Rhode Island Department of Environmental Management

REMEDIAL ACTION – PHASE II
LANDFILL CLOSURE
ROSE HILL LANDFILL
SUPERFUND SITE

CONSTRUCTION QUALITY ASSURANCE PLAN

Submitted To:
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TABLE OF CONTENTS

TABLE OF CONTENTS

1.0 INTRODUCTION 1

1.1 Overview 1
1.2 Scope of the Plan 1
1.3 Definitions 2
1.4 Applicable Regulations and Guidance 3

2.0 INVOLVED PARTIES - RESPONSIBILITY AND AUTHORITY 4

2.1 Organizational Structure 4
2.2 Responsibilities 5

3.0 PROJECT COMMUNICATIONS 8

3.1 Lines of Communication 8
3.2 Project Meetings 8
3.3 Document Transmittals 9

4.0 DESCRIPTION OF QUALITY ASSURANCE AND QUALITY CONTROL TESTING AND INSPECTION 12

4.1 General 12
4.2 Observation and Verification Testing 12
4.3 Subcontracts and Procurement 13
4.4 Construction Specifications 13
4.5 Earthwork - General 13
4.6 Base Layer 14
4.7 Low Hydraulic Conductivity Layer 14
4.8 Vegetative Support Layer 18
4.9 Gas Venting Layer 18
4.10 Plantable Soil Layer 21
4.11 Geosynthetic Clay Liner (GCL) 23
4.12 Composite Drainage Net (CDN) 26
4.13 Geotextiles 30
4.14 Low Linear Density Polyethylene (LLDPE) Geomembrane 34
4.15 Anchorage System 42
4.16 Landfill Gas Collection System 43
4.17 Concrete Revetment 46

5.0 REMEDIAL ACTION CERTIFICATION REPORT 49

5.1 General 49
5.2 Contents of the RA Report 49

List of Tables

Table 4-1: QC Schedule for Soil Testing - Low Hydraulic Conductivity Soil Test Pad.....15
Table 4-2: QC Schedule for Soil Testing - Low Hydraulic Conductivity Soil 16
Table 4-3: QC Schedule for Construction - Low Hydraulic Conductivity Soil Field Testing... ..17
Table 4-4: QC Schedule for Soil Testing - Vegetative Support Layer Soil 18
Table 4-5: QC Schedule for Construction - Vegetative Support Layer Soil Field Testing..... ...19
Table 4-6: QC Schedule for Soil Testing - Gas Venting Material.....20
Table 4-7: QC Schedule for Construction - Gas Venting Material Field Testing..... 21
Table 4-8: QC Schedule for Construction - Plantable Soil Layer 23
Table 4-9: QC Schedule for Material Testing - Geosynthetic Clay Liner ... .24
Table 4-10: QC Schedule for Construction - Geosynthetic Clay Liner ... .25
Table 4-11: QC Schedule for Material Testing - Geonet 26
Table 4-12: QC Schedule for Material Testing - Filter Geotextile Properties ... .27
Table 4-13: QC Schedule for Material Testing - Composite Drainage Net 27
Table 4-14: QC Schedule for Construction - Composite Drainage Net ... .30
Table 4-15: QC Schedule for Material Testing - Woven Geotextile ... .31
Table 4-16: QC Schedule for Material Testing - Non-Woven Geotextile Type I ... .31
Table 4-17: QC Schedule for Material Testing - Non-Woven Geotextile Type II ... .32
Table 4-18: QC Schedule for Construction - Geotextile 34
Table 4-19: QC Schedule for Material Testing - LLDPE Liner (60 mil) 35
Table 4-20: QC Schedule for Material Testing - LLDPE Liner (30 mil) 36
Table 4-21: QC Schedule for Material Testing - HDPE Pipe.....44
Table 4-22: QC Schedule for Construction - HDPE Pipe.....46
Table 4-23: QC Schedule for Material Testing – Concrete Revetment.....47
Table 4-24: QC Schedule for Construction - Concrete Revetment 48

1.0 INTRODUCTION

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1.1 OVERVIEW

This document presents the Construction Quality Assurance Plan (CQAP) for the construction of the Rose Hill Landfill cap, as part of the implementation of Phase II of the Remedial Action (RA) for the Site, Operable Unit 1 (OU1) Source Control Phase for the Rose Hill Landfill Superfund Site. Following the completion of landfill capping, the Long Term Environmental Monitoring Plan will commence. The purpose of this document is to specify in detail the methods, procedures, and frequency of inspection and testing activities in accordance with the requirements and consistent with the United States Environmental Protection Agency (EPA) Record of Decision (ROD) for the Site signed by the Director of the Office of Site Remediation and Restoration, Region 1, New England on December 12, 1999 and the Site Cooperative Agreement (CA) Statement of Work (SOW) dated May 28, 2004.

The drawings and specifications referred to within this plan are included under separate cover entitled *Project Manual for Rose Hill Landfill Superfund Site, Phase II – Landfill Closure, South Kingstown, Rhode Island, May 30, 2006.* The drawings and specifications were prepared by MACTEC Engineering and Consulting, Inc. of Wakefield, Massachusetts for the Rhode Island Department of Environmental Management (RIDEM), Office of Waste Management. RIDEM is responsible for administering the State's Comprehensive Environmental Response Liability and Compensation Act (CERCLA, as amended by SARA) funded cooperative agreements and state superfund contracts. RIDEM is serving as the Lead Agency in order to implement the work.

Quality Assurance (QA) activities are differentiated from Quality Control (QC) activities initiated by a manufacturer, fabricator, installer, or the construction contractor necessary to control the quality of the constructed project. It is the responsibility of the owner's QA representatives (referred to as the Engineer in the specifications) to verify that the contractor's QC plan is implemented and followed such that the project is completed in conformance with the project specifications and drawings. Thus, the specific function of the QA plan, as presented herein, is to focus on quality levels and requirements of specific elements of the design that are critical to the function of the facility.

There are two Contractors working directly for RIDEM to implement the RA: RA Contractor and Supervising Contractor. The E.T.& L. Corporation (E.T.& L.) is under contract with RIDEM to serve as the RA Contractor or construction contractor. The Louis Berger Group, Inc. (Berger) is under contract with RIDEM to serve as the Supervising Contractor responsible for oversight and independent quality assurance team (IQAT) services. Berger is also serving as the Engineer during Phase II RA construction. Berger's role on the project with regards to Construction Quality Assurance is also referred to as the CQA Engineer.

1.2 SCOPE OF THE PLAN

The scope of this construction quality assurance plan includes:

- Identifying the project participants,
- Defining participants' responsibility and authority,

- Outlining project communications, and
- Delineating quality levels and test requirements, as identified in the specifications.

The activities addressed in this document include construction of a multi-layer cap which meets the performance standards of a Resource Conservation and Recovery Act (RCRA) C cap to cover the Rose Hill Landfill, a total of 21 acres, and installation of a landfill gas collection and venting system as part of the landfill cap construction. The construction and installation of these systems will require verification of proper types and compositions of materials being delivered to the site, assurance of proper material placement, and field and laboratory testing of the in-place materials to verify both compliance with project plans and specifications, and good workmanship.

1.3 DEFINITIONS

The following is a list of definitions for reference:

"Authorized Representative" or "Owner's Representative" shall mean specifically named individuals (to be named prior to construction), any one of whom has the authority to execute a Change Order on behalf of the Owner.

"Classification System" shall mean the soil classification system shall be in accordance with the standard test method for classification of soils for engineering purposes, Unified Soil Classification System (USCS) (ASTM D2487)

"Compaction" shall mean the process of increasing the density or unit weight of soil by rolling, tamping, vibrating, or other mechanical means.

"Density" the mass density of a soil, or its weight per unit volume; usually reported in pounds per cubic foot.

"Geomembrane" shall mean an impermeable membrane liner or barrier used in civil engineering or geotechnical projects.

"Geotextile" shall mean a relatively porous construction or reinforcement fabric used in civil engineering for geotechnical projects. The fabric structure may be knit, woven or nonwoven. Filter geotextile is a material that provides separation of materials with different pore size openings to prevent clogging. Drainage geotextiles are materials with adequate transmissivity to provide planar flow of fluid. Reinforcing geotextile is a material with sufficient in-plane strength to support some or all of the load applied to a composite system (such as a soil-geotextile). Cushioning geotextile is a material with sufficient puncture strength to prevent damage to an underlying material.

"Hand Weld" shall mean a bond between two linear low density polyethylene (LLDPE) materials, or between an LLDPE sheet and a high density polyethylene (HDPE) sheet, which is achieved by extruding a bead of LLDPE over the overlap area followed by pressure, using a hand-held apparatus.

"Inspector" shall mean the consulting engineering, surveying, and/or testing firms(s) providing subsurface soil investigations, soil testing laboratory, monitoring of earthwork construction,

construction surveillance, and surveying services technically accountable to RIDEM; responsible for certification of cell liner construction according to the specifications outlined herein.

"Installer" shall mean the party entering into a contract with the owner to construct any item or group of items at this facility.

"*In Situ*" shall mean "as is", or as it exists in-place naturally.

"Machine Weld" shall mean a bond between two LLDPE materials, or between an LLDPE sheet and an HDPE sheet which is achieved by extruding a bead of LLDPE between the overlap areas followed by pressure, or by fusing both surfaces in a homogenous bond of the two surfaces. Either method must use a power-driven system for heating, extruding, and pressure.

"Moisture Content" shall mean the ratio of quantity of water in the soil (by weight) to the weight of the soil solids (dry soil), expressed in percentage; also referred to as water content.

"Optimum Moisture Content" shall mean the moisture content corresponding to maximum dry density as determined in the Modified Proctor (ASTM D1557) Test.

"Owner" shall mean RIDEM, under the basis as being designated the Lead Agency.

"Permeability" shall mean the ability of pore fluid to travel through a soil mass via interconnected voids. "High" permeability indicates relatively rapid flow of pore fluid and vice versa. Coefficients of permeability are generally reported in centimeters per second.

"Plasticity" shall mean the ability of soil mass to be remolded without raveling or breaking apart. The plasticity index, numerically equal to the difference between the liquid and plastic limit, is a comparative number that describes the range of moisture contents over which a soil behavior is plastic.

1.4 APPLICABLE REGULATIONS AND GUIDANCE

This CQAP has been prepared to meet the construction and quality assurance requirements of the following:

Construction Quality Assurance for Hazardous Waste Land Disposal Facilities, EPA/530-SW-86031, October 1986

Construction Quality Management for Remedial Action and Remedial Design Waste Containment Systems, EPA/540/R-92/073, October 1992.

2.0 INVOLVED PARTIES - RESPONSIBILITY AND AUTHORITY

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2.1 ORGANIZATIONAL STRUCTURE

Key members of the project organization include RIDEM, the Design Engineer, the Construction Quality Assurance Engineer, and the Contractor. Authorities and responsibilities of the key members are presented in the following paragraphs:

The following list of key members is provided for reference.

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2.2 RESPONSIBILITIES

2.2.1 RIDEM (Owner)

As the Lead Agency, RIDEM has overall responsibility for the planning, design, construction, and final closure of the Rose Hill Landfill. In this capacity, RIDEM will conduct project meetings, approve and disapprove all change requests, and provide general oversight of the project. Within this document and other contractual documents for the Rose Hill Landfill closure, RIDEM and the "State" are used interchangeably, and shall have the same meaning.

2.2.2 USEPA

As the Support Agency, USEPA has a responsibility to manage site-specific federal cost share funding under a Cooperative Agreement with the State Lead Agency. USEPA also provides technical support to the State in overseeing the construction activities that must comply with the Site's Record of Decision. As such, USEPA also provides review and comments to the State on construction work products and funding allocations.

2.2.3 Supervising Engineer

RIDEM, as the Lead Agency, has contracted with The Louis Berger Group, Inc. (Berger) to serve as the Supervising Engineer during Phase II. As Supervising Engineer, Berger will perform multiple roles on the Project. Berger will provide Construction Quality Assurance (CQA) services during the construction and certify the project upon its completion. Berger is also serving as the Design Engineer throughout the balance of the project. The responsibilities and duties to be fulfilled by Berger during the project are elaborated below.

