CONSTRUCTION QUALITY ASSURANCE (CQA) PLAN

GRAND TOWER ENERGY CENTER LLC (GTEC)
INACTIVE ASH BASIN CLOSURE

This Plan has been prepared on behalf of:

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Grand Tower, Illinois

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1.0 GENERAL

1.1 Introduction

This Construction Quality Assurance Manual (CQA Manual) for Grand Tower Energy Center, LLC (GTEC) has been prepared for the GTEC Inactive Ash Basin Closure project owned by GTEC. The CQA Manual is written to provide guidance on maintenance of quality during the proposed consolidation and capping of the coal combustion waste (CCW) basin and the GTEC facility in Grand Tower, Illinois.

The following guidelines were referenced during preparation of this document:

- USEPA Technical Guidance Document (TGD): Quality Assurance and Quality Control for Waste Containment Facilities (EPA/600-R-93/182, September 1993);
- USEPA Technical Guidance Document (TGD); Inspection Techniques for the Fabrication of Geomembrane Field Seams (EPA/530-SW-91-051, May 1991);
- ASTM Standards and Other Specifications and Test Methods on the Quality Assurance of Landfill Liner Systems;
- Code of Federal Regulations 40 CFR Part 257; Closure Requirements for Inactive CCR Impoundments; and
- Illinois's Administrative Code Title (IAC) 35 Part 840, Site-Specific Closures Of Coal Combustion Waste Surface Impoundments; Section 840.146 Construction Quality Assurance Program.

This CQA Manual also incorporates elements of the CQA manuals of the manufacturers and installers of containment system components as appropriate.

The purpose of the CQA Manual is to present the principles and practices of construction quality assurance required by State and Federal regulatory entities, to be implemented during the construction of its waste disposal, surface impoundment, and other waste containment facilities. Quality management involves both quality assurance and quality control activities performed to verify that construction activities meet the approved design plans and specifications.

For permitting purposes, the CQA Manual is written in general terminology (i.e., using "Permitting Agency," "Owner," or "CQA Consultant" versus actual names of entities). During the construction process, the specific parties involved will review this CQA Manual and modify it as necessary for site-specific conditions. The modifications will be amended to this CQA Manual and will become the site-specific CQA Plan, referred to as "CQA Plan" throughout this CQA Manual.

Title 35 of the IAC, Part 840 was developed specifically for closure of an ash basin in Hutsonville, Illinois. However, these regulations provide guidance on the CQA process, and are used as general guidance for the documentation of quality during the consolidation and cap alternative that is proposed for the GTEC CCW inactive ash basin.

1.2 Scope of the CQA Plan

The CQA Plan includes five primary elements:

- Responsibility and Authority;
- CQA Personnel Qualifications;
- Monitoring Activities;
- Sampling & Testing Strategies; and
- Documentation.

Activities and sampling strategies are presented for the individual components of the Inactive Ash Basin Closure system as follows:

- Earthwork, Grading and Fill;
- Geomembrane;
- Geocomposite;
- Geotextile
- Polyethylene Pipe and Fittings;
- Surveying; and
- Documentation.

This CQA Plan has been developed to work in conjunction with design/construction plans and technical specifications for the facility. In the case of conflict between this CQA Plan and standards set by the design/construction plans, and specifications, the design/construction plans shall take precedence over both specifications and the CQA Plan, and specifications shall take precedence over the CQA Plan.

1.3 Definitions and Use of Terms

The following provides general information regarding specific terms, references, and units as used in the CQA Manual.

1.3.1 Definitions Relating To CQA

In the context of this CQA Manual, Construction Quality Assurance and Construction Quality Control are defined as follows:

- ***Construction Quality Assurance (CQA)***
  CQA refers to measures taken by the Owner and/or Owner's representative to determine if the Contractors are in compliance with the design plans and specifications.

- ***Construction Quality Control (CQC)***
  CQC refers to measures taken by the contractor to determine compliance with the requirements for material and workmanship as stated in the contract drawings and specifications.

1.3.2 References to Standard

The CQA Manual includes references to test procedures of the American Society for Testing and Materials (ASTM), the Federal Test Method Standards (FTMS), and the Geosynthetics Research Institute (GRI).

1.3.3 Units

Properties and dimensions given in the CQA Manual are expressed in U.S. units and may be followed by approximate equivalent values in SI units in parentheses. The values given in SI units are typically accurate within ten percent. In cases of conflict, the U.S. units shall govern.

1.4 Responsibility and Authority

The principal parties involved in the CQA of the inactive ash basin closure system include the Permitting Agency, the Owner, the Project Manager, the Regional Engineer, the Design Engineer, the CQA Consultant, the Soils CQA Laboratory, the Geosynthetics CQA Laboratory, the Earthwork Contractor, the Geosynthetics Manufacturer, and the Geosynthetics Installer. The general responsibilities and authorities of each of these parties may be modified or expanded as dictated by specific project needs during Pre-Construction Meetings.

1.4.1 Permitting Agency

The Permitting Agency, which is the Illinois Environmental Protection Agency (IEPA), is authorized to issue the permit for construction of the inactive ash basin closure based on review and acceptance of the permit application.

1.4.2 Owner

The Owner is responsible for retaining qualified firms to coordinating the design and construction of the inactive ash basin closure system.

1.4.3 Regional Engineer

The Regional Engineer is retained by the Owner and is responsible for all correspondence with the Permitting Agency and manages the Design Engineer and the CQA Consultant. This responsibility includes compliance with the permit and the submission of CQA documentation demonstrating that the facility was constructed in accordance with the design specifications.

The Regional Engineer has the authority to select and dismiss parties charged with design and CQA. The Regional Engineer also has the authority to accept or reject design plans and specifications, CQA plans, and CQA reports. One individual or firm may serve the combined roles of Regional Engineer, Project Manager, Permit Engineer and Design Engineer.

1.4.4 Project Manager

The Project Manager is the representative retained by the Owner who is responsible for coordinating schedules, meetings, and field resources. This responsibility includes communications to the Owner, CQA Consultant, Surveyor, Contractors, Manufacturer, and other involved parties.

The Project Manager has the authority to select and dismiss parties charged with construction activities. The Project Manager also has the authority to direct contractors hired by the Owner and to accept or reject their material and workmanship. One individual or firm may serve the combined roles of Regional Engineer, Project Manager, Permit Engineer and Design Engineer.

1.4.5 Site Superintendent

The Site Superintendent is the official on-site representative retained by the Owner and is responsible for field coordination of schedules, contractors, meetings, and field activities. This responsibility includes communications to the Project Manager, Owner, CQA Consultant, Surveyor, Contractors, Manufacturer, and other involved parties. The Site Superintendent also has the authority to direct contractors hired by the Owner and to accept or reject their material and workmanship.

1.4.6 Permit Engineer(s)

The Permit Engineer(s) is a firm or person, retained by the Owner, to prepare permit documents for acceptance by the Permitting Agency. The permit documents include forms, narratives, CQA Plan, design plans, and specifications, which support the design of the landfill closure remedy. The permit documents establish the limits, type, and details of the liner system and leachate management system and all other components of the site. The permit documents provide minimum specifications and are the governing document when a specification contradiction arises.

During construction, the Permit Engineer(s), the site's Project Manager, and The Regional Engineer must approve substantive changes to the design plans or specifications for the facility. Substantive changes include any changes which modify of impact the technical basis for any engineered component of the facility design. One individual or firm may serve the combined roles of Regional Engineer, Project Manager, Permit Engineer and Design Engineer.

1.4.7 Design Engineer

The Design Engineer is a firm or person, retained by the Owner, to prepare permit and/or construction documents for acceptance by the Permitting Agency and necessary to construct the facility closure remedy. The permit documents include forms, narratives, CQA Plan, design of the landfill. The permit documents establish the limits, type, and details for liner system and leachate management system and all other components for the site. The permit documents provide minimum specifications and are the governing document when a specification contradiction arises.

During construction, the Design Engineer may be requested to clarify discrepancies in the construction documents or CQA Plan if necessary. The Design Engineer may also approve substantive changes to the design plans or specifications for the facility. Substantive changes include any changes which modify or impact the technical basis for any engineered component of the facility design. One individual or firm may serve the combined roles of Regional Engineer, Project Manager, Permit Engineer and Design Engineer.

1.4.8 CQA Consultant

The CQA Consultant is responsible for observing and documenting activities related to the permit documents and the CQA Plan. The CQA Consultant is represented by the CQA Consultant's Engineer of Record and supporting on-site CQA monitoring personnel as appropriate.

In general, the responsibilities and authorities of the CQA Consultant include:

- A working understanding of the permit documents, design plans, and specifications in relation to all aspects for the CQA Plan;
- Scheduling, coordinating, and performing CQA activities;
- Performing independent on-site observation of the work in progress to assess compliance with the CQA Plan, permit documents, design plans, and technical specifications;
- Recognizing and reporting deviations from the CQA Plan, permit document, design plans, and/or specifications to the Regional Engineer and Project Manager;
- Secure documents which approve changes to the CQA Plan, permit documents, design plans, and/or specifications;
- Verifying that the CQA Consultant's test equipment meets testing and calibration requirements, and that tests are conducted according to standardized procedures defined in the CQA Plan;
- Recording and maintaining test data accurately;
- Identifying CQA tested work that should be accepted, rejected, or further evaluated;
- Verifying that corrective measures are implemented;
- Documenting and reporting CQA activities;
- Collecting data needed for record documentation as defined in Section 8.0; and
- Maintaining open lines of communications with other parties involved in the construction.

The CQA Consultant is also responsible for insuring documentation for major construction activities. Construction activities include the following:

- Material moving and contouring of materials in the CCW basin;
- Final Cover System; and
- Erosion and sedimentation control structures.

Documentation shall bear the seal of a Professional Engineer registered in the state of Illinois.

1.4.9 Soils CQA Laboratory

The Soils CQA laboratory is responsible for performing the laboratory testing required by the CQA Plan to determine specific characteristics of the soils and aggregates. The Soils CQA Laboratory is also responsible for providing adequate documentation of analytical results, test methods followed, and testing equipment used. Work of the Soils CQA Laboratory will be administered by, and reported to, the CQA Consultant.

1.4.10 Geosynthetics CQA Laboratory

The Geosynthetics CQA Laboratory is responsible for performing the laboratory testing required by the CQA Plan to determine specific characteristics of the geosynthetics. The Geosynthetics CQA Laboratory is also responsible for providing adequate documentation of analytical results, test methods followed, and testing equipment used. Work of the Geosynthetics CQA Laboratory may be administered by the CQA Consultant. All results shall be reported to the CQA Consultant.

1.4.11 Earthwork Contractor

The Earthwork Contractor is responsible for moving earth/ash materials to establish the liner grades, the preparation of the surface for liner installation, and protective cover soils placed above the liner system for the closure system. The Earthwork Contractor will also be responsible for construction of sedimentation and erosion control facilities, anchor trenches for liner installation, and other support activities to support CCW basin closure.

It is the responsibility of the Earthwork Contractor that the construction be performed using the procedures and equipment necessary to produce results in conformance with contract documents.

The Earthwork Contractor may also be responsible for the placement of Geotextile, Geosynthetic reinforcement, piping and electrical systems. In this capacity, the Earthwork Contractor is responsible for the quality of the materials and installation of the materials in conformance with the contract documents.

1.4.12 Geosynthetics Manufacturer

The Geosynthetics Manufacturer(s) is responsible for the production of geosynthetics, which meet the requirements of the contract documents. The Geosynthetics Manufacturer is also responsible for providing adequate documentation regarding the characteristics of the rein, the characteristics of the finished product, the testing performed to determine the characteristics, and the quality control measures taken during manufacturing.

The Geosynthetics Manufacturer(s) may be responsible for the safe transportation of the geosynthetics between the manufacturing plant and the site. The Geosynthetics Manufacturer is responsible for carefully loading and transporting geosynthetics and accepts full responsibility for damage to the geosynthetics, which may occur during these operations.

1.4.13 Geosynthetics Installer

The Geosynthetics Installer(s) is responsible for unloading, field handling, storing, placing, seeming, temporarily anchoring against wind, and other aspects of geosynthetics installation in accordance with the contract documents. The Geosynthetics Installer may also be responsible for the preparation and completion of anchor trenches.

Prior to installation, the Geosynthetics Installer is responsible for the preparation of the panel layout drawing identifying fabricated and field seams including dimensions and details. Prior to mobilization, the Geosynthetics Installer is responsible for providing the installation schedule and a list of proposed field personnel and their qualifications. The Geomembrane Installer is responsible for providing quality control documentation and subgrade acceptance certificates. Upon completion of the installation, the Geosynthetics Installer shall provide the geomembrane installation certification, the Manufacturer's warranty, and the installation warranty.

The Geosynthetics Installer may be the same as or subcontracted by the Earthwork Contractor.

1.5 Project Meetings

To achieve a high degree of quality during installation, clear, open channels of communication are essential. The following meeting should be held when appropriate.

1.5.1 Pre-Construction

Following the completion of the contract documents and selection of a CQA Consultant for the project, a Pre-Construction Meeting may be held. At a minimum, the meetings shall be attended by the Owner, Regional Engineer, the Project Manager, the CQA Consultant's Engineer of Record, the CQA Consultant's monitoring personnel, the Earthwork Contractor, the Geosynthetics Installer, the Design Engineer, and other involved parties.

The purpose for this meeting is to begin planning for coordination of tasks, anticipate problems which might cause difficulties and delays in construction, and, above all, present the CQA Plan to the parties involve. It is very important that the rules regarding testing, repair, etc., be known and accepted.

The meeting shall include the following activities:

- Distribute relevant documents;
- Discuss Construction Scheduling;
- Review critical design details of the project;
- Review the CQA Manual;
- Make appropriate modifications to the CQA Manual to include CQA activities that are necessary;
- Reach a consensus on the site-specific CQA Plan and quality control procedures, especially on methods for determining acceptability of the soils and geosynthetics comprising the closure system and/or final cover system;

- Select testing equipment and review protocols for testing and placement of soil materials;
- Confirm the methods for documenting and reporting, and for distributing documents and reports; and
- Confirm the lines of authority and communication.

Two Pre-Construction Meetings may be held, one prior to earthwork construction, and one prior to geosynthetic placement. Regardless, all meetings must be documented by the CQA Consultant, and minutes will be transmitted within one (1) week to all parties involved.

1.5.2 Weekly Progress Meetings

A weekly progress meeting shall be held between the CQA Consultant, the Geosynthetic Installer, the Earthwork Contractor, the Project Manager, the Site Superintendent, and other involved parties. Those attending will discuss, plan, coordinate the work, and identify CQA activities to be completed that week. More frequent meetings may be held if necessary to address construction issues. The meeting will be documented by the CQA Consultant and minutes will be transmitted to all involved parties within one (1) week.

