow direction – machine direction of the geocomposite:
- Load stepping for cases where GCL is used adjacent the geocomposite;
- Seating time – See Transmissivity Test Protocol; and,
- Gradients – Above specified transmissivity required at a gradient of 0.33 and 0.02.

B. The CQA/CQC LABORATORY shall coordinate obtaining the GCD samples required for the OWNERS transmissivity testing with the PROJECT ENGINEER and the MANUFACTURER.

## 2.5 FASTENERS

A. GCD panel connections shall be secured with fasteners. Fasteners shall be approved locking plastic ties approximately six inches long, and the tensile strength shall be greater than a geonet strand, as confirmed by the PROJECT ENGINEER in a field test. Fasteners shall be leachate compatible and shall not be capable of damaging adjacent geosynthetic materials. Fasteners shall be of a color that contrasts with the color of the geonet core. Samples of the fasteners shall be submitted to the PROJECT ENGINEER for approval prior to use. Metallic ties shall not be used.

## 2.6 SEWING THREAD/NEEDLES

A. The upper geotextile of the geocomposite panels are to be joined by sewing and shall be sewn only as approved by the PROJECT ENGINEER.

B. Sewing thread shall consist of high strength polypropylene or polyester.

C. Materials means and methods for sewing adjoining panels shall be as approved by the PROJECT ENGINEER.

D. The GEOSYNTHETICS CONTRACTOR shall develop, and the PROJECT ENGINEER shall approve, a plan to account for sewing needles used in the joining of the GCD in order to prevent lost or broken needles from damaging the adjacent geomembrane liner(s).

## PART 3 EXECUTION

### 3.1 SURFACE PREPARATION

A. The surface to be covered by the GCD shall be cleared of loose soil, sharp objects, stones, sticks, or any materials that may contribute to clogging, punctures, shearing, rupturing or tearing of the geosynthetic materials. The geocomposite subgrade shall have a smooth, finished surface, free from pockets, holes, ruts, and discontinuities that will cause bridging of the material in the judgment of the PROJECT ENGINEER. All soil subgrade to be covered by GCD shall be inspected for unstable areas or soft spots before the GCD is placed and additional surface preparation may be required to eliminate any unsuitable areas as determined by the PROJECT ENGINEER.

### 3.2 INSTALLATION

A. The GEOSYNTHETICS CONTRACTOR shall install the GCD Layers to the lines and grades shown on the Contract Drawings in accordance with this Section and the Manufacturer's recommendations. GCD panels shall be deployed in a manner that will not damage the geocomposite or underlying materials, and that will minimize wrinkling.

B. The GCD Layer shall be deployed in a manner that will limit the placement of cross seams (seams perpendicular to the slope direction). No cross seams shall be permitted on slopes greater than 25% unless the slope length exceeds the manufactured roll length.

C. All cross seams shall be shingled downslope, such that the upgradient geonet lies above the downgradient geonet, and all side seams (along panel length) shall be shingled in the same direction along the width of the slope.

1. GCD panels shall be joined along all edges by sewing or thermal bonding with a hot wedge welding instrument of the upper geotextile, tying the net in a net to net contact, and overlapping the lower geotextile. For side-seams, panels shall be overlapped a minimum of 6-inches. Cross seams shall be overlapped a minimum of 12-inches. The geonet core shall be secured with approved plastic fasteners. The fasteners, after installation, shall be positioned in a way as not to damage the overlying geomembrane. The adjacent panels at side-seams shall be fastened with approved plastic fasteners at a spacing of 1 fastener every 5 feet of panel overlap, except on the top of the perimeter berm where the fasteners shall be spaced at six inches. The adjacent panels at cross seams shall be fastened every 12-inches on slopes less than 25%; on slopes greater than 25%, there shall be a double row (six-inches apart) of ties at a spacing of twelve inches.

2. For the panels on the side slope, overlaps for all seams oriented perpendicular to the flow path shall be achieved by pulling back the upper geotextile of the lower GCD and the

lower geotextile on the upper GCD. The adjoining geonet cores shall be shingled down slope with a minimum twelve-inch overlap. The upper geotextiles shall be rejoined by sewing, as approved by the PROJECT ENGINEER.

D. The upper geotextile of adjacent GCD panels shall be joined by sewing or thermal bonding. For sewn seams, the geotextile shall be overlapped a minimum of four inches, or as required by the sewing method approved by the PROJECT ENGINEER. For thermal seams, the overlap shall be fully bonded carefully to prevent burn through of the geotextile across a minimum three-inch overlap; that is, heat tacking will not be permitted.

E. Welding of the geonet to the HDPE geomembrane shall not be permitted.

F. The work shall be scheduled so that the GCD is covered within 30 days after placement. Failure to comply with this requirement will require replacement of the GCD unless the GEOSYNTHETICS CONTRACTOR demonstrates, to the satisfaction of the PROJECT ENGINEER, the material has not been adversely affected.

G. Smoking is not permitted on any geosynthetic material.

H. The GEOSYNTHETICS CONTRACTOR shall be responsible for the protection of the geomembrane during the installation of the GCD layer. In no way shall any tracked equipment, or any other equipment which may pose a risk of puncturing, tearing, or otherwise damaging the geosynthetics, be permitted for use during this phase of construction.

I. Any use of ATV's or other similar vehicles on the site must be pre-approved by the PROJECT ENGINEER. The GEOSYNTHETICS CONTRACTOR shall submit an S.O.P. describing how vehicles are to be used, if at all, in the deployment of geocomposite at the site. As a minimum, the following shall apply:

1. Any damage resulting from the use of vehicles, as determined by the PROJECT ENGINEER, shall be repaired according to Article 3.3, at no additional cost to the OWNER. If repeated repairs are required as the result of the use of vehicles operating on geosynthetic material, further use of such vehicles will be prohibited.

2. Any and all vehicles proposed to be used in the deployment of geosynthetics will be inspected by the PROJECT ENGINEER. Vehicles which are found to be leaking oil or fuel, or which in any other way exhibit the potential to damage the lining system components, will not be permitted.

3. Geosynthetics on which any oil or fuel leaks shall be replaced at the discretion of the PROJECT ENGINEER, at no additional cost to the OWNER.

4. Re-fueling of vehicles on geosynthetic materials is prohibited.

5. Vehicles shall have tires with low ground pressure, typically less than 5 psi, and shall have shallow treads.

6. Vehicles shall be operated by a single operator at speeds less than 5 mph.

7. Quick starts, stops, wheel spinning and sharp turns will not be permitted above any geosynthetic material.

J. All cover materials will be placed in such a manner to ensure:

1. Soil and other materials do not accumulate in the geonet portion of the geocomposite drainage layer;

2. The geocomposite layer and underlying lining materials areis not damaged;

3. Minimal slippage of the geocomposite drainage layer on underlying layers; and.

4. No excess tensile stresses develop in the geocomposite drainage layer.

## 3.3 REPAIRS

A. Any holes or tears in the GCD shall be repaired using material obtained from rolls approved by the PROJECT ENGINEER for use at the site.

B. Patching of the GCD shall be accomplished by tying the geonet at a minimum of four locations, but not exceeding an interval of six-inches, and sewing or thermal bonding of the upper geotextile as approved by the PROJECT ENGINEER. All approved patches shall extend a minimum of 6 inches in all directions from the edge of the defect.

# PART 4 QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

## 4.1 GENERAL

A. Before installation begins, and weekly thereafter, (more often if determined necessary by the PROJECT ENGINEER) project coordination meetings shall be held with the designated representative of the NYSDEC, GEOSYNTHETICS CONTRACTOR, PROJECT ENGINEER, and OWNER in attendance to review the following information:

B. Progress of the work.

C. Adherence to the Specifications.

D. Adherence to the Construction Quality Control Program described in this Section, including the timely submission of the pertinent forms.

E. Planned work and methods for the ensuing week, including estimate of time remaining to completion of the work.

1. Problem resolutions to be implemented during the upcoming week.

F. All information specified and required must be submitted to the PROJECT ENGINEER in a timely fashion.

G. Any changes in the proposed method of work, SUBCONTRACTORS to be utilized, manufacturing or materials must be approved in advance by the PROJECT ENGINEER. The GEOSYNTHETICS CONTRACTOR assumes all responsibility relevant to providing an acceptable final product.

## 4.2 INSTALLATION QA/QC

A. The PROJECT ENGINEER and GEOSYNTHETICS CONTRACTOR shall visually inspect all materials to be included in the work and compare roll identification numbers with those provided by the manufacturer to assure installation of the approved materials. No material shall be installed prior to furnishing the required test results.

B. All panel seams shall be inspected and approved by the PROJECT ENGINEER

C. The PROJECT ENGINEER shall observe for signs of nonlaminated areas in the form of blisters when the material is being deployed. If blisters are observed, more detailed inspection of those areas should be performed by pushing on the material with the soles of boots, particularly to investigate if there is a tendency for a machine-direction defect. The size of any blisters must be recorded and reported to the PROJECT ENGINEER.

D. The ends of panels (at least every fifth panel) must be periodically tested by the PROJECT ENGINEER by hand pulling the geotextile away from the geonet (on both sides of a double-sided product). If weak areas are found, which generally run in the machine direction, they must be reported to the PROJECT ENGINEER and be more thoroughly evaluated through additional sampling and laboratory testing.

E. If panels are found to contain weakly bonded areas in excess of what is deemed acceptable by the PROJECT ENGINEER, those panels must be removed, and a more detailed investigatory program undertaken that searches for the extent of the problem. It is also important to involve the manufacturer to try to understand the reason for the problem, which will be helpful in determining how much of the shipment might need to be rejected.

F. Damage to the GCD materials during installation shall be repaired according to Article 3.3. If the PROJECT ENGINEER determines the damage is un-repairable, the damaged material will be replaced.

G. The geotextiles shall be heat-bonded over the entire surface of the geonet. If a significant portion of the upper or lower geotextile, as determined by the PROJECT ENGINEER, is not bonded to the surface of the geonet, the PROJECT ENGINEER shall reject the questionable portion of the roll or require the unbonded area to be cut out and replaced in accordance with the requirements of this Specification.

## 4.3 WARRANTY

A. The GEOSYNTHETICS CONTRACTOR shall issue a warranty on the installation of GCD layer material for a minimum period of 1 year.

B. The GCD MANUFACTURER shall issue a warranty on the GCD layer material for a minimum period of 1 year.

END OF SECTION

# SECTION 02650

# POLYVINYL CHLORIDE (PVC) PIPE

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. Work covered by this Section includes the requirements, materials, and methods for installing PVC piping, appurtenances and fittings, as shown on the Drawings.

B. The CONTRACTOR shall furnish and install the various pipelines and appurtenant work as indicated in the Drawings and as specified herein, or as reasonably required to produce a complete, proper, and functional installation in accordance with the intent of the design.

### 1.2 RELATED SECTIONS

A. Section 02223 - Common Trench Backfill

B. Section 02233 - Bedding and Backfill

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM):

1. D2564Standard Specification for Solvent Cements for Poly (Vinyl Chloride) (PVC) Plastic Piping Systems

2. F656 Standard Specification for Primers for Use in Solvent Cement Joints of Poly (Vinyl Chloride) (PVC) Plastic Pipe and Fittings

B. The most current version of the specified test method shall be followed by the Manufacturer, EARTHWORK CONTRACTOR or authorized testing laboratory.

## 1.4 DELIVERY, STORAGE, AND HANDLING

A. The CONTRACTOR and PROJECT ENGINEER shall inspect the pipe shipment upon arrival to identify any apparent damage to the pipe and to verify and document that the proper pipe has been received by recording the pipe designations marked on the pipe and by spot measuring the pipe inside diameter (ID) and outside diameter (OD).

B. All pipes and fittings shall be carefully handled when loading and unloading. Lift by hoists or lower on skids in a manner to avoid shock or impact. Chains, cables, or hooks shall not be inserted into the pipe end.

C. Where required, due to weight of material and for the safety and protection of workmen, materials, equipment, property, and the work, use derricks, ropes, or other suitable equipment for lowering pipe into trenches or when handling the pipes. The CONTRACTOR shall take measures to avoid damaging the pipe.

D. The pipe shall be stored on a hard, clean, well drained and near level surface. The pipe may be set on wooden sleepers and shall not be stacked more than four feet high. When pipe is stacked for storage, the heaviest series of pipe shall be placed at the bottom.

E. All pipes, fittings, and appurtenances to be used in this work shall be handled with extreme care. Proper and suitable tools and appliances for safe convenient handling and laying of the pipes shall be used.

F. PVC pipe and fittings shall be protected from damage by sharp objects through all phases of work.

G. If any defective pipe is discovered after being laid or placed, removal and replacement with a sound pipe will be required without cost to the OWNER.

# PART 2 MATERIALS

## 2.1 POLYVINYL CHLORIDE (PVC) PIPE AND FITTINGS

A. All PVC piping shall be perforated, or solid wall PVC pipe as required and shown on the Drawings. The size of the pipe and any perforation design shall be as specified.

B. All pipe fittings shall be of the same schedule, or greater, as the adjoining pipe, except for transition or special couplers as noted on the Drawings.

C. Pipe and fittings of the same type shall be the products of a single manufacturer or as approved by the PROJECT ENGINEER.

D. If required, PVC primers conforming to ASTM F656, and PVC solvent cement conforming to ASTM D2564 shall be used for socket type connections as shown on the Drawings.

# PART 3 EXECUTION

## 3.1 INSPECTION

A. Each length of pipe and each fitting shall be carefully inspected prior to installation. All materials not meeting the requirements of these Specifications, or otherwise found defective or unsatisfactory by the PROJECT ENGINEER, shall be rejected and immediately marked and removed from the job site by the CONTRACTOR.

B. Bedding and other trench conditions shall be carefully inspected prior to laying pipe in each stretch of open trench. All conditions shall be made available to the PROJECT ENGINEER for inspection purposes, and the PROJECT ENGINEER shall be further advised where, in the CONTRACTOR's opinion, unstable or otherwise deleterious conditions exist.

C. Each stretch of completed pipeline shall be inspected prior to backfilling. Backfilling operations shall not be initiated prior to inspection by the PROJECT ENGINEER.

## 3.2 PREPARATION

A. All pipes and fittings shall be maintained in a clean condition before, during and after installation. Pipe and fitting interiors and joint surfaces shall be thoroughly inspected prior to installation to verify the all loose soil, debris or other foreign materials have been removed from the pipe prior to joining and burial.

## 3.3 PIPE INSTALLATION

A. Pipe installation shall be performed by skilled workers. Each pipe laying crew shall have a pipe laying foreman.

B. Pipe shall be accurately installed to the lines and grades shown in the Drawings, or as approved by the PROJECT ENGINEER, so that inverts are smooth. Each pipe length (20 feet) shall be field checked for grade and alignment during installation.

C. Deflections in horizontal or vertical alignment at joints are not permitted without the consent of the PROJECT ENGINEER. If so approved, the deflections shall not exceed the manufacturer's recommendation.

D. When requested by the PROJECT ENGINEER, a qualified field representative of the manufacturer shall be present at the job site for the first day of pipe laying to assure that proper procedures are followed, and during leakage testing (as applicable).

E. The PROJECT ENGINEER shall be notified in advance whenever an existing pipeline location conflicts with the proposed locations of the work.

F. Pipe Adapters - Join pipes of different materials with adapters specifically manufactured for that purpose and as approved by the PROJECT ENGINEER, or as detailed in the Drawings.

G. All piping shall be of the type and size as shown in the Drawings and described in this Section of the Specifications.

H. Pipes and fittings shall be carefully lowered into the trench.

I. Pipe and fittings shall be installed so that there will be no excess deviation at the joints and so that inverts present a smooth surface. Pipe and fittings that do not mate to form a tight-fitting joint are not permitted.

J. Excavations shall be maintained substantially free of water during pipe installation. No pipes shall be laid in soils that have become softened due to water exposure, or in water, nor shall there be any joints made up in water. All slides or cave-ins of the trenches or cuts shall be remedied to the satisfaction of the PROJECT ENGINEER.

K. Cleanliness of installed pipe and fitting interiors shall be maintained throughout the work.

L. Adjustments to the line and grade of pipe shall be done by scraping away or filling of bedding stone under the barrel of the pipe, and not by blocking or wedging.

M. Fittings shall be installed as required and in accordance with the Drawings and Specifications. The installation of fittings after the pipeline has been laid will not be permitted without the approval of the PROJECT ENGINEER. In such cases, details pertaining to the proposed type of fittings and the installation procedure shall be submitted by the CONTRACTOR to the PROJECT ENGINEER for review.

N. Approval by the PROJECT ENGINEER is required prior to changing the location of any of the Work due to field conditions. Changes in pipe sizes are prohibited without a written consent from the PROJECT ENGINEER.

O. All installed piping shall form completely connected systems including connections to appurtenances specified in other sections to result in a satisfactorily operating installation.

P. Perform field cutting of pipe with the use of a fine-toothed hacksaw, a handsaw, sawz-all, or a circular saw providing square ends for proper joints. Cut ends shall be beveled in accordance with manufacturer's instructions.

Q. All pipe ends not terminated by another specific fitting shall be capped with a slip cap or as directed by the PROJECT ENGINEER. Caps shall not be bonded to the pipe unless otherwise specifically noted in the Drawings.

R. Unless otherwise specified, pipe ends shall be temporarily capped and sealed securely to ensure no water or soil intrusion, pending future connection.

END OF SECTION

# SECTION 02660

# HIGH DENSITY POLYETHYLENE PIPE

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. Work covered by this Section includes the requirements, materials, and methods for installing High Density Polyethylene (HDPE) leachate collection and transfer piping, HDPE siderisers and sumps, HDPE landfill gas piping, fittings, and appurtenances, as shown on the Contract Drawings.

B. The CONTRACTOR shall furnish and install the various pipelines and appurtenant work as indicated in the Drawings and as specified herein, or as reasonably required to produce a complete, proper, and functional installation in accordance with the intent of the design.

### 1.2 RELATED SECTIONS

A. Section 02223 – Common Trench Backfill

B. Section 02233 – Bedding and Backfill

C. Section 02781 – LLDPE Geomembrane

D. Section 02599 – Geocomposite Drainage Layer

E. Section 02650 – Polyvinyl Chloride (PVC) Pipe

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM):

1. D3350 Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
2. F2164 Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Hydrostatic Pressure

B. American National Standards Institute (ANSI):

C. Code of Federal Regulations (CFR):
   1. DOT 49 CFR 192.283 Research and Special Programs Administration, Department of Transportation – Part 192 – Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards 192.283 – Plastic Pipe: Qualifying Joining Procedures

## 1.4 DELIVERY, STORAGE, AND HANDLING

A. The CONTRACTOR and PROJECT ENGINEER shall inspect the pipe shipment upon arrival to identify any apparent damage to the pipe and to verify and document that the proper pipe has been received by recording the pipe designations marked on the pipe and by spot measuring the pipe inside diameter (ID) and outside diameter (OD).

B. All pipes and fittings shall be carefully handled when loading and unloading. Lift by hoists or lower on skids in a manner to avoid shock or impact. Chains, cables, or hooks shall not be inserted into the pipe end. The pipe and fittings shall not be dropped during any phase of the work.

C. Where required, due to weight of material and for the safety and protection of workmen, materials, equipment, property, and the work; use derricks, ropes, or other suitable equipment for lowering pipe into trenches or when handling the pipes.

D. The pipe shall be stored on a hard, clean, well drained and near level surface. The pipe may be set on wooden sleepers, spaced suitably and of such a width as not to allow deformation of the pipe at the point of contact with the sleeper or between the supports. Stacking of the pipe shall be limited to a height that will not cause excessive deformation of the pipe under anticipated temperature conditions. When pipe is stacked for storage, the heaviest series of pipe shall be placed at the bottom.

E. For convenience of handling, HDPE pipe is best protected from sunlight exposure to prevent bending of the pipe caused by uneven heating. Such protection typically consists of canvas covering, or other material as recommended by the manufacturer and approved by the PROJECT ENGINEER.

F. HDPE pipe and fittings shall be protected from damage through all phases of work.

G. Pipe products which are cracked, chipped, dented or gouged for a depth greater than 10% of the pipe wall thickness, or are otherwise damaged will not be approved for installation.

# PART 2 MATERIALS

## 2.1 HIGH-DENSITY POLYETHYLENE (HDPE) PIPE AND FITTINGS

A. All HDPE pipe and fittings shall be closed profile (smooth exterior wall) outside diameter product manufactured from virgin polyethylene resin. The resin shall be PE3408 conforming to ASTM D3350.

B. All polyethylene fittings shall have a pressure rating equal to or higher than the design pressure rating of the system. Pipe and fittings of the same type shall be products of a single manufacturer, or as approved by the PROJECT ENGINEER.

C. The size, perforation design (if necessary) and dimension ratio of HDPE pipe and fittings shall be as shown in the Drawings.

D. All piping and valves shall be supported as required to provide a structurally sound installation.

E. Electrofusion couplings may be used where typical fusion welding is impractical, subject to the approval of the PROJECT ENGINEER.

# PART 3 EXECUTION

## 3.1 INSPECTION

A. Each length of pipe and each fitting shall be carefully inspected prior to placement in the work. All materials not meeting the requirements of these Specifications, or otherwise found defective or unsatisfactory by the PROJECT ENGINEER shall be rejected and will be marked by the PROJECT ENGINEER for removal from the job site by the CONTRACTOR.

B. Damaged pipe or fittings must be inspected and evaluated to determine if the damage impairs serviceability. For pressure piping systems, damage or butt fusion misalignment in excess of 10% of the minimum wall thickness required for pipeline operating pressure may be significant. If the pipeline is to operate at the maximum permissible pressure for the material and dimension ratio (DR), the damage allowance is 10% of the pipe minimum wall thickness. If the pipeline is to operate at atmospheric pressure, the damage allowance is 15% of the pipe minimum wall thickness. If the pipe is to operate at lower pressure, damage depth may be greater. The shape of the damage must also be considered. For small damage areas where the depth is not excessive, sharp notches and cuts should be dressed smooth, so the notch is blunted. Blunt scrapes or gouges less than the permissible depth will not require attention. Pipe or fittings that have sustained service impairing damage shall not be installed. Post-installation damage that exceeds

the allowable shall require that the damaged pipe or fitting be removed and replaced. Scrapes or gouges cannot be repaired by filling-in with extrusion or hot air welding.

C. Bedding, subgrade, and other trench conditions shall be carefully inspected prior to laying pipe. All pipe bedding and trench conditions shall be made viewable and accessible to the PROJECT ENGINEER for inspection purposes. The PROJECT ENGINEER shall be advised where, in the CONTRACTOR's opinion, unstable or otherwise deleterious conditions exist.

D. Backfilling operations shall not be initiated by the CONTRACTOR prior to inspection of the pipe bedding and trench conditions by the PROJECT ENGINEER.

E. If any defective pipe is discovered subsequent to placement in the trench or partial burial, the pipe shall be removed and replaced with good quality pipe.

## 3.2 PREPARATION

A. Pipe and fitting interiors, joint surfaces and gaskets shall be thoroughly inspected prior to installation. Pipes and fittings shall be maintained in a clean condition. A clean cotton cloth shall be employed for cleaning; polyester materials shall not be used.

## 3.3 HDPE PIPE JOINING

A. The preferred method for joining HDPE pipe shall be the butt-fusion method, producing a uniform and monolithic pipe in accordance with the butt fusion joining procedures provided by the pipe manufacturer. Electrofusion or mechanical joints may be used where butt fusion welding is impractical, subject to the approval of the PROJECT ENGINEER. Extrusion welding or other means of joining HDPE pipe methods will not be permitted without the approval of the PROJECT ENGINEER. The CONTRACTOR shall submit the Manufacturers standard operating procedures for all proposed pipe joining operations to the PROJECT ENGINEER for approval before work is initiated.

B. Randomly selected primary (carrier) pipe joints will be inspected and approved by the PROJECT ENGINEER prior to installing piping. All containment piping joints shall be visually inspected and approved by the PROJECT ENGINEER after pipe placement and temporary backfill.

C. The CONTRACTOR must consider ambient temperature when connections are to be made between two fixed points or structures in the work to compensate for the expansion and contraction potential of the pipe. Pipe length considerations shall be in accordance with the HDPE pipe manufacture’s guidelines.

D. Each individual performing fusion welding shall be certified by the Manufacturer to operate the butt fusion and electrofusion equipment through appropriate training in the

use of the procedure, and by making a specimen joint from pipe sections joined according to the procedure that passes the inspection and test set forth below:

1. The individual must make a sample joint that passes the following inspections and tests, to be performed by the PROJECT ENGINEER:

    a. The joint must be visually examined during and after joining and found to have the same appearance as a photograph or sample of an acceptable joint, made in accordance with the accepted standards and procedures.

    b. The joint must be tested or examined by one of the following methods:

        i. Pressure and tensile test as described in 49 CFR Part 192.283.

        ii. Ultrasonic inspection found to be free of flaws that would cause failure.

        iii. Butt-Fusion bend back test, as follows:

            - Allow the joint to cool for at least one hour before subjecting the pipe to a severe bond test;

            - Cut at least 3 longitudinal straps, 1-inch wide through the pipe joint such that a minimum of 12-inches of pipe remains on each side of the joint

            - Hold each strap at the ends, bend the sample until the ends touch. (A vice or another mechanical device may be used.);

            - Maintain each sample in the bent position, and thoroughly examine the entire fusion area. If any separation, cracks, or voids are observed, the joint is defective; and,

            - A joint is considered satisfactory if all bent samples are completely free of cracks or voids in the fusion area.

## 3.4 PIPE INSTALLATION

A. Skilled workers shall complete the pipe installation, with each pipe laying crew assigned a foreman in charge. The worker performing the welding (butt fusion and electrofusion) shall be certified by the pipe manufacturer.

B. Pipe shall be accurately installed to the lines and grades shown in the Drawings, or as approved by the PROJECT ENGINEER, so that inverts are smooth. Each pipe length, or 20-foot run, whichever is less, shall be field checked for grade and alignment during installation.

C. The PROJECT ENGINEER shall be notified in the event an existing pipeline location or other structure conflicts with the proposed location of the work.

D. Pipe sections shall be joined at ground level to a length not longer that that recommended by the manufacturer such that maximum, allowable stress, when pulling the pipe into position alongside the trench, is not exceeded. Use appropriate materials and equipment, when pulling butt-fused pipe sections alongside the trench to prevent pipe damage. Temporary end caps or plugs shall be used as necessary when pulling pipe into position to prevent soil or other debris from entering pipe barrel.

E. Pipe and fittings shall be carefully lowered into the trench.

F. Pipe and fittings shall be installed so that there will be no excess deviation at the joints and so that inverts present a smooth surface.

G. Excavations shall be maintained free of water during pipe installation. No pipes shall be laid in water nor shall there be any joints made up in water. All slides or cave-ins of the trenches or cuts shall be remedied to the satisfaction of the PROJECT ENGINEER.

H. All adjustments to the line and grade of pipe shall be done by scraping away or compacted filling of the bedding under the barrel of the pipe, and not by blocking or wedging.

I. All installed piping shall form completely connected systems including connections to valves and appurtenances specified in other sections to result in a satisfactory operating installation.

J. All solid-walled HDPE piping shall be leak tested except for the leachate sump side slope riser pipes, and landfill gas collection system piping. Leak testing shall be performed in accordance with Part 4 of this section.

## 3.5 HDPE DOUBLE WALL PIPE INSTALLATION

A. The diameter and dimension ratio of HDPE carrier and containment pipe shall be shown in the Drawings.

B. All HDPE pipe to be installed as a dual containment piping system shall be supplied with HDPE centralizers for centering the carrier pipe within the containment pipe. The centralizers shall be manufactured from virgin polyethylene resin. The centralizers shall be installed by the pipe manufacturer or be suitable for field extrusion welding to the pipe at intervals recommended by the manufacturer. The HDPE centralizers and centralizer spacing shall be as approved by the PROJECT ENGINEER.

C. HDPE pipe and fittings within manholes shall be flanged and gasketed connections unless otherwise shown on the Drawings. Backing rings shall be carbon steel and be

designed to conform to ANSI Class 150. All flanged connections shall use steel bolts of the same material as the backing rings unless otherwise shown on the Drawings.

D. Leak detection riser pipes shall be connected to the containment pipe at its low points, as shown in the Drawings. The pipe and fittings shall be solid-walled 4-inch diameter SDR 17 HDPE with a slip-on cap and lock with keys. The protective casings shall be painted with rust inhibitive exterior grade oil base paint, using a color approved by the OWNER.

E. Leak testing of both the carrier pipe and containment pipe shall be performed as specified in Part 4 of this section.

## PART 4 LEAK TESTING

### 4.1 GENERAL

A. The CONTRACTOR shall be responsible for providing hydrostatic and/or pneumatic leak testing of all solid-walled HDPE pipes outside the landfill liner system. All leak testing shall be completed in accordance with the requirements and procedures included in Technical Note 802 – Leak Testing, prepared by Performance Pipe of Chevron Phillips Chemical Company, LP.

B. Hydrostatic testing shall be completed in conformance with the requirements of ASTM F2164, the Standard Practice for Field Testing of Polyethylene (PE) Pressure Piping Systems Using Hydrostatic Pressure.

C. If pneumatic testing is proposed, the CONTRACTOR shall submit to the PROJECT ENGINEER, for approval, a written procedure that will be followed to test the system, and to secure the pipe system during the test. Temperature measurements must be made at appropriate locations to ensure adequate data for evaluation of test results.