2.2.3.1 Design Engineer

The Design Engineer, under contract with RIDEM, is responsible for design activities which may not end until construction is compete. The Design Engineer will perform the following duties:

- Clarify or interpret requirements of the design
- Review submittals for conformance to the design
- Review requests for design changes during construction
- Prepare design changes to account for unexpected site conditions or changes in construction methodology

Berger served as the original Engineer of Record for the Remedial Design. MACTEC was the designer responsible for project revisions required following Phase I construction. Berger will serve as the role of the Engineer throughout Phase II, including providing design services during construction.

2.2.3.2 Construction Quality Assurance (CQA) Engineer

The CQA Engineer is the primary construction quality assurance agent for RIDEM. The CQA Engineer is responsible for everyday observation, verification testing, and documentation of the Contractor's materials, workmanship, and quality control activities, as required in this CQAP. The CQA Engineer will coordinate the quality assurance activities with the independent testing laboratories.

The CQA Engineer and staff will perform the following duties:

- Review as-built records and final construction quality assurance documentation for the project.
- Perform oversight of CQA Engineer and Contractor retained independent testing laboratories to assure compliance with approved procedures for sampling and testing, frequency, locations, etc.
- Review quality assurance documentation, prepared by field inspectors.
- Review frequency and results of Contractor-submitted quality control tests for compliance with contract requirements.
- Review Contractor Daily Inspection Reports and test data for completeness.
- Attend pre-construction meetings and progress meetings to resolve quality problems, as required.
- Attend record-drawing review meetings.
- Observe the fabrication, manufacture, and testing of materials in the Contractor's or vendor's offsite or on-site work areas, as required.
- Observe and sample purchased materials upon delivery to verify that correct type, quantity, and size of material have been furnished.
- Observe performance of Contractor's work and identify any areas of non-compliance with the design including:
    a) Inspection of the subgrade surface prior to beginning the installation of geosynthetic clay liner (GCL) or geomembrane.
    b) Placement of the first layer of cover soil.
    c) Seaming operations for the installation of geomembrane.
- Prepare or review daily diaries of construction activities, observations, and verification tests performed.
- Advise RIDEM and the Design Engineer of site conditions or construction conditions that may affect the intent, completion, or quality of the work.

2.2.3.3 CQA Certifying Engineer

The CQA Engineer will be a registered Professional Engineer in the State of Rhode Island and will have the primary responsibility of certifying that the closure construction has been carried out successfully and that components addressed herein were constructed according to the plans and

specifications. The CQA Certifying Engineer may be the CQA Engineer or someone else in the CQA Engineer's organization who is a registered professional engineer with experience and competence in certifying similar closures. Berger will provide project certification of the Phase II construction in the Remedial Action Report.

2.2.3.4 Independent Testing laboratories

Independent testing laborites will be retained by the Contractor and the Engineer as specified in the contract documents. Responsibilities of the independent testing laboratories will include:

- Controlling and supervising independent-testing laboratory personnel assigned to the project.
- Assuring that all personnel assigned to the project are properly qualified and trained for the assigned tasks.
- Maintaining the proper equipment and supplies for accomplishing the assigned tasks in accordance with specified test procedures.
- Consulting with the CQA Engineer in selecting geotechnical and LLDPE membrane liner samples for quality assurance testing.
- Obtaining test specimens and performing quality assurance tests as requested.
- Documenting and submitting test results and observation records as established by the contract documents.
- Reporting any noncompliance to RIDEM, Contractor, and CQA Engineer immediately.

2.2.4 Construction Contractor (RA Contractor)

The Contractor, by way of a specific contract with RIDEM, is charged with performing and controlling the construction work in accordance with the design documents. The E.T.& L. Corporation (E.T.& L.) is under contract with RIDEM to serve as the RA Contractor.

2.2.4.1 Vendors and Subcontractors to the Construction Contractor

These organizations are agents of the Contractor by way of contracts, subcontracts, and similar arrangements. As such, they are responsible, through the Contractor, for maintaining quality control procedures in accordance with their contractual arrangements and the Contractor's quality control plans. These agents should also provide the Contractor with quality control data and reports necessary for his submittals.

3.0 PROJECT COMMUNICATIONS

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3.1 LINES OF COMMUNICATION

Accurate, timely communications are required to avoid construction-related conflicts and potential errors and omissions. RIDEM, USEPA, representatives from the towns of Narragansett and South Kingstown, the Contractor, Engineer, and their respective employees and staff must have an established communication network. Establishing open lines of communication is essential for maintaining strong working relationships and producing quality work.

Lines of communication will be reviewed and established by all parties at the preconstruction meeting.

Strict document control procedures will be established for items such as Contractor submittals, test results, plan or specification revisions, etc. These controls will include distribution and confirmation procedures to verify that documents are appropriately dispatched and incorporated into the project. Whenever possible, documents indicating revisions in plans, specifications, or procedures will be distributed immediately and explained to all parties at routine or special project meetings.

3.2 PROJECT MEETINGS

Routine project meetings will be scheduled by the Engineer or Contractor. The purpose of the routine project meetings is to keep all parties informed and provide a forum for solving design, construction, and quality assurance-related problems.

3.2.1 Pre-Construction Meeting

A meeting will be held to review the project, schedule and requirements for the Contractor's Quality Control plan, and to clarify or resolve issues before construction startup. At a minimum, RIDEM, Engineer, Contractor, USEPA, representatives from Narragansett and South Kingstown, and selected subcontractors should be present. The topics of this meeting should include, but not be limited to:

- Providing each organization with relevant CQA documents and supporting information. Supporting information may include design drawings, specifications, site health and safety plans, and other applicable documents. All parties should use the opportunity to distribute relevant documents.
- Familiarizing each organization with its specific responsibilities with respect to construction quality control and assurance relative to the design criteria, design drawings, schedules, and specifications.
- Reviewing lines of authority and communication for each organization.
- Reviewing the Contractor's work plan and schedule.
- Discussing the established procedures and protocol for observations and tests including sampling strategies.
- Discussing the procedures for handling construction deficiencies, repairs, and retesting.
- Reviewing methods for documenting and reporting inspection and testing data.

- Discussing procedures for protecting construction materials and preventing damage to the materials from inclement weather or other adverse events.

3.2.2 Progress Meetings

Progress meetings will be held, at a minimum, every week at the site project office. The meeting will be attended by the Contractor, RIDEM, USEPA, representatives from the towns of Narragansett and South Kingstown, and the CQA Engineer. The purpose of the meeting is to:

- Review activities and accomplishments;
- Review the Contractor's work plan for construction personnel and equipment assignments for the upcoming weeks; and
- Discuss existing or potential construction or schedule problems.

The CQA Engineer will keep an independent set of minutes.

3.2.3 Problem or Work Deficiency Meetings

A special meeting may be held when, and if, a problem or deficiency is present or likely to occur. At a minimum, the meeting should be attended by the Contractor, RIDEM, USEPA, representatives from the towns of Narragansett and South Kingstown, and the CQA Engineer. The purpose of the meeting is to define and resolve a problem or recurring work deficiency in the following manner:

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

3.3 DOCUMENT TRANSMITTALS

Documenting transmittals among the project parties and providing a record of communications are necessary for keeping appropriate construction and quality assurance personnel informed of project requirements, progress, and quality of the work. To prevent misunderstandings and omissions, the CQA Engineer will document his transmissions.

3.3.1 Contract Clarification/ Interpretation Requests

Contract Clarification/ Interpretation Requests are submitted when an explanation of the intent of specific construction requirements, as presented in the design documents, is required. These are generally submitted by the Contractor to the Engineer.

Contract Clarification/ Interpretation Requests will be submitted to the Engineer through RIDEM. All interpretations of design or specifications by the Engineer will be issued in writing. In special cases, the Engineer may communicate a design interpretation or clarification verbally followed by written confirmation. RIDEM is responsible for informing all parties of the Engineer's interpretations and will control the distribution of documents to construction, quality assurance, or regulatory personnel.

3.3.2 Change Orders

A Change Order is used whenever a change in drawings and specifications is deemed necessary for the following reasons:

- Changed site conditions;
- Changed materials conditions;
- Alternate design procedures proposed; and
- Alternate materials proposed.

Change orders which make changes to the Contract Price and/or Contract Time will be in accordance with Section 00700 Articles 10, 11 and 12 of the Project Specifications .

3.3.3 Contractor Submittals

Critical technical submittals will be submitted to the Engineer and RIDEM. Subcontractor and vendor submittals will be made to the Contractor. The Engineer will document actions taken on the submittals. The reviewed submittals or appropriate form will be transmitted to the Contractor and a copy will be provided to RIDEM and the CQA Engineer.

3.3.4 Daily Inspection Diary

Daily inspection diaries will be maintained by the CQA Engineer. At the end of each week, copies of the daily diary will be made available to RIDEM. The daily diary will be completed in ink and consecutively numbered.

The content of the diary will include at a minimum:

- Weather conditions.
- The content of all substantive conversations held with the Contractor at the site, and commitments made by either party.
- Item, condition, or activity observed or tested.
- Location, date, and type of observation or test.
- Observation or verification test source criteria (drawing, specification, etc.)
- Results or acceptability.
- Reference to corrective action taken in connection with non-comformances.
- Conditions that may cause a slowdown by the Contractor.
- Log of all work completed, status of work in progress, and all new work started.
- Location of the work as well as its description, and which Contractor or subcontractors performing it.
- Summary of verification testing performed for quality assurance.
- Signature of the person completing the daily report with full name, title, and date.

3.3.5 Record Keeping

Maintaining complete, accurate records of all work is crucial to verifying conformance to the design. The following identifies categories of forms and types of forms that will be used:

- Contract Submittals
  - a) Transmittal Form
  - b) Submittal Routing
  - c) Request for Information (RFI)
  - d) Design Clarification
- Contract Modification
  - a) Change Order Request
  - b) Request for Price (RFP)
  - c) Change Order
- Nonconformance
  - a) Field Order
  - b) Notice of Non-Compliance
  - c) Punch List
- Inspection Forms
  - a) Daily Diary
  - b) Progress Meeting Reports
  - c) Independent Testing Laboratory Results
  - d) Material Delivery
  - e) Photo Record
- General Office Forms
  - a) Site Visit Log
  - b) Memorandum
  - c) Meeting Notes
  - d) Telephone Log
  - e) Field Transmittal Letter

4.0 DESCRIPTION OF QUALITY ASSURANCE AND QUALITY CONTROL TESTING AND INSPECTION

4.0 DESCRIPTION OF QUALITY ASSURANCE AND QUALITY CONTROL TESTING AND INSPECTION

4.1 GENERAL

This section of the program describes the quality assurance and quality control (QA/QC) testing and inspection for every major phase of construction in accordance with the engineering design and specifications. The quality of materials and workmanship will be controlled by the Contactor or supplier who furnishes the work or material involved.

Quality Assurance personnel (i.e. the CQA Engineer, outside laboratories, or consultants) will perform observation and verification testing of the construction materials, workmanship, and the Contractor's quality control activities. Typically, the quality assurance verification testing is performed at a fraction of the frequency of quality control testing requirements. Actual QA/QC test frequency is a function of specific construction activities, as outlined in the Contractor's Quality Control Plan and the CQAP. Appropriate test methods and inspection techniques are outlined in the following sections.

All QC testing, sampling, and inspection will be conducted by the Contractor, the Contractor's supplier, or subcontracted quality control independent testing laboratories. The Contractor will provide the CQA Engineer with copies of QC inspection and testing reports in a timely manner. These reports will include documentation of failed tests and corrective actions taken.

The CQA Engineer will provide an independent firm for QA testing of geomembrane and soil, as part of the contract with RIDEM. Field personnel from this firm will be under the direction of the CQA Engineer.

4.2 OBSERVATION AND VERIFICATION TESTING

The CQA Engineer will obtain, review and become familiar with the applicable procedures, codes, standards, specifications, drawings, observation and verification testing requirements, and accept/reject criteria.

The CQA Engineer is responsible for construction and verification testing required. To accomplish this, random but pre-planned observation and verification testing will be conducted.

The CQA Engineer will document observations on the Daily Diary Inspection Report and will document verification tests on the appropriate testing forms. All documentation must be recorded in ink. To correct an error on an inspection report, a single line will be drawn through the error, and the correct information will be entered next to the error. All corrections will be legibly signed next to the printed name and dated.

Daily diary observation records and verification testing forms must, as a minimum, contain the following information:

- Item, condition or activity observed or tested.
- Location of observations or test.
- Date of the observation or verification test.
- Type of verification test or observation.
- Observation or verification test source criteria (drawing, specification, etc.)
- Results or acceptability.
- Reference to corrective action taken in connection with non-conformances.

