CONSTRUCTION QUALITY ASSURANCE PLAN

Macon County MSW Landfill
Phase II - Cell 1
June 1997
Revised August 19, 1997

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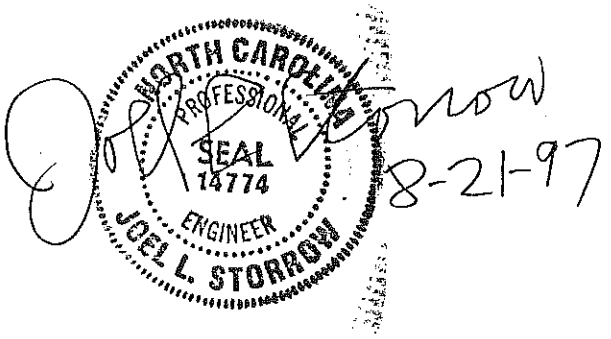

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Phase II - Cell 1

The Construction Quality Assurance Plan has been prepared as required under Rule .1917 and in accordance with Rule .1621.

1.0 INTRODUCTION

1.1 Project Background

The Macon County MSW Landfill Site has been utilized for disposal of Municipal Solid Wastes. The current project involves cell expansion over a 12.7 acre area, a portion of the total site that has been in operation for about seven (7) years. The cell expansion will consist of structural fill to achieve the desired gradients followed by a compacted, low-permeability clay liner layer, a 60-mil high density polyethylene (HDPE) geomembrane liner, and an aggregate drainage layer. The site is located in Macon County.

1.2 Project Scope

The purpose of this Site Specific Construction Quality Assurance Plan (SSCQAP) is to provide guidance to McGill Associates and sub-contractor personnel on required documentation activities during the construction of the engineered cell expansion. This guidance is intended to ensure that construction meets the requirements of Macon County and the Project Construction Quality Assurance (CQA) Plan and project drawings and specifications.

The overall goals of the SSCQAP are to ensure that proper construction techniques and procedures are used to verify that the materials and installation techniques used meet Project CQA Plan and project drawings and specifications. Additionally, the program will identify and define problems that may occur during construction and ensure that these problems are corrected before the construction is complete. At completion of work, the program will culminate in a certification report which documents that the clay and the geosynthetic liner have been constructed in substantial compliance with project CQA Plan and project drawings and specifications. The main emphasis of the SSCQAP is careful documentation during the preparation and placement of the clay and the geosynthetic liner.

1.2.1 Scope of Services

The Scope of Services provided by McGill Associates for the construction of engineered base is as follows:

1. Pre-Construction Materials Evaluation
2. Structural Fill Evaluation
3. Soil Barrier Construction Testing and Verification
4. Geosynthetics Liner Construction Testing and Verification
5. Report and Certification

1.2.2 Construction Schedule

Construction of stage 1 shall be completed within 90 consecutive calendar days and construction of stage 2 shall be completed within 365 consecutive calendar days.

Description
Preconstruction Meeting
Structural Fill Subgrade
Start of Geosynthetic Liner Installation
Completion of Liner/Drain/Cover Installation
Report/Certification Completion

2.0 Management Organization

2.1 Macon County

2.1.1 General Manager/Owner

Name:

Owner: Macon County

2.2 Design Engineer/Project Manager

Name: Joel L. Storrow, P.E.

Firm: McGill Associates, P.A.

2.3 General Contractor

Name:

Firm:

2.3.1 Surveyor

Name:

Firm:

2.4 Geosynthetic Contractor/Manufacturer

Name:

Firm:

2.5 Construction Quality Assurance Consulting Firm

2.5.1 Certifying Engineer

Name: Joel L. Storrow, P.E.

Firm: McGill Associates, P.A.

2.5.2 CQA Resident Engineer

Name:

Firm:

2.6 Laboratory Testing

2.6.1 On-Site Soils Laboratory

Name:

Firm:

2.6.2 Soil Laboratory (Permeability Testing)

Name:

Firm:

2.6.3 Geosynthetic Laboratory

Name:

Firm:

2.7 Project Work Plan

2.7.1 Preconstruction Meetings

Involves General Contractor, CQA Project Manager, Senior Lead Technician, Macon County Project Manager, subcontractors and Geosynthetic Installer.

Discuss any required modifications to the SSCQAP.

Review special permits and state and/or federal regulations.

Review responsibilities and roles of each party.

Review lines of authority and communication.

Review procedures for documentation and reporting information.

Review distribution and storage of documents and reports.

Establish protocol for testing and geosynthetic sample management.

Establish protocol for handling construction deficiencies.

Establish protocol for repairs and re-testing.

Conduct site walk through:

1. Discuss work plans
2. Inspect material handling and storage locations
3. Review office facilities (copy machine, mailing, etc.)

Review detailed time schedule for all operations.

Review work area security, check-in procedure, and safety protocol.

Discuss and establish procedures for material processing.

Review site health and safety requirements.

Meeting documented by McGill Associates, CQA Senior Lead Technician, or other authorized representative.

2.7.2 Roles and Responsibilities

The following is a listing of roles and responsibilities for each party involved in the cell construction process:

McGill Associates, P.A.	Providing CQA services from the completion of the subgrade through cap completion.
Surveyor	Subcontractor to General Contractor for on-site surveying for verification of final grades.
Laboratory	Soil and Geosynthetic Testing Laboratory
	General Contractor
	Geosynthetic Contractor/Manufacturer
Macon County	Owner and operator of Macon County MSW Landfill

2.8 Definitions

2.8.1 Construction Quality Assurance

A planned and systematic application of all means and actions designed to provide adequate confidence that items or services meet design and specifications requirements and will perform satisfactorily in service. In the context of the geosynthetic liner system, construction quality assurance refers to means and actions employed by the Resident Engineer, CQA Senior Lead Technician, and the CQA Monitors to ensure conformity of the liner system installation with guidelines set forth in the SSCQAP, plans, and specifications.

2.8.2 Construction Quality Control

Those actions which provide a means to measure and regulate the characteristics of an item or services to design, and specifications requirements. In the context of the geosynthetic liner system installation, quality control refers to those actions taken by the Geosynthetic Contractor/Manufacturer to ensure that the product and the workmanship meet the requirements of the plans and specifications.

2.8.3 Design Engineer

An individual or firm responsible for the design, drawings, plans, and specifications of the geosynthetic system.

2.84 General Contractor

The firm responsible for the construction of soil components of the landfill design, in conformance with plans and specifications.

2.8.5 Construction Quality Assurance Consultant

The firm responsible for observing, testing and documenting activities related to construction quality assurance during the installation of the clay and geosynthetic lining system. The CQA Resident Engineer is responsible for management of on-site CQA personnel and issuing a summary certification and documentation report bearing the seal of the Certifying Engineer.

3.0 DOCUMENTATION PROCEDURES

3.1 Standard Reporting Procedures

The CQA Technicians shall issue a daily report of construction activities. These reports shall include, as a minimum, the following information:

1. An identifying sheet number for cross-referencing and documentation control.
2. Date, project name, location and other identification.
3. Weather conditions.
4. Problems encountered and resolutions.
5. Descriptions and locations of ongoing construction.
6. Equipment and personnel in each work area, including subcontractors.
7. Descriptions and specific locations of areas, or units of work being tested and/or observed and documented (identified by coordinates or seam/panel numbers).
8. Locations where samples were taken.
9. A summary of test results, failures, and re-tests.

3.2 Monitors for the following operations for all Geosynthetics

a. material delivery
b. unloading and on-site storage and transport
c. sampling for conformance testing
d. deployment operations
e. joining/seaming operations
f. conditions of panel before and after placement
g. visual inspection of walkovers
h. repair locations

3.3 Monitors and Documents the Geomembrane Installation Operations

a. trial seams
b. seam preparation
c. seaming
d. nondestructive testing
e. sampling for destructive seam testing
f. repair operations
g. final walkovers

3.4 Applicable Forms

As a minimum, the CQA monitors will utilize the following forms for the project:

1. Daily Field Report Page 1
2. Daily Field Report Page 2
3. Weekly Progress Report
4. Letter of Transmittal
5. Telephone Memorandum
6. Speed Letter
7. Request for Information
8. Speed Memo/Notice of Condition
9. Contract Change Notice
10. Meeting Minutes Format
11. Nuclear Density Testing
12. Sand Cone Test Report
13. Drive Cylinder Test Report
14. Soil Testing Tracking Log

15. Soil Sample Test Request Record
16. Certificate of Acceptance of Soil Subgrade
17. Geomembrane Sample Test Request Record
18. Geonet Sample Test Request Record
19. Geosynthetic Sample Test Request Record
20. Geosynthetic Materials Inventory Checklist
21. Weather Log
22. Trial Weld Form
23. Panel Placement
24. Panel Seaming
25. Nondestructive Seam Testing
26. Destructive Sample Test Log
27. Geosynthetic Repair Log
28. Daily Field Report Geosynthetic Summary
29. Construction Site Safety Form
30. Construction Photo Log
31. Certificate of Completion

3.5 Problem/Deficiency Identification and Corrective Action Report

The CQA Monitor is required to inform the General Contractor and/or the Geosynthetic Contractor, or their representatives, in a timely manner, of any difference between the interpretation of the plans and specifications by the contractors versus the CQA Monitor interpretation. In addition, any actual or suspect work deficiencies shall be brought to the Owner's attention.

A special meeting shall be held when and if a problem or deficiency is present. At a minimum, the meeting shall be attended by the Geosynthetic Contractor, the General Contractor, the Owner, the CQA Resident Engineer, and the CQA Monitor. If the problem involves a possible design modification, the Design Engineer should be notified. The purpose of the meeting is to define and resolve the problem or work deficiency as follows:

1. Define and discuss the problem or deficiency
2. Review alternative solutions
3. Implement an action plan to resolve the problem or deficiency

The CQA Resident Engineer or his representative will document all proceedings.

The CQA Resident Engineer and the Design Engineer shall be authorized to stop work at the construction site.

3.6 Plan Modifications

Design and/or specification changes shall be made only with written approval of the Owner and the Design Engineer. Substantial design changes shall also require approval from the NCDEHNR, Solid Waste Division.

The CQA Engineer shall promptly complete a Plan Modification form whenever the Owner approves any changes made in the field that deviate from the design.

3.7 Scope Change

The CQA Resident Engineer shall complete a confirmation of Client's Request to Perform Services form whenever additional engineering services are requested by Owner that exceed the original scope of services.

3.8 Photographic Documentation

Photographs taken to document observations, problems, and/or deficiencies, or work in progress will include identification of the date, location, direction of view, and time period. Photographs will be filed in chronological order in a permanent protective file by the CQA team. One set of prints shall be turned over to the Owner at the conclusion of the project.

The permanent file will also contain a comprehensive index of each photo, which the CQA Monitor is responsible for preparing and maintaining. This index will include the following information:

1. Date of photograph
2. Provide a location and scale where photographed, including information regarding the orientation of the photograph itself for proper viewing
3. Subject description
4. Photo file number

The following is a list of minimum photographs to be taken during cell construction:

1. Subgrade/subbase proof rolling
2. Geosynthetic conformance sampling
3. Geomembrane deployment
4. Fusion welding devices
5. Extrusion welding devices
6. Air testing

7. Vacuum box testing
8. Seaming
9. Destructive sample location and removal
10. Trial welds
11. Tensiometer testing
12. Geotextile deployment
13. On-site lab soil testing
14. Progress photographs
15. Design modifications
16. Construction deficiencies
17. Completed construction

3.9 Final Construction Documentation Report

During placement of the drainage layer and stormwater control liner, the CQA Resident Engineer shall prepare a final certification-documentation report covering the installation and testing of the clay and geosynthetic lining system. This report shall certify that the clay and geosynthetic liner system has been constructed in substantial accordance with the plans. A Draft Copy of this report shall be issued to the Owner following completion of the lining system. The final report shall be issued to the Owner following completion of the drainage layer. For this project, two (2) copies of the draft version and five (5) copies of the final version of the report shall be issued.