1.5.3 Problem or Work Deficiency Meetings

A special meeting shall be held when and if a problem or deficiency, which would impact the construction schedule, is present or likely to occur and cannot wait to be addressed during regular weekly meetings. At a minimum, the meeting shall be attended by the affected Contractor, the Site Superintendent, and the CQA Consultant. The purpose of the meeting is to define and resolve the problem or work deficiency as follows:

- Define and discuss the problem or deficiency;
- Review alternative solutions; and
- Implement an action plan to resolve the problem or deficiency.

The meeting shall be documented by the CQA Consultant and minutes shall be transmitted within one (1) week to all involved parties.

1.6 Qualifications of Key Personnel and Organizations

The following Qualifications shall be required of the key personnel and organizations involved in the construction of Inactive Ash Basin Closure Systems:

1.6.1 CQA Consultant

The CQA Consultant shall be pre-qualified and approved by the Regional Engineer. The CQA Consultant shall be a qualified engineering firm with experience in construction quality assurance and quality control, particularly on projects involving similar containment/closure systems. The CQA Consultant shall designate an Engineer of Record who is a Professional Engineer registered in the state of Illinois. The Engineer of Record shall be solely responsible for the CQA personnel

and their activities, as well as the preparation of a documentation report to document the project has been constructed in general accordance with the CQA Plan, permit documents, permit, design plans, and specifications. The CQA Consultant shall be capable of assigning technically qualified personnel to the project, including on-site CQA Monitors, as needed. The person designated as the Engineer of Record shall possess a thorough knowledge of all aspects of earthwork and geosynthetic construction.

CQA Monitors shall be specifically trained in quality assurance of geosynthetics and earthwork. At a minimum, the CQA monitor shall be on-site, have a minimum of two years experience, and have worked on at least four projects of five acres of greater.

1.6.2 Soils and Geosynthetics CQA Laboratories

The Soils and Geosynthetics CQA Laboratories shall be pre-qualified by the Regional Engineer, and shall be experienced in performing laboratory tests to determine characteristics as required by this CQA Plan. The Soils and Geosynthetics Laboratories shall demonstrate that it follows the standard test methods listed in the CQA Plan and maintains the appropriately calibrated equipment to perform the tests. The Soils and Geosynthetics Laboratories shall also demonstrate to the CQA Consultant and Regional Engineer that it adheres to a formal in-house quality control program and can provide the required analytical documentation and reports.

1.6.3 Earthwork Contractor

The Earthwork Contractor shall be pre-qualified and approved by the Owner and Regional Engineer. The Earthwork Contractor shall be capable of assigning the personnel and equipment required to perform the work within the schedule.

1.6.4 Geosynthetics Manufacturer

The Geosynthetics Manufacturer(s) shall be able to provide sufficient production capacity and experience to meet the demands of the project. In particular, the Geosynthetics Manufacturer shall be pre-qualified and approved by the Regional Engineer. The Manufacturer of geosynthetics shall provide, upon request of owner, sufficient documentation of production capacity and experience to the satisfaction of the Regional Engineer.

1.6.5 Geosynthetics Installer

The Geosynthetic Installer(s) shall be trained and qualified to install geosynthetics. Prior to confirmation of contractual agreements, the Geomembrane Installer shall provide the Project Manager with a list of proposed seaming personnel and their professional records. This certificate shall be reviewed by the Project Manager and the CQA Consultant. Proposed seaming personnel deemed insufficiently experienced shall not be accepted by the Project Manager or shall be required to pass a seaming test.

The Geosynthetic Installer shall designate one representative as the Installation Supervisor, who will represent the Installer on-site and at site meetings. The Installation Supervisor shall be qualified by experience. The Installation Supervisor must have supervised the installation of a minimum of 2 million square feet of geomembrane. The Installation Supervisor shall be approved by the Project Manager.

In addition, the Geosynthetic Installer shall designate a Master Seamer, who shall not be the Installation Supervisor. The Master Seamer shall be present during all seaming operations and shall have a minimum of 5 million square feet of field seaming experience, and shall be thoroughly experienced with extrusion welding, fusion welding, and welding in both hot and cold weather.

2.0 EARTHWORK, GRADING AND FILL

2.1 Introduction

Section 2.0 of the CQA Manual addresses the CQA activities associated with components of the inactive ash basin closure system, which is to be constructed of soil or aggregate. These components may include:

- Subgrade
- Structural Fill
- Protective Cover

The soil and aggregate components of the closure system shall meet requirements related to material characteristics and construction quality. Both field and laboratory tests may be performed prior to construction to evaluate if the characteristics of soil and aggregate from proposed sources meet the material acceptance requirements of the permit and design specifications. Throughout construction, additional field and laboratory testing shall be performed to evaluate if the placed material meets the requirements of the permit and construction documents with regard to material acceptance and construction quality.

2.2 Test Methods and Sampling Requirements

Tables 3.2-1A and 3.2-1B present the laboratory and field test methods which shall be used to determine material characteristics and evaluate construction quality for the soil and aggregate components of the closure system. The tests shall be conducted in accordance with the current versions of the corresponding standard methods given.

Table 3.2-2 provides information regarding the minimum test frequencies. The table also includes the locations at which samples shall be collected, the sample size, and the acceptance criteria.

Four types of sampling location strategies shall be used for the various soil and aggregate components:

- As required by the CQA Consultant to evaluate material characteristics prior to the use of the material in construction. These samples may come from the source of a material such as a production plant or from a test pit in natural material.
- For specific bulk volumes of material in stockpiles (e.g., 1 sample per 5,000 cy), the samples are usually taken on material which has been processed or segregated for a particular purpose.
- For materials placed over long linear extent (such as roads and embankments), use stationing, offsets, and approximate elevation. Stationing should be designated as 1+00, 2+00, etc. and offsets should be designated as left or right of the stationing line based on view toward increased stations.

- Once per 10,000 square feet means that the project area will be split into 10,000 square foot sections with one sample being taken from an appropriate point within the section, selected by the CQA Consultant.

2.3 Subgrade

Subgrade refers to a surface, which is exposed after stripping topsoil or excavating to establish liner or filling to structural fill grades.

The prepared subgrade should conform to the contours shown on the grading plan, as verified by the Surveyor. Vegetation shall be stripped in accordance with the design specifications and the surface proofrolled. Potentially deleterious materials such as organics or soft materials shall be removed and the resulting voids filled with acceptable material, appropriately compacted.

Refer to Table 3.2-2 for the specific test methods to be used, a summary of the field and laboratory testing to be performed, sample locations, sample sizes, test frequencies, and acceptance criteria for the structural fill. After proofrolling and/or other suitable techniques, visual examination of the subgrade preparation by the CQA Consultant should be sufficient to evaluate its suitability as a foundation for the compacted low permeability soil. If necessary, structural fill will be used to establish subgrade elevations for the closure system and berms. Use of structural fill will require the following field-testing to be performed:

- Determination of moisture/density relationship for the subgrade and/or fill material through laboratory testing; and
- Evaluation of compaction of prepared subgrade and/or fill through field density testing.

The subgrade should be accepted by the CQA Consultant if it does not pump or rut excessively. If excessive pumping or rutting occurs, the area should be reworked or removed by undercutting to more suitable material.

The surface of the finished subgrade will be surveyed in accordance with Section 7.0 for record documentation prior to placement of the compacted soil liner.

For the purpose of the GTEC inactive ash basin closure, subgrade will also be defined as excavated and placed coal combustion residual (ash) materials within the inactive basin footprint. The majority of this project will involve utilizing ash materials as subgrade materials for the installation of the liner system.

2.4 Structural Fill

Structural fill may be used in several locations to establish design elevations for the closure system, construct berms, roads, sedimentation basins, and fill pads for structures, etc. Structural fill shall meet the requirements presented in Table 3.2-2.

Structural fill will be placed in 8-inch to 12-inch loose horizontal lifts unless otherwise approved by Design Engineer.

Refer to Table 3.2-2 for the specific test methods to be used, a summary of the field and laboratory testing to be performed, sample locations, sample sizes, test frequencies, and acceptance criteria for the structural fill.

The completed surface shall be smooth, firm, and free of loose debris. Any damaged areas of the compacted fill shall be excavated and repaired at no additional cost to the owner. Areas where pumping or rutting occurs shall be reworked or removed by undercutting to obtain a more suitable material.

The liner subgrade shall be proofrolled by the Contractor and examined by the CQA Consultant to detect unstable or loose soils. Proofrolling shall be accomplished with six (6) passes (minimum) of a self-propelled drum or tamping foot roller with a static weight of the drum of at least 15,000 pounds unless otherwise approved by the CQA Consultant.

Upon completion of the design grades, the Earthwork Contractor shall survey the surface to verify that the layer has been constructed to the design lines, grades, and thickness indicated on the Contract Drawings. Survey tolerances can be found in Section 7.0 of the CQA Plan.

Where appropriate, the CQA Consultant shall prepare a documentation report for the prepared structural fill/subgrade based on a review of the CQC information and CQA monitoring performed during installation of the structural fill.

2.5 Protective Cover

The protective cover layer shall be a 36-inch layer composed of soil meeting the gradation for this material as required in Table 3.2-2. The soil shall be substantially free of organics, frozen material, foreign objects, or other deleterious materials. The soil must be capable of supporting vegetation.

Refer to Table 3.2-2 for the specific test methods to be used, a summary of the field and laboratory testing to be performed, sample locations, sample sizes, test frequencies, and acceptance criteria for the protective cover.

Protective cover shall be placed as soon as possible after the placement of geosynthetics, in one 36-inch lift and in such a manner so as not to damage the underlying geosynthetic liner materials. Low ground-pressure equipment shall be used to place the material. The equipment shall be operated on a minimum lift thickness of 36 inches.

A ramp will be constructed on the liner in advance of any non-low ground pressure equipment, which will be utilized to haul or place protective cover. This ramp will be no less than 36 inches in height and will also be constructed of protective cover.

Surveying shall be performed to verify that finished protective cover dimensions/thicknesses are as specified in the design. Upon completion of the design grades, the Earthwork Contractor shall survey the surface to verify that the layer has been constructed to the design lines, grades, and thickness indicated on the Contract Drawings. Survey tolerances can be found in Section 7.0 of the CQA Plan.

The CQA Consultant shall prepare a Documentation Report for the Protective Cover layer based on a review of the CQC information and CQA monitoring performed during installation of the material.

The finished surface of the protective cover layer will be surveyed in accordance with Section 7.0 for record documentation.

2.6 Potential Problems and Deficiencies

During construction, the frequency of testing may be increased at the discretion of CQA Consultant or the Owner when visual observations of construction performance indicate a potential problem. Additional testing for suspected areas will be considered when:

- The roller slips during compaction operations;
- Dirt-clogged rollers are used to compact the material:
- The roller may not have used optimum ballast;
- Equipment break downs during placement;
- Excessive pumping or cracking of material occurs;
- Adverse weather conditions;
- Work conducted in difficult areas; or
- High frequency of failing tests.

If a defect is discovered in the earthwork product, the CQA Consultant shall immediately determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Consultant shall determine the extent of the deficient area by additional tests, observations, a review of records, or other appropriate means. All deficiencies shall be corrected by the Earthwork Contractor to the satisfaction of the CQA Consultant and the Owner.

2.6.1 Notification

The CQA Consultant shall notify the Earthwork Contractor immediately upon discovering the defect. After determining the extent and nature of the defect, the CQA Consultant shall notify the Project Manager as necessary.

2.6.2 Repairs and Retesting

The Earthwork Contractor shall correct the deficiency to the satisfaction of the CQA Consultant and Owner. If a design specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant shall develop and present to the Owner suggested solutions for approval.

The CQA Consultant shall schedule appropriate retests after the work deficiency has been corrected. Retests recommended by the CQA Consultant must verify that the defect has been corrected before any additional work is performed by the Earthwork Contractor in the area of the deficiency.

3.0 GEOMEMBRANE

3.1 Manufacture, Shipment and Storage

The following addresses the activities associated with the manufacture of the geomembrane; the shipment, handling, and delivery of geomembrane to the site; conformance testing of delivered geomembrane; and the storage of the geomembrane prior to installation.

3.1.1 Manufacturer of Polyethylene Geomembrane

The Geosynthetics Manufacturer shall provide documentation that the material meets the requirements of the design specifications, as listed in Table 3.4-4 [Liner Low Density Polyethylene (LLDPE)], and that adequate quality control measures have been implemented during the manufacturing process.

3.1.1.1 Resin Quality

The raw material shall be first quality polyethylene resin contain no more than 2 percent clean "reground", "reworked", or "trim" material by weight, and meeting the specification, outlined in Table 3.4-4 (LLDPE).

Prior to the shipment of polyethylene geomembrane material, the Geosynthetics Manufacturer shall provide the Project Manager and the CQA Consultant with the following information:

- The origin (Resin Supplier's name and resin production plant), identification (brand name number), and production date of the resin;
- A copy of the quality control certificates issued by the Resin Supplier;
- Reports on the tests conducted by the Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls and extrudate rods meet the requirements indicated above; and
- A statement that no reclaimed polymer is added to the resin (however, the use of polymer recycled during the manufacturing process may be permitted if done with appropriate cleanliness and if recycled polymer does not exceed 2 percent by weight).

At the Owner's discretion and cost, testing may be carried out on the resin by the Geosynthetics CQA Laboratory for purposes of verifying conformance. If the results of the manufacturer and the Geosynthetics CQA Laboratory testing differs, the testing will be repeated by the Geosynthetics CQA Laboratory, and the Geosynthetics Manufacturer will be permitted to monitor this testing. The results of this latter series of tests will prevail, provided that the applicable test methods have been followed.

3.1.1.2 Certification of Property Values

In addition to information regarding the raw material, the Geosynthetics Manufacturer shall provide the Project Manager and the CQA Consultant with the following prior to shipment of the geomembrane:

- A properties sheet certification including, at a minimum, guaranteed values for all specified properties presented in Table 3.4-4.
- A list of quantities and descriptions for materials other than the base polymer, which comprise the geomembrane.

The CQA Consultant shall verify that the property values certified by the Geosynthetics Manufacturer meet the test methods and values shown on Table 3.4-4.

3.1.1.3 Quality Control Certificates

Prior to shipment, the Geosynthetics Manufacturer shall provide the Project Manager and the CQA Consultant with quality control certificates for the geomembrane to be shipped to the site. The quality control certificate will be signed by a responsible party employed by the Geosynthetics Manufacturer. The quality control certificate will include:

- Roll numbers and identification; and
- Sampling procedures and results of quality control tests.

