CQA PLAN

PLANT WANSLEY ASH POND 1 (AP-1) CLOSURE

HEARD AND CARROLL COUNTIES, GEORGIA

FOR

Georgia Power

SEPTEMBER 2019

Geosyntec consultants

engineers | scientists | innovators

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LIST OF ACRONYMS

ASTM	American Society for Testing and Materials
CCR	Coal Combustion Residuals
CFR	Code of Federal Regulations
CQA	Construction Quality Assurance
CQC	Construction Quality Control
DSM	Deep Soil Mixing
GA EPD	Georgia Environmental Protection Division
GPC	Georgia Power Company
GRI	Geosynthetic Research Institute
HDPE	High Density Polyethylene
LGP	Low Ground Pressure
LLDPE	Linear-Low Density Polyethylene
MQC	Manufacturer Quality Control
QA	Quality Assurance
QC	Quality Control
UCS	Unconfined Compressive Strength

1. INTRODUCTION

1.1 OVERVIEW

This Construction Quality Assurance (CQA) Plan describes the quality assurance (QA) and quality control (QC) activities that will be undertaken during closure construction of Ash pond 1 (AP-1) at Georgia Power Company's (GPC's) Plant Wansley in Heard and Carroll Counties, Georgia. The purpose of this document is to define the scope, procedures, and acceptance criteria necessary to perform QA tasks such that the construction elements of AP-1 closure (hereafter referred to as "the Project") comply with the design as shown or indicated in the design drawings, technical specifications, approved design changes, and other relevant design documents (collectively referred to as "Design Documents" in the remainder of this CQA Plan). The technical specifications will be developed and included in the contract documents for construction to provide the detailed qualifications, processes, inspections, testing, and controls that will assure compliance with the CQA Plan, the construction drawings, and the permit.

1.2 PROJECT DESCRIPTION

AP-1 will be closed using a consolidation and in-place closure approach, whereby the coal combustion residuals (CCR) will be consolidated into an engineered structure (containment structure and final covered area) that will be constructed within the footprint of the current AP-1. The Project will include the general activities described below:

- construction of the containment structure to establish the final consolidated CCR footprint;
- CCR dredging and removal, dewatering, consolidation, and placement activities;
- construction of the final cover system components, including the associated stormwater management system; and
- other general site work.

Note that many of the activities described above will be conducted in a phased and overlapping manner.

1.3 CQA PLAN SCOPE

CQA services will be provided by a consulting engineering firm, reporting to GPC, specializing in the inspection and testing of soils and geosynthetics. Resumes and qualifications including experience with projects of similar type, size and complexity will be provided to GPC for their review and approval. The scope of the CQA Plan includes:

- defining the responsibilities of the CQA Consultant overseeing the construction activities;
- establishing testing protocols for the evaluation of the closure components;
- establishing procedures for construction documentation; and
- establishing the types of documentation that will be included in the final CQA Certification Report for verification that the overall construction conforms to the Design Documents.

The CQA Plan also presents the required properties of materials that will be used during closure construction, as established through the closure design process. The CQA Plan supplements the Design Documents that will be developed as part of detailed design.

2. CQA PLAN DEFINITIONS AND CQA/CQC APPROACH

2.1 CONSTRUCTION QUALITY ASSURANCE AND CONSTRUCTION QUALITY CONTROL

In the context of this document, construction quality assurance and construction quality control are defined as follows:

- Construction Quality Assurance (CQA) - The planned and systematic means and actions implemented to verify that materials and/or services meet technical (i.e., design), contractual and regulatory requirements and will perform satisfactorily in service. In the context of this document, CQA refers to means and actions employed by the CQA Consultant, Design Engineer, or GPC to verify conformity of the various components of the Project with the requirements of the Design Documents.
- Construction Quality Control (CQC) - Those actions that provide a means to measure and regulate the characteristics of an item or service in relation to technical (i.e., design), contractual and regulatory requirements. In the context of this document, CQC refers to those actions taken by the Contractor, Manufacturers, or Installers to verify that the materials and the workmanship of the various components of the Project meet the requirements of the Design Documents.

2.2 DESIGN DOCUMENTS

In this CQA Plan, Design Documents refer to the design drawings, technical specifications, approved design changes, and other relevant design documents issued as a part of a specific contract for the Project.

2.3 CQA VS. CQC

- QA and QC are <u>separate, but complementary</u> functions.

- Together, they provide a system of checks and balances, expected to result in a higher quality work product.

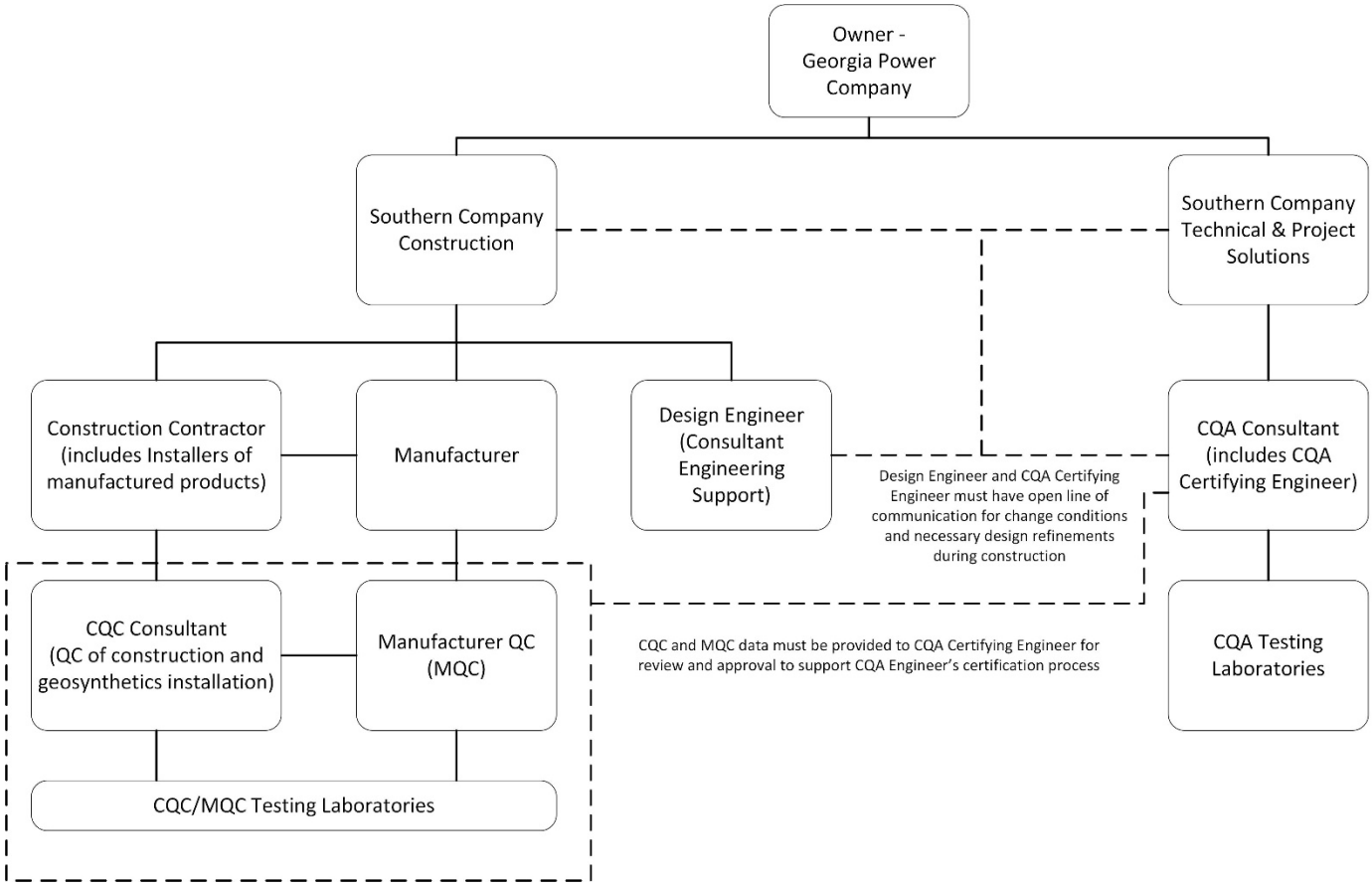
- This approach avoids potential conflicts of interest of a single party responsible for both constructing and testing/certifying the work.

- **CQA** refers to actions taken by an organization that operates separately from the contractor and the owner/operator (i.e., independent party) to confirm that construction materials and/or services meet technical, contractual, and regulatory requirements. This generally involves observation, review of submitted test results by others, and conducting independent tests –to confirm that various components of the Project meet the requirements of the Project Documents (i.e., CQA Plan, technical drawings and specifications, and other design documents).

- **CQC** refers to actions taken by the Contractor, Manufacturers, or Installers to check the quality of their own work (confirm that they are supplying materials and providing the workmanship as required by the Project Documents). **MQC** refers to QC functions performed by the manufacturers, and **CQC** refers to QC functions performed by construction contractors and installers. For this Project, CQC services will be subcontracted by the Contractor to an outside consultant.

2.4 ORGANIZATION CHART

An organization chart is presented below, illustrating the relationships between the various project parties. Further details on personnel, their roles, and required qualifications are provided in Section 3.



2.5 PLANT WANSLEY PROJECT-SPECIFIC CQA/CQC

The majority of laboratory and field testing is CQC's responsibility.

- Soils and Granular Materials and Work Products: Contractor's QC personnel or its subcontractor will conduct conformance testing (e.g. borrow source/supplied material consistency) and performance testing (e.g. completed work products as-installed).
- Geosynthetics Materials: Manufacturer will conduct MQC conformance testing.
- Geosynthetics Installation: Installer's QC personnel or its subcontractor will conduct installation QC activities and testing.

QA activities are as follows:

- Full-time observation and documentation of construction activities, including confirmation that i) construction/installation specifications are met; and ii) field QC activities are performed by the requisite methods and frequencies.

- Review all submitted QC documentation (QC test results, manufacturer data and certifications, etc.) for compliance with Project Documents (including test methods, frequencies, and values).

- Conduct limited prescribed testing of certain key properties to independently confirm that earthwork and geosynthetic materials and work products are in compliance with the Project Documents.

- Also conduct additional QA testing if deemed necessary by the CQA Certifying Engineer (e.g. if there is reason to believe based on observations or test results that non-conformances may be present).

- At the completion of construction phases, provide GPC with a final CQA Certification Report pertaining to each construction phase, for submittal to GQ EPD. This report will acknowledge that i) the works has been performed in compliance with the Project Documents; ii) physical sampling and testing has been conducted with appropriate standards and at pre-defined frequencies; iii) the QC and MQC documentation is in conformance with the submittal requirements and technical specifications; and iv) the test results met the minimum requirements defined in the Project Documents.

3. PERSONNEL

3.1 CQA CONSULTANT

3.1.1 Definition

The CQA Consultant is the party, retained by GPC, but independent from GPC and the Contractor, responsible for observing and documenting CQA activities related to the Project and reviewing CQC submittals prepared by the Contractor/Manufacturer related to the Project, as described in this CQA Plan. The qualifications and responsibilities of the CQA Consultant are described below.

3.1.2 Qualifications

The CQA Consultant will:

- have specialized experience in the design of geoenvironmental infrastructure involving earthwork, waste materials management, geosynthetics and piping installations, project-site water management, revegetation, containment systems, and final cover system design, and CQA of these components;

- possess the equipment, personnel, and licenses necessary to conduct the monitoring required by this CQA Plan and the Design Documents;

- be experienced in the CQA of earthwork, geosynthetics, piping systems, and other activities required for the Project;

- be experienced in the review of Contractor CQC submittals for conformance with the Project requirements and in the resolution of non-conformances; and

- be experienced in the preparation and/or review of CQA documentation including CQA plans, field documentation, field testing procedures, laboratory testing procedures, technical specifications, technical drawings, and CQA certification reports.

The CQA Consultant organization will be led by the CQA Certifying Engineer, who will be a Professional Engineer registered to practice in the state of Georgia. The CQA Site Manager will be the on-site representative of the CQA Consultant and will have experience in construction activities required for the Project.

3.1.3 Responsibilities

The CQA Consultant will be responsible for:

- reviewing the Design Documents prior to the start of the construction;

- monitoring the compliance of construction materials delivered to the site with the CQC submittals and conformance requirements and/or shop drawings previously reviewed and approved by the Design Engineer;

- monitoring and documenting the activities of the Contractor relative to the installation of the final cover system components as well as various general site work related to the Project;

- monitoring that the Contractor’s construction methods and workmanship are performed in accordance with the Design Documents;

- performing on-site field and/or laboratory QA verification testing if deemed necessary by the CQA Certifying Engineer;

- maintain calibration certificates of CQC field-testing equipment in the CQA Consultant's on-site project file;

- reviewing field and laboratory CQC test results and ensuring they are posted to the project database within a time frame that does not impede or delay construction activities; and

- promptly notifying GPC of any nonconformances of the Contractor's work with any CQC requirements of the Project, including those requirements related to the prompt delivery of CQC results to the CQA consultant.

The specific duties of the individual CQA personnel are discussed in the following subsections.

3.1.3.1 CQA Certifying Engineer

The CQA Certifying Engineer:

- reviews the Design Documents;
- attends scheduled, meetings related to Project construction quality activities;
- administers the CQA program (i.e., assigns and manages all on-site CQA personnel, reviews all field reports, provides engineering review of all CQA-related activities);
- provides quality control of CQA documentation;
- reviews and documents changes to the design during construction; and
- prepares and seals the final CQA Certification Report.

3.1.3.2 CQA Site Manager

The CQA Site Manager:

- serves as the on-site representative of the CQA Consultant;
- familiarizes all CQA field technicians with the site, Design Documents, and the CQA requirements;
- manages the daily activities of the CQA field technicians;
- attends regularly scheduled CQA-related meetings on-site;
- reviews the ongoing preparation of the construction record drawings;

- reviews test results, certifications, and documentation provided by the Contractor, Geosynthetics Manufacturer, and Installer and makes appropriate recommendations;
- reviews the CQA field technicians' daily notes and logs;
- prepares a daily report for the project;
- reviews the results of field and laboratory testing and makes appropriate recommendations;
- reports any unresolved deviations from the CQA Plan and Design Documents to the Construction Manager and CQA Certifying Engineer;
- assists with the preparation of the final CQA Certification Report;
- reviews the Geosynthetics Manufacturer's quality control (MQC) documentation; and
- performs duties of CQA field technician, as needed.

3.1.3.3 CQA Field Technicians

CQA field technicians:

- monitor material stockpiles for any deterioration of materials;
- monitor surface-water drainage in the areas of soil and geosynthetic material stockpiles;
- monitor earthwork placement and compaction operations;
- monitor the unloading, storage, and on-site handling of the geosynthetics;
- monitor geosynthetic material deployment and installation operations;
- monitor geosynthetic repair operations;
- document any on-site activities that could result in damage to the soils or geosynthetic components of the construction and report them as soon as practical to the CQA Site Manager;

- prepare daily field reports; and
- report problems to the CQA Site Manager.

