APPENDIX D-8
RMU-1 CONSTRUCTION QUALITY ASSURANCE MANUAL

QUALITY ASSURANCE MANUAL FOR THE INSTALLATION OF LINING SYSTEMS CWM MODEL CITY FACILITY

Prepared for

Construction of
Residual Management Unit No. 1

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QUALITY ASSURANCE MANUAL
FOR THE INSTALLATION OF
LINING SYSTEMS
CWM
MODEL CITY FACILITY

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APPENDICES

Note: The most current version of referenced ASTM documents to be used.

1.0 GENERAL

1.1 SCOPE

This Quality Assurance Manual (QAM) addresses quality assurance for the installation of soil and geosynthetic materials used by the Model City Facility, owned by Chemical Waste Management, Inc. (CWM) in their landfill. This manual is prepared as the specific Quality Assurance Plan (QAP) developed for the RMU-1 project. Extreme care and detailed documentation are required in the selection and installation of all soil materials and the production and installation of the geosynthetic materials used in waste containment applications.

This manual addresses quality assurance testing, observations, and documentation. In the context of this manual, **quality assurance** refers to means and actions employed to assure conformity of the lining system production and installation with the project-specific Quality Assurance Plan (QAP), contractual and regulatory requirements. Quality assurance is provided by a party independent from production and installation. **Quality control** refers only to those actions taken to ensure that materials and workmanship meet the requirements of the plans and specifications. Quality control is provided by the manufacturers, suppliers, contractor and installers of the various components of the lining system.

A project-specific QAP is required for each project in accordance with 40 CFR 264. This project specific plan consists of the following:

1. This QAM.
2. Project-Specific Addenda to the above QAMs. (Project-specific addenda shall be used to provide for additions, deletions, and changes necessary to the QAM(s) used for a particular project.)
3. Project-Specific Plans, Specifications, and other specified documents.
4. Permits for RMU-1.

The scope of this QAM applies to selecting, testing, handling and installation of soil components and to manufacturing, shipment, handling, and installation of geosynthetics components of the lining system. This plan should contain all of the elements necessary to ensure that the project is constructed in accordance with design plans and specifications.

This QAM was developed consistent with EPA guidance including "Construction Quality Assurance for Hazardous Waste Landfill Disposal Facilities," EPA/530-SW-86-031, October 1986, and regulations governing CQA requirements listed in 40 CFR 264 at the date of this document.

1.2 PARTIES

The parties discussed in this section are associated with the ownership, design, supply, manufacture, transportation, installation, and quality assurance of a lining system. The

definitions, qualifications, and responsibilities of these parties are outlined in the following subsections. A list of parties' names and addresses will be prepared during the pre-construction meeting.

1.2.1 Project Manager

1.2.1.1 *Definitions*

The Project Manager is the official project representative of the Model City Facility (CWM); in this manual, the term Project Manager shall apply equally to "Construction Coordinator," i.e., the individual responsible for coordinating construction and quality assurance activities for the project.

1.2.1.2 *Responsibilities*

The Project Manager is responsible for all construction quality assurance activities. The Project Manager is responsible for the organization and implementation of the QAM for the project as outlined in Section 1.1 of this manual. Other responsibilities include approval of earthwork contractor, geosynthetic installer, quality assurance consultant and the quality assurance laboratory.

The Project Manager shall serve as communications coordinator for the project, initiating the resolution, pre-construction, and construction meetings outlined in Section 1.3. As communications coordinator, the Project Manager shall serve as a liaison between all parties involved in the project to ensure that communications are maintained.

1.2.1.3 *Qualifications*

The selection of the Project Manager is the direct responsibility of CWM. Qualifications for this position include familiarity with the following:

1. Sections of this QAM or other Applicable QAMs.
2. General earthwork construction techniques.
3. General geosynthetic installation techniques.
4. All applicable regulatory requirements.
5. Company policies and procedures for project management.

1.2.2 Designer

1.2.2.1 *Definitions*

The Designer is the individual and/or firm responsible for the preparation of the design, including plans and project-specific specifications for the lining system.

1.2.2.2 *Responsibilities*

The Designer is responsible for performing the engineering design and preparing the associated drawings and specifications for the lining system. The Designer is responsible for approving all design and specification changes and making design clarifications necessitated during construction of the lining system. Design changes will be approved in writing by the designer(s). Design-related issues will be resolved through discussion directed by the Project Manager with the designer(s) responsible for the respective feature. Upon the request of the Project Manager, the Designer may attend the resolution and pre-construction meetings outlined in Section 1.3 of this manual.

1.2.2.3 *Qualifications*

The Designer shall be a qualified engineer, certified or licensed as required by regulation. The Designer shall be familiar with the use of soils and/or geosynthetics including detailed design methods and procedures. In addition, the Designer should be familiar with applicable regulatory requirements.

1.2.2.4 *Submittals*

The Designer shall submit the project design drawings, specifications and associated engineering calculations reports to the Project Manager. The Designer shall also submit completed design clarification forms to the Project Manager in a timely manner upon request. Other information may also be required by CWM.

1.2.3 Geosynthetic Manufacturer

1.2.3.1 *Definitions*

The Manufacturer is the firm responsible for production of any of the various geosynthetic liner system components outlined in this QAM. In the case of a geocomposite, the Manufacturer is the firm responsible for combining the components into the final product.

1.2.3.2 Responsibilities

Each Manufacturer is responsible for the production of its geosynthetic product. In addition, each Manufacturer is responsible for the condition of the geosynthetic until the material is accepted by the Project Manager upon delivery. Each Manufacturer shall produce a consistent product meeting the project specifications. Each Manufacturer shall provide quality control documentation for its product as specified in this QAM.

1.2.3.3 *Qualifications*

Each Manufacturer shall:

1. Be pre-qualified and approved by CWM.

2. Provide sufficient production capacity and qualified personnel to meet the demands of the project.
3. Have an internal quality control program for its product that meets the requirements presented in this QAM.

1.2.3.4 *Submittals*

Pre-qualification: A Manufacturer shall meet the following requirements and submit the following information to be considered for pre-qualification:

1. Corporate background and information.
2. Manufacturing capabilities:

    a. Information on plant size, equipment, personnel, number of shifts per day, and capacity per shift.
    b. Daily production quantity available for CWM facilities.
    c. A list of material properties including certified test results, to which are attached geosynthetic samples.
    d. A list of at least 15 completed landfill or surface impoundment facilities totalling a minimum of 15,000,000 ft^2 (1,500,000 m^2), for which the Manufacturer has manufactured a geosynthetic. For each facility, the following information shall be provided:

        (1) Name and purpose of facility, its location and date of installation.
        (2) Name of owner, project manager, designer, fabricator (if any) and installer.
        (3) Type of geosynthetic, surface area of geosynthetic manufactured.
        (4) Available information on the performance of the lining system.

3. The Manufacturer's quality control manual, including a description of the quality control laboratory facilities.
4. The origin (supplier's name and production plant) and identification (brand name and number) of resin used to manufacture the product.

Pre-installation: Prior to the installation of any geosynthetic material, a Manufacturer shall submit to the Project Manager all quality control documentation required by the appropriate section of this QAM. This documentation shall be reviewed and approved in writing by the Geosynthetic Quality Assurance Consultant as outlined in Section 1.2.7 of this QAM before installation can begin.

1.2.4 Earthwork Contractor

1.2.4.1 *Definitions*

The Earthwork Contractor is the firm responsible for the earthwork associated with site preparation, excavation and subgrade preparation, and construction of the soil components of the lining system.

The Superintendent is responsible for the Earthwork Contractor's field crew. The Superintendent shall represent the Contractor at all site meetings and shall be responsible for acting as the Contractor's spokesman on the project.

1.2.4.2 *Responsibilities*

The Earthwork Contractor is responsible for constructing soil components of the lining systems in conformance to the project design and specifications to a condition suitable for geomembrane placement. The Earthwork Contractor may also be responsible for locating and transporting the required earth and granular materials, concrete, piping, and other work, as outlined in the project specifications.

1.2.4.3 *Qualifications*

The Earthwork Contractor shall be:

1. Pre-qualified and approved by CWM.
2. Able to provide qualified personnel to meet the demands of the project.

At a minimum, the Earthwork Contractor shall provide a Superintendent as described below.

The Superintendent must be qualified based on previously demonstrated experience, management ability, and authority. The Superintendent, unless otherwise approved by the Project Manager, shall have previously managed, at a minimum, two projects which entailed the installation of at least 1,000,000 ft^2 (100,000 m^2) of soil liner or final cover components.

1.2.4.4 *Submittals*

Pre-qualification: To be considered for pre-qualification, the Earthwork Contractor shall provide the following information to the Project Manager:

1. Company background and information.
2. Demonstration of bonding capability.
3. List of outstanding contracts.
4. List of readily available equipment required to perform the work (i.e., scrapers, graders, scarifiers, compactors, discing equipment, water trucks, and admixing equipment, if required).
5. List of at least five comparable projects with the following information for each project:

    a. Name of the facility, its location, date of installation.
    b. Name of project manager or contact person for the installation.
    c. Description and purpose of installation and definition of contractor's scope of work.