The Geosynthetics Manufacturer shall be required to perform, at a minimum, the tests at the minimum frequencies presented in Table 3.4-4.

The CQA Consultant shall:

- Verify that the quality control certificates have been provided at the frequency specified in Table 3.4-4 for all rolls; and
- Review the quality control certificates and verify that the test methods and values meet the requirements presented in Table 3.4-4

3.1.2 Shipment and Handling

Shipment of the geomembrane to the site is the responsibility of the Owner, Geosynthetics Manufacturer, or Geosynthetics Installer depending on the contract documents. Handling of geomembrane on-site is the responsibility of the Geosynthetics Installer.

The CQA Consultant shall confirm that:

- Handling equipment used on-site poses minimal risk of damage to the geomembrane; and
- Personnel handle the geomembranes with care.

Upon delivery to the site, the Geosynthetics Installer and the CQA Consultant shall confirm that roll identification corresponds to quality control certificates, and shall conduct a visual examination of the exposed outer surface of each roll for defects, damage, and labeling. This examination shall be conducted without unrolling rolls unless defects or damages are found or suspected. All roll identifying labels shall be weatherproof. The CQA Consultant will indicate to the Project Manager:

- Rolls, or portions thereof, that should be rejected and removed from the site because they have severe flaws;
- Rolls that have minor repairable flaws; and
- Rolls without proper identification.

The Project Manager shall reject rolls without proper identification.

3.1.3 Conformance Testing Of Geomembrane

Upon, or prior to, delivery of the rolls of geomembrane, the CQA Consultant shall verify that samples are removed and forwarded to the Geosynthetics CQA Laboratory for testing to verify conformance with the test methods, values, and frequencies presented in Table 3.4-2) and Table 3.4-5.

3.1.3.1 Sample Collection

Using the packing list provided by the manufacturer or a sequential inventory list made by the CQA Consultant, rolls shall be selected for sampling at a minimum frequency as specified in Table 3.4-2 and Table 3.4-5. If the material is shipped in identifiable lots or manufacturing runs, sample selection should be adjusted to assure that the minimum frequency is met and that each different lot or manufacturing run is represented by at least one sample.

Samples will be taken across the entire width of the roll and will not include the first 3 lineal feet. Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Consultant will mark the machine direction on the samples with an arrow. Conformance testing shall be conducted in accordance with Table 3.4-2 and Table 3.4-5.

3.1.3.2 Test Results

The results of the conformance testing shall be evaluated in accordance to the following procedure:

- If the average test values for the sample meet the requirement presented in Table 3.4-2 and Table 3.4-5, and the Manufacturer's guaranteed minimum values, the sample passes.
- If the average test value for the sample does not meet one or more of the required values, additional evaluation procedures will be implemented by the CQA Consultant. Additional tests required for further evaluation shall be at no expense to the Owner.

- For the failing parameter(s), perform one additional test on the sample. This test may be performed by another CQA Geosynthetics Laboratory at the discretion of the CQA Consultant and the Project Manager.
- If the test values for the additional tests meet the required values, the roll and adjacent rolls pass are acceptable.
- If the test value does not meet requirements, reject the roll, collect samples from the closest numerical roll on both sides of the failed roll and test for the failed parameter(s). If one or both of these tests do not meet requirements, those roll(s) will be rejected and the CQA Consultant and Project Manager shall determine further testing protocol and criteria for identifying the limits of rejected rolls.

3.1.4 Storage

The Geosynthetics Installer shall be responsible for the storage of the geomembrane on site unless otherwise specified. Storage space should protect the geomembrane from theft, vandalism, passage of vehicles, damage from the supporting subgrade, water, and weather. The geomembrane shall be stored on sandy subgrade free of rocks and sharp objects. The maximum stacking height for rolls shall be four rolls high.

The CQA Consultant shall observe that storage of the geomembrane provides adequate protection against dirt, shock, and other sources of damage.

3.2 Geomembrane Installation

3.2.1 Earthwork

Installation of Geomembrane involves three primary tasks; earthwork, placement of geomembrane panels, and seaming the field panels. The installation of the geomembrane and anchoring it in place is crucial to the performance of the geomembrane. The CQA Consultant shall monitor Geomembrane Installation activities.

The CQA Consultant shall document that:

- A qualified Land Surveyor has verified lines and grades;
- The requirements of Section 2.0 of the CQA Plan are satisfied;
- The subgrade on which the overlying geosynthetic liner system is to be placed shall have been compacted and graded smooth in accordance with the CQA Plan. The surface shall be free of sharp or pointed stones, which would tend to puncture the overlying geomembrane. In addition, all stones within the top lift of compacted soil liner shall be smaller than ¾-inch diameter;
- If necessary, base and side slope surfaces shall be rolled with a smooth drum roller to smooth out rough or badly gouged compacted soil liner. Sharp-pointed fragments of stone, dried soil clods or other deleterious materials shall be removed. This work will be performed by the Earthwork Contractor; and

- The underlying subgrade provides a firm, smooth, unyielding foundation for the overlying geosynthetic liner system with no sudden, sharp or abrupt changes or break in grade. No standing water or excessive moisture shall be allowed. Areas that are soft, wet, or otherwise unsuitable for liner installation shall be excavated and replaced with suitable material by the Earthwork Contractor. Immediately prior to installation of the first component of the geosynthetic liner system, the Geosynthetics Installer and on-site Project Manager shall walk the entire surface of the soil liner to ensure that it is acceptable.

The Geosynthetics Installer shall certify in writing that the surface on which the geomembrane will be installed is acceptable. This subgrade acceptance certificates shall be given by the Geosynthetics Installer to the CQA Consultant prior to commencement of geomembrane installation in the area under consideration. The CQA Consultant will document the acceptance certification for the CQA Final Report.

It is the Geosynthetics Installer's responsibility to protect the subgrade after it has been accepted. After the supporting subgrade has been accepted by the Geosynthetics Installer, it shall be the responsibility of the Geosynthetics Installer and the CQA Consultant to indicate to the Project Manager any change in the subgrade condition that may require repair work.

3.2.2 Geomembrane Placement

The placement of field panels of geomembrane is the responsibility of the Geosynthetics Installer and shall be performed in accordance with the approved panel layout and the following.

3.2.2.1 Panel Layout

At the Pre-Construction Meeting, the Geosynthetics Installer shall provide the Project Manager and the CQA Consultant with a drawing of the facility to be lined showing expected panel layout. The CQA Consultant shall review the panel layout drawing and verify it is consistent with the accepted state of practice and the CQA Plan. The Panel Layout Drawing shall be approved by the CQA Consultant’s Engineer of Record.

Seams should be oriented parallel to the line of maximum slope, i.e., oriented along, not across the slope, unless approved by the engineer. In corners and odd-shaped geometric locations, the number of seams should be minimized. Horizontal seams should not be closer than 5 feet from the toe of slopes, or areas of potential stress concentration, unless otherwise authorized.

3.2.2.2 Field Panel Identification

The CQA Consultant shall document that the Geosynthetics Installer labels each field panel with an "identification code" (number and/or letter) consistent with the layout plan. This identification code shall be agreed upon by the Project Manager, Geosynthetics Installer, and CQA Consultant. It is the responsibility of the Geosynthetics Installer and the CQA Consultant to verify that each field panel placed can be tracked to the original roll number. The identification code will be marked at a location agreed upon by the Project Manager, Geosynthetics Installer, and the CQA Consultant at the Pre-Construction meeting.

The CQA Consultant shall establish a table or chart showing correspondence between roll numbers and field panel identification codes. The field panel identification code will be used for all quality assurance records.

3.2.2.3 Installation Schedule

Field panels shall be placed one at a time unless otherwise approved by the CQA Consultant and the Project Manager. Each field panel shall be seamed after its placement in order to minimize the number of unsealed field panels exposed to weather.

It is usually beneficial to "shingle" overlaps in the downward direction to facilitate drainage in the event of precipitation. It is also beneficial to proceed in the direction of prevailing winds. Scheduling decisions must be made during installation, in accordance with varying conditions. In any event, the Geosynthetics Installer shall be fully responsible for the decision made regarding placement procedures.

The CQA Consultant shall record the identification code, location, date of installation, time of installation, weather conditions and ambient temperature. The CQA Consultant shall evaluate field changes by the Geosynthetics Installer, which may have affected the original schedule proposed by the Geosynthetics Installer, and advise the Project manager on the acceptability of that change.

3.2.2.4 Weather Conditions

Geomembrane placement shall not proceed when sheet temperature, measured by placing a thermometer on the surface of the sheet, is below 40^{o}F or above 140^{o}F. Deviations from these temperature criteria shall only occur when authorized by the Project Manager and with the concurrence of the CQA Consultant. Geomembrane placement shall not be done during any precipitation, fog, snow, in an area of ponded water, or in the presence of excessive winds.

The CQA Consultant shall verify that the above conditions are fulfilled and shall inform the Project Manager if the conditions are not fulfilled.

3.2.2.5 Anchorage System

Anchor trenches shall be excavated by the Earthwork Contractor (unless otherwise specified) to the lines and widths shown on the plans prior to geomembrane placement. The CQA Consultant shall verify that anchor trenches have been constructed according to the plans.

Slightly rounded corners will be provided in trenches where the geomembrane adjoins the trench to avoid sharp bends in the geomembrane. Loose soil shall not underlie the geomembrane in the trenches. Seaming shall continue through the anchor trench.

Backfilling of anchor trenches shall be performed in accordance with Technical Specifications and Section 3.2.5 of the CQA Manual.

3.2.2.6 Method of Placement

The following is the responsibility of the Geosynthetics Installer. The CQA Consultant shall document that these conditions are satisfied:

- Equipment used does not damage the geomembrane by handling, traffic, excessive heat, leakage of liquids, or other means;
- The prepared surface underlying the geomembrane has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement;
- Geosynthetic material immediately underlying the geomembrane are clean and free of debris;
- Personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities that could damage the geomembrane;
- The method and equipment used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the subgrade;
- The method used to place the panels minimizes wrinkle (especially differential wrinkle 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 (in case of high winds, continuous loading, e.g., by adjacent sand bags, is recommended along the edges of panels to minimize the risk of wind flow under the panels); 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;
- Panels should be deployed such that minimal adjustments are required;
- The Earthwork Contractor and Geosynthetics Installer shall be responsible each day for taking all actions needed to prevent run on of stormwater above and beneath the geomembrane. Run on beneath the geomembrane may necessitate removal of underlying soils, depending on the soil condition as determined by the CQA Consultant. Once liner installation has started, the Owner will not be responsible for costs associated with repair of compacted soil liner damage due to stormwater run on.

The CQA Consultant shall inform the Project Manager if the above conditions are not fulfilled.

3.2.2.7 Damage

The CQA Consultant shall visually observe each panel, after placement and prior to seaming, for damage. The CQA Consultant shall advise the Project Manager which panels, or portions of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels, which have been rejected, shall be marked and their removal from the work area recorded by the

CQA Consultant. Repairs shall be made according to procedures described in the technical specifications and CQA Plan.

As a minimum, the CQA Consultant shall document that:

- The panel is placed in such a manner that it is unlikely to be further damaged; and
- Any tears, punctures, holes, thin spots, etc. are either marked for repair or the panel is rejected.

3.2.3 Field Seaming

Field seaming is the responsibility of the Geosynthetics Installer and shall be performed in accordance with the following procedures.At the Pre-Construction Meeting, the Geosynthetics Installer will provide the CQA Consultant with a list of proposed seaming personnel and their professional records. This document will be reviewed and approved by the Project Manager and CQA Consultant. Seaming personnel shall meet the requirements listed in Section 1.6.5 of this CQA Manual.

Approved processes for field seaming are extrusion seaming and fusion seaming. Proposed alternate processes shall be documented and submitted to the Owner for approval. Only seaming equipment which has been specifically approved by make and model shall be used. The Geosynthetics Installer shall submit seaming equipment documentation to the Project Manager and the CQA Consultant for the CQA report.

The flowing is the responsibility of the Installer. The CQA Consultant shall verify that these conditions are met:

- The Geosynthetics Installer maintains on-site the number of spare operable seaming apparatus decided at the Pre-Construction Meeting;
- Equipment used for seaming is not likely to damage the geomembrane;
- The extruder is purged prior to beginning seam unit heat-degraded extrudate has been removed from the barrel;
- For cross seams, the edge of the cross seam is ground to a smooth incline (top and bottom) prior to seaming;
- The electric generator is placed on a flat smooth base and a rub sheet such that no damage occurs to the geomembrane; and
- A smooth insulating plate or fabric is placed beneath the hot seaming apparatus after usage.

3.2.3.1 Extrusion Seaming

The extrusion seaming apparatus shall be equipped with gauges giving the relevant temperatures of the apparatus, including the temperatures of the extrudate, nozzle, and preheat.

The Geosynthetics Installer shall provide documentation on the extrudate to the Project Manager and the CQA Consultant, and shall certify that the extrudate is compatible with the design specifications, and is comprised of the same resin as the geomembrane sheeting, except in the case of LLDPE, where the extrudate shall be comprised of HDPE resin.

The CQA Consultant shall log apparatus temperatures, ambient temperatures, extrudate temperatures, and sheet temperatures at appropriate intervals.

3.2.3.2 Fusion Seaming

The fusion seaming apparatus must be automated vehicular mounted devices, equipped with gauges giving the applicable temperatures. Pressure settings shall be verified by the Geosynthetics Installer prior to each seaming period.

The CQA Consultant shall log ambient temperatures, sheet temperatures, and seaming apparatus temperatures, speeds, and pressures.

3.2.3.3 Seam Preparation

The following is the responsibility of the Geosynthetics Installer. The CQA Consultant shall verify that these conditions are met:

- Prior to seaming, the seam area is clean and free of moisture, dust, dirt, oils, greases, debris of any kind, and foreign material. If necessary, the material to be joined must be wiped with a clean cloth just prior to seaming;
- A rub sheet must be used to protect the liner while cutting any materials;
- If seam overlap grinding is required, the process is completed according to the Geomembrane Manufacturer's instructions within 1 hour of the seaming operation, and in a way that does not damage the geomembrane;
- As a general guidance, the panels of geomembrane shall have a finished overlap of a minimum of 3 inches for extrusion seaming and 6 inches for fusion seaming, but in any event sufficient overlap will be provided to allow peel tests to be performed on the seam;
- No solvent or adhesive is used unless the product is approved in writing by the Owner (samples will be submitted to the Owner for testing and evaluation);
- The procedure used to temporarily bond adjacent panels together shall not damage the geomembrane (in particular, the temperature of hot air at the nozzle of any seaming apparatus is controlled such that the geomembrane is not damaged);
- No abrading is visible when welding is complete;
- Seams are aligned with the fewest possible number of wrinkle and "fishmouths"; and
- No metal objects that could potentially damage the liner are permitted for use on the lined area.