3.2 CQC CONSULTANT

3.2.1 Definition

The CQC Consultant is the party, retained by the Contractor, responsible for observing construction, performing QC testing, and documenting CQC activities related to the Project. The CQC Consultant activities are to verify that the materials and workmanship of the various components of the Project meet the requirements of the Design Documents. Specific details of the CQC Consultant's role and responsibilities, CQC activities, and required material testing, will be provided in the Design Documents.

3.2.2 Qualifications

The minimum qualifications of the CQC Consultant will be as set forth in the Design Documents. In summary, the CQC Consultant will be experienced in the CQC of earthwork, geosynthetics, piping systems, and other activities required for the Project. The CQC Consultant will possess the necessary equipment and personnel to conduct the CQC activities specified in the Design Documents; and will be experienced in the preparation and/or review of CQC documentation including manufacturer and supplier documentation, field documentation, field testing procedures, and laboratory testing procedures and results. The CQC Consultant organization will be led by the CQC Engineer, who will be a Professional Engineer registered to practice in the state of Georgia.

Prior to construction, the CQC Consultant will be required to submit its qualifications and QA/QC procedures to the CQA Consultant and GPC for review and comment prior to the commencement of the Project.

3.3 EARTHWORK LABORATORY

3.3.1 Definition

The Earthwork Laboratory is a party of the CQC Consultant and will be responsible for conducting CQC geotechnical laboratory testing in accordance with standards referenced in the Design Documents and this CQA Plan. The testing results generated by the Earthwork Laboratory will be used by the CQC Consultant to verify compliance of the earthwork with the Design Documents and this CQA Plan.

3.3.2 Qualifications

The minimum qualifications of the Earthwork Laboratory will be set forth in the Design Documents. In summary, the Earthwork Laboratory will be experienced in testing of soils and CCR using methods in accordance with American Society of Testing and Materials (ASTM) and other applicable soil test standards. The Earthwork Laboratory will be capable of providing test results within a maximum of seven (7) working days of receipt of samples, except for those tests that require longer to perform, and will maintain that capability throughout the duration of the earthwork construction.

Prior to construction, the Earthwork Laboratory will be required to submit their qualifications and QA/QC procedures to the CQA Consultant and GPC for review and comment prior to the commencement of the Project.

3.4 GEOSYNTHETICS LABORATORY

3.4.1 Definition

The Geosynthetics Laboratory is a party of the CQC Consultant and will be responsible for conducting tests on samples of geosynthetic materials used in the construction in accordance with standards referenced in the Design Documents and this CQA Plan. The testing results generated by the Geosynthetics Laboratory will be used by the CQC Consultant to verify compliance of the geosynthetic materials with the Design Documents and this CQA Plan.

3.4.2 Qualifications

The minimum qualifications Geosynthetics Laboratory will be set forth in the Design Documents. In summary, the Geosynthetics Laboratory will be currently accredited by the Geosynthetic Research Institute (GRI) or be approved by the Certifying CQA Engineer and GPC and have experience in testing geosynthetics to be used for the Project. The Geosynthetics Laboratory will be familiar with ASTM and other applicable geosynthetic test standards. The Geosynthetics Laboratory will be capable of providing destructive test results for geomembrane field seams within 24 hours of receipt of samples and will maintain that capability throughout the duration of geosynthetic material installation.

Prior to construction, the Geosynthetics Laboratory will be required to submit their qualifications and QA/QC procedures to the CQA Consultant and GPC for review and comment prior to the commencement of the Project.

3.5 DESIGN ENGINEER

The Design Engineer is the engineer-of-record under whose direction the AP-1 Closure Design was prepared. The Design Engineer will be a Professional Engineer registered in the state of Georgia. The Design Engineer will be responsible for:

- approving all design and specification changes and making design clarifications that may be required during construction;
- assisting the Construction Manager in reviewing and approving the Contractor's shop drawings and submittals, as necessary;
- periodically visiting the site during construction and attending the project coordination meetings, as required, to verify conformance with the Design Documents and this CQA Plan; and
- discussing and interpreting all elements of the design and having the authority to recommend changes or modifications to the Design Documents for approval by GPC and GA EPD, as required.

The CQA Consultant and Design Engineer may be from the same organization.

3.6 SURVEYOR

The Surveyor is the party acceptable to GPC and retained by the Contractor, who will be responsible for performing surveying activities and issuing survey products in accordance with the Design Documents, and for signing and sealing the construction survey record drawings. The Surveyor will be a State of Georgia licensed Professional Land Surveyor, with personnel experienced in the provision of surveying services and their detailed documentation. GPC may also retain a third-party surveyor, having similar qualifications, to perform verification surveys.

3.7 CONSTRUCTION MANAGER

The Construction Manager is an individual, appointed by GPC, who will serve as the owner’s representative and who will be responsible for overall management of the construction Project. The Construction Manager will give direction to the Contractor. The CQA Consultant will provide the Construction Manager with notifications, reports, and monitoring logs as requested and as described further throughout this CQA Plan.

4. DOCUMENTATION

4.1 OVERVIEW

The CQA Consultant will prepare and retain necessary documentation related to the CQA monitoring activities performed, including review and evaluation of all CQC daily reports and other submittals provided by the CQC Consultant. The CQA Site Manager will provide these records to the Construction Manager as requested. The CQA Site Manager will also maintain a complete file of the Design Documents, CQA Plan, Contractor's QC Plan(s), checklists, test procedures, daily field reports, QC data sheets and logs, and other pertinent design, construction, and CQA documentation at the site.

4.2 DAILY RECORD KEEPING

The CQA Consultant's daily reporting procedures will include: (i) daily field report; (ii) monitoring logs; (iii) photographs; and (iv) when appropriate, non-conformance and corrective measures reports.

4.2.1 Daily Field Reports

The CQA Consultant's daily field reports will include the following information as applicable:

- date, project name, location, and other pertinent project identifiers;
- weather conditions;
- site equipment and personnel (including the CQA personnel);
- summary on meetings held and their results;
- a list of off-site materials received, including a list of all QC documentation received;
- process description(s) and location(s) of construction activities underway during the time frame of the report;
- descriptions and specific locations of areas, of work being tested and/or observed and documented;
- descriptions, maps, or sketches of locations where tests and samples were taken;
- a narrative summary of field test results;

- decisions made regarding acceptance of work, and/or corrective actions to be taken in instances of substandard testing results; and

- reference to data sheets and non-conformance reports used to substantiate the non-conformances described above.

4.2.2 Monitoring Logs

The CQA Consultant will record monitoring observations on appropriate monitoring logs. The CQA Consultant will use the monitoring logs to track completeness of the required CQA activities. Any corrections to the monitoring logs will be a single line cross-out initialed and dated by the CQA personnel responsible for the correction.

The CQA Consultant's monitoring logs will include the following information as applicable:

- project specific information such as project name, location, and other pertinent project identifiers;

- the date the CQA activity was performed;

- a unique identifying sheet number for cross-referencing and document control;

- description or title of the CQA activity, along with the location and type of activity;

- recorded observation;

- results of the CQA activity and comparison with specification requirements (pass/fail); and

- the initials or signature of personnel involved in CQA inspection activity.

The CQA Consultant will maintain separate monitoring logs to track and catalog all QC information received from the CQC Consultant and to document conformance or nonconformance of the information with the requirements of the Design Documents. The CQA Consultant may also maintain a log of periodic photographic documentation obtained as a pictorial record of construction.

4.2.3 Non-conformance and Corrective Measures Reporting

A non-conformance is defined herein as material or workmanship that does not meet the specified requirement(s) contained in the Design Documents. The CQA

Consultant will prepare non-conformance and corrective measures reports as needed and will cross-reference the reports to specific daily field reports or monitoring logs where the non-conformance was identified. The reports will include the following information, as applicable:

- a unique identifying sheet number for cross-referencing and document control;
- detailed description of the problem;
- location of the problem;
- probable cause;
- how and when the problem was located;
- estimation of how long problem has existed;
- suggested corrective measures;
- documentation of corrections (referenced to test data sheets);
- suggested methods to prevent similar problems; and
- signature of the appropriate CQA field technicians and the CQA Site Manager.

The CQA Consultant will inform the Construction Manager in writing of any significant recurring non-conformance with the Design Documents or CQA Plan. It will be the responsibility of the Construction Manager to direct the Contractor to make appropriate changes in materials or procedures to correct the non-conformance. The CQA Consultant will document the corrective actions taken to mitigate non-conformances.

4.3 CQA CERTIFICATION REPORT

At the completion of construction phases, the CQA Consultant will provide GPC with a final CQA Certification Report pertaining to each construction phase, for submittal to GA EPD. This report will acknowledge that: (i) the work has been performed in compliance with the Design Documents and this CQA Plan; (ii) physical sampling and testing has been conducted with appropriate standards and at pre-defined frequencies; (iii) the Contractor's and Manufacturer's CQC documentation is in conformance with the submittal requirements and technical specifications; and (iv) the test results met the minimum requirements defined in the Design Documents, the permit, and this CQA Plan.

At a minimum, the CQA Certification Report will include:

- summary of CQA activities;
- daily field reports;
- monitoring logs;
- QC test data sheets including sample locations;
- QC certifications and laboratory test results;
- non-conformance and corrective measures reports;
- documentation of design clarifications or revisions; and
- a summary statement indicating compliance with the Design Documents and any approved changes, signed and sealed by the CQA Certifying Engineer.

The record drawings, which include scaled drawings depicting the locations and details pertaining to the extent of construction (e.g., depths, plan dimensions, elevations, soil component thicknesses, etc.), and a geomembrane panel drawing will also be included as part of the final CQA Certification Report.

5. EARTHWORK

5.1 INTRODUCTION

CQA monitoring will be performed during earthwork construction. This earthwork will include: (i) general earthwork for preparation of subgrade and installation of dikes, channels, roads, ditches, etc.; (ii) installation of granular materials such as sand, gravel, base aggregate, and riprap; (iii) installation of soil components of the final cover system. Minimum acceptance criteria to be used for evaluation of acceptability of the various earthwork components are identified in Appendix A of this CQA Plan.

5.2 RECORD DRAWINGS AND AS-BUILT SURVEYS

During construction of the earthwork components, the CQA Consultant will routinely review record drawings submitted by the Contractor. Prior to the placement of successive soil or geosynthetic layers, the CQA Consultant will review as-built surveys that indicate compliance of the preceding layer thickness, limits, and grades.

5.3 SUBGRADE

During construction, the CQA Consultant will monitor and document subgrade preparation to confirm that a firm and smooth surface free of vegetation and other deleterious materials is achieved. Material placed to achieve design grades will be

monitored by the CQA Consultant to verify that the subgrade material and fill placement, grading, and compaction complies with the Design Documents.

It will be the responsibility of the CQC Consultant to delineate any areas of non-conformance and observe their mitigation to verify that acceptable results are achieved.

5.4 CONFORMANCE OBSERVATIONS AND TESTING

5.4.1 CQA Conformance Observations

The CQA Consultant will observe the earthwork components to verify they are uniform and conform to the requirements of the Design Documents. It's expected that most soils needed for the project will come from the on-site source near the contractor laydown area. For soil materials obtained from this on-site source, visual inspections will be performed by the CQA Consultant prior to the materials being used. Should soils need to be obtained from off-site borrow sources, the CQA Consultant will confirm those sources hold appropriate permits. Visual inspection may be performed by the CQA Consultant at off-site borrow source locations. Borrow area inspections may also be utilized by the CQA Consultant to verify that only suitable soil materials are transported to the site.

The CQA Consultant will confirm that granular materials (i.e., sand, gravel, base aggregate, and riprap) are certified by the Contractor's supplier to meet the requirements of the material type shown on the Design Documents and are free of contamination. All materials failing to comply with conformance standards will be rejected for use at the site.

Initial on-site evaluation of various soil types by CQA personnel during construction will be largely by visual and manual methods; therefore, the CQA personnel will be experienced with visual and manual soil classification procedures.

5.4.2 QC Conformance Test Methods and Frequencies

Conformance testing to evaluate the suitability of soil and granular materials during construction will be performed by the CQC Consultant in accordance with the current ASTM or other applicable test procedures and at the minimum frequencies indicated in the tables for each material type, as presented in Appendix A.

The CQA Consultant will review for conformance all CQC Consultant QC test results related to the foregoing activities. The CQA Consultant may also conduct independent verification QA testing if deemed necessary by the CQA Certifying Engineer.

5.5 CONSTRUCTION MONITORING

During installation of the earthwork components, the CQA Consultant will observe and document the earthwork components to verify they are installed in accordance with the requirements of the Design Documents and this CQA Plan. The CQA Consultant will also evaluate the procedures, methods, and equipment used by the Contractor to install the earthwork components. This will include visual observation and documentation of the Contractor's earthwork activities for the following:

- changes in soil consistency;
- thickness of lifts as loosely placed and compacted;
- soil conditioning prior to placement including general observations regarding moisture distribution, clod size, etc.;
- condition of final surfaces;
- placement methods which may damage or cause displacement or wrinkling of geosynthetics;
- the action of the compaction and heavy hauling equipment on the construction surface (sheepsfoot penetration, pumping, cracking, rutting, etc.);
- the number of passes used to compact each lift; and
- desiccation cracks or the presence of ponded water.

5.6 PERFORMANCE TESTING

Performance tests that are used to evaluate the suitability of in-place constructed soil and granular components will be performed by the CQC Consultant in accordance with the current ASTM or other applicable test procedures and at the minimum frequencies indicated in the tables for each material type, as presented in Appendix A.

The CQA Consultant will review for conformance all CQC Consultant QC test results related to the foregoing activities. The CQA Consultant may also conduct independent verification QA testing if deemed necessary by the CQA Certifying Engineer.

5.7 DEFICIENCIES

If a deficiency (i.e., non-conformance of the materials or workmanship with the requirements of the Design Documents) is discovered in the earthwork construction, the CQC Consultant will assess the extent and nature of the deficiency by performing additional tests, observations, review of records, or other means that the CQC Consultant

deems appropriate. If the defect is related to adverse site conditions, such as overly wet soils or surface desiccation, the CQC Consultant will define the limits and nature of the defect.

If the deficiency cannot be resolved by the Contractor immediately or as soon as practical after identification, the CQC Consultant will notify the CQA Site Manager and will schedule appropriate re-tests for after the work deficiency is corrected.

The CQA Consultant will verify that:

- the Contractor has corrected all noted deficiencies before any additional work can be performed in the area of the deficiency; and
- if a specified criterion cannot be met because of site-specific reasons or unusual weather conditions hindering the work, the Contractor will submit suggested solutions or alternatives to the Design Engineer and Construction Manager for review.

5.8 DOCUMENTATION

CQA monitoring observations will be documented by the CQA Consultant on forms specifically designed for this purpose. Reports and forms will be submitted to the Construction Manager.

6. CCR DREDGING AND PLACEMENT

6.1 INTRODUCTION

This section describes the construction oversight activities that will be performed by the CQA Consultant to verify the removal of CCR to the extents and grades shown on the Design Documents.