D. The tests can be made prior to backfilling as long as the PROJECT ENGINEER performs continuous inspection of the backfill process. Alternately, continuous inspection of the backfilling by the PROJECT ENGINEER may be waived by the OWNER if leak testing is performed when the pipe bedding, pipe, fittings, and appurtenances have been installed and the trench has been partially backfilled. If leak testing is performed after partial backfilling, the joints and fittings will be left exposed for inspection during the test. The CONTRACTOR shall replace failed sections of pipe and/or fittings at no additional cost to the OWNER.

E. For sections of pipe that include thrust blocks, the leak test will not be conducted sooner than five days following the placement of the concrete.

F. Ends of pipe sections being tested shall be tightly closed by plugs, blind flanges, gates or otherwise for the duration of the test. The CONTRACTOR shall furnish all such

material, supplies, apparatus, labor, and equipment as necessary for carrying out the test and shall make all necessary arrangements for securing and furnishing water for hydrostatic testing purposes. Any proposed changes to the specified test procedures in this Section shall be submitted to and approved by the PROJECT ENGINEER prior to testing.

G. If the test pressure varies, or a significantly lower but constant test pressure is maintained, the PROJECT ENGINEER will examine the pipe for leakage. The CONTRACTOR shall repair all leaks. If no leakage is found, the test will be repeated following depressurization, and a relaxation period of no less than 8 hours. The re-testing program shall continue for a duration determined by the PROJECT ENGINEER, not to exceed 8-hours. The results of the re-testing program will be reviewed by the PROJECT ENGINEER to determine whether the variable and/or lower test pressure results are acceptable.

H. All exposed pipes, fittings, joints, and other appurtenances shall be carefully examined by the PROJECT ENGINEER during the test. All joints showing visible or audible leakage shall be repaired and made leak proof. Any cracked or defective pipe or fitting discovered as a result of the leak tests, shall be removed, and replaced by the CONTRACTOR with new sound material, and the leak test shall be repeated until satisfactory results are achieved.

## 4.2 HYDROSTATIC LEAK TEST

A. Prior to hydrostatic testing, the pipe shall be cleared of debris and thoroughly flushed with clean water. Before applying the specified test pressure, the piping system (including fittings) must be adequately restrained against movement, and all air shall be expelled from the section being tested. Each section of the pipe to be tested shall be slowly filled with clean water and the test pressures shall be applied in a manner satisfactory to the PROJECT ENGINEER.

B. Water used in testing or flushing the piping system shall be approved by the PROJECT ENGINEER.

C. Hydrostatic testing will include an initial expansion phase, a test phase, and a depressurizing phase. During the initial expansion phase, the test section shall be pressurized to no more than 150 percent of the design pressure, or the pressure rating of the lowest pressure rated component in the test section, as determined by the PROJECT ENGINEER and as measured at the lowest elevation in the test section. Make-up water shall be added each hour for three (3) hours to maintain the expansion phase pressure. The volume of make-up water added during the initial expansion phase may be metered and recorded by the PROJECT ENGINEER.

D. The test phase shall follow immediately after the initial expansion phase and shall be a minimum of one (1) hour, or a maximum of three hours in duration. At the end of the

test phase, the test section shall be returned to test pressure by adding a metered amount of make-up water. Acceptance shall be determined based on allowable make-up water, as summarized below:

| NOMINAL PIPE SIZE (in) | 1 HOUR TEST (gal/100ft of pipe) | 2 HOUR TEST (gal/100ft of pipe) | 3 HOUR TEST (gal/100ft of pipe) |
|---|---|---|---|
| 2 | 0.07 | 0.11 | 0.19 |
| 3 | 0.10 | 0.15 | 0.25 |
| 4 | 0.13 | 0.25 | 0.40 |
| 6 | 0.3 | 0.6 | 0.9 |
| 8 | 0.5 | 1.0 | 1.5 |
| 10 | 0.8 | 1.3 | 2.1 |
| 12 | 1.1 | 2.3 | 3.4 |

## 4.3 PNEUMATIC LEAK TESTING

A. Compared to hydrostatic testing, testing the pipe system with compressed gas (pneumatic testing) can be more dangerous because failure during pneumatic testing releases more energy. If pneumatic testing is proposed, the pipe must be tested in the partially buried conditions to stabilize and restrain the pipe, and to moderate temperature fluctuations. The CONTRACTOR shall submit to the PROJECT ENGINEER for approval, a written procedure that will be followed to secure the pipe fittings and appurtenant during the test and maintain worker safety.

B. The testing medium shall be oil free, non-flammable and non-toxic. The test pressure shall not exceed the maximum allowable test pressure for any non-isolated component in the test section.

C. Temperature gauges (0° to 100° C) shall be installed at the locations necessary to adequately and accurately measure the internal temperature of the test gas in the entire test section.

D. The pressure in the carrier pipe test section shall be gradually increased to 20 psi and shall be held for 60 minutes. Pressure Reading and Internal Temperature readings shall be taken in ten-minute intervals until completion of the test. If the test pressure remains within 10% of the target value for the duration of the test, no leakage is indicated.

E. For containment pipe the expansion phase pressure shall be 6 psig, and the test pressure shall be 5 psig. Test pressure for the containment pipe shall be maintained for at least 15 minutes.

F. At the conclusion of the test, depressurize the test section by a controlled release of gas from the test section.

END OF SECTION

# SECTION 02781

# LLDPE GEOMEMBRANE LINER

## PART 1 GENERAL

### 1.1 SECTION INCLUDES

A. The GEOSYNTHETICS CONTRACTOR shall furnish all labor, materials, equipment, tools, and appurtenances required to complete the installation of all geomembrane, complete with appurtenances, as shown, specified or required by the Drawings.

### 1.2 RELATED SECTIONS

A. Section 02595 - Geotextiles

B. Section 02621 - Geocomposites

### 1.3 REFERENCES

A. American Society for Testing and Materials (ASTM):

1. D1004 Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting

2. D1238 Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer

3. D1505 Standard Test Method for Density of Plastics by the Density-Gradient Technique

4. D1603 Standard Test Method for Carbon Black in Olefin Plastics

5. D3895 Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry

6. D4218 Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique

7. D4354 Standard Practice for Sampling of Geosynthetics for Testing

8. D4833 Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products

9. D4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples

10. D5199 Standard Test Method for Measuring the Nominal Thickness of Geosynthetics

11. D5261 Test Method for Measuring Mass per Unit Area of Geotextiles

12. D5321 Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method

13. D5397 Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test

14. D5596 Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics

15. D5641 Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber

16. D5721 Standard Practice for Air-Oven Aging of Polyolefin Geomembranes

17. D5820 Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes

18. D5884 Test Method for Determining Tearing Strength of Internally Reinforced Geomembranes

19. D5885 Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry

20. D5994 Standard Test Method for Measuring Core Thickness of Textured Geomembrane

21. D6365 Standard Practice for the Nondestructive Testing of Geomembrane Seams Using the Spark Test

22. D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods

23. D6497 Standard Guide for Mechanical Attachment of Geomembrane to Penetrations or Structures

24. D6693 Standard Test Method for Determining Tensile Properties of Non-reinforced Polyethylene and Non-reinforced Flexible Polypropylene GeomembranesD7007 Standard Practices for Locating Leaks in Geomembranes Covered with Water or Earth Materials

25. D7004 Test Method for Grab Tensile Properties of Reinforced Geomembranes

B. Geosynthetic Research Institute (GRI):

1. GRI GM6 Pressurized Air Channel Test for Dual Seamed Geomembranes

2. GRI GM9 Standard Practice for "Cold Weather Seaming of Geomembranes"

3. GRI GM11 Accelerated Weathering of Geomembranes Using a Fluorescent UVA Device

4. GRI GM12 Asperity Measurement of Textured Geomembranes using a Depth Gauge

5. GRI GM17 Test Properties, Testing Frequency and Recommended Warranty for Linear Low-Density Polyethylene (LLDPE) Smooth and Textured Geomembranes

6. GRI GM14 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes

7. GRI GM29 Field Integrity Evaluation of Geomembrane Seams (and Sheet) using Destructive and/or Nondestructive Testing

8. GRI GM25 Test Methods, Test Properties and Testing Frequency of Reinforced Linear Low Density Polyethylene (LLDPE-R) Geomembranes

9. GRI GM19b Seam Strength and Related Properties of Thermally Bonded Reinforced Polyolefin Geomembranes/Barriers

C. Other:

1. ANSI/ASQC Z1.4 Sampling Procedures and Tables for Inspection by Attributes

D. The most current version of the specified test method shall be followed by the Manufacturer, GEOSYNTHETICS CONTRACTOR, or authorized testing laboratory.

## 1.4 DEFINITIONS

A. Minimum Value – Property value representing the lowest individual allowable value obtained when tested according to the specified test method. This applies to individual readings, such as thickness; or where only one specimen is tested for the specified parameter.

B. Minimum Average Value – Property value representing the lowest allowable value for the average of results for the specimens tested.

C. Minimum Average Roll Value (MARV) – Property value calculated as the average test result minus two standard deviations. Statistically, this implies a 97.5 percent confidence that any specimen tested during quality assurance will exceed the value reported.

D. Nominal Value – Property value that is representative of a measurable property, determined under a set of prescribed test conditions, by which a product may be described.

E. Typical Roll Value – Property value calculated as the average or mean obtained from test data.

F. Unit – For the purposes of this project, a "Unit" shall be a single roll of geo synthetic material.

G. Lot - For the purposes of this project, a "Lot" will be defined as a single run of geosynthetic material from the same production facility, where the tooling and raw materials of production have not changed during manufacturing.

## 1.5 SUBMITTALS

A. The GEOSYNTHETICS CONTRACTOR shall submit to the PROJECT ENGINEER all items included in this Article. Submittals shall be provided as follows:

1. With the GEOSYNTHETICS CONTRACTOR's BID:

a. A project reference list documenting the experience of the GEOSYNTHETICS CONTRACTOR on a minimum of 5 projects consisting of at least 10 million square feet of installed textured LLDPE geomembrane.

b. A copy of the Manufacturer's Manufacturing Quality Assurance/Manufacturing Quality Control (MQA/MQC) Plan for the complete geomembrane manufacturing process.

c. A schedule of operations, including means and methods of installation.

d. The width of the geomembrane panels to be used for the project and the proposed method of joining adjacent geomembrane panels.

e. The documented historic pass/fail rate for LLDPE geomembrane seam destructive tests performed on seams created by the proposed welding crew members.

2. At least 15 days prior to delivery of geomembrane to the site, unless otherwise noted below:

a. Working drawings, including proposed panel diagram and details of proposed work, extrusion welds, pipe boots, and details of sealing around all necessary geomembrane penetrations, to be submitted at least 30 days prior to delivery of geomembrane to the site. The panel diagram must depict and/or note the planned number and orientation of panels, the minimum panel size, seam orientation and overlap direction, placement of seams in corners, treatment of tee seams and the GEOSYNTHETICS CONTRACTOR's preferred sequence of panel placement. The LLDPE panels shall be orientated in a manner that minimizes seams and shall not have cross seams placed on slopes greater than 25% unless the slope length exceeds the manufactured roll length. The PROJECT ENGINEER prior to geomembrane installation must approve the panel diagram. The PROJECT ENGINEER, in writing, prior to altering the installation, must approve proposed revisions to the panel diagram.

b. Welding Rod - Manufacturing Quality Assurance (MQA) test data from the geomembrane Manufacturer demonstrating that the resin utilized in the production of the geomembrane and welding rod and/or pellets meets the requirements specified in Article 2.2. The packages containing the welding rod and/or pellets must contain a label identifying the resin lot utilized in their manufacture.

c. Geomembrane - Manufacturing Quality Control (MQC) data certificates for the geomembrane to be delivered to the site. The reports shall reference the resin lot used in the manufacture of the sheet and shall include the quality control test results obtained during the manufacture of the material. In the event material is delivered to the site prior to the receipt of the MQC certificates, the material without certificates will be stored separately from the material with certificates. Material with unacceptable MQC data will be segregated from approved material and shall be marked for rejection. The geomembrane will be rejected or if it is found to have defects, rips, holes, flaws, deterioration, or other damage deemed unacceptable by the PROJECT ENGINEER.

d. Resin - Resin Manufacturer's certificate for each resin lot utilized by the geomembrane Manufacturer in the production of the geomembrane and welding rod/pellets to be delivered to the site.

e. Geomembrane Sample - Samples of the proposed geomembrane shall be sent to the ENGINEER for interface shear testing to be done at the cost of the GEOSYNTHETICS CONTRACTOR within 5 days after the PROJECT ENGINEER makes such request. The GEOSYNTHETICS CONTRACTOR shall coordinate the quantity and dimensions of the samples with the PROJECT ENGINEER.

3. At least 15 days prior to installation:

a. Resumes of geomembrane crew; including, Supervisor, Quality Control (QC) Manager, Master Seamers, and all Welding Technicians. The resumes shall include prior experience in installing Textured LLDPE geomembrane. All individuals who will perform welding on this project shall be certified by the welding equipment manufacturer as having been trained in the use of the equipment; or, in lieu of such certification, the GEOSYNTHETICS CONTRACTOR shall provide other suitable evidence that demonstrates the proposed welding personnel possess intimate knowledge of welding equipment design, set-up, operation, and maintenance. Individual geomembrane crew members will be subject to the approval of the PROJECT ENGINEER.

b. A copy of the GEOSYNTHETICS CONTRACTOR's standard operating procedure (SOP) for operating an ATV or other utility vehicles should be on site, particularly with respect to specific uses of such vehicles and the prevention of damage to materials.

c. Field tensiometer calibration certificate showing that the equipment to be used for shear/peel testing in the field has been calibrated by a qualified individual within the previous 6 months.

4. During Installation Submitted Daily:

a. Completed Subgrade Acceptance Form, as endorsed by the PROJECT ENGINEER, prior to geomembrane deployment in any area.

b. Construction progress reports clearly showing geomembrane placed by date.

c. Passing and failing test results for trial seams.

d. Documentation of passing and failing destructive and non-destructive testing of installed seams.

5. Within 5 days after completion:

a. Summary and log of all field quality control work completed by the GEOSYNTHETICS CONTRACTOR.

b. Certification statement signed by the Supervisor that geomembrane installation is complete and in accordance with these Specifications, with details of any changes or exceptions noted.

c. Statement of material and installation warranties.

B. The above-noted requirements shall apply to all shop-fabricated materials and those items specified for fabrication in the field

## 1.6 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. The GEOSYNTHETICS CONTRACTOR shall protect the work described in this Section before, during, and after installation, and shall protect the installed work specified in other Sections, as well as work completed by the OWNER.

B. Geomembrane labeling, shipment and storage shall follow ASTM D4873 as modified according to this Specification.

C. Product weatherproof labels shall be placed on the ends of rolls such that they can be seen when rolls are stacked, clearly showing the manufacturer or supplier name, style name, roll number, and roll dimensions.

D. Upon delivery, the PROJECT ENGINEER will examine the rolls of geomembrane and obtain archive samples. Archive samples will be a minimum of three feet long by three feet wide.

E. Each roll of product shall include any additional information required to allow the PROJECT ENGINEER to relate that roll with the manufacturing quality control and raw material quality assurance documentation. Additionally, if any special handling is required, it shall be so marked on the outside surface of the wrapping, i.e., "Do not stack more than five rolls high," etc.

F. During storage, the geomembrane shall be placed on a stable, relatively flat, dry, well-drained surface. The geomembrane shall not be placed on skids or other objects that may cause deformation of the geomembrane rolls. Adequate space shall be left between stacked rolls, such that roll labels can be examined. The geomembrane shall be protected from the following:

   1. Mud and dust.

   2. Site construction damage.

   3. Chemicals that are strong acids or bases.

   4. Flames, sparks, geomembrane temperatures in excess of 150° F.

   5. Any environmental condition that might damage the geomembrane.

G. Roll numbers on partially used rolls must be maintained such that each roll number can be readily identified prior to deployment of the remaining portions of the roll. In the event roll numbers for partial rolls cannot be identified, such rolls will be marked for rejection.

H. If the PROJECT ENGINEER determines the geomembrane is damaged, the GEOSYNTHETICS CONTRACTOR shall make all repairs and replacements in a timely manner, to prevent delays in the progress of the work. As determined by the PROJECT

ENGINEER, any material damaged by the GEOSYNTHETICS CONTRACTOR, or damaged by others due to improper delivery and/or storage, as, shall be replaced by the GEOSYNTHETICS CONTRACTOR at no cost to the OWNER.

## PART 2 MATERIALS

### 2.1 GENERAL

A. The geomembrane shall be manufactured from first quality; virgin linear low-density polyethylene (LLDPE) resin with no more than 10% rework. If rework is used it must be identical to the parent materials. The LLDPE resin must blended with carbon black. The resin and finished product requirements are described in this Part, including the minimum Manufacturing Quality Assurance (MQA) and Manufacturing Quality Control (MQC) sampling and testing requirements.

B. The LLDPE sheet must be textured on both surfaces and shall have a uniform texturing appearance. It shall be free from agglomerated texturing material and such defects that would affect the specified properties of the geomembrane.

C. The geomembrane may have a white surface to minimize geomembrane surface temperatures and reduce overall wrinkling in the panels during construction. Any non-black geomembrane must be suitable for exposure during the installation process without degradation to the physical and mechanical properties required by this Specification.

D. The GEOSYNTHETICS CONTRACTOR shall be solely responsible for the quality of the material provided. Should any of the tests performed on the material yield unsatisfactory results, the GEOSYNTHETICS CONTRACTOR will be responsible for replacing the material with satisfactory materials without delay to the project or cost to the OWNER.

### 2.2 RESIN

A. The textured LLDPE geomembrane shall be manufactured from high quality LLDPE resin with superior stress crack resistance. No post consumer resin of any type shall be added to the formulation. While more than one resin may be suitable, and will be considered, the GEOSYNTHETICS CONTRACTOR is cautioned that the PROJECT ENGINEER and OWNER consider proper resin selection crucial to the successful completion of the project, and proposed resins will be most thoroughly and carefully reviewed. Once a resin has been accepted for use, all material for the project shall be manufactured from that resin unless approved by the PROJECT ENGINEER.

B. The following table represents the minimum required Manufacturing Quality Assurance (MQA) testing that must be conducted by the geomembrane Manufacturer on the resin used to produce the geomembrane:

**RESIN MQA**
**MINIMUM TESTING**

| PROPERTY | TEST METHOD | REQUIRED VALUES |
|---|---|---|
| Density, g/cm$^3$ (allowable range) | ASTM D1505/D792 | > 0.92 |
| Melt Index, g/10 min | ASTM D1238 | < 1.0 |

## 2.3 GEOMEMBRANE

A. The sheet material shall be formulated from the appropriate polymers and compounding ingredients to form LLDPE geomembrane that meets all requirements of this specification.

B. The geomembrane Manufacturer shall complete MQC testing on the geomembrane in accordance with the requirements summarized in the following table:

**TEXTURED GEOMEMBRANE MQA/MQC**
**MINIMUM TESTING**

| PROPERTY | TEST METHOD | TEXTURED SHEET VALUE |
|---|---|---|
| Core Thickness, mils (1) | ASTM D5994 | 40 nominal (-5%) |
| Asperity Height (min. avg.), mils (2,3) | GRI GM12 | 16 |
| Density (max. avg.), g/cm$^3$ | ASTM D1505/D792 | 0.939 |
| Tensile Properties (min. avg.) both directions | ASTM D6693 | |
| • Break strength, lb./in. | | 60 |
| • Break elongation, % | Notes (4,5) | 250 |
| 2% Modulus (max), (lb./in) | ASTM D5323 | 2,400 |
| Carbon Black Content (min. avg.), % (6,7) | ASTM D1603/D4218 | 2.0 - 3.0 |

| | | |
|---|---|---|
| Carbon Black Dispersion | ASTM D5596 | Note (8) |
| Oxidative Induction Time (OIT) (Standard) (minimum) | ASTM D3895 | 100 |
| Tear Resistance (min. avg.) (lb) | ASTM D1004 | 22 |
| Puncture Resistance (min. avg.) | ASTM D4833 | 44 |
| Axi-Symmetric Break Resistance Strain (min), (%) | ASTM D5617 | 30 |
| Oven Aging at 85°C (Standard OIT) (min. avg.) (% retained after 90 days) | ASTM D5721<br>ASTM D3895 | 35 |
| UV Resistance (High Pressure OIT) (min. avg.) (% retained after 1,600 hrs) (9) | ASTM D7238<br>ASTM D5885 | 35 |

NOTES:

1. The result obtained from D5994 will be an average of readings from 10 specimens per roll. The lowest allowable minimum average value shall be 38 mil, the lowest individual value for 8 out of the ten specimens shall be 36 mils, and the lowest individual value for any of the 10 specimens shall be 34 mil.
2. Of 10 readings, 8 out of 10 must be ≥ 7 mils, and the lowest individual reading must be ≥ 5 mils.
3. Both sides of the double-sided textured sheet shall be measured on each roll (reference Article 2.1B).
4. Break elongation is calculated using a gage length of 2.0 inches at 2.0 in./min.
5. Break elongation shall be determined based on the average of 5 specimens in the machine direction and the average of 5 specimens in the cross-machine direction (reported separately).
6. Other methods, such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.
7. Carbon black content is only measured on the black backing of the white-surfaced geomembrane. Prior to measuring the carbon black content, the white surface shall be scrapped or ground off to avoid misrepresentative results in the final result.
8. Carbon black dispersion for 10 different views: At least nine in Categories 1 or 2, one (max.) in Category 3.
9. UV Resistance is based on percent retained value regardless of the original HP-OIT value.

**REINFORCED TEXTURED LLDPE GEOMEMBRANE MQA/MQC MINIMUM TESTING**

| PROPERTY | TEST METHOD | TEXTURED SHEET VALUE |
|---|---|---|
| Core Thickness, mils (1) | ASTM D5199 | 36 nominal (-5%) |
| Asperity Height (min. avg.), mils (2,3) | GRI GM12 | 16 |
| Density (max. avg.), g/cm$^3$ | ASTM D1505/D792 | 0.939 |
| Grab Tensile (min. avg.) both directions<br>• Strength, lb<br>• Elongation, % | ASTM D7004<br><br>Notes (4,5) | <br>200<br>22 |
| Tongue Tear (min. avg.), (lb) both directions | ASTM D5884 | 55 |
| Carbon Black Content (min. avg.), % (6,7) | ASTM D1603/D4218 | 2.0 - 3.0 |
| Carbon Black Dispersion | ASTM D5596 | Note (8) |
| Oxidative Induction Time (OIT) (Standard) (minimum) | ASTM D3895 | 100 |
| Weight (lb/1000 ft$^2$) | ASTM D5261 | 168 nominal |
| Index Puncture (min. avg.) | ASTM D4833 | 75 |
| Ply Adhesion (lb), (min. avg.) | ASTM D6636 | 20 |
| Axi-Symmetric Break Resistance Strain (min), (%) | ASTM D5617 | 30 |
| Oven Aging at 85°C (Standard OIT) (min. avg.) (% retained after 90 days) | ASTM D5721<br>ASTM D3895 | 35 |
| UV Resistance (High Pressure OIT) (min. avg.) (% retained after 1,600 hrs) (9) | ASTM D7238<br>ASTM D5885 | 35 |

1. The result obtained from D5994 will be an average of readings from 10 specimens per roll. The lowest allowable minimum average value shall be 32 mil, the lowest individual value for

8 out of the ten specimens shall be 32 mils, and the lowest individual value for any of the 10 specimens shall be 32 mil.

2. Of 10 readings, 8 out of 10 must be ≥ 7 mils, and the lowest individual reading must be ≥ 5 mils.
3. Both sides of the double-sided textured sheet shall be measured on each roll (reference Article 2.1B).
4. Break elongation is calculated using a gage length of 2.0 inches at 2.0 in./min.
5. Break elongation shall be determined based on the average of 5 specimens in the machine direction and the average of 5 specimens in the cross-machine direction (reported separately).
6. Other methods, such as D4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.
7. Carbon black content is only measured on the black backing of the white-surfaced geomembrane. Prior to measuring the carbon black content, the white surface shall be scrapped or ground off to avoid misrepresentative results in the final result.
8. Carbon black dispersion for 10 different views: At least nine in Categories 1 or 2, one (max.) in Category 3.
9. UV Resistance is based on percent retained value regardless of the original HP-OIT value.

C. Non-conforming material will not be used in the work. Additional sampling required to address non-conforming test results shall be performed in accordance with the project CQA/CQC Plan. The PROJECT ENGINEER may reject the entire lot containing non-conforming rolls at any stage of extended sampling and testing.

E. Interface Shear Testing – Assignment and management of interface shear strength testing of the geomembrane and related materials is the responsibility of the PROJECT ENGINEER and will be completed at the cost of the OWNER. The results must comply with the criteria determined by the PROJECT ENGINEER, as specified in the Construction Drawings. All testing must demonstrate the minimum required peak shear strength and minimum large strain shear strength as specified on the Drawings, and those results must be completed by the PROJECT ENGINEER prior to delivery of the materials. Testing for geosynthetic to geosynthetic, or geosynthetic to soil interface, shall be conducted according to the current version of ASTM D5321-92.

## 2.4 WELDING ROD AND/OR WELDING PELLETS

A. The Manufacturer shall certify that the welding rod and/or pellets used for extrusion welding shall be produced from the same resin type as that used to manufacture the geomembrane supplied for this Project.

B. The Manufacturer shall certify that the welding rod and/or pellets meet the following requirements:

| PROPERTY | TEST METHOD | REQUIRED VALUES |
|---|---|---|
| Density, g/cm$^3$ | ASTM D1505/D792 | 0.920 (minimum avg.) |
| Carbon Black Content, % | ASTM D1603 or D4218 | 2.0 – 3.0 |

C. The PROJECT ENGINEER may perform conformance sampling and testing of the welding rod and/or pellets.

## 2.5 GEOMEMBRANE PENETRATION BOOTS

A. The GEOSYNTHETICS CONTRACTOR shall furnish any geomembrane penetration boots and other materials required for completion of the geomembrane installation. The geomembrane boots shall be of the same density and thickness as the geomembrane panels.

B. The geomembrane Manufacturer shall provide a statement of hydraulic or pneumatic testing demonstrating that any shop-fabricated unit does not leak. A description of the method used for testing in the shop shall be submitted to the PROJECT ENGINEER for approval prior to shipping the shop-fabricated boots to the site.

C. Geomembrane penetrations are to be constructed only at the locations shown on the Plans. The GEOSYNTHETICS CONTRACTOR is cautioned that no deviation in the quantity or configuration of geomembrane penetrations will be accepted without the advance written approval of the PROJECT ENGINEER.

D. The GEOSYNTHETICS CONTRACTOR shall construct penetrations in accordance with the procedures described in ASTM D6497-00, Standard Guide for Mechanical Attachment of Geomembrane to Penetrations or Structures, or as described by this Specification.

E. All penetrations through the geomembrane shall be thoroughly and securely sealed. The seal between the geomembrane and the pipe shall be without any detectable leakage.

F. In attaching the geomembrane penetration boot in the field, no field seams will be allowed in locations or configurations that do not allow for Construction Quality Control testing. Visual observation is not considered a sole acceptable method for in-field quality control.

G. Where clamps, fasteners, gasket seals or sealants are used, the GEOSYNTHETICS CONTRACTOR shall use only materials that are compatible with the geomembrane.

## PART 3 EXECUTION

### 3.1 SITE PREPARATION

A. All required grading, grooming and construction quality assurance (CQA) testing on any low permeability soil or other subgrade to be covered by the geomembrane shall be complete and accepted by the PROJECT ENGINEER prior to geomembrane placement.

B. The surface to be covered by the geomembrane shall be cleared of sharp objects, angular stones, sticks, or any materials that may contribute to punctures, shearing, rupturing or tearing of the geosynthetic materials. The geomembrane subgrade surface shall be cleared of sharp objects, angular stones sticks, or any materials that may contribute to punctures, shearing, rupturing or tearing of the geosynthetic materials. The geomembrane subgrade shall have a smooth, finished surface, free from pockets, holes, soft spots, ruts greater than 1 inch in depth, discontinuities that will cause bridging and overstress the material, and free of substantial amounts of loose soil as determined by the PROJECT ENGINEER. The subgrade shall be inspected for unsuitable areas or soft spots before the geomembrane is placed, and additional surface preparation will be required to eliminate any unsuitable areas as determined by the PROJECT ENGINEER.

C. The GEOSYNTHETICS CONTRACTOR and PROJECT ENGINEER shall carefully and completely inspect the geomembrane subgrade surface immediately prior to the deployment of each geomembrane panel. No geomembrane shall be placed on unsuitable subgrade surface, or without the PROJECT ENGINEER's written approval. The PROJECT ENGINEER and the GEOSYNTHETICS CONTRACTOR's Quality Control (QC) inspector shall furnish their signatures on a Subgrade Acceptance Log prior to the installation of each panel or series of panels placed on a daily basis.

D. Under no condition shall the geomembrane be placed over standing water on the subgrade.

### 3.2 SEAMING METHODS

A. The geomembrane panels shall be joined utilizing approved seaming methods. Dual-track fusion welding shall be the required method on all seams where it is feasible. Extrusion welds shall be made only where approved by the PROJECT ENGINEER.

B. The GEOSYNTHETICS CONTRACTOR shall properly maintain and set-up the welding equipment prior to seaming operations on a regular as needed basis, in the manner specified by the Manufacturer. For wedge welding equipment this is expected to include as a minimum; checking the condition and adjusting the position of the nip rollers, hot wedge, and contour rollers. As well, the GEOSYNTHETICS CONTRACTOR shall properly examine and check the cartridge heaters, thermocouples, drive chains and

electronics for proper operation at the frequency recommended by the Manufacturer. The CQA Observers shall record and document the set-up, maintenance, and adjustment process, as well as the settings/conditions each time acceptable seaming of the geomembrane has been confirmed by trial weld results.