3.9.1 Draft Table of Contents

As a minimum, the certification report will contain the following items for discussion in the narrative portion of the report. The proposed table of contents is:

Table of Contents

Section

1.0 Summary of Information

1.1 Narrative
1.2 Reference Information

2.0 Soil Preconstruction Data

2.1 Proctors
2.2 Soil Density/Moisture

2.3 Soil Classification

3.0 Clay Liner Field Data

3.1 Field Density Testing
3.2 Permeability Testing

4.0 Soil Laboratory Data

4.1 Construction Proctors
4.2 Soil Classification
4.3 Permeability

5.0 Geosynthetic Quality Control

5.1 Manufacturer's Q.C.
5.2 Installer Resumes
5.3 Material Conformance Testing

6.0 Geosynthetic Liner Field Data

6.1 Weather Log
6.2 Trial Welds
6.3 Panel Placement
6.4 Panel Seaming
6.5 Non-Destruct Test
6.6 Destruct Test
6.7 Repair Log
6.8 Installed Quantities

7.0 Protective/Drainage Layer Data

8.0 Project Meeting Minutes

9.0 Construction Photographs

10.0 Pertinent Information

11.0 Record Drawings

3.9.2 Draft List of Drawings

As a minimum, the certification will include in an appendix the following proposed list of drawings:

List of Drawings

Drawing

Title and Index
Site Plan
Top of Subgrade
Top of Clay Liner
Primary HDPE Panel Layout
Top of Drainage Layer
Geomembrane Details

3.10 Site Surveying Requirements

The CQA Resident Engineer shall coordinate all survey activities with the surveyor, Survey services will be required for initial site layout, final grade verification, and primary geomembrane as-built survey. All grade surveying shall be conducted on a 50-foot grid. The geomembrane survey will be as directed by the CQA Resident Engineer and shall include the following items:

- panel placement and seaming locations
- location of destruct samples
- location of all significant repairs

4.0 LANDFILL CONSTRUCTION-EARTHWORK

4.1 Subgrade Preparation

Subgrade preparation shall be performed by the General Contractor. See Appendix A.

4.2 Structural Fill Placement

Structural fill shall be the soil placed to achieve the design subgrade contours. The subgrade will be tested for field density and field moisture content at a minimum frequency of one (1) test per 1,000 cubic yards placed. Testing will also consist of visual observation and documentation of proofrolling with loaded rubber-tired earthmoving equipment. If a nuclear gauge is used as the primary means of construction testing, the instrument shall be calibrated properly and test data shall be verified using alternate test methods such as drive cylinders. An alternate test method shall be used at least once for every hundred tests performed with the nuclear gauge. The

alternate test method should be performed in the same area as an instrument reading in order to allow accurate comparison of the data resulting from the two tests.

4.3 Clay Liner Material

The clay liner shall consist of low-permeability soils placed on the subgrade.

Table 1 - QA Testing Frequencies and Criteria for Clay Liner Layer

Preconstruction Qualification		
Test	**ASTM Method**	**Quantity**
Moisture Content	D2216	1/1,000 YD^3
Grain Size	D422 or D1140	1/5,000 YD^3
Atterberg Limits	D4318	1/5,000 YD^3
Laboratory Compaction	D698 - Standard	1/5,000 YD^3
Permeability	D5084	1/10,000 YD^3
*** Preconstruction test samples shall be taken from the borrow source and or clay stockpiled prior to construction.**		
Construction Testing		
Test	**ASTM Method**	**Quantity**
Field Density	D2922, D1556, D2167	1/10,000 FT^2/Lift
Field Moisture	D2216, D3017, D4643	1/10,000 FT^2/Lift
Permeability	D5084	1/40,000 FT^2/Lift
Atterberg Limits	D4318	1/5,000 YD^3
Grain Size	D422 or D1140	1/5,000 YD^3
Testing Criteria		
Classification	CL or CH	
Maximum Particle Size		3-inch diameter (lower 18 inches) 1/4-inch diameter (top 6 inches)

I f a nuclear gauge is used as the primary method for construction testing of the clay liner, the test data shall be verified by alternate test methods at least once for every 25 tests performed.

Any modifications made to these testing frequencies will require prior approval from the Division of Solid Waste.

Clay liner material generally consists of cohesive soils with low hydraulic conductivity used as barriers in lining systems. Soils used in clay liners shall consist of clean, select material free of debris, excessive coarse particles or other deleterious matter. Soils with a visibly identifiable organic content, or soils classified according to the Unified Soil Classification System as organic silt or organic clay (OL, OH) shall not be used.

4.4 Clay Liners

Prior to the construction of a clay liner, soil evaluation tests shall be performed to confirm the adequacy of clay liner materials procured from each on-site or off-site source area. All tests shall be performed in a geotechnical laboratory, which may be the Soil QAL or another laboratory approved by the Project Manager. The Earthwork Contractor shall submit the results of source evaluation tests to the Project Manager. Previous testing and evaluations of the soil sources may also be used to evaluate the soil material. The material shall be accepted or rejected by the Project Manager according to these results. The acceptance and rejection criteria for the clay liner material will be verified by the construction of two (2) test pads. One (1) test pad will be constructed for the cell floor and one (1) will be constructed for the slope. Refer to section 4.4.3 for additional test pad requirements.

4.4.1 Quality Control Acceptance Criteria

The following tests and/or information shall be conducted and provided prior to acceptance of clay liner material:

1. Moisture content (ASTM D2216)
2. Particle size distribution analysis (ASTM D1140, D422)
3. Atterberg limits (ASTM D4318)
4. Laboratory compaction (ASTM D1557 for Modified or ASTM D698 for Standard)
5. Triaxial cell laboratory permeability (ASTM D5084)
6. Percent bentonite admixed with soil
7. Moisture-density-permeability relation

* Refer to Section 4.3, Table 1 for testing frequencies.
* Acceptance of the clay liner will be based on the material's ability to achieve a permeability not greater than 1.0×10^{-7} cm/sec.

The project engineer shall approve the materials prior to construction and verify that testing was performed according to Division approved plans and specifications.

If identification of additional clay liner material sources becomes necessary during construction, the same material qualification and testing procedures shall be applied to each new source.

Additional testing may be required by the project specifications. Project specifications may modify testing frequencies if the clay liner material has been previously evaluated or used.

4.4.2 Quality Assurance Testing

Each lift of the compacted clay liner shall be tested for moisture content, density, and permeability. Permeability tests shall be performed at a confining pressure of 15 psi +/- 1 psi and with a gradient in accordance with ASTM method D5084. Samples taken from each location shall be compared to the approved moisture-density-permeability relation. Test frequencies for construction testing are given in Table 1 of section 4.3. The project engineer shall certify that the clay liner was constructed using the same methods and acceptance criteria consistent with test pad construction and tested according to the Division approved plans. Index tests will be performed during construction at a frequency of one (1) test/5,000 YD^3. The index tests will consist of an Atterberg Limits test and Grain Size test performed from the same bulk sample taken from the field.

4.4.3 Test Pad Construction

Test pads 20 ft x 50 ft in area shall be constructed prior to beginning installation of the compacted clay liner and whenever there is a significant change in soil material properties or the borrow source is changed. The equipment used, liner thickness, subgrade slope, and all other conditions shall be representative of full scale construction. Acceptance and rejection criteria shall be verified for the tests specified in Sections 4.4.1 and 4.4.2. For each lift, a minimum of three (3) test locations shall be established for testing moisture content and density. At least one shelby tube sample for lab permeability testing, one (1) composite sample for remolded permeability, one (1) Atterberg Limits test, and one (1) grain size test shall be obtained per lift. One test pad shall be constructed for the side slope clay liner and one for the cell bottom. Compaction and soil moisture content shall be in accordance with Table 1 and the previously approved moisture-density-permeability relationship established from preconstruction testing. Field moisture and density tests and laboratory permeability tests will be performed by the CQA Engineer for each lift placed on the test pads to verify the construction method, equipment, and material achieve a permeability not greater than 1.0×10^{-7} cm/sec for the clay liner. If the contractor chooses to construct the test pads within the cell, all lifts of the test pads must pass to enable them to remain as part of the clay liner. The Contractor shall allow sufficient time for construction and testing of the test pad prior to placement of the Compacted Clay Liner.

4.4.4 Clay Liner Placement

Construction methods, sampling and testing will be recommended by the Engineer. Typical tests to be included will be moisture content, in-place density, Atterberg limits, grain size and permeability testing.

Prior to fill placement, the prepared subgrade shall be proofrolled with a loaded dump truck (minimum 20 tons) or similar rubber tired pneumatic vehicle by a minimum of two passes in each direction. Proofrolling shall be conducted at the discretion of the Engineer or his representative. Any soft, saturated or yielding areas exhibited by pumping and/or rutting will require removal and replacement with the appropriate soil at no additional cost to the Owner.

Clay liner fill lift thickness, after compaction, shall be a maximum of six (6) inches. Thinner lifts are permissible to achieve design grade.

Equipment or truck traffic shall not be permitted during the period between scarifying and compaction or a lift unless approved by the Engineer.

After the lift to be compacted is conditioned, representative samples will be taken by the Engineer and tested for moisture content prior to any compactive efforts. If the moisture content is within the range specified by the moisture-density-permeability relation, compaction may begin. If the moisture content is outside of this range, the clay liner fill will be wetted or dried and reworked accordingly. The clay liner fill should be sprinkled or sprayed with water utilizing equipment creating a uniform application and dozed, wind-rowed, and/or disc-plowed to uniformly increase the moisture content of the clay liner if the material moisture content is too low. The clay liner fill shall be dozed, wind-rowed, and/or disc-plowed to help air dry the soil if the moisture content is too high.

Each lift shall be thoroughly compacted and satisfy moisture and density controls through field testing before a subsequent lift is placed.

Compaction of lifts shall be as follows:

1) Compaction of lifts shall be performed with an appropriately heavy, properly ballasted, sheepsfoot compactor. The deep penetrating feet shall have a minimum length of 7 inches with a pedestal diameter greater than the foot shaft and shall be subject to approval of the Engineer. A minimum of four passes will be required on each lift regardless of whether the lift meets density specifications. A pass is defined as one trip of the compacting equipment over the lift and back to the starting point by a single drum roller or one trip across the lift surface from one side to the other if the compacting equipment has front and back compacting rollers. This requirement is to allow thorough remolding of the soil by kneading action.

2) The daily work area shall extend a distance so as to maintain moist soil conditions (facilitate bonding) and continuous operations. Desiccation and crusting of the lift surface shall be avoided as much as possible. Each lift shall be protected, at all times after placement, from desiccation and crusting.

3) If desiccation cracks wider than 1/16 of an inch in width form on the lift surface or the moisture content of the lift surface is substantially reduced from optimum and appears

dry before placement of the next lift, this area shall be scarified to a sufficient depth to mix with moist materials, or sprinkled with water and then scarified at the direction of the Engineer.

4) The transition between the bottom and side slopes shall be accomplished by compacting parallel (bottom to top) to the slope.

5) Dozer equipment shall not be used for primary compaction efforts.