In addition to the activities listed in the below subsections, the CQA Consultant will photograph the Work being conducted and document the following information while they are onsite:

- type of equipment and number of personnel onsite;
- current work being performed;
- QC checks performed by Contractor;
- general observations of the Work; and

- notes explaining any deviations from the Design Documents or Contractor's Work Plan and the proposed resolutions.

6.2 DREDGING AND VERIFICATION PROTOCOL

CCR from AP-1 will be dredged, either hydraulically or mechanically, and transported to the closure footprint. CCR removal activities will be observed and documented by the CQC Consultant. The CCR in AP-1 will be dredged to the bottom CCR plus a minimum 6-inches of additional soil. The Contractor will be allowed an additional 6-inches of soil for overdredge allowance, for a total removal of 6-12 inches of soil below the bottom of CCR. Removal confirmations will be made with reference to a 200-foot by 200-foot alphanumeric grid system established for the closure project so that each grid location is assigned a unique label for reference and documentation purposes. The following CCR removal verification protocol will be conducted:

- Multibeam hydrographic surveys will be conducted throughout the work (before dredge [BD] and after dredge [AD]) to track and verify dredging progress. The AD survey will be utilized to develop the bathymetric surface denoting the bottom of CCR across AP-1. These surveys will be performed in accordance with the United States Army Corps of Engineers Hydrographic Surveying Engineer Manual. The CQA Consultant will review all surveys to calculate dredge volumes and final elevations and to verify that dredging is performed as specified depths.

- The dredged surface will be jointly observed and documented via collection of soil samples using hand augers, drop cores, vibracores, or another approved method to confirm removal of visible CCR by a representative of GPC Environmental Affairs and by the CQA Consultant. At a minimum frequency of one per 200-foot grid, using the approximate centers of the 200-foot by 200-foot project grid system, the cores will be photographed by the CQA Consultant.

- Following the CQA Consultant's approval, concurrence by GPC Environmental Affairs, and completion of the CCR-soil interface survey, dredging will continue by removing at least six inches of additional soil (residuum) underlying the bottom of CCR. Verification of removal thicknesses will be performed by the Surveyor by surveying the excavated area and comparing the final elevations to the surveyed bottom-of-CCR elevations. If excavation depths are found to be less than six inches by survey (provided that competent bedrock has not been encountered), the affected area(s) of the dredged surface will be jointly observed and documented consistent with the procedures in the second bullet point above. The CQA Consultant will confirm that the area has been re-excavated and re-surveyed and that the work conforms with the Design Documents.

6.3 CCR PLACEMENT

The CQA Consultant will monitor the following activities related to CCR placement. CCR from the dredging operations will be conveyed to the Site closure footprint using floating pipes or by other means, methods, and techniques described in the Contractor's Work Plan. The CQA Consultant will monitor any field pilot studies required by the Design Documents to evaluate the optimum CCR placement methods (i.e., geotextile tube use, windrow use, filter press use, lift thickness, optimum moisture window, type of compaction equipment, and number of passes). Compacted CCR will be placed in a manner such that it is firm and unyielding. It is generally expected that the compacted CCR will be specified to 95 percent of the standard Proctor and plus three or minus three percent of optimum moisture content. The compaction criteria may be further refined during construction with the approval of the Design Engineer and CQA Consultant. Note that specification for the standard Proctor and moisture content are only for compacted CCR. Should geotextile tubes be utilized to dewater dredged CCR and be left in place, the stability and settlement of the stacked geotextile tubes with dewatered CCR will be evaluated and approved by the Design Engineer and CQA consultant. Typically, conventional compaction criteria cannot be applied to stacked geotextile tubes; however, well established procedures for geotextile tube dewatering and stacking will be utilized to ensure stability and settlement to meet project requirements. The CQA Consultant will also monitor CCR placement for conformance with the Design Documents, including:

- earthwork grading and preparation of pads for geotextile tube placement;
- geomembrane lining for geotextile tube pads will be monitored in accordance with the geomembrane requirements set forth in this CQA Plan;
- Contractor's means, methods, and techniques for filling geotextile tubes in accordance with the Contractor's Work Plan;
- lift thicknesses and placement of CCR in relatively horizontal lifts;
- CCR surface being firm and unyielding after several passes of the compaction equipment;
- grading of the working surface in such a way to minimize stormwater run-on and to route water from the consolidation area into the forebay;
- sealing of the surface to the extent possible at the end of each day's activities; and
- scarification of the sealed CCR surface prior to the placement of the next lift to promote lift bonding.

7. DEEP SOIL MIXING (DSM)

7.1 INTRODUCTION

This section addresses CQA for the DSM construction. The following CQA activities are discussed in the remainder of this section:

- pre-construction qualifying of material sources;
- pre-construction material conformance testing;
- field evaluation/monitoring of construction implementation;
- field sample collection and laboratory testing;
- material performance testing; and
- deficiencies, problems, and repairs.

7.2 PRE-CONSTRUCTION QUALIFYING OF MATERIAL SOURCES

The materials that require pre-construction qualifications will be based on the final DSM mix design and may include: (i) bentonite, (ii) slag cement, (iii) Portland cement, and (iv) mix water. Prior to construction, the Contractor will provide the CQA Consultant with the following information, as applicable to the DSM mix design:

- Bentonite: copies of manufacturer's test reports on bentonite powder tested in accordance with API 13A, Section 5, indicating material meets or exceeds the criteria specified in the Technical Specifications;
- Slag Cement: copies of manufacturer's test reports indicating material meets or exceeds meets or exceeds the criteria specified in the Technical Specifications;
- Portland Cement: copies of manufacturer's test reports indicating material meets or exceeds the criteria specified in the Technical Specifications; and
- Mix Water: copies of test data and treatment performed by the Contractor in accordance with the Technical Specifications, if required, indicating mix water meets or exceeds the criteria specified in the Technical Specifications.

CQA personnel will examine the Contractor's submittals to verify the work represented by the submittals meet or exceed the requirements specified in the Technical Specifications. CQA personnel will report deviations from the applicable requirements to the Design Engineer, the Project Construction Manager, and the Contractor. The

Contractor will be required to correct identified deficiencies and re-submit documentation of the correction to CQA personnel for review and confirmation.

Additionally, CQA personnel will review the Contractor's material supply/ transportation documentation showing that the materials delivered to the site are of type and quality specified and identified in Design Documents. CQA personnel will field check the material supply (e.g., 4,000 lb. sacks or tank trucks) to verify that it matches the delivery documentation.

7.3 PRE-CONSTRUCTION MATERIAL CONFORMANCE TESTING

Conformance sampling of bentonite, slag cement, Portland cement, and mix water is not required unless requested by the Owner's Representative, CQA Consultant, or Design Engineer. CQA personnel will review the Contractor's submittals to confirm compliance with the Design Documents.

7.4 FIELD EVALUATION/MONITORING OF CONSTRUCTION IMPLEMENTATION

CQA personnel will periodically monitor the Contractor's material storage and grout and slurry batching process. CQA personnel will document the type of equipment and methods used by the Contractor. Results of monitoring and documentation will be included in CQA daily reports. CQA personnel will notify the Owner's Representative and Design Engineer if monitoring indicates poor or unacceptable grout and/or slurry mixing operations.

QC Conformance testing of DSM mixes will be the responsibility of the Contractor. Conformance testing of grout and/or slurry will be in accordance with the procedures specified the Contractor's Work Plan. CQA personnel will observe the Contractor measure and record grout and/or slurry density in accordance with API 13B-1 at least twice per day during grout and/or slurry production. Additional testing may be performed by CQA personnel if requested by the Owner's Representative or Design Engineer.

CQA personnel will monitor and record the following for each DSM element during construction:

- identification number and location;
- mixing time;
- mixing speed;
- penetration rate;
- auger configuration and diameter;

- mixing depth;
- verticality;
- number of mixing passes;
- grout mix data, including mix proportions and density measurements;
- grout flow rate;
- obstructions encountered;
- rotary head pressure; and
- amounts of grout (reagents and water) added to each mixed zone.

Where appropriate, CQA personnel will request and record the above data from the Contractor's on-board instrumentation system during construction.

Mixing time, mixing speed, and mix design will be maintained within the limits specified in the approved Contractor's Work Plan and the Design Documents.

The Contractor will collect samples from random locations as outlined in the Contractor's Work Plan. CQA personnel may request samples to be collected at additional locations if the Contractor encounters problems with maintaining mixing time, mixing speed, or mix design.

7.4.1 Field Sample Collection and Laboratory Testing

The DSM performance criteria and sampling frequency are provided in Table 7-1. Guidelines for Contractor's field sample collection include the following:

- The Contractor will provide a sampling tool capable of collecting discrete wet-grab samples to a depth equal to the maximum mixing depth. The sampling tool will collect enough DSM treated material to create sample molds for all physical tests required, typically about five (5) gallons. The sampling tool will be equipped with a mechanical or hydraulic control, which can be opened and closed from the ground surface.

- One wet-grab sample will be collected from a single DSM column for each day of production per mixing operation. Twelve (12) test cylinders will be cast for each sample taken and they will be prepared and cured in accordance to ASTM D4832. Each test cylinder will be cast in a 3-in. diameter by 6-in. high cylindrical mold. Cylinders will be tested for unconfined compressive strength (UCS) in accordance with ASTM D1633 and unit weight in accordance with

ASTM D6023. The collected samples will be tested after 7, 14, and 28 days of standard curing method for UCS and after 28 days of standard curing method for unit weight.

- Discrete wet-grab samples will be collected from the "shallow" and/or "deep" zones of the selected DSM element immediately following installation and placed into appropriate molds, in accordance with the Technical Specifications. The samples will be tamped and sealed to contain sufficient moisture and stored in a temperature-controlled space between 60 to 80 degrees Fahrenheit. The samples will be tested at the Contractor's on-site testing laboratory. CQA personnel may observe laboratory testing of the samples at any time.

- Samples will be visually inspected for color, homogeneity, unmixed soil clods greater than 6-inches in diameter, and free liquids by CQA personnel. Should the CQA personnel determine materials from any depth fail one or more of these criteria, the mixed zone will be considered not adequately mixed, and the Contractor will be instructed to re-mix the DSM element.

- The laboratory data will be made available to the CQA personnel upon completion of testing by the Contractor. If a sample does not meet the DSM performance requirements set forth in the Technical Specifications, the CQA personnel will immediately notify the Contractor. The Owner's Representative may request additional testing or require the Contractor to reprocess the element, and other elements included in the work shift of material treated, from which the failed representative sample was collected. This work will be conducted in the presence of the Owner's Representative.

7.5 MATERIAL PERFORMANCE TESTING

CQA personnel may obtain cored samples of DSM elements (in addition to wet-grab samples described earlier) to verify that the performance criteria have been achieved by the Contractor. If implemented, coring will be performed on select DSM elements at the request of the CQA Engineer and/or the Design Engineer.

Coring will occur after the soil-cement mixture has cured for at least 21 days. Full depth core sampling will be performed in accordance with ASTM D2113. The sample diameter will be at least 2 inches and core runs will be no longer than 5 feet. A split inner barrel and wireline coring tool will be required to minimize mechanical disturbance to the cores. The holes will be filled with a bentonite/cement grout or cement grout.

The core samples will be logged in the field by CQA personnel. The core samples will be prepared and packaged for transport in accordance with ASTM D5079, Section 7.5.2. Core

boxes will be photographed and documented prior to transport away from the work area. The samples will also be stored in a moisture room or an on-site curing facility.

The Design Engineer will select samples from the cores for UCS testing; additional testing may be performed at the Design Engineer's discretion. Each selected specimen will have a length to diameter ratio of 2 after trimming and end preparation. UCS testing of the cylinders will be performed in accordance with ASTM D1633 at the Contractor's on-site material testing laboratory or at an independent off-site testing laboratory.

7.6 DEFICIENCIES, PROBLEMS, AND REPAIRS

If a deficiency or noncompliance is discovered, CQA personnel will promptly evaluate the extent and nature of the defect. The extent of the deficient area will be evaluated by additional tests, observations, records review, or other means deemed appropriate.

After defining the extent and nature of a defect, CQA personnel will notify the Contractor, Owner's Representative, and the Design Engineer. The Design Engineer will evaluate the deficiency and its impact to the DSM performance (i.e. effect on the structural integrity of the containment structure). As necessary, additional assessment and/or mitigation strategies will be developed. Additional assessment may include sampling within the same DSM column and/or adjacent columns. Corrective measures may include re-drilling of the DSM column or installation of additional DSM columns surrounding the deficient column.

The Contractor will correct the deficiency to the satisfaction of the CQA personnel, Owner's Representative, and the Design Engineer. If a criterion in the Technical Specifications cannot be met, or unusual weather conditions hinder work, then the CQA personnel will develop and present the Owner's Representative and Design Engineer with alternative solutions for approval. Retests recommended by CQA personnel must verify that the deficiency has been corrected before additional work is performed by the Contractor in the area of the deficiency.

8. SHEET PILE INSTALLATION

8.1 INTRODUCTION

The CQA Consultant will monitor construction during sheet pile installation (utilized at both ends of the containment structure to tie into existing grades) to document that the work is performed in accordance with the Design Documents.

8.2 DOCUMENTATION REVIEW

Prior to delivery of sheet pile materials to the site, the Contractor will provide documentation to the Construction Manager which demonstrates that the properties of

the steel sheet piles to be used at the Site meet the requirements of the Design Documents. These submittals will include, but not be limited to, mill certificates, material dimensions, and material cross section. In addition, the Contractor will provide a Work Plan to the Construction Manager for approval detailing sheet pile installation means, methods, and techniques.

The CQA Consultant will review the documents provided by the Contractor to verify that the proposed materials and installation methods meet the minimum requirements of the Design Documents. The CQA Consultant will report any deviations from the above requirements to the Contractor, Construction Manager, and Design Engineer.

8.3 INSTALLATION QUALITY ASSURANCE

The CQA Consultant will verify the alignment, orientation, and use of the correct materials through visual observation, documentation of the materials used, and review of as-built survey of the sheet pile installation. The CQA Consultant will observe that the steel sheet piles are driven without damage and verify the proper depth is achieved by review of as-built survey. If necessary, the CQA Consultant may use a hand level, bench mark, and survey rod to perform field checks during construction.

9. CONCRETE

9.1 INTRODUCTION

The CQA Consultant will monitor Contractor's construction and testing of all concrete materials and finished products to verify compliance with the Design Documents.

9.2 INSPECTIONS

The CQA Consultant will monitor concrete workmanship to verify that the Contractor does not place concrete until foundations, forms, reinforcing steel, pipes, conduits, sleeves, anchors, hangers, inserts, and other work required to be built into concrete has been inspected and approved by the CQA Consultant and Construction Manager.

9.3 FIELD QUALITY CONTROL TESTING

QC Conformance testing of placed concrete will be the responsibility of the Contractor. The concrete test program will be developed as part of detailed design.

The CQA Consultant will review for conformance all QC test results related to the foregoing activities. Any nonconformances will be reported to the Contractor and Construction Manager.