The CQA Consultant shall observe all appropriate temperatures and conditions, and shall log and report to the Project Manager any deviation.

3.2.3.4 Weather Conditions for Seaming

The required weather conditions for seaming are as follows:

- The sheet temperatures shall be measured by the Geosynthetics Installer using a thermometer placed on the surface of the geomembrane sheet;
- Unless authorized in writing by the Project Manager, (extrusion or fusion welding) seaming shall not be attempted at a sheet temperature below 40°F or above 140°F; and
- The geomembrane shall be dry and protected from wind.

If the Geosynthetics Installer wishes to use methods that may allow seaming at ambient temperatures below 40°F or above 140°F, the Geosynthetics Installer shall demonstrate and certify in writing that such methods produce seams which are entirely equivalent to seams produced at acceptable ambient temperatures. The Geosynthetics Installer shall also demonstrate that the overall quality of the geomembrane is not adversely affected.

The CQA Consultant shall verify that the above guidelines regarding weather are adhered to, and will advise the Project Manager and Engineer of Record accordingly.

3.2.3.5 Pre-Weld Testing

Test welds shall be made on fragment pieces of geomembrane liner to verify that seeming conditions are adequate and in accordance with Table 3.4-3 and Table 3.4-6. Such test welds shall be made upon each start of work for each seamer, upon every four (4) hours of continuous seaming, every time seaming equipment is changed, if significant changes in geomembrane temperature and weather condition are observed, and/or at the discretion of the CQA Consultant. A passing test weld shall be made for each seaming device and technician. A change in technician or machine on a previously passed test weld warrants the welding of a new passing test weld. A test weld shall also be made in the event that the sheet temperature varies more than 18°F since the last passing test weld. Test welds shall be made under the same conditions as actual seams. If seaming apparatus is turned off for more than 30 minutes, a new passing test weld must be completed for that specific seaming apparatus.

The Geosynthetics Installer shall provide the tensiometer required for shear and peel testing of test welds in the field. The tensiometer shall be automatic and shall have a direct digital readout. The tensiometer shall be calibrated prior to use. The Geosynthetics Installer shall provide the Project Manager with the calibration certification.

The test weld sample shall be at least 5 feet long by 1 foot wide (after seaming) with the seam centered lengthwise. Seam overlap will be as indicated in Subsection 3.2.3.3.

Six specimens, each 1-inch wide, shall be cut from the test weld sample by the Geosynthetics Installer. Three specimens shall be tested in shear and three in peel using a field tensiometer. For each fusion specimen, both tracks shall be tested. A passing welded seam is achieved in peel and shear when the specimen meets the criteria of Table 3.4-3 and Table 3.4-6.

If a specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus and seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful full test welds are achieved.

The CQA Consultant shall observe test weld procedures. The remainder of the successful test weld sample shall be assigned a number and marked accordingly by the CQA Consultant, who will also log the data, hour, ambient temperature, number of seaming unit, name of seamer, and pass or fail description. The remainder of the successful test weld samples shall be archived at the site until the Permitting Agency has approved the final documentation.

3.2.3.6 General Seaming Procedure

Unless otherwise specified, the general seaming procedure used by the Installer shall be as follow:

- For fusion seaming, a movable protective layer of plastic may be required to be placed directly below each overlap of geomembrane that is to be seamed. This is to help prevent any moisture build-up between the sheets to be seamed;
- In general, seams should be oriented parallel to the line of maximum slope, i.e., oriented up and down, not across the slope. In corners and odd-shaped geometric locations, the number of field seams shall be minimized;
- All production field seaming shall be hot wedge fusion welding. Extrusion welding is permitted only in areas where hot wedge fusion welding is not possible. Solvent welding or adhesive tape is not acceptable for either temporary or permanent seams. The CQA Consultant and Owner reserve the right to reject any proposed seaming method they believe is unacceptable;
- The composition of the extrudate shall be identical to the lining material and shall be manufactured from the same resin and same additives and proportions thereof as the geomembrane sheet so as to ensure the best possible bonding of extrudate to the geomembrane sheet. Each extrusion welder shall be completely purged of heat-degraded extrudate prior to beginning a seam;
- All foreign matter (dust, dirt, moisture, oil, etc.) shall be removed from the edges of panels to be bonded. If an extrusion weld is required, the bonding surfaces must be thoroughly cleaned by mechanical abrasion or alternative methods approved by the CQA Consultant to remove surface debris, cure, and prepare the surfaces for bonding. No solvents will be allowed to clean the geomembrane. Mechanical abrasion shall occur within one hour prior to extrusion welding the seam;

- No extrusion welding should be attempted above 140°F sheet temperature for extrusion and fusion welding. If seaming is to be performed when the ambient air temperature is below 40°F, preheating of the geomembrane will be required and acceptable test welds, which duplicate as closely as possible actual field conditions, shall be achieved. Preheating may be achieved by natural and/or artificial means (shelters and heating devices). Between 40°F and 50°F ambient air temperature, seaming is possible if the geomembrane is preheated by either the sun or a hot air device provided no excessive cooling of the geomembrane results from environmental conditions. No preheating is required above 50°F. In all cases, the geomembrane will be dry and protected from wind damage;
- While welding a seam, the Geosynthetics Installer shall monitor temperature gages of the welding device to assure that proper settings are maintained. The welding equipment used shall be capable of continuously monitoring and controlling the temperatures and pressures in the zone of contact where the machine is actually welding the lining material so as to ensure that changes in environmental conditions will not affect the integrity of the weld;
- All cross-butt seams between two rows of seamed panels shall be welded during the coolest time of the day to allow for contraction of the geomembrane;
- All "T" joints shall have the overlap from the fusion welder seam trimmed back to allow an extrusion fillet weld. The Geosynthetics Installer shall then grind 2 inches minimum on either side of the fusion welded seam and extrusion weld a patch over all of the prepared area;
- At the end of each day or installation segment, all unseamed edges shall be adequately anchored by sandbags or other approved devices. Sandbags securing the geomembrane on the sideslopes should be connected by a rope fastened at the top of the slope by a temporary anchor. If high winds are expected, boards along the edge of unseamed panels, with weighted sandbags on top, should be used to anchor the geomembrane on the bottom of the cell. Staples, U-shaped rods, or other penetrating anchors may not be used to secure the geomembrane on the sideslopes;
- If required, a firm substrate will be provided by using a flat board or similar hard surface directly under the seam overlap to achieve proper support;
- Wrinkles at the seam overlaps will be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut wrinkles will be seamed and any portion where the overlap is inadequate will then be patched with an oval or round patch of the same geomembrane extending a minimum of 6 inches beyond the cut in all directions;
- Seaming will extend to the outside edge of panels to be placed in the anchor trench; and
- The CQA Consultant should observe all test weld procedures. The remainder of the successful test weld sample will be assigned a number and marked accordingly by the CQA Consultant, who will also log the date, hour, ambient

temperature, number of seaming units, name of seamer, and pass or fail description. The sample itself should be retained in the Owner's archives. In addition, at least one tested specimen from each test as selected by the CQA Consultant will be retained by the CQA Consultant. The CQA Consultant will transmit these specimens to the Owner following substantial completion of the geomembrane installation. No field seaming shall take place without the Master Seamer being present.

The CQA Consultant shall verify that the above seaming procedures are followed, and shall inform the Project Manager if they are not.

3.2.3.7 Non-Destructive Seam Continuity Testing

The Geosynthetics Installer shall non-destructively test 100 percent of the field seams over their full length using a vacuum test unit (for extrusion seams only), air pressure test (fusion seams), or other approved method. The testing shall be carried out to the accepted standards of the industry. The purpose of non-destructive tests is to check the continuity of seams. It does not provide any information on seam strength. Continuity testing shall be carried out as the seaming work progresses (maximum of 3,000 lineal feet of seam) and not at the completion of all field seaming, unless otherwise approved by the Project Manager. The Geosynthetics Installer shall complete any required repairs in accordance with technical specifications and the CQA Plan. Non-destructive testing shall not be permitted before sunrise or after sunset unless the Geosynthetics Installer demonstrates capabilities to do so.

Air Pressure Testing:

Unless otherwise specified, the general air pressure testing procedure used by the Geosynthetics Installer shall be as follows:

- Seal both ends of the seam to be tested.
- Insert needle of other approved pressure feed device into the airspace created by the double fusion welds.
- Inflate the test channel to 30 to 35 psi, close valve, and observe initial pressure after approximately 2 minutes.
- Initial pressure settings are read after a 2 minute "relaxation period". Initial pressure setting shall be between 30 to 35 psi. The purpose of the "relaxing period" is to permit the air temperature and pressure to stabilize.
- Observe and record the air pressure 5 minutes after "relaxing period" ends and initial pressure setting is used. If loss of pressure exceeds 10 percent, or if the pressure does not stabilize, the Geosynthetics Installer shall locate the faulty area and repair it in accordance with the Technical Specifications and Section 3.2.4 of the CQA Manual.

- At the conclusion of the pressure test, the end of the seam opposite the pressure gauge is cut. A decrease in a gauge pressure must be observed or the air channel will be considered "blocked" and the test will have to be repeated after the blockage is corrected.
- Remove needle or other approve pressure feed device and seal the resulting hole by extrusion welding.
- Test results will be recorded by the CQA Consultant.

Non-complying Air Pressure Test:

In the event of a non-complying air pressure test, the following procedure shall be followed:

- Check the seam and seals and retest the seam.
- If deviation with specified maximum pressure differential reoccurs, cut 1 inch samples from each end suspect area.
- Perform destructive peel tests on the samples using the field tensiometer.
- If all samples pass destructive testing, the installer may:
  - Cap-strip the suspect area; or
  - Further isolate the air pressure failure as agreed upon by the CQA Consultant and Project Manager.
- If one or more samples fail the peel tests, additional samples will be taken. When two passing samples are located, the suspect areas will be considered non-complying. In this section, the seam shall be cap stripped, or the overlap left by the wedge welder will be heat tacked in place along the entire length of the seam will be extrusion welded. Test the entire length of the repaired seam by vacuum testing.
- If the seam is in non-compliance due to air channel blockage, the blockage shall be isolated, as agreed upon by the CQA Consultant.
- All sections shall be retested and repaired in accordance with this section.

Vacuum Testing:

Unless otherwise specified, the general vacuum testing procedure used by the Geosynthetics Installer shall be as follows:

- Turn on the vacuum pump to reduce the vacuum box to approximately 5 psi.
- Apply a generous amount of a solution of liquid soap and water to the area to be tested.
- Place the vacuum box over the area to be tested and apply sufficient downward pressure to "seat" the seal strip against the liner.
- Close the bleed valve and open the vacuum valve.
- Ensure that a leak tight seal is created between the vacuum box and the Geomembrane.

- For a period of not less than 10 seconds, examine the geomembrane through the viewing window for the presence of soap bubbles.
- If no bubbles appear after 10 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 3-inch overlap, and repeat the process.

Non-Complying Vacuum Test:

In the event of a non-complying vacuum test, the following procedure shall be followed:

- Mark all areas where soap bubbles appear and repair the marked areas, as specified in this section.

CQA Responsibilities:

The CQA Consultant shall:

- Document all continuity testing;
- Record location, date, unit number, name of tester, and outcome of all testing; and
- Inform the Geosynthetics Installer and Project Manager of any required repairs.

When defects are located, the CQA Consultant shall:

- Observe the repair and retesting of the repair;
- Mark on the geomembrane that the repair has been made; and
- Document the results.

Non-Testable Areas:

The Geosynthetics Installer shall use the following procedures at locations where seams cannot be non-destructively tested:

- All such seams shall be cap-stripped with the same geomembrane material.
- If the seam is accessible to testing equipment prior to final installation, the seam shall be non-destructively tested.
- If the seam cannot be tested prior to final installation, the seaming and cap-stripping operations shall be observed by the CQA Consultant and Geosynthetics Installer for uniformity and completeness.
- The seam number, date of observation, name of tester, and outcome of the test or observation shall be recorded by the CQA Consultant.

Destructive Testing:

The Geosynthetics Installer will not be informed in advance of the locations where the seam samples will be taken. The purpose of these tests is to evaluate seam strength.

Sampling Procedure:

Samples shall be cut by the Geosynthetics Installer as the seaming progresses in order to have passing laboratory test results before the geomembrane is covered by another material. The CQA Consultant shall:

- Observe sample cutting;
- Assign a number to each sample, and mark it accordingly;
- Record the sample location on the layout drawing; and
- Record the reason for taking the sample at this location (e.g., statistical routine, suspicious feature of the geomembrane).

All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in this Section of the CQA Plan. The continuity of the new seams in the repaired area will be tested.

Size of Samples:

The destructive sample will be 12 inches wide by 36 inches with the seam centered lengthwise. The sample for Laboratory testing shall be located between the two specimens for field testing. The sample shall be cut into three parts and distributed as follows:

- One portion to the Geosynthetics Installer for field testing, 12 inches x 12 inches;
- One portion to the Owner for archive storage, 12 inches x 12 inches; and
- One portion for Geosynthetics CQA Laboratory testing, 12 inches x 12 inches.

Final determination of the sample sizes shall be made at the Pre-Construction meeting.

Geosynthetics CQA Laboratory Testing:

Destructive test samples shall be packaged and shipped, if necessary, by the CQA Consultant in a manner that will not damage the test sample. The Project Manager shall be responsible for storing the archive samples. Test samples shall be tested by the Geosynthetics CQA Laboratory. Testing will include shear and peel and shall meet the requirements in Table 3.4-3 and 3.4-6. At least five specimens will be tested for each test method. The Geosynthetics CQA Laboratory shall provide test results, in writing, on more than 24 hours after they receive the samples. The Geosynthetic Laboratory shall document the results of seam testing. The CQA Consultant shall review laboratory test results as soon as they become available, and make appropriate recommendations to the Project Manager. Results from the Geosynthetics Installer's laboratory testing, if conducted, shall be presented to the Project Manager and the CQA Consultant for review.

Destructive Test Failure:

The following procedures shall apply whenever a sample fails a destructive test, whether that test is conducted by the Geosynthetics CQA Laboratory, the Installers Laboratory, or by the field tensiometer.

- The Geosynthetics Installer can reconstruct the seam between any two passed destructive seam test locations; or
- The Geosynthetics Installer can trace the seaming path to an intermediate location (at least 10 ft from the point of the failed test in each direction) and obtain full size destructive laboratory samples. If these destructive laboratory samples pass the tests, then the seam is reconstructed between these locations by capping or by extrusion welding the flap for fusion welds (see Section 3.2.4.1 for definitions). If the new samples fail the laboratory testing, then the process is repeated to establish the zone in which the seam should be reconstructed.