C. All geomembrane surfaces that are to become a seam interface are to be free of dust, dirt, excess moisture, or any other condition that may affect the quality of the seam.

D. Seaming will not be allowed during rain or snowfall, unless proper precautions are made to allow the seam to be made on dry subgrade and geomembrane materials. Seaming is also subject to wind and temperature restrictions as described in Article 3.3.M.

E. The seams shall be produced using one of the following methods:

1. Dual-Track Fusion (Wedge) Weld – A seam produced by melting the two intimate surfaces by running a hot metal wedge between the surfaces, followed immediately by pressure to form a homogeneous bond. This seam has a center air channel for non-destructive testing of the seam. Panels to be seamed shall be overlapped sufficiently to allow proper destructive testing of seams. The GEOSYNTHETICS CONTRACTOR shall mark the liner where the Duel-Track Fusion Welding machine settings are adjusted (including speed, temperature, and pressure). Measurable setting values shall be indicated on the liner.

2. Extrusion Weld – A seam produced by extruding molten LLDPE at the edge of two overlapped panels. A bonded seam is completed when molten LLDPE melts portions of the overlapping sheets to form a homogeneous weld. The center of the extrudate bead shall be located directly over the edge of the upper geomembrane. Panels to be seamed shall be overlapped a minimum of 4 inches. An electric rotary grinder and #80 grit paper, or finer, shall be used to remove the surface sheen in the area to be seamed. Grinding shall be completed no more than 10 minutes prior to seaming. Any grinding marks shall be oriented perpendicular to seam direction, and their depth shall be less than 5% of the sheet thickness. Grinding marks shall not appear beyond 0.25” of the extrudate after it is applied. The leading edge of the upper sheet shall be ground to a 45-degree bevel. Beveling shall be completed prior to tack welding to control damage to the lower sheet.

## 3.3 INSTALLATION

A. Based on the approved geomembrane panel diagram and material certifications, the individual panels will be numbered, and seams will be identified by using the panel numbers that create the seam. The LLDPE panels shall be installed in a manner that minimizes seams. Seams shall be placed where normally applied stresses will be minimal. Longitudinal seams shall be oriented to be no greater than ten degrees from parallel with the direction of the slope. All panels placed on slopes greater than 25% shall extend down the full length of the slope unless the slope length is greater then the

manufactured roll length. Any cross seams on slopes greater than 25% shall be staggered such that seams between adjacent panels are separated by a minimum of 10 feet. On slopes less than 25%, cross seams shall be placed no closer than five feet from the top of a steeper slope, or five feet from the toe of a steeper slope. All seam overlaps shall be shingled in a downslope direction. In no case shall parallel seams be placed within five feet of the centerline of any leachate collection pipe.

B. Piecework resulting in the placement and seaming of small panels not identified by the panel diagram shall not be permitted. Any material variation from the approved panel diagram must be pre-approved by the PROJECT ENGINEER prior to altering the installation.

C. During installation, and any other period of exposure of geomembrane, pedestrian and equipment activity over the geomembrane shall be kept to a minimum and restricted to only that which is necessary for geomembrane construction. Smaller equipment is preferred to reduce potential for damage.

D. Smoking is not permitted on the geomembrane.

E. Construction workers shall take precautions not to damage the geomembrane surface. Construction workers shall wear smooth-soled footwear, and exercise care not to drag tools across the geomembrane surface. All large tools are to have smooth base plates or shoes. Construction and landfill staff shall be informed of the restricted access to areas of geomembrane placement by use of barriers and signs posted, as necessary. Only hook blade knives shall be used to cut geomembrane.

F. The GEOSYNTHETICS CONTRACTOR shall perform all activities of geomembrane construction in such a way as to avoid damage to the geomembrane, including the prudent use of rub sheets. Any damage caused to the geomembrane by the GEOSYNTHETICS CONTRACTOR shall be repaired or the material replaced at the expense of the GEOSYNTHETICS CONTRACTOR.

   Generators and other stationary equipment that must be lubricated, fueled and/or oiled and that are staged on the geosynthetics must be placed within spill containment pads designed to prevent spillage of gasoline, diesel fuel or oil on the geosynthetics. If any such equipment is not placed in a spill containment structure, it must not be fueled on the geosynthetics.

G. No tracked or wheeled vehicles, other than low ground pressure ATVs or other similar vehicles as pre-approved by the PROJECT ENGINEER, shall be permitted on the geomembrane prior to placement of adequate soil cover, as determined by the PROJECT ENGINEER.

H. The GEOSYNTHETICS CONTRACTOR shall complete his work in a manner that will prevent water or wind from getting under the partially installed geomembrane. This could include, but is not limited to, installing sandbags along the leading edges. Should excessive moisture become trapped below the geomembrane or should wind damage

occur due to the negligence of the GEOSYNTHETICS CONTRACTOR, the GEOSYNTHETICS CONTRACTOR, at no extra cost to the OWNER, will be required to perform all work, including removing and replacing as much of the in-place geosynthetic material as the PROJECT ENGINEER directs, to assure that the integrity of the geomembrane and the underlying subbase or has not been compromised.

I. Seams shall be welded throughout the entire length of the panels during initial panel seaming.

J. Sandbags or other approved ballast shall be used to prevent bridging or material movement in areas such as toe of slope or near sumps. Ballast shall not be used to force the geomembrane into contact with the subgrade.

K. Special care shall be taken to prevent tensile stress in the geomembrane and geomembrane seams in all corners and grade changes.

L. The GEOSYNTHETICS CONTRACTOR shall exercise his best judgment and care to provide sufficient slack in the geomembrane to allow for thermal contraction without "trampolining", but to also avoid excessive slack such that wrinkling will be minimized during seaming and placement of overlying soil or geosynthetic materials.

M. The geomembrane shall not be seamed when ambient or sheet temperatures are below 32° F, when the sheet temperature exceeds 158° F, or when the air temperature is above 120° F unless the GEOSYNTHETICS CONTRACTOR demonstrates, to the satisfaction of the ENGINEER, that procedures can be implemented which will result in the proper installation and seaming of the geomembrane.

For seaming activities below 32° F the GEOSYNTHETICS CONTRACTOR shall use procedures set forth in GRI GM 9. Maximum allowable time between trail welds shall be adjusted to 2 hours, decreasing one-half hour for each 10 deg F below 32 deg F.

N. Adjacent geomembrane panels shall be allowed to reach essentially equivalent temperatures prior to seaming to avoid development of fish mouths.

O. If fish mouths are created at the seam overlaps, they shall be cut to achieve a flat overlap. The cut shall be made with keyhole ends, and a patch shall be placed over the cut as required by Article 3.4.

P. Wrinkles shall not exceed a height to width ratio of 0.5, or as deemed acceptable by the PROJECT ENGINEER. The height of the wrinkle shall be measured from the base or subgrade to the peak of the wrinkle. The width of the wrinkle shall be measured along the base of the wrinkle.

Q. Geomembrane covering operations shall be performed in a manner that does not damage the geomembrane lining system. Geomembrane covering operations shall be performed only in the presence of a Construction Observer such that the condition and cleanliness of

the geomembrane is observed at the time the material is covered, and any effects of the covering operation on the geomembrane lining system can be observed.

R. In the event wrinkles develop during any covering operation that are capable of folding over, the excess material shall be cut out to achieve a flat overlap, or the covering operation shall be delayed until such time wrinkling subsides to acceptable levels. Any geomembrane cut shall be made with keyhole ends, and a patch shall be placed over the cut as required by Article 3.4. Wrinkles that do not lay flat and whose height to width ratio does not exceed 0.5 are susceptible to damage by soil placement equipment and shall be carefully monitored by the PROJECT ENGINEER during cover operations.

S. Any use of ATV's or other similar vehicles on the site must be pre-approved by the PROJECT ENGINEER. The GEOSYNTHETICS CONTRACTOR shall submit a Standard Operating Procedure (S.O.P.) describing how vehicles are to be used, if at all, in the deployment of geomembrane at the site. As a minimum, the following shall apply:

1. Any damage resulting from the use of vehicles, as determined by the PROJECT ENGINEER, shall be repaired according to Article 3.4, at no additional cost to the OWNER. If repeated repairs are required as the result of the use of vehicles operating on geosynthetic material, further use of such vehicles will be prohibited.

2. All vehicles proposed to be used in the deployment of geosynthetics will be inspected by the PROJECT ENGINEER. Vehicles which are found to be leaking oil or fuel, or which in any other way exhibit the potential to damage the lining system components, will not be permitted.

3. Any oil or fuel which leaks onto geosynthetic materials shall be thoroughly removed (cleaned) by the GEOSYNTHETICS CONTRACTOR, or the geosynthetic material shall be replaced at the discretion of the PROJECT ENGINEER, at no additional cost to the OWNER.

4. Re-fueling of vehicles on geosynthetic materials is prohibited.

5. Vehicles shall have tires with low ground pressure, typically less than 5 psi, and shall have shallow treads.

6. Vehicles shall be operated by a single operator at speeds less than 5 mph.

7. Quick starts, stops, spinning wheels and sharp turns will not be permitted above any geosynthetic material.

## 3.4 REPAIRS

A. All geomembrane panels and seams shall be examined by the ENGINEER for uniform texturing, defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. The geomembrane surface shall be clean at the time of

examination. Each suspect location shall be repaired, and all repairs shall be non-destructively tested.

B. Damaged and/or unacceptable geomembrane shall be removed and replaced with acceptable geomembrane if damage cannot be repaired to the satisfaction of the PROJECT ENGINEER.

C. Any portion of the geomembrane, or any portion of a seam exhibiting a flaw or failing a destructive or non-destructive test, or an area where a wrinkle had been cut out shall be repaired, as follows:

1. Geomembrane patches shall be used for holes over 1/8 of an inch in diameter, tears, and contamination by foreign matter. Patches shall be constructed of the same geomembrane and will be joined to the panel using extrusion welding, or fusion welding where possible.

2. Geomembrane patches or caps shall extend at least 6 inches beyond the edge of the defect or failed seam area, and all corners of material to be patched. The corners of the patch shall be rounded to a radius of at least 3 inches.

3. Spot extrusion welding shall be used to repair pinholes, or other minor localized flaws, only as approved by the PROJECT ENGINEER.

4. Geomembrane caps shall be used to repair failed seams that are left in-place. Seams that fail destructive or non-destructive testing may also be removed and replaced if determined necessary by the PROJECT ENGINEER.

## PART 4 FIELD QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

### 4.1 GENERAL

A. Before installation begins, and weekly thereafter (more often if determined necessary by the PROJECT ENGINEER) project coordination meetings shall be held with the designated representative of the GEOSYNTHETICS CONTRACTOR, PROJECT ENGINEER and OWNER in attendance to review the following information:

1. Progress of the work.

2. Adherence to the Specifications.

3. Adherence to the Construction Quality Assurance Program described in this Section, including the timely submission of the pertinent forms.

4. Planned work and methods for the ensuing week, including estimate of time remaining to completion of the work.

5. Problem resolutions to be implemented during the upcoming week.

The NYSDEC site engineer shall be invited to each construction meeting.

B. All of the Forms specified and required must be submitted to the PROJECT ENGINEER in a timely fashion.

C. The OWNER and PROJECT ENGINEER must approve any changes in the proposed method of work, subcontractors to be utilized, geomembrane resin, or manufacturing in advance.

D. The GEOSYNTHETICS CONTRACTOR assumes all responsibility relevant to providing an acceptable product.

## 4.2 INSTALLATION QA/QC

A. The PROJECT ENGINEER and GEOSYNTHETICS CONTRACTOR shall visually inspect all material to be included in the work and compare roll identification numbers with those on the certifications provided by the manufacturer to assure delivery of the appropriate material.

B. Damage to geomembrane during installation shall be repaired according to Article 3.4. If the PROJECT ENGINEER determines that any damage cannot adequately be repaired, the damaged material will be replaced.

C. The GEOSYNTHETICS CONTRACTOR will be required to conduct both destructive and non-destructive testing on seams during the geomembrane installation, as part of the Construction Quality Control program. All trial and installed seam samples shall be tested according to ASTM D6392-99, as modified by this Specification. Numbering (writing) on panels will be done using two different colors; one color for CQA personnel, and a different color for the Geosynthetic Contractor.

D. The GEOSYNTHETICS CONTRACTOR will be required to complete trial seams throughout the project. The GEOSYNTHETICS CONTRACTOR will be required to utilize control charts to determine whether adjustments in the welding parameters are required during production seaming, per GRI GM14. The trial seams shall be provided in a timely fashion such that adequate time is available for field destructive testing, and preparation of the associated documentation by the PROJECT ENGINEER prior to production welding.

E. Trial Seams

1. Trial seams shall be produced:

a. each day, at the start of each workday,

b. after every five hours of continuous operation,

c. after equipment maintenance, repair, or replacement,

d. after lunch and/or dinner,

e. and if the geomembrane temperature changes by more than 45°F.

Trial seams shall be required each day for each piece of seaming equipment and each welding crew combination (including welding technician, seam cleaners and/or grinders). The trial seams will be performed on strips of geomembrane from approved rolls and shall be produced at the work location such that the conditions mimic those under which production seams will be made. In the case of tie-ins to old liner, the trial seams are not required because these seams are not expected to pass the testing requirements, therefore all tie-in seams shall be over-capped.

2. A trial seam shall be a minimum of 5 feet in length for self-propelled seaming devices, and a minimum of 3 feet for hand-held seaming devices. The material for the trial seam and the test fixture for making the field tests shall be provided by the GEOSYNTHETICS CONTRACTOR at no additional cost. One-inch wide cutouts of the trial seams will be subject to shear and peel testing by the GEOSYNTHETICS CONTRACTOR's QC technician at the site. A minimum of 5 cutouts will be tested for shear, and a minimum of 5 cutouts will be tested for peel. The PROJECT ENGINEER shall document the locus of break code for each specimen as shown in Figure 3 and Figure 4 of ASTM D6392-99, included at the end of this Section.

3. All trial seam specimens must be acceptable, or the trial seam will be repeated until all results from a given trial seam are found acceptable. If any trial seam fails at any time during the workday, the reason for the failure shall be resolved before any production seaming of the geomembrane by the subject equipment and crew. All trial seam welding and testing must be observed by the PROJECT ENGINEER.

4. The PROJECT ENGINEER must observe and document the proper setup of the equipment prior to completing trial welds.

For hot wedge welders, this shall include:

a. Surface grinding before application of the hot wedge is not necessary and shall not be done;

b. The hot wedge, or "anvil," should be inspected to see that it is symmetrically balanced and gradually tapered. It is imperative that the wedge has no sharp edges on any surface that contacts the liner during the welding process;

c. The chain drive powering any portion of the welder should be synchronized, properly lubricated, and physically sound;

d. Contour roller heights are adjustable to allow for varying liner thickness. Normal adjustments are made while the welder is at ambient temperature. The procedure is as follows:

- Insert two material samples into the nip drive rollers;
- Place two other material samples above and below the wedge;
- Lock the wedge into its operating position. This is done by shifting the wedge forward, into the clutch of the upper and lower nip rollers;
- Adjust the contour rollers until they are snug against the liners, which sandwich the wedge to assure proper roller pressure;
- Set the maximum distance that the wedge can move into the nip rollers. Unsecured, the wedge might make direct contact with the nip rollers when the machine has no liner material running through it and damage the machine;
- The forward face of the welding machine should be inspected for sharp corners and irregular details which may damage the liner as it advances during the seaming process; and,
- Temperature controllers on the wedge device should be set according to liner thickness, ambient temperature, and seaming rate. Temperature gauges should be checked for accuracy and repeatability.

For extrusion welders:

a. Ensure the proper shoe is attached to the gun, and it is in a clean condition;

b. Check and record pre-heat air temperature;

c. Check and record extrusion screw temperature;

d. Purge gun to remove old material from chamber; and,

e. Warm Teflon shoe by running unit along scrap material prior to trial welding.

5. A trial seam specimen will be considered a failure if:

a. For the hot wedge seams:

i. Textured LLDPE: the bonded thickness of the seam fails before the adjacent sheet material; or, the shear strength of the specimen is less than 60 lb/in; or, the peel strength is less than 50 lb/in or greater than 25% of the originally bonded area separates as determined in accordance with Paragraph 6.1 of GRI GM 19.

ii. Reinforced Textured LLDPE: the bonded thickness of the seam fails before the adjacent sheet material; or, the shear strength of the specimen is less than 75 lb/in; or, the peel strength is less than 30 lb/in or greater than 25% of the originally bonded area separates as determined in accordance with Paragraph 7.1 of GRI GM 19B.

b. For extrusion fillet seams:

iii. Textured LLDPE: the bonded thickness of the seam fails before the adjacent sheet material; or, the shear strength of the specimen is less than 60 lb/in; or, the peel strength is less than 44 lb/in or greater than 25% of the originally bonded area separates as determined in accordance with Paragraph 6.1 of GRI GM 19.

iv. Reinforced Textured LLDPE: the bonded thickness of the seam fails before the adjacent sheet material; or, the shear strength of the specimen is less than 80 lb/in; or, the peel strength is less than 30 lb/in or greater than 25% of the originally bonded area separates as determined in accordance with Paragraph 7.1 of GRI GM 19B.

c. In the shear or peel test, locus of break codes AD, AD1, AD2 or AD-WLD are reported by the PROJECT ENGINEER.

d. Upon visual inspection, the weld shows:

i. Excessive deformation or stepping of the bottom sheet when viewed in cross-section.

ii. Discoloration of the sheet such as that occurring from brittle failure.

iii. Inadequate or excessively narrow or flat weld bead (for extrusion seams).

iv. Water blisters in weld bead (for extrusion seams).

v. Misaligned weld bead, i.e., weld not reasonably centered with respect to overlap (for extrusion seams).

vi. Thinning of the sheet adjacent to the weld.

vii. Overgrinding marks outside of the extrudate bead (for extrusion seams).

F. The field tensiometer shall be strong enough to permit the operator to determine that the seam is at least as strong as either sheet and shall permit accurate measurement of specimen elongation. The tensiometer shall have been calibrated within the 6-month period prior to its use on-site.

G. Should the PROJECT ENGINEER, at any time during the installation, believe the production seaming process may not be performing adequately, he may, to avoid destructive sampling of the installed geomembrane, request additional trial seams. The GEOSYNTHETICS CONTRACTOR shall do this at no additional cost.

H. The GEOSYNTHETICS CONTRACTOR shall complete non-destructive testing of all seams along their entire length, in the manner approved prior to installation, in the presence of the ENGINEER. The recommended test methods are as follows:

1. Pressurized Air Channel

a. All field seams made by a dual-track fusion wedge welding device will be tested by applying air pressure within the air channel to a sealed length of seam and monitoring the pressure over time. The testing shall be conducted in accordance with GRI GM6.

b. For the 40-mil geomembrane, the initial inflation pressure shall be a minimum of 25.0 psi and a maximum of 30.0 psi. The maximum allowable pressure drops, over a 5-minute period, shall be 2.0 psi.

c. A pressure gauge shall be inserted into the far end of the air channel to check for continuity in the air channel. Alternately, the far end of the seam may be cut to relieve the air pressure. An audible rush of air shall serve as an indicator that the test represents the entire length of seam.

d. Air channels that do not hold the minimum specified air pressure shall be further inspected to identify the location and nature of any defects or unbonded sections of seam. The seam will then be repaired and retested. The PROJECT ENGINEER may, at his discretion, require the entire questionable seam area to be capped or replaced.

2. Vacuum Box Testing

a. Extrusion seams shall be inspected for unbonded areas or defects by applying a vacuum to a soaped section of seam. The vacuum shall be applied by a vacuum box equipped with a vacuum gauge, a clear glass view panel in the top, and a soft rubber gasket on the periphery of the open bottom. The testing shall be completed in accordance with ASTM D5641-94.

b. A section of the seam shall be soaped thoroughly, and the inspection box shall be placed over the soaped seam section and the gasket sealed to the geomembrane. A vacuum of between 4 and 8 inches of Mercury (Hg) shall be applied to the box for a minimum of 10 seconds by use of a gasoline or electric driven power-vacuum pump apparatus. Adjacent placements of the vacuum box shall overlap the seam a minimum of 2 inches as viewed through the vacuum box-viewing window.

c. The PROJECT ENGINEER shall witness the testing, and the seam shall be clearly visible to the PROJECT ENGINEER and GEOSYNTHETICS CONTRACTOR during the test. Unbonded areas or defects shall be marked by the PROJECT ENGINEER for repair by the GEOSYNTHETICS CONTRACTOR.

3. Spark Testing

a. Spark testing may be used on short, detail (sump, penetration) extrusion welds that cannot be tested by vacuum box testing and can use Alternating Current (AC) or Direct Current (DC) equipment. The DC equipment (using the latest version of ASTM D6365) is required for use on this project unless the GEOSYNTHETICS CONTRACTOR provides a detailed Workplan to the ENGINEER regarding AC testing for approval, at least two weeks prior to beginning the testing.

b. The DC method typically uses a metal brush for the search electrode. For seams, a copper wire or tape is placed within the geomembrane/seam overlap, just to the inside of the center of the extruded bead. Prior to testing, a trial calibration seam must be made to confirm the minimum voltage required to discharge across a hole in the seam between the search electrode and the copper wire.

c. Spark testing must not be performed when the liner is wet. The test procedure for DC equipment can generally be describes as follows:

i. Connect the negative (ground) electrode of the testing equipment to the exposed end of the copper wire, or to a grounding rod if the copper wire is buried in the subgrade;

ii. Calibrate using a seam with a known leak path of the largest reached distance;

iii. Connect the positive electrode to the wire brush or other type of search electrode;

iv. Clean all debris and moisture from the seam area;

v. Apply a potential difference of between 20 and 55 kVDC, as determined in the calibration test, between the electrodes;

vi. Sweep the search electrode over the surface of the seam, maintaining contact with the extruded bead and the top of the lower geomembrane at the edge of the bead; and,

vii. Monitor for audible and/or visible spark discharges that are indicative of a defect. Mark defects for repair.

d. The exposed end of the wire must be cut short, and an extruded bead of molten polyethylene must be placed over the remaining wire exposure to ensure the wire is covered completely.

I. All inadequate seams or portions thereof that fail the non-destructive testing shall be repaired in accordance with this Specification and the method approved by the PROJECT ENGINEER. Should differences of opinion between the GEOSYNTHETICS CONTRACTOR and the PROJECT ENGINEER develop during the installation relevant to seam integrity, the PROJECT ENGINEER may, at his discretion, obtain samples of the seams in dispute for field and/or laboratory testing. The GEOSYNTHETICS CONTRACTOR will be responsible for patching the resulting void in accordance with the previously approved procedures at no additional cost to the OWNER.

J. Destructive Sample Collection - Samples of the in-place seams shall be cut from the installed geomembrane at a frequency one per 1,000 feet of production seaming.

K. In the case where extrusion seaming equipment is started solely for patching, a destructive sample of the in-place welds will only be obtained if more than 250 feet of seaming is accomplished in one day, or at the discretion of the ENGINEER.

L. The destructive sample cutout sections shall be 12 inches wide by 40 inches long with the seam centered lengthwise. The sample size can be reduced to 30” if the GEOSYNTHETICS CONTRACTOR does not elect to have a cutout section for their use. A 1-inch wide specimen shall be cut from each end of the sample, and these two specimens shall be peel tested in the field in accordance with 4.2.E.4. The remaining sample shall be cut into two parts and distributed as follows:

1. One 12-inch by 18-inch sample to the ENGINEER for independent laboratory testing; and,

2. One 12-inch by 18-inch sample to the OWNER for archive storage.

3. The remainder of the sample shall be available for the GEOSYNTHETICS CONTRACTOR if requested at the time of sample collection.

M. The 12-inch by 18-inch laboratory sample will provide 5 specimens for shear testing and 5 specimens for peel testing. Specimens that will be subject to peel and shear testing shall be selected alternately from the sample. All peel tests shall be performed on the outer track of dual track fusion welds. The laboratory shall report the locus of break code for each specimen according to the definitions included in Figure 3 and Figure 4 of ASTM D6392, included at the end of this Section. The laboratory sample will be considered acceptable only if all 10 specimens meet the minimum requirements. The specimen will be considered a failure if:

1. For hot wedge seams - 1.) the bonded thickness of the seam fails before the adjacent sheet material; or, the shear strength of the specimen is less than 60 lb/in; or, the peel strength is less than 50 lb/in or greater than 25% of the originally bonded area separates as determined in accordance with Paragraph 6.1 of GRI GM 19; or, 2.) the shear percent elongation is less than 50% as determined in accordance with Paragraph 6.1 of GRI GM 19.

2. For extrusion fillet seams - 1.) the bonded thickness of the seam fails before the adjacent sheet material; or, the shear strength of the specimen is less than 60 lb/in; or, the peel strength is less than 44 lb/in or greater than 25% of the originally bonded area separates as determined in accordance with Paragraph 6.1 of GRI GM 19; or, 2.) the shear percent elongation is less than 50% as determined in accordance with Paragraph 6.1 of GRI GM 19.

3. In the shear or peel test, locus of break codes AD, AD1, AD2 or AD-WLD are reported by the PROJECT ENGINEER.

4. Upon visual inspection, the weld shows:

   a. Excessive deformation or stepping of the bottom sheet when viewed in cross-section.

   b. Discoloration of the sheet such as that occurring from brittle failure.

   c. Inadequate or excessively narrow or flat weld bead (for extrusion seams).

   d. Water blisters in weld bead (for extrusion seams).

   e. Misaligned weld bead, i.e., weld not reasonably centered with respect to overlap (for extrusion seams).

   f. Thinning of the sheet adjacent to the weld.

g. Overgrinding marks outside of the extrudate bead (for extrusion seams).

N. The independent laboratory will be required to provide the PROJECT ENGINEER with results of laboratory testing within 48 hours of obtaining the sample.

O. If a sample fails destructive testing, the welding path must be retraced to intermediate locations at least 10 feet in each direction from the location of the sample that failed the test, and a second sample shall be taken for an additional field test. If the tracking samples pass, the seam must be reconstructed between the location of the two tracking samples and the original sampled location. If the tracking sample fails, this process must be repeated. The seam between 2 passing test locations shall be capped, the cap seams shall be nondestructively tested, and shall include one field peel and shear test location along the reconstructed seam.

P. The PROJECT ENGINEER and GEOSYNTHETICS CONTRACTOR shall visually inspect all geomembrane seams. Extrusion welds shall be centered above the overlap, shall be free from blisters, and shall not include grinding marks that show more than 0.25" outside of the extrusion bead. If such grinding marks are found, the seam shall be repaired to the PROJECT ENGINEER's satisfaction.

Q. All welds shall be observed for traces of deformation to the geomembrane panels. Any seams, which in the opinion of the PROJECT ENGINEER, have caused excessive deformation of the sheet, show signs of discoloration, exhibit thinning or stepping of the sheet, or show visual signs of overheating of the geomembrane panels, shall be repaired at no additional cost to the OWNER regardless of the result of any destructive testing on the seam. The deficient seam or portion thereof shall be cut out, the geomembrane panels again overlapped and seamed, or the questionable seam length shall be capped, as approved by the PROJECT ENGINEER.

R. The GEOSYNTHETICS CONTRACTOR shall not place overlying materials on the installed geomembrane until the PROJECT ENGINEER has reviewed and accepted the written test results for the geomembrane to be covered. At a minimum, the pre-delivery testing, the daily log of trial seam results, laboratory destructive sample results, non-destructive test results, record drawings of the completed area, and approval of the seams in place will be reviewed.

S. The GEOSYNTHETICS CONTRACTOR shall provide a report to the OWNER and the PROJECT ENGINEER at the conclusion of the work which shall include the following:

1. The quality control tests used as specified and/or directed, including all requirements of the Report section of the specified test method.

2. Complete description of field sampling procedure, number of test specimens, size of test specimens.

3. Log of all Construction Quality Control work.

T. The GEOSYNTHETICS CONTRACTOR shall be responsible for all costs incurred by the OWNER including, but not limited to, additional field and laboratory CQA testing resulting from greater than 5 percent of the CQA testing not meeting or exceeding the Specifications.

U. All seams must be subjected to accepted Construction Quality Control or Construction Quality Assurance (CQA/CQC) testing.

## 4.3 WARRANTY

A. The GEOSYNTHETICS CONTRACTOR shall issue a warranty on the installation of geomembrane for a minimum period of 1 year.

B. The GEOSYNTHETICS CONTRACTOR shall issue a warranty on the geomembrane material for a minimum period of 5 years.

END OF SECTION

# SECTION 02936

# SEEDING

## PART 1 GENERAL

### 1.1 SUMMARY

A. The EARTHWORK CONTRACTOR shall furnish all labor, materials, equipment, tools, and appurtenances required to prepare the seedbed and complete the seeding of all areas of the Project as required by the Specifications as shown on the Drawings or as directed by the PROJECT ENGINEER.

### 1.2 RELATED SECTIONS

A. Section 02228 - Barrier Protection Layer Soil

B. Section 02235 - Soil Suitable for Vegetative Growth

### 1.3 REFERENCES

A. FS O-F-241 - Fertilizers, Mixed, Commercial.

### 1.4 DEFINITIONS

A. Weeds - Includes Dandelion, Jimsonweed, Quackgrass, Horsetail, Morning Glory, Rush Grass, Mustard, Lambsquarter, Chickweed, Cress, Crabgrass, Canadian Thistle, Nutgrass, Poison Oak, Blackberry, Tansy Ragwort, Bermuda Grass, Johnson Grass, Poison Ivy, Nut Sedge, Nimble Will, Bindweed, Bent Grass, Wild Garlic, Perennial Sorrel, and Broome Grass.