10. GEOMEMBRANE AND CLOSURETURF®

10.1 INTRODUCTION

The CQA Consultant will review the QC documentation and destructive seam testing results and will monitor the installation of geomembranes to verify that the Manufacturer's specifications and the requirements of the Design Documents and this CQA Plan are met. These procedures will also be followed by the CQA Consultant during installation of the geomembrane component of the ClosureTurf® system that may be used as an alternative final cover system.

10.2 MANUFACTURING PLANT VISIT

At the request of GPC, the CQA Consultant will visit the plant of the geomembrane Manufacturer to verify that manufacturing quality control procedures are in conformance with the Design Documents. If possible, such a visit will be performed prior to or during the manufacturing of the geomembrane rolls for the Project.

During the project-specific manufacturing plant visit, the CQA Consultant will:

- verify that the measurements of properties by the Manufacturer are properly documented, and test methods used are acceptable;
- spot-inspect the rolls and verify that they are free of holes, blisters, or any sign of contamination by foreign matter;
- review packaging and transportation procedures to verify that these procedures are not damaging the geomembrane;
- verify that all rolls are properly labeled; and
- verify that extrusion rods and/or beads manufactured for the field seaming of the geomembrane are derived from the same base resin type as the geomembrane.

Upon completion of the manufacturing plant visit, a report describing the findings and observations will be completed by the CQA Consultant and be included as an attachment to the final CQA Certification Report.

10.3 TRANSPORTATION, HANDLING, AND STORAGE

The CQA Consultant will monitor the transportation, handling, and storage of the geomembrane on the Project site. Upon delivery at the site, the Contractor, Installer, CQC Consultant, and CQA Consultant will conduct an inspection of the rolls for defects and damage. This inspection will be conducted without unrolling the materials unless defects

or damages are found or suspected in the rolled material. The CQA Consultant will indicate to the Construction Manager:

- rolls, or portions thereof, that will be rejected and removed from the site because they have severe or non-repairable flaws that may compromise geomembrane quality; and
- rolls that include minor and repairable flaws that do not compromise geomembrane quality.

The CQA Consultant will also monitor that equipment used to handle the geomembrane on-site is adequate and does not pose any risk of damage to the geomembrane during handling.

10.4 MANUFACTURER QC (MQC) TESTING AND CONFORMANCE TESTING

10.4.1 Geomembrane Material MQC Testing Requirements

The geomembrane Manufacturer will perform QC testing on the geomembrane materials and panels that will be used on this Project in accordance with the current versions of the ASTM and other applicable test procedures, and at the minimum MQC frequencies presented in the Appendix B tables corresponding to each geomembrane material type that will be used.

The CQA Consultant will review the MQC certifications and test results to verify that the Manufacturer's specifications and the requirements of the Design Documents and this CQA Plan are met. The CQA Consultant may conduct independent conformance testing if deemed necessary by the CQA Certifying Engineer.

10.4.2 Geomembrane Seam Conformance Testing Requirements

Destructive seam testing to evaluate conformance of the geomembrane seams with the requirements of the Design Documents will be performed by the CQC Consultant (using the qualified Geosynthetics Laboratory described previously) as required by the Design Documents and this CQA Plan. The testing will be performed in accordance with the current versions of the ASTM and other applicable test procedures and at the minimum frequencies presented in the Appendix B tables corresponding to each geomembrane material type that will be used.

The CQA Consultant will review the destructive seam test results to verify that the requirements of the Design Documents and this CQA Plan are met. The CQA

Consultant may conduct independent destructive seam testing if deemed necessary by the CQA Certifying Engineer.

10.4.3 Interface Shear Strength Testing Requirements

The CQC Consultant will coordinate, and the Geosynthetics Laboratory will perform, interface shear strength tests for final cover system interface configurations. Testing will be conducted at the minimum frequencies presented below for final cover system interfaces.

10.4.3.1 Final Cover System

Final cover system interface shear strength tests will be conducted in accordance with ASTM D5321 and under testing conditions prescribed in the Design Documents. Tests on the soil-geosynthetic final cover system (if used) interfaces will be conducted at a minimum frequency of one per 25 acres of final cover installation or change in product or material type. Testing on the ClosureTurf® option interface will be as prescribed in the Design Documents. Both peak and large displacement strengths will be evaluated in the tests. Cover system interface shear strength tests will include the following interfaces:

- Geomembrane with CCR;
- Geomembrane with geocomposite (not applicable for ClosureTurf® option; and
- Geocomposite with protective soil layer (not applicable for ClosureTurf® option).

10.4.4 Test Results

All MQC and conformance test results will be reviewed, accepted, and reported by the CQC Consultant before deployment of the geomembrane. The CQA Consultant will review for conformance all MQC and conformance test results related to the foregoing activities. Any non-conformance of the material properties with the requirements of the Design Documents will be reported to the Contractor and Construction Manager.

10.4.5 Test Failure

In the case of failing test results, the Contractor may request that another sample from the failing roll be re-tested. If the re-test fails or if the option to re-test is not exercised, then two isolation conformance samples will be obtained by the CQC

Consultant. These isolation samples will be taken from rolls, which have been determined by correlation with the Manufacturer's roll number, to have been manufactured prior to and after the failing roll. This method for choosing isolation rolls for testing will continue until passing tests are achieved. All rolls that fall numerically between the passing roll numbers will be rejected.

The CQA Consultant will verify that the Contractor has replaced all rejected rolls. The CQA Consultant will document all actions taken in conjunction with geomembrane conformance failures.

10.5 ANCHOR TRENCH

The CQA Consultant will monitor, verify, and document that the anchor trench has been constructed as shown in the Design Documents and meets the minimum requirements of this CQA Plan as described below. To confirm conformance with the Design Documents, the CQA Consultant will:

- monitor that the anchor trench is constructed with a slightly rounded corner where the geosynthetics enter the trench and is backfilled as soon as possible after all geosynthetics are installed;
- verify that the CQC Consultant performs in-place moisture/density testing of the compacted anchor trench backfill as required by the Design Documents;
- observe that geosynthetic materials in the anchor trench are temporarily anchored with sand bags or other suitable methods if the trench will remain open after the installation of geosynthetics;
- monitor that no loose soils are left to underlie the geosynthetics in the anchor trench and all temporary ballast (i.e., sandbags) and deleterious materials are removed from the anchor trench prior to backfilling; and
- monitor that backfilling of the anchor trench is performed using extreme care when the geomembrane is in its most contracted state to minimize wrinkling and stress concentrations.

10.6 GEOMEMBRANE PLACEMENT

10.6.1 CQA Consultant Responsibility During Placement

The CQA Consultant will monitor, verify, and document that geomembrane placement is conducted in accordance with the Design Documents and that CQC activities are performed as described in the subsections below.

10.6.2 Field Panel Identification

A field panel is a piece of geomembrane larger than approximately 10 square feet (ft2) that is to be seamed in the field, i.e., a field panel is a roll or a portion of roll to be seamed in the field. The CQC Consultant will verify that each field panel is given an "identification code" (number or letter-number) that will:

- be selected as simple and logical as possible;
- be substantially consistent with the as-built layout plan; and
- allow tracing of the Manufacturer's roll numbers to the field panel identification code.

The CQC Consultant will document the correspondence between roll numbers, factory panels, and field panel identification codes. The field panel identification code will be used for all QA/QC records.

10.6.3 Field Panel Placement

The CQC Consultant will monitor that field panels are installed substantially at the location indicated in the Installer's layout plan, as approved or modified. The CQC Consultant will record the field panel identification code, Manufacturer's roll number, location, date of installation, time of installation, and dimensions of each field panel.

The CQC Consultant will monitor that geomembrane placement does not proceed:

- at an ambient temperature below 40°F or above 104°F unless authorized by the Design Engineer; or
- during any precipitation, in the presence of excessive moisture (e.g., fog, dew), in an area of ponded water, or in the presence of excessive winds.

The CQC Consultant will monitor that the above conditions are fulfilled and that the supporting soil has not been damaged by adverse weather conditions. The CQC Consultant will monitor geomembrane deployment for conformance with the Design Documents, including that:

- the geomembrane is deployed under acceptable temperature and weather conditions;
- any equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons, or other means;

- the prepared surface underlying the geomembrane has not deteriorated since previous acceptance and is still acceptable immediately prior to geomembrane placement;

- any geosynthetic elements immediately underlying the geomembrane are clean and free of foreign objects or debris;

- all personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities that could damage the geomembrane;

- the method used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting subbase;

- the method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels);

- adequate temporary loading and/or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent uplift by wind; and

- direct contact with the geomembrane is minimized; i.e., the geomembrane is protected by geotextiles, extra geomembrane, or other suitable materials, in areas where excessive traffic may be expected.

The CQC Consultant will observe the geomembrane panels, after placement and prior to seaming, for damage. The CQC Consultant will advise the Construction Manager of any panels, or portions of panels, that should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels that have been rejected will be marked and their removal from the work area recorded by the CQC Consultant. CQA and CQC for geomembrane repairs will be in accordance with Section 10.8.

10.7 FIELD PANEL SEAMING

10.7.1 CQA Consultant Responsibility During Seaming

The CQA Consultant will monitor, verify, and document that geomembrane panel layout and field panel seaming is conducted in accordance with the Design Documents and that CQC activities are performed as described in the subsections below.

10.7.2 Panel Layout

The CQC Consultant will review the panel layout drawing previously submitted to the Construction Manager by the Installer and verify that:

- seams are generally oriented parallel to the line of maximum slope, i.e., oriented along, not across, the slope;
- the number of seams is minimized in corners and odd-shaped geometric locations;
- a seam numbering system is used that is compatible with the field panel identification numbering system and is agreed upon by the CQC Consultant and the Installer prior to any seaming; and
- the panel layout is consistent with accepted state of practice.

10.7.3 Seaming Equipment and Products

The CQC Consultant will verify that only extrusion welding and fusion welding are used for field seaming. The CQC Consultant will document that any alternate process proposed by the Installer is reviewed and approved by the Design Engineer and Construction Manager.

The CQC Consultant will verify that no geomembrane seaming is performed unless the CQC Consultant is on-site. The CQC Consultant will monitor the general seaming procedure used as follows:

- the Installer uses of seaming equipment specifically recommended by the Geosynthetics Manufacturer by make and model, and marked with an identification number;
- the Installer uses of a firm substrate such as a flat board, a conveyor belt, or similar hard surface directly under the seam overlap, if required, to achieve proper support;
- the Installer cuts fishmouths or wrinkles at the seam overlaps along the ridge of the wrinkle in order to achieve a flat overlap;
- the Installer cuts fishmouths or wrinkles, and patches any portion, where the overlap is inadequate, with an oval or round patch of the same geomembrane extending a minimum of 6 inches beyond the cut in all directions;
- the Installer/Contractor provides adequate illumination if seaming operations are carried out at night, and
- the Installer extends seaming to the outside edge of panels to be placed in the anchor trench.

10.7.3.1 Fusion Process

The CQC Consultant will monitor ambient temperatures, geomembrane surface temperatures, apparatus speed, and apparatus temperatures at appropriate intervals. The CQC Consultant will also monitor that:

- the fusion-welding apparatus is an automated, self-propelled device;
- the fusion-welding apparatus is equipped with gauges giving the applicable temperatures and welding speed;
- the number of spare operable seaming apparatus agreed by the Construction Manager are maintained on-site;
- equipment used for seaming will not damage the geomembrane;
- the seaming zone is dry and clean;
- there is sufficient overlap between panels;
- the electric generator is placed on a smooth base such that no damage occurs to the geomembrane;
- for cross seams, the edge of the cross seam is cut or ground to a smooth incline (top and bottom) prior to welding;
- an insulating material is placed beneath the hot welding apparatus after usage; and
- a movable protective layer is used, as necessary, directly below each overlap of geomembrane that is to be seamed to prevent build-up of moisture between the sheets.

10.7.3.2 Extrusion Process

The CQC Consultant will verify that the extrudate is comprised of the same resin as the geomembrane sheeting. The CQC Consultant will monitor extrudate temperatures, ambient temperatures, and geomembrane surface temperatures at appropriate intervals to document that they conform to the Design Documents. The CQC Consultant will also monitor that:

- the extrusion-welding apparatus is equipped with gauges giving the temperature in the apparatus and at the nozzle;

- the number of spare operable seaming apparatus agreed by the Construction Manager are maintained on-site;
- equipment used for seaming is not likely to damage the geomembrane;
- the seaming zone is dry and clean;
- the extruder is purged prior to beginning a seam until all heat-degraded extrudate has been removed from the barrel;
- the electric generator is placed on a smooth base such that no damage occurs to the geomembrane; and
- an insulating material is placed beneath the hot welding apparatus after usage.

10.7.4 Seam Preparation

To confirm conformance with the Design Documents, the CQC Consultant will monitor that:

- prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material;
- seams are overlapped in accordance with the requirements of the Design Documents;
- if seam overlap grinding is required, the process is completed according to the Geosynthetics Manufacturer's instructions or the Design Documents, whichever is the more stringent, prior to the seaming operation, and in a way that does not damage the geomembrane;
- the grind depth is constructed in accordance with the requirements of the Design Documents;
- grinding marks do not appear beyond the extrudate after it is placed; and
- seams are aligned with the fewest possible number of wrinkles and fishmouths.

10.7.5 Weather Conditions for Seaming

The CQC Consultant will monitor that the weather conditions for seaming are within the acceptable range, as follows:

- the ambient temperature is not below 40°F or above 104°F, unless authorized by the Design Engineer;
- geomembrane is preheated by either sun or hot air device between ambient temperatures of 40°F and 50°F prior to performing seaming; and
- geomembrane seam areas are dry and protected from rain and wind.

The CQC Consultant will verify and document that methods used by the Installer for seaming at ambient temperatures below 40°F or above 104°F will produce seams that are entirely equivalent to seams produced at ambient temperatures between 40°F and 104°F and will protect the overall quality of the geomembrane. The CQC Consultant will monitor that seaming conducted during abnormal weather conditions is performed in accordance with the methods approved by the Design Engineer.

10.7.6 Overlapping and Temporary Bonding

The CQC Consultant will monitor that:

- the panels of geomembrane have a finished overlap of a minimum of 4 inches for both extrusion and fusion welding, but in any event sufficient overlap is provided to allow peel tests to be performed on the seam;
- no solvent or adhesive is used; and
- the procedure used to temporarily bond adjacent panels together does not damage the geomembrane and specifically that the temperature of hot air at the nozzle of any spot-welding apparatus is controlled such that the geomembrane is not damaged.

10.7.7 Trial Seams

The CQC Consultant will verify that the Installer performs trial seam tests in accordance with the Design Documents. The CQC Consultant will observe and document the Installer's trial seam testing procedures. The trial seam samples will be assigned an identification number and marked accordingly by the CQC Consultant. Each sample will be marked with the date, time, machine temperature(s) and setting(s), number of seaming unit, and name of seaming technician. Trial seam samples will be maintained until destructive seam testing of the applicable seams are tested and pass.