If a fusion type seam fails destructive testing and the Geosynthetic Installer chooses to cap the seam, only acceptable capping methods will be allowed.

All acceptable seams must be bounded by two locations from which destructive samples passing laboratory tests have been taken. In cases exceeding 150 feet of reconstructed seam, a sample shall be taken from the zone in which the seam has been reconstructed. This sample must pass destructive testing or the procedure outlined here must be repeated.

The CQA Consultant shall document all actions taken in conjunction with destructive test failures.

3.2.4 Defects and Repairs

Seams and non-seam areas of the geomembrane shall be examined by the CQA 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 defeats, the surface of the geomembrane will be clean at the time of examination. The surface shall be swept or washed by the Geosynthetics Installer if the amount of dust or mud inhibits examination.

3.2.4.1 Repair Procedures

Any portion of the geomembrane exhibiting a flaw, failing a destructive test, or failing a non-destructive test, shall be repaired. Several procedures exist for the repair of these areas. The Project Manager and the CQA Consultant shall approve the final decision as to the appropriate repair procedure. The procedures available include:

- Patching - Apply a new piece of geomembrane sheet over, and at least 6 inches beyond the limits of a defect. The patch shall be extrusion seamed to the underlying geomembrane. This method should be used to repair large holes, tears, destructive test locations, undispersed raw materials, and contamination by foreign matter.
- Spot Seaming - Apply a "bead" of extrudate, maximum length of 6 inches, over a defect. Spot seaming should be used only to repair dents, pinholes, pressure test air holes, or other minor, localized flaws.
- Capping - Apply a new strip of geomembrane along the length of a delineated faulty seam. The cap strip shall extend at least 6 inches beyond the limit of the seam and the edges will be extrusion seamed to the underlying geomembrane. This method should be used to repair lengths of extrusion or fusions seamed to the underlying geomembrane.

- Welding Flap - Where an adequate flap exists (at least 1-1/2 inches), it is permissible to extrusion weld the flap of a fusion seam. At the ends of this repair, the flap shall be cut to allow the extrusion weld to enclose the failed area.
- Replacement - The faulty seam is removed and replaced.

In addition, the following provisions shall be satisfied:

- Surfaces of the geomembrane which are to be repaired will be abraded no more than one hour prior to extrusion welding of the repair;
- All surfaces must be clean and dry at the time of the repair;
- All seaming equipment used in repairing procedures must be approved;
- The repair procedures, materials, and techniques will be approved in advance of the specific repair by the CQA Consultant and Geosynthetics Installer;
- Patches or caps will extend at least 6 inches beyond the edge of the defect, and all corners of patches will be rounded; and
- Seam repairs over 150 feet long will require a destructive test to be taken from the repair.

3.2.4.2 Verification of Repairs

Each repair shall be numbered and logged by the CQA Consultant and the Geosynthetics Installer. Each repair shall be non-destructively tested using the methods described in this section as appropriate. Repairs, which pass the non-destructive test, will be taken as an indication of an adequate repair. However, if the CQA Consultant suspects a repair to be questionable, although it passes non-destructive testing, a destructive test can be requested. Failed tests will require the repair to be redone and retested until a passing test result is achieved. The CQA Consultant shall observe non-destructive testing of repairs and shall record the date of the repair and test outcome.

3.2.4.3 Large Wrinkles

When seaming of the geomembrane is completed (or when seaming of a large area of the geomembrane is completed) and prior to placing overlying materials, the CQA Consultant shall observe the geomembrane wrinkles. The CQA Consultant will indicate to the Project Manager which wrinkle should be cut and resealed by the Geosynthetics Installer. The seam thus produced will be tested like any other repair.

3.2.5 Backfilling of Anchor Trench

Anchor trenches will be adequately drained to prevent ponding or otherwise softening of the adjacent soils while the trench is open. Anchor trenches shall be backfield and compacted as soon as possible. General fill used when backfilling the trench shall be material with 100 percent of the particles finer than 12 inches. Care shall be taken when backfilling the trenches to prevent any damage to the geosynthetics.

Unless otherwise approved by the Engineer, each lift of backfill material spread for compaction shall not exceed a loose lift thickness of 8 to 12 inches, depending upon material type. Each lift of backfill shall cover the length and width of the area to be backfilled, shall be uniform in thickness, and shall be spread and compacted as specified before the next lift is started unless otherwise permitted.

The CQA Consultant shall approve each lift before successive lifts are placed. The CQA Consultant shall observe the backfilling operation and advise the Project Manager of any problems.

3.2.6 Liner System Certification/Acceptance

The Geosynthetics Installer and the Manufacturer shall retain ownership and responsibility for the geosynthetics in the facility until acceptance by the Owner.

The liner system shall be accepted by the Owner when:

- The installation is finished;
- Verification of the adequacy of seams and repairs, including associated testing, is complete;
- Geosynthetics Installer's representative furnishes the Project Manager with documentation that the geomembrane was installed in general accordance with the Manufacturer's recommendations as well as the design plans and specifications;
- All documentation of installation is completed including the CQA Consultant final report; and
- Record Documentation, including record drawings, sealed by a Professional Engineer has been received by the Owner.

The CQA Consultant shall provide documentation that installation has proceeded in general accordance with this CQA Plan for the project except as noted to the Owner or Project Manager.

3.2.7 Materials In Contact With the Geomembranes

The quality assurance procedures indicated in this Subsection are only intended to verify that the installation of these materials does not damage the geomembrane. Additional quality assurance procedures provided in other sections of this CQA Manual are necessary to verify that the systems built with these materials are constructed to perform as designed.

3.2.7.1 Geocomposite

The CQA Consultant shall verify that the geocomposite is installed in accordance with the procedures described in Section 4.0 of the CQA Manual. Extreme care shall be exercised so as not to damage the geomembrane during placement of the geocomposite and the materials overlying the geocomposite.

3.2.7.2 Appurtenances

The Design Engineer shall provide design specifications for appurtenances to the Project Manager and the CQA Consultant. The CQA Consultant shall verify that:

- Installation of the geomembrane in appurtenance areas, and connection of geomembrane to appurtenances, have been made according to the design specifications;
- Extreme care is taken while seaming around appurtenances since nether non-destructive nor destructive testing may be feasible in these areas; and
- The geomembrane has not been visibly damaged while making connections to appurtenances.

The CQA Consultant will inform the Project Manager if the above conditions are not fulfilled.

4.0 GEOCOMPOSITE (GEOSYNTHETIC DRAINAGE COMPOSITE)

4.1 Manufacturer's Documentation

Prior to deliver, the Geocomposite Manufacturer shall provide documentation which demonstrates that the property values of the material meet design specifications. Delivered rolls of geocomposite shall be appropriately labeled.

4.1.1 Certification of Property Values

The Geocomposite Manufacturer shall provide the Project Manager with a list of guaranteed minimum properties (as defined by the Design Engineer) for the type of geocomposite to be supplied. The Geocomposite Manufacturer shall provide the Project Manager with Quality Control Test Results signed by a responsible party that the geocomposite actually delivered have properties which meet or exceed the guaranteed properties.

The CQA Consultant shall examine the Manufacturer's Quality Control Tests to verify that the property values listed on the certifications meet or exceed the Manufacturer's guaranteed minimum values and the design specifications given on Table 3.5-1. Deviations shall be reported to the Project Manager.

4.1.2 Labeling

The Geocomposite Manufacturer shall identify all rolls of geocomposite. Each geocomposite roll shall have a weatherproof label, which contains the following:

- Manufacturer's name;
- Product identification;
- Lot number;
- Roll number;
- Roll dimensions; and
- Top and bottom geotextile roll numbers.

The CQA Consultant shall examine rolls upon delivery and any deviation from the above requirements shall be reported to the Project Manager.

4.2 Shipment and Storage

Geocomposite cleanliness is essential to performance; therefore, measures must be taken during shipment and storage to protect the geonet from dust and dirt. Geocomposite rolls shall be wrapped in plastic sheets or otherwise protected. Wrappings protecting the Geocomposite rolls should be removed less than one (1) hour prior to unrolling the geocomposite.

4.3 Conformance Testing of Geocomposite

Upon or prior to delivery of the rolls of geocomposite, the CQA Consultant shall remove and forward samples to the Geosynthetics CQA Laboratory for testing to verify conformance with the design specifications given on Table 3.5-1.

4.3.1 Sample Collection

Using the packing list provided by the manufacturer or a sequential inventory list made by the CQA Consultant, rolls shall be selected for sampling at a minimum frequency of one sample per 100,000 square feet of material. If the material is shipped in identifiable lots or manufacturing runs, sample selection should be adjusted to assure that the minimum frequency is met and that each different lot or manufacturing run is represented by at least one sample. If a roll is not identifiable by roll number, the CQA Consultant shall notify the Project Manager immediately. If the roll cannot be tracked, the Project Manager shall reject the roll.

Samples will be taken across the entire width of the roll and will not include the first 3 lineal feet. Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Consultant will mark the machine direction on the samples with an arrow.

4.3.2. Test Results

The results of the conformance testing shall be evaluated in accordance to the following procedure:

- If the average test values for the sample meet all of the values given in Table 3.5-1 and the Manufacturer's guaranteed minimum values, the sample passes.
- If the average test value for the sample does not meet one or more of the required values, the CQA Consultant will implement additional evaluation procedures. Additional tests required for further evaluation shall be done at no expense to the Owner.
- For the failing parameter(s), perform one additional test on the sample. This test may be performed by another CQA Geosynthetics Laboratory at the discretion of the CQA Consultant and the Project Manager.
- If the test values for the additional tests meet the required values, the roll and adjacent rolls pass and are acceptable.
- If the test value does not met requirements, reject the roll, collect samples from the closest numerical roll on both sides of the failed roll, and test for the failed parameter(s). If one or both of these tests do not meet requirements, those roll(s) will be rejected and the CQA Consultant and Project Manager shall determine further testing protocol and criteria for identifying the limits of rejected rolls.

4.4 Handling and Placement

The Geosynthetics Installer shall handle geocomposite in such a manner as to minimize damage and comply with the following:

- On slopes, the geocomposite shall be secured in the anchor trench and then rolled down the slope in such manner as to continually keep the geocomposite sheet in tension. If necessary, the geocomposite shall be positioned by hand after being unrolled to minimize wrinkles. Geocomposite can be placed in the horizontal direction (i.e., across the slope) in some special location (e.g., at the toe of the slope, or, if an extra layer of

geocomposite required, this extra layer can be placed in the horizontal direction). Such locations shall be identified by the Design Engineer in the plans.

- In the presence of wind, geocomposite shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during placement and remain until replaced with overlying material.
- Sandbags shall be filled with fine-grained material and must be handled with care to prevent rupture.
- Unless otherwise specified, geocomposite shall not be welded to geomembranes.
- The Geosynthetics Installer shall take necessary precautions to prevent damage to underlying layers during placement of the geocomposite. Care should be taken not to leave tools on or under the geocomposite.
- During placement of geocomposite, care shall be taken not to entrap dirt or excessive dust that could cause clogging of the drainage system, and/or stones that could damage the adjacent geomembrane.

The CQA Consultant shall note any deviation and report it to the Project Manager.

4.5 Stacking and Joining

Stacked geocomposite shall be placed in the same direction to prevent the stands of one layer from penetrating the channels of the lower layer, thereby significantly reducing the transmissivity. Geocomposite shall not be laid in direction perpendicular to the underlying geonet unless otherwise specified by the Design Engineer.

Adjacent geocomposite shall be joined according to the plans and design specifications. As a minimum, the following requirements shall be met:

- The geonet portion of adjacent rolls shall be overlapped by at least 4 inches. Ends of adjacent rolls shall be overlapped by at least 8 inches.
- These overlaps shall be secured by tying with plastic fasteners or polymer braid. Tying devices will be white or yellow for easy observation. Metallic devices are not allowed.
- Tying devices shall be placed every 5 feet down the slope, every 2 feet across the slope, every 6 inches in the anchor trench, and every 6 feet on horizontal surfaces.
- When more than one layer of geocomposite is installed, joints shall be staggered so that the joints do not lie above one another.
- The upper non-woven geotextile shall be continuously sewn using the procedures outlined in Section 4.5 of the CQA Manual unless otherwise directed by the Project Manager.

The CQA Consultant shall document the roll numbers placed and approximate installed square footage and shall note any deviation and report it to the Project Manager.

4.6 Repair

Any holes or tears in the geocomposite shall be repaired by placing a patch extending 2 feet beyond the edges of the hole or tear. The patch shall be secured to the original net by tying every 6 inches. Tying devices shall be as indicated in Section 4.5. If the hole or tear width across the roll is more than one-half the width of the roll, the damaged area shall be cut out and the two portions of the geonet shall be joined as indicated in Section 4.5.

The CQA Consultant shall observe any repair, note any deviation with the above requirements, and report them to the Project Manager.

4.7 Placement of Materials on Geocomposite

The placement of materials on geocomposite shall be as soon as possible, such that:

- The geocomposite and underlying geomembrane are not damaged;
- Minimal slippage of the geocomposite on the underlying geomembrane occurs;
- No excess tensile stresses occur in the geocomposite; and
- In sloped areas, placement of soil/aggregate is started at the toe and extended up the slope. Placement of soil/aggregate will never start at the top of the slope.

If portions of the geocomposite are exposed, the CQA Consultant shall periodically place marks on the geocomposite and the underlying geomembrane and measure the elongation of the geocomposite during the subsequent construction activities. Before a subsequent layer of material is placed on the geocomposite, the CQA Consultant should observe the geocomposite and underlying liner to determine if any dirt, excessive dust, or any stones are entrapped in or below the material. If so, the geocomposite must be cleaned or the geocomposite removed so that the liner can be cleaned.

Any deviation shall be noted by the CQA Consultant and reported to the Project Manager.

5.0 GEOTEXTILE

5.1 Manufacturer's Documentation

The following addresses the activities associated with the manufacture of geotextile used as filters, separators and composite drainage systems; the shipment, handling and delivery of geotextile to the site; conformance testing of geotextile; and the storage of geotextile prior to installation. The word "geotextile" as used in this section primarily refers to non-woven geotextile.

Prior to delivery, the Geotextile Manufacturer shall provide documentation which demonstrates that the property values of the material meet requirements. Delivered rolls of geotextile shall be appropriately labeled.