### 1.5 REGULATORY REQUIREMENTS

A. Comply with regulatory agencies for fertilizer and herbicide composition and application.

### 1.6 TESTS

A. The PROJECT ENGINEER shall review the nutrient and composition analysis of soil suitable to sustain vegetation to ascertain percentage of organic matter, soluble salt content, and pH value.

B. Soil suitable for vegetative growth shall have an organic matter content of at least 2% by weight and no greater than six percent, or as approved by the PROJECT ENGINEER.

C. Soil suitable for vegetative growth used shall have a pH between 6.0 and 8.0, or as approved by the PROJECT ENGINEER

D. Soil suitable for vegetative growth shall have not less than 20 percent fine textured material (passing the No. 200 sieve) and not more than 15 percent clay, or as approved by the PROJECT ENGINEER.

E. Soil suitable for vegetative growth shall be relatively free of stones over 1 & 1/2 inches in diameter, trash, noxious weeds such as nut sedge and quackgrass, and will have less than 10 percent gravel by volume, or as approved by the PROJECT ENGINEER.

F. Soil suitable for vegetative growth that contains soluble salts greater than 500 ppm shall not be used, or as approved by the PROJECT ENGINEER.

### 1.7 MAINTENANCE

A. The EARTHWORK CONTRACTOR shall submit maintenance data for continuing maintenance from the seed supplier. This information will include maintenance instructions, cutting method and maximum grass height; types, application frequency, and recommended coverage of fertilizer.

### 1.8 DELIVERY, STORAGE, AND HANDLING

A. Grass seed mixture shall be in sealed containers showing weight, seed mix, year of production, date of packaging, and location of packaging. Seed in damaged packaging is not acceptable.

B. Fertilizer shall be in waterproof bags showing weight, chemical analysis, and name of manufacturer. Fertilizer in damaged packaging is not acceptable.

## PART 2 PRODUCTS

### 2.1 SEED MIXTURE

A. Temporary Vegetation:

| **Mixture Type 1** | **Rate** | **Seeding Season** |
|---|---|---|
| Common White Clover | 8 lbs/ac | Spring, Summer, or Fall |
| *Perennial Rye Grass | 30 lbs/ac | Spring, Summer, or Fall |
| *"Aroostook" Winter Rye | 100 lbs/ac | Spring, Summer, or Fall |
| Annual Rye | 75 lbs/ac | Spring, Summer, or Fall |

*If temporary vegetation is undertaken during late fall, certified winter rye (cereal rye) may be substituted for perennial rye grass.

B. Permanent Slope Vegetation:

| **Mixture Type 2** | **Rate** | **Seeding Season** |
|---|---|---|
| Empire Birdsfoot Trefoil or White Clover | 8 lbs/ac | Early Spring |
| Tall Fescue | 20 lbs/ac | Early Spring |
| Redtop | 2 lbs/ac | Early Spring |
| Annual Rye | 90 lbs/ac | Early Spring |
| Perennial Rye | 90 lbs/ac | Early Spring |

| **Mixture Type 3** | **Rate** | **Seeding Season** |
|---|---|---|
| Creeping Red Fescue | 20 lbs/ac | Early Spring, Fall |
| Tall Fescue | 20 lbs/ac | Early Spring, Fall |
| Redtop | 2 lbs/ac | Early Spring, Fall |
| Annual Rye | 90 lbs/ac | Early Spring, Fall |
| Perennial Rye | 90 lbs/ac | Early Spring, Fall |

Legumes that may be mixed with the grasses are Alfalfa, Birdsfoot Trefoil, Sweet and White Clover, and Hairy and Crown Vetch. If used, inoculates for legumes are to be added immediately prior to seeding.

C. Drainage Swale/Channel:

| **Mixture Type 4** | **Rate** | **Seeding Season** |
|---|---|---|
| Ladino Clover | 8 lbs/ac | Early Spring, Fall |
| Tall Fescue or Smooth Bromegrass | 20 lbs/ac | Early Spring, Fall |
| Redtop | 2 lbs/ac | Early Spring, Fall |
| Annual Rye | 90 lbs/ac | Early Spring, Fall |
| Perennial Rye | 90 lbs/ac | Early Spring, Fall |

## 2.2 ACCESSORIES

A. Mulching Material - Oat or wheat straw, free from weeds, foreign matter detrimental to plant life, and dry. Hay or chopped cornstalks are not acceptable.

B. Fertilizer - FS O-F-24, Type I, Grade A; recommended for grass, with 50 percent of the elements derived from organic sources; of proportion necessary to eliminate any deficiencies of topsoil (as indicated in analysis) to the following proportions: nitrogen, 5 percent; phosphoric acid, 10 percent; soluble potash, 10 percent.

C. Water - Clean, fresh, and free of substances or matter that could inhibit vigorous growth of grass.

# PART 3 EXECUTION

## 3.1 INSPECTION

A. The PROJECT ENGINEER shall verify that prepared soil base is ready to receive the work of this Section.

## 3.2 SEEDBED PREPARATION AND FERTILIZING

A. The EARTHWORK CONTRACTOR shall grade the seedbed to remove high spots and depressions. The EARTHWORK CONTRACTOR shall clean the surface of the seedbed of roots, plants, stones, clay lumps and other materials harmful or toxic to plant growth or detrimental to mowing and maintenance activities. The surface of the seedbed shall be scarified to a depth of two inches with a disk or other suitable implement.

B. Apply fertilizer at the rate determined by the PROJECT ENGINEER based on the seedbed soil test results. Typical rates are 600 lbs./acre for permanent seeding using a 5-10-10 (5% Nitrogen, 10% Phosphorous, 10% Potash) or equivalent fertilizer. Unless otherwise directed by the PROJECT ENGINEER, use a rate of 150 lbs./acre for drainage swales/channels using a 5-10-10 fertilizer. Soil amendments shall be mixed into the top two inches of the seedbed.

C. The EARTHWORK CONTRACTOR shall apply lime as needed to provide a final pH of 6.0 for the temporary and permanent seeding areas and a pH of 6.5 for the drainage swales/channels.

## 3.3 SEEDING

A. The EARTHWORK CONTRACTOR can mechanically and/or hydraulically plant the seed with the goal of evenly distributing the seed and maximizing soil to seed contact. Mulch shall be used to retain moisture, reduce soil temperature fluctuations, and reduce runoff and

erosion. Seed mixtures, fertilizers and liming will be applied in accordance with local Soil Conservation Service recommendations.

B. When applying seed, lime, fertilizer, or mulch materials with the hydroseeder, do not use more than 100 to 150 pounds of solids per 100 gallons of water. If inoculant is used in a seed, fertilizer, and lime slurry, it shall be used within 3 to 4 hours of introduction, or a fresh supply of inoculant shall be added. When legumes are to be included in a slurry mixture containing fertilizer, the pH shall be checked prior to application in that a low pH is detrimental to the inoculants. In a slurry mixture, the amount of inoculant added to the tank should be four times the rate prescribed by the manufacturer. The seedbed shall be wetted prior to application of the slurry by hydroseeding.

C. Do not seed area in excess of that which can be mulched on same day.

D. Do not sow immediately following rain, when ground is too dry, or during windy periods.

E. Refer to seeding time listed in Part 2.1.

## 3.4 MULCHING AND MAINTENENACE

A. The EARTHWORK CONTRACTOR shall spread straw uniformly over the seeded area with no less than 100% coverage and at least a one-inch loose thickness.

B. Due to accessibility or steepness of slope, hydraulic mulching may be required. Hydraulic mulching shall consist of the mixing of virgin wood fiber mulch, pre-blended tackifier and/or other additives with water. The hydraulic mulch shall be mixed in standard hydraulic mulching equipment to form a homogenous slurry. The slurry shall be sprayed under pressure uniformly over the soil surface at the material application rate recommended by the supplier. The hydraulic mulching equipment shall include a motorized continuous agitation system that keeps all materials in uniform suspension throughout the mixing and distribution cycles.

C. Upon application, hydraulic mulch shall form a blotter-like mat covering of the seedbed. This mat shall have good water absorption and percolation characteristics and shall cover and bond grass seed in contact with the soil.

D. Maintenance of the completed seeding shall begin immediately after mulch is applied. The soil shall be kept moist to a depth of 2 inches during the seed germination period.

E. Reseed and mulch all areas greater than 4 square feet not having uniform coverage, until such time a uniform stand of grass is obtained.

END OF SECTION

## APPENDIX B

# ASTM D6392
# Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods

# GRI GM19
# Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes Technical Specifications

Designation: D6392 – 12 (Reapproved 2018)

# Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods[1]

This standard is issued under the fixed designation D6392; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method describes destructive quality control and quality assurance tests used to determine the integrity of geomembrane seams produced by thermo-fusion methods. This test method presents the procedures used for determining the quality of nonbituminous bonded seams subjected to both peel and shear tests. These test procedures are intended for nonreinforced geomembranes only.

1.2 The types of thermal field seaming techniques used to construct geomembrane seams include the following:

1.2.1 *Hot Air*—This technique introduces high-temperature air or gas between two geomembrane surfaces to facilitate melting. Pressure is applied to the top or bottom geomembrane, forcing together the two surfaces to form a continuous bond.

1.2.2 *Hot Wedge (or Knife)*—This technique melts the two geomembrane surfaces to be seamed by running a hot metal wedge between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Some seams of this kind are made with dual bond tracks separated by a nonbonded gap. These seams are sometimes referred to as dual hot wedge seams or double-track seams.

1.2.3 *Extrusion*—This technique encompasses extruding molten resin between two geomembranes or at the edge of two overlapped geomembranes to effect a continuous bond.

1.3 The types of materials covered by this test method include the following:

1.3.1 Very low-density polyethylene (VLDPE).
1.3.2 Linear low-density polyethylene (LLDPE).
1.3.3 Very flexible polyethylene (VFPE).
1.3.4 Linear medium-density polyethylene (LMDPE).
1.3.5 High-density polyethylene (HDPE).
1.3.6 Polyvinyl chloride (PVC).
1.3.7 Flexible polypropylene (fPP).

NOTE 1—The polyethylene identifiers presented in 1.3.1 – 1.3.5 describe the types of materials typically tested using this test method. These are industry-accepted trade descriptions and are not technical material classifications based upon material density.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]
D638 Test Method for Tensile Properties of Plastics
D4439 Terminology for Geosynthetics
D5199 Test Method for Measuring the Nominal Thickness of Geosynthetics
D5994/D5994M Test Method for Measuring Core Thickness of Textured Geomembranes
2.2 *EPA Standard:*[3]
EPA/600/2-88/052 Lining of Waste Containment and Other Containment Facilities, Appendix N—Locus of Break Codes for Various Types of FML Seams

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *geomembrane, n*—essentially impermeable geosynthetic composed of one or more synthetic sheets.

3.1.2 *quality assurance, n*—all planned and systematic actions necessary to provide adequate confidence that an item or a facility will perform satisfactorily in service.

3.1.3 *quality control, n*—the operational techniques and the activities which sustain a quality of material, product, system,

[1] This test method is under the jurisdiction of ASTM Committee D35 on Geosynthetics and is the direct responsibility of Subcommittee D35.10 on Geomembranes.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from the Superintendent of Documents, US Government Printing Office, Washington, DC 20402.

or service that will satisfy given needs; also the use of such techniques and activities.

## 4. Significance and Use

4.1 The use of geomembranes as barrier materials to restrict liquid migration from one location to another in soil and rock has created a need for a standard test method to evaluate the quality of geomembrane seams produced by thermo-fusion methods. In the case of geomembranes, it has become evident that geomembrane seams can exhibit separation in the field under certain conditions. Although this is an index-type test method used for quality assurance and quality control purposes, it is also intended to provide the quality assurance engineer with sufficient seam peel and shear data to evaluate seam quality. Recording and reporting data, such as separation that occurs during the peel test and elongation during the shear test, will allow the quality assurance engineer to take measures necessary to ensure the repair of inferior seams during facility construction, and therefore, minimize the potential for seam separation in service.

## 5. Apparatus

5.1 Tensile instrumentation shall meet the requirements outlined in Test Method D638.

5.2 *Grip Faces*—Grip faces shall be 25 mm (1 in.) wide and a minimum of 25 mm (1 in.) in length. Smooth rubber, fine serrated, or coarse serrated grip faces have all been found to be suitable for testing geomembrane seams.

## 6. Sample and Specimen Preparation

6.1 *Seam Samples*—Cut a portion of the fabricated seam sample from the installed liner in accordance with the project specifications. It is recommended that the cutout sample be 0.3 m (1 ft) wide and 0.45 m (1.5 ft) in length with the seam centered in the middle.

6.2 *Specimen Preparation*—Ten specimens shall be cut from the sample submittal. The specimens shall be die cut using a 25 mm (nominal 1 in.) wide by a minimum of 150 mm (nominal 6 in.) long die. Specimens that will be subjected to peel and shear tests shall be selected alternately from the sample and labeled as shown in Fig. 1. Specimens shall be cut such that the seam is perpendicular to the longer dimension of the strip specimen.

6.3 *Conditioning*—Samples should be conditioned for 40 h in a standard laboratory environment that conforms to the requirements for testing geosynthetics as stated in Terminology D4439. Long sample conditioning times typically are not possible for most applications that require seam testing. Prior to testing, samples should be conditioned for a minimum of 1 h at 23 ± 2 °C and a relative humidity between 50 and 70 %.

## 7. Destructive Test Methods

7.1 *Peel Testing*—Subject five specimens to the 90° "T-peel" test (see Fig. 2). If the tested sample is a dual hot wedge seam, five specimens must be examined for each external track of the seam. Maintaining the specimen in a horizontal position throughout the test is not required. Fully grip the test specimen across the width of the specimen. Grip the peel specimen by securing grips 25 mm (1 in.) on each side of the start of the seam bond, a constant machine crosshead speed of 50 mm (2 in.)/min for HDPE, LMDPE, and PVC, 500 mm (20 in.)/min for LLDPE, VLDPE, VFPE, and fPP. The test is complete when the specimen ruptures.

7.2 *Shear Testing*—Subject five specimens to the shear test (see Fig. 2). Fully support the test specimen within the grips across the width of the specimen. Secure the grips 25 mm (1 in.) on each side of the start of the seam bond, a constant machine crosshead speed of 50 mm (2 in.)/min for LMDPE and HDPE, 500 mm (20 in.)/min for fPP, LLDPE, VFPE, VLDPE, and PVC. The test is complete for HDPE and LMDPE

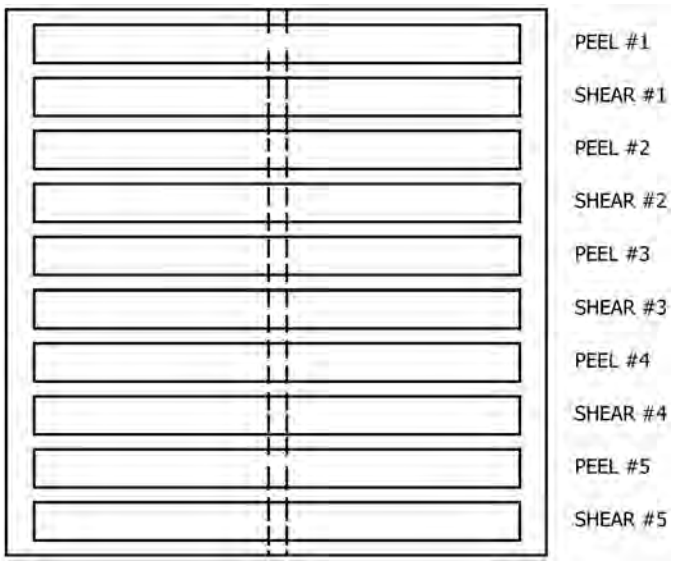


**FIG. 1 Seam Sample**

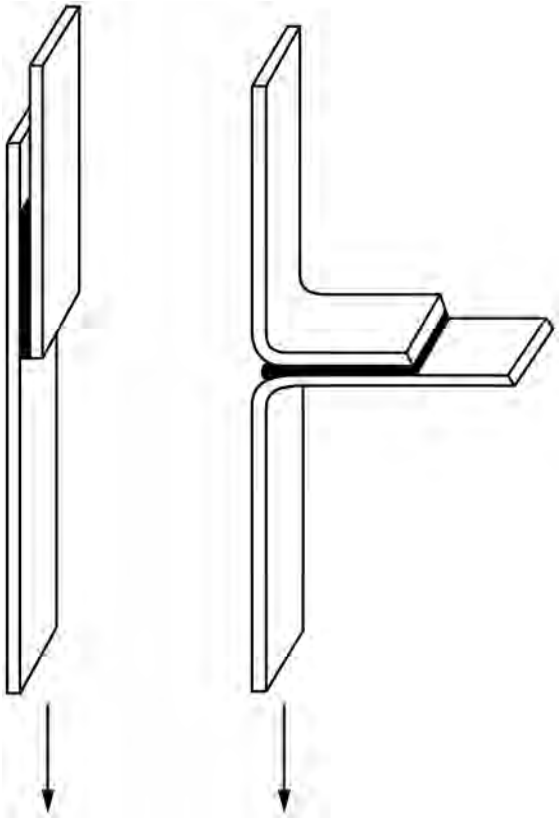

**FIG. 2 Shear and T-Peel Specimens**

once the specimen has elongated 50 %. PVC, fPP, LLDPE, VFPE, and VLDPE geomembranes should be tested to rupture.

NOTE 2—Both peel and shear tests for fPP, LLDPE, VLDPE, and PVC geomembranes have been tested routinely at both 2 and 20 in./min. When conducting seam peel or shear testing for quality control or quality assurance purposes, or both, it may be necessary to select the manufacturer's recommended testing speed. In the absence of explicit testing speed requirements, follow those recommended in 7.1 and 7.2.

## 8. Calculations and Observations

8.1 *Estimate of Seam Peel Separation*—Visually estimate the seam separation demonstrated prior to rupture for peel specimens. The estimate shall be based upon the proportion of the area of the separated bond, to the area of original bonding to the nearest 5 %. However, if at any point across the width of the peel specimen seam separation continues to the other side of the bonded area, the estimate of seam peel separation shall be 100 % regardless of the proportion of the area of the separated bond to the area of the original bonding.

8.1.1 In cases of dispute, the peel separation estimate may be documented via direct measure.

8.1.2 *Procedure*—Determine the total area of bonded area for which the peel test was performed using calipers to span measure the maximum length of the bond, being careful not include squeeze-out or tack-welded areas. Verify the seam width of one inch.

8.1.3 Assign appropriate geometric shapes to approximate the area of each separated portion of the peeled zone.

8.1.4 Place the peeled specimen flat against the surface of a flatbed scanner set at 100 % scale.

8.1.5 Produce a record of the peeled area for easier shape assignment and peeled area determination. Care should be taken to ensure intimate contact between the peeled specimen and the scanner surface so as to preserve dimensions.

8.1.6 Using the same calipers, record the dimensions of each peeled area.

8.1.7 Using the recorded dimensions, calculate percent peel as follows and round to the nearest 5%.

$$S = 100^{*}\ A/A_o \quad (1)$$

*where:*

$S$ = percent peel separation,
$A$ = area of peel separation measured, and
$A_o$ = area of original bonded region (not including track weld, tack weld, or squeeze-out, see Notes 3 and 4).

NOTE 3—During the thermo-fusion welding process, some of the melted polymer may be shifted to the outside of the weld during the pressing of the geomembrane panels together. This melted polymer is sometimes called "squeeze-out" or "bleed-out" and is not considered part of the bond. Care must be exercised during estimation of the seam peel separation to segregate the squeeze or bleed-out area from the peeled bond area. The reported peel separation shall include the peeled bond area only.

NOTE 4—The exact area of original bond ($A_o$) for use in Eq 1 for peel separation is sometimes ambiguous. For most cases, the area of peel measured for thermo-fusion extrusion seams is that area defined by the width of the specimen multiplied by the distance between the termination of the top geomembrane and the outermost edge of the extrusion weld along the bottom geomembrane. To be counted as part of the weld, the extruded material must be at least as thick as the nominal thickness of the geomembrane.

8.2 *Rupture Mode Selection*—Determine the locus of break for both the peel and shear specimens as shown in Figs. 3 and 4. The locus of break for shear specimens that do not rupture prior to test end (50 % elongation) shall be interpreted as occurring in the membrane that exhibits yielding.

8.3 *Shear Percent Elongation*—Calculate the percent elongation on shear specimens according to Eq 2. Divide the extension at test end by the original gage length of 25 mm and multiply by 100.

$$\text{Elongation(E)} = \frac{L}{L_0} \times 100 \quad (2)$$

where:

$L$ = extension at test end, and
$L_0$ = original gauge length.

NOTE 5—The intent of measuring elongation using this test method is to identify relatively large reductions in typical break elongation values of seam samples. Length is defined as the distance from one grip to the seam edge. Using this definition implies that all strain experienced by the specimen during the shear test occurs on one side of the seam. Of course this assumption is inaccurate, since some strain will occur on each side of the seam, and in the seam area itself; however, it is difficult to make an accurate measurement of the strain distribution which occurs in the specimen during testing. Further, it is not critical to know the exact location of all the strain which occurs during testing but rather to simply identify when significant reductions in elongation (when compared with the typical elongation of a new material) have occurred.

## 9. Report

9.1 The report shall include the following information:

9.1.1 Report the individual peel and shear specimen maximum unit tension values in N/mm of width (lb/in.).

NOTE 6—If requested, report the maximum peel or shear stress. This calculation will require an accurate measurement of thickness for each specimen. These measurements should be made in accordance with Test Method D5199 for smooth geomembranes and Test Method D5994/D5994M for textured geomembranes.

9.1.2 Report the crosshead speed used during peel and shear testing.

9.1.3 Report the average of the individual peel and shear sample values recorded.

9.1.4 If the peel or shear specimen does not rupture, report the elongation at the maximum crosshead travel limitation. If the gage length is reduced to less than 25 mm (1 in.), this must be noted in the report.

9.1.5 Report the mode of specimen rupture for peel and shear specimens according to Fig. 3 or Fig. 4.

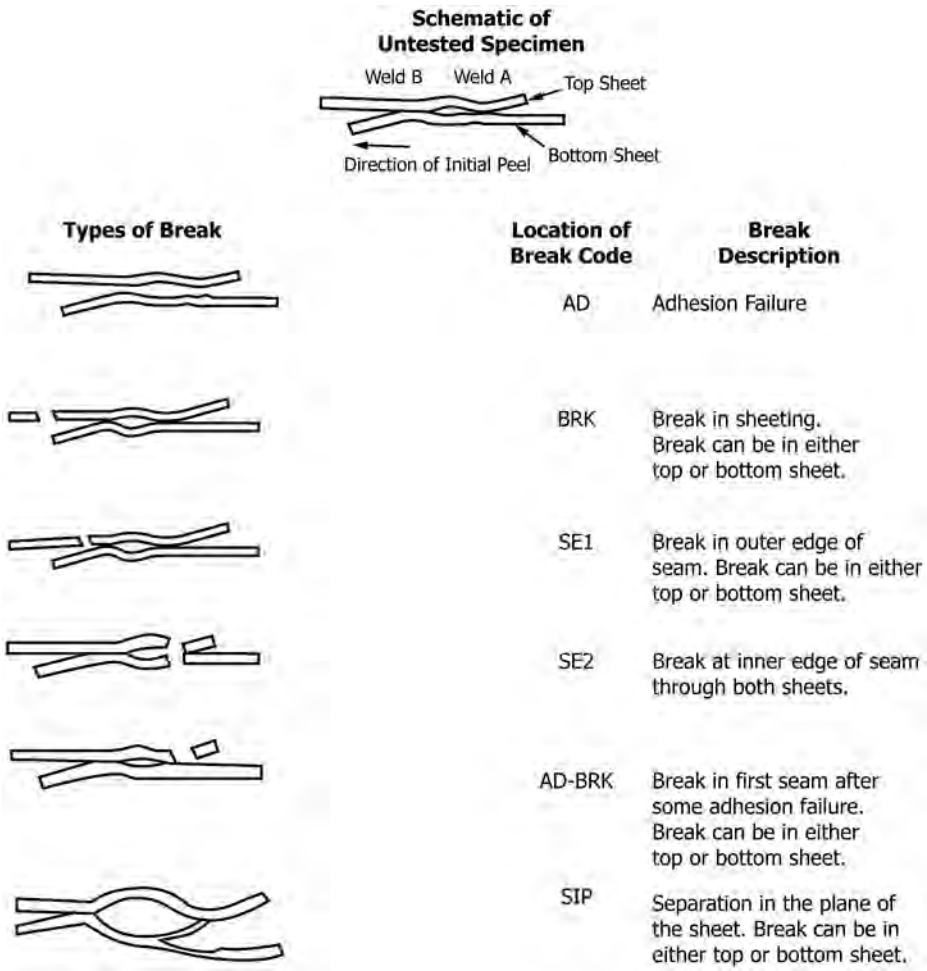


**FIG. 3 Locus-of-Break Codes for Dual Hot Wedge Seams in Unreinforced Geomembranes Tested for Seam Strength in Shear and Peel Modes**

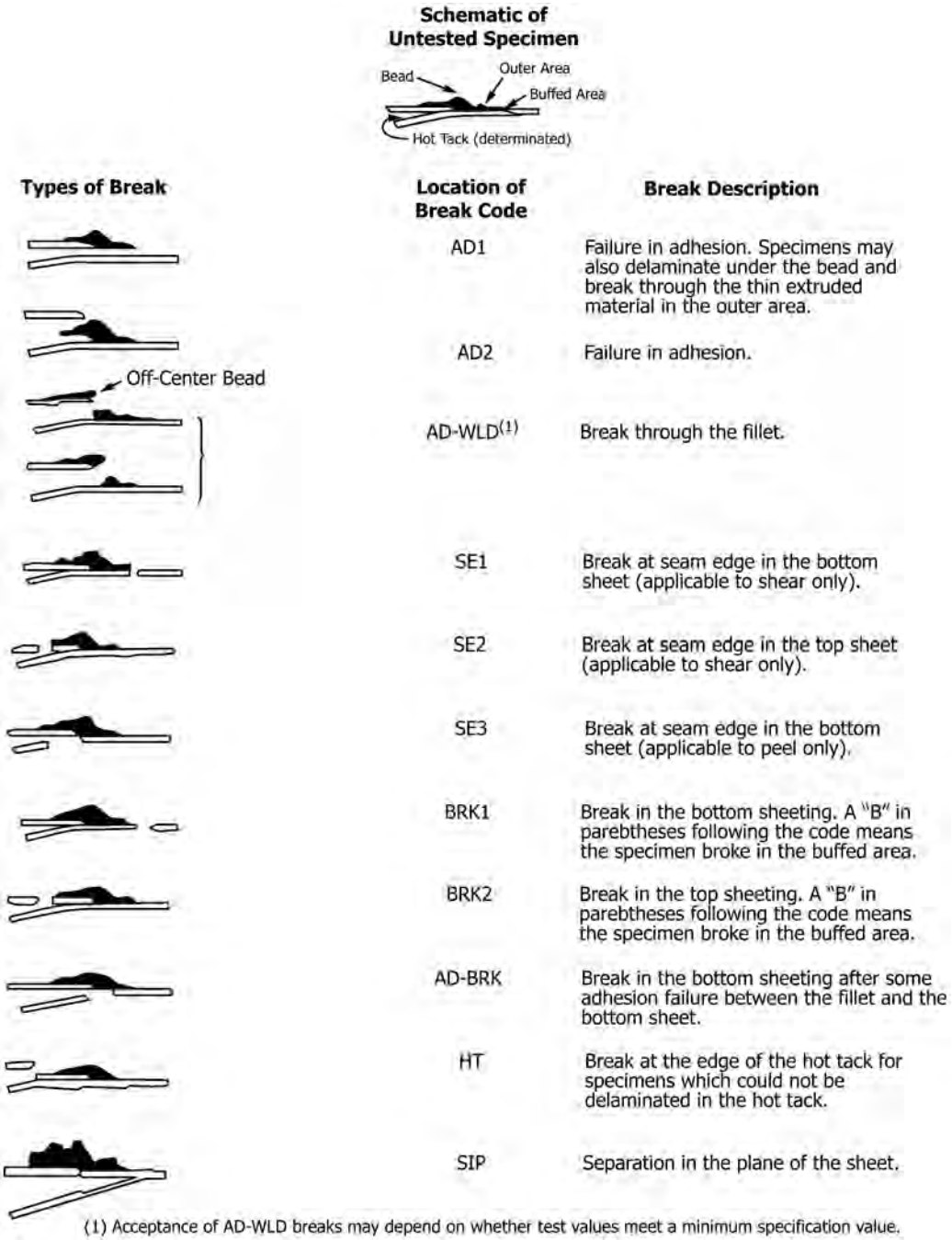


**FIG. 4 Locus-of-Break Codes for Fillet Extrusion Weld Seams in Unreinforced Geomembranes Tested for Seam Strength in Shear and Peel Modes**

NOTE 7—"Locus of failure" (Figs. 3 and 4) includes only some of the typically found seam configurations found in the industry. When this test method is applied to seams bonded in configurations other than those identified in Fig. 3 or Fig. 4, the users of this test method must agree on applicable descriptions for modes of specimen rupture.