10.7.8 Nondestructive Seam Continuity Testing

The CQC Consultant will monitor that the Installer nondestructively tests all field seams over their full length using a vacuum test unit or air pressure test (for double fusion seams only). The CQC Consultant will monitor that the Installer performs spark testing if the seam cannot be tested using the vacuum or air pressure test methods. The purpose of nondestructive tests is to check the continuity of seams. The CQC Consultant will monitor that the Installer performs continuity testing as the seaming work progresses, not at the completion of all field seaming. The CQC Consultant will:

- monitor nondestructive testing;
- document the results of the nondestructive testing; and
- inform the Contractor and Construction Manager of any non-conformance.

The CQC Consultant will monitor that the Installer performs any required seam repairs in accordance with the Design Documents. The CQC Consultant will:

- observe the repair procedures;
- observe the re-testing procedures; and
- document the results.

The seam number, date of observation, dimensions and/or descriptive location of the seam length tested, name of person performing the test, and outcome of the test will be recorded by the CQC Consultant.

10.7.9 Destructive Testing

The CQC Consultant will monitor the Installer performing destructive seam testing during the geomembrane installation. The purpose of this testing is to evaluate seam strength. The CQC Consultant will monitor that the Installer performs destructive seam testing as the seaming work progresses, not at the completion of all field seaming.

10.7.9.1 Location and Frequency

The CQC Consultant will select all destructive seam test sample locations. Sample locations will be established as follows.

- Destructive testing will be performed at a minimum frequency of one test location per 500 feet of seam length. This minimum frequency is

to be determined as an average taken throughout the entire installation. This minimum frequency will be increased for seams made outside the normal ambient temperature range of 40°F to 104°F.

- Test locations will be determined during seaming at the CQC Consultant's discretion. Selection of such locations may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential cause of imperfect welding.

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

10.7.9.2 Sampling Procedures

Destructive seam testing will be performed by the Geosynthetics Laboratory as seaming progresses in order to obtain test results prior to the geomembrane being covered by overlying materials. The CQC Consultant will:

- observe sample cutting;
- assign a number to each sample, and mark it accordingly; and
- record sample location on geomembrane panel layout drawing.

The CQC Consultant will monitor that the Installer performs repairs to all holes in the geomembrane resulting from destructive seam test sampling in accordance with repair procedures described in the Design Documents. In addition, the CQC Consultant will monitor that the Installer performs non-destructive testing as described in this Section to ensure the continuity of the new seams.

10.7.9.3 Size of Samples

The CQC Consultant will monitor that at a given sampling location, two types of samples (field test samples and laboratory test samples) are taken:

- First, a minimum of two field samples or test strips are taken for field testing. Each of these test strips are approximately 1 inch wide by 12 inches long, with the seam centered parallel to the width. The distance between these two specimens is approximately 42 inches. If both specimens pass the field test described in this Section, a second

full laboratory destructive sample is taken for testing by the Geosynthetics Laboratory.

- The full destructive sample is located between the two field test strips. The sample is approximately 12 inches wide by 42 inches long with the seam centered lengthwise. The sample is cut into three parts and distributed as follows:

- one approximately 12 inches by 12 inches portion to the Installer;

- one approximately 12 inches by 12 inches portion to the Construction Manager for archive storage; and

- one approximately 12 inches by 18 inches portion for Geosynthetics Laboratory testing.

10.7.9.4 Field Testing

The CQC Consultant will monitor that the test strips are tested in the field, for peel adhesion, using a gauged tensiometer by the Installer. In addition to meeting the strength requirements outlined in Appendix B, the CQC Consultant will monitor that all specimens exhibit a film tear bond and do not fail in the weld. If any field test sample fails to meet these requirements, the destructive sample has failed.

The CQC Consultant will witness all field tests and mark all samples and portions with their number. The CQC Consultant will also log the date, number of seaming unit, seaming technician identification, destructive sampling, and pass or fail description.

10.7.9.5 Geosynthetics Laboratory Testing

Destructive test samples will be tested by the Geosynthetics Laboratory. Testing will include "Bonded Seam Strength" and "Peel Adhesion". The minimum acceptable values to be obtained in these tests are presented in Appendix B. At least five specimens will be tested for each test method (i.e., five for peel and five for shear). Specimens will be selected alternately by test from the samples (i.e., peel, shear, peel, shear, etc.). Both the inside and outside tracks of the double track fusion seams will be tested for peel adhesion. A passing test will meet the minimum required values in Appendix B.

The Geosynthetics Laboratory will provide test results no more than 24 hours after they receive the samples. The CQC Consultant will review

laboratory test results as soon as they become available and report the results to the Construction Manager.

10.7.9.6 Procedures for Destructive Test Failure

The CQC Consultant will monitor that the following procedures apply whenever a sample fails a destructive test, whether that test was conducted in the field or by the Geosynthetics Laboratory. The CQC Consultant will monitor that the Installer follows one of the two options below:

- The Installer can reconstruct the seam (e.g., remove the old seam and re-seam) between any two passed destructive test locations or between points judged by the CQC Consultant to represent conditions of the failed seam (e.g., a tie-in seam or a seam made by the apparatus and/or operator used in the failing seam); or

- The Installer can trace the welding path to an intermediate location a minimum of 10 feet from the point of the failed test in each direction and take a small sample for additional field testing in accordance with the destructive test procedure at each location. If these additional isolation samples pass the field test, then full laboratory samples are taken at both locations. If these laboratory samples meet the specified strength criteria, then the seam is reconstructed between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed or repaired.

The CQC Consultant will monitor that all failed seams are bound by two locations from which samples passing laboratory destructive tests have been taken or the entire seam is reconstructed and re-tested. In cases exceeding 150 feet of reconstructed seam, a sample will be taken from the reconstructed portion of the seam and must pass destructive testing. The CQC Consultant will observe that any repairs are made in accordance with Section 10.8. The CQC Consultant will document all actions taken in conjunction with destructive test failures.

10.8 DEFECTS AND REPAIRS

10.8.1 CQA Consultant Responsibility for Monitoring Defects and Repairs

The CQA Consultant will monitor, verify, and document that geomembrane defects are addressed and repairs are made in accordance with the Design

Documents and that CQC activities are performed as described in the subsections below.

10.8.2 Identification

All seams and non-seam areas of the geomembrane will be examined by the CQC Consultant for identification of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane will be clean at the time of examination. The CQC Consultant will request that the Contractor broom or wash the geomembrane surface if the amount of dust or mud inhibits examination.

10.8.3 Repair Procedures

The CQC Consultant will monitor that any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, is repaired by the Installer in accordance with the Design Documents. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure, materials, and equipment will be agreed upon between the Installer and CQC Consultant.

In addition, the following conditions will be monitored by the CQC Consultant:

- surfaces of the geomembrane which are to be repaired are abraded no more than one hour prior to the repair;
- all surfaces are clean and dry at the time of the repair;
- patches or caps extend at least 6 inches beyond the edge of the defect, and all corners of patches are rounded with a radius of at least 3 inches; and
- the geomembrane below large caps is appropriately cut to avoid water or gas collection between the two sheets.

10.8.4 Verification of Repairs

Each repair will be numbered and logged by the CQC Consultant. The CQC Consultant will monitor that each repair is non-destructively tested by the Installer using approved methods. Repairs which pass the non-destructive test will be taken as an indication of an adequate repair. Large caps may be of sufficient extent to require destructive test sampling, at the discretion of the CQC Consultant or as specified in Appendix B. The CQC Consultant will observe all non-

destructive testing of repairs and will record the number of each repair, date, and test outcome.

10.9 GEOMEMBRANE AND CAP SYSTEM ACCEPTANCE

In accordance with the Design Documents, the Contractor retains all responsibility for the geosynthetics until acceptance by the Construction Manager. The terms and conditions for geomembrane and cover system acceptance are described in the Design Documents.

10.10 MATERIALS IN CONTACT WITH THE GEOMEMBRANE

The procedures outlined in this section are intended to allow the CQA Consultant to verify that the installation of materials in contact with the geomembrane do not cause damage to it.

10.10.1 Soils

The CQA Consultant will monitor that the Contractor conforms with the requirements of the Design Documents and takes all necessary precautions to verify that the geomembrane is not damaged during its installation, during the installation of other components of the final cover systems, or by other construction activities. The CQA Consultant will monitor the following:

- placement of soil materials above the geomembrane and that soils are not placed at an ambient temperature below 40°F or above 104°F unless otherwise approved by the Design Engineer and Construction Manager;
- soil and riprap placement operations above the geomembrane are performed by the Contractor to minimize wrinkles in the geomembrane;
- equipment used for placing soil and riprap are not driven directly on the geomembrane or other geosynthetic layers;
- a minimum soil or riprap thickness of 1 foot is maintained between a low ground pressure (LGP - having a maximum ground pressure of 5 pounds per square inch [psi]) track-mounted dozer and the geomembrane;
- a minimum soil and riprap thickness of 3 feet is maintained between rubber-tired or non-low ground pressure tracked vehicles and the geomembrane during construction activities; and
- soil thickness is greater than 3 feet in heavily trafficked areas such as access ramps.

10.10.2 Appurtenances

The CQA Consultant will monitor that:

- installation of the geomembrane in appurtenant areas and connection of geomembrane to appurtenances (e.g., concrete pads or concrete embedment strips at geomembrane termination) are made in accordance with the Design Documents;
- extreme care is given by the Installer when seaming around appurtenances since neither non-destructive nor destructive testing may be feasible in these areas; and
- the geomembrane is not visibly damaged when making connections to appurtenances.

11. GEOTEXTILES

11.1 INTRODUCTION

The CQA Consultant will review the QC documentation and will monitor the installation of geotextile layers to verify that the Manufacturer's specifications and the requirements of the Design Documents and this CQA Plan are met.

11.2 TRANSPORTATION, HANDLING, AND STORAGE

The CQA Consultant will monitor the transportation, handling, and storage of the geotextile on the Project site. The CQA Consultant will verify that the geotextile is protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions.

The CQA Consultant will monitor that transportation, handling, and storage of geotextile conforms with the Design Documents, including:

- handling of the geotextile rolls is performed in a competent manner such that damage does not occur to the geotextile or to its protective wrapping;
- geotextile rolls are not stacked upon one another to the extent that deformation of the core occurs or to the point where accessibility can cause damage in handling;
- geotextile rolls are stacked in such a way that access for conformance sampling is possible;
- protective wrappings are removed less than one hour prior to unrolling the geotextile;

- after unrolling, a geotextile is not exposed to ultraviolet light for more than 30 calendar days;
- outdoor storage of geotextile rolls does not exceed the Manufacturer's recommendations or longer than six months, whichever is less;
- for storage periods longer than six months, a temporary enclosure is placed over the rolls, or they are moved to an enclosed facility; and
- the location of temporary field storage is not in areas where water can accumulate, and the rolls are elevated off the ground to prevent contact with ponded water.

Upon delivery at the site, the Contractor, Installer, CQC Consultant, and CQA Consultant will conduct an inspection of the rolls for defects and damage. This inspection will be conducted without unrolling the materials unless defects or damages are found or suspected. The CQA Consultant will indicate to the Construction Manager:

- rolls, or portions thereof, that will be rejected and removed from the site because they have severe flaws; and
- rolls that include minor repairable flaws that do not compromise geotextile functionality.

The CQA Consultant will also monitor that equipment used to handle the geotextiles on-site is adequate and does not pose any risk of damage to the geotextiles during handling.

11.3 MANUFACTURER QC (MQC) TESTING AND CONFORMANCE TESTING

11.3.1 Geotextile Material MQC Testing Requirements

The geotextile Manufacturer will perform QC testing on the geotextile materials that will be used on this Project in accordance with the current versions of the ASTM and other applicable test procedures, and at the minimum MQC frequencies presented in the Appendix C tables corresponding to each geotextile material type that will be used.

The CQA Consultant will review the MQC certifications and test results to verify that the Manufacturer's specifications and the requirements of the Design Documents and this CQA Plan are met. The CQA Consultant may conduct independent conformance testing if deemed necessary by the CQA Certifying Engineer.

11.3.2 Test Results

All MQC and conformance test results will be reviewed, accepted, and reported by the CQC Consultant before deployment of geotextiles. The CQA Consultant will review for conformance all MQC and conformance test results related to the foregoing activities. Any non-conformance of the material properties with the requirements of the Design Documents will be reported to the Contractor and Construction Manager.

11.3.3 Test Failure

In the case of failing test results, the Contractor may request that another sample from the failing roll be re-tested. If the re-test fails or if the option to re-test is not exercised, then two isolation conformance samples will be obtained by the CQC Consultant. These isolation samples will be taken from rolls that have been determined by correlation with the Manufacturer's roll number to have been manufactured prior to and after the failing roll. This method for choosing isolation rolls for testing will continue until passing tests are achieved. All rolls that fall numerically between the passing roll numbers will be rejected. The CQA Consultant will verify that the Contractor has replaced all rejected rolls. The CQA Consultant will document all actions taken in conjunction with geotextile conformance failures.

11.4 PLACEMENT

The CQA Consultant will monitor, verify, and document that geotextile placement is conducted in accordance with the Design Documents and that CQC activities are performed as described below.

The CQC Consultant will monitor the placement of all geotextiles to verify that they are not damaged in any way, and the following requirements of the Design Documents are met:

- on slopes, the geotextiles are securely anchored in the anchor trench and then deployed down the slope in such a manner as to continually keep the geotextile in tension;

- in the presence of wind, all geotextiles are weighted with sandbags or equivalent; such sandbags are installed during placement and will remain until replaced with earth cover material;

- trimming of the geotextiles are performed using only an upward cutting hook blade and special care is given to protect other materials from damage which could be caused by the cutting of the geotextiles;

- the Installer is taking necessary precautions to prevent damage to underlying layers during placement of the geotextile;
- during placement of geotextiles, care is given not to entrap stones, excessive dust, or moisture that could generate clogging of drains or filters; and
- a visual examination of the geotextile is carried out over the entire surface, after installation, to verify that no potentially harmful foreign objects, (e.g., stones, sharp objects, small tools, sandbags, etc.) are present.

11.5 SEAMS AND OVERLAPS

The CQA Consultant will monitor, verify, and document that geotextile seams and overlaps are in accordance with the Design Documents and that CQC activities are performed as described below.

The CQC Consultant will monitor that the following requirements of the Design Documents are met:

- all geotextiles are continuously sewn (i.e., no spot sewing);
- geotextiles are overlapped 6 inches prior to seaming;
- no horizontal seams are constructed on side slopes that are steeper than 10 horizontal to 1 vertical (i.e., seams to be aligned along, not across the slope), except as part of a patch;
- sewing uses polymeric thread with chemical and ultraviolet resistance properties equal to or exceeding those of the geotextile; and
- seams are sewn using a single row Stich Type 401 two-thread chain stitch.

11.6 REPAIRS

The CQA Consultant will monitor, verify, and document that geotextile repairs are made in accordance with the Design Documents and that CQC activities are performed as described below.

The CQC Consultant will monitor that any holes or tears in the geotextile are repaired as follows:

- For slopes steeper than 10 horizontal:1 vertical, a patch made from the same geotextile is double seamed into place (with each seam 1/4 inches to 3/4 inches apart and no closer than 1 inch from any edge) with a minimum 12-inch overlap.