5.1.1 Certification of Property Values

The Geotextile Manufacturer shall provide the Project Manager with a list of guaranteed "minimum average roll value" properties (as defined by the Design Engineer) for the type of geotextile to be supplied. The Geotextile Manufacturer shall provide the Project Manager with a written certification signed by a responsible party that the geotextiles actually delivered have properties which meet or exceed the guaranteed "minimum average roll values" properties given in Table 3.6-1.

The CQA Consultant shall examine the Manufacturer's certifications to verify that the property values listed on the certifications meet or exceed the Manufacturer's guaranteed minimum values and the design specifications. Deviations shall be reported to the Project Manager.

5.1.2 Labeling

The Geotextile Manufacturer shall identify all rolls of geotextile. Each geotextile roll shall have a weatherproof label, which contains the following:

- Manufacturer's name;
- Product identification;
- Lot number;
- Roll number;
- Roll weight; and
- Roll dimensions.

In addition, if any special handling of the geotextile is required, it shall be so marked on the top surface of the geotextile, e.g., "This Side Up". Rolls without proper identification shall be rejected by the Project Manager.

The CQA Consultant shall examine rolls upon delivery and any deviation from the above requirements shall be reported to the Project Manager.

5.2 Shipment and Storage

During shipment and storage, the geotextile shall be protected from ultraviolet light exposure, precipitation, snow or other inundation, mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions. Geotextile rolls shall be wrapped in plastic sheets or otherwise protected. Wrappings protecting the geotextile rolls should be removed less than one hour prior to unrolling the geotextile.

Geotextiles shall not be exposed to precipitation prior to being installed. Wet geotextiles are heavy which makes them difficult to deploy and can also effect liner welding when the geomembrane is adjacent to the geotextile. During cold weather, geotextiles must be protected from freezing.

The CQA Consultant shall observe rolls upon delivery and prior to installation. Any deviation from the above requirements shall be reported to the Project Manager. Any damaged rolls shall be rejected and replaced at no cost to the Owner.

5.3 Conformance Testing of Geotextile

Prior to the deployment of the rolls of geotextile, the CQA Consultant shall remove and forward samples to the Geosynthetics CQA Laboratory for testing to verify conformance with the design specifications, per Table 3.6-2.

5.3.1 Sample Collection

Using the packing list provided by the manufacturer or a sequential inventory list made by the CQA Consultant, rolls shall be selected for sampling at a minimum frequency of one sample per 100,000 square feet of material. If the material is shipped in identifiable lots or manufacturing runs, sample selection should be adjusted to assure that the minimum frequency is met and that each different lot or manufacturing run is represented by at least one sample. If a roll is not identifiable by roll number, the CQA Consultant shall inform the Project Manager immediately. If the roll cannot be tracked, the Project Manager shall reject the roll.

Samples will be taken across the entire with of the roll and will not include the first 3 lineal feet. Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Consultant will mark the machine direction on the samples with an arrow.

5.3.2 Test Results

The results of the conformance testing shall be evaluated in accordance to the following procedure:

- If the average test values for the sample meet all of the values given in the design specifications and the Manufacturer's guaranteed minimum values, the sample passes.
- If the average test value for the sample does not meet one or more of the required values, the CQA Consultant will implement additional evaluation procedures. Additional tests required for further evaluation shall be done at no expense to the Owner.

- For the failing parameter(s), perform one additional test on the sample. This test may be performed by another CQA Geosynthetics Laboratory at the discretion of the CQA Consultant and the Project Manager.
- If the test values the additional test meets the required values, the roll and adjacent rolls pass and are acceptable.
- If the test values do not meet requirements, reject the roll, collect samples from the closest numerical roll on both sides of the failed roll and test for the failed parameter(s). If one or both of these tests do not meet requirements, those roll(s) will be rejected and the CQA Consultant and Project Manager shall determine further testing protocol and criteria for identifying the limits of rejected rolls.

5.4 Handling and Placement

The Installer shall handle geotextiles in such a manner as to minimize damage and shall comply with the following:

- Geotextile shall not be placed until the underlying layer has been properly documented and approved by the CQA Consultant.
- After the wrapping has been removed, a geotextile shall not be exposed to sunlight for longer than the allowable time specified by the Geotextile Manufacturer.
- On slopes, the geotextiles shall be securely anchored and then rolled down the slope in such a manner as to continually keep the geotextile panel in tension.
- In the presence of wind, geotextiles shall be weighted with sandbags or the equivalent. Sandbags shall be installed during the placement and shall remain until replaced with the appropriate overlying material.
- Sandbags shall be filled with fine-grained material and must be handled with care to prevent rupture.
- Geotextile shall be kept continually under tension to minimize the presence of wrinkles in the geotextile.
- Geotextiles shall be cut using an approved geotextile cutter only. If in-place, special care must be taken to protect other materials from damage, which could be caused by the cutting of the geotextiles.
- The Geosynthetics Installer shall take necessary precautions to prevent damage to the underlying layers during placement of the geotextile.
- During placement of geotextiles, care shall be taken not to entrap stones, excessive dust, or moisture that could damage the geomembrane, generate clogging of drains or filters, or hamper subsequent seaming.
- After installation, the entire surface of the geotextile shall be examined, and harmful foreign objects, such as needles, shall be removed.

- If white geotextile is used, precautions will be taken against "snow blindness" of personnel.

The CQA Consultant shall witness the installation of all geotextile material and shall not accept any deviations without reporting it to the Project Manager. The CQA Consultant shall record roll numbers used and approximate square footage placed.

5.5 Seams and Overlaps

Where geotextiles are specified or indicated on the plans to be sewn, all seams shall be continuously sewn using thread, which is as chemically resistant and UV resistant as the geotextiles. Thread shall be approved by the CQA Consultant and Owner. Spot sewing is not permitted, except for repairs, and thermal bonding shall not be permitted without the written approval of the Project Manager. Geotextiles shall be overlapped a minimum of 6 inches prior to seaming. Horizontal seams on side slopes steeper than 20 percent should be avoided, except as part of a patch. However, if horizontal seams are necessary, at least 100 feet shall be maintained between horizontal seams of adjacent panels. Seam overlaps shall be "flat" or "prayer" (Federal Standard Type SSa-1), and seams shall be single-row two thread chainstitch (stitch type 401). The Geosynthetics Installer shall pay particular attention that no material is inadvertently inserted beneath the geotextile.

The CQA Consultant shall inspect 100 percent of the seams for continuous and proper sewing and shall note any deviation and report it to the Project Manager.

5.6 Repairs

Any holes or tears in the geotextile shall be repaired by the Installer as follows:

- On slopes steeper than 20 percent: A patch made from the same geotextile shall be sewn into place and extend at least 12 inches beyond any damaged edge of the parent geotextile. Should any horizontal tear exceed 10 percent of the width of the roll, that roll shall be removed from the slope and replaced.
- On slopes less than or equal to 20 percent: A patch made from the same geotextile shall be sewn in place with a minimum of 24 inches overlap in all directions.

Care shall be taken to remove any soil or other material which may have penetrated the torn geotextile.

The CQA Consultant shall observe any repair, note any deviation with the above requirements, and report them to the Project Manager.

5.7 Placement of Materials on Geotextiles

The Geosynthetics Installer shall place materials on the Geotextile in the following manner:

- Cause no damage to geotextile and underlying geosynthetics;
- Prevent slippage of the geotextile on underlying layers;

- Equipment used for placing the overlying material shall not be driven directly on the geotextile;
- On side slopes, the placement of soil on top of the geotextile shall proceed from the bottom of the slope upward;
- A minimum thickness of 1 foot of soil must be maintained between light, low ground pressure equipment (such as a wide pad Caterpillar D-6 or lighter) and the geotextile;
- A minimum thickness of 1.5 feet of soil must be maintained between rubber-tired vehicles and the geotextile unless approved by the Design Engineer and Owner; and
- In heavily trafficked areas such as access ramps, soil thickness shall be at least 3 feet.

The CQA Consultant shall observe the placement of all overlying material and any deviation shall be noted by the CQA Consultant and reported to the Project Manager.

6.0 POLYETHYLENE PIPE AND FITTINGS

6.1 Material Requirements

High Density Polyethylene (HDPE) pipe and its associated fittings and joints shall meet material acceptance and construction quality requirements as stated in this Section of the CQA Plan and in the design specifications.

6.1.1 Pipe

PE pipe shall consist of Standard Dimension Ratio (SDR) pipe, as specified in the design specification, and must conform to the requirements of ASTM D2837, Class PE3408 for a pressure rating of 160 psi at 73.4^{o}F. HDPE pipe shall comply with the following standards:

- ASTM F714 - pipe S.T.D;
- ASTM D1248 - Type III, Class C, Category 5 - Grade P34
- ASTM D3350 – Cell Classification PE345434C
- ASTM D2837 – Class PE3408
- PPI - PE3408; and
- NSF - Listed STD No. 14.

The pipe and fittings shall be manufactured from pre-compounded resin manufactured by the pipe manufacturer, with a minimum of two percent carbon black to withstand outdoor exposure without loss of properties. In-plant blending of non-compounded resins is not acceptable. HDPE pipe shall be furnished perforated or non-perforated as required by the Contract Drawings with each pipe length marked with the Manufacturer's Name/Trademark, size, material code, and SDR value. The pipe shall contain no recycled compound except that generated in the manufacturer's own plant from resin of the same specification or from the same raw material. The pipe shall be homogeneous throughout and free of visible cracks, holes (other than manufactured perforation), foreign inclusions, or other deleterious defects, and shall be identical in color, density, melt index, and other physical properties.

6.1.2 Fittings

PE pipe fittings shall be furnished by the Manufacturer of the pipe with which they are used and shall conform to the requirements of ASTM D3261 for standard fittings.

6.1.3 Joints

Pipe joints shall be fusion welded using only Manufacturer-approved methods and equipment. Unless otherwise approved, joints inside manholes shall be joined with mechanical transition couplings, electrofusion couplings, or by extrusion welding.

6.2 Manufacturer's Documentation

The HDPE Pipe Manufacturer shall submit documentation that demonstrates that the property values of the pipe meet the design specifications and that quality control are taken during manufacture.

6.2.1 Certification of Property Values

Prior to the installation of HDPE Pipe, Manufacturer will provide to the CQA Consultant:

- A properties sheet including, at a minimum, all specified properties measured using test methods indicated in the contract documents or equivalent;
- A list of quantities and descriptions of materials other than the base resin which comprise the pipe; and
- A certification that property values given in the properties sheet are guaranteed by the PE Pipe Manufacturer.

The CQA Consultant shall verify that:

- The property values certified by the HDPE Pipe Manufacturer meet the design specifications; and
- The measurements of properties by the HDPE Pipe Manufacturer are properly documented and that the test methods used are acceptable.

6.2.2 Quality Control Certificates

The PE Pipe Manufacturer shall provide the Project Manager and the CQA consultant with a quality control certificate for each lot/batch of HDPE Pipe provided. The quality control certificate shall be signed by a responsible party employed by the HDPE Pipe Manufacturer, such as the Production Manager.

The quality control certificate shall include:

- Lot/batch numbers and identification; and
- Sampling procedures and results of quality control tests.

The CQA Consultant shall:

- Verify that the quality control certificates have been provided at the specified frequency for all lots/batches of pipe, and that each certificate identifies the pipe lot/batch related to it; and
- Review the quality control certificates and verify that the certified properties meet the design specifications.

The CQA Consultant shall notify the Project Manager of any deviation.

6.3 Fusion Process for Joints

The primary means of joining HDPE pipe shall be butt fusion. However, in certain instances where butt fusion is not suitable, due to space restrictions, electrofusion couplings or extrusion welding may be used in lieu of butt fusion. HDPE pipes and fittings shall be joined by the Pipe Installer using the procedures outlined below, unless otherwise specified.

6.3.1 Preparation

Delivered pipes and fittings shall be examined by the Pipe Installer. The Installer shall verify that pipes and fittings are not broken, cracked, or contain otherwise damaged or unsatisfactory material.

Prior to fusing, the Installer shall verify that the fusion surface area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material.

The CQA Consultant shall notify the Project Manager of any deviation.

6.3.2 Weather Conditions for Butt-Fusion

Butt-fusion of HDPE pipe joints is normally done in uncontrolled atmospheres. Fusion of the HDPE joints shall be performed at temperatures above 32^{o}F, unless otherwise authorized in writing by the Project Manager.

6.3.3 General Butt-Fusion Procedure

Unless otherwise specified, the general butt-fusion procedure used by the Installer shall be as follows:

- Be sure that the surfaces of the fusion tools, pipe, and fittings are free of moisture and debris;
- Heat the surfaces to be joined - both the pipe and fittings - simultaneously at the prescribe temperatures for a specified time;
- Remove the heater - bring melted surfaces together; and
- Hold until solidified.

These steps are described in more detail below.

- With a clean rag, wipe both inside and outside surfaces of the two ends to be joined to remove dirt and foreign material;
- Install pipe in fusion machine, allowing pipe ends to protrude 1 to 2 inches past face of jaw;
- Slide facer so that it can be placed between pipe ends. Cut pipe until the stops on each side of the facer are against the clamp bushings at the front and rear.

Separate the two pipe ends by opening pipe jaws, turn off motor, and move facing unit to storage position. The ends are properly faced when both stationary and movable clamps are against the stops on each side of the facing unit.

- Bring the two pipe sections together and feel for any high-low difference at the junction of the two ends. If necessary, tighten the appropriate inside clamp until the two sections are aligned as closely as possible. After facing pipe ends, if any adjustment is made on one or both inside clamps, the facing unit should be re-installed and the pipe ends given several turns with the cutter until the motor speeds up before continuing with heating and fusing.
- Separate the two pipe sections. Slide heater to position where it will come between pipe ends. Bring the movable pipe section against the heater until both pipe ends are in firm contact with the heater.
- During the heating period, as the pipe ends melt while against the heater, the molten plastic will expand and form a melt bead around the end of the pipe. The melt bead will vary in width from about 1/16 to 3/16 of an inch, depending on pipe size but should be 3/16 of an inch for 6 inch nominal diameter pipes or greater. The melt bead should be the same size around the pipe.
- After melting has been completed, separate the pipe ends just enough to remove the heater and immediately bring the pipe ends together with the pressure recommended by the manufacturer.
- Maintain the pressure and allow the joint to cool for 30 to 90 seconds per inch of pipe diameter before removing from machine.
- Remove fused pipe sections from fusion machine. Allow joint to cool at least 20 minutes after removal before subjecting it to testing, bending or backfilling stresses. Reposition fusion machine so that the end of the newly fused section lies in the stationary clamps while a new pipe section is placed in the movable clamps. Repeat fusion procedure.

The CQA Consultant shall verify that the general butt-fusion procedure has been followed by the pipe installer. If a different joining method is proposed, the Owner and CQA Consultant shall approve it in advance.