6. Other information required by CWM Project Management.

Pre-installation: Prior to commencement of the earthwork activities, the Earthwork Contractor shall submit to the Project Manager:

1. Resume of the Superintendent to be assigned to this project, including the dates and duration of employment.
2. Schedule of construction activities.
3. List of specific equipment and personnel to be used on the project.

Installation: During the installation, the Earthwork Contractor shall be responsible for the submission of:

1. Quality control documentation recorded during installation.
2. Subgrade surface acceptance certificates for each area to be covered by the lining system, signed by the Installer.

Completion: Upon completion of the installation, the Earthwork Contractor shall submit a letter certifying completion of the work.

1.2.5 Geosynthetic Installer

1.2.5.1 *Definitions*

The Geosynthetic Installer is the firm responsible for installation of the geosynthetics components of the lining system. The Installer may be affiliated with the Manufacturer.

The Superintendent is responsible for the Installer's field crew. The Superintendent shall represent the Installer at all site meetings and shall be responsible for acting as the Installer's spokesman on the project.

The Master Seamer shall be the most experienced seamer of the Installer's field crew. The Master Seamer shall provide direct supervision over less experienced seamers.

1.2.5.2 *Responsibilities*

The Installer shall be responsible for field handling, storing, deploying, seaming, temporary restraining and all other aspects of the geosynthetics installation. The Installer may also be responsible for transportation of these materials to the site and for anchor systems, if required by the project specifications. The Installer shall be responsible for submittal of the documentation listed in Section 1.2.5.4.

1.2.5.3 *Qualifications*

The Installer shall be pre-qualified and approved by CWM. The Installer shall be able to provide qualified personnel to meet the demands of the project. At a minimum, the Installer shall provide a Superintendent and a Master Seamer as described below.

The Superintendent must be qualified based on previously demonstrated experience, management ability, and authority. The Superintendent, unless otherwise approved by the Project Manager, shall have previously managed, at a minimum, two installation projects which entailed the installation of at least a total of 1,000,000 ft^2 (100,000 m^2) of polyethylene geomembrane.

For geomembrane installation all personnel performing seaming operations shall be qualified by experience or by successfully passing seaming tests. These seam tests shall be performed under similar site weather conditions and using seaming methods adopted for this project. The Master Seamer shall have experience seaming a minimum of 1,000,000 ft^2 (100,000 m^2) of polyethylene geomembrane using the same type of seaming apparatus to be used at the site.

1.2.5.4 *Submittals*

Pre-qualification: To be considered for pre-qualification, the Installer shall submit the following information:

1. Corporate background and information.
2. Description of installation capabilities:

   a. Information on equipment (numbers and types), and personnel (number of Superintendents, number of crews).
   b. Average daily production anticipated.
   c. Samples of field geomembrane seams and a list of minimum values for geomembrane seam properties.

3. A list of at least ten completed facilities, totalling a minimum of 10,000,000 ft^2 (1,000,000 m^2) for which the Installer has installed geosynthetics. For each installation, the following information shall be provided:

   a. Name and purpose of facility, its location, and date of installation.
   b. Name of owner, project manager, designer, manufacturer, fabricator (if any), and name of contact at the facility who can discuss the project .
   c. Name and qualifications of the Superintendent(s) and Master Seamer of the Installer's crew(s).
   d. Type of geosynthetic, and surface area installed.
   e. Type of seaming and type of seaming apparatus used.
   f. Duration of installation.
   g. Available information on the performance of the lining system.

4. The Installer's quality control manual.
5. A copy of a letter of recommendation supplied by the geomembrane manufacturer.

Pre-installation: Prior to commencement of the installation, the Installer must submit to the Project Manager:

1. Resume of the Superintendent to be assigned to this project, including dates, duration of employment, and managerial experience as specified in Section 1.2.5.3.
2. Resume of the Master Seamer to be assigned to this project, including dates, duration of employment, and square footage of lines seamed as specified in Section 1.2.5.3.
3. A panel layout drawing showing the installation layout identifying field seams as well as any variance or additional details which deviate from the engineering drawings. The layout shall be adequate for use as a construction plan and shall include dimensions, details, etc.
4. Installation schedule.
5. A list of personnel performing field seaming operations along with pertinent experience information.
6. All geosynthetic quality control certificates as required by this QAM (unless submitted directly to the Project Manager by the Manufacturer).
7. Certification that extrudate to be used is comprised of the same resin type as the geomembrane to be used.

This documentation shall be reviewed and approved in writing by the Geosynthetic Quality Assurance Consultant, as outlined in Section 1.2.5 of this QAM, before installation of the geosynthetic can begin.

Installation: During the installation, the Installer shall be responsible for the submission of:

1. Quality control documentation recorded during installation.
2. Subgrade surface acceptance certificates for each area to be covered by the lining system, signed by the Installer.

Completion: Upon completion of the installation, the Installer shall submit:

1. The warranty obtained from the Manufacturer.
2. The installation warranty.

1.2.6 Soil Quality Assurance Consultant

1.2.6.1 *Definitions*

The Soil Quality Assurance Consultant (Soil QAC) is the firm responsible for observing and documenting activities related to the quality assurance of the installation of the soil components of the lining system. The Soil QAC is independent of Project Manager. The Soil QAC and Geosynthetic QAC may be the same party.

In this QAM, the term Lead Soil Quality Assurance Monitor (LSM) refers to the engineer who is personally in charge of the soil quality assurance work. In some cases, the duties of the LSM described below may be shared by two individuals: a Soil Quality Assurance

Managing Engineer (Soil QAME) located at the headquarters of the Soil QAC, and a Soil Quality Assurance Resident Engineer located at the site. The personnel of the Soil QAC also include Soil Quality Assurance Monitors who are located at the site for construction observation and documentation.

1.2.6.2 *Responsibilities*

The Soil QAC is responsible for observing and documenting activities related to the quality assurance of the construction of the soil components of the lining systems. The Soil QAC is responsible for the implementation of the project QAM prepared by the Project Manager. The Soil QAC is also responsible for issuing a certification report, signed by a registered professional engineer, as outlined in Section 2.6 of this QAM. Other duties of the Soil QAC shall include overseeing the soil laboratory testing.

The specific duties of the Soil QAC personnel are as follows:

1. The LSM:

    a. Reviews all design drawings and specifications.
    b. Develops, if necessary, a site-specific addendum for quality assurance of soil components with the assistance of the Project Manager.
    c. Administers the soil portions of the QAM, including assigning and managing all soil quality assurance personnel, reviews all field reports, and provides engineering review of all quality assurance related issues.
    d. Reviews all changes to design drawings and specifications as issued by the Designer.
    e. Acts as on-site (resident) representative of the Soil QAC.
    f. Familiarizes all Soil Quality Assurance Monitors with the site and the project QAM.
    g. Attends all quality assurance related meetings, including resolution, pre-construction, daily, weekly meetings.
    h. Reviews the Earthwork Contractor's personnel qualifications for conformance with those qualifications pre-approved for work on-site.
    i. Manages the preparation of the soil documentation drawings.
    j. Reviews the Soil Quality Assurance Monitor's daily reports, logs, and photographs.
    k. Notes any on-site activities that could result in damage to the installed soil components.
    l. Reports to the Project Manager, and logs in the daily report, any relevant observations reported by the Soil Quality Assurance Monitors.
    m. Prepares his own daily report.
    n. Prepares a daily summary of the soil component quantities installed each day of construction activity.
    o. Prepares a summary of soil quality assurance activities at the end of each week of the construction activity.
    p. Oversees marking, packaging and shipping of all laboratory test samples.
    q. Reviews the results of laboratory testing and makes appropriate recommendations.
    r. Designates a Soil Quality Assurance Monitor to represent the LSM whenever he is absent from the site while operations ongoing.

s. Reports any unapproved deviations from the QAM to the Project Manager.
t. Prepares the final certification report.

2. The Soil Quality Assurance Monitor:

a. Monitors, logs, photographs and/or documents all soil component installation operations. Photographs shall be taken routinely and in critical areas of the installation sequence. These duties shall be assigned by the LSM.
b. Monitors following operations for all soil components:

(1) Material delivery.
(2) Unloading and on-site transport and storage.
(3) Sampling and conformance testing.
(4) Deployment operations.
(5) Condition of the soil components as placed.
(6) Visual observation, by walkover, of the finished soil components.
(7) Sampling and field testing of the finished soil components.
(8) Repair operations, if and when necessary.

c. Documents any on-site activities that could result in damage to the constructed soil components. Any problems noted shall be reported as soon as possible to the LSM.