6) The surface of the underlying lift shall be scarified a minimum of 2 inches prior to compaction of each subsequent lift (i.e., Lift 2 to Lift 3) to facilitate bonding of the lifts.

During compaction of the clay liner material, the soil moisture content and dry density shall be maintained within the limits specified below.

1) To determine the moisture content and dry density requirements of the compacted soil are being satisfied, field and laboratory tests shall be made at intervals and locations designated by the Engineer. Refer to Section 4.3, Table 1 for construction testing frequencies.

2) Compaction moisture content shall be between 2 and 5 percent wet of OMC on the side slopes.

3) The clay liner shall be compacted to a minimum dry density of 95 percent of the maximum dry density determined from the Standard Proctor Test (ASTM D-698). Where densities less than 95 percent of the maximum dry density determined from the Standard Proctor Test are measured, the clay liner shall be recompacted and/or removed and reworked to meet density objectives. In addition, the dry density/moisture content coordinate shall lie above the 95 percent saturation line, which will be established by laboratory specific gravity tests.

The clay liner shall, in addition to the other provisions of this section, achieve a permeability not greater than 1.0 x 10-7 cm/sec on thin wall tube samples taken from the completed clay liner. If representative permeability tests do not achieve the required permeability, the cell bottom clay liner shall be reworked to meet permeability requirements regardless of its previously achieved density.

Clay liner fill shall not be placed or compacted during sustained periods with air temperature below 32°F. Clay liner fill may be placed and compacted during periods of early morning and early evening freezing temperatures with warming trends above 45°F during the day. No fill shall be placed on frozen subgrade. If the clay liner or structural fill freezes or ices the fill section shall be rescarified and recompacted, at the discretion of the Engineer.

During construction, finished lifts or sections of compacted clay liner shall be sprinkled with water twice a day if needed.

At the end of each construction day's activities, completed lifts or sections of compacted clay liner shall be sealed by rolling with a rubber tired or smooth drum rollers and sprinkled with water as needed.

The compacted clay liner shall be a minimum of twenty-four (24) inches thick in the secure cell. Thickness of the compacted clay liner on the side slopes shall be measured perpendicular to the slope face.

The as-built thickness of the compacted clay liner shall be primarily determined by survey methods (non-destructive) or periodically by destructive sampling as described below. An individual lift may be sampled upon completion (but prior to subsequent lift placement) with an approved sampler or other investigative tool. The resulting penetration shall be promptly backfilled by the Contractor with hand tamped soil and bentonite fill. Samples of the in place compacted clay liner shall be tested and evaluated in accordance with provisions of the Construction Quality Assurance Plan. All test locations shall be filled with a mixture of one part bentonite and three parts soil.

After completion of a segment of compacted clay liner, but before installation of the geomembrane liner, the surface of the clay liner shall be surveyed by the Contractor to ensure the specified thickness of Compacted Clay Liner (24 inches) has been achieved.

The surface of the Compacted Clay liner shall be smooth drum rolled and maintained free of rocks, organics, voids and sharp edges.

No vehicles other than a smooth-drum roller will be allowed on the clay liner once the clay liner has been approved. This includes equipment used to deploy geomembrane material. Any exceptions should have prior approval from the project engineer.

4.4.5 Clay liner Acceptance

Upon written recommendation by the Soil CQA Monitors, the Project Manager shall consider accepting the soil components of the lining system. The Earthwork Contractor will retain all ownership and responsibility for the soil lining components until acceptance by the Project Manager. At the Project Manager's discretion, the lining system may be accepted in sections or at points of substantial completion.

The soil components of the lining system will be accepted by the Project Manager when:

1. The installation of the soil components is finished.

2. Verification of the adequacy of the constructed components, including repairs, if any, is completed in accordance with the project-specific QA.

3. All documentation of installation is completed.

4. The depth and grade of the clay liner has been verified by a licensed surveyor and has been approved by the project engineer.

5. The appropriate frequency of permeability tests have been performed and the results have been approved by the CQA Engineer.

6. The Soil QA monitors are able to recommend acceptance.

The Soil QA Monitors shall certify that installation of the soil components has proceeded in accordance with the soil portions of the project-specific QAP except as noted to the Project Manager.

4.5 Permeability Testing

Permeability testing shall be performed on bulk and undisturbed samples. The samples shall be shipped to an approved lab for appropriate testing. Permeability tests shall be performed using ASTM Test method D5084. The tests will be performed at a confining pressure of 15 psi +/- 1psi and with a gradient in accordance with test method D5084.

4.6 Granular Drainage and Protective Layer

4.6.1 Materials and Construction

The drainage layer shall consist of an aggregate material with a maximum nominal diameter of 5/8". The chemical properties of the aggregate material shall not be adversely affected by waste placement or leachate generated by the landfill. The aggregate material shall contain less than one (1) % Calcium Carbonate by weight. The aggregate shall have a minimum permeability of 1.0×10^{-2} cm/sec which allows lateral drainage through the drainage layer and along the surface of the base liner. The aggregate material shall not have more than five (5) % by weight passing the no. 200 sieve.

The friction angle between the geotextile and the drainage layer shall be a minimum of 24 degrees. This friction angle shall be verified by Direct Shear Box testing prior to construction. The tests shall be performed using representative bulk samples of the proposed construction materials.

The drainage layer shall be placed with a minimum compacted thickness of 24 inches. Equipment used during placement of the drainage layer shall not be allowed to operate directly on the geomembrane. Equipment will not be allowed on any portion of the geomembrane without the protective geotextile

and a minimum of 18 inches of drainage layer material in place. Drainage layer material shall not be pushed along the surface of the geomembrane under any circumstances. Pushing of the drainage layer material will only be allowed on areas where the material has a depth greater than 24 inches, and the required 24-inch depth shall be maintained at all times.

QA Testing Frequencies and Criteria for Granular Drainage Layer

Preconstruction Qualification		
Test	**ASTM Method**	**Quantity**
Moisture Content	D2216	1 per source***
Grain Size	D422 or D1140	1 per source***
Classification		1 per source
Calcium Carbonate	D4373	1 per source
Permeability	D2434	1 per source
*** The minimum angle of friction between the geotextile cushion and the drainage layer material shall be twenty-four (24) degrees.**		
***In addition to quarry certificate		
Construction Testing		
Test	**ASTM Method**	**Quantity**
Grain Size	D422	1/1,500 YD^3
Permeability	D2434	1/4,500 YD^3
Testing Criteria		
Classification	SW, SP, GW, or GP (on base only) GW or GP	
Permeability	1×10^{-2} cm/sec or greater	
Grain Size	Drainage Layer	
	<5% passing #200 sieve Max. 2" diameter with 16 oz/yd geotextile installed Max. 3/8" diameter without geotextile.	
Calcium Carbonate	< 1% by weight	

4.6.2 Placement

Placement of the granular drainage layer shall be performed by a light tracked dozer or light dump truck not in direct contact with the geomembrane. A minimum depth of 2 feet of drainage layer material must be maintained at all times during placement activities when vehicles other than the light tracked dozer are needed. High traffic areas, such as access roads constructed to transport material into the landfill, should have a minimum depth of three (3) feet. This depth may be changed by written approval from Owner or an engineered design approved by the Design Engineer.

The drainage layer shall be placed in the coolest part of the day when possible in order to reduce the potential for wrinkles forming in the geomembrane. See Sections 1.4.2 and 1.1.5 of Appendix C for information on evaluating and repairing wrinkles in the geomembrane.

McGill Associates will observe placement activities. The General Contractor is to provide laborers ahead of drainage material placement to assist in minimizing wrinkle formation of the geomembrane. Temperature variations may impact the Contractor's ability to place this material.

4.6.3 Depth Verification

CQA Monitor(s) will randomly verify granular drainage layer depth utilizing test pits or survey means. A Licensed Surveyor will survey the top of the drainage layer to certify proper depth was achieved. The General Contractor may use depth markers (i.e., painted tubes, flags, traffic cones, etc.) during placement to provide depth control and minimize possible damage to geomembrane. Depth markers shall be removed as the and layer is completed.

5.0 LANDFILL CONSTRUCTION-GEOMEMBRANE

5.1 Geosynthetic Liner

Upon written recommendation of the Geosynthetic QA Testing, the Project Manager shall consider accepting the geosynthetic components of the lining system. The Installer will retain all ownership and responsibility for the geosynthetics in the lining system until acceptance by the Project Manager. At the Project Manager's discretion, the lining system may be accepted in sections or at points of substantial completion.

The geosynthetic components of the lining system will be accepted by the Project Manager when:

1. The installation of the geosynthetic components is finished.

2. Verification of the adequacy of all seams including associated testing and repairs, if any, is completed in accordance with the project-specific QAP.

3. All documentation of installation is completed.

4. The Geosynthetic CQA Monitor(s) are able to recommend acceptance.

All installation procedures, techniques, testing frequencies will be in compliance with all acceptable practices for geosynthetic liner Installation of Lining Systems. Writing on the liner shall be strictly limited to documentation purposes only. Ambient temperature readings shall be taken on the liner out of direct sunlight and a height of 4 feet above the surface of the liner.

5.2 Geomembrane Quality Control

The Geosynthetic Contractor/Manufacturer will provide geosynthetic quality control in accordance with Appendix B.

5.3 Geomembrane Quality Assurance

5.3.1 Conformance Sampling

Conformance testing will be done on-site as material arrives and is inventoried. Conformance sampling procedures will be in accordance with Appendix B.

5.4 Geomembrane Seaming

Field seaming will be done in accordance with Appendix C.

5.4.1 Fusion Welding

5.4.1.1 Double Tracked Fusion Welding

Majority of seaming to be performed shall utilize the double tracked fusion welding process. Detailing and toe seams do not require double tracked fusion welding.

5.4.1.2 Single Fusion Welding

A single fusion welding device may be utilized in the areas of multiple seam intersections. The resulting seam shall have the flap removed and the seam vacuum boxed.

5.4.2 Extrusion Welding

Extrusion welding should only be used when double-tracked fusion welding is not possible. The extrusion process will be utilized for repair or detail work, attaching temporary rain flaps, capping a failed seam, or completion of other appurtenances which cannot be performed with fusion welding.

5.6 Geomembrane/Seam Repairs

All repairs to the geomembrane or seams shall be done utilizing the extrusion welding process. All repair work shall be conducted in accordance with Appendix C.

5.7 Geotextile Quality Control

The Geosynthetic Contractor/Manufacturer shall provide quality control information in accordance with Appendix D.

5.8 Geotextile Quality Assurance

5.8.1 Conformance Testing

Conformance sampling will be performed on-site as material arrives and is inventoried. All conformance sampling will be in accordance with Appendix D.

6.0 Leachate Collection Piping

Materials

Pipe for the LCR System shall be High Density Polyethylene (HDPE) pipe.

1. HDPE piping shall have nominal diameters as noted on the Contract Drawing.

2. HDPE piping shall have a maximum Standard Dimension Ratio (SDR) of 17 or as specified on the Contract Drawings.

3. The HDPE pipe shall be manufactured from first quality virgin polyethylene with the following nominal properties.

Density	0.95 gm/cm^3
Melt Flow (Cond. °F)	1.5 gms/10 min.
Environmental Stress	5000 hours
Ultimate Tensile Strength	5000 psi
Tensile Strength @ Yield	3500 psi
Modulus of Elasticity	110,000 psi

The HDPE pipe section to be perforated shall be as follows or approved by the Engineer:

1) Only leachate piping located on the cell floor will be perforated.

2) Four rows of perforations; Two rows on each side of pipe at 45° and 80° from bottom center of pipe.