## 10. Precision and Bias

10.1 No statement can be made at this time concerning precision or bias.

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Original: February 28, 2002
Revision 9: July 28, 2017
Revision schedule is on pg. 13

**GRI -GM19a Standard Specification***

Standard Specification for

# "Seam Strength and Related Properties of Thermally Bonded Homogeneous Polyolefin Geomembranes/Barriers" SM

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

## 1. Scope

1.1 This specification addresses the required seam strength and related properties of thermally bonded homogeneous, i.e., nonreinforced, polyolefin geomembranes. Included herein are high density polyethylene (HDPE), linear low density polyethylene (LLDPE) and flexible polypropylene (fPP).

Note 1: See GRI Standard GM19b for reinforced geomembrane seams of all types including scrim reinforced LLDPE-R and fPP-R.

1.2 Numeric values of seam strength and related properties are specified in both shear and peel modes.

Note 2: This specification does not address the test method details or specific testing procedures. It refers to the relevant ASTM test methods where applicable.

*This GRI standard specification is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 5-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version and it is kept current on the Institute's Website <<geosynthetic-institute.org>>.

1.3 The thermal bonding methods focused upon are hot wedge (single and dual track) and extrusion fillet.

Note 3: Other acceptable, but less frequently used, methods of seaming are hot air and ultrasonic methods. They are inferred as being a subcategory of hot wedge seaming.

1.4 This specification does not suggest a specific distance between destructive seam samples to be taken in the field, i.e., the sampling interval. Two separate GRI Standard Practices are focused on this issue, see GRI-GM14 and GRI-GM20.

1.5 This specification is only applicable to laboratory testing.

1.6 This specification does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

## 2. Referenced Documents

2.1 ASTM Standards

D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods

D7747 Standard Test Method for Determining Integrity of Seams Produced Using Thermo-Fusion Methods for Reinforced Geomembranes by the Strip Tensile Method

2.2 EPA Standards

EPA 600/2.88/052 (NTIS PB-89-129670)
Lining of Waste Containment and Other Containment Facilities

2.3 GRI Standards

GM13 Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes

GM14 Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes

GM17 Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes

GM18 Test Properties and Testing Frequency for Flexible Polypropylene (fPP and fPP-R) Geomembranes

GM20 Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts

GM25 Test Property and Testing Frequency for Scrim Reinforced Linear Low Density Polyethylene Geomembranes

## 3. Definition

3.1 Geomembrane, n – An essentially impermeable geosynthetic composed of one or more synthetic sheets used for the purpose of liquid, gas or solid containment.

Note 4: This specification addresses homogeneous, or nonreinforced, geomembranes. GRI-GM19b addresses scrim, or fabric, reinforced geomembranes.

3.2 Hot Wedge Seaming – A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a hot metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Seams of this type can be made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual hot wedge seams or double-track seams.

3.3 Hot Air Seaming – This seaming technique introduces high-temperature air or gas between two geomembrane surfaces to facilitate localized surface melting. Pressure is applied to the top or bottom geomembrane, forcing together the two surfaces to form a continuous bond.

3.4 Ultrasonic Seaming - A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a ultrasonically vibrated metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Some seams of this type are made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual-track seams or double-track seams.

3.5 Extrusion Fillet Seaming – This seaming technique involves extruding molten resin at the edge of an overlapped geomembrane on another to form a continuous bond. A depreciated method called “extrusion flat” seaming extrudes the molten resin between the two overlapped sheets. In all types of extrusion seaming the surfaces upon which the molten resin is applied must be suitably prepared, usually by a slight grinding or buffing.

## 4. Significance and Use

4.1 The various methods of field fabrication of seams in homogeneous, or nonreinforced, polyolefin geomembranes are covered in existing ASTM standards mentioned in the referenced document section. What is not covered in those documents is the numeric values of strength and related properties that the completed seam must meet, or exceed. This specification provides this information insofar as minimum, or maximum, property values are concerned when the field

fabricated seams are sampled and laboratory tested in shear and peel. Separate GRI standards, GM14 and GM20, provide guidance as to the spacing that destructive samples should be taken in typical field installation projects.

## 5. Sample and Specimen Preparation

5.1 The spacings for taking field seam samples for destructive testing can be a fixed, or variable, interval or can be statistically related as provided in GRI-GM14 and GRI-GM20. These statistical processes describe a progression from the most restrictive interval of 1 per 500 feet (1 per 150 m) to the complete use and reliance of the electrical leak location survey (ELLS) method. Intermediate between these extremes are variations depending upon the installers experience and performance.

Note 5: The job-specific spacing is decided upon the design engineer or CQA organization.

5.2 The size of field seam samples is to be according to the referenced test method, e.g., ASTM D6392 or site-specific CQA plan.

5.3 The individual test specimens taken from the field seam samples are to be tested according to the referenced test method, i.e., ASTM D6392 for HDPE, LLDPE and fPP. The specimens are to be conditioned prior to testing according to these same test methods and evaluated accordingly.

## 6. Assessment of Seam Test Results

6.1 HDPE seams – For HDPE seams (both smooth and textured), the strength of all five out of five 1.0 inch (25 mm) wide strip specimens in shear should meet or exceed the values given in Tables 1(a) and 1(b). In addition, all five specimens should meet the shear percent elongation, calculated as follows, and exceed the values given in Tables 1(a) and 1(b):

$$E = \frac{L}{L_o}(100) \quad (1)$$

where

E = elongation (%)
L = extension at end of test (in. or mm)
$L_o$ = original average length (usually 1.0 in. or 25 mm)

Note 6: The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

For HDPE seams (both smooth and textured), the strength of all five out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 1(a) and 1(b).

In addition, the peel separation (or incursion) should not exceed the values given in Tables 1(a) and 1(b) for all five out of five specimens. The value shall be based on the proportion of area of separated bond to the area of the original bonding as follows:

$$S = \frac{A}{A_o}(100) \qquad (2)$$

where

S = separation (%)
A = average area of separation, or incursion ($in^2$ or $mm^2$)
$A_0$ = original bonding area ($in^2$ or $mm^2$)

Note 7: The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%
Extrusion Fillet: AD1, AD2
Exception: AD-WLD (unless strength is achieved)

Note 8: Separation-in-plane (SIP) is a locus-of-break where the failure surface propagates within one of the seamed sheets during destructive testing (usually in the peel mode). It is not merely a surface skin effect producing a few ductile fibrils (sometimes called ductile drawdown). SIP is acceptable if the required strength, shear elongation and peel separation criteria are met.

In this regard, five out of five specimens shall result in acceptable break patterns.

6.2 LLDPE seams – For LLDPE seams (both smooth and textured), the strength all five out of five 1.0 in. (25 mm) wide strip specimens in shear should meet or exceed the values given in Tables 2(a) through 2(d). Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips. In addition, the shear percent elongation, calculated as follows, should exceed the values given in Tables 2(a) through 2(d). All five specimens should meet the shear elongation requirement.

$$E = \frac{L}{L_o}(100) \quad (1)$$

where

E = elongation (%)
L = extension at end of test (in. or mm)
$L_o$ = original average length (usually 1.0 in. or 25 mm)

Note 6 (Repeated): The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

For LLDPE seams (smooth, textured and scrim reinforced), the strength of all five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 2(a) through 2(d).

In addition, the peel separation (or incursion) should not exceed the values given in Tables 2(a) through 2(d). All five out of five specimens shall meet the peel separation value. The value shall be based on the proportion of area of separated bond to the area of the original bonding as follows:

$$S = \frac{A}{A_o}(100) \quad (2)$$

where

S = separation (%)
A = average depth of separation, or incursion ($in.^2$ or $mm^2$)
$A_0$ = original bonding distance ($in.^2$ or $mm^2$)

Note 6 (Repeated): The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%
Extrusion Fillet: AD1, AD2
Exception: AD-WLD (unless strength is achieved)

Note 8 (Repeated): Separation-in-plane (SIP) is a locus-of-break where the failure surface propagates within one of the seamed sheets during destructive testing (usually in the peel mode). It is not merely a surface skin effect producing a few ductile fibrils (sometimes called ductile drawdown). SIP is acceptable if the required strength, shear elongation and peel separation criteria are met.

In this regard, all five specimens shall result in acceptable break patterns.

6.3 fPP Seams – For fPP seams, the strength all five out of five specimens in shear should meet or exceed the values given in Tables 3(a) and 3(b). Note that the specimens are 1.0 in. (25 mm) wide strips. In addition, the shear percent elongation on the specimens, calculated as follows, should exceed the values given in Tables 3(a) and 3(b). All five out of five specimens should meet the shear elongation requirement.

$$E = \frac{L}{L_o}(100) \quad (1)$$

where
E = elongation (%)
L = extension at end of test (in. or mm)
$L_o$ = original gauge length (usually 1.0 in. or 25 mm)

Note 4 (Repeated): The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

For fPP seams, the strength of all five out of five specimens in peel should meet or exceed the values given in Tables 3(a) and 3(b). Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips. In addition, the peel percent separation (or incursion) should not exceed the values given in Tables 3(a) and 3(b). All five out of five specimens should meet the peel separation value. The values should be based on the proportion of area of separated bond to the area of the original bonding as follows.

$$S = \frac{A}{A_o}(100) \quad (2)$$

where

S = separation in (%)
A = average depth of separation, or incursion ($in.^2$ or $mm^2$)
$A_o$ = original bonding distance ($in.^2$ or $mm^2$)

Note 7 (Repeated): The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%
Extrusion Fillet: AD1, AD2
Exception: AD-WLD (unless strength is achieved)

Note 8 (Repeated): Separation-in-plane (SIP) is a locus-of-break where the failure surface propagates within one of the seamed sheets during destructive testing (usually in the peel mode). It is not merely a surface skin effect producing a few ductile fibrils (sometimes called ductile drawdown). SIP is acceptable if the required strength, shear elongation and peel separation criteria are met.

In this regard, five out of five specimens shall result in acceptable break patterns.

## 7. Retest and Rejection

7.1 If the results of the testing of a sample do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the construction quality control or construction quality assurance plan for the particular site under construction.

## 8. Certification

8.1 Upon request of the construction quality assurance officer or certification engineer, an installer's certification that the geomembrane was installed and tested in accordance with this specification, together with a report of the test results, shall be furnished at the completion of the installation.

Table 1(a) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** High Density Polyethylene (HDPE) Geomembranes **(English Units)**

| Geomembrane Nominal Thickness | 30 mils | 40 mils | 50 mils | 60 mils | 80 mils | 100 mils | 120 mils |
|---|---|---|---|---|---|---|---|
| Hot Wedge Seams[1] | | | | | | | |
| shear strength, lb/in. | 57 | 80 | 100 | 120 | 160 | 200 | 240 |
| shear elongation at break[2], % | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| peel strength, lb/in. | 45 | 60 | 76 | 91 | 121 | 151 | 181 |
| peel separation, % | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Extrusion Fillet Seams | | | | | | | |
| shear strength, lb/in. | 57 | 80 | 100 | 120 | 160 | 200 | 240 |
| shear elongation at break[2], % | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| peel strength, lb/in. | 39 | 52 | 65 | 78 | 104 | 130 | 156 |
| peel separation, % | 25 | 25 | 25 | 25 | 25 | 25 | 25 |

Notes for Tables 1(a) and 1(b):
1. Also for hot air and ultrasonic seaming methods
2. Elongation measurements should be omitted for field testing

Table 1(b) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** High Density Polyethylene (HDPE) Geomembranes **(S.I. Units)**

| Geomembrane Nominal Thickness | 0.75 mm | 1.0 mm | 1.25 mm | 1.5 mm | 2.0 mm | 2.5 mm | 3.0 mm |
|---|---|---|---|---|---|---|---|
| Hot Wedge Seams[1] | | | | | | | |
| shear strength, N/25 mm. | 250 | 350 | 438 | 525 | 701 | 876 | 1050 |
| shear elongation at break[2], % | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| peel strength, N/25 mm | 197 | 263 | 333 | 398 | 530 | 661 | 793 |
| peel separation, % | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Extrusion Fillet Seams | | | | | | | |
| shear strength, N/25 mm | 250 | 350 | 438 | 525 | 701 | 876 | 1050 |
| shear elongation at break[2], % | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| peel strength, N/25 mm | 170 | 225 | 285 | 340 | 455 | 570 | 680 |
| peel separation, % | 25 | 25 | 25 | 25 | 25 | 25 | 25 |

Table 2(a) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** Linear Low Density Polyethylene (LLDPE) Geomembranes (English Units)

| Geomembrane Nominal Thickness | 20 mils | 30 mils | 40 mils | 50 mils | 60 mils | 80 mils | 100 mils | 120 mils |
|---|---|---|---|---|---|---|---|---|
| Hot Wedge Seams[1] | | | | | | | | |
| shear strength, lb/in. | 30 | 45 | 60 | 75 | 90 | 120 | 150 | 180 |
| shear elongation[2], % | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| peel strength, lb/in. | 25 | 38 | 50 | 63 | 75 | 100 | 125 | 150 |
| peel separation, % | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Extrusion Fillet Seams | | | | | | | | |
| shear strength, lb/in. | 30 | 45 | 60 | 75 | 90 | 120 | 150 | 180 |
| shear elongation[2], % | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| peel strength, lb/in. | 22 | 34 | 44 | 57 | 66 | 88 | 114 | 136 |
| peel separation, % | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |

Notes for Tables 2(a) and 2(b):
1. Also for hot air and ultrasonic seaming methods
2. Elongation measurements should be omitted for field testing

Table 2(b) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** Linear Low Density Polyethylene (LLDPE) Geomembranes (S.I. Units)

| Geomembrane Nominal Thickness | 0.50 mm | 0.75 mm | 1.0 mm | 1.25 mm | 1.5 mm | 2.0 mm | 2.5 mm | 3.0 mm |
|---|---|---|---|---|---|---|---|---|
| Hot Wedge Seams[1] | | | | | | | | |
| shear strength, N/25 mm | 131 | 197 | 263 | 328 | 394 | 525 | 657 | 788 |
| shear elongation[2], % | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| peel strength, N/25 mm | 109 | 166 | 219 | 276 | 328 | 438 | 547 | 657 |
| peel separation, % | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Extrusion Fillet Seams | | | | | | | | |
| shear strength, N/25 mm | 131 | 197 | 263 | 328 | 394 | 525 | 657 | 788 |
| shear elongation[2], % | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| peel strength, N/25 mm | 95 | 150 | 190 | 250 | 290 | 385 | 500 | 595 |
| peel separation, % | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |

Table 3(a) – Seam Strength and Related Properties of Thermally Bonded Homogeneous Flexible Polypropylene (fPP) Geomembranes (English Units)

| Geomembrane Nominal Thickness | 30 mil | 40 mil |
|---|---|---|
| Hot Wedge Seams[1] | | |
| shear strength, lb/in. | 25 | 30 |
| shear elongation[2], % | 50 | 50 |
| peel strength, lb/in. | 20 | 25 |
| peel separation, % | 25 | 25 |
| Extrusion Fillet Seams | | |
| shear strength, lb/in. | 25 | 30 |
| shear elongation[2], % | 50 | 50 |
| peel strength, lb/in. | 20 | 25 |
| peel separation, % | 25 | 25 |

1. Also for hot air and ultrasonic seaming methods
2. Elongation measurements should be omitted for field testing

Table 3(b) – Seam Strength and Related Properties of Thermally Bonded Homogeneous Flexible Polypropylene (fPP) Geomembranes (S.I. Units)

| Geomembrane Nominal Thickness | 0.75 mm | 1.0 mm |
|---|---|---|
| Hot Wedge Seams[1] | | |
| shear strength, N/25 mm | 110 | 130 |
| shear elongation[2], % | 50 | 50 |
| peel strength, N/25 mm | 85 | 110 |
| peel separation, % | 25 | 25 |
| Extrusion Fillet Seams | | |
| shear strength, N/25 mm | 110 | 130 |
| shear elongation[2], % | 50 | 50 |
| peel strength, N/25 mm | 85 | 110 |
| peel separation, % | 25 | 25 |

1. Also for hot air and ultrasonic seaming methods
2. Elongation measurements should be omitted for field testing

**Adoption and Revision Schedule**
**for**
**Seam Specification per GRI-GM19**

"Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes"

Adopted: February 18, 2002

Revision 1: May 15, 2003; Increased selected shear and peel test requirements, per the following:

| Material | Test | Seam Type | Current GM19 | Proposed GM19 | Difference |
|---|---|---|---|---|---|
| HDPE | Shear | Hot Wedge | 95% yield | 95% yield | no change |
| | | Extrusion | 95% yield | 95% yield | no change |
| | Peel | Hot Wedge | 62% yield | 72% yield | 16% increase |
| | | Extrusion | 62% yield | 62% yield | no change |
| LLDPE | Shear | Hot Wedge | 1300 psi break | 1500 psi break | 15% increase |
| | | Extrusion | 1300 psi break | 1500 psi break | 15% increase |
| | Peel | Hot Wedge | 1100 psi break | 1250 psi break | 14% increase |
| | | Extrusion | 1100 psi break | 1100 psi break | no change |

Revision 2: January 28, 2005; added Note 6 (in three locations) stating that incursion is measured on an area basis and not depth as in ASTM D6392.

Revision 3: June 4, 2010; Removed Note 6 on peel incursion since ASTM D6392 (2008) now uses area of incursion whereas previously they used linear length of incursion. Thus ASTM is now in agreement with GM19 in this regard.

Revision 4: November 15, 2010; Added Note 6 (in three locations) stating what separation-in-plane (SIP) is, and is not, and that it is acceptable if the required strength, shear elongation and peel separation criteria are met.

Revision 5: July 12, 2011; AD1 and AD2 breaks are now unacceptable even if strength is achieved.

Revision 6: October 3, 2011; Added LLDPE-R to the various geomembrane types, in particular, Tables 2(c) and 2(d) and made editorial changes.

Revision 7: November 3, 2013; clarified issues of 4 out of 5 passing strength and 5 out of 5 passing locus-of-break, shear elongation and peel separation.

Revision 8: February 12, 2015; upgraded standards and terminology

Revision 9: July 28, 2017: eliminated reinforced LLDPE-R and fPP-R geomembranes in deference to GRI-GM19b which includes them and other scrim-reinforced geomembranes and barriers. Also now required are 5 out of 5 passing strength tests for all materials.

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Original: October 13, 2017
Rev. 1: April 17, 2020

**GRI -GM19b Standard Specification***

Standard Specification for

**"Seam Strength and Related Properties of Thermally Bonded Reinforced Polyolefin Geomembranes/Barriers" SM**

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

## 1. Scope

1.1 This specification addresses the required seam strength and related properties of thermally bonded reinforced polyolefin geomembranes and barriers. Included herein are the following.

- reinforced linear low density polyethylene (LLDPE-R)
- reinforced polyethylene (PE-R)
- reinforced coated polyethylene (RCPE)
- reinforced flexible polypropylene (fPP-R)
- reinforced chlorosulfonated polyethylene (CSPE-R)

Note 1: The existing GRI sheet specifications for the above are available at www.geosynthetic-institute.org/specs.htm.

Note 2: Also see the complimentary GRI Seam Specification GM19a for homogenous (or nonreinforced) geomembrane seams made from high density polyethylene (HDPE), linear low density polyethylene (LLDPE) and flexible polypropylene (fPP).

*This GRI standard specification is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 5-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version and it is kept current on the Institute's Website <<geosynthetic-institute.org>>.

Note 3: The distinction between geomembranes and barriers is very subjective at present. One possible distinction is based on thickness since the U.S. EPA requires a minimum thickness of 30 mils (0.75 mm) for waste containment in its RCRA regulations. Barriers would then consist of thicknesses less than 30 mils (0.75 mm).

Note 4: The reinforcement component of geomembranes and barriers is usually polymeric textiles in various forms. Woven multifilament yarns and woven monofilaments of various percent open areas are relatively common. Such fabric reinforcement is also referred to as "scrim" reinforcement.

1.2 Numeric values of seam strength and related properties are specified herein in both shear and peel modes.

Note 5: This specification does not address the test method details or specific testing procedures. It refers to the relevant ASTM test method in this regard, i.e., ASTM D7747.

1.3 The thermal bonding methods focused upon in this standard are hot wedge (single and dual track) and hot air. Other acceptable, but less frequently used, methods of seaming are extrusion fillet, ultrasonic and sewing methods.

1.4 This specification does not suggest a specific distance between destructive seam samples to be taken in the field, i.e., the sampling interval. Two separate GRI Standard Practices are focused on this issue, see GRI-GM14 and GRI-GM20.

1.5 This specification is only applicable to the laboratory testing of geomembrane/barrier seams.

Note 6: Field trial seams, or test strip seams, can also utilize this specification but acceptance depends on the construction quality assurance plan and/or parties involved.

1.6 This specification does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

## 2. Referenced Documents

2.1 ASTM Standards

D76 Standard Specification for Tensile Testing Machines for Textiles
D751 Standard Test Method for Coated Fabrics

D5199 Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods
D7747 Standard Test Method for Determining Integrity of Seams Produced Using Thermo-Fusion Methods for Reinforced Geomembranes by the Strip Tensile Method
E4 Standard Practice for Force Verification of Testing Machines

2.2 EPA Standards

EPA 600/2.88/052 (NTIS PB-89-129670)
Lining of Waste Containment and Other Containment Facilities

2.3 GRI Standards

GM22 Test Methods, Required Properties, and Testing Frequencies for Scrim Reinforced Polyethylene (PE-R) Barriers Used in Exposed Temporary Applications
GM30 Test Method, Required Properties and Testing Frequencies for Coated Tape Polyethylene (cPE) Barriers
GM14 Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes
GM18 Test Properties and Testing Frequency for Flexible Polypropylene (fPP and fPP-R) Geomembranes
GM20 Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts
GM25 Test Property and Testing Frequency for Scrim Reinforced Linear Low Density Polyethylene (LLDPE-R) Geomembranes
GM28 Test Method, Test Properties and Testing Frequencies for Reinforced Chlorosulfonated Polyethylene (CSPE-R) Geomembranes
GM30 Test Methods, Test Properties and Testing Frequency for Reinforced Composite Polyethylene (RCPE) Geomembranes

## 3. Definitions

3.1 Geomembrane, n – An essentially impermeable geosynthetic composed of one or more synthetic sheets used for the purpose of liquid, gas or solid containment.

Note 7: This specification addresses seams of reinforced geomembranes and barriers. GRI-GM19a addresses homogeneous (or nonreinforced) geomembranes.

3.2 Hot Wedge Seaming – A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a hot metal wedge between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Seams can be made single (solid wedge) or double (split wedge) tracked. Seams of the double track type can be made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual hot wedge seams or double-track seams with an air channel between the two tracks.

3.3 Hot Air Seaming – This seaming technique introduces high-temperature air or gas between two geomembrane surfaces to facilitate localized surface melting. Pressure is applied to the top or bottom geomembrane, forcing together the two surfaces to form a continuous bond.

3.4 Ultrasonic Seaming - A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a ultrasonically vibrated metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Some seams of this type are made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual-track seams or double-track seams.

3.5 Extrusion Fillet Seaming – This seaming technique involves extruding molten resin at the edge of overlapped geomembranes to form a continuous bond. A depreciated method called "extrusion flat" seaming extrudes the molten resin between the two overlapped sheets. In all types of extrusion seaming the surfaces upon which the molten resin is applied must be suitably roughened, usually by a slight grinding or buffing.

3.6 Sewn Seams - Some very thin reinforced barriers can be made by sewing. Depending upon conditions and the parties involved this can be acceptable.

3.7 U.S. EPA (1991) - Resource Conservation and Recovery Act (RCRA), Title 40, Code of Federal Regulations (CFR), Part 261 (40 CFR 261), Subpart D and Subpart C.

## 4. Significance and Use

4.1 The various test methods of seamed polyolefin geomembrane/barriers in shear and peel are covered in existing ASTM standards mentioned in the referenced document section. For example, D6392 is for nonreinforced and D7747 is for reinforced seams. What is not covered in those documents are the numeric values of shear and peel strength and related properties that the completed seam must meet, or exceed. *This specification provides this information insofar as minimum test values are concerned after the field fabricated seams are sampled and laboratory tested in shear and peel.* Such results must meet or exceed the values given in the attached tables for the respective types of geomembranes/barriers.

## 5. Apparatus

5.1 Tensile Testing Machine - A constant rate of extension (CRE) device meeting the requirements of ASTM Specification D76. The load cell shall be accurate to within ± 1% of the applied force and verified per ASTM E4. The drive mechanism shall be able to control the rate of extension to within ± 1% of the targeted rate. The maximum allowable error in recorded grip displacement shall be ± 1% of the recorded values. The maximum allowable variation in nominal gage length on repeated return of the grips to their starting position shall be less than 0.01 in. (0.25 mm).

5.2 Grip Faces - The clamping mechanism and clamp surfaces shall hold the specimen firmly without causing damage.

5.2.1 Clamp faces shall be a minimum of 1.0 in. (25 mm) in the dimension parallel to direction of test and wide enough to grip full width of the specimen.

Note 8: Test specimens failing at the grip faces or within the grips shall be discarded, i.e., failure must be within the test specimen's gage length.

## 6. Sample and Specimen Preparation

6.1 The spacings for taking field seam samples for destructive testing can be a fixed or variable interval, or can be statistically related as provided in GRI-GM14 and GRI-GM20. These statistical processes describe a progression from the most restrictive interval of 1 per 500 feet (1 per 150 m) to the complete use and reliance of the electrical leak location survey (ELLS) methods. Intermediate between these extremes are variations depending upon the inspectors requirements and the installers experience and performance.

Note 9: The project-specific sampling spacing is decided upon by the design engineer or CQA organization.

6.2 The size of field seam samples is to be according to the referenced test method, e.g., ASTM D7747 or site-specific CQA plan.

6.3 The individual test specimens taken from the field seam samples are to be tested according to ASTM D7747. The specimens are to be conditioned prior to testing according to this same test method and evaluated accordingly.

## 7. Assessment of Seam Test Results

The tables to follow for the five specific types of geomembranes or barriers under consideration all use ASTM D7747 as the test protocol. As such, the seam test specimens are 1.0 in. (25 mm) in width with the seamed area central to the opposing grip faces. The orientation of the specimens should be indicated accordingly. For each seam sample there will be five replicate tests conducted in shear and an adjacent five replicate tests conducted in peel. All ten test specimens must meet or exceed the values given in the respective tables to follow.

7.1 Linear low density polyethylene reinforced (LLDPE-R) seams - For LLDPE-R seams (following the LLDPE sheet material specification of GRI-GM25) the strength of all five-out-of-five strip tensile shear tests and five-out-of-five peel tests should meet or exceed the values given in Tables 1(a) or 1(b). See ASTM D7747 for procedures in conducting the shear and peel tests. Regarding location of break (LOB) codes, AD1, AD2 and AD-WLD are not allowed whereas SIP-R, SIP-CI and SIPCO are allowed provided that the respective strength values are achieved.

7.2 Polyethylene reinforced (PE-R) barrier seams - For PE-R seams (following the PE-R sheet material specification of GRI-GM22) the strength of all five-out-of-five strip tensile shear tests and five-out-of-five peel tests should meet or exceed the values given in Tables 2(a) or 2(b). See ASTM D7747 for procedures in conducting the shear and peel tests. Regarding location of break (LOB) codes, they do not apply due to orientation of the scrim reinforcement yarns.

7.3 Reinforced coated polyethylene geomembrane (RCPE) seams - For RCPE geomembrane seams (following the RCPE sheet material specification of GRI-GM30) the strength of all five-out-of-five strip tensile shear tests and five-out-of-five peel tests should meet or exceed the values given in Tables 3(a) or 3(b). See ASTM D7747 for procedures in conducting the shear and peel tests. Regarding location of break (LOB) codes, AD1, AD2 and AD-WLD are not allowed whereas SIP-R, SIP-CI and SIPCO are allowed provided that the respective strength values are achieved.

7.4 Flexible polypropylene reinforced (fPP-R) seams - For fPP-R seams (following the fPP sheet material specification for GRI-GM18) the strength of all five-out-of-five strip tensile shear tests and five-out-of-five peel tests should meet or exceed the values given in Tables 4(a) or 4(b). See ASTM D7747 for procedures in conducting the shear and peel tests. Regarding location of break (LOB) codes, AD1, AD2 and AD-WLD are not allowed whereas SIP-R, SIP-CI and SIPCO are allowed provided that the respective strength values are achieved.

7.5 Chlorosulphonated polyethylene reinforced (CSPE-R) seams - For CSPE-R seams (following the CSPE sheet material specification of GRI-GM28 the strength of all five-out-of-five strip tensile shear tests and five-out-of-five peel tests should meet or exceed the values given in Tables 5(a) or 5(b). See ASTM D7747 for procedures in conducting the shear and peel tests. Regarding location of break (LOB) codes, AD1, AD2 and AD-WLD are not allowed whereas SIP-R, SIP-CI and SIPCO are allowed provided that the respective strength values are achieved.

Note 10: The conversion from the original U.S. Standard Units to SI (Metric) Units is “soft”.