4.3 SUBCONTRACTS AND PROCUREMENT

The anticipated quality assurance subcontracts include the following:

- Independent testing laboratories (Owner and Contractor retained)
- Special consultants (Contractor retained)
- Surveyors (Contractor retained)

4.4 CONSTRUCTION SPECIFICATIONS

Specifications for construction are presented the *Project Manual for Rose Hill Landfill Superfund Site, Phase II – Landfill Closure, South Kingstown, Rhode Island, May 30, 2006.*

4.5 EARTHWORK - GENERAL

The subgrade on which soil materials will be placed shall be prepared in accordance with the specifications, including scarification and compaction. All materials shall be free from roots, organic material, trash, debris and other deleterious or objectionable materials. The soils shall be preprocessed, if necessary, to adjust water content, remove oversized particles or break down clods of soil. The soil materials shall be placed in lifts of relatively uniform and appropriate thickness. In-place soils shall be protected from damage caused by desiccation or freezing temperatures. The final surface of each soil component of the landfill cap shall be at the design line and grade, plus or minus one-tenth of a foot when measured across any 10-foot section, and shall be properly prepared to support succeeding cap components.

Materials will be tested *in situ*. If tests indicate that in-place material do not meet the specific requirements and design criteria, the materials will be replaced or reworked, and retested.

All imported soil material shall be sampled by the Contractor at a minimum frequency of one per 10,000 cubic yards to verify that the material is free from contamination. The soil shall be tested for the following: volatile organic compounds (VOCs) using EPA Method 8260, Poly-Nuclear Aromatic Hydrocarbons (PAHs) using EPA Method 8270, total Petroleum Hydrocarbons (TPH) and RCRA 8 Metals. Soils with levels above the residential exposure criteria shall not be used above or as part of the Cover System Construction. Imported soils with levels above the industrial/commercial exposure criteria shall not be used on-site.

Copies of all QC test results will be provided to the CQA Engineer by the Contractor. The CQA Engineer will verify that QC testing frequency and minimum value requirements are met. The CQA Engineer will periodically observe material testing and will track results to ensure materials and construction are in accordance with the plans and specifications.

4.6 BASE LAYER

4.6.1 Preconstruction

Base Layer Soil shall consist of imported or processed imported material, reasonably free from rocks larger than 12 inches, from roots and other organic matter, ashes, cinders, trash, debris, and other deleterious materials. Imported material shall be tested as required for Vegetative Support soil and shall conform with the requirements for Vegetative Support material (see Section 4.8 below).

4.6.2 Construction

Minor waste excavation will be required in some areas to Phase II Subgrade. In areas where disturbance of the waste is required, the Contractor shall strip and stockpile existing base layer material installed during Phase I construction. The Contractor will grade the waste to a minimum of 6 inches below the Phase I Subgrade and place 6 inches of stockpiled base layer material over the waste. The base layer soil will be compacted to 85 percent relative compaction at a moisture content within 3 percent of optimum as determined by ASTM D1557.

Fill is required in most areas of the landfill to achieve Phase II Subgrade. The Contractor will place base layer soil as specified to the elevations and grades shown on the Drawings.

The surface of the final lift shall be smooth, free from roller marks, holes, depressions more than 1 inch deep, or protrusions extending above the surface more than 1/2 inch.

The applicable standards, test methods, and minimum test frequency requirements for imported base layer material are the same as for the vegetative support material and are summarized in Tables 4-4 and 4-5, below.

4.6.3 Post Construction

The base layer shall be protected from surface water erosion, prior to placement of the overlying layers.

4.7 LOW HYDRAULIC CONDUCTIVITY LAYER

4.7.1 Preconstruction

Low Hydraulic Conductivity soil shall consist of a natural soil with a maximum particle size of 0.5 inches that is capable of being worked to produce a soil layer of thickness shown on the Drawings that has a uniform isotropic hydraulic conductivity of 1.0×10^{-4} cm/sec or less.

The Low Hydraulic Conductivity Soil shall be imported. The Contractor shall conduct tests, including particle size, Atterberg limits, moisture-density, and hydraulic conductivity tests (using ASTM Test Method D5084), as necessary to initially locate an acceptable source of material.

Once a potential source of material has been located, the Contractor shall develop and undertake a Borrow Source Characterization testing program to demonstrate the acceptability of the proposed material. Prior to implementation of the Contractor's Borrow Source Characterization Study, the Contractor shall coordinate, attend and run a pre-study planning meeting with the Engineer.

Certified results of all tests shall be submitted to the Engineer upon completion of tests. Tentative acceptance of the borrow source by the Engineer will be based upon the results of the study. The testing program shall include construction of a test pad with dimensions of at least 50 feet by 50 feet square prior to construction of Low Hydraulic Conductivity Soil layer. The same equipment, procedures, and materials shall be used in constructing the test pad as will be used in constructing the Low Hydraulic Conductivity Soil layer required by this Contract.

Following construction of the Low Hydraulic Conductivity Soil layer in the test pad, the Contractor shall conduct tests in accordance with the Table 4-1 below. Sampling locations shall be selected by the Engineer. All tests shall be conducted in accordance with these specifications.

TABLE 4-1
QC SCHEDULE FOR SOIL TESTING
LOW HYDRAULIC CONDUCTIVITY SOIL TEST PAD

Test/Sampling Method	Standard	Minimum Frequency
Two-Stage Borehole (Boutwell) Permeameter	ASTM D6391	5
Shelby Tube Sampling	ASTM D1584	4
Flexible-Wall Hydraulic Conductivity Test with Backpressure Saturation	ASTM D5084	1 per Shelby tube sample
Particle Size Analysis	ASTM D422	1 per Shelby tube sample
Atterberg Limits	ASTM D4318	1 per Shelby tube sample
In-Place Density Test and Water Content Measurement by Nuclear Methods	ASTM D2922 and ASTM D3017	4 per lift
In-Place Density Test by Sand Cone Method	ASTM D1556	1 per day
Moisture Content	ASTM D2216	1 per day
Direct Shear	ATSM D3080	2 per day

The Contractor shall conduct the following tests using the methods and at the frequencies shown below in Table 4-2 and provide results to the Engineer for approval prior to bringing the Low Hydraulic Conductivity Soil to the site.

TABLE 4-2
QC SCHEDULE FOR SOIL TESTING
LOW HYDRAULIC CONDUCTIVITY SOIL

Test	Method	Minimum Frequency
Particle Size	ASTM D422	1 per 1,500 cy or when material changes
Atterberg Limits	ASTM D4318	1 per 1,500 cy or when material changes
Moisture Content	ASTM D2216	1 per 1,500 cy or when material changes
Moisture Density	ASTM D1557	1 per 5,000 cy or when material changes

4.7.2 Construction

The compacted Low Hydraulic Conductivity Soil layer shall have a minimum thickness of 18 inches, measured after compaction. Each loose lift shall have maximum thickness of 8 inches. Each compacted lift shall have a maximum thickness of 6 inches.

All lifts shall be compacted to a minimum density of 90 percent relative compaction with a moisture content within a range of -1 to +3 percent above optimum. The Contractor shall meet additional compaction requirements established by the Engineer on the basis of test results from the test pad.

Low Hydraulic Conductivity Soil shall be compacted using equipment that provides a kneading action, having tines that will fully penetrate the compacted lift thickness such as Caterpillar 815 or equal. Alternative compaction equipment shall be allowed if approved by Engineer and demonstrated in test pad testing.

The surface of the final lift shall be smooth, free from roller marks, holes, depressions more than 1 inch deep, or protrusions extending above the surface more than 1/2 inch. Material larger than 0.5 inches or with jagged or sharp edges shall be removed from the surface prior to placement of geomembrane. The finished surface of the final lift shall be rolled with a smooth steel drum roller or rubber-tired roller to eliminate tine or roller marks and provide a smooth, dense surface.

The Contractor shall compact exposed surfaces to protect Low Hydraulic Conductivity Soil from moisture changes (loss or gain) and shall wet exposed surfaces as needed to protect from dessication. If Low Hydraulic Conductivity Soil layer becomes cracked or becomes softened due to moisture changes, the Contractor shall scarify full depth of lift and recompact and retest as previously specified. Construction traffic shall be routed to away from the top of the Low Hydraulic Conductivity Soil layer once material has been placed and compacted.

During compacting operations, the Contractor shall maintain moisture content in each lift of Low Hydraulic Conductivity Soil material within the specified range. If the material is too dry, in the Engineer's sole opinion, the Contractor shall add water to material by sprinkling the fill, then mix it by discing to make moisture content uniform throughout the lift. If too wet, in the Engineer's sole opinion, the Contractor shall aerate material by blading, discing, harrowing, or other methods, to hasten the drying process.

The compacted Low Hydraulic Conductivity layer shall have a hydraulic conductivity of 1.0×10^{-4} cm/sec or less. If a shelby tube sample collected by the Contractor fails to meet the maximum hydraulic conductivity requirements, at least two replicate samples shall be obtained in the vicinity of the failed test. Should any of the replicate samples confirm the failure, the area of failure shall be located, reconstructed, and retested at the Contractor's sole expense. The area of failure is defined as the area closed to the failure location, with its boundaries located at the half distance between the failed sample location and the nearest passing sample location.

The applicable standards, test methods and minimum test frequency requirements for construction of the Low Hydraulic Conductivity Soil layer are summarized in Table 4-3 below.

TABLE 4-3
QC SCHEDULE FOR CONSTRUCTION
LOW HYDRAULIC CONDUCTIVITY SOIL FIELD TESTING

Test	Method	Minimum Frequency
In place Nuclear Density and Moisture Content	ASTM D2922 and D3017	5 per acre or minimum of 1 per lift per day of placement
Sand Cone Density	ASTM D 1556	1 per day of placement
Moisture Content	ASTM D2216	1 per day of placement
Shelby Tube Sample	ASTM D1587	1 per 100,000 sf per lift or minimum of 1 per lift
Hydraulic Conductivity	ASTM D5084	1 per Shelby Tube
Atterberg Limits	ASTM D4318	1 per Shelby Tube
Particle Size	ASTM D422	1 per Shelby Tube
Lift Thickness	Measurement	8 per acre
Maximum Particle Size	Measurement/Visual Observation	Periodic/Random

The CQA Engineer shall perform verification testing on a split sample of the Low Hydraulic Conductivity Soil material and the in-place density and moisture content testing initially, and then at a frequency of approximately 20 percent of the QC samples tested by the Contractor. If verification test results are consistent with the Contractor's QC results, verification testing may be decreased or eliminated.

4.7.3 Post Construction

Before placement of the geomembrane, the Low Hydraulic Conductivity Soil layer shall be inspected for cracks, holes, defects or any other features that may increase in permeability. All defective areas shall be removed, repaired and retested.

The Low Hydraulic Conductivity Soil layer shall be protected from rain, drying, dessication, surface water erosion and freezing.

4.8 VEGETATIVE SUPPORT LAYER

4.8.1 Preconstruction

Soil materials shall meet classification SC, SM or ML as determined by ASTM D2487, with a maximum particle size of 1 inch for the first 12-inch lift and 3-inches for the second 6-inch lift. The uniform isotropic hydraulic conductivity shall be 1 x 10^{-4} cm/sec. or less, or other value as determined by the Engineer.

The Vegetative Support Layer Soil shall be imported. The Contractor shall conduct tests, including particle size, Atterberg limits, moisture-density, and hydraulic conductivity tests (using ASTM Test Method D5084), as necessary to initially locate an acceptable source of material.

The Contractor shall conduct the following tests using the methods and at the frequencies shown in Table 4-4 below and provide results to the Engineer for approval prior to bringing the Vegetative Support Layer Soil to the site.

TABLE 4-4
QC SCHEDULE FOR SOIL TESTING
VEGETATIVE SUPPORT LAYER SOIL

Test	Method	Minimum Frequency
Particle Size	ASTM D422	Initially, then 1 per 3,000 cy or when material changes
Atterberg Limits	ASTM D4318	Initially, then 1 per 3,000 cy or when material changes
Moisture Content	ASTM D2216	Initially, then 1 per 3,000 cy or when material changes
Moisture Density	ASTM D1557	Initially, then 1 per 5,000 cy or when material changes

The CQA Engineer shall perform verification testing on a split sample of the Vegetative Support Layer Soil material initially, and then at a frequency of approximately 20 percent of the QC samples tested by the Contractor. If verification test results are consistent with the Contractor's QC results, verification testing may be decreased or eliminated.