3) Each row of perforations shall have holes approximately 6 inches on center; and

4) Each hole shall be 3/8-inch diameter.

5) Piping located between the toe of slope and cleanouts should be solid HDPE pipe.

The dual contained force main shall consist of a 3" HDPE carrier pipe inside a HDPE containment pipe. The carrier pipe shall be concentrically located within containment pipe with spacers. The maximum standard dimension ratio of the pipe shall be 17.

The chemical resistance of the HDPE pipe and all fittings shall be in keeping with typical properties of high quality polyethylene products currently available through commercial sources. All mechanical fasteners or fittings shall be stainless steel.

Construction

The perforated high density polyethylene collector pipe shall be as shown on the Contract Drawings.

a) The pipe section connections shall be made by:

(1) Heat fusion weld;
(2) Material extrusion weld;
(3) Threaded connection;
(4) Snap-couplings (approved mechanical); and/or
(5) Combination of any two or more of the above. No solvent or glued joints are allowed.

7.0 Landfill Cap System

The landfill cap system will consist of the following layers:

1. A twelve (12)-inch layer of intermediate cover will be placed and compacted directly on top of the waste. This material shall be primarily a cohesive soil which is relatively free or organic matter.

2. A minimum eighteen (18)-inch thick clay layer will be placed on top of the intermediate cover layer. The compacted clay material shall have a minimum permeability of 1.0 x 10-5 cm/sec. Refer to section 4.4.2 for construction testing criteria. The clay liner shall be constructed in accordance with section 03260 of the construction specifications.

3. A textured geomembrane with a minimum thickness of 40 mils will be placed on top of the clay layer. Refer to Appendix B for conformance testing requirements. The geomembrane shall be constructed in accordance with section 04800 of the construction specifications. The minimum angle of friction between the textured HDPE liner and the clay liner shall be sixteen (16) degrees. This friction angle shall be verified by Direct Shear Box testing prior to construction.

4. A double-sided, eight (8)-ounce geocomposite will be placed on top of the 40 mil textured geomembrane. Refer to section 9.0 of Appendix D for testing requirements of the geonet geocomposite. The minimum angle of friction between the geocomposite and the textured geomembrane shall be twenty (20) degrees.

5. The geocomposite will be covered with an eighteen (18)-inch thick vegetative\erosion layer. The lower twelve (12) inches of the vegetative layer can be constructed of native, on-site soils which are capable of supporting vegetative growth. The upper six (6) inches of the vegetative layer shall be constructed of topsoil. The minimum angle of friction between the geocomposite and the vegetative cover shall be 22 degrees. This friction angle shall be verified by Direct Shear Box testing prior to construction.

APPENDIX A

1.0 Subgrade Preparation

1.1 Surface Preparation

The Earthwork Contractor shall be responsible for preparing the underlying soil prior to placement of the base liner system. The Project Manager shall coordinate the work of the Earthwork Contractor and the Geosynthetic Installer so that the requirements of the project-specific QAP are met.

Before beginning placement of the compacted clay liner:

1. The project engineer shall document that a licensed land surveyor has verified that all grades and elevations are consistent with Division approved engineering plans.

2. The project engineer shall document that he/she has visually inspected the subgrade surface to evaluate it's suitability and that the subgrade meets the criteria specified in the project specifications.

3. The subgrade shall be proof-rolled using a motor grader, smooth-drum roller, or other procedures and equipment specified by the project engineer.

4. The project engineer shall document that the subgrade has been tested at the following minimum frequencies:

SUBGRADE TESTING FREQUENCIES			
TEST	ASTM METHOD	QUANTITY	ACCEPTABLE VALUES
Field Density	D2922, D1556, D2937	1/1,000 YD^3	95% maximum dry density
Field Moisture	D2216, D3017, D4643	1/1,000 YD^3	+/- 1% optimum

Before the geomembrane installation begins, the Geosynthetic QAC and the project engineer shall verify that:

1. A licensed land surveyor has verified all lines and grades of the compacted clay liner.

2. A qualified and licensed Professional Engineer has verified that the clay liner surface meets the criteria specified in the project specifications.

3. The clay liner surface to be lined has been rolled, compacted, or hand-worked so as to be free of irregularities, protrusions, loose soil, and abrupt changes in grade.

4. The surface of the clay liner does not contain stones, which may be damaging to the geomembrane.

5. There is no area excessively softened by high water content.

6. There is no area where the clay liner surface contains desiccation cracks, which may damage the geomembrane.

7. The clay liner has sufficient thickness and that all permeability tests have not exceeded a permeability of 1.0×10^{-7} cm/sec.

8. The geomembrane to be deployed has a minimum thickness of 60 mils.

The Installer shall certify in writing that the surface on which the geomembrane will be installed is acceptable. A certificate of acceptance shall be given by the Installer to the Geosynthetic QAC prior to commencement of geomembrane deployment in the area under consideration. The Project Manager shall be given a copy of this certificate by the Geosynthetic QAC.

After the underlying soil has been accepted by the Installer, it is the Installer's responsibility to indicate to the Project Manager any change in the underlying soil condition that may require repair work. The Project Manager may consult with the Geosynthetic QAC regarding the need for repairs. If the Geosynthetic QAC concurs with the Installer, the Project Manager shall ensure that the underlying soil is repaired.

At any time before or during the geomembrane installation, the Geosynthetic QAC shall indicate to the Project Manager any locations which may not be adequately prepared for the geomembrane.

1.1.1 Anchor Trench

The Geosynthetic QAC shall verify:

1. The anchor trench has been constructed according to the project plans and specifications.

2. If the anchor trench is excavated in a clay material susceptible to desiccation, the amount of trench open at any time is minimized. The Geosynthetic QAC shall inform the Project Manager of any signs of significant desiccation associated with the anchor trench construction.

3. Rounded corners are provided in the trench so as to avoid sharp bends in the geomembrane.

4. Excessive amounts of loose soil are not allowed to underlie the geomembrane in the anchor trench.

5. The anchor trench is adequately drained to prevent ponding or softening of the adjacent soils while the trench is open.

6. The anchor trench is backfilled and compacted as outlined in the project specifications.

Care shall be taken when backfilling the trenches to prevent any damage to the geosynthetic components. The Geosynthetic QAC shall observe the backfilling operation and advise the Project Manager of any problems. Any problems shall be documented by the Geosynthetic QAC in his daily report.

Appendix B

1.0 Geomembranes

1.1 Description and Applicability

Geomembranes are low permeability geosynthetic barriers used in lining systems. This Section is applicable to smooth and textured high density polyethylene (HDPE) geomembranes. This Section may need to be modified when using other geomembranes.

1.2 Manufacturing Plant Inspection

The Owner or other appropriate representative will conduct an annual inspection of the Manufacturer's plant. In addition, the Project Manager, or his designated representative, may visit the manufacturing plant for a project-specific inspection if deemed necessary. If possible, the project-specific inspection shall be prior to or during the manufacturing of the geomembrane rolls for that particular project. The purpose of the plant inspection is to review the manufacturing process and quality control procedures.

The manufacturing plant inspection shall include:

1. Verification that properties guaranteed by the manufacturer are met and meet all the project specifications.

2. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.

3. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.

4. Review of handling, storage, and transportation procedures, and verification that these procedures will not damage the geomembrane.

5. Verification that roll packages have a label indicating the name of the manufacturer, type of geomembrane, thickness, roll number, and roll dimensions.

6. Verification that extrusion rods and/or beads are produced from the same base resin type as the geomembrane.

A report describing the inspection shall be retained by the Owner for annual inspections and by the Project Manager for project-specific inspections.

1.3 Quality Control Documentation

Prior to the installation of any geomembrane, the Manufacturer or Installer shall provide the Project Manager with the following information:

1. The origin (supplier's name and production plant) and identification (brand name and number) of the resin used to manufacture the geomembrane.

2. Copies of dated quality control certificates issued by the resin supplier.

3. Results of tests conducted by the Manufacturer to verify that the resin used to manufacture the geomembrane meets the project specifications.

4. A statement indicating that the amount of reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness.

5. A list of the materials which comprise the geomembrane, expressed in the following categories as percent by weight: polyethylene, carbon black, other additives.

6. A specification for the geomembrane which includes all properties contained in the project specifications measured using the appropriate test methods.

7. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.

8. Quality control certificates, signed by a responsible party employed by the Manufacturer. Each quality control certificate shall include roll identification numbers, testing procedures, and results of quality control tests. At a minimum, results shall be given for the following:

Property	Test Method	Frequency
Thickness	ASTM D-1593 Par. 8.1.3	Each Roll
Sheet Density	ASTM D-792 Method A	Every 5th roll
Tensile Properties	ASTM D638 (As modified in NSF54)	Each Roll
Tear Resistance	ASTM D1004 Die C	Each Roll
Environmental Stress Crack	ASTM D-1693 Appendix A (As modified in NSF541)	One Per Batch
Puncture Resistance	FTMS 101B Method 2065	Each Roll
Carbon Black Content	ASTM D1603	Every 5th Roll
Carbon Black Dispersion	ASTM D-3015 (As modified in NSF54)	Every 5th Roll

1. Results of environmental stress crack resistance tests (GRI GM-5b). At a minimum, tests shall be performed once every resin lot.

The Manufacturer shall identify all rolls of geomembranes with the following:

1. Manufacturer's name
2. Product identification
3. Thickness
4. Roll number
5. Roll dimensions

The Geosynthetic QAE shall review these documents and shall report any discrepancies with the above requirements to the Project Manager. The Geosynthetic QAE shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.

2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.

4. Rolls are appropriately labeled.

5. Certified minimum properties meet the project specifications.

6. Project specifications and a copy of the QAP are provided by the Project Manager to the Installer.

1.4 Conformance Testing

1.4.1 Sampling Procedures

Upon delivery of the rolls of the geomembrane, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geomembrane. The geomembrane rolls to be sampled shall be selected by the Geosynthetic QAC. Samples shall be taken across the entire width of the roll judged by the Geosynthetic QAC not to be damaged. Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the Geosynthetic QAC based on a review of all roll information including quality control documentation and manufacturing records.

If the Project Manager desires, the Geosynthetic QAC can perform the conformance test sampling at the manufacturing plant. This may be advantageous in expediting the installation process for very large projects.

Unless otherwise specified in the project specifications, samples shall be taken at a rate of one per lot and not less than one per 100,000 ft^2 (10,000 m^2) of geomembrane. These samples shall be forwarded to the Geosynthetic QAL for testing.

1.4.2 Conformance Tests

The following conformance tests shall be conducted:

1. Density (ASTM D1505)
2. Carbon black content (ASTM D1603)
3. Carbon black dispersion (ASTM D3015)
4. Thickness (ASTM D751)
5. Tensile properties (ASTM D638)

Other conformance tests may be required by the project specifications.

1.4.3 Test Results

All conformance test results shall be reviewed and accepted or rejected by the Geosynthetic QAE prior to the deployment of the geomembrane. The Geosynthetic QAE shall examine all results from laboratory conformance testing and shall report any non-conformance to the Project Manager. The Geosynthetic QAE shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of a Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be re-tested by the Geosynthetic QAL with a technical representative of the manufacturer present during the testing. Alternatively, the Manufacturer may have the sample re-tested at two different Owner-approved Geosynthetic Gals. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic Al's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager.

If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out-of-specification and rejected. Alternatively, at the option of the Project

Manager, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting the project specification. This procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line. To isolate the out-of-specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next large roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

1.5 Geomembrane Specifications

1.5.1 Materials

The geomembrane liner shall be made of high density polyethylene (HDPE) that is 60 mil. minimum thickness.