U.S. Standard Units

Table 1(a) – Seam Strength of Thermally Bonded Reinforced Linear Low Density Polyethylene (LLDPE-R) Geomembranes Made According to GRI-GM25(2)

| Property | Test Method | Min. Value | Min. Value |
|---|---|---|---|
| Sheet Thickness<br>• nominal (mils) | D5199<br>(Method A) | <br>36 | <br>45 |
| Hot Wedge/Air Seams(1)<br>• shear strength, lb<br>• peel strength, lb | D7747 | <br>75<br>30 | <br>90<br>30 |
| Other Seam Types<br>• shear strength, lb<br>• peel strength, lb | D7747 | <br>80<br>30 | <br>100<br>30 |

(1) Also for other possible seaming methods, e.g., ultrasonic
(2) Values are based on 1.0 in. (25 mm) wide strip tensile strength per D7747 for laboratory tested specimens

SI (Metric) Units

Table 1(b) – Seam Strength of Thermally Bonded Reinforced Linear Low Density Polyethylene (LLDPE-R) Geomembranes Made According to GRI-GM25(2)

| Property | Test Method | Min. Value | Min. Value |
|---|---|---|---|
| Sheet Thickness<br>• nominal (mm) | D5199<br>(Method A) | <br>0.91 | <br>1.14 |
| Hot Wedge/Air Seams(1)<br>• shear strength, N<br>• peel strength, N | D7747 | <br>330<br>130 | <br>400<br>130 |
| Other Seam Types<br>• shear strength, N<br>• peel strength, N | D7747 | <br>350<br>130 | <br>440<br>130 |

(1) Also for other possible seaming, e.g., ultrasonic
(2) Values are based on 25 mm (1.0 in.) wide strip tensile strength per D7747 for laboratory tested specimens

U.S. Standard Units

Table 2(a) - Seam Strength of Thermally Bonded Polyethylene Reinforced (PE-R) Barrier Seams Made According to GRI-GM22(2)

| Property | Test Method | Min. Value | Min. Value | Min. Value |
|---|---|---|---|---|
| Sheet Thickness<br>• nominal (mils) | D5199 | <br>8.0 | <br>12.0 | <br>20.0 |
| Hot Wedge/Air Seams(1)<br>• shear strength (lb)<br>• peel strength (lb) | D7747 | <br>12<br>6 | <br>18<br>7 | <br>24<br>9 |

(1) Also for other possible seaming methods, e.g., ultrasonic
(2) Values are based on 1.0 in. (25 mm) wide strip tensile strength per D7747 for laboratory tested specimens

SI (Metric) Units

Table 2(b) - Seam Strength of Thermally Bonded Polyethylene Reinforced (PE-R) Barrier Seams Made According to GRI-GM22(2)

| Property | Test Method | Min. Value | Min. Value | Min. Value |
|---|---|---|---|---|
| Sheet Thickness<br>• nominal (mm) | D5199<br>(Method A) | <br>0.20 | <br>0.30 | <br>0.50 |
| Hot Wedge/Air Seams(1)<br>• shear strength (N)<br>• peel strength (N) | D7747 | <br>53<br>53 | <br>80<br>66 | <br>106<br>80 |

(1) Also for other possible seaming methods, e.g., ultrasonic
(2) Values are based on 25 mm (1.0 in.) wide strip tensile strength per D7747 for laboratory tested specimens

U.S. Standard Units

Table 3(a) - Seam Strength of Thermally Bonded Coated Polyethylene (cPE) Reinforced Barrier Seams Made According to GRI-GM30(2)

| Property | Test Method | Min. Value | Min. Value | Min. Value |
|---|---|---|---|---|
| Sheet Thickness<br>• nominal (mils) | D751 | <br>24 | <br>30 | <br>40 |
| Hot Wedge/Air Seams(1)<br>• shear strength (lb)<br>• peel strength (lb) | D7747 | <br>30<br>10 | <br>60<br>10 | <br>90<br>10 |
| Other Seam Types<br>• shear strength (lb)<br>• peel strength (lb) | D7747 | <br>30<br>10 | <br>60<br>10 | <br>90<br>10 |

(1) Also for other possible seaming methods, e.g., ultrasonic
(2) Values are based on 1.0 in. (25 mm) wide strip tensile strength per D7747 for laboratory tested specimens

SI (Metric) Units

Table 3(b) - Seam Strength of Thermally Bonded Coated Polyethylene (cPE) Reinforced Barrier Seams Made According to GRI-GM30(2)

| Property | Test Method | Min. Value | Min. Value | Min. Value |
|---|---|---|---|---|
| Sheet Thickness<br>• nominal (mm) | D751 | <br>0.61 | <br>0.76 | <br>1.02 |
| Hot Wedge/Air Seams(1)<br>• shear strength (N)<br>• peel strength (N) | D7747 | <br>130<br>45 | <br>270<br>45 | <br>400<br>45 |
| Other Seam Types<br>• shear strength (N)<br>• peel strength (N) | D7747 | <br>130<br>45 | <br>270<br>45 | <br>400<br>45 |

(1) Also for other possible seaming methods, e.g., ultrasonic
(2) Values are based on 25 mm (1.0 in.) wide strip tensile strength per D7747 for laboratory tested specimens

U.S. Standard Units

Table 4(a) – Seam Strength of Thermally Bonded Reinforced Flexible Polypropylene (fPP-R) Geomembranes Made According to GRI-GM18(2)

| Property | Test Method | Min. Value | Min. Value | Min. Value |
|---|---|---|---|---|
| Sheet Thickness<br>• nominal (mils) | D5199<br>(Method A) | <br>36 | <br>45 | <br>60 |
| Hot Wedge/Air Seams(1)<br>• shear strength (lb)<br>• peel strength (lb) | D7747 | <br>50<br>25 | <br>60<br>25 | <br>70<br>25 |
| Other Seam Types<br>• shear strength (lb)<br>• peel strength (lb) | D7747 | <br>50<br>25 | <br>60<br>25 | <br>70<br>25 |

(1) Also for other possible seaming methods, e.g., ultrasonic
(2) Values are based on 1.0 in. (25 mm) wide strip tensile strength per D7747 for laboratory tested specimens

SI (Metric) Units

Table 4(b) – Seam Strength of Thermally Bonded Reinforced Flexible Polypropylene (fPP-R) Geomembranes Made According to GRI-GM18(2)

| Property | Test Method | Min. Value | Min. Value | Min. Value |
|---|---|---|---|---|
| Sheet Thickness<br>• nominal (mm) | D5199<br>(Method A) | <br>0.91 | <br>1.14 | <br>1.52 |
| Hot Wedge/Air Seams(1)<br>• shear strength (N)<br>• peel strength (N) | D7747 | <br>220<br>110 | <br>270<br>110 | <br>310<br>110 |
| Other Seam Types<br>• shear strength (N)<br>• peel strength (N) | D7747 | <br>220<br>110 | <br>270<br>110 | <br>310<br>110 |

(1) Also for other possible seaming methods, e.g., ultrasonic
(2) Values are based on 25 mm (1.0 in.) wide strip tensile strength per D7747 for laboratory tested specimens

U.S. Standard Units

Table 5(a) - Seam Strength of Thermally Bonded Chlorosulphonated Polyethylene Reinforced (CSPE-R) Geomembrane Seams Made According to GRI-GM28(2)

| Property | Test Method | Min. Value | Min. Value | Min. Value |
|---|---|---|---|---|
| Sheet Thickness<br>• nominal (mils) | D5199<br>(Method A) | <br>36 | <br>45 | <br>60 |
| Hot Wedge/Air Seams(1)<br>• shear strength (lb)<br>• peel strength (lb) | D7747 | <br>40<br>20 | <br>50<br>20 | <br>60<br>20 |
| Other Seam Types<br>• shear strength (lb)<br>• peel strength (lb) | D7747 | <br>40<br>20 | <br>50<br>20 | <br>60<br>20 |

(1) Also for other possible seaming methods, e.g., ultrasonic
(2) Values are based on 1.0 in. (25 mm) wide strip tensile strength per D7747 for laboratory tested specimens

SI (Metric) Units

Table 5(b) - Seam Strength of Thermally Bonded Chlorosulphonated Polyethylene Reinforced (CSPE-R) Geomembrane Seams Made According to GRI-GM28(2)

| Property | Test Method | Min. Value | Min. Value | Min. Value |
|---|---|---|---|---|
| Sheet Thickness<br>• nominal (mm) | D5199<br>(Method A) | <br>0.91 | <br>1.14 | <br>1.52 |
| Hot Wedge/Air Seams(1)<br>• shear strength (N)<br>• peel strength (N) | D7747 | <br>180<br>90 | <br>220<br>90 | <br>270<br>90 |
| Other Seam Types<br>• shear strength (N)<br>• peel strength (N) | D7747 | <br>180<br>90 | <br>220<br>90 | <br>270<br>90 |

(1) Also for other possible seaming methods, e.g., ultrasonic
(2) Values are based on 25 mm (1.0 in.) wide strip tensile strength per D7747 for laboratory tested specimens

**Adoption and Revision Schedule**
**for**
**HDPE Specification per GRI-GM19b**

Standard Specification for "Seam Strength and Related Properties of Thermally Bonded Reinforced Polyolefin Geomembranes/Barriers"

| | |
|---|---|
| Adopted: | October 13, 2017 |
| Revision 1: | Editorial changes to accommodate Reinforced Composite Polyethylene (RCPE) geomembranes per GRI-GM30 |

# APPENDIX C

# Construction Record Survey Requirements

# Lockwood Hills LLC
# Construction Record Survey Requirements

Construction and Record Drawing survey requirements are summarized below for construction stakeout and the acceptance criteria requirements for the Final Cover and Baseliner Systems.

**Final Cover Record Survey and Mapping Requirements**

The various layers that are to be surveyed and mapped for record purposes are, in ascending order for the Final Cover System:

1. Prepared Soil Cover after Stripping
2. 40 mil LLDPE Geomembrane Panels and Sample Locations
3. Extent of Geocomposite Infiltration Drain
4. Top of 12-inch minimum Barrier Protection Soil Layer
5. Top of 6-inch minimum Topsoil Layer
6. Piping- Stormwater Collection and Infiltration Drain
7. Piping- Leachate Transfer System
8. Miscellaneous

**Slope Acceptance/Frequency Criteria for Record Surveys**

The Final Cover will be considered acceptable provided the following design and/or regulatory slope criteria/frequency is met (accounting for significant figures):

**Layer 1 – Prepared Soil Cover after Stripping, Layer 5 – Top of 12-inch minimum Barrier Protection Soil Layer, and Layer 6 – Top of 6-inch minimum Topsoil Layer**

- Design for overall final cover slope must be less than or equal to 33% (Regulatory Basis) as measured on the prepared subgrade surface. The Record Survey point frequency criteria will be at a 50-foot grid spacing and slope changes/breaklines.
- The slope shall be determined using points at the top-of-slope, approximate mid-elevation of the slope and the toe of slope, taken along the line of maximum slope.
- The survey shall locate the entire certified vertical and horizontal limits of the layers.

**Layer 2 – 40 mil LLDPE Geomembrane Panels and Sample Locations**

- Corners of each panel;
- All destructive sample locations and repairs;
- Other repairs (not including "bead only" repairs);
- Penetrations; and,
- Certified vertical and horizontal limits.

**Layer 3- Geocomposite Infiltration Drain**

- The Record Survey points will be obtained for the certified horizontal and vertical limits.

**Layer 6- Piping for Stormwater Collection and Infiltration Drain, and Layer 7 Piping Leachate Transfer**

- The Record Survey points will be for the top of the pipe at fittings, and all slope and direction changes.

**Baseliner Record Survey and Mapping Requirements**

The various layers that are to be surveyed and mapped for record purposes are, in ascending order for the Baseliner System:

1. Prepared Subgrade
2. Extent of Porewater Geocomposite
3. Piping – Porewater Collection System
4. Top of Secondary Soil Liner
5. Secondary Geomembrane Panels and Sample Locations
6. Extent of Secondary Geocomposite
7. Top of 12-inch minimum Secondary Soil Drainage Layer
8. Piping – Secondary Leachate Collection and Removal System
9. Primary Geomembrane Panels and Sample Locations
10. Piping – Primary Leachate Collection and Removal System
11. Top of lower 12-inch minimum Primary Drainage Layer
12. Top of upper 12-inch minimum Primary Drainage Layer
13. Miscellaneous

**Slope Acceptance/Frequency Criteria for Record Surveys**

The Baseliner will be considered acceptable provided the following design and/or regulatory slope criteria/frequency is met (accounting for significant figures):

**Layer 1 – Subgrade, Layer 4 – 12-inch Minimum Secondary Soil Liner and Layer 5 – 12-inch Minimum Secondary Soil Drainage Layer**

- Floor area design for slope must be >/= 2% (Regulatory Basis). This equates to 2% or greater. The Record Survey point frequency criteria will be at a 50-foot grid spacing at ridges and valleys and slope changes/breaklines.

- The horizontal and vertical extent of all over-excavations of the design Subgrade will be located by Record Survey.

**Layer 2 – Piping – Porewater Collection System, Layer 7 – Piping - Secondary Leachate Collection and Removal System, Layer 9 – Piping - Primary Leachate Collection and Removal System**

All collection pipe designed for 1% must be >/= 1% overall from the upgradient end to the downgradient end for any pipe run. The Record Survey points will be for the top of the pipe/fittings, and at all slope and direction changes. This will be taken as a tolerance range of 0.80% to 1.20% slope calculated at a spacing of approximately 60-feet along the pipe, and >/= 1% overall.

- Lined side slopes must range between > 25% and </= 33% (Regulatory Basis) or as approved by the Project Engineer. The slope shall be measured on points including as a minimum the top-of-slope, approximate mid-elevation of the slope and the toe of slope, taken along the line of maximum slope. The Record Survey points will include the certified horizontal and vertical limits of the Layers.

- Certified vertical and horizontal limits of the layers.

**Layer 2 and Layer 4 – Extent of Porewater and Secondary Geocomposite Drainage Layer**

- Certified horizontal limits of the layers.

**Layer 5 and Layer 9 –** Primary and Secondary HDPE Geomembrane Panels and Sample Locations

- Corners of each panel;
- All destructive sample locations and repairs;
- Other repairs (not including "bead only" repairs);
- Pipe penetrations;
- Leak location survey defects and repairs; and,
- Certified horizontal limits.

**Layer 11 and Layer 12 - Top of Lower Minimum 12-inch Primary Drainage Layer and Top of Upper 12 inch Minimum Primary Drainage Layer**

- The Record Survey points will be obtained on a 50' grid spacing, all slope changes, and the certified horizontal and vertical limits.

**Special Considerations**

- The thickness of the secondary soil liner, the liner structural fill, the primary drainage layer stone and the tire shreds will be verified by comparison of the record survey elevations at the common/shared horizontal coordinates. The design layer thickness on the lined sideslopes is established perpendicular to the slope, and adjustments must be made to the measured vertical differences obtained at shared horizontal coordinates.

# APPENDIX D

# Interface Shear Testing Protocol

# Geocomposite Drain Transmissivity Test Protocol

Lockwood Hills LLC
Baseliner System Construction
**Draft Interface Shear Test Protocol**

The following specifies the interface shear testing materials and requirements for the above referenced project. The test will be completed in general accordance with the ASTM Standards referenced and specified below. The test specimens will be constructed to model the design layering of the liner system, as delineated below.

Laboratory equipment used for the test must be modern, state-of-the-art, and of first-rate quality.

The following general requirements relate to all testing:

**1.0 General Requirements**

1.1 Shear testing shall be completed in a minimum 12" by 12" shear box.

**1.2 Shear failure shall be forced to the tested interface.**

1.3 The following normal loads shall be used: 3,000 pounds per square foot (psf), 6,000 psf, 10,000 psf, and 18,000 psf.

1.4 Shear displacement shall be a minimum of 3 inches.

1.5 Testing shall be performed in general accordance with ASTM D6243 for those interfaces Involving a Geosynthetic Clay Liner (GCL), or ASTM D5321 for all other interfaces, except when or if in conflict with a specific requirement stated herein.

1.6 All tests are to be conducted at displacement rates sufficiently slow to achieve drained conditions in the samples. For tests involving a GCL or compacted clay soil, the time to failure shall be no faster than 3 inches in 7 hours (maximum rate of displacement of 0.007 in/min.)

1.7 For all interface shear tests involving compacted clay or GCL materials:

1.7.1 Inundation of samples shall occur following placement of no less than a 1,000 psf normal load. Free draining faces shall be provided for the GCL and the compacted clay sample boundary that is opposite any geomembrane face.

1.7.2 For each normal load in any test series, the test specimen must experience the same seating time, which shall be at least 24 hours, prior to shearing.

1.7.3 Consolidation loadings should be held for a minimum of 24 hours for normal stresses up to 8,000 psf and 48 hours for stresses higher than 8,000 psf but less than 16,000 psf and 72 hours for stresses above 16,000 psf. Loads can be applied by using a load ratio of 1 and waiting at least 1 hour between applied loadings.

**2.0 Specimen Preparation**

2.1 Specimens are to be oriented in the same direction as the liner system is constructed in the field, and the anticipated direction of failure, as directed by the Project Engineer. The machine direction must be marked on the geosynthetic samples used for testing.

2.2 All non-GCL interfaces shall be inundated in the apparatus at the time the normal load exceeds 1,000 psf. GCL specimens are to be immersed in water for 15 seconds prior to placement in the shearing apparatus.

2.3 Use tap water for hydration.

2.4 The subgrade soil sample shall be placed against the Porewater Geocomposite having a dry density and a moisture content, as specified by the Project Engineer.

2.5 The Subgrade soil barrier sample (if required) shall be placed against the Geocomposite having a dry density and a moisture content, as specified by the Project Engineer.

2.6 The secondary soil liner sample shall be placed against the Geomembrane having a dry density and a moisture content as specified by the Project Engineer.

2.7 The alternate secondary soil liner sample (if required) shall be placed against the Geomembrane having a dry density and a moisture content, as specified by the Project Engineer.

2.8 The Secondary Soil Drainage Layer sample shall be placed against the Secondary Geocomposite and the GCL as specified by the Project Engineer.

2.9 The Lower Primary Drainage Layer sample shall be placed against the Type C Geotextile, as specified by the Project Engineer.

## 3.0 Reporting

3.1 Reporting as required by ASTM.

3.2 Report all raw test data including stress verses displacement curves.

3.3 Geosynthetic Product and Sample Names are to be identified in the Report.

3.4 Report the following observations:

- 3.4.1 Where and how the sample failed.
- 3.4.2 Condition of failure interface including striations, condition of fibers, bentonite extrusion, slippage in test box, etc.
- 3.4.3 Peak and large strain values.

## 4.0 Test Interfaces and Strain Rate – (Italicized text* denotes interface to be tested)

**Interface - 1: Subgrade Soil/Porewater Geocomposite**

**Test Layers:** *Geocomposite Roll # _____*
*Subgrade Soil **
Porous Plate

**Soil Conditions:** Subgrade Soil Sample – see 2.4 above- Onsite Soil

**Strain Rate:** 0.007 in/min

**Interface - 2: 60-mil Textured Geomembrane/Secondary Soil Liner**

**Test Layers:** *Geomembrane Roll # _____*
*Secondary Soil Liner **
Porous Plate

**Soil Conditions:** Secondary Soil Liner Sample – see 2.6 and 2.7 above

**Strain Rate:** 0.007 in/min

**Interface - 3: Secondary Geocomposite/60-mil Textured Geomembrane**

**Test Layers:** *Geocomposite Roll # _____**
*60 mil Textured Geomembrane Roll # _____**

**Soil Conditions:** N.A.

**Strain Rate:** 0.04 in/min

**Interface - 4:** **Secondary Soil Drainage Layer/ Secondary Geocomposite**

**Test Layers:** Porous Plate
*Geocomposite Roll # _____*
*Secondary Soil Drainage Layer **

**Soil Conditions:** Secondary Soil Drainage Layer Sample – see 2.8 above - Onsite Soil

**Strain Rate:** 0.007 in/min

**Interface - 5:** **Geosynthetic Clay Liner/Secondary Soil Drainage Layer**

**Test Layers:** Porous Plate
*GCL Roll #_____*
*Secondary Soil Drainage Layer**
Porous Plate

**Soil Conditions:** Secondary Soil Drainage Layer Sample – see 2.8 above- Onsite Soil

**Strain Rate:** 0.007in/min

**Interface - 6:** **60-mil Textured HDPE Geomembrane/Geosynthetic Clay Liner**

**Test Layers:** *Geomembrane Roll # _____*
*GCL Roll # _____*
Porous Plate

**Soil Conditions:** N.A.

**Strain Rate:** 0.007 in/min

**Interface - 7:** **Lower Primary Drainage Layer Material/ Type C Geotextile/60-mil Textured HDPE Geomembrane**

**Test Layers:** Lower Primary Drainage Layer Material
*Geotextile Roll # _____*
*Geomembrane Roll # _____*

**Soil Conditions:** Lower Primary Drainage Layer Material – see 2.9 above

**Strain Rate:** 0.04 in/min

Lockwood Hills LLC
Final Cover
**Draft Interface Shear Test Protocol**

The following specifies the interface shear testing materials and requirements for the above referenced project. The test will be completed in general accordance with the ASTM Standards referenced and specified below. The test specimens will be constructed to model the design layering of the final cover system, as delineated below.

Laboratory equipment used for the test must be modern, state-of-the-art, and of first-rate quality.

The following general requirements relate to all testing:

**1.0 General Requirements**

1.1 Shear testing shall be completed in a minimum 12" by 12" shear box.

**1.2 Shear failure shall be forced to the tested interface.**

1.3 The following normal loads shall be used: 200 pounds per square foot (psf), 1,100 psf, and 6,200 psf.

1.4 Shear displacement shall be a minimum of 3 inches.

1.5 Testing shall be performed in general accordance with ASTM D5321, except when or if in conflict with a specific requirement stated herein.

1.6 All tests are to be conducted at displacement rates sufficiently slow to achieve drained conditions in the samples. For tests involving compacted clayey soil, the time to failure shall be no faster than 3 inches in 7 hours (maximum rate of displacement of 0.007 in/min.).

1.7 For all interface shear tests involving compacted clayey soil:

1.7.1 Inundation of samples shall occur as soon as possible following placement of the normal load. Free draining faces shall be provided for the GCL and the compacted clayey soil sample boundary that is opposite any geomembrane face.

1.7.2 For each normal load in any test series, the test specimen must experience the same seating time, which shall be at least 24 hours, prior to shearing, or until it is determined that primary consolidation is complete.

**2.0 Specimen Preparation**

2.1 Specimens are to be oriented in the same direction as the final cover system is constructed in the field, and the anticipated direction of failure, as directed by the Project Engineer. The machine direction must be marked on the geosynthetic samples used for testing.

2.2 All non-GCL interfaces shall be inundated in the apparatus as soon as possible after placement of the desired normal load. GCL specimens are to be immersed in water for 15 seconds prior to placement in the shearing apparatus.

2.3 Allow the specimen to drain and consolidate under the desired normal load or increments thereof prior to shearing.

2.4 Use tap water for hydration.

2.5 The Barrier Protection Soil Layer soil sample (onsite soil) shall be placed against the Infiltration Geocomposite having a dry density and a moisture content, as specified by the Project Engineer.

## 3.0 Reporting

3.1 Reporting as required by ASTM.
3.2 Report all raw test data including stress verses displacement curves.
3.3 Geosynthetic Product and Sample Names are to be identified in the Report.
3.4 Report the following observations:
- 3.4.1 Where and how the sample failed.
- 3.4.2 Condition of failure interface including striations, condition of fibers, bentonite extrusion, slippage in test box, etc.
- 3.4.3 Peak and large strain values.

## 4.0 Test Interfaces and Strain Rate – (Italicized text* denotes interface to be tested)

**Interface - 1:** **Prepared Soil Cover /40-mil LLDPE Textured Geomembrane**
**Test Layers:** *Geomembrane Roll # _____**
*Prepared Soil Cover (onsite soil) **
Porous Plate

**Soil Conditions:** Prepared Soil Cover Sample – see 2.5 above – Onsite Soil

**Strain Rate:** 0.007 in/min

**Interface - 2:** **Prepared Soil Cover/GCL**
**Test Layers:** *GCL Roll # _____**
*Prepared Soil Cover (onsite soil) **
Porous Plate

**Soil Conditions:** Prepared Soil Cover Sample – see 2.5 above – Onsite Soil

**Strain Rate:** 0.007 in/min

**Interface - 3:** **GCL/40-mil LLDPE Textured Geomembrane**
**Test Layers:** *Geomembrane Roll # _____**
*GCL Roll # _____**

**Soil Conditions:** N/A

**Strain Rate:** 0.007 in/min

**Interface - 4:** **Infiltration Geocomposite / 40-mil LLDPE Textured Geomembrane**
**Test Layers:** *Geocomposite Roll # _____**
*Geomembrane Roll # _____**

**Soil Conditions:** N.A.

**Strain Rate:** 0.04 in/min

| **Interface - 5:** | **Barrier Protection Soil Layer / Infiltration Geocomposite** |
|---|---|
| **Test Layers:** | Porous Plate<br>*Barrier Protection Soil (onsite soil)**<br>*Geocomposite Roll # _____**  |
| **Soil Conditions:** | Barrier Protection Soil Sample – see 2.5 above – Onsite Soil |
| **Strain Rate:** | 0.007 in/min |

Lockwood Hills LLC
**Geocomposite Transmissivity Testing**
**Draft Test Protocol**

The following specifies the geocomposite transmissivity testing materials and requirements for the above referenced project.

The test is intended to provide data to help support the estimation of the long-term flow capacity of the Baseliner Porewater and Secondary Geocomposite Drain and the Final Cover Infiltration Geocomposite Drain (GCD). The test will be completed in accordance with ASTM D4716, and as specified below. The 12-inch by 12-inch test specimens will be constructed to model the design layering of the liner system.

Laboratory equipment used for the test must be modern, state-of-the-art, and of first-rate quality. Due to the use of relatively low hydraulic gradients in this test, it is important to utilize precise instrumentation for maintaining and measuring hydraulic heads, head loss and gradient across the specimen.

## 1.0 General Requirements

1.1 Test to be performed in strict accordance with ASTM D4716.

1.2 All testing must be observed and certified by a Senior Technician with at least 10 years of experience in scientific-laboratory test equipment and procedures.

1.3 Prior to transmissivity testing, determine:

- Thickness of the geonet core (ASTM D5199) from trimmings of the GCD test specimen.

1.4 In ascending order, the test specimens shall consist of the following materials:

**Test Section 1 – Porewater Geocomposite**

- Top – Fine grained medium plasticity Clay & Silt soil (to be provided by Project Engineer) placed in the test equipment against the Geocomposite with a dry density and a moisture content to be provided by Project Engineer;
- Porewater GCD –to be obtained by the Laboratory from the Manufacturer; and
- Bottom - Fine grained medium plasticity Clay & Silt soil (to be provided by Project Engineer) placed in the test equipment against the Geocomposite with a dry density and a moisture content to be provided by Project Engineer.

**Test Section 2 – Secondary Geocomposite**

- Top – Secondary Soil Drainage Layer Material (to be provided by Project Engineer) placed in the test equipment against the Geocomposite with a dry density and a moisture content to be provided by Project Engineer;
- Secondary GCD –to be obtained by the Laboratory from the Manufacturer; and

- Bottom – Secondary 60-mil Textured HDPE Geomembrane to be obtained by Laboratory from the Manufacturer.

**Test Section 3 – Infiltration Geocomposite**

- Top – Barrier Protection Layer Material (to be provided by Project Engineer) placed in the test equipment against the Geocomposite with a dry density and a moisture content to be provided by Project Engineer;
- Infiltration GCD –to be obtained by the Laboratory from the Manufacturer; and
- Bottom – 40-mil Textured LLDPE Geomembrane to be obtained by Laboratory from the Manufacturer.

1.5 A strain gauge shall be set at the top of the load plate under zero confining pressure to document the initial unconfined "thickness" of the multi-layered test specimen (geomembrane, GCD and soil).

## 2.0 Test Parameters

2.1 The flow direction for the test shall be oriented in the machine direction of the geocomposite. The test permeant shall be de-aired water at 5 ppm or lower.

2.2 Test temperature shall be 70 degrees F.

2.3 The geocomposite core shall be flushed or otherwise conditioned to remove air bubbles or pockets.

## 3.0 Seating Loads

3.1 **Secondary Geocomposite**

- 00:00 to 02:00 hr (250 psf)
- 02:01 to 04:00 hrs (4,500 psf step)
- 04:01 to 6:00 hrs (9,000 psf, step)
- 6:01 to 8:00 hrs (18,000 psf step)
- At 24 hours – the vertical datum shall be recorded for the top of the plate under the normal load of 18,000 psf.

3.2 **Porewater Geocomposite**

- 00:00 to 02:00 hr (250 psf)
- 02:01 to 04:00 hrs (1,500 psf step)
- 04:01 to 6:00 hrs (3,000 psf, step)
- 6:01 to 8:00 hrs (7,000 psf step)
- At 24 hours – the vertical datum shall be recorded for the top of the plate under the normal load of 7,000 psf.

3.3 The seating load for Test Section 3 shall be 200 psf.

## 4.0 Flow Measurement

4.1 Flow measurements and total vertical deformation of the test specimen shall be taken at 1 hour, 24 hours and 100 hours after maximum normal load application.

4.2 Flow measurements shall be obtained at each of two gradients: 0.02 and 0.33.

4.3 A digital photograph of water flow from the test specimens shall be taken at each flow measurement for inclusion in the final lab report.

## 5.0 Disassembly

5.1 The test specimen shall be removed from the test apparatus and dismantled, taking care to preserve the condition of the materials as tested.

5.2 Each step of dismantling, and all materials, shall be photographed. Digital photographs shall be suitable for illustrating the deformation of the materials and the degree of any soil intrusion-migration into geotextiles or geonet core.

5.3 Measure post-test thickness of the geonet core (ASTM D5199).

## 6.0 Reporting

6.1 Reporting as required by ASTM D4716.

6.2 Reporting to include, but not be limited to:

- 6.2.1 Diagram and photograph of the test apparatus;
- 6.2.2 Specimen layering;
- 6.2.3 Normal stresses;
- 6.2.4 Seating times;
- 6.2.5 Hydraulic heads;
- 6.2.6 Flow quantities;
- 6.2.7 Unit flow rate;
- 6.2.8 Specimen length;
- 6.2.9 Temperature correction factor;
- 6.2.10 Transmissivity;
- 6.2.11 Soil properties (placement and mechanical); and
- 6.2.12 Total vertical strain for each measurement.