4.8.2 Construction

The Vegetative Support layer shall have a minimum thickness of 18 inches, measured after compaction. The first lift shall have a minimum loose thickness of 12-inches. All lifts shall be compacted to a minimum density of 85 percent relative compaction with a moisture content within a range of -3 to +3 percent above optimum, as determined by ASTM D1557.

No Vegetative Support Layer soil material shall be placed until underlying geomembrane, and CDN layers have been approved by the Engineer. If damage occurs to the geosynthetics during the installation, the Vegetative Support Layer soil shall be carefully removed from above the CDN and the damaged area repaired as specified at the Contractor's sole expense.

Track-mounted equipment, no larger than a Caterpillar Model D-5 LGP or equal, with less than 5.0 pounds per square inch pressure shall be used for spreading. No tracked equipment shall be operated on less than 12 inches of cover. The operator shall not make any quick turns or quick changes in direction while operating on top of the cover system. Wheeled equipment and vehicles may operate on the capped area after a minimum of 3 feet of soil is in place; however traffic on the capped area shall be restricted to necessary operations.

Soil shall be spread in the direction of fabric overlap and in a manner to prevent displacement or wrinkling of the underlying geosynthetics. In general, soil deployment shall occur in an uphill direction. The blade of the dozer shall be lifted at the end of the push to deploy soil in a forward tumbling motion without exerting excessive stresses on the underlying geosynthetics.

The applicable standards, test methods and minimum test frequency requirements for construction of the Vegetative Support layer are summarized below in Table 4-5.

TABLE 4-5
QC SCHEDULE FOR CONSTRUCTION
VEGETATIVE SUPPORT LAYER SOIL FIELD TESTING

Test	Method	Minimum Frequency
In place Nuclear Density and Moisture Content	ASTM D2922 and D 3017	5 per acre or a minimum of 1 per lift per day of placement
Sand Cone Density	ASTM D1556	1 per day of placement
Moisture Content	ASTM D2216	1 per day of placement
Lift Thickness	Measurement/Visual Observation	5 per acre
Maximum Particle Size	Measurement/Visual Observation	Periodic/Random

The CQA Engineer shall perform verification testing of the Vegetative Support Layer Soil in-place density and moisture content at a frequency of approximately 20 percent of the QC samples tested by the Contractor. If verification test results are consistent with the Contractor's QC results, verification testing may be decreased or eliminated.

4.8.3 Post Construction

The Vegetative Support layer shall be protected from rain, drying, dessication, surface water erosion and freezing.

4.9 GAS VENTING LAYER

4.9.1 Preconstruction

Gas Venting Material shall be inert, of natural origin, such as coarse sand or gravel, processed natural materials; or recycled materials such as crushed glass cullet. Compressible materials, such as tire chips shall be subject to higher performance standards than those presented in 4.9.2 and such standards must be approved by the Engineer. The Gas Venting Material shall have a minimum hydraulic conductivity of 1.0×10^{-2} cm/sec measured under a load of 1,000 psf.

The Contractor shall conduct the following tests using the methods and at the frequencies shown in Table 4-6 below and provide results to the Engineer for approval prior to bringing the Gas Venting Material to the site.

TABLE 4-6
QC SCHEDULE FOR SOIL TESTING
GAS VENTING MATERIAL

Test	Method	Minimum Frequency
Particle Size	ASTM D422	Initially, then 1 per 3,000 cy
Permeabilility tested at loading of 1000 psf at 90% modified proctor density	ASTM D2434	Initially, then 1 per 5,000 cy
Internal Shear Strength, tested at loading of 500, 1000, and 2000 psf at 90% modified proctor density at a minimum friction angle of 25 degrees	ASTM D5321	Initially, then 1 per 5,000 cy
Moisture Density	ASTM D1557	Initially, then 1 per 5,000 cy

The CQA Engineer shall perform verification testing on a split sample of the Gas Venting Material initially, and then at a frequency of approximately 20 percent of the QC samples tested by the Contractor. If verification test results are consistent with the Contractor's QC results, verification testing may be decreased or eliminated.

4.9.2 Construction

The Gas Venting Material layer shall have a minimum thickness of 6 inches, measured after compaction. All lifts shall be compacted to a minimum density of 90 percent relative compaction with a moisture content within a range of -3 to +3 percent above optimum, as determined by ASTM D1557.

The verification of the Gas Venting Layer thickness shall by via hand-dug test holes dug by the Contractor at a 100 foot control grid and witnessed by the Engineer.

During construction, no foreign material shall be mixed into the Gas Venting Layer that may produce clogging or restriction of the ability of the layer to transmit gas. The Contractor shall maintain the material free of contamination and prevent the introduction of fines.

The applicable standards, test methods and minimum test frequency requirements for construction of the Gas Venting Material are summarized below in Table 4-7.

TABLE 4-7
QC SCHEDULE FOR CONSTRUCTION
GAS VENTING MATERIAL FIELD TESTING

Test	Method	Minimum Frequency
In place Nuclear Density and Moisture Content	ASTM D2922 and D 3017	5 per acre or a minimum of 1 per lift per day of placement
Sand Cone Density	ASTM D1556	1 per day of placement
Moisture Content	ASTM D2216	1 per day of placement
Lift Thickness	Measurement of hand-dug holes	100 foot grid

The CQA Engineer shall perform verification testing of the Gas Venting Material in-place density and moisture content at a frequency of approximately 20 percent of the QC samples tested by the Contractor. If verification test results are consistent with the Contractor's QC results, verification testing may be decreased or eliminated.

4.9.3 Post Construction

The Gas Venting Layer shall be protected from contamination, introduction of fines, surface water erosion and freezing.

4.10 PLANTABLE SOIL LAYER

4.10.1 Preconstruction

Plantable Soil shall be manufactured from a combination of on-site available Sewage Sludge and a Blending Material mixed at a 1 to 1 ratio. Soil shall meet the minimum requirements, including an organic content of not less than 4% nor greater that 20% by weight, pH in the range of 5.5 to 7.5 and a soluble salt content not to exceed 500 ppm.

All manufactured Plantable Soil shall be reasonably free from subsoil, clay, lumps, stones, stumps, roots and similar objects, any of which are larger than two (2) inches in diameter, brush, objectionable weeds or other litter, excess acid or alkali or any other material or substance which may be harmful to plant growth or a hindrance to grading and maintenance operations.

Blending Material is imported or suitable on-site material used to mix with the available on-site Sewage Sludge to manufacture Plantable Soil. The Blending Material may be a composted material, or naturally occurring sandy or silty loam. The Contractor shall propose a Blending Material that when mixed at a 1 to 1 ratio with the Sewage Sludge, is capable of producing a manufactured Plantable Soil that meets the requirements of this Specification.

Soil testing for pH fertility, percentage of organics and soluble salts shall be required for each on-site batch or stockpile of Plantable Soil and for each off-site source utilized. Testing shall be performed by governmental or recognized private testing laboratories. Test results and their recommendations shall be submitted to Engineer prior to any Work.

4.10.2 Construction

The minimum thickness of the Plantable Soil layer shall be not less than the minimum 12 inch thickness as indicated on the Contract Drawings.

Placement of Plantable Soil shall be uniformly distributed and compacted on the areas designated to be grassed in sufficient depth to compensate for any shrinkage. Plantable Soil shall not be placed when the soil or subgrade is frozen, excessively wet, extremely dry or in a condition which would be detrimental to the operations.

The surfaces of loamed areas shall be compacted with a roller weighing not more than 100 pounds per foot of width. During the rolling, all depressions caused by settlement or rolling shall be filled with additional loam and the surfaces shall be regraded and rolled until they present a smooth and uniform finish, free from depressions where water will stand and with all surfaces at the required grade. Slopes steeper than 4 horizontal to 1 vertical shall be compacted by a tracked vehicle with the final pass in a direction perpendicular to the contours. The surface shall be left with a cleated pattern parallel to the contours and shall not be smoothed.

The soil surface shall be brought to the required finished grades free from ridges and depressions, through successive stages of light rolling, fine grading and raking operations. The surfaces shall be cleared of all objectionable weeds and shall be free from stone, roots or objects larger than one (1) inch in diameter and other materials which would be a hindrance to planting operations or to plant growth. The final soil surface shall be finely pulverized which shall be obtained by light raking or dragging.

The applicable standards, test methods and minimum test frequency requirements for construction of the Plantable Soil layer are summarized in Table 4-8 below.

TABLE 4-8
QC SCHEDULE FOR CONSTRUCTION
PLANTABLE SOIL LAYER

Test	Method	Minimum Frequency
Lift Thickness	Measurement Visual Observation	Periodic - Random
Surface Preparation	Measurement Visual Observation	Periodic - Random

4.10.3 Post Construction

The Plantable Soil layer shall be protected from surface water erosion prior to growth of vegetative cover.

4.11 GEOSYNTHETIC CLAY LINER (GCL)

4.11.1 Certification of Property Values

The GCL shall consist of a layer of domestic, natural, high swelling, granular, (<1% passing #200 sieve), sodium bentonite clay encapsulated between two geotextiles. The GCL shall be manufactured in a manner that holds the sodium bentonite clay between the geotextiles in a stable, uniform thickness that does not shift or become dislodged during handling.

The Contractor shall provide the CQA Engineer with a mill certificate or affidavit signed by a legally authorized official from the company manufacturing the materials. The mill certificate or affidavit shall attest that the GCL materials meet the chemical, physical, and manufacturing requirements stated in the project specifications. The materials shall be the end products of one manufacturer in order to achieve standardization for performance, replacement, and maintenance.

The CQA Engineer will verify that the property values certified by the installer meet the physical property and test method requirements for the GCL.

The Contractor shall submit complete material specifications including typical amount of bentonite by weight, typical moisture content, swell index, fluid loss, grab and peel strength and index flux measurements. Documents also submitted by the Contractor will include a description of methods used to lap the panel edges which will provide a seam that performs as effectively as the panels, and layout and installation drawings and procedures for carrying out the work

In addition, the Contractor will submit the manufacturer's certification that material furnished is similar and of the same formulation as that for which the test results are submitted. The tests and test frequency requirements are presented in Table 4-9 below.

TABLE 4-9
QC SCHEDULE FOR MATERIAL TESTING
GEOSYNTHETIC CLAY LINER

Property	Test Frequency
Bentonite Swell Index	1 per 50 tons
Bentonite Fluid Loss	1 per 50 tons
Bentonite Mass/Area	1 per 40,000 sq ft
GCL Grab Strength	1 per 200,000 sq ft
GCL Peel Strength	1 per 40,000 sq ft
GCL Permeability	Weekly, with 20 week history
GCL Hydrated Internal Shear Strength	1 per 200,000 sq ft

If manufacturer's test results indicate that the GCL provided does not conform with specified physical property requirements, the Contractor will be required to submit conformance test results indicating that the material conforms with these specifications.

4.11.2 Labeling

The GCL manufacturer will identify all rolls of GCL with the following:

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

4.11.3 Shipment and Storage

Handling of GCL rolls should be done in a competent manner such that damage does not occur to the product or its protective wrapping, in accordance with ASTM D4873.

During shipment and storage, the GCL shall be protected from exposure to moisture. GCL rolls shall be shipped and stored in a relatively watertight wrapping. GCL rolls shall be stored at the site in a dry and protected facility, or in a protected area on pallets off the ground. GCL rolls shall be covered with a heavy, waterproof membrane that allows free flow of air between the rolls and the cover. GCL will be removed from the protected area only in amounts that can be used in one day.

The rolls should be elevated off of the ground so as not to form a dam creating the ponding of water. The rolls should not be stacked so high as to cause thinning of the product at points of contact. The rolls should be stacked in such a way that access for conformance testing is possible.

4.11.4 Conformance Testing

If the GCL provided by the installer does not appear to conform with the specified physical property requirements, the CQA Engineer will require material sampling, in accordance with ASTM D4354, and conformance testing to verify the physical property values summarized in Section 4.11.1. The Contractor will not be allowed to deploy any GCL from the lot under review until conformance test results are submitted and verified by the CQA Engineer. The CQA Engineer may also perform verification testing, if necessary in the CQA Engineer's opinion.

4.11.5 Construction

The Contractor shall remove the protective wrapping from the GCL rolls to be deployed only after the bedding layer has been documented and approved by the CQA Engineer. The CQA Engineer shall be present at all times during the handling, placement and covering of the GCL.