The geomembrane used shall meet, at a minimum, the standards included in Table 1 and Table 2 at the end of this section.

The geomembrane installed on the side slopes shall be textured and the geomembrane installed on the cell floor shall be smooth. The minimum angle of friction between the textured HDPE and the clay liner shall be17.2 degrees. This angle of friction shall be verified by Direct Shear Box testing prior to construction. The tests shall be performed using representative bulk samples of the proposed construction materials.

The chemical resistance of the geomembrane liner shall be in keeping with typical properties of high quality polyethylene products currently available through commercial sources.

Geomembrane liner shall be shipped rolled with a protective wrap around each roll, labeled with roll number and manufacturer's batch number. Manufacturer's quality control documentation shall be included with each roll.

The geomembrane shall (does not cover shipping and handling) be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter. Any such defect shall be repaired in accordance with the geomembrane manufacturer's recommendations. The Engineer may reject all or portions of units (or rolls) of the geomembrane if in his opinion significant quantities of production flaws are observed.

The Installer shall submit proposed geomembrane panel layouts to the Engineer at least 14 days prior to mobilization of crews (2 copies). Once the panel layout is

approved, the Installer may not change the layout without permission of the Engineer.

Table 1

Required Physical Properties of Smooth Membrane Liner (HDPE) Sheet

Property	Test Method	Required Values (60 Mil. HDPE)
Thickness	ASTM D-751	60 mil minimum
Sheet Density	ASTM D-1505	0.940 g/cm^3 min.
% Elongation at Yield	ASTM D-638	13
% Elongation at Break	ASTM D638	700
Tensile Stress at Yield	Test Specimen Type IV	132 lb/in. min.
Tensile Strength at Break	ASTM D-638	228 lb/in. min
Carbon Black Content	ASTM D-1603	2% min. - 3% max.
Carbon Black Dispersion	ASTM D-3016	A1, A2, or B1
Environmental Stress-Crack Resistance	ASTM D-1693 (As modified in NSF54 Appendix A)	1500 hours min.
Low Temperature Impact	ASTM D-746	-60°F or lower
Dimensional Stability	ASTM D-1204 (As modified in NSF54 Appendix A)	± 2.0% max.
Puncture Resistance	ASTM D4833	108 lb. min.
Tear Resistance	ASTM D 1004 DIE C	45 lb. min.
Water Vapor Transmission Rate	ASTM E96	0.03 gm/m^2-day

Seam Strengths

Shear Strength	ASTM D4437, NSF Modified	120 psi
Shear Strain @ Yield	ASTM D4437, NSF Modified	10% (min.)
Peel Strength (Fusion Weld)	ASTM D4437, NSF Modified	90 psi
Peel Strength (Extrusion Weld)	ASTM D4437, NSF Modified	78 psi

Non-Destructive Testing

Single Weld	Continuous Vacuum Box; Impact	Maintain vacuum of 3 psi, hold vacuum for 15 seconds.
Double Weld	Air Testing	Maintain 30 psi for no less than 5

		min.; pressure loss not greater than 3 psi for last 3 minutes.

Table 2

Required Physical Properties of Textured Membrane Liner (HDPE) Sheet

Property	Test Method	Required Values (60 Mil. HDPE)
Thickness	ASTM D-751	60 mil minimum
Sheet Density	ASTM D-1505	0.940 g/cm^3 min.
% Elongation at Yield	ASTM D-638	13
% Elongation at Break	ASTM D638	200
Tensile Stress at Yield	Test Specimen Type IV	132 lb/in. min.
Tensile Strength at Break	ASTM D-638	132 lb/in. min
Carbon Black Content	ASTM D-1603	2% min. - 3% max.
Carbon Black Dispersion	ASTM D-3016	A1, A2, or B1
Environmental Stress-Crack Resistance	ASTM D-1693 (As modified in NSF54 Appendix A)	1500 hours min.
Low Temperature Impact	ASTM D-746	-60°F or lower
Dimensional Stability	ASTM D-1204 (As modified in NSF54 Appendix A)	± 2.0% max.
Puncture Resistance	ASTM D4833	108 lb. min.
Tear Resistance	ASTM D 1004 DIE C	45 lb. min.
Water Vapor Transmission Rate	ASTM E96	0.03 gm/m^2-day

Seam Strengths

Shear Strength	ASTM D4437, NSF Modified	120 psi
Shear Strain @ Yield	ASTM D4437, NSF Modified	10% (min.)
Peel Strength (Fusion Weld)	ASTM D4437, NSF Modified	90 psi
Peel Strength (Extrusion Weld)	ASTM D4437, NSF Modified	78 psi

Non-Destructive Testing

Single Weld	Continuous Vacuum Box; Impact	Maintain vacuum of 3 psi, hold vacuum for 15 seconds.
Double Weld	Air Testing	Maintain 30 psi for no less than 5

		min.; pressure loss not greater than 3 psi for last 3 minutes.

1.5.2 Construction

The geomembrane liner shall be constructed as soon as practical after completion and approval of the compacted clay liner or portion thereof. The top of the compacted clay liner will be surveyed to ensure adequate thickness of clay material and proper grades toward the collection sump area have been achieved. The geomembrane is to cover the bottom of the secure cell and the side slopes in accordance with the Contract Drawings.

Areas to receive liner installation should be relatively smooth and even, free of ruts, voids, etc., to the extent required by the Engineer. This shall be accomplished by final dressing of the compacted liner with smooth drum rollers. No vehicles are permitted on final dressed surfaces unless authorized by the Engineer.

An anchor trench (as illustrated on the Contract Drawings) will be required to secure the geomembrane. No loose soil will be allowed to underlie the geomembrane in the anchor trenches. The time schedule for excavation and backfilling of the anchor trenches is to be approved by the Engineer so that desiccation of trench soils does not occur prior to backfilling.

Appendix C

1.0 Field Seaming

1.1.1 Seam Layout

Before installation begins, the Installer shall provide the Project Manager and the Geosynthetic QAC with a panel layout drawing. This drawing shall present all the proposed seams of the lining system at the facility. The Geosynthetic QAE shall review the panel layout drawing and verify that it is consistent with accepted state-of-practice. No panels may be seamed until written approval of the panel layout drawing has been provided by the Project Manager. In addition, panels not specifically shown on the panel layout drawing may not be used without the Project Manager's prior approval.

In general, seams should be oriented parallel to the line of maximum slope, thus, oriented along, not across, the slope. In corners and odd-shaped geometric locations, the number of seams should be minimized. No horizontal seam should be less than 10 ft (3.0m) from the toe or crest of the slope, or areas of potential stress concentrations, unless otherwise authorized by the Project Manager.

A seam numbering system compatible with the panel numbering system shall be used by the Geosynthetic QAC.

1.1.2 Accepted Seaming Methods

Approved processes for field seaming are fusion welding and extrusion welding. Proposed alternate processes shall be documented and submitted by the Installer to the Project Manager for approval. Only apparatus which have been specifically approved by make and model shall be used. The Project Manager shall submit all documentation regarding seaming methods to be used to the Geosynthetic QAC for review.

1.1.2.1 *Fusion Process*

The Geosynthetic QAC shall log ambient, seaming apparatus, and geomembrane surface temperatures at appropriate intervals and report any noncompliances to the Project Manager.

The Geosynthetic QAC shall also verify that:

1. The Installer maintains on-site the number of spare operable seaming apparatuses agreed upon at the pre-construction meeting.

2. Equipment used for seaming is not likely to damage the geomembrane.

3. The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.

4. A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage such that no damage occurs to the geomembrane.

5. A movable protective layer is used as required by the Installer directly below each overlap of geomembrane that is to be seamed to prevent buildup of moisture between the sheets and to prevent debris from collecting around the pressure rollers.

6. In general, the geomembrane panels are aligned to have an overlap of 4 to 6 in (100 mm to 150 mm) for fusion welding. In any event, the final overlap shall be sufficient to allow peel tests to be performed on the seam.

7. No solvent or adhesive is used.

8. The geomembrane is protected from damage in heavy traffic areas.

1.1.2.2 *Extrusion Process*

The Geosynthetic QAC shall log ambient, seaming apparatus, and geomembrane surface temperatures at appropriate intervals and report any noncompliances to the Project Manager.

The Geosynthetic QAC shall verify that:

1. The Installer maintains on-site the number of spare operable seaming apparatuses agreed upon at the pre-construction meeting.

2. Equipment used for seaming is not likely to damage the geomembrane.

3. Prior to beginning a seam, the extruder is purged until all heat-degraded extrudate has been removed from the barrel.

4. Clean and dry welding rods or extrudate pellets are used.

5. The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.

6. Grinding is completed no more than one hour prior to seaming.

7. A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage such that no damage occurs.

8. The geomembrane is protected from damage in heavy traffic areas.

9. Exposed grinding marks adjacent to an extrusion weld shall be minimized. In no instance shall exposed grinding marks extend more than 1/8 in (6 mm) from the finished seamed area.

10. In general, the geomembrane panels are aligned to have a nominal overlap of 3 in (75 mm) for extrusion welding. In any event, the final overlap shall be sufficient to allow peel tests to be performed on the seam.

11. No solvent or adhesive is used.

12. The procedure used to temporarily bond adjacent panels together does not damage the geomembrane; in particular, the temperature of hot air at the nozzle of any temporary welding apparatus is controlled such that the geomembrane is not damaged

1.1.3 Seam Preparation

The Geosynthetic QAC shall verify that prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris or foreign material of any kind. If seam overlap grinding is required, the Geosynthetic QAC must ensure that the process is completed according to the Manufacturer's instruction within one hour of the seaming operation, and in a way that does not damage the geomembrane. The Geosynthetic QAC shall also verify that seams are aligned with the fewest number of wrinkles and "fishmouths".

1.1.4 Test Seams

Trial seams shall be made on fragment pieces of geomembrane liner to verify that conditions are adequate for production seaming. At a minimum, such trial seams shall be made upon each start of work for each seaming crew, upon every four hours of continuous seaming, every time seaming equipment is changed of if significant changes in geomembrane temperature and weather conditions are observed. Trial seams shall be made under the same conditions as production seams.

The trial seam sample shall be at least 6 ft (1.8 m) long by 1 ft (0.3 m) wide (after seaming) with the seam centered lengthwise. Seam overlap shall be as indicated in Section 1.1.2.1. Two specimens shall be cut from the sample with a 1 in (25 mm) wide die. The specimens shall be cut by the Installer at locations selected randomly along the trial seam sample by the Geosynthetic QAC.

The specimens shall be tested in peel using a field tensiometer. The tensiometer shall be capable of maintaining a constant jaw separation rate of two inches per minute. They should not fail in the seam and should achieve minimum values as given in the specifications. If a specimen fails, the entire trial seam operation shall be repeated. If the additional specimen fails, the seaming apparatus and seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved. The Geosynthetic QAC shall observe all trial seam procedures.

The remainder of the successful trial seam sample shall be retained in the Project Manager's archives for possible laboratory testing. Each sample shall be assigned a number and marked accordingly by the Geosynthetic QAC, who shall also log the date, hour, ambient temperature, number of seaming unit, name of seamer, and pass or fail description.

If agreed upon between the Project Manager and the Geosynthetic QAE, and documented by the Geosynthetic QAE in his daily report, the remaining portion of the trial seam sample can be subjected to destructive testing as indicated in Section 1.3.6. If a trial seam sample fails a test conducted by the Geosynthetic QAL, then a destructive seam test sample shall be taken from each of the seams completed by the seamer during the shift related to the subject trial seam. These samples shall be forwarded to the Geosynthetic QAL and, if they fail the tests, the procedure indicated in Section 1.3.7 shall apply. The conditions of this paragraph shall be considered satisfied for a given seam if a destructive seam test sample has already been taken.