6.3 The means and methods for establishing and measuring flow and hydraulic gradient shall be reported.

## APPENDIX E

# ASTM D7007
# Standard Practices for Locating Leaks In Geomembranes Covered With Water or Earth Materials

Designation: D 7007 – 09

# Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials[1]

This standard is issued under the fixed designation D 7007; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 These practices describe standard procedures for using electrical methods to locate leaks in geomembranes covered with water or earth materials containing moisture.

1.2 These practices are intended to ensure that leak location surveys are performed with demonstrated leak detection capability. To allow further innovations, and because various leak location practitioners use a wide variety of procedures and equipment to perform these surveys, performance-based operations are used that specify the minimum leak detection performance for the equipment and procedures.

1.3 These practices require that the leak location equipment, procedures, and survey parameters used are demonstrated to result in an established minimum leak detection sensitivity. The survey shall then be conducted using the demonstrated equipment, procedures, and survey parameters.

1.4 Separate procedures are given for leak location surveys for geomembranes covered with water and for geomembranes covered with earth materials. Separate procedures are given for leak detection sensitivity tests using actual and artificial leaks.

1.5 Leak location surveys can be used on geomembranes installed in basins, ponds, tanks, ore and waste pads, landfill cells, landfill caps, and other containment facilities. The procedures are applicable for geomembranes made of materials such as polyethylene, polypropylene, polyvinyl chloride, chlorosulfonated polyethylene, bituminous material, and other electrically-insulating materials.

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 **Warning**—The electrical methods used for geomembrane leak location could use high voltages, resulting in the potential for electrical shock or electrocution. This hazard might be increased because operations might be conducted in or near water. In particular, a high voltage could exist between the water or earth material and earth ground, or any grounded conductor. These procedures are potentially VERY DANGEROUS, and can result in personal injury or death. The electrical methods used for geomembrane leak location should be attempted only by qualified and experienced personnel. Appropriate safety measures must be taken to protect the leak location operators as well as other people at the site.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

D 4439 Terminology for Geosynthetics

D 6747 Guide for Selection of Techniques for Electrical Detection of Potential Leak Paths in Geomembranes

## 3. Terminology

3.1 For general definitions related to geosynthetics, see Terminology D 4439.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *artificial leak*, *n*—an electrical simulation of a leak in a geomembrane.

3.2.2 *current source electrode*, *n*—the electrode that is placed in the water or earth material above the geomembrane.

3.2.3 *dipole measurement*, *n*—an electrical measurement made on or in a partially conductive material using two closely-spaced electrodes.

3.2.4 *earth material*, *n*—sand, gravel, clay, silt, combinations of these materials, and similar materials with at least minimal moisture for electrical current conduction.

3.2.5 *leak*, *n*—any unintended opening, perforation, slit, tear, puncture, crack, hole, cut, or similar breaches through an installed geomembrane. Significant amounts of liquids or solids might or might not flow through a leak. Scratches, gouges, dents, or other aberrations that do not completely penetrate the geomembrane are not considered to be leaks.

3.2.6 *leak detection sensitivity*, *n*—the smallest size leak that the leak location equipment and survey methodology are

[1] These practices are under the jurisdiction of ASTM Committee D35 on Geosynthetics and is the direct responsibility of Subcommittee D35.10 on Geomembranes.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

capable of detecting under a given set of conditions. The leak detection sensitivity specification is usually stated as a diameter of the smallest leak that can be reliably detected.

3.2.7 *noise*, *n*—the unwanted part of a measured signal contributed by phenomena other than the desired signal.

3.2.8 *pole measurement*, *n*—an electrical measurement made on or in a partially conductive material using one measurement electrode and a remote reference electrode.

3.2.9 *potential*, *n*—electrical voltage measured relative to a reference point.

## 4. Summary of the Leak Location Methods

4.1 The principle of the electrical leak location method is to place a voltage across a geomembrane and then locate the points of anomalous potential distribution where electrical current flows through leaks in the geomembrane. Additional information can be found in Guide D 6747.

4.2 *General Principles*:

4.2.1 Figs. 1 and 2 show diagrams of the electrical leak location method for a geomembrane covered with water and for a geomembrane covered with earth materials respectively. One output of an electrical excitation power supply is connected to a current source electrode placed in the material covering the geomembrane. The other output of the power supply is connected to an electrode in contact with electrically conductive material under the geomembrane.

4.2.2 When there are leaks, electrical current flows through the leaks, which produces high current density and a localized anomaly in the potential distribution in the material above the geomembrane. Electrical measurements are made to locate those areas of anomalous signal at the leaks.

4.2.3 Measurements are made using a dipole or pole measurement configuration. Various types of data acquisition are used, including audio indications of the signal level, manual measurements with manual recording of data, and automated digital data acquisition.

4.2.4 Direct current and alternating current excitation power supplies and potential measurement systems have been used for leak location surveys.

4.3 *Leak Location Surveys of Geomembranes Covered with Water*:

4.3.1 Leak location surveys for geomembranes covered with water can be conducted with water on the geomembrane or with water covering a layer of earth materials on the geomembrane.

4.3.2 For leak location surveys with water on the geomembrane, usually a dipole probe is systematically scanned through the water covering the geomembrane to locate the points of anomalous potential distribution. The dipole spacing is typically 0.2 to 1 metres.

4.3.3 Various types of probes can be used to perform the surveys. Some are for when the operator wades in the water; some are for towing the probe back and forth across the geomembrane; and some are for raising and lowering along vertical or sloping walls.

4.3.4 The probe is typically connected to an electronic detector assembly that converts the electrical signal from the probe to an audible signal that increases in pitch and amplitude as the leak signal increases.

4.3.5 When a leak signal is detected, the point with the maximum signal is then determined. This point of maximum signal corresponds to the location of the leak. The location of the leak is then marked or measured relative to fixed points.

4.3.6 The leak detection sensitivity depends on the conductivity of the materials within, above, and below the leak, the electrical homogeneity of the material above the leak, the output level of the excitation power supply, the design of the measurement probe, the sensitivity of the detector electronics, the distance away from the leak, and the survey procedures. Leaks as small as 1 mm in diameter have been routinely found, including tortuous leaks through welds in the geomembrane. Leaks larger than 25 mm in diameter can usually be detected from several metres away.

4.3.7 The survey rate depends primarily on the spacing between scans and the depth of the water. A close spacing between scans is needed to detect the smallest leaks.

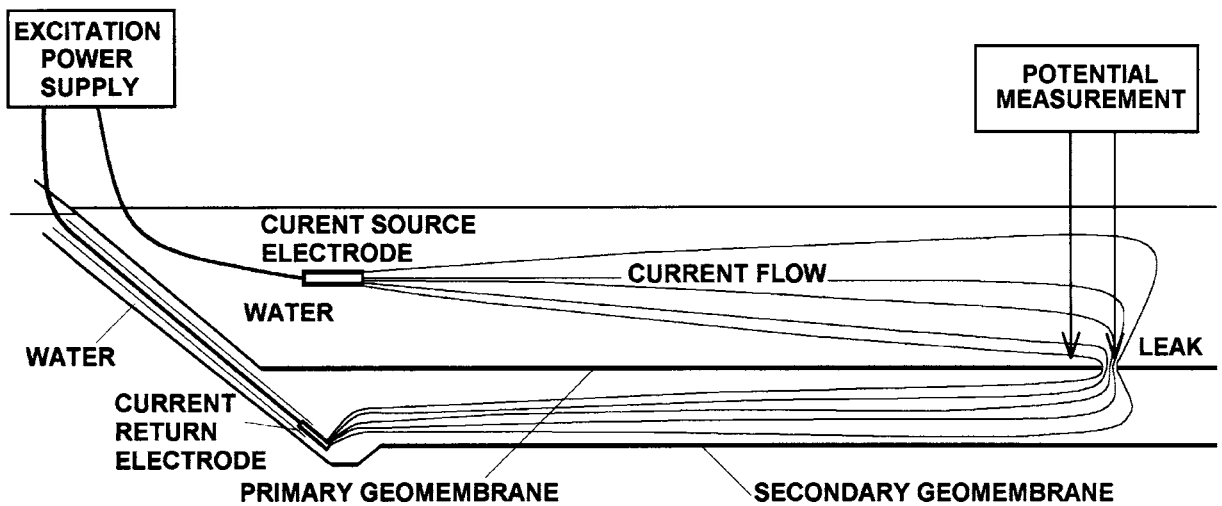



**FIG. 1 Diagram of the Electrical Leak Location Method for Surveys with Water Covering the Geomembrane**

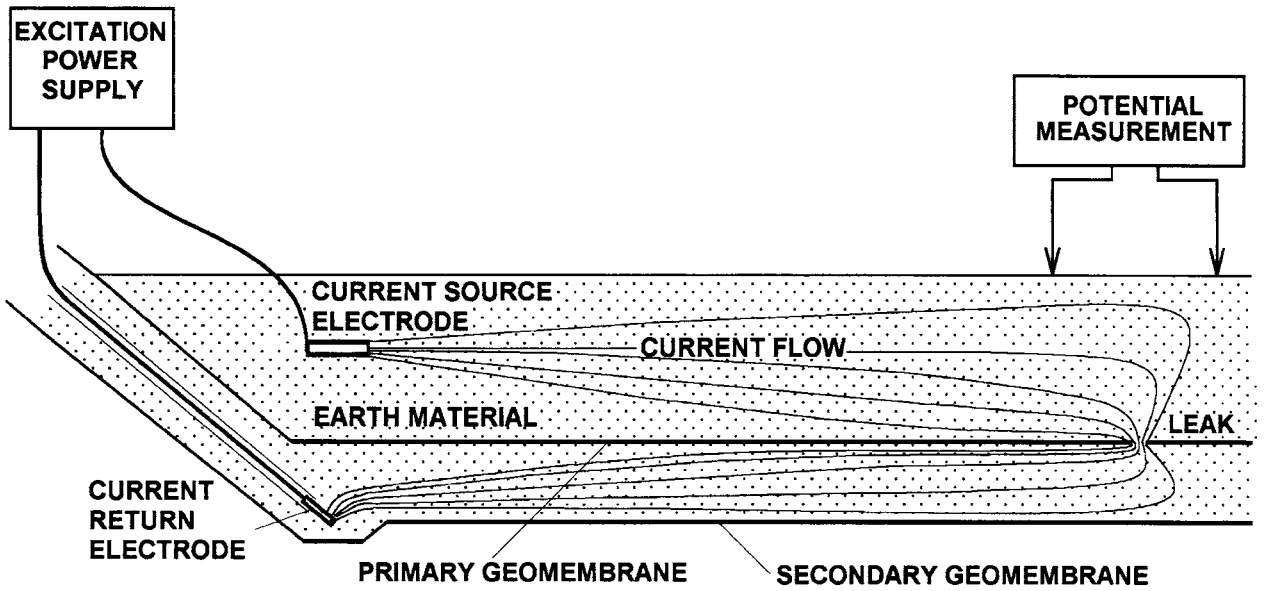



**FIG. 2 Diagram of the Electrical Leak Location Method for Surveys with Earth Material Covering the Geomembrane**

4.4 *Leak Location Surveys of Geomembranes Covered with Earth Materials*:

4.4.1 For leak location surveys with earth materials covering the geomembrane, point-by-point measurements are made on the earth material using either dipole measurements or pole measurements. Dipole measurements are typically made with a spacing of 0.5 to 5 metres. Measurements are typically made along parallel survey lines or on a grid pattern.

4.4.2 The survey procedures are conducted in a systematic data collection mode. The measurements and positions are recorded manually or using a digital data acquisition system.

4.4.3 The data is typically downloaded or manually entered into a computer and plotted. Sometimes data is taken along survey lines and plotted in raster. Sometimes data is taken in a grid pattern and plotted in two-dimensional contour, shade of gray, or color contour plots, or in three-dimensional representations of the contours. The data plots are examined for characteristic leak signals.

4.4.4 The approximate location of the leak signal is determined from the data plots and additional measurements are made on the earth material in the vicinity of the detected leak signal to more accurately determine the position of the leak.

4.4.5 The leak detection sensitivity depends on the conductivity of the materials within, above, and below the leak, the electrical homogeneity of the material above the leak, the design of the measurement electrodes, the output level of the excitation power supply, the sensitivity of the detector electronics, the distance away from the leak, the survey procedures, and data interpretation methods and expertise. Usually leaks as small as 5 mm in diameter can be located under 600 mm of earth material. Leaks larger than 25 mm in diameter can usually be detected from several metres away.

4.4.6 The survey rate depends primarily on the spacing between the measurement points, the type of data acquisition, and whether data interpretation is accomplished in the field. A close spacing between measurement points is needed to adequately replicate the leak signals and to detect smaller leaks.

## 5. Significance and Use

5.1 Geomembranes are used as impermeable barriers to prevent liquids from leaking from landfills, ponds, and other containments. The liquids may contain contaminants that if released can cause damage to the environment. Leaking liquids can erode the subgrade, causing further damage. Leakage can result in product loss or otherwise prevent the installation from performing its intended containment purpose. For these reasons, it is desirable that the geomembrane have as little leakage as practical.

5.2 Geomembrane leaks can be caused by poor quality of the subgrade, poor quality of the material placed on the geomembrane, accidents, poor workmanship, and carelessness.

5.3 The most significant causes of leaks in geomembranes that are covered with only water are related to construction activities including pumps and equipment placed on the geomembrane, accidental punctures, and punctures caused by traffic over rocks or debris on the geomembrane or in the subgrade.

5.4 The most significant cause of leaks in geomembranes covered with earth materials is construction damage caused by machinery that occurs while placing the earth material on the geomembrane. Such damage also can breach additional layers of the lining system such as geosynthetic clay liners.

5.5 Electrical leak location methods are an effective final quality assurance measure to locate previously undetected or missed leaks.

## 6. General Leak Location Survey Procedures

6.1 The following measures shall be taken to optimize the leak location survey:

6.1.1 Conductive paths such as metal pipe penetrations, pump grounds, and batten strips on concrete should be isolated or insulated from the water or earth material on the geomembrane whenever practical. These conductive paths conduct electricity and mask nearby leaks from detection.

6.1.2 In applications where a single geomembrane is covered with earth materials that overlap the edges of the geomembrane, if practical, measures should be taken to isolate the edges. If earth materials overlap the edges of the survey area to earth ground, electrical current will flow from the earth material to earth ground, causing a large signal that will mask small leak signals near the edges of the survey area. Isolation can be accomplished by either: performing the leak location survey before the edges of the geomembrane are covered; removing the earth materials from a narrow path around the perimeter of the geomembrane; or allowing the edge of the geomembrane to protrude above the earth materials.

6.1.3 There must be a conductive material directly below the electrically-insulative geomembrane being tested. Typically leak location surveys on a properly-prepared subgrade will have sufficient conductivity. Under proper conditions and preparations, geosynthetic clay liners (GCLs) can be adequate as conductive material. There are some conductive geotextiles or other conductive materials with successful field experience which can be installed beneath the geomembrane to facilitate electrical leak location survey (i.e. on dry subgrades, or as part of a planar drainage geocomposite).

6.1.4 For lining systems where an electrically-insulative geomembrane is overlain by a drainage geonet geocomposite, if the geocomposite is not saturated or is not manufactured to be conductive, only leaks that penetrate both geosynthetics can be detected; as a dry drainage geonet geocomposite is electrically-insulative.

6.1.5 For lining systems comprised of two geomembranes with only a geonet or only a geocomposite between them, the volume between the geomembranes shall be filled with water to provide the conductive material. The water level in the area between the geomembranes should be limited so that it exerts a pressure less than the pressure exerted by the water and any earth materials on the primary geomembrane. When the head pressure of the water under the geomembrane exceeds the downward pressure exerted by the weight of the water and any earth materials on the geomembrane, the primary geomembrane will begin to float. For surveys with only water on the geomembrane, the survey area will be limited to the area of the geomembrane that is covered with water. For surveys with earth materials on the geomembrane, the survey area can be calculated from the relative density of the earth materials, the thickness of the earth materials and the slope of the geomembrane. Additional area can be surveyed by placing water on the earth material on the primary geomembrane.

6.1.6 For surveys with earth materials on the geomembrane, the earth materials shall have adequate moisture to provide a continuous path for electrical current to flow through the leak. Earth materials usually have sufficient moisture at depth, but sometimes the surface of the earth materials becomes too dry. This dry material shall be scraped away at the measurement points, or the surface shall be wet with water. The earth materials do not have to be saturated with water. The amount of moisture required depends on the earth material, the equipment and procedures.

## 7. Leak Location Survey Procedures for Surveys with Water Covering the Geomembrane

7.1 The leak location survey shall be performed by scanning the leak location probe along the submerged geomembrane. The maximum distance between adjacent scans shall be determined by a leak detection sensitivity test using an artificial or actual leak. The advantages and disadvantages of using the artificial or actual leak are listed in Table 1. A leak detection sensitivity test shall be conducted on each geomembrane being tested for each set of equipment used before the set is used on that geomembrane. Periodic leak detection sensitivity tests are also specified tests are specified in 7.8.

7.2 *Artificial Leak Procedures*—Annex A1 contains the procedures for using an artificial leak to conduct a leak detection sensitivity test and determine the detection distance for surveys with water on the geomembrane.

7.3 *Actual Leak Procedures*—Annex A2 contains the procedures for using an actual leak to conduct a leak detection sensitivity test and determine the detection distance for surveys with water on the geomembrane.

7.4 *Leak Location Survey*—The leak location survey shall be conducted using procedures whereby the leak location probe passes within the detection distance of all locations on the geomembrane being surveyed for leaks. Because the probe

**TABLE 1 Comparison of Artificial Leaks versus Actual Leaks for Leak Detection Sensitivity Test with Water on the Geomembrane**

| Factor | Actual Leak | Artificial Leak |
|---|---|---|
| Repairs | Geomembrane must be repaired after test | No geomembrane repair |
| Mobility | Moving location requires making another hole in the geomembrane and subsequently repaired | Can be easily moved without needing geomembrane repair |
| Test adequacy of the conductivity of the material under the geomembrane | Yes, could be important for double geomembranes | No, but not critical for single geomembranes because water leaking through any leaks to the material under the geomembrane will provide sufficient conductivity |
| Signal measurement accuracy during leak detection sensitivity test | Less accurate because increase in signal due to leak must be determined by arbitrarily sweeping the probe near the leak | Accurate because measurements are made while switching the artificial leak on and off |
| Convenience | Must drill hole, sometimes under water, position is difficult to determine | Artificial leak is just placed in the water, can usually see the position |

detects leaks within the detection distance on both sides of the probe, the distance between leak detection sweeps can be no more than twice the detection distance. In addition to these procedures, any seams that can be visually located, or located by feel as the probe is scanned on the geomembrane, shall be surveyed for leaks by passing the probe directly along the seam or seam flap.

7.5 The leak detection sensitivity test shall be conducted at the farthest distance where the leak location survey will be performed from where the current source electrode is located.

7.6 The percent of full scale criteria used to define the system leak detection sensitivity as required in 7.3 and 7.4 and described in Annex A1 and Annex A2 shall not to be used as the leak detection criteria. Any definite, repeatable leak signal indication shall be considered to be a leak.

7.7 The locations of all leaks found shall be marked or measured relative to fixed points.

7.8 *Periodic Leak Detection Sensitivity Test*—The leak detection sensitivity test using the artificial or actual leak shall be conducted for each set of equipment, as a minimum, at the beginning and end of each day of survey. For this test, the current source electrode shall be no closer to the artificial or actual leak than the maximum distance used during the survey. The periodic leak detection sensitivity tests shall produce a leak detection distance larger than the leak detection distance used for the leak location survey. If any leak detection distance is smaller, then the area surveyed with that set of equipment in the period since the previous leak detection sensitivity test shall be repeated.

## 8. Leak Location Survey Procedures for Surveys with Earth Material Covering the Geomembrane

8.1 The leak location survey measurements shall be made on survey lines or on a survey grid. The maximum distance between adjacent survey lines or grid points shall be determined by a leak detection sensitivity test using an artificial or actual leak. The advantages and disadvantages of using the artificial leak and actual leak are listed in Table 2. A leak detection sensitivity test shall be conducted on each geomembrane being tested for each set of equipment used before the set is used on that geomembrane. Periodic leak detection sensitivity tests are also specified in 8.12

8.2 *Artificial Leak Procedures*—Annex A3 contains the procedures for using an artificial leak to conduct a leak detection sensitivity test and determine the detection distance for surveys with earth materials on the geomembrane.

8.3 *Actual Leak Procedures*—Annex A4 contains the procedures for using an actual leak to conduct a leak detection sensitivity test and determine the detection distance for surveys with earth materials on the geomembrane.

8.4 *Leak Location Survey*—The results of the leak detection sensitivity test shall determine the maximum measurement spacings for the leak location survey. The leak location data shall be taken on survey lines or on a grid spaced no farther apart than twice the leak detection distance determined in the leak detection sensitivity test.

8.5 For dipole measurements, the measurement electrode spacing shall be no more than that used for the leak detection sensitivity test.

8.6 The spacing between measurements along the survey line or longitudinally along the grid shall be no more than that used during the leak detection sensitivity test.

8.7 The leak detection sensitivity test shall be conducted at the farthest distance where the leak location survey will be performed from where the current source electrode is located.

8.8 **Warning**—Because of the high voltage that could be involved, and the shock or electrocution hazard, do not come in electrical contact with any leak unless the excitation power supply is turned off.

8.9 Data shall be recorded, plotted and analyzed for leak signals. The positions of these leak signals shall be located and the leaks excavated. The leaks shall be repaired or electrically isolated from the earth material on the geomembrane. The leak signals have a certain spatial distribution that can mask other nearby leaks, therefore, these additional measurements must be taken after the initial pinpointed leaks have been isolated or insulated. In some instances, such as when the leak is under water, it may not be practical to isolate the leak while the leak location crew is on site. In those cases, when the leak is repaired, the earth materials should be removed from an area

**TABLE 2 Comparison of Artficial Leaks versus Actual Leaks for Leak Detection Sensitivity Test with Earth Material on the Geomembrane**

| Factor | Actual Leak | Artificial Leak |
|---|---|---|
| Repairs | Geomembrane must be repaired after test. If a geotextile cushion is on the geomembrane, it also must be removed and repaired. | No geomembrane or geotextile cushion repair. |
| Mobility | Moving location requires another actual leak to be made and repaired. | Can be easily moved without needing geomembrane repair |
| Test adequacy of the conductivity of the material under the geomembrane | Yes | No |
| Signal measurement accuracy during leak detection sensitivity test | Less accurate because current from excitation power supply flowing through inhomogeneities produce noise, but noise test as detailed in Annex A4 must be conducted with the excitation power supply off. Likewise, any noise in the excitation power supply is not taken into consideration. | More accurate because current to the artificial leak can be switched off, allowing noise test detailed in Annex A3 to be conducted with excitation power supply on. |
| Convenience | Must drill hole and take measures to prevent damage to secondary geomembrane. | No drilling of hole or possible damage to secondary geomembrane. |

corresponding to the spatial distribution of the leak signal and the geomembrane should be visually inspected for leaks.

8.10 The leak location data shall then be re-collected for in an area extending five metres before and beyond and on both sides of the position of the original leak. If another leak signal is detected, this process shall be repeated until no additional leaks are detected.

8.11 The signal plus noise to noise ratio (*R* value) used to define the system leak detection sensitivity as required in 8.2 and 8.3 and described in Annex A3 and Annex A4 shall not to be used as the leak detection criteria. Any definite, repeatable characteristic leak signal indication shall be investigated to be a leak.

8.12 *Periodic Leak Detection Sensitivity Tests*—A partial leak detection sensitivity test using the artificial or actual leak shall be conducted for each set of equipment at the beginning and end of each day of survey as a minimum. Each set of equipment used shall be tested on a survey line that passes by the artificial or actual leak. The survey line must pass no closer from the artificial or actual leak than half of the survey line spacing or grid spacing used for the leak location survey. The current source electrode shall be no closer to the artificial or actual leak than the maximum distance used during the survey. The periodic leak detection sensitivity test shall produce a signal plus noise to noise ratio, *R*, greater than 3.0 as described in Annex A3 or Annex A4. If any signal plus noise to noise ratio is smaller, the area surveyed with that set of equipment in the period since the previous leak detection sensitivity test shall be repeated.

## 9. Reporting Requirements

9.1 The leak location survey report shall contain the following information:

9.1.1 Description of the survey site,
9.1.2 Climatic conditions,
9.1.3 Cover material description,
9.1.4 Type of geomembrane,
9.1.5 Liner system layering,
9.1.6 Description of the leak location method,
9.1.7 Survey methodology,
9.1.8 Description of the artificial or actual leak used,
9.1.9 Results of leak detection sensitivity tests,
9.1.10 Results of periodic leak detection sensitivity tests,
9.1.11 Specific parameters of survey including dipole spacing, spacing between measurements or scans, spacing between survey lines, and dipole orientation along survey lines as applicable,
9.1.12 Location of detected leaks,
9.1.13 Where visible, type and size of leaks, and
9.1.14 Map of the surveyed areas showing the approximate locations of the leaks.

9.2 If specified or requested by the client, ASCII files of the raw data for surveys with earth materials covering the geomembrane shall be provided on a compact disc labeled with the site name, cell name, survey dates, and name of the leak location company.

## 10. Keywords

10.1 construction quality assurance; electrical leak location method; geomembrane; leak detection; leak location

# ANNEXES

**(Mandatory Information)**

## A1. PROCEDURES FOR LEAK DETECTION SENSITIVITY TEST FOR SURVEYS WITH WATER COVERING THE GEOMEMBRANE USING AN ARTIFICIAL LEAK

A1.1 *Artificial Leak*—If an artificial leak is used, the artificial leak shall be constructed using an electrically insulating container. Fig. A1.1 shows the construction of the artificial leak that shall be used for the leak detection sensitivity test with water on the geomembrane. The container has a lid with a thickness greater than the geomembrane under test or a means for sealing a disk of geomembrane to the opening of the container. The disk is constructed of geomembrane with the same thickness as the geomembrane to be tested. Initially the lid or disk will have no hole. An insulated wire enters a sealed penetration into the container. The wire is terminated with a metal electrode. A weight should be used in the container so the filled container is not buoyant.

A1.2 **Warning**—Because of the high voltage that could be involved, and the shock or electrocution hazard, do not touch the artificial leak or the end of the artificial leak wire or electrode unless the excitation power supply is turned off. The switch or disconnect must be properly rated and insulated and it must not be operated by anyone that is in contact with the water. Do not drill a hole in the artificial leak unless the excitation power supply is turned off and disconnected.

A1.3 The other end of the insulated wire shall be connected through a suitable switch to a ground electrode or an electrode between the geomembranes in a double geomembrane installation.

A1.4 The artificial leak shall be filled with some water that is on the geomembrane being tested. The lid or lid with the geomembrane disk (with no hole) shall be sealed onto the container. The artificial leak shall be placed in the water on the geomembrane. If not visible, the artificial leak location shall be adequately marked or its position accurately referenced so its position is known. If a wading survey is to be performed, the artificial leak shall be more than three metres from the edge of the water.

A1.5 The artificial leak shall be turned on using the switch

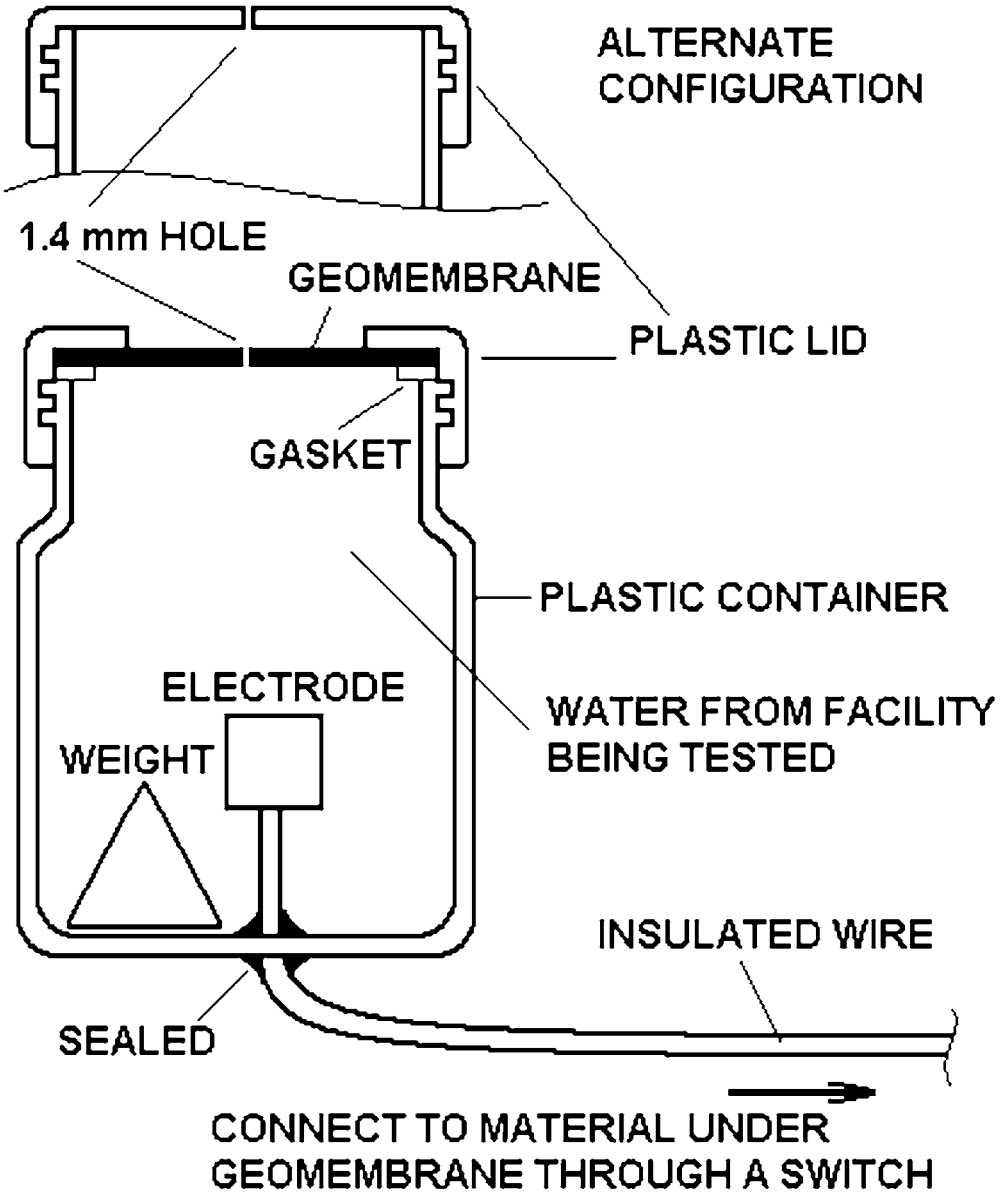



**FIG. A1.1 Artificial Leak for Surveys with Water Covering the Geomembrane**

or disconnect, the excitation power shall be turned on, and the leak location probe shall be swept within 50 mm of the lid and the sealed penetration. If a signal is detected, either the artificial leak is defective or it happens to be near an actual leak. The artificial leak shall be repaired or replaced, or moved and the test shall be repeated until no signal is measured.