The Contractor shall take necessary precautions to protect the underlying bedding layer from excessive rutting. No GCL shall be installed on a wet subgrade, while it is raining, or when rain may begin before the GCL can be covered with geomembrane. The minimum overlap distance for GCL panels shall be 12 inches on longitudinal seams, and 24 inches on transverse seams. Seams shall be completed by applying ¼ pound per linear foot of granular bentonite between the seam overlap. During placement, care shall be taken not to entrap in or beneath the GCL fugitive clay, stones or sand that could damage a geomembrane, cause clogging of drains or filters, or hamper subsequent seaming of materials above the GCL.

Any holes, tears or rips in the GCL shall be repaired using a patch of GCL. The size of the patch must extend at least 12 inches beyond the damaged area of GCL and shall be adhesive or heat bonded to the product.

The GCL should be covered with geomembrane the same day it is placed and before rain or snow occurs. The GCL should not be covered before observation and approval by the CQA Engineer. GCL panels should not be dragged over the bedding layers surface, except for slight corrections to the alignment of a GCL panel.

The applicable standards, test methods and minimum test frequency requirements for deployment of GCL are summarized in Table 4-10 below.

TABLE 4-10
QC SCHEDULE FOR CONSTRUCTION
GEOSYNTHETIC CLAY LINER

Test	Method	Minimum Frequency
Minimum Panel Overlap	Measurement Visual Observation	Periodic - Random
Subgrade Preparation	Proof Roll	100%

4.11.6 Post Construction

The GCL shall be protected from damage and exposure to moisture.

4.12 COMPOSITE DRAINAGE NET (CDN)

4.12.1 Certification of Property Values

The CDN shall consist of two geotextiles heat-bonded to both sides of a high density polyethylene (HDPE) geonet. The specified material shall be Model TENFLOW 70-2 as manufactured by TENAX® Corporation or approved equal. Should the Contractor submit an alternate product, then transmivitty testing with 1,000 hours at the specified boundary conditions must be submitted prior to material being considered for use on the project.

The geonet drainage core of the CDN shall be manufactured by extruding polyethylene to form a triaxial void maintaining structure.

The geonet shall conform to the requirements indicated in Table 4-11 below.

TABLE 4-11
QC SCHEDULE FOR MATERIAL TESTING
GEONET

PHYSICAL PROPERTY REQUIREMENTS		
Property	**Test Method**	**Requirement[1]**
Tensile strength, lb/ft (minimum)	ASTM D4595	450
Reduction Factor for Compressive Creep @ 1,000 psf after 10,000 hours, (maximum)[2]	GRI GC8	1.1
Density, g/cm^3 (minimum)	ASTM D1505	0.94
Melt Flow Index, g/10 min. (maximum)	ASTM D1238	1.0
Carbon Black content, %	ASTM D4218	2-3
Thickness, mils (minimum)	ASTM D5199	325

Notes:
[1] Properties prior to lamination.
[2] The creep reduction factor is determined from 10,000 hour test duration, extrapolated to 30 years and using a compressive load of 1,000 psf. SIM method is acceptable for confirmation only, but is not acceptable for baseline data to determine the creep reduction factor.

The non-woven geotextile component of the CDN shall consist of a pervious sheet of polypropylene or polyester filaments oriented into a stable network so that the filaments retain their relative position with respect to each other. The geotextile shall be composed of continuous filaments held together by

needle-punching and the edges shall be salvaged or otherwise finished to prevent the other material from pulling away. The geotextile continuous filament process shall allow increased UV resistance and ability to manufacture orange textile for use as visual warning barrier to delineate potential over-excavation of cap.

The geotextile shall be high UV resistant, continuous filament, needle punched, nonwoven polypropylene geotextile. The geotextile color shall be orange to serve as a visual warning barrier. The strength retained after 500 hours of UV exposure shall be at least 70% per ASTM G154. The geotextile shall meet the property requirements listed in Table 4-12 below.

TABLE 4-12
QC SCHEDULE FOR MATERIAL TESTING
FILTER GEOTEXTILE PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUE
Color	Orange		
Serviceability Class	Class 2		
AOS (MaxARV)	ASTM D4751	US Sieve (mm)	70 (0.21)
Permittivity (MARV)	ASTM D4491 Falling head	sec^{-1}	0.5
Grab Tensile Strength (MARV)	ASTM D4632	lbs	157
Trapezoid Tear (MARV)	ASTM D4533	Lbs	56
Puncture Strength (MARV)	ASTM D4833	Lbs	56
UV Resistance @500 Hours (MIN)	ASTM G154	%	70

The CDN shall conform to the requirements in Table 4-13 below.

TABLE 4-13
QC SCHEDULE FOR MATERIAL TESTING
COMPOSITE DRAINAGE NET

PHYSICAL PROPERTY REQUIREMENTS		
Property	**Test Method**	**Requirement**
Ply Adhesion, lb/in	ASTM F904	0.5
Transmissivity 1,000 psf Load in Soil Boundary Condition and after 100 hours, and gradient: m^2/sec 0.1 0.3	GRI-GC8	 $7.0x10^{-3}$ $4.0x10^{-3}$
Interface Friction Angle between Type I Geomembrane/CDN and CDN/Vegetative Support Layer Soil, degrees	ASTM D5321	25 degree minimum residual

The Contractor shall provide Certification of Compliance showing test results for all physical properties specified at a minimum frequency of one test per 100,000 square feet.

The CQA Engineer will verify that the property values certified by the Contractor meet the physical property and test method requirements for the CDN.

4.12.2 Labeling

The CDN manufacturer will identify all rolls of CDN with the following:

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

4.12.3 Shipment and Storage

Handling of CDN rolls should be done in a competent manner such that damage does not occur to the product or its protective wrapping, in accordance with ASTM D4873.

During shipment and storage, the GCL shall be protected from ultra violet deterioration. GCL rolls shall be shipped and stored in a protective plastic covering. CDN rolls shall be stored at the site in areas where water will not accumulate. The rolls should be elevated off of the ground so as not to form a dam creating the ponding of water. The rolls should be stacked in such a way that cores are not crushed nor is the CDN damaged. The rolls should be stacked in such a way that access for conformance testing is possible. Outdoor storage of rolls should not exceed manufacturer's recommendations or longer than six months, whichever is less. For storage periods longer than six months, a temporary enclosure should be placed over the rolls, or they should be moved within an enclosed facility.

4.12.4 Conformance Testing

If the CDN provided by the Contractor does not appear to conform with the specified physical property requirements, the CQA Engineer will require material sampling, in accordance with ASTM D4354, and conformance testing to verify the physical property values summarized in Section 3.12.1. Conformance test results should be provided to the CQA Engineer prior to deployment of any CDN from the lot under review. The CQA Engineer may also perform verification testing, if necessary in the CQA Engineer's opinion.

4.12.5 Construction

The Contractor shall remove the protective wrapping from the CDN rolls to be deployed only after the geomembrane layer has been documented and approved by the CQA Engineer.

The Contractor shall take necessary precautions to protect the underlying geomembrane. Deployment of the CDN shall be by hand, by use of small jack lifts on pneumatic tires having low ground contact

pressure, or by use of all-terrain vehicles (ATV) having low ground contact pressure. During placement, care shall be taken not to entrap in or beneath the CDN, stones, excessive dust or moisture that could damage a geomembrane, cause clogging of drains or filters, or hamper subsequent seaming of materials. On sideslopes, the CDN should be anchored at the top and then unrolled so as to keep the CDN free of wrinkles and folds. CDN shall be unrolled downslope, and not across the slope, with the panel upslope overlying the panel downslope. Trimming and cutting of the CDN should be performed using an approved cutter only. To provide resistance against wind uplift, CDN should be weighted with sandbags, which will be installed during CDN placement and remain until replaced with earth cover material.

At or before the time of installation, CDN shall be rejected if it has defects, rips, holes, flaws, deterioration, or damage incurred during manufacture, transportation, or storage.

The CDN panels shall be laid smooth to provide a minimum width of 4 inches of geonet overlap along each joint and 1 foot at the end of rolls. The CDN joints shall be tied at 5-foot intervals along edges and 2 foot along end using a method approved by the CQA Engineer. Plastic ties or tying materials shall be of contrasting color to the CDN panels for inspection. Metallic connectors shall not be allowed. Secure and leakproof bags of sand shall be used to secure the CDN during installation. Securing pins shall not be used.

The Contractor shall protect the CDN at all times during construction from siltation by surface runoff, removing all silt-laden CDN and replacing with clean CDN.

Should the geotextile on the CDN be damaged during any step of the installation, the torn or punctured sections shall be repaired by placing a piece of geotextile which extends at least 6 inches in all directions beyond the damaged area. Geotextile repair patches shall be secured by sewing or bonding as approved by the CQA Engineer.

The orientation of CDN panels shall result in approximate alignment of the drainage paths between bottom ribs of the geonet with the drainage paths indicated by the elevations shown.

Placement of the CDN shall be result in overlapping the excess geotextile at each edge of the geonet panels in a manner that results in a smooth geotextile surface free of wrinkles and openings across the overlapped panels of geonet. The Contractor shall seam the geotextile so that no slack material remains between seams. Acceptable seaming methods shall be in accordance with approved methods presented in the project specifications.

Copies of all QC test results will be provided to the CQA Engineer by the Contractor. The CQA Engineer will verify that QC testing frequency and minimum value requirements are met. The CQA Engineer will periodically observe material testing and will track results to ensure materials and construction are in accordance with the plans and specifications.

The applicable standards, test methods and minimum test frequency requirements for deployment of the CDN are summarized in Table 4-14 below.

TABLE 4-14
QC SCHEDULE FOR CONSTRUCTION
COMPOSITE DRAINAGE NET

Test	Method	Minimum Frequency
Minimum Panel Overlap	Measurement Visual Observation	Periodic - Random
Folds or Wrinkles	Measurement Visual Observation	100%
Subgrade Preparation	Measurement Visual Observation	100%

4.12.6 Post Construction

The CDN shall be protected from damage by direct vehicle traffic and by precipitation.

4.13 GEOTEXTILES

4.13.1 Certification of Property Values

The Contractor shall provide the CQA Engineer will certification from each geotextile manufacturer that furnished products have specified property values. Certified property values shall be either minimum or maximum average rolls values, as appropriate, for geotextiles furnished.

Woven geotextile shall be composed of polymeric yarn interlaced to form a planar structure with uniform weave pattern. The woven geotextile shall be calendared or finished so that yarns will retain their relative position with respect to each other. The polymeric yarn shall consist of long-chain synthetic polymers (polyester or propylene) with stabilizers or inhibitors added to make filaments resistant to deterioration due to heat and ultraviolet light exposure. The material's sheet edges shall be salvaged or finished to prevent outer material from separating from sheet. The unseamed sheet width shall be a minimum 6 feet. This material is used to provide filtration and erosion controls, and is typically utilized in silt fence construction.

Acceptable materials shall consist of ProPex 2006, manufactured by Amoco Fabrics and Fibers Co., Atlanta, GA or approved equal on the basis of minimum physical properties listed in Table 4-15 below.

TABLE 4-15
QC SCHEDULE FOR MATERIAL TESTING
WOVEN GEOTEXTILE

PHYSICAL PROPERTY REQUIREMENTS		
Property	**Test Method**	**Requirement**
Grab Tensile Strength, lb (min)	ASTM D4632	300
Puncture Strength, lb (min)	ASTM D4833	120
Mullen Burst Strength, psi (min)	ASTM D3786	600
Trapezoidal Tearing Strength, lb (min)	ASTM D4533	115
Apparent Opening Size (AOS), U.S. Standard Sieve Size (max)	ASTM D4751	30
Water Permitivity, sec1, falling head (min)	ASTM D4491	0.02

Non-woven geotextile fabric shall be specifically designed for drainage and materials separation applications and shall be a pervious sheet of polypropylene or polyester fibers oriented into a stable network so that the fibers retain their relative positions with respect to each other. The fabric shall be composed of continuous or discontinuous (staple) fibers held together through needle punching. The edges of the fabric shall be salvaged or otherwise finished to prevent these outer fibers from pulling away from fabric. The fabric shall be made into widths of 12 feet, or greater.

Non-woven Geotextile Type I shall be used for separation and filtering applications, including around drains, around gas collection and drainage piping, under riprap, etc. and shall be ultraviolet (UV) stabilized for potentially-exposed application. Acceptable materials shall meet the following minimum physical properties listed in Table 4-16 below.