Any differences of the Soil QAC's interpretation of the plans and specifications from the Contractor's interpretation shall be properly and adequately assessed by the Soil QAC. If such assessment indicates any actual or suspected work deficiencies, the Soil QAC shall inform the Contractor, or the Contractor's representative, of these deficiencies.

1.2.6.3 *Qualifications*

The Soil QAC shall be pre-qualified and approved by CWM. The Soil QAC shall be experienced in the preparation of quality assurance documentation including quality assurance forms, reports, certifications, and manuals.

The Soil QAC shall have a representative, (LSM or QAME) who has a B.S., M.S., or Ph.D. degree in civil engineering or related fields and be registered as a Professional Engineer. The LSM shall also comply with the experience requirements listed in the previous paragraph. The LSM shall be specifically experienced in the installation of soil liners and shall have the necessary training and certification by the Soil QAC in the duties of an LSM.

Soil Quality Assurance Monitors shall have specific training in construction quality assurance of engineered soil structures. At a minimum, one of every four monitors shall have a minimum of 1,000,000 ft^2 (100,000 m^2) field experience in soil liner construction.

1.2.6.4 *Submittals*

Pre-qualification: To be considered for pre-qualification, the Soil QAC shall provide the following information in writing to the Project Manager.

1. Corporate background and information:

    a. General company information.
    b. Proof of insurance.

        (1) Professional liability.
        (2) "Umbrella" coverage.
        (3) Other coverages as required by statute and/or proposed contractual agreement.

2. Quality assurance capabilities:

    a. A summary of the firm's experience in quality assurance, specifically quality assurance of soil components of the liner system.
    b. A summary of quality assurance documentation and methods used by the firm, including sample quality assurance forms, reports, certifications, and manuals prepared by the firm.
    c. Resumes of key personnel.

Pre-construction: Prior to beginning work on a project, the Soil QAC shall, in writing, provide the Project Manager with the following:

1. Resumes of personnel to be involved in the project including LSM, and Soil Quality Assurance Monitors.
2. Qualifications engineer to be designated as the Soil QAME.
3. Proof of the required soil components quality assurance experience of all of the quality assurance personnel.

1.2.7 Geosynthetic Quality Assurance Consultant

1.2.7.1 *Definitions*

The Geosynthetic Quality Assurance Consultant (QAC) is a firm independent from the Project Manager that is responsible for observing and documenting activities related to the quality assurance of the production and installation of the geosynthetic system on behalf of CWM. The Geosynthetic QAC and Soil QAC may be the same party.

In this QAM, the term Lead Geosynthetic Quality Assurance Monitor (LGM) shall be used to designate the engineer (working for the Geosynthetic QAC) in charge of the geosynthetic quality assurance work. In some cases the duties of the LGM described below may be shared by two individuals: a Geosynthetic Quality Assurance Managing Engineer (Geosynthetic QAME) located at an office of the Geosynthetic QAC, and a Geosynthetic

Quality Assurance Resident Engineer located at the site. The personnel of the Geosynthetic QAC also include Geosynthetic Quality Assurance Monitors who are located at the site for construction observation and documentation. Although not located at the site, the Geosynthetic Quality Assurance Managing Engineer shall visit the site often enough to be familiar with the project specifics.

1.2.7.2 *Responsibilities*

The Geosynthetic QAC is responsible for observing and documenting activities related to the quality assurance of the production and installation of the geosynthetic system. The Geosynthetic QAC is responsible for implementation of the project QAM prepared by the Project Manager. The Geosynthetic QAC is also responsible for issuing a final geosynthetic certification report, signed by a registered professional engineer, as outlined in Section 2.0 of this QAM.

The specific duties of the Geosynthetic QAC personnel are as follows:

1. The LGM:

   a. Reviews all design drawings and specifications.
   b. Reviews other site-specific documentation, including proposed layouts and manufacturer's and installer's literature.
   c. Develops a site-specific addendum for quality assurance of geosynthetics (if necessary) with the assistance of the Project Manager.
   d. Administers the geosynthetic portions of the QAM, e.g., assigns and manages all geosynthetic quality assurance personnel, reviews all field reports, and provides engineering review of all quality assurance related issues.
   e. Reviews all changes to design drawings and specifications as issued by the Designer.
   f. Acts as the on-site (resident) representative of the Geosynthetic QAC.
   g. Familiarizes all Geosynthetic Quality Assurance Monitors with the site and the project QAM.
   h. Attends all quality assurance related meetings, e.g., resolution, pre-construction, daily, weekly.
   i. Reviews all Manufacturer and Installer certifications and documentation and makes appropriate recommendations.
   j. Reviews the Installer's personnel qualifications for conformance with those qualifications pre-approved for work on site.
   k. Manages the preparation of the geosynthetic documentation drawing(s).
   l. Reviews the calibration certification of the on-site geosynthetic testing equipment, if applicable.
   m. Reviews all Geosynthetic Quality Assurance Monitor's daily reports, logs and photographs.
   n. Notes any on site activities that could result in damage to the geosynthetics.
   o. Reports to the Project Manager, and logs in the daily report, any relevant observations reported by the Geosynthetic Quality Assurance Monitors.
   p. Prepares his own daily report.

q. Prepares a daily summary of the quantities of geosynthetics installed that day.
r. Prepares the weekly summary of geosynthetic quality assurance activities.
s. Oversees the marking, packaging and shipping of all laboratory test samples.
t. Reviews the results of laboratory testing and makes appropriate recommendations.
u. Designates a Geosynthetic Quality Assurance Monitor to represent the LGM whenever he is absent from the site while operations are ongoing.
v. Reports any unapproved deviations from the QAM to the Project Manager.
w. Prepares the final certification report.

2. The Geosynthetic Quality Assurance Monitor:

a. Monitors, logs, photographs and/or documents all geosynthetic installation operations. Photographs shall be taken routinely and in critical areas of the installation sequence. These duties shall be assigned by the LGM.
b. Monitors the following operations for all geosynthetics:

(1) Material delivery.
(2) Unloading and on-site transport and storage.
(3) Sampling for conformance testing.
(4) Deployment operations.
(5) Joining and/or seaming operations.
(6) Condition of panels as placed.
(7) Visual inspection by walkover.
(8) Repair operations.

c. Monitors and documents the geomembrane seaming operations, including:

(1) Trial seams.
(2) Seam preparation.
(3) Seaming.
(4) Nondestructive seam testing.
(5) Sampling for destructive seam testing.
(6) Field tensiometer testing.
(7) Laboratory sample marking.
(8) Repair operations.

d. Documents any on-site activities that could result in damage to the geosynthetics. Any problems noted shall be reported as soon as possible to the LGM.

Any differences in the Geosynthetic QAC's interpretation of the plans and specifications from the Installer's interpretation shall be properly and adequately assessed by the Geosynthetic QAC. If such assessment indicates any actual or suspected work deficiencies, the Geosynthetic QAC shall inform the Installer, or the Installer's representative, of these deficiencies.

1.2.7.3 *Qualifications*

The Geosynthetic QAC shall be pre-qualified by CWM. The Geosynthetic QAC shall be experienced in quality assurance of geosynthetics with emphasis on polyethylene geomembranes. The Geosynthetic QAC shall be experienced in the preparation of quality assurance documentation including: quality assurance forms, reports, certifications, and manuals.

A representative of the geosynthetic QAC (LGM or QAME) who has a B.S., M.S. or Ph.D. degree in civil engineering or related fields and be registered as a Professional Engineer. LGM shall comply with the experience requirements listed in the previous paragraph. The LGM shall be specifically experienced in the installation of geosynthetics and shall be trained and certified by the Geosynthetic QAC in the duties of a LGM.

Geosynthetic Quality Assurance Monitors shall be quality assurance personnel who have been specifically trained in the quality assurance of geosynthetics. At a minimum, one of every four monitors (or at least one monitor per project) shall have a minimum of 1,000,000 ft^2 (100,000 m^2) field experience in polyethylene geomembrane quality assurance.

1.2.7.4 *Submittals*

Pre-qualification: To be considered for pre-qualification, the Geosynthetic QAC shall provide, in writing, the following information:

1. Corporate background and information.

    a. General company information.

2. Quality assurance capabilities:

    a. A summary of the firm's experience with geosynthetics.
    b. A summary of the firm's experience in quality assurance, including installation quality assurance of geosynthetics.
    c. A summary of quality assurance documentation and methods used by the firm, including sample quality assurance forms, reports, certifications, and manuals prepared by the firm.
    d. Resumes of key personnel.

Pre-installation: Prior to beginning work on a project, the Geosynthetic QAC must provide the Project Manager with the following information:

1. Resumes of personnel to be involved in the project including LGM, and Geosynthetic Quality Assurance Monitors.
2. Proof of professional engineering registration for the engineer to be designated as the Geosynthetic QAME.