1.1.5 General Seaming Procedures

During general seaming, the Geosynthetic QAC shall ensure the following:

1. Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut fishmouths or wrinkles shall be seamed and any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane extending a minimum of 6 in (150 mm) beyond the cut in all directions.

2. If seaming operations are carried out at night, adequate illumination shall be provided.

3. Seaming shall extend to the outside edge of panels placed in the anchor trench.

4. All cross seam tees should be extrusion welded to a minimum distance of 4 in (100 mm) on each side of the tee.

5. No field seaming shall take place without the Master Seamer being present.

6. A firm substrate may be required to be provided by using a flat board, a conveyor belt, or similar hard surface directly under the seam overlap to achieve proper support.

The Geosynthetic QAC shall verify that the above seaming procedures or any other procedures agreed upon and indicated in the project QAP are followed, and shall inform the Project Manager of any nonconformance.

1.1.6 Seaming Weather Conditions

1.1.6.1 *Cold Weather Conditions*

To ensure a quality installation, if seaming is conducted when the ambient temperature is below 41°F (5°C), the following conditions shall be met:

1. Geomembrane surface temperatures shall be determined by the Geosynthetic QAC at intervals of at least once per 100 feet (30 m) of seam length to determine if preheating is required. For extrusion welding, preheating is required if the surface temperature of the geomembrane is below 41°F (5°C).

2. For fusion welding, preheating may be waived by the Project Manager based on a recommendation from the Geosynthetic QAE, if the Installer demonstrates to the Geosynthetic QAE's satisfaction that welds of equivalent quality may be obtained without preheating at the expected temperature of installation.

3. If preheating is required, the Geosynthetic QAC shall observe all areas of geomembrane that have been preheated by a hot air device prior to seaming, to ensure that they have not been overheated.

4. Care shall be taken to confirm that the surface temperatures are not lowered below the minimum surface temperatures specified for welding due to winds or other adverse conditions. It may be necessary to provide wind protection for the seam area.

5. All preheating devices shall be approved prior to use by the Project Manager.

6. Additional destructive tests shall be taken at an interval between 250 feet and 500 feet 75 to 150 m) of seam length, at the discretion of the Geosynthetic QAE.

7. Sheet grinding may be performed before preheating, if applicable.

8. Test seams, as described in Section 1.1.4, shall be conducted under the same ambient temperature and preheating conditions as the production seams. Under cold weather conditions, no trial seams shall be conducted if the ambient temperature drops by more than 10°F from the initial trial seam test conditions. Such new seams shall be conducted upon completion of seams in progress during temperature drop.

1.1.6.2 *Warm Weather Conditions*

At ambient temperatures above 104°F, no seaming of the geomembrane shall be permitted unless the Installer can demonstrate to the satisfaction of the Project Manager that geomembrane seam quality is not compromised. Test seams, as described in Section 1.1.4, shall be conducted under the same ambient temperature conditions as the production seams. At the option of the Geosynthetic QAC, additional destructive tests may be required for any suspect areas.

1.2 Nondestructive Seam Testing

1.2.1 Concept

The Installer shall nondestructively test all field seams over their full length using an air pressure test (for double fusion seams only, a vacuum test or other approved method. Air pressure testing and vacuum testing are described elsewhere respectively. The purpose of nondestructive tests is to check the continuity of seams. It does not provide quantity information on seam strength. Nondestructive testing shall be carried out as the seaming work progresses, not at the completion of all field seaming.

For all seams, the Geosynthetic QAC shall:

1. Observe nondestructive testing procedures.

2. Record location, data, test unit number, name of tester, and outcome of all testing.

3. Inform the Installer and Project Manager of any required repairs.

Any seams that cannot be nondestructively tested shall be cap-stripped with the same geomembrane. The cap-stripping operations shall be observed by the Geosynthetic QAC and Installer for uniformity and completeness.

1.2.2 Air Pressure Testing

Air pressure testing is applicable to double fusion welding which produces a double seam with an enclosed space.

1. The Equipment for air pressure testing shall consist of the following:

    a. An air pump (manual or motor driven), equipped with pressure gauge and capable of generating and sustaining a pressure between 25 and 30 psi (160 and 200 kPa) and mounted on a cushion to protect the geomembrane.

    b. A rubber hose with fittings and connections.

    c. A sharp hollow needle, or other pressure feed device, approved by Project Manager.

2. The following procedures shall be followed:

    a. Seal both ends of the seam to be tested.

b. Insert needle or other approved pressure feed device into the air channel created by the fusion weld.

c. Insert a protective cushion between the air pump and the geomembrane.

d. Pressurize the air channel to a pressure of approximately 30 psi (200 Kpa). Close valve, allow 2 minutes for pressure to stabilize, and sustain pressure for at least 5 minutes. Pressure loss over the 5-minute period should not exceed 3psi.

e. If loss of pressure exceeds the maximum permissible pressure differential as outlined in the project specifications or does not stabilize, locate fault area and repair in accordance with Section 1.4.3.

f. Cut opposite end of tested seam area once testing is complete to verify continuity of the air channel. If air does not escape, locate blockage and retest unpressurized area. Seam the cut end or the air channel.

g. Remove needle or other approved pressure feed device and seal the hole in the geomembrane.

1.2.3 Vacuum Testing

Vacuum testing is applicable to extrusion welding.

1. The equipment shall consist of the following:

   a. A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, a porthole or valve assembly, and a vacuum gauge.

   b. A pump assembly equipped with a pressure controller and pipe connections.

   c. A rubber pressure/vacuum hose with fittings and connections.

   d. A soapy solution. (Geosynthetic QAC shall ensure solution makes bubbles when air is passed through.)

   e. A bucket and wide paint brush, or other means of applying the soapy solution.

2. The following procedures shall be followed:

   a. Wet a strip of geomembrane approximately 12 in X 48 in (0.3 m X 1.2 m) with the soapy solution.

   b. Place the box over the wetted area.

   c. Close the bleed valve and open the vacuum valve.

   d. Ensure that a leak-tight seal is created.

   e. Energize the vacuum pump and reduce the applied pressure to approximately 5 psi (10 in of Hg/35kPa) gauge.

   f. For a minimum of 10 seconds, apply vacuum with the box placed and maintaining a seal, examine the geomembrane through the viewing window for the presence of soap bubbles.

   g. If no bubble appears after 10 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 3 in (75 mm) overlap, and repeat the process.

   h. All areas where soap bubbles appear shall be marked and repaired in accordance with Section 1.4.3.

1.2.4 Test Failure Procedures

The Installer shall complete any required repairs in accordance with Section 6.4. For repairs, the Geosynthetic QAC shall:

1. Observe the repair and testing of the repair.

2. Mark on the geomembrane that the repair has been made.

3. Document the repair procedures and test results.

1.3 Destructive Seam Testing

1.3.1 Concept

The purpose of destructive tests is to evaluate seam strength. Destructive seam tests shall be performed at selected locations. Seam strength testing shall be done as the seaming work progresses, not at the completion of all field seaming.

1.3.2 Location and Frequency

The Geosynthetic QAC shall select where seam samples will be cut out for laboratory testing. The frequency and locations shall be established as follows:

1. A minimum frequency of one test location per 500 feet (150 m) of seam length performed by each welding machine. This frequency is to be determined as an average taken throughout the entire facility.

2. Test locations shall be determined during seaming at the Geosynthetic QAC's discretion. Special consideration shall be given to locations where the potential for imperfect welding, such as overheating, contamination, offset welds exists.

The Installer shall not be informed in advance of the location where the seam samples will be taken.

1.3.3 Sampling Procedures

Samples shall be cut by the Installer at locations chosen by the Geosynthetic QAC as the seaming progresses so that laboratory test results are available before the geomembrane is covered by another material. The Geosynthetic QAC shall:

1. Observe sample cutting.

2. Assign a number to each sample, and mark it accordingly.

3. Record sample location on layout drawing.

4. Record reason for taking the sample at this location (e.g., statistical routine, suspicious feature of the geomembrane).

All holes in the geomembrane resulting from destructive seam sampling shall be repaired in accordance with repair procedures described in Section 1.4.3 immediately following receipt of successful test results. The continuity of the new seams in the repaired area shall be tested according to Section 1.2.3. All holes in the geomembrane shall be temporarily patched or repaired in accordance with section 1.4.3 before the end of each work day in order to protect the clay liner from inclement weather.

1.3.4 Sample Dimensions

At each sampling location, two types of samples shall be taken by the Installer. First, two specimens for field testing should be taken. Each of these samples shall be cut with a 1 in (25 mm) wide die, with the seam centered parallel to the width. The distance between these two samples shall be 42 in (1.1 m). If both samples pass the field test described in Section 1.3.5, a sample for laboratory testing shall be taken.

The sample for laboratory testing shall be located between the samples for field testing. The sample for laboratory testing shall be 12 in (0.3 m) wide by 42 in (1.1 m) long with the seam centered lengthwise. The sample shall be cut into three parts and distributed as follows:

1. One 12 in wide x 18 in long (0.3 m x 0.5 m) portion for Geosynthetic QAL testing.

2. One 12 in wide x 12 in long (0.3 m x 0.3 m) portion to the Installer for optional laboratory testing.

3. One 12 in wide x 12 in long (0.3 m x 0.3 m) portion to the Project Manager for archive storage.

Final determination of the sample sizes shall be made at the pre-construction meeting.

1.3.5 Field Testing

The two 1 in (25 mm) wide specimens mentioned in Section 1.1.4 and Section 1.3.4 shall be tested in the field using a tensiometer for peel adhesion and shall not fail according to the criteria in the project specifications. The tensiometer shall be capable of maintaining a constant jaw separation rate of two inches per minute. If the test passes in accordance with this section, the sample qualifies for testing in the laboratory. If it fails, the seam should be repaired in accordance with Section 1.3.7. Final judgment regarding seam acceptability, based on the failure criteria provided in the project specifications, rests with the Geosynthetic QAE.

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

1.3.6 Laboratory Testing

Destructive test samples shall be packaged and shipped, if necessary, under the responsibility of the Geosynthetic QAC in a manner which will not damage the test sample. The sample shall be shipped as soon as possible to expedite laboratory testing. The Project Manager will be responsible for storing the archive samples. Test samples shall be tested by the Geosynthetic QAL.

Testing shall include seam strength and peel adhesion (ASTM D4437). The minimum acceptable values to be obtained in these tests shall be provided in the project specifications. At least 5 specimens shall be tested, each in both shear and peel. Specimens shall be selected alternately by test from the samples (i.e., peel, shear, peel, shear). A passing test shall meet the minimum acceptable values in at least 4 of the 5 specimens tested for each method.

1.3.7 Destructive Test Failure

When a sample fails a destructive test, whether that test is conducted by the Geosynthetic QAL or by field tensiometer, the Installer has two options:

1. The Installer can repair the seam between any two passing destructive test locations.

2. The Installer can trace the welding path to any intermediate location 10 ft (3 m) minimum from the point of the failed test in each direction and take a sample with a 1 in (25 mm) wide die for an additional field test at each location. If these additional samples pass the test, then full laboratory samples are taken. If these laboratory samples pass the tests, then the seam is repaired between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be repaired.