TABLE 4-16
QC SCHEDULE FOR MATERIAL TESTING
NONWOVEN GEOTEXTILE TYPE 1

PHYSICAL PROPERTY REQUIREMENTS		
Property	**Test Method**	**Requirement**
Mass, oz/sy (Nominal)	ASTM D5261	6
Grab Tensile Strength, lb (min)	ASTM D4632	150
Puncture Strength, lb (min)	ASTM D4833	56
CBR Puncture Strength, lbs (min)	ASTM D6241	346
Trapezoidal Tearing Strength, lb (min)	ASTM D4533	56
Apparent Opening Size (AOS), U.S. Standard Sieve Size (max)	ASTM D4751	70
Permittivity, sec^{-1}, (MARV)	ASTM D4491	0.5
Grab Elongation, % (max)	ASTM D4632	50
UV Radiation Resistance, Strength Retention, % (min) at 500 hour exposure	ASTM D4355	80

Non-woven Geotextile Type II shall be used for protection of the geomembrane, such as in construction of the downchute. Acceptable materials shall meet the following minimum physical properties in accordance with GRI GT12(a) listed in Table 4-17 below.

TABLE 4-17
QC SCHEDULE FOR MATERIAL TESTING
NONWOVEN GEOTEXTILE TYPE II

PHYSICAL PROPERTY REQUIREMENTS		
Property	**Test Method**	**Requirement**
Mass, oz/sy (Nominal)	ASTM D5261	12
Grab Tensile Strength, lb (MARV)	ASTM D4632	300
Puncture Strength, lb (MARV)	ASTM D4833	140
CBR Puncture Strength, lbs (min)	ASTM D6241	800
Trapezoidal Tearing Strength, lb (min)	ASTM D4533	115
Apparent Opening Size (AOS), U.S. Standard Sieve Size (max)	ASTM D4751	70
Grab Elongation, % (max)	ASTM D4632	70
UV Radiation Resistance, Strength Retention, % (min) at 500 hour exposure	ASTM D4355	70

4.13.2 Labeling

The CDN manufacturer will identify all rolls of CDN with the following:

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

4.13.3 Shipment and Storage

Handling of geotextile rolls should be done in a competent manner such that damage does not occur to the product or its protective wrapping, in accordance with ASTM D4873.

During shipment and storage, the geotextile shall be protected from moisture and ultra violet deterioration. Geotextile rolls shall be shipped and stored in a protective plastic covering. Geotextile rolls shall be stored at the site in areas where water will not accumulate. The rolls should be elevated off of the ground so as not to form a dam creating the ponding of water. The rolls should be stacked in such a way that cores are not crushed nor is the geotextile damaged. The rolls should be stacked in such a way that access for conformance testing is possible. Outdoor storage of rolls should not exceed manufacturer's recommendations or longer than six months, whichever is less. For storage periods longer than six months, a temporary enclosure should be placed over the rolls, or they should be moved within an enclosed facility.

4.13.4 Conformance Testing

If the geotextile provided by the Contractor does not appear to conform with the specified physical property requirements, the CQA Engineer will require material sampling, in accordance with ASTM D4354, and conformance testing to verify the physical property values summarized in Section 3.13.1. Conformance test results should be provided to the CQA Engineer prior to deployment of any geotextile from the lot under review. The CQA Engineer may also perform verification testing, if necessary in the CQA Engineer's opinion.

4.13.5 Construction

The Contractor shall remove the protective wrapping from the geotextile rolls to be deployed only after the geomembrane layer has been documented and approved by the CQA Engineer.

The Contractor shall take necessary precautions to protect the underlying materials. During placement, care shall be taken not to entrap in or beneath the geotextile, stones, excessive dust or moisture that could damage a geomembrane, cause clogging of drains or filters, or hamper subsequent seaming of materials. On sideslopes, the geotextiles should be anchored at the top and then unrolled so as to keep the geotextile free of wrinkles and folds. Geotextile shall be unrolled downslope, and not across the slope, with the panel upslope overlying the panel downslope. To provide resistance against wind uplift, geotextiles should be weighted with sandbags, which will be installed during geotextile placement and remain until replaced with earth cover material.

Should the geotextile be damaged during any step of the installation, the torn or punctured sections shall be repaired by placing a piece of geotextile which extends at least 6 inches in all directions beyond the damaged area. Geotextile repair patches shall be secured by sewing or bonding as approved by the CQA Engineer.

The minimm overlap distances for geotextiles shall be 18 inches. Sewn seams shall be overlapped 3 inches or as recommended by the manufacturer. Acceptable seaming methods shall be in accordance with approved methods presented in the project specifications.

Copies of all QC test results will be provided to the CQA Engineer by the Contractor. The CQA Engineer will verify that QC testing frequency and minimum value requirements are met. The CQA Engineer will periodically observe material testing and will track results to ensure materials and construction are in accordance with the plans and specifications.

The applicable standards, test methods and minimum test frequency requirements for deployment of the geotextile are summarized in Table 4-18 below.

TABLE 4-18
QC SCHEDULE FOR CONSTRUCTION
GEOTEXTILE

Test	Method	Minimum Frequency
Minimum Overlap	Measurement Visual Observation	Periodic - Random
Folds or Wrinkles	Measurement Visual Observation	100%
Temporary Anchorage	Measurement Visual Observation	100%

4.13.6 Post Construction

The geotextile shall be protected from damage by surface water sediments, by direct vehicle traffic and by precipitation.

4.14 LINEAR LOW DENSITY POLYETHYLENE (LLDPE) GEOMEMBRANE

4.14.1 Certification of Property Values

As part of the LLDPE Geomembrane Quality Control/Quality Assurance Program, the Contractor shall submit for the CQA Engineer's review and approval a complete description of the membrane manufacturer's and the installer's formal quality control/quality assurance programs for manufacturing, fabricating, handling, installing, testing, repairing, and providing a watertight geomembrane. The description shall include, but not be limited to, polymer resin supplier and product identification, acceptance testing, production testing, installation testing, documentation of changes, alterations, repairs, retests, and acceptance. The document shall include a complete description of seaming and repairing by extrusion welding and hot wedge welding. Rough-surface geomembrane coefficient of friction test results shall include, but not be limited to specimen size, supporting substrate, soil installation method and unit weight, soil moisture at molding and test, rate of strain and normal loads, and test results.

As part of the pre-submittal process, the Contractor will submit documented evidence of the ability and capacity of the membrane manufacturer and the installer, each, to perform this work. Each shall have previously and successfully manufactured/ installed a minimum of 10 million square feet of similar LLDPE geomembrane in liquid containment or landfill structures.

The Contractor shall also submit complete manufacturer's specifications, descriptive drawings, and literature for the membrane, including the product identification and supplier of the polymer resin and recommended method for handling and storage of all materials prior to installation.

Six samples each of membrane sheeting and membrane seams will be submitted by the Contractor. Sheeting samples shall be 8 inches by 10 inches and seam samples shall be 12 inches plus the seam width by 18 inches, and shall be numbered and dated. Seam samples shall be fabricated by the

installer using the specified materials and the methods described in the Quality Control/Quality Assurance Program (extrusion and hot wedge).

The Contractor shall also submit a statement of the production dates for the resin and the membrane for this work.

The CQA Engineer will verify that the property values certified by the installer meet the physical property and test method requirements for the geomembrane.

The Geomembrane (Type I) shall be 60 mil textured on two sides. The geomembrane shall be a textured linear low density polyethylene (LLDPE) geomembrane containing no plasticizers, fillers, chemical additives, reclaimed polymers, or extenders. The material shall have smooth edge and not textured edge to edge, as manufactured by GSE, Houston, TX (special order not standard product); Solmax International, Quebec, Canada; Agru-America, Georgetown, SC, or approved equal. The material proposed shall meet the manufacturer's most recent published specifications and the required physical property requirements, test methods and minimum test requirements summarized below in Table 4-19.

TABLE 4-19
QC SCHEDULE FOR MATERIAL TESTING
LOW LINEAR DENSITY POLYETHYLENE LINER (60 MIL)

PHYSICAL PROPERTY REQUIREMENTS		
Property	Test Method	Requirement
Geomembrane Type I, Textured Both Sides		
Thickness, in (min)	ASTM D5994	0.056
Density, g/cc	ASTM D1505	0.920 – 0.939
Tensile Elongation at Break, %, each direction (min)	ASTM D638 Type IV Dumbell (2 in/min)	250
Tensile Strength at Break, lb/in, each direction (min)	ASTM D638 Type IV Dumbell (2 in/min)	90
Tear Resistance, lb (min.)	ASTM D1004	33
Low Temperature Impact. °F (min)	ASTM D746	-94
Dimensional Stability, % (max.)	ASTM D1204	+/- 2
Puncture Resistance, lb (min)	ASTM D4833	66
Carbon Black Content, % (min)	ASTM D1603	2 to 3
Interface Friction Angle between LLDPE and Low Hydraulic Conductivity Soil (degree)	ASTM D5321	25°

The Geomembrane (Type II) shall be 30 mil textured on two sides. The geomembrane shall be a linear low density polyethylene (LLDPE) geomembrane containing no plasticizers, fillers, chemical additives, reclaimed polymers, or extenders. The material shall have smooth edge and not textured edge to edge. The material proposed shall meet the manufacturer's most recent published specifications and the required physical property requirements, test methods and minimum test requirements summarized in Table 4-20 below.

TABLE 4-20
QC SCHEDULE FOR MATERIAL TESTING
LOW LINEAR DENSITY POLYETHYLENE LINER (30 MIL)

PHYSICAL PROPERTY REQUIREMENTS		
Property	Test Method	Requirement
Geomembrane Type II, Smooth		
Thickness, in (min)	ASTM D5994	0.027
Density, g/cc	ASTM D1505	0.920 – 0.939
Tensile Elongation at Break, %, each direction (min)	ASTM D638 Type IV Dumbell (2 in/min)	200
Tensile Strength at Break, lb/in, each direction (min)	ASTM D638 Type IV Dumbell (2 in/min)	90
Tear Resistance, lb (min.)	ASTM D1004	15
Low Temperature Impact. °F (min)	ASTM D746	-94
Dimensional Stability, % (max.)	ASTM D1204	+/- 2
Puncture Resistance, lb (min)	ASTM D4833	40
Carbon Black Content, % (min)	ASTM D1603	2 to 3

4.14.2 Labeling

The geomembrane manufacturer will identify all rolls of geomembrane with the following:

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

4.14.3 Shipment and Storage

Handling of geomembrane rolls should be done in a competent manner such that damage does not occur to the product.

During shipment and storage, the geomembrane shall be protected from exposure to ultra violet light, precipitation and accidental damage. Pushing, sliding or dragging of rolls shall not be permitted. Geomembrane rolls shall be stored at the site in areas where water will not accumulate. The rolls should be elevated off of the ground so as not to form a dam creating the ponding of water. The rolls should be stacked in such a way that cores are not crushed nor is the geotextile damaged. The rolls should be stacked in such a way that access for conformance testing is possible. Outdoor storage of rolls should not exceed manufacturer's recommendations or longer than six months, whichever is less. For storage periods longer than six months, a temporary enclosure should be placed over the rolls, or they should be moved within an enclosed facility.

4.14.4 Conformance Testing

If the geomembrane provided by the Contractor does not appear to conform with the specified physical property requirements, the CQA Engineer will require material sampling and conformance testing to verify the physical property values summarized in Section 4.14.1. Conformance test results should be provided to the CQA Engineer prior to deployment of any geomembrane from the lot under review. The CQA Engineer may also perform verification testing, if necessary in the CQA Engineer's opinion.

4.14.5 Construction

The Contractor shall provide written certification to the CQA Engineer that the surface on which the geomembrane will be installed is acceptable. The certification of acceptance shall be made and approved by the CQA Engineer before commencement of geomembrane installation in the area under consideration.

Construction equipment deploying the rolls shall not deform or rut the soil subgrade excessively. Tire or track deformations beneath the geomembrane shall not be greater than 1 inch in depth.

The geomembrane shall not be deployed on frozen subgrade. Geomembrane placement will not be done in the presence of excessive moisture, humidity, in an area of ponded water or in the presence of excessive winds. Geomembranes, when unrolled, shall not stick together to the extent where tearing or visually observed straining of the geomembrane occurs. A sheet temperature of approximately 120 degrees F should be the upper limit that a geomembrane will be unrolled. Geomembranes, when unrolled in cold weather, should not crack, crease or distort in texture. A sheet temperature of 32 degrees F should be the lower limit that a geomembrane will be unrolled.