Should any tear exceed 50 percent of the width of the roll, that roll is removed from the slope and replaced.

- For slopes milder than 10 horizontal:1 vertical, a patch made from the same geotextile is sewn in place with a minimum of 12-inch overlap in all directions away from the repair area.

The CQC Consultant will observe that care is given to remove any soil or other material which may have penetrated the torn geotextile, and all repairs and verify that any non-conformance with the above requirements is corrected.

11.7 PLACEMENT OF SOILS OR GRANULAR MATERIALS

The CQA Consultant will monitor, verify, and document that placement of soils or granular materials on top of geotextiles is conducted in accordance with the Design Documents and that CQC activities are performed as described below.

The CQC Consultant will monitor that the Contractor's placement of soil or granular materials on top of the geotextile is in conformance with the Design Documents, including:

- that no damage occurs to the geotextile;
- that no shifting of the geotextile from its intended position occurs and underlying materials are not exposed or damaged;
- that excess tensile stress does not occur in the geotextile;
- that equipment does not drive directly on the geotextile; and
- the Contractor uses only LGP equipment on layers less than 3-feet thick above the geomembrane and geotextile separator or cushion layer in accordance with Section 10.10.1 of this CQA Plan.

The CQC Consultant will monitor that covering of the geotextile with overlying layers is completed within 30 days of installation to prevent UV degradation and on side slopes, soil and granular layers are placed over the geotextile from the bottom of the slope upward.

12. GEOCOMPOSITE DRAINAGE LAYERS

12.1 INTRODUCTION

The CQA Consultant will review the QC documentation and will monitor the installation of the geocomposite drainage layer to verify that the Manufacturer's specifications and the requirements of the Design Documents and this CQA Plan are met.

12.2 TRANSPORTATION, HANDLING, AND STORAGE

The CQA Consultant will monitor the transportation, handling, and storage of the geocomposite on the Project site. The CQA Consultant will verify that during transportation, handling, and storage, the geocomposite is protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions.

The CQA Consultant will monitor that transportation, handling, and storage of geocomposite conforms with the Design Documents, including:

- geocomposite rolls are handled in a competent manner such that damage does not occur to the geocomposite or to its protective wrapping;
- geocomposite rolls are not to be stacked upon one another to the extent that deformation of the roll occurs or to the point where accessibility can cause damage in handling;
- geocomposite rolls are stacked in such a way that access for conformance sampling is possible;
- protective wrappings are removed less than one hour prior to unrolling the geocomposite; and
- after unrolling, a geocomposite is not exposed to ultraviolet light for more than 30 calendar days.

The CQA Consultant will monitor that outdoor storage of geocomposite rolls does not exceed the Manufacturer's recommendations or longer than six months whichever is less. For storage periods longer than six months, the CQA Consultant will monitor:

- a temporary enclosure is placed over the rolls, or they are moved to an enclosed facility;
- the location of temporary field storage is not in areas where water can accumulate; and

- rolls are elevated off the ground to prevent contact with ponded water.

Upon delivery at the site, the Contractor, Installer, CQC Consultant, and CQA Consultant will conduct an inspection of the rolls for defects and damage. This inspection will be conducted without unrolling the materials unless defects or damages are found or suspected. The CQA Consultant will indicate to the Construction Manager:

- rolls, or portions thereof, that will be rejected and removed from the site because they have severe flaws; and

- rolls that include minor repairable flaws, that do not compromise geocomposite functionality.

The CQA Consultant will also monitor that equipment used to handle the geocomposite on-site is adequate and does not pose any risk of damage to the geocomposite when used properly.

12.3 MANUFACTURER QC (MQC) TESTING AND CONFORMANCE TESTING

12.3.1 Geocomposite Material MQC Testing Requirements

The geocomposite drainage layer Manufacturer will perform QC testing on the geocomposite rolls that will be used on this Project in accordance with the current versions of the ASTM and other applicable test procedures, and at the minimum MQC frequencies as presented in Appendix D.

The CQA Consultant will review the MQC certifications and test results to verify that the Manufacturer's specifications and the requirements of the Design Documents and this CQA Plan are met. The CQA Consultant may conduct independent conformance testing if deemed necessary by the CQA Certifying Engineer.

12.3.2 Geocomposite Conformance Testing Requirements

The CQC Consultant will coordinate, and the Geosynthetics Laboratory will perform, interface shear strength tests for the final cover system interface configurations involving geocomposite drainage layer materials, as described in Section 10.4.3 of this CQA Plan.

The CQA Consultant may conduct independent conformance testing if deemed necessary by the CQA Certifying Engineer.

12.3.3 Test Results

All MQC and conformance test results will be reviewed, accepted, and reported by the CQC Consultant before deployment of geocomposites. The CQA Consultant will review for conformance all MQC and conformance test results related to the foregoing activities. Any non-conformance of the material properties with the requirements of the Design Documents will be reported to the Contractor and Construction Manager.

12.3.4 Test Failure

In the case of failing test results, the Contractor may request that another sample from the failing roll be re-tested. If the re-test fails or if the option to re-test is not exercised, then two isolation conformance samples will be obtained by the CQC Consultant. These isolation samples will be taken from rolls, that have been determined by correlation with the Manufacturer's roll number, to have been manufactured prior to and after the failing roll. This method for choosing isolation rolls for testing will continue until passing tests are achieved. All rolls that fall numerically between the passing roll numbers will be rejected. The CQA Consultant will verify that the Contractor has replaced all rejected rolls. The CQA Consultant will document all actions taken in conjunction with geocomposite conformance failures.

12.4 PLACEMENT

The CQA Consultant will monitor, verify, and document that placement of geocomposites is conducted in accordance with the Design Documents and that CQC activities are performed as described below.

The CQC Consultant will monitor the placement of all geocomposites to verify that they are not damaged in any way, and the following conditions are met:

- on slopes, the geocomposites are securely anchored in the anchor trench and then deployed down the slope in such a manner as to continually keep the geocomposites in tension;

- in the presence of wind, all geocomposites are weighted with sandbags or equivalent. Such sandbags are installed during placement and will remain until replaced with the cover material;

- trimming of the geocomposites is performed using only an upward cutting hook blade. Special care must be given to protect other materials from damage which could be caused by the cutting of the geocomposites;

- the Installer is taking necessary precautions to prevent damage to underlying layers during placement of the geocomposite;

- during placement of geocomposites, care is given not to entrap stones, soil, excessive dust, or moisture that could damage the geomembrane, generate clogging of drains or filters, or hamper subsequent drainage function; and

- a visual examination of the geocomposite is carried out over the entire surface, after installation, to verify that no potentially harmful foreign objects, (e.g., stones, sharp objects, small tools, sandbags, etc.) are present.

12.5 JOINING, SEAMS, AND OVERLAPS

The CQA Consultant will monitor, verify, and document that geocomposite joining, seaming, and/or overlaps are made in accordance with the Design Documents and that CQC activities are performed as described below.

The CQC Consultant will monitor that the geocomposites are joined, seamed, and/or overlapped in conformance with the Design Documents, including:

- the components of the geocomposite (e.g., geotextile and geonet) are seamed, joined, and overlapped to like components in adjacent geocomposites;

- lower geotextile components of the geocomposites are overlapped such that the overlap is a minimum of 4 inches. Adjacent edges of geonet component along the length of the geocomposite are overlapped a minimum 2 to 3 inches and joined by tying the geonet together with plastic fasteners or polymeric thread at a spacing recommended by the Manufacturer. Geonet for adjoining geocomposite panels (end to end) along the roll width are shingled down in direction of slope and overlapped a minimum of 12 inches;

- upper geotextile components of the geocomposites are continuously sewn (i.e., spot sewing is not allowed). Geotextiles are overlapped a minimum of 4 inches prior to sewing;

- no horizontal seams are constructed on side slopes that are steeper than 10 horizontal to 1 vertical (i.e., seams to be aligned along, not across the slope), except as part of a patch;

- sewing of geotextiles uses polymeric thread with chemical and ultraviolet resistance properties equal to or exceeding those of the geotextile; and

- seams are sewn using a single row type "401" two-thread chain stitch.

The CQC Consultant will monitor the geotextile seaming and geonet tying procedures to verify that joining, seams, and overlaps are performed in accordance with the Design Documents.

12.6 REPAIRS

The CQA Consultant will monitor, verify, and document that geocomposite repairs are made in accordance with the Design Documents and that CQC activities are performed as described below.

The CQC Consultant will monitor that any holes or tears in the geocomposite are repaired in accordance with the Design Documents, including:

- a patch made from the same geocomposite is secured into place by tying fasteners through the bottom geotextile and the geonet of the patch, and through the top geotextile and geonet of the geocomposite needing repair;
- the patch extends 2 feet beyond the edges of the hole or tear;
- the patch is secured every 6 inches and heat-sealed to the top geotextile of the geocomposite needing repair; and
- if the hole or tear is more than 50 percent of the width of the roll, the damaged area will be cut out and the two portions of the geocomposite will be joined.

The CQC Consultant will monitor that care is given to remove any soil or other material which may have penetrated the torn geocomposite component. The CQA Consultant will observe any repair and verify that any non-conformance with the above requirements is corrected.

12.7 PLACEMENT OF SOILS OR GRANULAR MATERIALS

The CQA Consultant will monitor, verify, and document that placement of soils or granular materials on top of geocomposites is conducted in accordance with the Design Documents and that CQC activities are performed as described below.

The CQC Consultant will monitor that the Contractor's placement of soil or granular materials on top of the geocomposite is in conformance with the Design Documents, including:

- no damage occurs to the geocomposite;
- no shifting of the geocomposite from its intended position occurs and underlying materials are not exposed or damaged;

- excess tensile stress does not occur in the geocomposite; and
- equipment does not drive directly on the geocomposite and the Contractor only uses LGP equipment on layers less than 3-feet thick above the geocomposite layer in accordance with Section 10.10.1 of this CQA Plan.

The CQC Consultant will monitor that covering of the geocomposite with overlying layers is completed within 30 days, and on side slopes, soil layers are placed over the geocomposite from the bottom of the slope upward.

13. HDPE PIPES AND FITTINGS

13.1 INTRODUCTION

The CQA Consultant will review the QC documentation and will monitor the installation of HDPE pipes and fittings to verify that the Manufacturer's specifications and the requirements of the Design Documents and this CQA Plan are met.

13.2 BUTT-FUSION WELDING PROCESS

The CQA Consultant will monitor the assembling of lengths of HDPE pipe into suitable installation lengths by the butt-fusion welding process. Butt-fusion welding is the butt-joining of the pipe by softening the aligned faces of the pipe ends in a suitable apparatus and pressing them together under controlled pressure. The CQA Consultant will monitor that butt-fusion welding of the HDPE pipes and fittings is performed by the Contractor in accordance with the Design Documents and Pipe Manufacturer's recommendations as to equipment and technique.

13.3 TRANSPORTATION, HANDLING, AND STORAGE

The CQA Consultant will monitor:

- the off-loading of the pipes to verify that handling is done in a competent manner and that the pipes are not placed in areas where water can accumulate;
- the pipes are not stacked more than three layers high or in such a manner that could cause damage to the pipe; and
- for outdoor storage periods longer than 12 months, a temporary covering is placed over the pipes, or they are moved to within an enclosed facility.

13.4 INSTALLATION

The CQA Consultant will monitor that pipes are installed in accordance with the Design Documents, including:

- care is given during installation of the pipes such that they are not be cut, kinked, or otherwise damaged;
- ropes, fabric, or rubber-protected slings and straps are used by the Contractor when installing pipes; chains, cables, or hooks inserted into the pipe are not used for this purpose;
- the Contractor installs the pipes and fittings in such a manner that the materials are not damaged;
- slings for handling the pipe are not positioned at butt-fused joints of HDPE pipes;
- sections of the pipes with deep cuts and/or gouges are removed and the ends of the pipeline re-joined; and
- care is exercised when lowering pipe into the trench to prevent damage or twisting of the pipe.

13.5 TESTING

The CQA Consultant will monitor the testing of all pipes as required by the Design Documents and as necessary to verify that workmanship conforms to the state-of-practice.

14. ROAD CONSTRUCTION

14.1 INTRODUCTION

The CQA Consultant will review the supplier documentation and will monitor construction of the roads to verify that the materials used in the construction of roads and the completed roadways are in conformance with the requirements of the Design Documents and this CQA Plan.

14.2 SUBGRADE PREPARATION

The CQA Consultant will monitor that road subgrade is prepared in accordance with requirements in the Design Documents. For road subgrade, nuclear moisture/ density tests are not required. The CQA Consultant will monitor the preparation of the subgrade in accordance with the Design Documents and this CQA Plan.

14.3 GEOTEXTILE SEPARATOR

The CQA Consultant will monitor that the geotextile separator is installed in accordance with requirements of the Design Documents and Sections 11 of this CQA Plan. The CQA Consultant will monitor the installation of the geotextile separator.

14.4 BASE AGGREGATE LAYER

The CQA Consultant will monitor the base aggregate to verify it is constructed to the thickness, grades, and limits shown on Design Documents. The CQA Consultant will confirm that base aggregate material is certified by the supplier to meet the requirements of the material type shown on Design Documents. A test strip including the entire road section (i.e., subgrade, geotextile separator, and base aggregate) will be prepared in the field to determine the requirements for placement, compaction, and moisture conditioning of base aggregates. The CQA Consultant will monitor the construction of the test strip and assist the Contractor with evaluating placement methods. The CQA Consultant will document and monitor road construction to verify that materials are placed in accordance with placement methods recommended during test strip construction.

14.5 REPAIRS

If a defective area of road is discovered during construction, the CQA Consultant will evaluate the extent and nature of the defect. After this evaluation, the CQA Consultant will observe that the Contractor corrects the deficiency to the satisfaction of the Construction Manager and does not perform additional work in the area until the Construction Manager approves the correction of the defect. In the event of damage, the CQA Consultant will observe the repairs and replacements made by the Contractor, as necessary, to the satisfaction of the Construction Manager.

15. GENERAL SITE WORK

15.1 INTRODUCTION

The CQA Consultant will monitor the activities that are to be performed for various general site work items including, but not limited to installation of riprap, erosion and sediment control measures, guard rails, prefabricated modular bridges, culverts, outfall weirs, pipes, vegetative cover, topsoil, and vegetation for compliance with the Design Documents.

In addition, the CQA Consultant will verify that materials are in accordance with the Design Documents and are installed in accordance with Manufacturer’s recommendations.

15.2 CONFORMANCE

Conformance of materials and construction techniques to verify compliance with the Design Documents will be performed by the CQA Consultant. If non-conformances or other deficiencies are found by the CQA Consultant in the materials or completed work,

they will be reported to the Contractor and Construction Manager. The CQA Consultant will observe the repairs or replacements of any non-conforming items.