6.4 Pressure Testing of Joints

The joints of non-perforated HDPE pipes shall be tested by the Pipe Installer using the pressure test procedure given in ASTM C924. Other non-destructive test methods may be used only when approved by the Owner.

6.4.1 Segment Testing: Pre-Installation

- Similar sized of polyethylene piping shall be butt welded together into testing segments not to exceed 2,000 feet. Segments shall be fitted with a cap on one end and testing apparatus on the other.

- The segment to be tested should be laid on the ground surface and allowed time to reach constant and/or ambient temperature before initialing the test.
- The test should be performed during a period when the pipe segment will be out of direct sunlight when possible, i.e., early morning, late evening, or cloudy days. This will minimize the pressure changes, which will occur during temperature fluctuations.
- The test pressure shall be minimum 10 psi.
- Contractor shall submit verification and results of gauge calibration prior to (no more than 60 days) completion of project.
- The test periods shall not be less than 1 hour. The allowable pressure drop observed during the test shall not exceed one percent of the test pressure. Test pressure shall be corrected for temperature changes before determining pass or failure.
- Owner shall be notified before testing procedure and shall have the option of being present during the test.
- Contractor will furnish equipment for this testing procedure. This shall consist of a polyethylene flange adapter with a PVC blind flange equal in size to the blower inlet valve. Tapped and threaded into the blind flange will be a temperature gauge 32^{o}F to 212^{o}F, a pressure gauge 0 to 15 psi, a "tire valve" to facilitate an air compressor hose, and a ball valve to release pipe pressure at completion of test. Polyethylene reducers shall be utilized to adapt test flange to size of pipe being tested.

6.4.2 Test Failure

The following steps shall be performed when a pipe segment fails the 4-hour test:

- The pipe and all fusions shall be inspected for cracks, pinholes or perforations.
- All blocked risers and capped ends shall be inspected for leaks
- Leaks shall be verified by applying a soapy water solution and observing soap bubble formation.

All pipe and fused joint leaks shall be repaired by cutting out the leaking area and re-fusing the pipe.

After all leaks are repaired, a retest shall be performed in accordance with Section 6.4.1.

6.4.3 Final Test

A final test shall be made on the completed inner conveyance pipeline in accordance with Section 6.4.1 and 6.4.2.

The completed systems when tested should be in its proper trench location and allowed time to reach constant and/or ambient temperature before initiating the test.

Testing apparatus can be placed at location of the valve inlet before the blower.

6.4.4 Test Reporting

All testing shall be reported in writing to the Owner and shall include the following information:

- Date and time;
- Person performing test;
- Name of Owner representative;
- Pipe length, size(s), and location;
- Test pressure at test start and finish; and
- Ambient temperature at test start and finish.

The following information shall be reported in writing if a failure occurs:

- Nature of all leaks found, and
- Details of repair.

The CQA Consultant shall report any deviation of testing methods or test results to the Project Manager.

7.0 SURVEYING

7.1 Introduction

Surveying of lines and grades shall be conducted on an ongoing basis during construction of the soil layers and geosynthetics placement. Surveying shall be performed to provide documentation for record plans, verify quantities of soils and geosynthetics, and assist the Earthwork Contractor to comply with the required grades. Surveying conducted at the site shall be part of the construction quality assurance program.

7.2 Survey Control

One or more permanent benchmark(s) will be established for the site at location(s) indicated on the drawings. The vertical and horizontal controls for this benchmark will be established within normal land surveying standards. The benchmark(s) horizontal and vertical position(s) shall be tied to the Illinois State Plane Coordinate System and the National Geodetic Vertical Datum of 1929.

7.3 Surveying Personnel

Surveying will be performed under the direct supervision of a qualified, licensed Land Surveyor, who may also be the Senior Surveyor on-site. The survey crew will consist of the Senior Surveyor and as many Surveying Assistants as are required to satisfactorily undertake the work. Surveying personnel will be experienced in the provision of these services, including detailed, accurate documentation.

7.4 Precision and Accuracy

The survey instruments used for this work shall be precise and accurate to meet the needs of the project. Survey instruments shall be capable of reading to a precision of 0.01 of a foot and with a setting accuracy of 10 seconds. Calibration certificates for survey instruments shall be submitted to the CQA Consultant prior to initiation of surveying activities.

7.5 Lines and Grades

When required, the following surfaces shall be surveyed to determine the lines and grades achieved during construction:

- Surface of prepared subgrade (prior to liner installation);
- Surface and limits of geosynthetics;
- Anchor trench;
- Alignment and inverts of piping including anchor trench drains; and
- Surface of protective cover soils.

7.6 Frequency and Spacing

Surveying shall be performed as soon as possible after completion of a given installation to facilitate progress and avoid delaying the next installation. In addition, spot checks during construction will be necessary to assist the Earthwork Contractor in complying with the required grades.

The following spacing and locations shall be provided, as minimum, for survey points:

- Surfaces, with slopes less than 10 percent, will be surveyed on a square grid not wider than 100 feet linear;
- On slopes greater than 10 percent, a square grid not wider than 100 feet will be used, but in any case, a line at the crest, midpoint, and toe of the slope will be taken;
- A line of survey points no farther than 100 feet apart will be taken along any slope break (this will include the inside edge and outside edge of any bench on a slope); and
- Along linear features, survey sections or points should be at 50-foot centers.

7.7 Tolerances

Acceptable tolerances on survey coordinates, within the closure area, shall be 0 to -0.2 feet on subgrade elevations, and 0 to +0.2 feet on soil liner and protective cover/leachate collection layers, provided minimum permit conditions and state regulations are adhered to (i.e., thickness, grades, etc.). Surveying tolerances may need to be more stringent in the sump area to measure accurate construction of the leachate management system. More stringent tolerances may be required at the sump location to ensure all piping correctly aligns.

7.8 Documentation

The Senior Surveyor shall retain original field survey notes. The surveyor should produce record plans for the CQA Consultant as the job progresses. The results from the field surveys will be documented on a set of record plans. At a minimum, these plans shall show the final elevations of the surfaces listed in Section 7.5 of the CQA Manual at a scale of 1 inch equal 100 feet with contour intervals no greater than 2 feet.

Survey results will be certified by a land surveyor licensed by the state at the location of work.

8.0 DOCUMENTATION

8.1 Introduction

An effective CQA Plan depends largely on recognition of all construction activities that should be monitored, and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The CQA Consultant shall document that quality assurance requirements have been addressed and satisfied.

The CQA Consultant shall provide the Project Manager with signed descriptive remarks, data sheets, and logs to verify that all monitoring activities have been carried out. The CQA Consultant shall also maintain at the job site a complete file of design plans, design specifications, the CQA Plan, checklists, test procedures, daily logs, and other pertinent documents.

8.2 Daily Recordkeeping

Standard reporting procedures shall include preparation of a daily report which, at a minimum, shall consist of a daily summary report including memoranda of meetings and/or discussions with the Owner and/or site contractors, observation logs, and test data sheets. Other forms of daily recordkeeping to be used as appropriate include construction problem and solution data sheets and photographic reporting data sheets.

8.2.1 Daily Summary Report

The CQA Consultant shall prepare a daily summary report, which may include the following information as appropriate:

- Date, project name, location, and other identification;
- Data on weather condition;
- Information on meetings held or discussions which took place:
- Names of parties to discussion;
- Relevant subject matter or issues;
- Decisions reached;
- Activities planned and their schedule;
- A reduced-scale site plan showing all proposed work areas and test locations;
- Descriptions and locations of ongoing construction;
- Descriptions and locations of work being tested and/or observed and documented, as well as test results;
- Calibrations or recalibration of test equipment and actions taken as a result of recalibration, or reference to specific observation logs and/or test data sheets;
- Off-site materials received, including quality verification documentation; and
- Decisions made regarding acceptance of units of work, and/or corrective actions to be taken in instances of substandard quality.

8.2.2 Construction Problem and Solution Report

The CQA Consultant, as required by the Owner, shall prepare reports describing special construction situations or clarifications to technical specifications or construction deficiencies.

These reports may include the following information as appropriate:

- A detailed description of the clarification or construction deficiency;
- The location and probable cause of the situation or construction deficiency;
- Documentation of the corrective action taken to address the situation or deficiency;
- Final results of any responses; and
- The signature of the CQA Consultant Engineer of Record, Regional Engineer, and the Project Manager indicating concurrence.

The Project Manager shall be made aware of any significant recurring non-conformance with the design specifications. The Project Manager shall then determine the cause of the non-conformance and recommend appropriate changes in procedures or specifications to the Regional Engineer. If these changes are significant in nature, they will be submitted to the Design Engineer for approval. When this type of evaluation is made, the results shall be documented, and any revision to procedures design specification, or permit specifications will be approved by the Regional Engineer, Design Engineer, and if necessary, the Permitting Agency.

8.2.3 Photographic Reporting Data Sheets

Photographic reporting data sheets, where used, shall be cross-referenced with observation logs and test data sheets and/or construction problem and solution reports.

These photographs will serve as a pictorial record of work progress, problems, and mitigation activities. The basic file shall contain color prints. These records will be presented to the Project Manager upon completion of the project.

8.2.4 Design and/or Specification Changes and Clarifications

Design and/or permit specification changes or clarification may be required during construction. In such cases, the CQA Consultant shall notify the Regional Engineer and Project Manager. The Regional Engineer shall then notify the Permitting Agency, if necessary.

Significant design and/or permit specification changes shall be made only with the written agreement of the Regional Engineer and the Design Engineer, and shall take the form of an addendum to the specifications. The CQA Consultant shall document clarifications to specifications as they are made.

8.3 Reports

At the end of each week of construction until construction is complete, a summary report must be either prepared by the CQA officer or under the supervision of the CQA officer. The report must include descriptions of the weather, locations where construction occurred during the previous

week, materials used, results of testing, inspection reports, and procedures used to perform the inspections. The CQA officer must certify the report. The owner or operator shall retain all weekly summary reports certified by the CQA officer until the completion of the post-closure care period and must make those reports available at reasonable times for inspection and photocopying by the Agency.

At the completion of the work, final documentation shall be prepared and shall include a professional engineer's seal and supporting field and laboratory test results.

8.3.1 Final Record Documentation

At the completion of the work, the CQA Consultant shall submit to the Regional Engineer the signed Final Record Documentation. Record Documentation shall describe activities associated with the construction of the item including construction procedures and observations and tests performed by CQA personnel. The report shall be organized into sections discussing the major components of liner construction, including subgrade, synthetic liner, protective cover, and piping and anchor trenches. At a minimum, the Final Report shall include:

- Summaries of all construction activities;
- Observation logs and test data sheets including sample location plans and supporting field and laboratory test results;
- Construction problems and solutions reports;
- Changes from design and material specifications;
- Record plans; and
- A summary statement sealed and signed by a professional engineer registered in the state of where the permit was issued.

The record plans shall include scale plans depicting the location of the construction and details pertaining to the extent of construction (e.g., depths, plan dimensions, elevations, soil component thicknesses, etc.). A qualified land surveyor shall prepare surveying and base maps required for development of the record plans.

TABLES

TABLE 3.2-1A

LABORATORY TEST METHODS
FOR THE EVALUATION OF SOIL AND AGGREGATE

Common Test Name	Parameter Defined	Standard Method
Sieve and Hydrometer Analysis	Particle Size Distribution of Coarse and Fine Grained Soils	ASTM D422
Atterberg Limits	Liquid and Plastic Limits, Plasticity Index	ASTM D4318
Standard Proctor Density	Moisture/Density Relationship Using 5.5 lb (2.46 kg) Rammer and 12 inch (305 mm) Drop	ASTM D698
Modified Proctor Density	Moisture/Density Relationship Using 10 lb (4.54 kg) Rammer and 18 inch (457 mm) Drop	ASTM D1557
Moisture Content	Water Content of Soil by Mass	ASTM D2216
Permeability: Flexible Wall Permeameter	Permeability (Hydraulic Conductivity) on Undisturbed or Remolded Samples of Soil	ASTM D5084
Permeability: Constant Head	Permeability (Hydraulic Conductivity) of Granular Soils	ASTM D2434
Carbonate Content	Carbonate Content	ASTM D3042 or ASTM D4373

Note:

Not all tests are required for this site, refer to the permit, technical specifications, and Table 2-2 in the CQA Plan.

TABLE 3.2-1B

FIELD TEST METHODS
FOR THE EVALUATION OF SOIL AND AGGREGATE

Common Test Name	Parameter Defined	Standard Method
Visual Classification	Maximum Particle Size, General Material Characteristics	ASTM D2488
USDA Classification	Classification of Ability to Support Vegetation	USDA Method
Nuclear Density Gauge	In-Place Density and Moisture Content	ASTM D2922 and ASTM D3017
Moisture Content	In-Place Moisture as Check on Nuclear Densometer Measurements	ASTM D2216
Sand Cone Density	In-Place Density as Check on Nuclear Densometer Measurements	ASTM D1556
Drive Tube Sample	In-Place Density as Check on Nuclear Densometer Measurements	ASTM D2937
Lift Depth Check	Thickness of Placed Soils or Aggregates	Visual Confirmation

Note:

Not all tests are required for this site, refer to the permit, technical specifications, and Table 2-2 in the CQA Plan.

TABLE 3.2-2

MINIMUM TEST FREQUENCIES
FOR SOIL AND AGGREGATE MATERIALS

Liner Component	Required Test	Minimum Frequency[1]	Sample Size[2]	Acceptance Criteria[3]
Excavation to Subgrade	Visual Observation	As required	N/A	Subgrade does not pump or rut excessively once area is proof rolled.
	Standard Proctor Density	As required to provide representative values for in-situ soils	50 lb.	Determination of laboratory value for comparison to field tests.
	Nuclear Density Gauge In-Place Density and Moisture Content	Native material - 1 per 15,000 sf	N/A	≥95% standard proctor maximum dry density moisture no greater than 10% above optimum
Structural Fill Placed to Subgrade	Visual Observation	Borrow Areas: As required Stockpiles: As required Placed Material: As required	N/A	Substantially free of debris, large rocks, plant materials, or other deleterious material. Final surface: firm, smooth, and uniform.
	Sieve Analysis	Placed Material: 1 per 10,000 cy	5-10 lb	Max. 6 in. particle size Max. 50% passing #200 sieve
	Standard Proctor Density	Placed Material: As required	50 lb	Determination of window of acceptable moisture content given required dry density.
	Nuclear Density Gauge In-Place Density and Moisture Content	Placed Material: 1 per 100 foot grid per lift	N/A	≥95% Standard Proctor maximum dry density
	Moisture Content	Placed Material: 1 per day that nuclear densometer is used	Varies	Check of nuclear densometer measurements to determine if recalibration is necessary.
	Sand Cone Density or Drive Tube Sample	Placed Material: 1 per day that nuclear densometer is used	Varies	Check of nuclear densometer measurements to determine if recalibration is necessary.