3. Proof of the required quality assurance experience of all of the quality assurance personnel with emphasis on polyethylene geomembranes.

1.2.8 Construction Quality Assurance CQA Officer

1.2.8.1 *Definitions*

The Construction Quality Assurance (CQA) Officer will be selected by the Project Manager from the Soil or Geosynthetic Quality Assurance Consultant based on the personnel resumes.

1.2.8.2 *Responsibilities*

The CQA Officer is that individual assigned the responsibility for all aspects of CQA Plan implementation. The CQA Officer will report directly to the Project Manager.

1.2.8.3 *Qualifications*

The CQA Officer should possess adequate formal academic training with sufficient practical, technical, and managerial experience to successfully oversee and implement Construction Quality Assurance activities for hazardous waste land disposal facilities. The CQA Officer should be expected to ensure that communication of all CQA-related matters is conveyed to and acted upon by the affected organizations.

1.2.8.4 *Submittals*

Pre-qualification: At the request of CWM for consideration in pre-qualification, the Geosynthetic QAC and/or soil QAC shall provide, in writing, the following information:

1. Corporate background and information.

    a. General company information.

2. Quality assurance capabilities:

    a. A summary of the firm's experience with soils and geosynthetics.
    b. A summary of the firm's experience in quality assurance, including installation quality assurance of soils and geosynthetics.
    c. A summary of quality assurance documentation and methods used by the firm, including sample quality assurance forms, reports, certifications, and manuals prepared by the firm.
    d. Resumes of key personnel.

1.2.9 Soil Quality Assurance Laboratory

1.2.9.1 *Definitions*

The Soil Quality Assurance Laboratory (QAL) is a firm independent from the Earthwork Contractor or CWM. The Soil QAL and Geosynthetic QAL may be the same party.

1.2.9.2 *Responsibilities*

The Soil QAL is responsible for conducting the appropriate laboratory tests as directed by the LSM. The test procedures shall be done in accordance with the test methods outlined in this QAM and/or the project QAM. The Soil QAL shall be responsible for providing tests results as outlined in this QAM and the technical specifications.

1.2.9.3 *Qualifications*

The Soil QAL shall be approved by CWM. The Soil QAL shall have properly maintained and regularly calibrated appropriate testing equipment. The Soil QAL shall also ensure that laboratory soil testing is performed by personnel with experience and/or training in soil testing fundamentals. The laboratory personnel shall be familiar with American Society for Testing and Materials (ASTM), American Association of State Highway and Transportation Officials (AASHTO), the U.S. Army Corps of Engineers (COE) and other applicable test standards. The Soil QAL shall be capable of providing test results within project deadlines throughout the installation phase of the soil components.

The soil QAL shall submit to the Project Manager sample data and analysis to be used during the lab tests.

1.2.9.4 *Submittals*

The Soil QAL shall submit all test results within project deadlines to the LSM. Soil test results shall be provided verbally to the LSM as soon as possible after test completion. Written test results shall be in an easily readable format and include references to the standard test methods used.

1.2.10 Geosynthetic Quality Assurance Laboratory

1.2.10.1 *Definitions*

The Geosynthetic Quality Assurance Laboratory (QAL) is a firm, independent from the Project Manager, Manufacturer(s), and Installer, responsible for conducting tests on samples of geosynthetics taken from the site. The Geosynthetic QAL and the Soil QAL may be the same party.

1.2.10.2 *Responsibilities*

The Geosynthetic QAL shall be responsible for conducting the appropriate laboratory tests as directed by the LGM. The test procedures shall be done in accordance with the test methods outlined in this QAM and/or the project QAM. The Geosynthetic QAL shall be responsible for providing test results as outlined in Section 1.2.9.4.

1.2.10.3 *Qualifications*

The Geosynthetic QAL shall have experience in testing geosynthetics and be familiar with ASTM, Federal Test Method Standard (FTMS), National Sanitation Foundation (NSF), and other applicable test standards. The Geosynthetic QAL shall be capable of providing verbal results of destructive seam tests within 24 hours of receipt of test samples and shall maintain that standard throughout the installation. The Geosynthetic QAL shall be approved by CWM.

1.2.10.4 *Submittals*

The Geosynthetic QAL shall submit all destructive seam test results to the LGM in written form within 48 hours of receipt of test samples unless otherwise specified by the Project Manager. Geomembrane destructive test results shall typically be provided verbally to the LGM within 24 hours of receipt of test samples. Written test results shall be in an easily readable format and include references to the standard test methods used.

1.3 COMMUNICATION

To guarantee a high degree of quality during installation and assure a final product that meets all project specifications, clear, open channels of communication are essential. This section discusses appropriate lines of communication and describes all necessary meetings.

1.3.1 Lines of Communication

The typical lines of communication necessary during a project are illustrated in Exhibit 1-1. The CQA Officer designated as the LSM or LGM shall be capable of direct communication with the Project Manager at all times. Access to CWM personnel is also available for issue resolution if necessary.

1.3.2 Resolution Meeting

Following permit approval and the completion of the construction drawings and specifications for the project, a resolution meeting will be held. The resolution meeting is recommended to be held prior to bidding the construction work and include all parties then involved, typically including the Project Manager, Designer, QAME(s) LSM/LGM, and a CWM representative.

The purpose of this meeting is to establish lines of communication, review construction drawings and specifications for completeness and clarity, begin planning for coordination of tasks, anticipate any problems which might cause difficulties and delays in construction, and complete the QAM. All aspects of the design shall be reviewed during this meeting so that clarification and/or design changes may be made before the construction work is bid. In addition, the guidelines regarding quality assurance testing and problem resolution must be known and accepted by all. In addition, design-related issues will be resolved through discussion directed by the Project Manager with the designer(s) responsible for the respective feature.

A recommended agenda for the resolution meeting is presented in Exhibit 1-2. The meeting shall be documented by a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties.

1.3.3 Pre-Construction Meeting

A pre-construction meeting shall be held at the site prior to beginning of the lining system installation. Typically, the meeting shall be attended by the Project Manager, Designer, Earthwork Contractor, Geosynthetic Installer, LSM/LGM, and a CWM representative.

Specific topics considered for this meeting include review of the project QAM for any problems or additions. In addition, the responsibilities of each party should be reviewed and understood clearly. A recommended agenda with specific topics for the pre-construction meeting is presented in Exhibit 1-3. The meeting shall be documented by a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties.

An additional meeting, a prework conference, will be held at the request of the Project Manager to further define project CQA requirements identified in the preconstruction meeting.