Shifting or "spotting" of deployed geomembrane shall be done without damage or disturbance of the subgrade materials. A "slip sheet" of smooth geomembrane shall be used to position and align the textured geomembrane over the top of the GCL or Low Hydraulic Conductivity soil layer.

Sufficient slack shall be placed in the geomembrane during deployment to compensate for the coldest temperature anticipated, so that no tensile stresses are generated in the geomembrane or its seams during installation. The deployed geomembrane shall have adequate slack to prevent lifting up or "trampolining" of the geomembrane off the subgrade at any location. Slack in the deployed geomembrane shall not result in creases which fold over upon themselves during deployment,

seaming or placement of CDN and protective cover materials. Permanent, fold-over type creases in the covered geomembranes shall not be permitted.

In general, seams should be oriented downslope. In corners and odd-shaped geometric locations, the number of seams shall be minimized. No horizontal seams shall be allowed on slopes greater than 10%, or in areas of potential stress concentrations, unless otherwise authorized.

The CQA Engineer shall verify that:

- Before seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material.
- Abrading (overgrinding) will not be allowed.
- Seams are aligned with the fewest possible number of wrinkles and "fish mouths".
- The panels of geomembrane have a finished minimum overlap of 3 inches or per the manufacturer's specifications.
- No solvent or adhesive is used on the LLDPE geomembrane.
- The procedure used to temporarily bond adjacent panels together does not damage the geomembrane; in particular for the LLDPE geomembrane, the temperature of hot air at the nozzle of any spot welding apparatus is controlled so that the geomembrane is not damaged.
- Fish mouths or wrinkles at the seam overlaps will be cut along the ridge of the wrinkle to achieve a flat overlap. The cut fish mouths or wrinkles will be seamed and any part 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 shall extend to the outside edge of panels to be placed in the anchor trench.

The weather conditions normally required for seaming are as follows:

- Unless authorized in writing, no seaming shall be attempted at an ambient temperature below 35 degrees F or above 90 degrees F with relative humidity greater than 80%. The temperature will be measured 18 inches above the geomembrane surface.
- Between ambient temperatures of 35 degrees F and 50 degrees F, seaming is possible if the geomembrane is heated by either sun or hot air device, and there is no excessive cooling resulting from wind, and if satisfactory test welds are performed.
- Above an ambient temperature of 50 degrees F, no preheating is required.
- In all cases, the seaming area of the geomembrane will be dry and protected from wind.

Tests seams shall be made on fragment pieces of geomembrane liner to verity that seaming conditions are adequate. Test seams shall be made at the beginning of each 4-hour seaming period, if seaming has been suspended for more than ½ hour, for each seaming apparatus used in the welding period. Test seams will be made under the same conditions as actual seams.

The test seam sample will be at least 5.5 feet long and 1 foot wide with the seam centered lengthwise. Five specimens, 1 inch wide and spaced approximately 6 inches apart will be die cut from the test seam sample. These specimens will be tested in the field with a tensiometer for peel. Test seams will be tested by the Installer under observation of the CQA Engineer. The specimens should not fail in the weld. The Installer shall supply all necessary knowledgeable personnel and testing equipment. No strain measurements need be obtained in the field. If a test seam fails, the entire operation will be

repeated. If the additional test seam fails, the seaming apparatus or seamer will not be accepted and will not be used for seaming until the deficiencies are corrected and two consecutive successful full test seams are achieved. Test seam failure is defined as failure of any one of the specimens tested in peel. A passing machine or hand welded test seam will be achieved when the specified criteria are satisfied with the exclusion of any strain requirements.

The CQA Engineer will observe all test seam procedures. The remainder of the successful test seam sample will be assigned a number and marked accordingly by the CQA Engineer, who will also log the date, hour, ambient temperature, number of seaming unit, name of seamer, and pass or fail description. The sample itself should be retained in the CQA Engineer's archives until final acceptance of the geomembrane. In addition, at least one tested specimen from each test as selected by the CQA Engineer will be retained by the CQA Engineer. The CQA Engineer will transmit these specimens to RIDEM following acceptance of the geomembrane materials and installation by RIDEM.

4.14.6 Nondestructive Testing

Production seams will be tested by the Contractor continuously using non-destructive techniques and at intervals using destructive tests. Nondestructive of LLDPE seams shall be vacuum box testing, air testing or ultrasonic thickness testing.

Requirements for non-destructive and destructive testing are as follows:

For fillet extrusion seams, the Contractor shall maintain and use equipment and personnel at the site to perform continuous vacuum box testing on all single weld production seams in accordance with ASTM D5641. The system shall be capable of applying a vacuum of at least 5 psi. The vacuum shall be held for a minimum of 15 seconds for each section of seam.

The equipment for vacuum testing of LLDPE seams will include:

- A vacuum box assembly with a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly and a vacuum gauge;
- A steel vacuum tank and pump assembly equipped with a pressure controller and pipe connections;
- A rubber pressure/vacuum hose with fittings and connections;
- A bucket and wide paint brush or other approved applicators; and
- A soapy solution.

Procedures for vacuum testing of the LLDPE seams shall be as follows:

- Energize the vacuum pump and reduce the tank pressure to approximately 5 psi (10 inches of Hg).
- Wet a strip of geomembrane approximately 12 inches by 48 inches with the soapy solution.
- Place the box over the wetted area.
- Close the bleed valve and open the vacuum valve.
- Ensure that a leak tight seal is crated.
- If no bubble appears after 15 seconds, close the vacuum valve and open the bleed valve.

- With an approved marking template, make a mark 3 inches inside the leading edge of the vacuum box. Move the box over the next adjoining area while overlapping the previous mark by 3 inches.
- Repeat the process.
- All areas where soap bubbles appear will be marked and repaired in accordance with the specifications.
- For vacuum testing fusion seams, the overlap must be cut back to the edge of the weld, and the procedure above may then be followed.

For double weld seams, the Contractor shall maintain and use equipment and personnel to perform air pressure testing of all double weld seams in accordance with ASTM D5820. The Contractor shall perform all pressure and vacuum testing under the supervision of the CQA Engineer. The equipment and procedures which apply to those processes that produce a double seam with an enclosed space are as follows:

The equipment shall include:

- An air pump (manual or motor driven with a pressure gauge capable of generating and sustaining a pressure between 25 and 30 psi and mounted on a cushion to protect the geomembrane);
- A rubber hose with fittings and connections; and
- A sharp hollow needle, or another approved pressure-feed device.

Procedures for the testing shall be as follows:

- Seal both ends of the seam to be tested.
- Insert needle or other approved pressure-feed device into the annulus created by the fusion weld.
- Insert a protective cushion between the air pump and the geomembrane.
- Energize the air pump to a pressure between 25 and 30 psi, close the valve and sustain pressure for 5 minutes.
- If loss of pressure exceeds 3 psi or does not stabilize, locate faulty area and repair in accordance with the specifications.
- To verify there is airflow through the entire annulus, remove the seal at the end of the annulus away from the air source and listen for the escaping air and observe drop in pressure gauge. If there is a blockage in the channel, the entire seam shall be vacuum tested.
- Remove needle or other approved pressure-feed device and seal all needle holes and other penetrations into the channel.

Non-destructive ultrasonic testing will also utilize an ultrasonic thickness measuring instrument, performed on an average of every 25-linear feet or production seam. The seam thickness reduction for each welded seam shall be within 8 to 24 mils. Seam thickness reduction shall be defined as thickness of two panels minus thickness of welded section.

4.14.7 Destructive Testing

Ultrasonic thickness measurements that do not meet the criteria specified above shall have a destructive sample cut from the failing location. The sample shall be tested in accordance with the procedures and acceptance criteria as specified in the project manual. A passing welded seam will be achieved in peel (ASTM D6392) when (1) peel strength for the seam is greater than 70% of material yield strength for double wedge and 60% of material yield for extrusion weld, and (2) no greater than 10% of the seam width peels (separates) at any point. The test speed shall be at 2 in/min. Load versus displacement shall be provided. Test shall conclude upon 100% elongation of sample.

Damaged and sample coupon areas of geomembrane shall be repaired by the Contractor by construction of a cap strip. No repairs shall be made to seams by application of an extrusion bead to a seam edge previously welded by fusion or extrusion methods. Repaired areas will be tested for seam integrity as outlined in the project manual. Damaged materials are the property of the Contractor and will be removed from the site at the Contractor's expense. The Contractor will retain all ownership and responsibility for the geomembrane until acceptance by RIDEM. The geomembrane shall be accepted by RIDEM after the installation and repair are complete, and after RIDEM has received documentation for the installation by the CQA Engineer.

4.14.8 Repair of Seams

Any part of the geomembrane exhibiting a flaw or a failing destructive or non-destructive test, shall be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure will be agreed upon between the CQA Engineer and RIDEM.

The procedures available include:

- Patching, used to repair holes, tears, undispersed raw materials and contamination by foreign matter.
- Grinding and rewelding, used to repair small sections of extruded seams.
- Spot welding or seaming, used to repair pinholes or other minor localized flaws.
- Capping, used to repair large lengths of failed seams.
- Topping, used to repair large lengths of inadequate seams, which have an exposed edge.
- Removing bad seams and replacing with a strip of new material welded into place (used with large lengths of fusion seams).

Surfaces of LLDPE geomembrane that are to be repaired will be abraded no more than 1 hour before the repair. All surfaces must be clean and dry at the time of repair. All seaming equipment or compounds used in repairing procedures must be approved. The repair procedures, materials and techniques shall be approved in advance of the specified repair. Patches or caps will extend at least 6 inches beyond the edge of the defect and all corners of patches shall be rounded with a radius of at least 3 inches.

Each repair shall be numbered and logged. Each repair shall be non-destructively tested, using the methods previously described. Repairs that pass the nondestructive test will be taken as an indication of an adequate repair. Large caps may be of sufficient extent to require destructive test sampling, at

the discretion of the CQA Engineer. Failed tests indicate that the repairs will be redone and retested until a passing test results.

4.14.9 Geomembrane Acceptance

The Contractor and the manufacturer will retain ownership and responsibility for the geomembrane until acceptance by RIDEM.

The geomembrane system installation will be accepted by RIDEM when:

- The installation is finished.
- Verification of the adequacy of all seams and repairs, including associated testing, is complete.
- Contractor's representative furnishes the CQA Engineer with certification that the geomembrane was installed in accordance with the manufacturer's recommendations as well as the plans and specifications.
- All documentation of installation is completed.
- Final report, including record drawing(s), has been received by RIDEM. Record drawings shall be prepared by the Contractor and shall include the following information:
  1) Dimensions for all geomembrane panels.
  2) Locations, as closely as possible, of each panel relative to the surveyor's plan.
  3) Identification of all seams and panels with appropriate numbers or "identification codes."
  4) Location of all patches and repairs.
  5) Location of all destructive testing samples.

The final reports shall be prepared by the CQA Engineer and shall be submitted upon completion of the work. This report will include all reports prepared by the installer, summarize the activities of the project and document all aspects of the quality control and assurance program performed. The final reports will include as a minimum the following information:

- Personnel involved with the project;
- Scope of work;
- Outline of project;
- Quality assurance methods;
- Test results (destructive and non-destructive, including laboratory tests); and
- Final report sealed and signed by a registered Professional Engineer.

4.15 ANCHORAGE SYSTEM

The Contractor shall excavate only the length of anchor trench that will be used in one day, unless otherwise specified, to minimize the potential of stormwater runoff collecting in the trenches. The anchor trench shall be adequately drained to prevent ponding or otherwise softening of the adjacent soils while the trench is open.

Rounded corners shall be provided in the trenches where the geomembrane enters the trench to allow the geomembrane to be completely supported by the subgrade and to avoid sharp bends in the

geomembrane. No loose soil will be allowed to underlie the geomembrane in the anchor trenches. The geomembrane should be seamed completely to the ends of all panels to minimize the potential of tear propagation along the seam. Seams of adjacent sheets of geomembranes terminating in the anchor trenches shall be continuous into the anchor trench to the full extent indicated in the plans and specifications.

The Contractor shall backfill anchor trenches with protective soil layer materials. All lifts shall be compacted to a minimum of 90 percent of the maximum dry density as determined by ASTM D1557 Modified Proctor test.