All acceptable repaired seams shall be bound by two locations from which samples passing laboratory destructive tests have been taken. Passing laboratory destructive tests of trial seam samples taken as discussed in Section 1.1.4 may be used as a boundary for the failing seam. In cases exceeding 150 ft (50 m) of repaired seam, a sample taken from the zone in which the seam has been repaired must pass destructive testing. Repairs shall be made in accordance with Section 1.4.3.

The Geosynthetic QAC shall document all actions taken in conjunction with destructive test failures.

1.4 Defects and Repairs

1.4.1 Identification

All seams and non-seam areas of the geomembrane shall be examined by the Geosynthetic QAC for identification of defects, holes, blisters, undispersed raw materials, large wrinkles and any sign of contamination by foreign matter. The geomembrane surface shall be cleaned by the Installer prior to examination if the Geosynthetic QAC determines that the amount of dust or mud inhibits examination.

1.4.2 Evaluation

Each suspect location both in seam and non-seam areas shall be nondestructively tested using the methods described in Section 1.2. Each location which fails the nondestructive testing shall be marked by the Geosynthetic QAC and repaired by the Installer. Work shall not proceed with any materials which will cover locations which have been repaired until successful nondestructive and/or laboratory tests are obtained.

When seaming of the geomembrane is completed, and prior to placing overlying materials, the Geosynthetic QAC shall indicate to the Project Manager any large wrinkles which should be cut

and reseamed by the Installer. The number of wrinkles to be repaired should be kept to an absolute minimum. Therefore, wrinkles should be located during the coldest part of the installation period, while keeping in mind the forecasted weather to which the undercover geomembrane may be exposed. Wrinkles are considered to be large when the geomembrane can be folded over onto itself which is generally a wrinkle that extends 12 in (0.3 m) from the subgrade. Seams produced while repairing wrinkles shall be nondestructively tested.

When placing overlying material on the geomembrane, every effort must be made to minimize wrinkle development. If possible, cover should be placed during the coolest weather. In addition, small wrinkles should be isolated and covered as quickly as possible to prevent their growth. The placement of cover materials shall be observed by the Geosynthetic QAC to ensure that wrinkle formation is minimized and that, in all cases, the geomembrane is not folded over on itself.

1.4.3 Repair Procedures

Any portion of the geomembrane exhibit a flaw, or failing a destructive or nondestructive test, shall be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be agreed upon between the Project Manager, Installer, Designer, and Geosynthetic QAC.

1. The repair procedures available include:

    a. Patching, used to repair holes, tears, undispersed raw materials, and contamination by foreign matter.

    b. Spot welding used to repair pinholes, or other minor, localized flaws.

    c. Capping, used to repair large lengths of failed seams.

    d. Extrusion welding the flap, used to repair areas of inadequate fusion seams which have an exposed edge. Repairs of this type shall be approved by Geosynthetic QAC and shall not exceed 100 ft (30 m) in total length.

    e. Removing bad seam and replacing with a strip of new material welded into place.

2. For any repair method, the following provisions shall be satisfied:

    a. Surfaces of the geomembrane which are to be repaired using extrusion methods shall be ground no more than on one hour prior to the repair.

    b. All surfaces shall be clean and dry at the time of the repair.

c. All seaming equipment used in repairing procedures shall meet the requirements of the project QAP.

d. Patches or caps shall extend at least 6 in (150 mm) beyond the edge of the defect, and all corners of patches shall be rounded with a radius of approximately 3 in (75 mm).

1.4.4 Repair Verification

The Geosynthetic QAC shall observe all nondestructive testing of repairs and shall record the number of each repair, date and test outcome. Each repair shall be nondestructively tested using the method described in Section 1.2 as appropriate. Repairs which pass the nondestructive test shall be taken as an indication of an adequate repair. Repairs more than 1250 ft (50 m) long require destructive test sampling. Failed tests require that the repair shall be redone and re-tested until a passing test results.

When placing overlying material on the geomembrane, every effort must be made to minimize wrinkle development. If possible, cover should be placed during the coolest weather available. In addition, small wrinkles should be isolated and covered as quickly as possible to prevent their growth. The placement of cover materials shall be observed by the Geosynthetic QAC to ensure that wrinkle formation is minimized and that, in all cases, the geomembrane is not folded over on itself.

1.5 Geomembrane Protection

The quality assurance procedures indicated in this Section are intended only to assure that the installation of adjacent materials does not damage the geomembrane. The quality assurance of the adjacent materials themselves are covered in separate Sections of this manual.

1.5.1 Soils

A copy of the project specifications prepared by the Designer for placement of soils shall be given to the Geosynthetic QAE by the Project Manager. The Geosynthetic QAE shall verify that these project specifications are consistent with geosynthetic state of practice such as:

1. Placement of gravel on the geomembrane shall not proceed at an ambient temperature below 32 degrees F (0 degrees C) nor above 104 degrees F (40 degrees C) unless otherwise specified.

2. Placement of gravel on the geomembrane should be done during the coolest part of the day to minimize the development of wrinkles in the geomembrane.

3. Equipment used for placing gravel shall not be driven directly on the geomembrane.

4. A minimum thickness of 1 ft. (0.3 m) of gravel and the geotextile cushion is specified between a light dozer, ground pressure of 5 psi (35 kPa) or lighter, and the geomembrane. Trucks shall have a minimum thickness of 2 feet between them and the geomembrane.

5. In any areas traversed by heavy construction, any vehicles other than low ground pressure vehicles approved by the Project Manager, the gravel layer shall have a minimum thickness of 3 ft (09 m). This requirement may be waived if provisions are made to protect the geomembrane through an engineered design. Drivers shall proceed with caution when traveling on the overlying gravel and prevent spinning of tires or sharp turns.

6. Leachate collection pipes shall not be crossed with construction equipment without the full two (2) feet of stone in place. In areas where trucks must repeatedly cross the leachate piping, a temporary stone road shall be build to bridge over the pipe and maintain a minimum thickness of three (3) feet.

7. Care shall be taken to avoid creating wrinkles in the geomembrane during placement of the gravel layer. Refer to Sections 1.1.5 and 1.4.2 for information on evaluating and repairing wrinkles.

The Geosynthetic QAC shall measure soil thickness and verify that the required thickness is present. The Geosynthetic QAC must also verify that final thickness is consistent with the design and verify that placement of the gravel is done in such a manner that geomembrane damage is unlikely. The Geosynthetic QAE shall inform the Project manager if the above conditions are not fulfilled.

1.5.2 Sumps and Appurtenances

A copy of the plans and project specifications prepared by the Designer for sumps and appurtenances shall be given by the Project Manager to the Geosynthetic QAC. The Geosynthetic QAC shall review these plans and verify that:

1. Installation of the geomembrane, sumps, equipment, and appurtenant areas has been performed properly, and connections of geomembrane to sumps and appurtenances have been made according to project specifications.

2. Extreme care is taken while welding around appurtenances since neither nondestructive or destructive testing may be feasible in these areas.

3. The geomembrane has not been visibly damaged while making connections to sumps and appurtenances.

4. A representative of the Geosynthetic QAC shall be present at all times when the Installer is welding geomembrane to appurtenant structures.

The Geosynthetic QAC shall inform the Project manager in writing if the above conditions are not fulfilled.

1.5.3 Concrete

A copy of the project specifications prepared by the Designer for placement of concrete shall be given by the Project Manager to the Geosynthetic QAC. The Geosynthetic QAC shall verify that these specifications are consistent with the state of practice, including the use of geosynthetic layers between concrete and geomembrane. The Geosynthetic QAC shall verify that geosynthetic layers are placed between the concrete and the geomembrane according to design specifications. The Geosynthetic QAC will also verify that construction methods used are not likely to damage the geomembrane.

Appendix D

1.0 Geotextiles

1.1 Definition and Applicability

Geotextiles are used in protection and filtering applications in lining systems. This Section does not describe procedures for other applications such as erosion control or reinforcement. This Section is applicable to nonwoven geotextiles made of polyester of polypropylene and not applicable to nonwoven geotextiles made of other materials or woven geotextiles.

1.2 Manufacturing Plant Inspection

The Owner or an appropriate representative will conduct a periodic inspection of the Manufacturer's plant. In addition, the Project Manager or his designated representative, may visit the manufacturing plant for a project-specific inspection if deemed necessary. If possible, the project-specific inspection shall be prior to or during the manufacturing of the geotextile rolls for that particular project. The purpose of the plant inspections is to review the manufacturing process and quality control procedures.

The manufacturing plant inspection shall include:

1. Verification that properties of the geotextile guaranteed by the Manufacturer are met and meet the project specifications.

2. Verification that the measurement of properties by the manufacturer is properly documented and test methods used are acceptable.

3. Soot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.

4. Review of packaging, handling, storage, and transportation procedures and verification that these procedures will not damage the geotextile.

5. Verification that roll packages have a label indicating the name of the manufacturer, type of geotextile, roll number and roll dimensions.

6. Verification that the geotextiles are inspected continuously for the presence of needles using a metal detector.

A report describing the inspection will be retained by the Owner for periodic inspections and by the Project Manager for project-specific inspections.

1.3 Quality Control Documentation

Prior to the installation of any geotextile, the Manufacturer or Installer shall provide the Project Manager with the following information:

1.4 Roll Dimensions

The Geosynthetic QAE shall review these documents and shall report any discrepancies with the above requirements to the Project Manager. The Geosynthetic QAE shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.

2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.

4. Roll packages are appropriately labeled.

5. Certified minimum roll properties meet the project specifications.

6. Project specifications and a copy of the QAP were submitted by the Project Manager to the Installer.

1.5 Conformance Testing

Upon delivery of the rolls of geotextiles, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geotextile. The rolls to be sampled shall be selected by the Geosynthetic QAC. Samples shall be taken from any portion of a roll which has not been damaged. Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow. All lots of material and the particular test sample that represents each lot should be defined before the samples are taken.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the Geosynthetic QAC based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified in the project specifications, samples shall be taken at a rate of one per lot, not to be less than one per 100,000 ft^2 of geotextile. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance with the project specifications.

1.6 Geotextile Deployment

During shipment and storage, the geotextile shall be protected from ultraviolet light exposure, moisture, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions. Geotextile rolls shall be shipped and stored in relatively opaque and watertight wrappings. Wrapping shall not be removed until shortly before deployment.

The Geosynthetic QAC shall observe rolls upon delivery at the site. Any apparently damaged or improperly wrapped rolls shall be reported to the Project Manager.

The installer shall ensure that geotextiles are not damaged during handling. The geotextile shall be deployed as described below:

1. On slopes, the geotextiles shall be securely anchored and then rolled down the slope in such a manner as to continually keep the geotextile sheet in tension.

2. In the presence of wind, all geotextiles shall be weighted with sandbags or the equivalent. Such sand bags shall be installed during deployment and shall remain until replaced with cover material.

3. Geotextiles shall be cut using a geotextile cutter (hook blade) only. If in place, special care shall be taken to protect other materials from damage which could be caused by the cutting of the geotextiles.

4. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geotextile.

5. During placement of geotextiles, care shall be taken not to entrap, in or beneath the geotextile, stones, excessive dust, or moisture that could damage the geomembrane, cause clogging of drains or filters, or hamper subsequent seaming.

6. A visual examination of the geotextile shall be carried out over the entire surface, after installation, to ensure that no potentially harmful foreign objects, such as needles, are present.

The Geosynthetic QAC shall note any noncompliance and report it to the Project Manager.