TABLES

TABLE 7-1

MINIMUM PERFORMANCE TESTING FREQUENCIES AND MINIMUM REQUIREMENTS FOR DSM INSTALLATION

TEST DESCRIPTION	TEST STANDARD	FIELD SAMPLING FREQUENCY	TOTAL NUMBER SAMPLES	DSM PERFORMANCE CRITERIA	CURING DURATION	TECHNICAL SPECIFICATION REFERENCE
Density[(1)]	API 13B-1	2 every day of DSM production	*Estimate based on number of days of production	To be determined during final design	N/A	To be provided with Construction Design Package
UCS[(2)]	ASTM D1633	1 sample from a single DSM column for each day of DSM production	10 cylinders per sampling event *Total Estimate based on number of days of production	To be determined during final design, but estimated to target ≥ 110 psi	7, 14, and 28-day Standard Curing	To be provided with Construction Design Package
Unit Weight	ASTM D6023	1 sample from a single DSM column for each day of DSM production	2 cylinders per sampling event *Total Estimate based on number of days of production	To be determined during final design, but estimated to target a minimum 105 to 115 pcf	28-day Standard Curing	To be provided with Construction Design Package

Notes:

1. Performed on grout and/or slurry.
2. One (1) additional test cylinder will be taken during cold weather (< 40 degrees F). Cylinders will be cured in a water bath or moisture room at temperatures between 60 to 80 degrees Fahrenheit.
3. DSM testing parameters are generally consistent with guidance provided by “Federal Highway Design Manual: Deep Mixing for Embankment and Foundation Support”, Publication No. FHWA-HRT-13-046, October 2016.

APPENDIX A

Material Properties and Acceptance Criteria for Earthwork

TABLE A.1
MATERIAL PROPERTIES AND ACCEPTANCE CRITERIA
FOR SOIL MATERIALS USED AS FILL

SYSTEM COMPONENT	REQUIRED TEST	MINIMUM FREQUENCY	ACCEPTANCE CRITERIA
Soil Fill Conformance Testing[1]	Visual Observation	As required	Substantially free of debris, large rocks, plant materials, or other deleterious material.
	Particle Size Analysis ASTM D422	1 per source & 1 per 10,000 yd^3	Max. 3 in. particle size
	Atterberg Limits ASTM D4318	1 per source & 1 per 10,000 yd^3	Required for soil classification
	Soil Classification ASTM D2487	1 per source & 1 per 10,000 yd^3	SC, CL, CH, MH, ML, or other Engineer approved classifications
	Moisture Content ASTM D2216	1 per source & 1 per 10,000 yd^3	Determine if adequate moisture is present prior to compaction
	Standard Proctor ASTM D698	1 per source & 1 per 25,000 yd^3	Determine compaction conditions
Soil Fill Performance Testing[2]	Visual Observation	As required	Final surface firm, smooth, and uniform no protrusions greater than 0.5-in at final surfaces that will receive geomembrane.
	Lift Depth Check	As required	6 to 8 in. compacted lift (8 to 10 in. loose lifts)
	Nuclear Densometer In-place Density and Moisture Content ASTM D6938	1 per 10,000 sf per lift or 1 test per 200 lf per lift for linear features	≥ 95% Standard Proctor maximum dry density and within specified moisture range
	Moisture Content ASTM D2216	1 per 10 nuclear densometer tests	Check nuclear densometer measurements to verify moisture correction.
	Sand Cone Density or Drive Tube Sample ASTM D1556 or ASTM D2937	1 per 25 nuclear densometer tests	Check nuclear densometer measurements to verify moisture correction and density.

Notes:
in – inch lf – linear feet psf – pounds per square feet sf – square feet yd^3 – cubic yards

1. Conformance testing is performed on borrow sources prior to placement of material to verify the minimum required values are met and the material remains consistent.
2. Performance testing is performed on materials after placement is complete to verify that the lift or layer meets design requirements.

TABLE A.2
MATERIAL PROPERTIES ACCEPTANCE CRITERIA
FOR SOIL COMPONENTS OF THE FINAL COVER SYSTEM

SYSTEM COMPONENT	REQUIRED TEST	MINIMUM FREQUENCY	ACCEPTANCE CRITERIA
Protective Soil Layer (Final Cover System) Conformance Testing[1]	Visual Observation	As required	Substantially free of debris, large rocks, plant materials, or other deleterious material
	Sieve Analysis ASTM D422	1 per source & 1 per 10,000 yd^3	2.0 in. max. particle size
	Atterberg Limits ASTM D4318	1 per source & 1 per 10,000 yd^3	Required for soil classification
	Soil Classification ASTM D2487	1 per source & 1 per 10,000 yd^3	SC, CL, CH, ML, MH, or other Engineer approved classifications
Protective Soil Layer (Final Cover System) Performance Testing[2]	Visual Observation	As required	Material compacted by tracking in with dozer; final surface firm, smooth, and uniform.
	Lift Depth Check	As required	First lift 12 in. compacted lift then, 6 to 8 in. compacted lift (8 to 10 in. loose lift)
Vegetative Cover Layer (Final Cover System) Conformance Testing[1]	Visual Observation	As required	Substantially free of debris, large rocks, plant materials, or other deleterious material.
	Sieve Analysis ASTM D422	1 per source & 1 per 10,000 yd^3	100% passing 1 in. sieve
	Atterberg Limits ASTM D4318	1 per source & 1 per 10,000 yd^3	Required for soil classification
	Soil Classification ASTM D2487	1 per source & 1 per 10,000 yd^3	ML, SM, or SC, or other Design Engineer approved classification
Vegetative Cover Layer (Final Cover System) Performance Testing[2]	Visual Observation	As required	Substantially free of debris, large rocks, plant materials, or other deleterious material. Must not pump or rut excessively.
	Lift Depth Check	As required	6 in. (min) lift

Notes:
in – inch yd^3 – cubic yards

1. Conformance testing is performed on borrow sources prior to placement of material to verify the minimum required values are met and the material remains consistent.
2. Performance testing is performed on materials after placement is complete to verify that the lift or layer meets design requirements.

APPENDIX B

Material Properties and Acceptance Criteria for Geomembranes and Seams

TABLE B.1
MATERIAL PROPERTIES AND MANUFACTURER QUALITY CONTROL REQUIREMENTS
TEXTURED 40-MIL HDPE GEOMEMBRANE

Properties	Manufacturer QC Test Frequency	Units[1]	Specified Values	Test Method
Physical Properties				
Thickness	Every Roll	mils	38 (min. avg.) 36 (lowest individual reading for 8 out of 10) 34 (lowest individual reading for any of 10)	ASTM D5994
Asperity Height	Every 2nd Roll	mils	16 (min. average) (top and bottom)	ASTM D7466
Sheet Density and Resin Specific Gravity	one per 200,000 lb	g/cm^3	0.940 (minimum for sheet density) 0.932 (minimum for resin density)	ASTM D1505 / ASTM D792
Carbon Black Content	one per 20,000 lb	%	2.0-3.0 (range)	ASTM D1603 / ASTM D4218
Carbon Black Dispersion	one per 45,000 lb	None	9 of 10 views in Category 1 or 2[2]	ASTM D5596
Resin - Melt Flow Index	one per 200,000 lb	g/10 min.	≤1.0	ASTM D1238
Tensile Properties (each direction)				
1. Tensile Strength at Yield	one per 20,000 lb	lb/in	84 (min. average)	ASTM D6693 - Type IV
2. Tensile Strength at Break	one per 20,000 lb	lb/in	60 (min. average)	ASTM D6693 - Type IV
3. Elongation at Yield	one per 20,000 lb	%	12 (min. average)	ASTM D6693 - Type IV
4. Elongation at Break	one per 20,000 lb	%	100 (min. average)	ASTM D6693 - Type IV
Tear Resistance	one per 45,000 lb	lb	28 (min. average)	ASTM D1004 Die C Puncture
Puncture Resistance	one per 45,000 lb	lb	60 (min. average)	ASTM D4833
Oxidative Induction Time (OIT) Standard OIT or High Pressure OIT	one per 200,000 lb	Minutes	100 (min. average) 400 (min. average)	ASTM D3895 or ASTM D5885
Notched Constant Tensile Load Stress Cracking (NCTLSC) [3]	one per 200,000 lb	hours	≥300	ASTM D5397
Oven Aging at 85°C [3] Std. OIT - retained after 90 days High Pressure OIT - retained after 90 days	Per Formulation	 % %	 55 80	ASTM D5721 ASTM D3895 ASTM D5885
UV Resistance [3] High Pressure OIT	Per Formulation	 %	 50	GRI GM11 ASTM D5885

Notes:

1. % = percent; g = grams; g/cm^3 = grams per cubic centimeter; lb = pound; lb/in = pounds per inch; mils = milli-inches
2. Carbon dispersion for 10 different views. One view allowed in Category 3.
3. For NCTLSC, oven aging, and UV resistance, Manufacturer's certification may be accepted in lieu of actual test results.

TABLE B.2

SEAM PROPERTY AND INSTALLATION ACCEPTANCE CRITERIA
TEXTURED 40-MIL HDPE GEOMEMBRANE

Material Property	Minimum Frequency	Value	Units	Test Method
Shear Strength Fusion and Extrusion [(1)]	1 test every 500 ft	80 (min)	lb/in	ASTM D6392 Strain rate: 2 in./min. 1 in. strips.
Peel Adhesion Fusion[(2)] Extrusion [(3)]	1 test every 500 ft	60 (min) 52(min)	lb/in. lb/in.	ASTM D6392 Strain Rate: 2 in./min 1 in. strips.
Vacuum Testing Welded Seams	100% of extrusion welds	-	-	-
Air Pressure Testing Welded Seams	100% of fusion welds	-	-	-

Notes:

in - inch
lb - pound
min. - minute

1. For shear testing of both fusion and extrusion welds, the strength of 4 out of 5 specimens must meet or exceed the given value. The 5th specimen must meet at least 80 percent of the specified value. Shear elongation at break must be at least 50 percent.
2. For peel testing of fusion welds, the strength of 4 out of 5 specimens must meet or exceed the specified value. The 5th specimen must achieve at least 80% of the specified value. All specimens shall fail due to film tear bond or with less than 25% incursion of the weld (peel).
3. For peel testing of extrusion welds, the strength of 4 out of 5 specimens must meet or exceed the specified value with less than 25% incursion at the weld. The 5th specimen must achieve at least 80% of the specified value. One specimen may exhibit greater than 25% incursion at the weld if the specified strength value is achieved.
4. For double fusion welded seams, both tracks will be tested for compliance with the specified minimum seam peel strengths.
5. Required laboratory seam testing will be performed by the Geosynthetics Laboratory at a frequency of one test per 500 linear feet of constructed seam for both extrusion and fusion welding equipment.

TABLE B.3

MATERIAL PROPERTIES AND MANUFACTURER QUALITY CONTROL REQUIREMENTS
TEXTURED 40-MIL LLDPE GEOMEMBRANE

Properties	Manufacturer QC Test Frequency	Units[1]	Specified Values	Test Method
Physical Properties				
Thickness	Every Roll	mils	38 (min. avg.) 36 (lowest individual reading for 8 out of 10) 34 (lowest individual reading for any of 10)	ASTM D5994
Asperity Height	Every 2nd Roll	mils	16 (min. average) (top and bottom)	ASTM D7466
Sheet Density and Resin Specific Gravity	one per 200,000 lb	g/cm^3	0.939 (max.)	ASTM D1505/ ASTM D792
Carbon Black Content	one per 20,000 lb	%	2.0-3.0 (range)	ASTM D4218/ ASTM D1603
Carbon Black Dispersion	one per 45,000 lb	None	9 out of 10 in Category 1 or 2[2]	ASTM D5596
Resin - Melt Flow Index	one per 200,000 lb	g/10 min.	≤1.0	ASTM D1238
Tensile Properties (each direction)				
1. Tensile Strength at Break	one per 20,000 lb	lb/in	60 (min. average)	ASTM D6693 – Type IV
2. Elongation at Break	one per 20,000 lb	%	250 (min. average)	ASTM D6693 – Type IV
Tear Resistance	one per 45,000 lb	lb	22 (min. average)	ASTM D1004
Puncture Resistance	one per 45,000 lb	lb	44 (min. average)	ASTM D4833
Oxidative Induction Time (OIT) Standard OIT or High Pressure OIT	one per 200,000 lb	Minutes	100 (min. average) 400 (min. average)	ASTM D3895 or ASTM D5885
2% Modulus	Per Formulation	lb/in	2400 (max.)	ASTM D5323
Axi-symmetric Break Resistance Strain [3]	Per Formulation	%	30 (min.)	ASTM D5617
Oven Aging at 85°C [3] Std. OIT - retained after 90 days High Pressure OIT - retained after 90 days	Per Formulation	% %	35 (min. average) 60 (min. average)	ASTM D5721 ASTM D3895 ASTM D5885
UV Resistance [3][4] High Pressure OIT	Per Formulation	%	35 (min. average)	ASTM D7238 ASTM D5885

Notes:

1. % = percent; g = grams; g/cm^3 = grams per cubic centimeter; lb = pound; lb/in = pounds per inch; mils = milli-inches
2. Carbon dispersion for 10 different views. One view allowed in Category 3.
3. For 2% modulus, axi-symmetric break resistance, oven aging, and UV resistance, Manufacturer's certification may be accepted in lieu of actual test results.
4. The condition of the test will be 20-hour UV cycle at 75°C followed by 4-hour condensation at 60°C.

TABLE B.4

SEAM PROPERTY AND INSTALLATION ACCEPTANCE CRITERIA
TEXTURED 40-MIL LLDPE GEOMEMBRANE

Material Property	Minimum Frequency	Value	Units	Test Method
Shear Strength Fusion and Extrusion [(1)]	1 test every 500 ft	60 (min)	lb/in.	ASTM D6392 Strain rate: 12 in./min. 1 in. strips.
Peel Adhesion Fusion[(2)] Extrusion [(3)]	1 test every 500 ft	50 (min) 44 (min)	lb/in. lb/in.	ASTM D6392 Strain Rate: 12 in./min. 1 in. strips.
Vacuum Testing Welded Seams	100% of extrusion welds	-	-	-
Air Pressure Testing Welded Seams	100% of fusion welds	-	-	-

Notes:

in - inch
lb - pound
min. - minute

1. For Shear Testing of both fusion and extrusion welds, the strength of 4 out of 5 specimens must meet or exceed the given value. The 5th specimen must meet at least 80 percent of the specified value. Shear elongation at break must be at least 50 percent.

2. For Peel Testing of fusion welds, the strength of 4 out of 5 specimens must meet or exceed the specified value. The 5th specimen must achieve at least 80% of the specified value. All specimens shall fail due to film tear bond or with less than 25% incursion of the weld (peel).

3. For Peel Testing of extrusion welds, the strength of 4 out of 5 specimens must meet or exceed the specified value with less than 25% incursion at the weld. The 5th specimen must achieve at least 80% of the specified value. One specimen may exhibit greater than 25% incursion at the weld if the specified strength value is achieved.

4. For double fusion welded seams, both tracks will be tested for compliance with the specified minimum seam peel strengths.

5. Required laboratory seam testing will be performed by the Geosynthetics Laboratory at a frequency of one test per 500 linear feet of constructed seam for both extrusion and fusion welding equipment.