TABLE 3.2-2 (con't.)

MINIMUM TEST FREQUENCIES
FOR SOIL AND AGGREGATE MATERIALS

Liner Component	Required Test	Minimum Frequency[1]	Sample Size[2]	Acceptance Criteria[3]
Protective Cover	Visual Observation	Placed Material: As required	N/A	Substantially free of debris, large rocks, plant materials, or other deleterious materials.
	Sieve Analysis	Placed Material: 1 per 5,000 cy	5-10 lbs.	Max. 6 in. size. Min. 30% passing #4 sieve.
	Lift Depth Check	Placed Material: As required	N/A	Per Drawings.
	Survey	As-Built Conformation	N/A	Per Section 3.8 and Drawings.

Notes:

(1) See Section 3.2.2 for further definition of sampling frequency.
(2) In general, where the symbol "N/A" (not applicable) is used, the test is performed on in-place materials.
(3) See technical specifications for further definition of acceptance criteria.

TABLE 3.4-1

REQUIRED 40 MIL TEXTURED LLDPE GEOMEMBRANE PROPERTIES

Material Property	Value	Units	Test Method	Test Frequency
Thickness	≥38/34[(1)]	mil	ASTM D5994	1 per roll
Asperity Height[(2)]	≥16	mil	GRI GM12 / ASTM D7466	1 every 2nd roll
Density	≥0.939	N/A	ASTM D792	1 per 200,000 lb
Tensile Properties (each direction)[(3)]			ASTM D6693; Type IV	1 per 20,000 lb
1. Tensile Strength at Break	≥112	lb/in.		
2. Elongation at Break	≥400	percent		
Tear Resistance	≥25	lb	ASTM D1004	1 per 45,000 lb
Puncture Resistance	≥50	lb	ASTM D4833	1 per 45,000 lb
Carbon Black Content	2 – 3	percent	ASTM D1603	1 per 20,000 lb
Carbon Black Dispersion	9 of 10 Category 1 or 2 1 of 10 Category 3	N/A	ASTM D5596	1 per 45,000 lb
Oxidative Induction Time (OIT)	≥100	min	ASTM D3895	1 per 200,000 lb
Oven Aging at 85°C/ High Pressure OIT - percent retained after 90 days	≥60	percent	ASTM D5721/ ASTM D5885	1 per formulation
UV Resistance/ High Pressure OIT - percent retained after 1600 hrs[(5)(6)]	≥35	percent	GM 11/ ASTM D5885	1 per formulation

Notes:

(1) The first value represents the minimum average thickness measurements of 10 measurements the second value represents the lowest allowable individual thickness measurement.
(2) Of 10 readings; 8 out of 10 must be ≥ 7 mils, and lowest individual reading must be ≥ 5 mils.
(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
    - Yield elongation is calculated using a gage length of 1.3 inches.
    - Break elongation is calculated using a gage length of 2.0 inches.
(4) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials. The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(5) The condition of the test should be 20 hr. UV cycles at 75°C followed by 4 hr. condensation at 60°C.
(6) UV resistance is based on percent retained value regardless of the original HP-OIT value.

TABLE 3.4-2

REQUIRED MATERIAL CONFORMANCE TESTING
40 MIL TEXTURED LLDPE GEOMEMBRANE

Material Property	Value	Units	Test Method	Test Frequency
Thickness[(1)]	≥40	mil	ASTM D5994	1 per 100,000 ft^2 or 1 per lot[(2)]
Density	≥0.939	g/cc	ASTM D1505	1 per 100,000 ft^2 or 1 per lot[(2)]
Tensile Properties (each direction)[(3)]			ASTM D638;	1 per 100,000 ft^2 or
1. Tensile Strength at Break	≥112	lb/in.	Type IV	1 per lot[(2)]
2. Elongation at Break	≥400	percent		
Carbon Black Content	2 - 3	percent	ASTM D4218	1 per 100,000 ft^2 or 1 per lot[(2)]
Carbon Black Dispersion	9 of 10 Category 1 or 2 1 of 10 Category 3	N/A	ASTM D5596	1 per 100,000 ft^2 or 1 per lot[(2)]

Notes:

(1) Minimum of five readings must average nominal thickness or greater, no single reading falling more than 10% below the specified value.
(2) Whichever results in the greater number of samples tested.
(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Yield elongation is calculated using a gage length of 1.3 inches.
- Break elongation is calculated using a gage length of 2.0 inches.

TABLE 3.4-3

REQUIRED 40 MIL TEXTURED HDPE SEAM PROPERTIES

Material Property	Value	Test Method	Test Weld Frequency	Destructive Seam Frequency
Bonded Shear Strength	100 percent of yield strength of parent material and FTB	ASTM D6392/ ASTM D4437	1 per 4 hours	1 per 500 ft seamed
Seam Peel Adhesion	65 percent of yield strength of parent material and FTB	ASTM D6392/ ASTM D4437 .	1 per 4 hours	1 per 500 ft seamed

Notes:

1. For laboratory testing only, a maximum of 1 non-FTB (film tear bond) per 5 specimens is acceptable provided that strength requirements are met on that sample.

2. For double-fusion welded seams, both tracks shall be tested to meet compliance with the minimum seam values specified.

3. Strain Rate: 2in./min. and 1 inch wide strips.

4. Test Welds shall be made upon start of work for each seamer, every four (4) hours of continuous seaming, every time seaming equipment is changed, if significant changes in geomembrane temperature and weather conditions are observed, and at the discretion of the CQA Consultant.

TABLE 3.5-1

REQUIRED MATERIAL PROPERTIES
GEOSYNTHETIC DRAINAGE COMPOSITE

Material Property	Value	Units	Test Method	Test Frequencies
Geonet Density	$\geq$0.940[(1)]	gm/cm³	ASTM D1505	1 per 100,000 ft^2
Geonet Thickness	$\geq$0.25	inches	ASTM D5199	1 per 100,000 ft^2
Geonet Mass per Unit Area	$\geq$0.16	lbs/ft²	ASTM D3776	1 per 100,000 ft^2
Geonet Carbon Black Content	2 - 3	percent	ASTM D1603	1 per 100,000 ft^2
Geonet Tensile Strength at Break	$\geq$55	lbs/in	ASTM D5035	1 per 100,000 ft^2
Drainage Composite Transmissivity @ 10,000 psf[(2)]	$\geq 5 \times 10^{-4}$	m²/sec	ASTM D4716	1 per 200,000 ft^2
Drainage Composite Ply Adhesion	≥1	lb/in	ASTM F904	1 per 200,000 ft^2

Notes:

(1) Must be less than or equal to the specific density of the geomembrane.
(2) Transmissivity will be measured in the laboratory using water at 20°C with a gradient of 0.25, between the materials specified in the permit (i.e., 60-mil HDPE geomembrane and Protective Cover material), and will be tested after a seating period of 24 hours (minimum).
(3) Geotextile to meet properties of Table 3.6-1, 10 oz/sy for the base liner drainage composite and 6 oz/sy for the enhanced liner system and cap drainage composite.

TABLE 3.5-2

REQUIRED MATERIAL CONFORMANCE TESTING
GEOSYNTHETIC DRAINAGE COMPOSITES

Material Property	Value	Units	Test Method	Test Frequencies
Transmissivity @ 10,000sf[(1)]	$\geq 5 \times 10^{-4}$	m^2/s	ASTM D4716	1 per 250,000 ft^2
Ply Adhesion	≥1	Lb/in	ASTM F904	1 per 250,000 ft^2

Note:

(1) Transmissivity will be measured in the laboratory using water at 20°C with a gradient of 0.25, between the materials specified in the permit (i.e., 60-mil HDPE geomembrane and Protective Cover material), and will be tested after a seating period of 24 hours (minimum).

TABLE 3.6-1

REQUIRED MATERIAL PROPERTIES
GEOTEXTILES

Material Property	Minimum Average Roll Values 6 oz/sy	10 oz/sy	Units	Test Method	Test Frequencies
Mass per Unit Area	6	10	oz/yd^2	ASTM D5261	1 per 100,000 ft^2
Grab Tensile Strength	150	250	lbs	ASTM D4632	1 per 100,000 ft^2
Grab Elongation	50	50	percent	ASTM D4632	1 per 100,000 ft^2
Puncture Strength	90	125	lbs	ASTM D4833	1 per 100,000 ft^2
Trapezoidal Tear Strength	70	100	lbs	ASTM D4533	1 per 100,000 ft^2
Apparent Opening Size(1)	70-100	70-120	sieve size	ASTM D4751	1 per 100,000 ft^2
Permittivity	1.3	1.3	sec^{-1}	ASTM D4491	1 per 100,000 ft^2

Notes:

(1) Required only on material, which is to be used in filter applications.

TABLE 3.6-2

REQUIRED MATERIAL CONFORMANCE TESTING
GEOTEXTILES

Material Property	Minimum Average Roll Values 6 oz/sy	10 oz/sy	Units	Test Method	Test Frequencies
Mass per Unit Area	6	10	oz/yd^2	ASTM D5261	1 per 100,000 ft^2
Grab Tensile Strength	150	250	lbs	ASTM D4632	1 per 100,000 ft^2
Puncture Strength	90	125	lbs	ASTM D4833	1 per 100,000 ft^2
Trapezoidal Tear Strength	70	100	lbs	ASTM D4533	1 per 100,000 ft^2

FORMS

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DAILY LOG				
	DATE			
	NO.			
	SHEET		OF	

FIELD ACTIVITY DAILY LOG

PROJECT NAME:	PROJECT NO.:
FIELD ACTIVITY SUBJECT:	
DESCRIPTION OF DAILY ACTIVITIES AND EVENTS:	
CHANGES FROM PLANS AND SPECIFICATIONS, AND OTHER SPECIAL ORDERS AND IMPORTANT DECISIONS:	VISITORS ON-SITE:
WEATHER CONDITIONS:	IMPORTANT TELEPHONE CALLS:
PREPARED BY:	DATE:

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Charlotte, NC 28226 (704) 541-8345

SHEET _____ OF _____

FIELD INVENTORY RECORD
GEOSYNTHETICS

PROJECT NAME:	INVENTORY DATE:
PROJECT NO.:	TECHNICIAN:
OWNER:	WEATHER CONDITIONS:
STORAGE AREA:	

GEOSYNTHETIC PRODUCT DESIGNATION:	
GEOSYNTHETIC MATERIAL TYPE:	
SHIPMENT NUMBER:	DELIVERY DATE:
GENERAL COMMENTS ON ROLL CONDITION:	GENERAL COMMENTS ON STORAGE CONDITIONS:

MATERIAL		ROLL DIMENSIONS		CONFORMANCE	
ROLL NUMBER	BATCH/LOT NUMBER	WIDTH (FEET)	LENGTH (FEET)	SAMPLE NO.	REMARKS

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SHEET NO. _____ OF _____

DATE _____

PROJECT NAME: _____

PROJECT NO.: _____ TECHNICIAN _____

MATERIAL DESCRIPTION: _____

GEOMEMBRANE DEPLOYMENT LOG

PANEL NO.	PANEL DATE	ROLL NO.	LENGTH	WIDTH	SQUARE FOOTAGE
				TOTAL SQUARE FOOTAGE	

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TRIAL SEAM REPORT

SHEET ________ OF ________

PROJECT NAME:	TECHNICIAN:	Passing Peel = Fusion: _____ ppi Extrusion: _____ ppi Passing Shear = Fusion: _____ ppi Extrusion: _____ ppi
PROJECT NO.:	GEOMEMBRANE TYPE:	
INSTALLER:		

SAMPLE NO.	DATE/ TIME	AMBIENT TEMP (°F)	SEAMER NAME	MACHINE NUMBER	MACHINE SETTINGS		PEEL TEST RESULTS			SHEER TEST RESULTS			PASS/ FAIL	COMMENTS
					TEMP (°F)	SPEED	1 (LB/IN)	2 (LB/IN)	3 (LB/IN)	1 (LB/IN)	2 (LB/IN)	3 (LB/IN)		

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GEOMEMBRANE SEAMING SUMMARY

PROJECT NAME: ______________________________ TECHNICIAN: ____________________

PROJECT NUMBER: ______________________________ SHEET ________ OF ________

SEAM NUMBER	DATE SEAMED	SEAM TYPE	SEAM LENGTH (FEET)	SEAMER INITIALS	MACHINE NUMBER	TIME		AMBIENT TEMP (°F)	COMMENTS
						START	FINISH		

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GEOMEMBRANE NON-DESTRUCTIVE TESTING SUMMARY

PROJECT NAME ____ TECHNICIAN ____________________

PROJECT NUMBER ___________________________________ SHEET ________ OF ______

SEAM NUMBER	DATE TESTED	LENGTH (FEET)	AIR TEST				RESULTS (P/F)	DATE SEAM REPAIRED	DATE VACUUM TESTED	SEAM STATUS (P/F)	COMMENTS
			STARTING		ENDING						
			TIME	PRESS.	TIME	PRESS.					

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GEOMEMBRANE DESTRUCTIVE TESTING SUMMARY

PROJECT NAME ______________________________ TECHNICIAN ____________________

PROJECT NUMBER ______________________________ SHEET ________ OF ________

DESTRUCTIVE SAMPLE NUMBER	SEAM NO.	SEAM TYPE	DATE SAMPLED	WELDER	MACHINE NUMBER	FIELD TEST RESULTS			LAB TEST RESULTS			COMMENTS
						PEEL (P/F)	SHEAR (P/F)	CQA INITIALS	PEEL (P/F)	SHEAR (P/F)	DATE TESTED	

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GEOMEMBRANE DEFECT LOG

PROJECT NAME _____ TECHNICIAN _____

PROJECT NUMBER _____ SHEET _____ OF _____

REPAIR NO.	LOCATION OF DEFECT	DEFECT TYPE	DATE	REMARKS	REPAIR TYPE	REPAIR DATE	REPAIR (P/F)	CQA INITIALS

Repair Type: P – Patch, T – Weld, CAP – Cap Strip, DS – Destructive Sample, B – Bead

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SHEET NO. _____ OF _____

DATE _____

PROJECT NAME: _____ COMPUTED BY: _____

PROJECT NO.: _____ CHECKED BY: _____

MATERIAL DESCRIPTION: _____

DRAINAGE COMPOSITE DEPLOYMENT LOG

PANEL DATE	ROLL NO.	LENGTH	WIDTH	SQUARE FOOTAGE
			TOTAL SQUARE FOOTAGE	