Exhibit 1-1

LINES OF COMMUNICATION

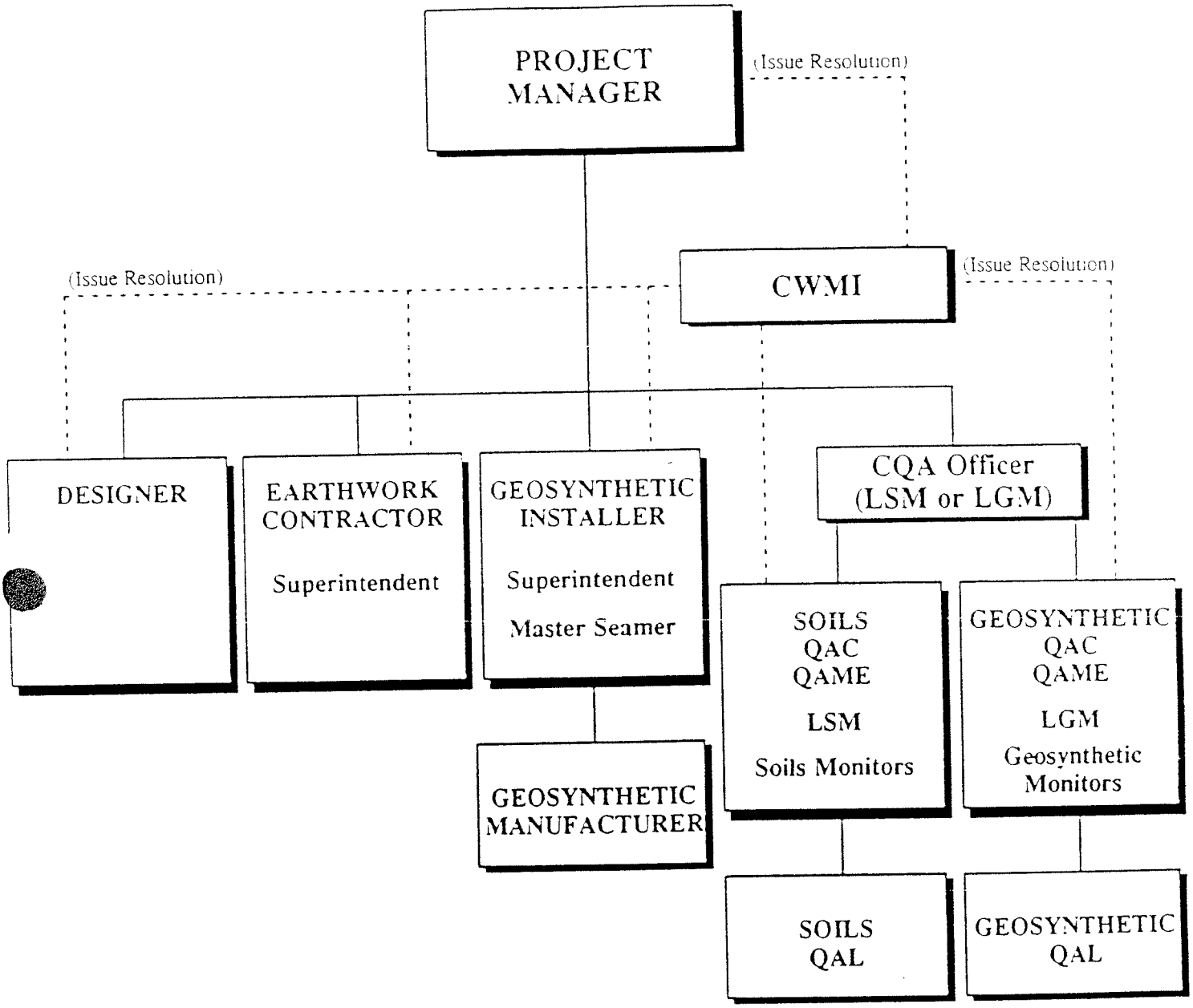


Exhibit 1-2
RESOLUTION MEETING AGENDA

1. Introductions

   A. Assign Minute Taker
   B. Identify Parties

      1. Project Manager
      2. Designer
      3. Soil/Geosynthetic Quality Assurance Consultant
      4. CWM Representative
      5. Others

2. Tour Project Site

3. Distribute and Review Documents

   A. Design and Construction Drawings
   B. Specifications
   C. Construction Quality Assurance Manuals
   D. Permit Documents

4. Complete Quality Assurance Plan

   A. Project-specific Addendum to Quality Assurance Manual(s)
   B. Project-specific Addendum to Specifications

5. Discuss Contract Administration and Construction Issues

6. Define Lines of Communication

7. Define Project Deliverables

8. Determine Time Schedule

Exhibit 1-3

PRE-CONSTRUCTION MEETING AGENDA

1. Introductions

   A. Assign Minute Taker
   B. Identify Parties

      1. Project Manager
      2. Designer
      3. Surveyor
      4. Earthwork Contractor
      5. Geosynthetic Installer
      6. Soil/Geosynthetic Quality Assurance Consultant
      7. Soil/Geosynthetic Quality Assurance Laboratory
      8. CWM Representative
      9. Others

2. Tour Project Site

3. Distribute and Review Documents

   A. Design and Construction Drawings
   B. Specifications
   C. Geosynthetic Panel Layout
   D. Project Quality Assurance Plan

4. Define Lines of Communication

   A. Lines of Communication
   B. Reporting Methods
   C. Distribution Methods
   D. Progress Meetings
   E. Procedures for Approving Design Clarifications and Changes During Construction

5. Review Site Requirements

   A. Safety Rules
   B. Site Rules
   C. Work Schedule
   D. Storage of Materials
   E. Available Facilities

Exhibit 1-3 Continued
PRE-CONSTRUCTION MEETING AGENDA

6. Discuss Construction Issues

   A. Scope of Work
   B. Review Design

      1. Construction Drawings
      2. Specifications
      3. Geosynthetic Panel Layout

   C. Construction Procedures

      1. Proposed Construction Sequencing
      2. Development of Soil Test Fill
      3. Location of Soil Stockpile Areas
      4. Location of Geosynthetic Storage Area
      5. Equipment

   D. Construction Schedule
   E. Procedures for Preparing and Approving Change Orders

7. Complete Construction Quality Assurance Plan

   A. Soils
   B. Geosynthetics
   C. Structural Systems (e.g., risers, piping, etc.)

8. Establish Project Deliverables

   A. Responsibilities

      1. Designer
      2. Installer
      3. Earthwork Contractor
      4. Soil/Geosynthetic Quality Assurance Consultant
      5. Soil/Geosynthetic Quality Assurance Laboratory
      6. Project Manager

   B. Distribution of Deliverables
   C. Approval Procedures

1.3.4 Progress Meetings

A weekly progress meeting shall be held between the LSM/LGM, Contractor's/Installer's Superintendent, Project Manager, and any other concerned parties. This meeting shall discuss current progress, planned activities for the next week, issues requiring resolution, and any new business or revisions to the work. The first progress meeting shall be held prior to the start of work and follow the agenda of the pre-work conference requirements of the specification. The LSM/LGM shall log any problems, decisions, or questions arising at this meeting in his weekly report. If any matter remains unresolved at the end of this meeting, the Project Manager shall be responsible for the resolution of the matter and the communication of the decision to the appropriate parties. Additional meetings can be called by any of the parties at any time such that it is the responsibility of the LSM/LGM to request a meeting if problems arise without resolution.

On-site NYSDEC personnel will be invited to weekly meetings for purposes of staying informed on current construction details. Schedules for such meetings will be distributed to NYSDEC prior to construction.

1.3.5 Training Program

The soil and geosynthetic CQA Consultants will provide a training program to CQA personnel and may be observed by on-site NYSDEC engineers. This training program will consist of weekly meetings to highlight permit requirements and implementation of QA/QC activities including construction observations, documentation procedures, and data management. An outline of the training program will be primarily based on preparation of progress reports as found in Section 2.3 which includes those items found in reporting requirements and changes or additions to details. Also, the soil and geosynthetic CQA consultants will provide checklists that will serve as guidelines for the CQA inspectors to successfully complete inspection.

2.0 DOCUMENTATION

An effective QAM depends largely on identification of all construction activities that shall be monitored, and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The Soil/Geosynthetic QAC shall document that all requirements in the lining portions of the project QAM have been addressed and satisfied.

The Soil/Geosynthetic QAC shall provide the Project Manager with signed descriptive remarks, data sheets, and checklists to verify that all monitoring activities have been carried out. The Soil/Geosynthetic QAC shall also maintain at the job site a complete file of all documents which comprise the QAM, including plans and specifications, this QAM, checklists, test procedures, daily logs, and other pertinent documents.

All testing of soils and geosynthetic shall be done in accordance with the current version of the ASTM number stated in this manual.

2.1 DAILY REPORTS

2.1.1 Soils Reports

Each Soil Quality Assurance Monitor shall complete a daily report and/or logs on prescribed forms, outlining monitoring activities for that day. The report at a minimum shall consist of field notes, observations and test data sheets, and construction problems and solution data sheets. A summary of all supporting data sheets along with final testing results and LSM's approval of the work shall be required upon completion of construction.

The Project Manager shall be made aware of any significant recurring non-conformance with the project specifications. The Project Manager shall then determine their cause and recommend appropriate changes. When this type of evaluation is made, the results must be documented, and any revision to procedures or specifications shall be approved by the Owner and Designer.

2.1.2 Geosynthetic Reports

Each Geosynthetic Quality Assurance Monitor shall complete a daily report and/or logs on prescribed forms, outlining monitoring activities for that day. The precise areas, panel numbers, seams completed and approved, and measures taken to protect unfinished areas overnight shall be identified. Location of failed seams or other panel areas requiring remedial action shall be identified with regard to nature of action, required repair, and precise location. Repairs completed must also be identified. Any problems or concerns with regard to operations on site should also be noted. This report must be completed at the end of each monitor's shift, prior to leaving the site, and submitted to the Soils/Geosynthetic QAC.

The Geosynthetic Installer will provide the CQA Officer with daily reports outlining:

1. Total amount of geomembrane deployed and location according to the panel layout drawing.
2. Total amount and location of seams completed, seamer, and units used.
3. Changes to the panel layout drawing.

The LGM will provide to the CQA Officer with daily reports outlining, at a minimum:

1. Results of test seams completed.
2. Indicate location on panel layout drawings and results of non-destructive/destructive testing.
3. Indicate location and results of repairs.

The LSM/LGM shall review the daily reports submitted by the Quality Assurance Monitors, and incorporate a summary of their reports into the QAE's daily report. Any matters requiring action by the Project Manager shall be identified. The report shall include a summary of the quantities of all material installed that day. This report must be completed daily, summarizing the previous day's activities, and a copy submitted to the Project Manager at the beginning of the work day following the report date.

2.2 TEST REPORTS

2.2.1 Soils Field Testing Reports

Records of field and laboratory testing performed on the soil components of the landfill shall be collated by the Soil QAC. A summary list of test results shall be prepared by the Soil QAC on an ongoing basis, and submitted with the weekly progress reports.