The CQA Engineer will periodically observe construction of the anchor trenches to ensure construction is in accordance with the plans and specifications.

4.16 LANDFILL GAS COLLECTION SYSTEM

4.16.1 Certification of Property Values

Header pipe shall be smooth high density polyethylene (HDPE) pipe, with nominal diameter indicated on the drawings. The pipe shall be extruded from a polyethylene compound and shall conform to the following requirements:

- The polyethylene resin shall meet or exceed the requirements of ASTM D3350 for PE 3408 material with a cell classification of 355434C.
- The polyethylene compound shall be suitably protected against degradation by ultraviolet light by means of carbon black, well dispersed by pre-compounding in a concentration of not less than 2 percent.
- The maximum allowable hoop stress shall be 800 psi at 73.4 degrees F, based on a material with 1,600 psi design basis in accordance with ASTM D2837.
- The pipe manufacturer shall be listed with the Plastic Pipe Institute as meeting the recipe and mixing requirements of the resin manufacturer for the resin used to manufacture the pipe for this project.
- Pipe sizes shall conform to ASTM F714.
- The HDPE pipe shall be homogenous throughout and free of visible cracks, holes, foreign inclusions, or other injurious defects.
- All HDPE pipes shall have a standard dimensional ratio (SDR) of 17.
- Pipe lengths, fittings, and flanged connections to be joined by thermal butt-fusion shall be of the same type, grade, and class of polyethylene compound and supplied from the same raw material supplier.
- Fittings shall be ASTM D3550, butt fusion molded and shall be pressure rated to match system piping to which they are fused.
- All pipe and fitting shall be provided by the same manufacturer.

Joints shall be thermal butt-fusion, except where connecting to unions, valves and other fittings with mechanical (flanged) connections. No mechanical couplings shall be used unless shown on the Drawings. Where disassembly of the gas collection system is needed for making new gas piping connections or grading activities, the header pipes shall be disconnected from the gas wells and cut in approximately 200-foot sections, or at such locations and lengths as is appropriate to the site conditions as approved by the CQA Engineer, to facilitate removal and reinstallation. Header pipes shall be cut clean and square in accordance with the recommendations of the pipe manufacturer. Header pipe sections shall be reinstalled and joined by thermal butt-fusion and flanged connections as shown on the drawings. For very short term reinstallation, and if approved by the CQA Engineer, the header pipe sections may be joined by slip-on rubber expansion joints.

Rubber expansion joints shall be triple area style slip on units secured to the piping with stainless steel screw clamps. The expansion joint shall be made of neoprene rubber reinforced with high quality synthetic fabric and a cover wrap used to protect the unit against contact with oil, weathering, ozone and corrosives. The expansion joint shall be designed for vacuum service with a minimum working pressure of -10 psi and a maximum working pressure of +25.0 psi.

HDPE pipe shall have the minimum physical properties as shown in Table 4-21 below.

TABLE 4-21
QC SCHEDULE FOR MATERIAL TESTING
HIGH DENSITY POLYETHYLENE (HDPE) PIPE

PHYSICAL PROPERTY REQUIREMENTS		
Property	**Test Method**	**Requirement**
Density, g/cc (min)	ASTM D1505	0.941-0.959 (cell 3)
Melt Index, g/10 (min)	ASTM D1230 Condition F	< 0.4 (cell 5)
Flexural Modulus, psi (min)	ASTM D790	120,000-160,000 (cell 5)
Tensile Strength at Yield, psi (min)	ASTM D638	3,000-3,500 (cell 4)
Environmental Stress Crack, hrs. (min)	ASTM D1693 Condition C	192 (cell 3)
Hydrostatic Design Basis, psi at 73.4 degr. F (min)	ASTM D2837	1,600 (cell 4)
Carbon Black	ASTM D1603	2

4.16.2 Labeling

The pipe manufacturer will identify all pipe and associate materials with the following:

- Manufacturer's name;
- Product identification; and
- Lot/Batch number.

4.16.3 Shipment and Storage

Handling of pipe and associated materials should be done in a competent manner such that damage does not occur to the product.

The location of field storage should not be in areas where water can accumulate. The materials should be elevated off of the ground so as not to form a dam creating the ponding of water. The materials should be stacked no more than three pallets high and in such a way that access for conformance testing is possible. Outdoor storage of materials should not exceed manufacturer's recommendations or longer than twelve months, whichever is less. For storage periods longer than twelve months, a temporary enclosure should be placed over the rolls, or they should be moved within an enclosed facility.

4.16.4 Conformance Testing

If the materials provided by the Contractor do not appear to conform with the specified physical property requirements, the CQA Engineer will require material sampling and conformance testing to verify the physical property values summarized in Section 4.16.1. Conformance test results should be provided to the CQA Engineer prior to installation of any gas collection materials from the lot/batch under review. The CQA Engineer may also perform verification testing, if necessary in the CQA Engineer's opinion.

4.16.5 Construction

The Contractor shall install pipe and associated materials in accordance with ASTM D2321.

The Contractor shall install all pipe and associated materials in a properly graded and sloped trench as specified. The Contractor will join the HDPE pipe into continuous lengths using the butt fusion method, unless otherwise specified. The butt fusion welding will be performed in a strict accordance with the manufacturer's recommendations. Pipe fittings shall be in accordance with the manufacturer's recommendations, unless otherwise specified. The Contractor shall place cover materials over the pipe so as to ensure no damage to the pipe.

Copies of all QC tests will be provided to the CQA Engineer by the Contractor. The CQA Engineer will verify that QC testing frequency minimum value requirements are met. The CQA Engineer will periodically observe material testing and will track results to ensure materials and construction are in accordance with the plans and specifications.

The applicable standards, test methods, and minimum test frequency requirements for installation of pipe and associated materials are summarized in Table 4-22 below.

TABLE 4-22
QC SCHEDULE FOR CONSTRUCTION
HIGH DENSITY POLYETHYLENE (HDPE) PIPE

Test	Method	Minimum Frequency
Placement	Measurement Visual Observation	100%
Location and Grade	Survey	N/A
Joint Continuity	Pressure Test	100%

4.17 CONCRETE REVETMENT

4.17.1 Certification of Property Values

The downchute system shall consist of the installation of the concrete revetment system, including articulating concrete blocks placed on geotextile fabric.

The articulating concrete blocks shall consist of individual concrete blocks, and shall exhibit the ability to interlock in two or more horizontal directions without requiring a connection device such as but not limited to cables, ropes, grids or clips. Each articulating block shall exhibit one cable tunnel which provides for binding, by use of revetment cables, the articulating blocks into an integrated matrix of grids.

The articulating concrete blocks shall comply with the minimum requirements:

- The concrete revetment system shall comply with most recent and revised test procedures under FHSW Guidelines.
- The system shall exhibit a capacity to withstand the specified hydraulic shear stress with a Factor of Safety of not less than 1.5 when placed as shown on the drawings and using an anchorage system recommended by the manufacturer.
- The hydraulic shear stress shall be based on a flow rate of 140 cfs and channel slope of 33.3%.
- The Contractor shall submit documentation for testing of random block samples for compressive strength, water absorption and specific weight by a certified testing laboratory.

The articulating concrete blocks shall have the minimum physical properties, expressed as an average value, as shown in Table 4-23 below.

TABLE 4-23
PHYSICAL REQUIREMENTS

PHYSICAL PROPERTY REQUIREMENTS		
Property	**Test Method**	**Requirement**
Compressive Strength, psi (min)	ASTM C 140	4,000
Water Absorption, % (max)	ASTM C 140	10%
Specific Weight, pcf (min)	ASTM C 140	130
Freeze-Thaw Durability, %	ASTM C 67	<1% per 50 cycles

4.17.2 Labeling

The articulating block manufacturer will identify the concrete revetment system and associated materials with the following:

- Manufacturer's name; and
- Product identification.

4.17.3 Shipment and Storage

Handling of concrete revetment system and associated materials should be done in a competent manner such that damage does not occur to the product.

The location of field storage should not be in areas where water can accumulate. The materials should be elevated off of the ground so as not to form a dam creating the ponding of water. The materials should be stacked according to manufacturer's recommendations and in such a way that access for conformance testing is possible. Outdoor storage of materials should not exceed manufacturer's recommendations or longer than twelve months, whichever is less.

4.17.4 Conformance Testing

If the materials provided by the Contractor do not appear to conform with the specified physical property requirements, the CQA Engineer will require material sampling and conformance testing to

verify the physical property values summarized in Section 4.17.1. Conformance test results should be provided to the CQA Engineer prior to installation of the concrete revetment system. The CQA Engineer may also perform verification testing, if necessary in the CQA Engineer's opinion.

4.17.5 Construction

The Contractor shall install the concrete revetment system and associated materials in accordance with manufacturer's recommendations.

The applicable standards, test methods, and minimum test frequency requirements for installation of the concrete revetment system and associated materials are summarized in Table 4-24 below.

TABLE 4-24
QC SCHEDULE FOR CONSTRUCTION
CONCRETE REVETMENT SYSTEM

Test	Method	Minimum Frequency
Placement	Measurement Visual Observation	100%
Location and Grade	Survey	N/A
Mat/ Joint Continuity	Visual Observation	100%

5.0 REMEDIAL ACTION CERTIFICATION REPORT

5.0 REMEDIAL ACTION CERTIFICATION REPORT

5.1 GENERAL

In accordance with the Cooperative Agreement SOW dated May 28, 2004, the Engineer shall submit a RA Report to RIDEM, the towns of South Kingstown and Narragansett and USEPA. The RA Report will be submitted within 60 days of the Final Inspection.

The RA Report will document that all components of the source control remedy are constructed and operating as designed (Operational and Functional). The Report will provide a full documentation of all construction activities including: shop drawings, QA testing, QC testing and a summary of all design clarifications.

5.2 CONTENTS OF THE RA REPORT

The RA Report will include, at a minimum, the following documentation:

- Introduction and chronology of events and procedures used from Site listing, through ROD signature, and to RA completion;
- Tabulation of all analytical data and field notes prepared during the course of the RD and Construction activities including, but not limited to, monitoring data for the systems' effluent and air emissions to confirm with ARARs, data on treatment residues, environmental monitoring data, and QA/QC documentation of these results;
- Documentation, with appropriate photographs, maps and tables of Remediation Area excavation, including volumes, areas of placement and disturbance, description of capping activities and the materials used, and treatment;
    - A description and verification of Institutional Controls established;
    - A description and verification of all established access agreements, controls and anticipated future use(s) pertaining to the Site;
    - Summary of the performance standards and the implementation of the construction quality control plan;
    - Documentation of the Pre-Final and Final Site Inspections, including description of the deficient construction items identified during these inspections and documentation of the final resolution of all deficient items;
- Certification that the work was performed consistent with the ROD, RD, and RA plans and that the remedy is Operational and Functional;
- Schedule for remaining O&M activities, including summary of the O&M Plan and discussion of any deficiencies and modifications to the O&M Plan;
- A descriptive summary of ongoing monitoring and expectations for maintaining protective standards for any reasonably anticipated future use of the Site;
- Summary of project costs and their comparison with the original RA estimate, including the cost of any modifications during construction;
- Conclusions regarding conformance of all components of the Remedy with the Performance

Standards;

- Descriptions of actions taken and a schedule of any potential future actions to be taken to gather data to monitor groundwater and surface water contamination in accordance with the ROD;
- All information necessary to demonstrate compliance with the requirements of EPA's guidance for Monitored Natural Attenuation and 40 C.F.R.264.97;
- All data, collected and tabulated to date, and with provisions for future submissions, necessary for RIDEM, in consultation with EPA, to conduct the First (and subsequent) Five Year Reviews as specified in Section VI-B of the May 28, 2004 SOW.
- Under separate cover, a report on the cost and performance during the course of the RA in accordance with "EPA Region I Remediation Case Study Report Format (November, 1995)" and the "Guide to Documenting Cost and Performance for Remediation Projects, EPA-542-B-95-002, March 1995." shall also be submitted.

Provided below is an outline for the proposed RA:

- Section 1.0 Introduction
- Section 2.0 Waste Consolidation and Landfill Cap Preparation
- Section 3.0 Landfill Cap Construction
- Section 4.0 Certificates of Compliance for Construction
- Section 5.0 Operation and Maintenance Requirements
- Section 6.0 Summary of Project Costs
- Section 7.0 Conformance with Performance Standards