6. LLDPE field samples will be allowed to cool to a minimum of 75 degrees Fahrenheit prior to testing. Testing will be performed in a climate-controlled environment at the site such as an office or trailer.

TABLE B.5

MATERIAL PROPERTIES AND MANUFACTURER QUALITY CONTROL REQUIREMENTS
MICRODRAIN® 50-MIL HDPE GEOMEMBRANE
(FOR CLOSURETURF® ALTERNATIVE)

Properties	Manufacturer QC Test Frequency	Units[1]	Specified Values	Test Method
Physical Properties				
Thickness	Every Roll	mils	48 (min. avg.) 45 (lowest individual reading for 8 out of 10) 43 (lowest individual reading for any of 10)	ASTM D5994
Drainage Stud Height	Every 2nd Roll	mils	130 (min. average)	ASTM D7466
MicroSpike Height	Every 2nd Roll	mils	20 (min. average)	ASTM D7466
Sheet Density and Resin Specific Gravity	one per 200,000 lb	g/cm^3	0.940 (minimum for sheet density) 0.932 (minimum for resin density)	ASTM D1505 / ASTM D792
Carbon Black Content	one per 20,000 lb	%	2.0-3.0 (range)	ASTM D4218/ ASTM D1603
Carbon Black Dispersion	one per 45,000 lb	None	9 out of 10 in Category 1 or 2 [2]	ASTM D5596
Resin - Melt Flow Index	one per 200,000 lb	g/10 min.	≤1.0	ASTM D1238
Tensile Properties (each direction)				
1. Tensile Strength at Yield	one per 20,000 lb	lb/in	105 (min. average)	ASTM D6693 - Type IV
2. Tensile Strength at Break	one per 20,000 lb	lb/in	75 (min. average)	ASTM D6693 - Type IV
3. Elongation at Yield	one per 20,000 lb	%	12 (min. average)	ASTM D6693 - Type IV
4. Elongation at Break	one per 20,000 lb	%	100 (min. average)	ASTM D6693 - Type IV
Tear Resistance	one per 45,000 lb	lb	35 (min. average)	ASTM D1004 Die C Puncture
Puncture Resistance	one per 45,000 lb	lb	75 (min. average)	ASTM D4833
Oxidative Induction Time (OIT) Standard OIT or High Pressure OIT	one per 200,000 lb	minutes	100 (min. average) 400 (min. average)	ASTM D3895 or ASTM D5885
Notched Constant Tensile Load Stress Cracking (NCTLSC) [3]	one per 200,000 lb	hours	≥300	ASTM D5397
Oven Aging at 85°C [3] Std. OIT - retained after 90 days High Pressure OIT - retained after 90 days	Per Formulation	% %	55 80	ASTM D5721 ASTM D3895 ASTM D5885
UV Resistance [3] High Pressure OIT	Per Formulation	 %	 50	ASTM D7238 ASTM D5885

Notes:

1. % = percent; g = grams; g/cm^3 = grams per cubic centimeter; lb = pound; lb/in = pounds per inch; mils = milli-inches
2. Carbon dispersion for 10 different views. One view allowed in Category 3.
3. For NCTLSC, oven aging, and UV resistance, Manufacturer's certification may be accepted in lieu of actual test results.

TABLE B.6

SEAM PROPERTY AND INSTALLATION ACCEPTANCE CRITERIA
MICRODRAIN® 50-MIL HDPE GEOMEMBRANE
(FOR CLOSURETURF® ALTERNATIVE)

Material Property	Minimum Frequency	Value	Units	Test Method
Shear Strength Fusion and Extrusion [(1)]	1 test every 500 ft	100 (min)	lb/in	ASTM D6392 Strain rate: 2 in./min. 1 in. strips.
Peel Adhesion Fusion[(2)] Extrusion[(3)]	1 test every 500 ft	76 (min) 65 (min)	lb/in. lb/in.	ASTM D6392 Strain Rate: 2 in./min. 1 in. strips.
Vacuum Testing Welded Seams	100% of extrusion welds	-	-	-
Air Pressure Testing Welded Seams	100% of fusion welds	-	-	-

Notes:

in - inch
lb – pound
min. - minute

1. For shear testing of both fusion and extrusion welds, the strength of 4 out of 5 specimens must meet or exceed the given value. The 5th specimen must meet at least 80 percent of the specified value. Shear elongation at break must be at least 50 percent.

2. For peel testing of fusion welds, the strength of 4 out of 5 specimens must meet or exceed the specified value. The 5th specimen must achieve at least 80% of the specified value. All specimens shall fail due to film tear bond or with less than 25% incursion of the weld (peel).

3. For peel testing of extrusion welds, the strength of 4 out of 5 specimens must meet or exceed the specified value with less than 25% incursion at the weld. The 5th specimen must achieve at least 80% of the specified value. One specimen may exhibit greater than 25% incursion at the weld if the specified strength value is achieved.

4. For double fusion welded seams, both tracks will be tested for compliance with the specified minimum seam peel strengths.

5. Required laboratory seam testing will be performed by the Geosynthetics Laboratory at a frequency of one test per 500 linear feet of constructed seam for both extrusion and fusion welding equipment.

TABLE B.7

MATERIAL PROPERTIES AND MANUFACTURER QUALITY CONTROL REQUIREMENTS
MICRODRAIN® 50-MIL LLDPE GEOMEMBRANE
(FOR CLOSURETURF® ALTERNATIVE)

Properties	Manufacturer QC Test Frequency	Units[1]	Specified Values	Test Method
Physical Properties				
Thickness	Every Roll	mils	48 (min. avg.) 45 (lowest individual reading for 8 out of 10) 43 (lowest individual reading for any of 10)	ASTM D5994
Drainage Stud Height Friction Spike Height	Every 2nd Roll	mils	130 (min. average) 20 (min. average)	ASTM D7466
Sheet Density and Resin Specific Gravity	one per 200,000 lb	g/cm^3	0.939 (max.)	ASTM D1505/ ASTM D792
Carbon Black Content	one per 20,000 lb	%	2.0-3.0 (range)	ASTM D4218/ ASTM D1603
Carbon Black Dispersion	one per 45,000 lb	None	9 in Category 1 or 2 [2]	ASTM D5596
Resin - Melt Flow Index	one per 200,000 lb	g/10 min.	≤1.0	ASTM D1238
Tensile Properties (each direction)				
1. Tensile Strength at Break	one per 20,000 lb	lb/in	75 (min. average)	ASTM D6693 – Type IV
2. Elongation at Break	one per 20,000 lb	%	250 (min. average)	ASTM D6693 – Type IV
Tear Resistance	one per 45,000 lb	lb	27 (min. average)	ASTM D1004
Puncture Resistance	one per 45,000 lb	lb	55 (min. average)	ASTM D4833
Oxidative Induction Time (OIT) Standard OIT or High Pressure OIT	one per 200,000 lb	Minutes	100 (min. average) 400 (min. average)	ASTM D3895 or ASTM D5885
2% Modulus	Per Formulation	lb/in	3000 (max.)	ASTM D5323
Axi-symmetric Break Resistance Strain [3]	Per Formulation	%	30 (min.)	ASTM D5617
Oven Aging at 85°C [3] Std. OIT - retained after 90 days High Pressure OIT - retained after 90 days	Per Formulation	%	35 60	ASTM D5721 ASTM D3895 ASTM D5885
UV Resistance [3], [4] High Pressure OIT	Per Formulation	%	35 (min. average)	ASTM D7238 ASTM D5885

Notes:

1. % = percent; g = grams; g/cm^3 = grams per cubic centimeter; lb = pound; lb/in = pounds per inch; mils = milli-inches
2. Carbon dispersion for 10 different views. One view allowed in Category 3.
3. For 2% modulus, axi-symmetric break resistance, oven aging, and UV resistance, Manufacturer's certification may be accepted in lieu of actual test results.
4. The condition of the test will be 20-hour UV cycle at 75°C followed by 4-hour condensation at 60°C.

TABLE B.8

SEAM PROPERTY AND INSTALLATION ACCEPTANCE CRITERIA
MICRODRAIN® 50-MIL LLDPE GEOMEMBRANE
(FOR CLOSURETURF ® ALTERNATIVE)

Material Property	Minimum Frequency	Value	Units	Test Method
Shear Strength Fusion and Extrusion (1)	1 test every 500 ft	75 (min)	lb/in	ASTM D6392 Strain rate: 12 in./min. 1 in. strips.
Peel Adhesion Fusion(2) Extrusion (3)	1 test every 500 ft	63 (min) 57 (min)	lb/in. lb/in.	ASTM D6392 Strain Rate: 12 in./min. 1 in. strips.
Vacuum Testing Welded Seams	100% of extrusion welds	-	-	-
Air Pressure Testing Welded Seams	100% of fusion welds	-	-	-

Notes:

in - inch
lb - pound
min. - minute

1. For shear testing of both fusion and extrusion welds, the strength of 4 out of 5 specimens must meet or exceed the given value. The 5th specimen must meet at least 80 percent of the specified value. Shear elongation at break must be at least 50 percent.

2. For peel testing of fusion welds, the strength of 4 out of 5 specimens must meet or exceed the specified value. The 5th specimen must achieve at least 80% of the specified value. All specimens shall fail due to film tear bond or with less than 25% incursion of the weld (peel).

3. For peel testing of extrusion welds, the strength of 4 out of 5 specimens must meet or exceed the specified value with less than 25% incursion at the weld. The 5th specimen must achieve at least 80% of the specified value. One specimen may exhibit greater than 25% incursion at the weld if the specified strength value is achieved.

4. For double fusion welded seams, both tracks will be tested for compliance with the specified minimum seam peel strengths.

5. Required laboratory seam testing will be performed by the Geosynthetics Laboratory at a frequency of one test per 500 linear feet of constructed seam for both extrusion and fusion welding equipment.

6. LLDPE field samples will be allowed to cool to a minimum of 75 degrees Fahrenheit prior to testing. Testing will be performed in a climate-controlled environment at the site such as an office or trailer.

APPENDIX C

Material Properties and Acceptance Criteria for Geotextiles

TABLE C.1

MATERIAL PROPERTIES AND MANUFACTURER QUALITY CONTROL REQUIREMENTS
20 OZ/YD^2 NON-WOVEN GEOTEXTILE CUSHION LAYER

Material Property	Qualifier	Manufacturer QC Test Frequency	Units	Specified Value	Test Method
Polymer Composition	Minimum	N/A	% polypropylene or polyester by weight	95	Certification
Mass per Unit Area	Minimum Average	90,000 ft^2	oz/yd^2	20	ASTM D5261
Grab Tensile Strength	Minimum Average	90,000 ft^2	lbs	450	ASTM D4632
Grab Elongation	Minimum	90,000 ft^2	%	50	ASTM D4632
CBR Puncture Strength	Minimum Average	540,000 ft^2	lbs	1,437	ASTM D6241
Trapezoidal Tear Strength	Minimum Average	90,000 ft^2	lbs	125	ASTM D4533
Ultraviolet Resistance	Minimum	Per Formulation	%	70	ASTM D4355

Notes:
in - inch
lbs - pounds
oz - ounce
yd^2 - square yard

TABLE C.2

MATERIAL PROPERTIES AND MANUFACTURER QUALITY CONTROL REQUIREMENTS 8 OZ/YD^2 NON-WOVEN GEOTEXTILE SEPERATOR FOR OUTLET PROTECTION AND GRAVEL/SOIL SEPARATION

Material Property	Qualifier	Manufacturer QC Test Frequency	Units	Specified Value	Test Method
Polymer Composition	Minimum	N/A	% polypropylene or polyester by weight	95	Certification
Mass per Unit Area	Minimum Average	90,000 ft^2	oz/yd^2	8	ASTM D5261
Grab Tensile Strength	Minimum Average	90,000 ft^2	lbs	220	ASTM D4632
Grab Tensile Elongation	Minimum	90,000 ft^2	%	50	ASTM D4632
CBR Puncture Strength	Minimum Average	540,000 ft^2	lbs	575	ASTM D6241
Trapezoidal Tear Strength	Minimum Average	90,000 ft^2	lbs	90	ASTM D4533
Ultraviolet Resistance	Minimum	Per formulation	%/hrs	70/500	ASTM D4355

Notes:

in - inch

lbs - pounds

oz - ounce

yd^2 - square yard

APPENDIX D

Material Properties and Acceptance Criteria for Geocomposites

TABLE D.1

MATERIAL PROPERTIES AND MANUFACTURER QUALITY CONTROL REQUIREMENTS DOUBLE-SIDED GEOCOMPOSITE WITH NON-WOVEN GEOTEXTILE BACKING

Properties	Qualifier	Manufacturer QC Test Frequency	Units	Specified Values[1]	Test Method
Geonet Component: (HDPE, bi-planar/bi-axial)					
Polymer composition	Minimum	Certify	%	95 polyethylene by weight	N/A
Polymer density	Minimum	1 per 50,000 ft^2	g/cm^3	0.94	ASTM D792 (Method B) or ASTM D1505
Carbon black content	Range	1 per 50,000 ft^2	%	2 - 3	ASTM D1603 or D4218
Nominal thickness	Minimum	1 per 50,000 ft^2	mil	300	ASTM D5199
Tensile Strength	Minimum	1 per 50,000 ft^2	lb/in.	75	ASTM D7179
Geotextile Component: (non-woven needle punched polypropylene)					
Type	N/A	N/A	N/A	Needle punched non-woven	N/A
Polymer composition	Minimum	Certify	%	95 polyester or polypropylene	N/A
Mass per unit area	Minimum	1 per 90,000 ft^2	oz/yd^2	8	ASTM D5261
Apparent opening size	Maximum	1 per 540,000 ft^2	mm	$O_{95} \leq 0.21$ mm	ASTM D4751
Permittivity	Minimum	1 per 540,000 ft^2	sec^{-1}	1.3	ASTM D4491
Grab strength	Minimum	1 per 90,000 ft^2	lb	200	ASTM D4632 [2]
Tear strength	Minimum	1 per 90,000 ft^2	lb	75	ASTM D4533 [2]
CBR puncture strength	Minimum	1 per 540,000 ft^2	psi	500	ASTM D6241
UV Resistance	Minimum	1 per Formulation	% retained after 500 hr.	70	ASTM D4355
Geocomposite: (double sided with geotextile heat laminated on both sides of the geonet)					
Transmissivity[3]	Minimum	1 per 540,000 ft^2	m^2/s	9×10^{-4}	ASTM D4716
Ply Adhesion	Minimum	1 per 50,000 ft^2	lb/in.	1.0	ASTM D7005

Notes:

in – inch | yd^2 – square yard | mm – millimeter | oz – ounce | cm – centimeter

lb – pounds | psi – pounds per square inch | m – meter | N/A – Not Applicable

1. All values represent minimum average roll values.
2. Minimum value measured in machine and cross-machine direction.
3. Specified value must be met at the following conditions:
   a. For the final cover system geocomposite, a gradient of 0.15, normal load of 250 psf, and water temperature at 70° F, between steel plates for 15 minutes.