2.2.2 Geosynthetic Destructive Testing Reports

The destructive test reports from all sources shall be collated by the Geosynthetic QAC. This includes field tests, Installer's laboratory tests (if performed), and Geosynthetic QAL tests. A summary list of test samples' pass/fail results shall be prepared by the Geosynthetic QAC on an ongoing basis, and submitted with the weekly progress reports.

2.3 PROGRESS REPORTS

Progress reports shall be prepared by the LSM/LGM and submitted to the Project Manager. These reports shall be submitted every week, starting the first Friday of soil placement or geosynthetics deployment on site. This report shall include: an overview of progress to date; an outline of any changes made to the plans, drawings, or specifications. The report shall also include any problems or deficiencies in installation at the site, an outline of any action

taken to remedy the situation, a summary of weather conditions, and a brief description of activities anticipated for the next reporting period. All daily reports for the period should be appended to each progress report.

2.3.1 Reporting Requirements

Submit the following to the Project Manager for submittal to the NYSDEC:

- Borrow Area(s) Report(s)
- Geomembrane Material Properties Report and Quality Control Certificates
- Geotextile Conformance Testing Results Report
- Geonet/Geocomposite Properties Report
- Geonet/Geocomposite Conformance Testing Results Report
- Geosynthetic Clay Liner (GCL) Properties Report and Conformance Test Results
- Geomembrane Installer Qualifications
- Certifying Engineers Personnel Information
- Inspection of Exposed Surface Following Excavation Report
- Weekly Reports on Construction, including inspection of all installation practices and quality assurance and quality control monitoring including:
    - Clay placement and compaction.
    - Prepared surface inspection (including proof rolling) and acceptance.
    - Flexible membrane liner.
    - Flexible membrane liner installation and seam testing.
    - Geotextile installation.
    - Geonet/Geocomposite installation.
    - Geosynthetic Clay Liner (GCL) installation.
    - Placement and compaction of granular drainage layers.
    - Leachate pipe installation.
    - Concrete sump, side wall piping, and pump installation.
    - Double containment leachate transmission pipe installation.

- Miscellaneous installation.
- Documentation drawings and summary report.
- Certification of construction before operation.

Note: Weekly construction reports will be submitted by the Project Manager to the NYSDEC's Central and Region 9 office.

2.3.2 Changes or Additions to Details

For all changes and/or additions to details the Project Manager shall:

- Obtain verbal approval of NYSDEC representatives.
- Report changes or additions in reports.
- Obtain written agreement from the Designer.
- Detail changes or additions in documentation drawings.

Failure in any of above may be basis for qualification of approval by the Commissioner.

2.3.3 Punchlist Completion

A punchlist for soils and geosynthetics shall be prepared by the LSM/LGM and submitted to the Project Manager for items to be completed prior to liner placement. LSM/LGM is responsible for distribution to CQA Monitors and completion of punchlists.

2.4 DOCUMENTATION DRAWINGS

2.4.1 Soils Drawings

Documentation drawings shall be prepared by the Soil QAC. The documentation drawings shall include, at a minimum, the following information for soils:

1. Measured grade of the prepared subgrade.
2. Measured grade of the clay liner and other soil components.
3. Measured dimensions of any excavation within the subgrade and also within the soil liner.
4. Locations of all field tests and those samples obtained for laboratory testing.
5. Locations of all repairs performed on soil components.
6. Location of grade changes relative to site survey grid.

If necessary, for the purpose of clarity in the drawings, separate sheets shall be used to illustrate the locations of test sampling points. The applicable drawings shall be shown in both plan and in cross section views. All surveying for documentation information shall be performed by a qualified land surveyor.

2.4.2 Geosynthetic Drawings

Documentation drawings shall be prepared by the Geosynthetic QAC. The documentation drawings shall include, at a minimum, the following information for geomembranes:

1. Dimensions of all geomembrane field panels.
2. Location, as accurate as possible, of each panel relative to the site survey grid (furnished by the Project Manager).
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 documentation drawings shall illustrate each layer of geomembrane and, if necessary, another drawing shall identify problems or unusual conditions of the GCL, geotextile or geonet/geocomposite layers. In addition, applicable cross sections shall show layouts of GCL, geonets/geocomposites, geotextiles, or geogrids in sump areas or any other areas which are unusual or differ from the design drawings. All surveying for documentation information shall be performed by a qualified land surveyor.

2.5 CERTIFICATION

Provide the following certification items:

1. Warranty on Flexible Membrane Liner

   The Geomembrane Installer shall provide warranty certification to the LGM for inclusion in the record documents. The warranty for material will be for a period no less than 10 years.

2. Geomembrane Acceptance

   The Geomembrane shall be accepted by the OWNER when: i) the installation is finished; ii) all documentation of installation is completed; and iii) verification of the adequacy of all field seams and repairs, and associated testing is complete.

   A passing test seam shall be an indicator of the adequacy of the seaming unit and seamer working under prevailing site conditions, but not necessarily an indicator of seam adequacy. A passing nondestructive test of seams and repairs shall be taken to indicate the adequacy of field seams and repairs. If the laboratory tests of the field test seams fail, they shall be taken as an indicator of the possible inadequacy of the entire seamed length corresponding to the test seam. Destructive test portions shall then be taken by the FML Installer at locations suggested by the CQA Engineer and the same laboratory test required of test seams shall be performed. Passing tests shall be taken as an indicator

of non-adequate seams and the seams represented by the destructive test location shall be repaired. The repair shall be non-destructively tested and repaired, as required, until adequacy of the seams is achieved.

- The geomembrane shall be accepted by the NYSDEC when: i) the installation is finished; ii) the Engineer's acceptance and supporting documentation is submitted to the NYSDEC by CWM and the NYSDEC notifies CWM in writing of its acceptance.

3. Certification of Construction

   The QAME(s) and CWM will submit to NYSDEC certification that the unit has been constructed in accordance with the specifications and requirements of the issued permit, and is fully capable of operation in accordance with the specifications and requirements of the permit.

2.6 FINAL CERTIFICATION REPORT

Upon completion of the work, the QAC shall submit a final certification report to the Project Manager. This report shall summarize the activities of the project and document all aspects of the quality assurance program performed.

The final certification report shall include, at a minimum, the following information:

1. Parties and personnel involved with the project.
2. Scope of work.
3. Outline of project.
4. Quality assurance methods.
5. Test results (conformance, destructive and non-destructive, including laboratory tests).
6. NYSDEC/CWM correspondence.
7. Design changes differing from original approved plans and specifications.

A recommended outline for the final certification report is given in Exhibit 2-1.

8. Certification, sealed and signed by a registered professional engineer.
9. Documentation drawings, sealed and signed by a registered professional engineer.

Exhibit 2-1

FINAL CONSTRUCTION QUALITY ASSURANCE CERTIFICATION REPORT GENERAL OUTLINE

1. Introduction

   A. Purpose
   B. Scope
   C. Unit Description

2. Project Specifications

   A. Scope
   B. Design Changes

3. Quality Assurance Plan

   A. Scope
   B. Project-Specific Addenda

4. Quality Assurance Work Performed

   A. Weather Constraints
   B. Pre-construction Testing
   C. Conformance Testing
   D. Visual Monitoring
   E. Construction Testing
   F. Nondestructive Testing
   G. Destructive Testing
   H. Repairs

5. Summary and Conclusions

6. Project Certification

7. Appendices

   A. Geosynthetic and/or Soils QAC Personnel
   B. Contractor Personnel
   C. Quality Assurance Plan (QAP) and Specification Modifications
   D. Design Change Forms
   E. Earthwork Testing Records (if required)
   F. Conformance Testing Records
   G. Manufacturer Quality Control Records
   H. Quality Assurance Reports
   I. Subgrade Acceptance Certificates

Exhibit 2-1 Continued

FINAL CONSTRUCTION QUALITY ASSURANCE CERTIFICATION REPORT
GENERAL OUTLINE

J. Panel Placement Records
K. Non-Destructive Seam Testing Records
L. Destructive Seam Testing Records
M. Repairs
N. Documentation Drawings
O. NYSDEC/CWM Correspondence

3.0 LINING SYSTEM ACCEPTANCE

3.1 SOIL COMPONENTS ACCEPTANCE

Upon written recommendation by the Soil QAC, the Project Manager shall consider accepting the soil components of the lining system. The Earthwork Contractor will retain all responsibility for the soil lining components until acceptance by CWM. At CWM's discretion, the geosynthetic lining system may be accepted in sections or at points of substantial completion. The conditions of acceptance are described below.

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

1. The installation of the soil components is finished.
2. Verification of the adequacy of the constructed components, including repairs, if any, is completed in accordance with the project specific QAM.
3. All documentation of installation is completed.
4. The Soil QAC is able to recommend acceptance.

The Soil QAC shall certify that installation of the soil components has proceeded in accordance with the project specific QAM except as noted by the Project Manager. This certification shall be provided in the final certification report as outlined in Section 2.5.