A1.6 When no signal is detected, the excitation power shall be turned off and a circular hole with a diameter no greater than 1.4 mm (0.055 inch) shall be placed in the lid or disk without removing the lid or disk or disturbing the seal. (An alternative sized hole may be used if specified. Usually this larger size is specified to allow for adverse site conditions. Caution must be exercised to avoid specifying a too small hole size, which cannot be practically detected.)

A1.7 The artificial leak shall be placed back in the water on the geomembrane at the same position as before.

A1.8 *Leak Detection Sensitivity Test*—The excitation power supply shall be turned on and the leak location probe for each set of equipment shall be slowly moved towards the artificial leak as the artificial leak is connected and disconnected using the switch or disconnect. The excitation power supply shall remain on during this test. When the signal increases at least 10 percent of the full scale reading of the detection electronics as the switch or disconnect is turned on, the distance from the probe to the artificial leak shall be measured and recorded. This is the detection distance.

A1.9 If an audio tone is used as an indicator for the leak location survey, the meter on the detector electronics shall move no more than zero to full scale as the audio indicator changes from minimum to maximum indication.

## A2. PROCEDURES FOR LEAK DETECTION SENSITIVITY TEST FOR SURVEYS WITH WATER COVERING THE GEOMEMBRANE USING AN ACTUAL LEAK

A2.1 **Warning**—Because of the high voltage that could be involved, and the shock or electrocution hazard, do not attempt to drill the actual leak hole or touch the leak when the excitation power supply is turned on.

A2.2 The actual leak shall be constructed by drilling a hole with a diameter no greater than 1.4 mm (0.055 in.) in the installed geomembrane that is to be tested. For a double geomembrane system, measures shall be taken to ensure that the drill bit does not damage the secondary geomembrane. The hole shall be drilled, and the drill bit moved forward and backward in the hole so the geomembrane material is removed rather than displaced. The leak location shall be adequately marked or its position referenced so its position will be known when the actual leak is covered with water.

A2.3 *Leak Detection Sensitivity Test*—The excitation power supply shall be turned on and the leak location probe for each set of equipment shall be scanned in the vicinity of the leak. The scans shall be made in the manner that the actual leak location survey will be conducted. The probe shall be scanned at various distances from the leak to determine the distance where the signal increases at least 10 percent of the full scale reading of the detection electronics. This distance to the actual leak shall be measured and recorded. This is the detection distance.

A2.4 If an audio tone is used as an indicator for the leak location survey, the meter on the detector electronics shall move no more than zero to full scale as the audio indicator changes from minimum to maximum indication.

## A3. PROCEDURES FOR LEAK DETECTION SENSITIVITY TEST FOR SURVEYS WITH EARTH MATERIAL COVERING THE GEOMEMBRANE USING AN ARTIFICIAL LEAK

A3.1 *Artificial Leak*—If an artificial leak is used, the artificial leak shall be a circular metal surface on a flat, electrically insulating substrate. An insulated wire is connected to the metal surface. The artificial leak shall have no sharp edges that could damage the geomembrane. Fig. A3.1 shows the maximum dimensions and typical construction for the artificial leak for surveys with earth materials covering the geomembrane. The diameter of the metal surface shall be no greater than 6.4 mm (0.25 in.) unless a geometry or size or both are specified otherwise. This artificial leak size is intended for leak location surveys with up to 600 mm of earth materials on the geomembrane. If the thickness of the earth material is greater, or unfavorable site conditions exist, a larger artificial leak size should be specified. Caution must be exercised to avoid specifying a too small hole size that cannot be practically detected.)

A3.2 **Warning**—Because of the high voltage that could be involved, and the shock or electrocution hazard, do not touch the artificial leak or the end of the artificial leak wire or

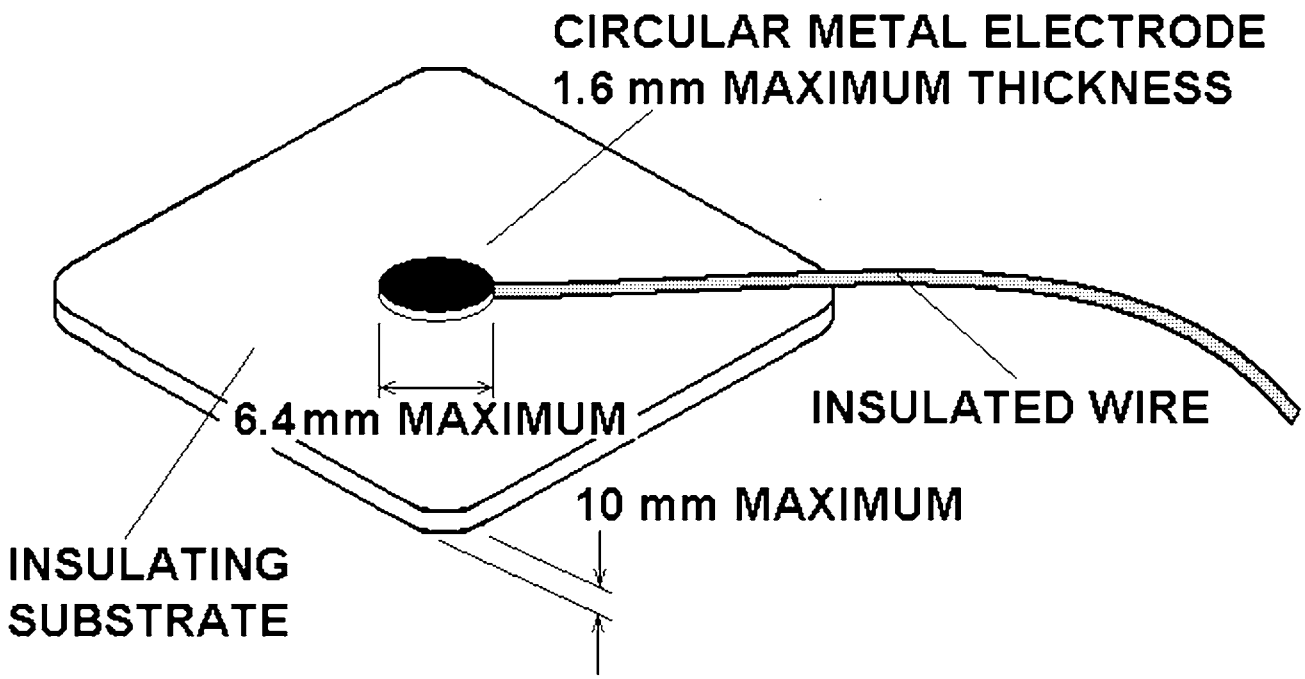



**FIG. A3.1 Artificial Leak for Surveys with Earth Materials Covering the Geomembrane**

electrode, or pour water on it when the excitation power supply is turned on. The switch or disconnect described below must be properly rated and insulated.

A3.3 The other end of the insulated wire shall be connected through a suitable switch or disconnect to a ground electrode or an electrode between the geomembranes in a double geomembrane installation.

A3.4 The artificial leak shall be buried to within 25 mm of the geomembrane. The artificial leak shall be at least 10 m from any edge of the survey area. The artificial leak shall be backfilled with at least 50 mm of earth material and then no more than 250 mL of water should be poured over the partially buried artificial leak. The excavation shall then be backfilled. The location of the artificial leak shall be clearly marked on the surface. The addition of water above the artificial leak is to simulate the natural conditions of real leaks, which typically have been exposed to moisture draining from the earth material and concentrating at the surface of the impermeable geomembrane.

A3.5 *Leak Detection Sensitivity Test*—Closely-spaced measurements shall be taken to determine the leak signal and background noise signal as follows:

A3.5.1 With the switch or disconnect in the artificial leak wire turned off, and the excitation power supply turned on, a line of data shall be taken and recorded over the artificial leak to measure and quantify the background noise level ($N$). Measurements shall be taken on a line that extends at least five metres in front of and in back of the artificial leak. The spacing of the measurements shall be the same as that planned for the leak location survey.

A3.5.2 The background noise level ($N$) shall be defined as the difference between the maximum and minimum measured potential with the artificial leak turned off and the excitation power supply turned on.

A3.5.3 With the switch in the artificial leak wire turned on, and the excitation power supply turned on, leak location measurements shall be made and recorded along closely-spaced parallel lines or on a grid centered on the artificial leak. The distance from each of the parallel lines or grid points to the surface projection of the artificial leak shall be measured. Fig. A3.2 shows the geometry of the measurements. The measurement layout is such that the artificial leak is at the farthest distance from the adjacent measurements. The lines shall be centered on the artificial leak and extend at least 5 metres in front and in back of the artificial leak.

A3.5.4 These signals are the artificial leak signal plus noise ($S + N$). The recorded leak location data shall be examined to determine the peak-to-peak leak signal plus noise to noise ratio $R = (S + N)/N$ for each of the recorded data lines. Fig. A3.3 shows an example of the measurements of $N$ and $S + N$. The

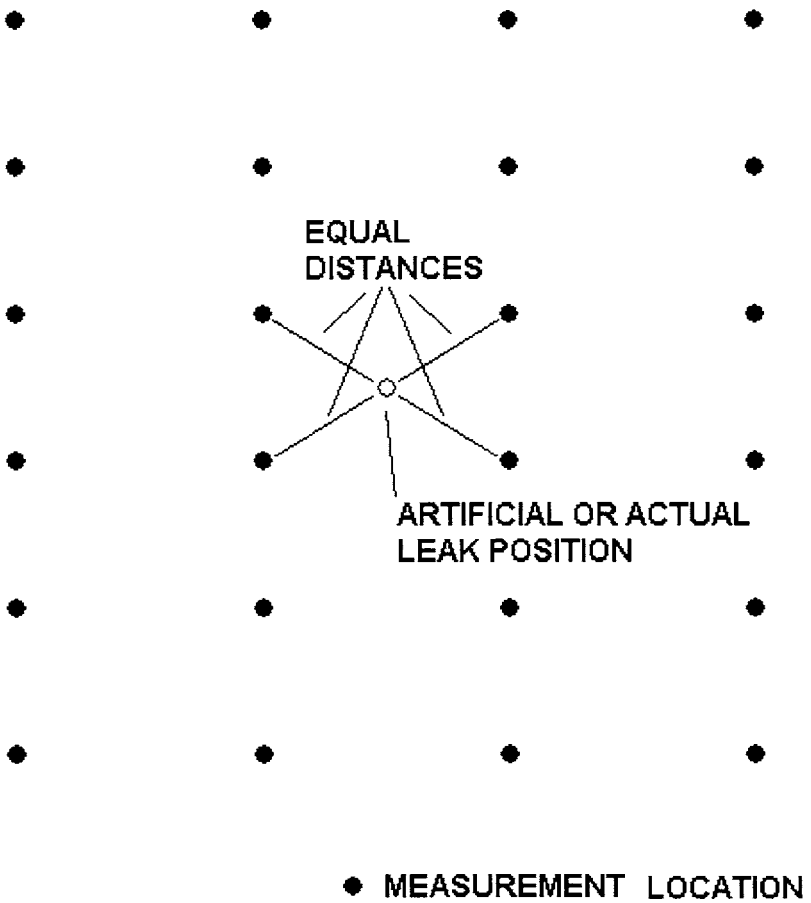
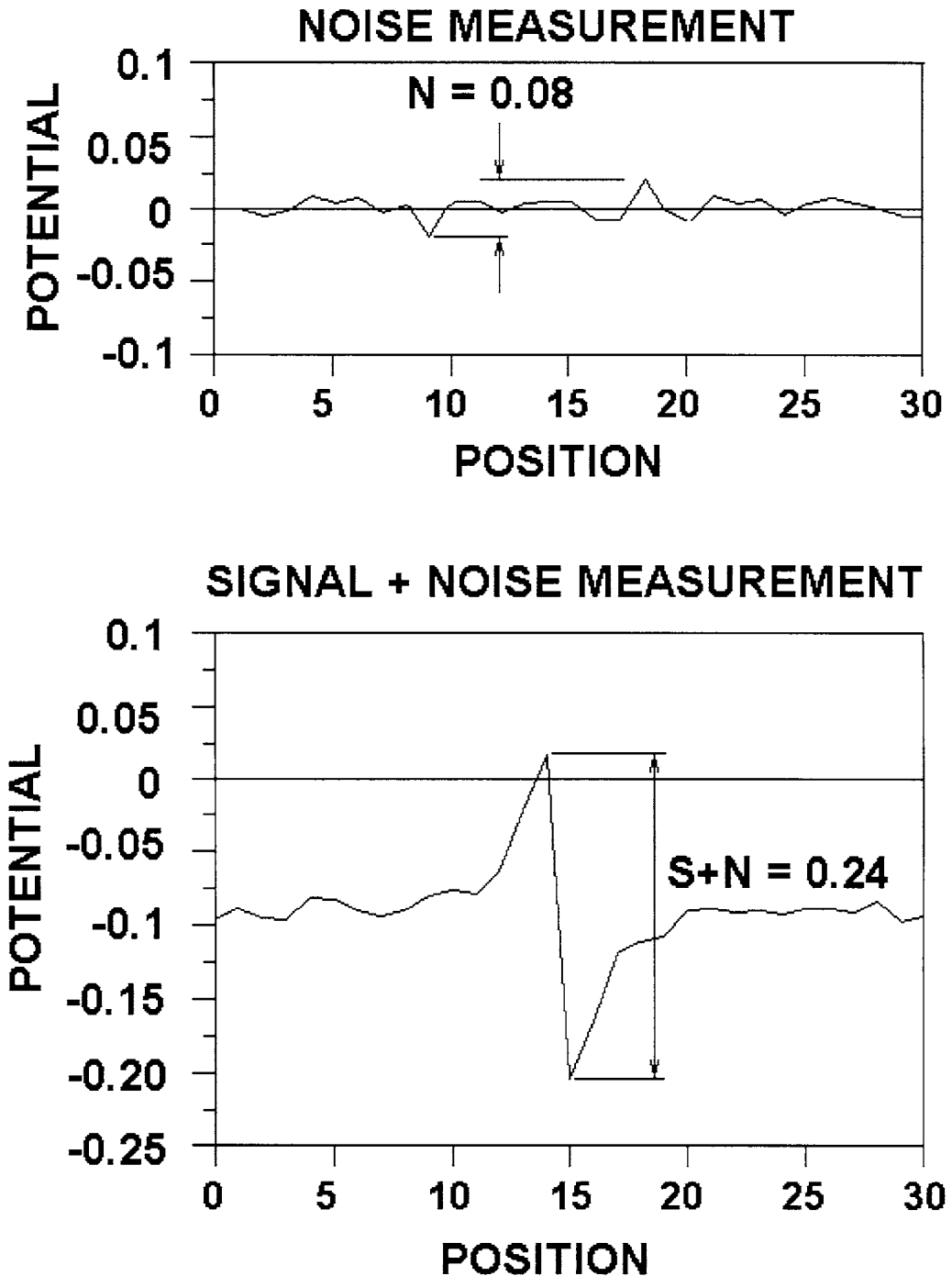



**FIG. A3.2 Geometry for Measurements With Artificial or Actual Leak for Surveys with Earth Materials Covering the Geomembrane**




$$(S+N) / N = 0.24 / 0.08 = 3.0$$

**FIG. A3.3 Example of Determining (*S* + *N*) / *N***

measured leak signals shall have the characteristics of a leak. Spurious, false, and unrepeatable data points that deviate from the theoretical leak signal shall not be used to determine *R*. The leak signal shall be represented by five or more data points in the data.

A3.5.5 The two farthest lateral lines or grid lines of data with an *R* value greater than 3.0 shall be noted and their distance to the surface projection of the artificial leak shall be recorded. The average of these distances is defined to be the leak detection distance.

A3.5.6 If site conditions prevent an *R* value greater than 3.0 from being obtained, the leak detection distance shall be defined to be 0.5 metres and the leak location survey shall be conducted with a uniform density of 1 measurement per square metre. These procedures can be followed provided the leak location equipment can be demonstrated to detect a shallower artificial leak from a lesser distance, and that the periodic leak detection sensitivity tests described in 8.12 are made at the lesser distance.

A3.5.7 The distance from the artificial leak to the current source electrode shall be measured and recorded.

## A4. PROCEDURES FOR LEAK DETECTION SENSITIVITY TEST FOR SURVEYS WITH EARTH MATERIAL COVERING THE GEOMEMBRANE USING AN ACTUAL LEAK

A4.1 **Warning**—Because of the high voltage that could be involved, and the shock or electrocution hazard, do not attempt to drill the actual leak hole, or touch the leak, or pour water on it when the excitation power supply is turned on.

A4.2 *Actual Leak*—If an actual leak is used, it shall be constructed by drilling a hole with a diameter no greater than 6.4 mm (0.25 in.) in the installed geomembrane that is to be tested. For a double geomembrane system, measures shall be taken to ensure that the drill bit does not damage the secondary geomembrane. The hole shall be drilled, and the drill bit moved forward and backward in the hole so the geomembrane material is removed rather than displaced. The leak shall be placed at least 10 m from any edge of the survey area.

A4.3 The leak shall be backfilled with no less than 50 mm of earth material and then no more than 250 mL of water should be poured over the partially buried actual leak. The excavation shall then be backfilled. The location of the actual leak shall be clearly marked on the surface. The addition of water above the artificial leak is to simulate the natural conditions of real leaks, which typically have been exposed to moisture draining from the earth material and concentrating at the surface of the impermeable geomembrane.

A4.4 *Leak Detection Sensitivity Test*—Closely-spaced measurements shall be taken to determine the leak signal and background noise signal as follows:

A4.4.1 With the excitation power supply turned off, a line of data shall be taken and recorded over the actual leak to measure and quantify the background noise level (*N*). Measurements shall be taken on a line that extends at least five metres in front of and in back of the actual leak. The spacing of the measurements shall be the same as that planned for the leak location survey.

A4.4.2 The background noise level (*N*) shall be defined as the difference between the maximum and minimum measured potential with the excitation power supply turned off.

A4.4.3 With the excitation power supply turned on, leak location measurements shall be made and recorded along closely-spaced parallel lines or on a grid centered on the actual leak. The distance from each of the parallel lines or grid points to the surface projection of the actual leak shall be measured. Fig. A3.2 shows the geometry of the measurements. The measurement layout is such that the actual leak is at the farthest distance from the adjacent measurements. The lines shall be centered on the actual leak and extend at least 5 metres in front and in back of the actual leak.

A4.4.4 These signals are the actual leak signal plus noise ($S + N$). The recorded leak location data shall be examined to determine the peak-to-peak leak signal plus noise to noise ratio $R = (S + N)/N$ for each of the recorded data lines. Fig. A3.3 shows an example of the measurements of $N$ and $S + N$. The measured leak signals shall have the characteristics of a leak. Spurious, false, and unrepeatable data points that deviate from the theoretical leak signal shall not be used to determine $R$. The leak signal shall be represented by five or more data points in the data.

A4.4.5 The two farthest lateral lines or grid lines of data with an *R* value greater than 3.0 shall be noted and their distance to the surface projection of the actual leak shall be recorded. The average of these distances is defined to be the leak detection distance.

A4.4.6 If site conditions prevent an *R* value greater than 3.0 from being obtained, the leak detection distance shall be defined to be 0.5 metres and the leak location survey shall be conducted with a uniform density of 1 measurement per square metre. These procedures can be followed provided the leak location equipment can be demonstrated to detect a shallower actual leak from a lesser distance, and that periodic leak detection sensitivity tests described in 8.12 are made at the lesser distance.

A4.4.7 The distance from the actual leak to the current source electrode shall be measured and recorded.

# APPENDIX F

# Groundwater Monitoring Well Specifications

# GROUNDWATER MONITORING WELL DECOMMISSIONING SPECIFICATIONS

## Objective

The objective of these well decommissioning procedures is to prevent contaminant migration through the decommissioned borehole. Decommissioned boreholes in both soil and rock must be fully sealed in a manner appropriate for the geologic conditions. Following this specification will result in the decommission of a monitoring well that complies with the NYCRR Title 6 Part 360 requirements.

## Procedure

The following procedures must be carried out during the decommissioning of each monitoring well:

1. The monitoring well identification and location must be confirmed by Lockwood Hills LLC or their designated representative;
    a. The identification of the well should be verified by measuring the total depth of the well and comparing it to the well construction diagram.
2. The surface seal must be broken up and removed.
3. The protective casing must be removed;
    a. Whenever possible the protective casing should be removed so that it can be reused.
4. The well riser shall remain in place;
    a. At a minimum, any riser in the upper five feet of the boring must be removed;
    b. Any riser left in place must be perforated.
5. The following standard grout mixture shall be used:

a. One 94-pound bag Type I Portland cement;

b. 3.9 pounds powdered bentonite; and,

c. 7.8 gallons potable water.

6. Boreholes in which well screen remains must be sealed by pressure injection with cement bentonite grout by Tremie pipe to the top of the screened interval;

    a. once the grout has been allowed to set-up (minimum four hours) the sealed screened interval must be pressure tested with a packer to ensure the seal is adequate before the rest of the borehole is grouted.

7. The grout must extend the entire length of the riser to within five feet below the ground surface or the proposed excavation level.

8. The upper five feet must be backfilled with appropriate native materials. These materials must be compacted to avoid settlement.

9. Every precaution must be taken during the work to avoid introducing contaminates into the existing well. Only potable water of known chemistry may be used for any purpose associated with such work.

10. All equipment placed in contact with the well must be properly decontaminated before use at the site. The initial cleaning must ensure that no contaminates from offsite will be introduced into the wells.

# GROUNDWATER MONITORING WELL DEVELOPMENT SPECIFICATIONS

## Objective

The main purpose of developing new monitoring wells is to remove the residual materials remaining in the wells after installation has been completed, and to try to re-establish the natural hydraulic flow conditions of the formations which may have been disturbed by well construction, around the immediate vicinity of each well.

## Procedure

The following procedures must be carried out during the development of the monitoring well:

1. A newly completed monitoring well should not be developed for at least 24 hours after the surface pad and outer protective casing are installed. This will allow sufficient time for the well materials to cure before development procedures are initiated.

2. Water from the new monitoring well should be pumped until the column of water in the well is free of visible sediment, and regularly taken measurements of pH, temperature, turbidity, and specific conductivity have stabilized.

    a. If the pH, temperature, and specific conductivity have stabilized but the water remains turbid.

    b. Continuous flushing over a period of several days may be necessary to complete the well development.

    c. If the well is pumped to dryness or near dryness, the water table should be allowed to sufficiently recover (to the static water level) before the next development period is initiated.

3. Caution should be taken when using high rate pumps and/or large volume air compressors during well development to prevent damage to the well screen and filter pack.

4. All field decisions should be documented in the field log form (attached).

5. The following development procedures, listed in approximate increasing order of the energy applied to the formation materials, may be used for well development as approved by the Engineer.

    a. Bailing/swabbing;

    b. Pumping/overpumping

    c. Surging;

6. Every precaution must be taken during the work to avoid introducing contaminates into the existing well. Only potable water of known chemistry may be used for any purpose associated with such work.

7. All equipment placed in contact with the well must be properly decontaminated before use at the site. The initial cleaning must ensure that no contaminates from offsite will be introduced into the wells.

# GROUNDWATER MONITORING WELL INSTALLATION

## Objective

The objective of these monitoring well construction procedures is to ensure the monitoring well will provide groundwater samples and hydraulic head level measurements that characterize discrete stratigraphic units of concern with the critical stratigraphic section and to prevent leakage of groundwater or contaminants along the well annulus. Following these specifications will result in a monitoring well that meets NYCRR Title 6 Part 360 requirements.

## Installation

The following procedures must be followed during the installation of monitoring wells or replacement of monitoring wells:

1. All equipment including the drill rig, augers, casing tools, etc. must be steam cleaned and decontaminated prior to use on the site and between well installations.

2. Every precaution must be taken during the drilling and installation of monitoring wells to avoid introducing contaminants into the borehole or well. For instance, tools, augers, casing, etc. are not to be placed on the ground but should be stored on a platform cover with clean plastic. All well materials must be steam cleaned prior to installation and should be stored in plastic until ready to use. Clean latex or nitrile gloves should be used whenever handling well materials.

3. If the use of water is necessary during well installation, only potable water will be used. A sample of this water will be collected for analysis, if necessary.

4. Drilling muds will not be used.

5. Drilling lubricants must consist of materials which will not introduce contaminants into the borehole or monitoring well.

6. The inside diameter of augers and casing must be at least two inches larger than the outside diameter of the monitoring well so that a Tremie can be properly used.

7. The sand pack and the bentonite seal must be Tremied into place as the augers or casing are pulled back. Measurements must be taken during the installation to ensure the accurate placement of the sand pack and bentonite seal.

8. After the installation of the bentonite seal, cement-bentonite grout or bentonite must be Tremied under pressure to seal the rest of the annual space to the surface seal. Auger flights or casing must be left in the hole before grouting to prevent caving.

## Construction

Figure 1A shows a typical monitoring well construction. The following outlines the current New York State Department of Environmental Conservation (NYSDEC) requirements:

1. Monitoring well screens and riser must be constructed of two inch inside diameter polyvinylchloride (PVC). Joints, caps, and end plugs must be secured by welds, threads and Teflon® tape or force fittings. Solvents and glues or other adhesives are not to be used in any part of the well construction. A permanent mark must be placed at the top of the riser pipe to provide a datum for water level measurements.

2. Well screens must be factory constructed, non-solvent welded or bonded, continuous slot, wire wrap screens. A 0.006-inch slot screen will be used.

3. The sand pack must consist of size 100 clean inert silica sand. The sand pack must be placed so that there is six inches below the bottom of the screen and that it extends two feet or 20 percent of the screen length (whichever is greater) above the top of the screen. A finer grained filter pack, or sacrificial sand pack (100 percent passing number 30 sieve and less than two percent passing the number 200 sieve), six inches thick must be placed at the top of the sand pack between the sand and the bentonite seal.

4. A bentonite seal, a minimum of three feet thick, must be placed above the sand packs. Sufficient time must be allowed for full hydration of the bentonite prior to grouting the

remainder of the annular space. The time for hydration varies with the type of bentonite and the type of material used for grout above the seal. At a minimum, the following time to hydrate in hours is recommended.

| **Bentonite Form** | **Cement Grout** | **Bentonite Grout** |
|---|---|---|
| Pellets | 2-4 hours | 0.5 hour |
| ¾-inch Chips | 4-8 hours | 1 hour |
| ¼-inch Chips | 2-4 hours | 0.5 hour |
| Slurry | 4-6 hours | 0.75-1.0 hour |

5. Once the bentonite seal has hydrated, the remainder of the annular space must be filled with cement-bentonite grout.

6. A protective steel casing, at least two inches larger in diameter than the well casing, must be placed over the well casing or riser pipe and secured in a surface well seal to adequately protect the well casing. A distinctive, readily visible marker must be permanently affixed to the protective casing or near the well to identify the well number and ensure visibility even in periods of high snow cover. A drain hole must be drilled at the base of the protective casing. A vent hole must be located near the top of the protective casing to prevent explosive gas build up and to allow water levels to respond naturally to barometric pressure changes. The annulus of the protective casing should be filled with gravel. A locking cap must be installed with one to two inches clearance between the top of the well cap and the bottom of the locking cap when in the locked position and a weather resistant padlock must be placed on the protective casing. Duplicate keys must be provided.

7. A concrete surface seal designed to last throughout the planned life of the monitoring well must be constructed. The surface seal must extend below the frost depth to prevent potential well damage. A sonotube or other pre-built form with a minimum of

three-foot sides will be used to install the surface seal. The seal must be designed to prevent surface runoff from ponding and entering the well casing.