1.7 Geotextile Material Specification and Seaming Procedures

Non-woven Filter and cushion Geotextile shall be as indicated below:

Non-woven Geotextile

The geotextile used shall be ultraviolet stabilized 1) a non-woven, needlepunched, continuous filament polyester material or, 2) a non-woven, needlepunched continuous filament polypropylene material or, 3) a non-woven, needlepunched staple fiber polypropylene material.

A 16 oz. geotextile cushion will be placed between the geomembrane and the drainage layer.

The minimum angle of friction between the 16 oz. geotextile cushion and the textured geomembrane shall be twenty (20) degrees.

A 6 oz. geotextile will be used to wrap the leachate collection lines and the 5/8" washed stone bedding material.

The non-woven material shall meet or exceed the following criteria using Minimum Average Values:

		6 oz. Geotextile	16 oz. Geotextile
Grab Strength	ASTM D4623	160 lbs.	395 lbs.
Grab Elongation	ASTM D4632	50 Percent	50 Percent
Puncture Strength	ASTM D4833	110 lbs.	260 lbs.
Fabric Weight		6.0 oz.	16.6 oz.
Apparent Opening Size (AOS)	ASTM D4751	.212 mm (70 Sieve max.)	0.150 mm (100 Sieve max.)

Seaming

The geotextile for the bottom of the cell shall be installed as follows:

1. Panels of geotextile shall be 6" and overlapped continuously sewn along the entire length of the seams.

The specified geotextile shall be placed over the HDPE liner. The geotextile shall be immediately sewn by a methodology approved by the Engineer. The geotextile shall be extended up the side slopes and placed in the anchor trench as indicated on the Contract Drawings. In general, no horizontal seams shall be allowed on sideslopes (seams along, not

across, the slope) except as part of a patch. When horizontal seams are necessary, adjacent seams shall be staggered horizontally.

1.8 Geotextile Protection

All soil materials located on top of a geotextile shall be deployed in such a manner as to ensure:

1. The geotextile and underlying lining materials are not damaged.

2. Minimal slippage of the geotextile on underlying layers occurs.

3. No excess tensile stresses occur in the geotextile.

All noncompliance with these guidelines or the project specifications shall be noted by the Geosynthetic QAC and reported to the Project Manager.

2.0 Geonets

2.1 Definition and Applicability

Geonets are geosynthetic nets used as a drainage medium in lining systems. This Section is applicable to geonets made of high density polyethylene (HDPE), including "foamed" HDPE products but is not applicable to geonets made of other polymers.

2.2 Manufacturing Plant Inspection

The Owner or appropriate representative will conduct a periodic inspection of the Manufacturer's plant. In addition, the Project Manager, or his designated representative may visit the manufacturing plant for a project-specific inspection if deemed necessary. If possible, the project-specific inspection shall be prior to or during the manufacturing of the geonet rolls for that particular project. The purpose of the inspection is to review the manufacturing process and quality control procedures.

The manufacturing plant inspection shall include:

Verification that properties guaranteed by the Manufacturer are met and meet all project specifications.

1. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.

2. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.

3. Review of packaging, handling, storage, and transportation procedures and verification that these procedures will not damage the geonet.

4. Verifications that roll packages have a label indicating the name of the manufacturer, type of geonet, roll number an roll dimensions.

A report describing the inspection will be retained by the Owner for periodic inspections and by the Project Manager for project-specific inspections.

2.3 Quality Control Documentation

Prior to the installation of any geonet, the Manufacturer or Installer shall provide the Project Manager with the following information:

1. The origin (supplier's name and production plant) and identification (brand name and number) of the resin.

2. Copies of dated quality control certificates issued by the resin supplier.

3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.

4. Roll packages are appropriately labeled.

5. Certified minimum properties meet the project specifications.

6. Project specifications and a copy of the QAP were submitted by Project Manager to the Installer.

2.4 Conformance Testing

2.4.1 Sampling Procedures

Upon delivery of the rolls of geonet, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geonet. The rolls to be sampled shall be selected by the Geosynthetic QAC. Samples shall be taken from any portion of a roll which has not been damaged. Unless otherwise specified, samples shall be 3 ft. (2 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designed by the Geosynthetic QAC based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified in the project specifications, samples shall be taken at a rate of one per lot, not to be less than one per 100,000 ft^2 of geonet. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance to the project specifications.

2.4.2 Conformance Tests

At a minimum, the following tests shall be performed:

1. Density (ASTM D1505)
2. Mass per unit area (ASTM D3776)
3. Thickness (ASTM D751)

Other conformance tests may be required by the project specifications.

1. On slopes, the geonet shall be secured and rolled down the slope in such a manner as to continually keep the geonet sheet in tension. If necessary, the geonet shall be positioned by hand after being unrolled to minimize wrinkles.

2. In the presence of wind, all geonet shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.

3. Unless otherwise specified, geonet shall not be welded to geomembrane.

4. Geonet shall only be cut using scissors or other cutting tools approved by the Project Manager that will not damage the underlying geosynthetics. Care shall be taken not to leave tools in the geonet.

5. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geonet.

6. During placement of geonet, care shall be taken not to entrap dirt, excessive dust, or fugitive bentonite clay in the geonet that could cause clogging of the drainage system, and/or stones that could damage the adjacent geomembrane. If dirt or excessive dust is entrapped in the geonet, it should be cleaned prior to placement of the next material on top of it. In this regard, care shall be taken with the handling of sandbags, to prevent puncturing the sandbag.

The Geosynthetic QAC shall note any noncompliance and report it to the Project Manger.

2.5 Seams and Overlaps

At a minimum, the following requirements for joining the adjacent geonet shall be met:

1. Adjacent rolls shall be overlapped by at least 4 inch (100 mm).

2. The geonet overlaps shall be tied with plastic fasteners. Tying devices shall be white or yellow for easy inspection. metallic devices are not allowed.

3. Tying shall be every 5 ft (1.5 m) along the length at the adjacent rolls, every 6 in (0.25 m) in the anchor trench and every 6 in (0.15 m) along end-to-end seams.

4. In general, no horizontal seams shall be allowed on sideslopes.

5. In the corners of the sideslopes of rectangular landfills, where overlaps between perpendicular geonet strips are required, an extra layer of geonet shall be unrolled along the slope, on top of the previously installed geonet, from top to bottom of the slope.

The Geosynthetic QAC shall observe any repair and report any noncompliance with the above requirements in writing to the Project Manager.

3.0 Geocomposites

3.1 Definition and Applicability

Geocomposites are geosynthetic nets with geotextile heat bonded to the surface. The geocomposite can be single-sided or double-sided depending on the application. They are used as a drainage medium in lining systems, where the properties of the geotextile can either serve as a filter media from clogging the geonet or increase stability of the lining system. This Section is applicable to geocomposites where the geonet portion is made of high density polyethylene (HDPE), including "foamed" HDPE products but is not applicable to geocomposites where the geonet is made of other polymers.

3.2 Manufacturing Plant Inspection

The Owner or appropriate representative will conduct a periodic inspection of the Manufacturer's plant. In addition, the Project Manager, or his designated representative may visit the manufacturing plant for a project-specific inspection if deemed necessary. If possible, the project-specific inspection shall be prior to or during the manufacturing of the geocomposite rolls for that particular project. The purpose of the inspection is to review the manufacturing process and quality control procedures.

The manufacturing plant inspection shall include:

Verification that properties guaranteed by the Manufacturer are met and meet all project specifications.

1. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.

2. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.

3. Review of packaging, handling, storage, and transportation procedures and verification that these procedures will not damage the geocomposite.

4. Verifications that roll packages have a label indicating the name of the manufacturer, type of geocomposite, roll number and roll dimensions.

A report describing the inspection will be retained by the Owner for periodic inspections and by the Project Manger for project-specific inspections.

3.3 Production

The geocomposite shall be manufactured by heat bonding the geotextile to the HDPE drainage net on one or both sides. No burn through geotextiles shall be permitted. No glue or adhesive shall be permitted.

The geonet portion of the geocomposite shall be manufactured by extruding two sets of strands to form a three (3) dimensional structure to provide planar water flow.

3.4 Quality Control Documentation

Prior to the installation of any geocomposite, the Manufacturer or Installer shall provide the Project Manager with the following information:

1. The origin (supplier's name and production plant) and identification (brand name and number) of the resin used for geonet.

2. Copies of dated quality control certificates issued by the geonet resin supplier.

3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.

4. Roll packages are appropriately labeled.

5. Certified minimum properties meet the project specifications.

6. Project specifications and a copy of the QAP were submitted by Project Manager to the Installer.

3.5 Conformance Testing

3.5.1 Sampling Procedures

Upon delivery of the rolls of geocomposite, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geocomposite. The rolls to be sampled shall be selected by the Geosynthetic QAC. Samples shall be taken from any portion of a roll which has not been damaged. Unless otherwise specified, samples shall be 3 ft. (2 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designed by the Geosynthetic QAC based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified in the project specifications, samples shall be taken at a rate of one per lot, not to be less than one per 100,000 ft^2 of geocomposite. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance to the project specifications.

3.5.2 Conformance Tests

At a minimum the geotextile used to produce the geocomposite shall be tested in accordance with section 1.0. The geonet used to produce the geocomposite shall be tested in accordance with section 2.0. The bond between the geotextile and the HDPE drainage net shall be tested at a minimum rate of one (1) test per 600 linear feet of geocomposite produced. The bond shall exhibit a minimum average peel strength of 2 lbs per inch, and a typical peel strength of 4 lbs. per inch as per ASTM D-413.

Other conformance tests may be required by the project specifications.

1. On slopes, the geocomposite shall be secured and rolled down the slope in such a manner as to continually keep the geocomposite sheet in tension. If necessary, the geocomposite shall be positioned by hand after being unrolled to minimize wrinkles.

2. In the presence of wind, all geocomposite shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.

3. Unless otherwise specified, geocomposite shall not be welded to geomembrane.

4. Geocomposite shall only be cut using scissors or other cutting tools approved by the Project Manager that will not damage the underlying geosynthetics. Care shall be taken not to leave tools in the geocomposite.

5. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geocomposite.

6. During placement of geocomposite, care shall be taken not to entrap dirt, excessive dust, or fugitive bentonite clay in the geocomposite that could cause clogging of the drainage system, and/or stones that could damage the adjacent geomembrane. If dirt or excessive dust is entrapped in the geocomposite, it should be cleaned prior to placement of the next material on top of it. In this regard, care shall be taken with the handling of sandbags, to prevent puncturing the sandbag.

The Geosynthetic QAC shall note any noncompliance and report it to the Project Manger.

3.6 Seams and Overlaps

At a minimum, the following requirements for joining the adjacent geocomposite shall be met:

1. Adjacent rolls shall be overlapped by at least 4 inch (100 mm).

2. The geocomposite overlaps shall be tied with plastic fasteners. Tying devices shall be white or yellow for easy inspection. metallic devices are not allowed.

3. Tying shall be every 5 ft (1.5 m) along the length at the adjacent rolls, every 6 in (0.25 m) in the anchor trench and every 6 in (0.15 m) along end-to-end seams.

4. In general, no horizontal seams shall be allowed on sideslopes.

5. In the corners of the sideslopes of rectangular landfills, where overlaps between perpendicular geocomposite strips are required, an extra layer of geocomposite shall be unrolled along the slope, on top of the previously installed geocomposite, from top to bottom of the slope.

6. Any areas where the geotextile portion of the geocomposite was damaged for the purpose of tying shall be covered by an extra geotextile prior to backfilling. The geotextile used to patch the geocomposite can be thermally bonded to the geotextile on the geocomposite.

The Geosynthetic QAC shall observe any repair and report any noncompliance with the above requirements in writing to the Project Manager.

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