3.2 GEOSYNTHETIC COMPONENTS ACCEPTANCE

Upon written recommendation by the Geosynthetic QAC, the Project Manager shall consider accepting the geosynthetic components of the lining system. The conditions of acceptance are described below. The Installer and Manufacturer(s) will retain all ownership and responsibility for the geosynthetics in the lining system until acceptance by CWM.

The geosynthetic lining system will be accepted by CWM when:

1. The installation of the geosynthetic component of the lining system, or section thereof, is finished.
2. Verification of the adequacy of all seams and repairs, including associated testing, is completed.
3. Geosynthetic Installer provides a warranty in accordance with Section 2.5 - Certification.
4. All documentation of installation is completed.
5. The Geosynthetic QAC is able to recommend acceptance.

The Geosynthetic QAC shall certify that installation has proceeded in accordance with the geosynthetic portions of the project QAM except as noted to the Project Manager. This certification shall be provided in the final certification report as outlined in Section 2.5.

4.0 SOIL LINER MATERIAL

4.1 DESCRIPTION AND APPLICABILITY

Soil liner material generally consists of cohesive soils with low hydraulic conductivity used as barriers in lining systems. Soils used in soil liners shall consist of clean, select material free of trash, excessive coarse particles, or other deleterious matter. Soils proposed for liner construction shall be classified according to the Unified Soil Classification System as CL or CH. Soils with organic content in excess of specifications, or soils classified as organic silt or clay (OL, OH) shall not be used as soil liner materials.

4.2 PREQUALIFICATION SOURCE TESTING

Prior to construction of a soil liner, tests to confirm the adequacy of soil liner materials shall be performed on specimens procured from each source area. All material evaluation tests are to be performed in a geotechnical laboratory, which may be the Soil QAL or another laboratory approved by the Project Manager. The Earthwork Contractor shall submit to the Project Manager the results of source evaluation tests. The following information will be forwarded to the NYSDEC for review and approval prior to the installation of the soil liner.

1. Moisture Content (ASTM D2216).
2. Particle Size (ASTM D1140, D422).
3. Atterberg Limits (ASTM D4318).
4. Laboratory Compaction (ASTM D1557 for Modified).
5. Laboratory Hydraulic Conductivity (ASTM D5084).
6. Unconsolidated Undrained Triaxial Test (ASTM D2850).

Perform conformance testing specified in Section 4.3 - Conformance Testing and Project Specifications. Materials which do not meet minimum required properties shall be rejected.

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

The compaction method necessary to achieve the required hydraulic conductivity can be established by defining the acceptable zone. The acceptable zone is the zone of compaction moisture dry unit weights which achieve the hydraulic conductivity. If necessary, another zone for the compacted strength can be defined in a similar manner. The overlapping portion of these zones indicates moisture content and dry density zone acceptable both for hydraulic conductivity and strength. Definition of the acceptable zone can greatly simplify the field quality assurance work, and increases the confidence level in the quality of the field compaction work as well as its overall acceptability.

A test fill will be constructed to establish a sequential logical approach for development of the placement and compaction procedure to be used during construction to achieve the required

performance standard. Samples of compacted liner soil obtained from the fill can be tested for hydraulic conductivity to establish the acceptability of the liner soil and the construction techniques. Appendix A contains a detailed test fill procedure.

The following placement and compaction procedures may be performed in areas of limited access where the width of an area is less than twice the width of a Caterpillar 815B segmented wheel compactor (or equivalent):

1) Place a loose lift of clay to a depth of between 4 and 5 inches but not greater than the height of the pads on the padfoot.

2) Compact this 4 to 5 inch loose lift with a minimum of 10 passes with the Ingersoll Rand SD100F or the Caterpillar CP563 padfoot compactors (or equivalent).

3) Perform field testing in accordance with Section 4.6.1.

4) Compaction equipment must be equivalent to equipment used to construct the test fill.

4.3 CONFORMANCE TESTING

Conformance testing of the soil liner materials shall be performed to ensure the consistency of the properties of the soil quality received from the borrow source. These tests are to be performed prior to construction and after the completion of any necessary conditioning of the liner soil Conditioning may include gradation adjustments, addition of admix materials, or adjustments in the compaction moisture content.

The following tests shall be performed:

1. Moisture Content (ASTM D2214, D4643)
2. Particle Size (ASTM D1140, D422)
3. Atterberg Limits (ASTM D4318)
4. Laboratory Compaction (ASTM D1557 for Modified)
5. Laboratory Hydraulic Conductivity (ASTM D5084)
6. Unconsolidated Undrained Triaxial Testing (ASTM D2850)

The following tests should be performed on representative samples from each borrow source. Samples shall be obtained at least 1,000 cubic yards in advance of the borrow source excavation at the frequencies specified below for each test. The CQA Engineer must review the test results for each area of the borrow source and grant his/her acceptance, or qualified acceptance, of each area based upon test results and field observations, prior to commencing excavation of that area. The CQA Engineer's acceptance including test results and documented field observations shall be made available to the NYSDEC for review, upon request.

1. **Organics Content**

Frequency During Construction: Whenever organic materials are suspected, based on visual observation and cannot be removed (i.e., roots can be removed, peat cannot).

Method: T267-86 of AASHTO (American Association of State Highway Transportation Officials).

Pass Criteria: Less than 3.0 percent.

2. **Particle Size Analysis (Except Hydrometer)**

Frequency During Construction: Every 1,000 cubic yards on a sample taken about 1,000 cubic yards in advance of the present excavation.

Method: ASTM D422.

Pass Criteria: Similar to material for which the most recent moisture density curve has been developed.

3. Particle Size Analysis of Fines by Hydrometer

Frequency During Construction: Every 5,000 cubic yards on a sample taken about 1,000 cubic yards in advance of the present excavation.

Method: ASTM D422.

Pass Criteria: Similar to material for which the most recent moisture density curve has been developed.

4. Moisture Content (Drying Oven and Microwave)

Frequency During Construction: Every 1,000 cubic yards on one sample taken at the site of present excavation and another sample taken about 1,000 cubic yards in advance of the present excavation.

Method: ASTM D2216 - Drying Oven
ASTM D4643 - Microwave

Pass Criteria: The results of each test should be compared to the acceptable compaction window to assure that the proper percent compaction and moisture content are being attained.

5. Atterberg Limits (Liquid Limit, Plastic Limit, and Plasticity Index of Soils)

Frequency During Construction: Every 1,000 cubic yards on a sample taken about 1,000 cubic yards in advance of the present excavation.

Method: ASTM D4318.

Pass Criteria: Similar to material for which the most recent moisture density curve has been developed.

6. Modified Proctor Moisture Density Curve

Frequency During Construction: Every 5,000 cubic yards on a sample taken about 1,000 cubic yards in advance of the present excavation, or changes in materials. This frequency may be extended to once every 10,000 cubic yards, if a one point Proctor test is determined after 5,000 cubic yards on a sample which is dried to a moisture content below the Optimum Moisture Content.

Method: ASTM D1557.

7. **Lab Hydraulic Conductivity (Remolded Sample)**

Note: The test sample shall be compacted to at least 90 percent Modified Proctor from 0 to 3 percent wet of optimum moisture content.

Frequency: One prior to test fill construction and one at each change in soil characteristics as documented by ± 5-pound change in the maximum dry density of Proctor; based on a running average of maximum dry densities of previous Proctor tests of same material.

Method: ASTM D5084.

8. **Triaxial Tests (Remolded Samples)**

Note: This test may be deleted by the Designer if the soil is being used where strength parameters are not a concern.

Frequency During Construction: Every 5,000 cubic yards on a sample taken about 1,000 cubic yards in advance of the present excavation and whenever the plasticity index changes. The frequency of every 5,000 cubic yards may be extended by the CQA Engineer if the borrow source has been determined to be consistent during the initial construction of this unit.

Method: ASTM D2850.

Pass Criteria: Designer shall review results to determine if the soil has sufficient strength for the facility as designed to remain stable as indicated by two-dimensional stability analysis, for both static and dynamic cases.

Material removed from the clay source will be excavated sequentially. The material encountered, which testing has shown does not meet the specifications, will be stockpiled in the spoil area. Suitable material will be placed in the stockpile area or used directly in the landfill.

The LSM shall examine all test results and report any non-conformance to the Project Manager. The Project Manager shall accept or reject the soil based on this review and the requirements of the project specifications.

If proposed soils fail to meet the specification requirements and cannot be economically obtained, then at a minimum special quality control measures may be imposed, such as more frequent or additional tests. Soil amendments or alternative materials may be proposed to the NYSDEC.

4.4 SUBGRADE PREPARATION

The Earthwork Contractor shall be responsible for preparing the subgrade soil for liner placement. Upon completion of the subgrade preparation work, the Soil QAC shall inspect the subgrade and prepare a notice of acceptance to be submitted to the Project Manager. In this notice of acceptance, the Soil QAC shall, at a minimum:

1. Verify that a qualified land surveyor has verified all lines and grades.
2. Verify that a qualified engineer has verified that the subgrade soil meets the criteria in the project specifications.
3. Determine the suitability of the subgrade for fill placement by:

    a. Continuous visual inspection during proofrolling.
    b. Pocket penetrometer test in suspected soil areas.

At any time during construction of the liner, the Soil QAC shall indicate to the Project Manager any locations which are not adequate for the placement of the soil liner. Such defects in the subgrade soil shall be repaired by the Earthwork Contractor, at the direction of the Project Manager, such that the properties of the repaired areas meet the project specifications.

4.5 CONSTRUCTION OBSERVATION AND INSPECTION

Observation and inspection of the soil liner construction shall be coordinated with the construction testing described in Section 4.6. Acceptance criteria for construction work shall be as identified in the project specifications.

Soil QAC shall observe, inspect, and record the following during the construction of soil liners:

1. Water content and consistency of the soil during processing, placement, and compaction.
2. Type and level of compactive effort:

    a. Roller type.
    b. Roller weight.
    c. Number of passes.

3. Action of compaction equipment on the soil surface (sheepsfoot penetration, pumping, cracking, etc.).
4. Maximum clod size.
5. Condition of any soil stockpile.
6. Loose and compacted lift thickness.
7. Method of tying together the lifts.
8. Dimensions of the compacted embankment.
9. Areas where damage due to excess moisture, insufficient moisture, or freezing may have occurred.

Upon completion of subgrade and the soil liner construction, the Soil QAC shall inspect the liner and prepare a certificate of acceptance to be submitted to the Project Manager. The Soil QAC shall verify, at a minimum, that:

1. A qualified land surveyor has verified all lines and grades on 50-foot grid pattern. Also, document additional features such as undercuts and sumps.
2. A qualified engineer has verified that the liner soil meets the criteria in the project specifications.

4.6 CONSTRUCTION TESTING

All construction quality assurance testing shall be conducted in accordance with the project specifications, or as directed by the Project Manager and as documented in the site specific addenda to this manual. All field and laboratory tests shall be conducted on samples taken from the soil liner materials during the course of the construction work. Construction quality testing shall consist of laboratory and field testing as described in Sections 4.6.1 and 4.6.2. Testing and sampling procedures shall be observed and documented by the Soil QAC. Documentation and reporting of test results shall be in accordance with the requirements identified in Section 2 of this manual.

4.6.1 Field Testing

The Soil QAC shall perform the following field tests on each lift of the compacted soil:

4.6.1.1 *Soil Compaction and Moisture Content*

Note: The calibration of each nuclear densitometer shall be checked when standard counts on instrument indicate or when daily moisture varies by 3%, by comparison to density measured on the same material by ASTM D1556, D2167, or D2937. Zone of Troxler moisture content of each instrument shall be checked daily by ASTM D2216.

Frequency During Construction: 9 per acre per lift but no fewer than 1 per 300 cubic yards in long thin areas and no fewer than one per lift.

Location of probe: Shall be located at bottom of the upper lift or slightly lower.

Method: Nuclear densitometer per ASTM D2922 and ASTM D3017.

Pass Criteria: The results of each test should be compared to the most recent moisture density curve above (refer to Appendix C), to assure that the proper percent compaction is being attained.

4.6.1.2 *Lab Hydraulic Conductivity*

Frequency During Construction: One per acre per lift, but no fewer than one per 800 cubic yards in long thin areas.

Method: ASTM D5084

Note: Utilize a small hydraulic jack between the shelby tube and an equipment bucket or blade to push tube into the soil liner (straight, not at an angle) no more than 2 inches past the first lift interface, unless otherwise directed by Soil CQA. An equivalent method to jacking may be employed if samples are not over consolidated. Damage tube shall not qualify as lab samples. Sample shall be recovered from density test location between probe and source.

Pass Criteria: 1×10^{-7} cm/sec or less.

Identification test on tubes shall include moisture content, dry density, wet density, particle size, and Atterberg limits; at a frequency of one each per tube. Laboratory shall report condition of tube and extruded soil prior to testing. Dry lenses and rocks shall be documented and reported to the LSM.

Unless otherwise noted in the project specifications, or as directed by the Project Manger, all perforations of the clay liner shall be backfilled. Perforations that must be backfilled shall include, but not be limited to, the following:

- Nuclear density test probe locations.
- Sand-cone test locations.
- Hydraulic conductivity sampling locations.
- Grade stakes.

All perforations shall be backfilled with a soil bentonite mixture and be compacted in-place with a tamping rod, Modified or Standard Proctor hammer, or a hand tamper as specified in the project specifications depending upon the size of the perforation. At a minimum, the Soil QAC shall perform routine tests and observations on the backfilled areas.

At the discretion of the Project Manager, if one or more of the following conditions develop during construction, an increased frequency of testing shall be used based on recommendations from the Soil QAC:

1. Rollers slip during operation.
2. Earthfill is at improper and/or variable moisture content.
3. Dirt-clogged rollers are used to compact the material.
4. The uniformity of compaction of the material is suspect.

Additional testing may also be considered when:

1. Weather conditions are adverse.
2. Rollers have not used optimum ballast.
3. Equipment breaks down frequently.
4. Grading is being started or finished.

4.7 DEFECTS AND REPAIRS

At locations where the field density and moisture content testing indicates compaction performed below the requirements of the specifications, the Soil QAC shall determine the extent and the nature of the defect.

If the compacted soil liner has been subject to adverse weather conditions, the Soil QAC shall reinspect the liner for possible damage.

Evaluation of layer bonding may be determined by using test pits to make visual observations. All test pits shall be excavated in a manner acceptable to the Geosynthetic CQA Monitor. Test pits shall be at least 1 foot in depth. All pits shall be backfilled and compacted in accordance with the project specifications. The backfill shall be compacted using hand compaction equipment or other methods approved by the Geosynthetic CQA Monitor.

4.7.1 Notification

After determining the extent and nature of the defect, the Soil QAC shall promptly notify the Project Manager and the Earthwork Contractor. A work deficiency meeting shall be held as needed between the Earthwork Contractor, Soil QAC, and the Project Manager to assess the problem, review alternative solutions, and implement an action plan.

4.7.2 Repairs and Retesting

The Earthwork Contractor shall correct all deficiencies to the satisfaction of the Soil QAC. If a project specification criteria cannot be met, or unusual weather conditions hinder work, the Soil QAC shall develop and present to the Project Manager suggested solutions for his approval.

The Soil QAC shall schedule appropriate retests when the work defect has been corrected. All retests by the Soil QAC shall verify that the defect has been corrected before any additional work is performed by the Earthwork Contractor in the area of the deficiency.

5.0 GRANULAR DRAINAGE MEDIA

5.1 DESCRIPTION AND APPLICABILITY

Granular drainage media consists of high permeable materials used in leachate collection, final cover drainage and gas venting systems. The types of materials shall consist of clean sands and/or gravels or other permeable material classified as SW, SP, GW, or GP. Gravel placed in pipe trenches shall be classified as GW or GP, and be of gradation whereby 95% of the materials is larger than the perforations of the drainage pipe.

5.2 QUALITY CONTROL DOCUMENTATION

Prior to the construction of a granular drainage layer, tests to confirm the adequacy of the granular drainage materials shall be performed on specimens procured form each source area. All material evaluation tests are to be performed in a geotechnical laboratory, which may be the Soil QAL or another laboratory approved by the Project Manager. The Earthwork Contractor shall submit to the Project Manager the results of source evaluation tests. The sources shall be ranked for acceptability based on test results, unit material price, and transportation cost. The material shall be accepted or rejected by the Project Manager according to these results.

The following tests shall be conducted:

1. Particle Size (ASTM D1140, D422).
2. Laboratory Hydraulic Conductivity (ASTM D2434).

Unless otherwise specified in the project specifications, one series of these tests shall be performed per source, or upon visually observable changes in the material type. If identification of additional drainage material sources becomes necessary during construction, the same material qualification and consistency checking procedures shall be applied to each such source.

5.3 CONFORMANCE TESTING

Conformance testing of the granular drainage materials shall be performed to establish the consistency of the drainage layer material properties received from the borrow source.

The following tests shall be performed:

1. Particle Size (ASTM D1140, D422).
2. Laboratory Hydraulic Conductivity (ASTM D2434).

Unless otherwise specified in the project specifications, particle size tests shall be performed at a frequency of one per 1,000 yd^3 of drainage layer material, or upon visually observable changes in the material type. The laboratory hydraulic conductivity tests shall

be performed upon visually observable changes in the material type or, as required in the project specifications.

The LSM shall examine all test results and report any non-conformance to the Project Manager. The Project Manager shall accept or reject the material based on this review and the requirements of the project specifications.

5.4 CONSTRUCTION OBSERVATION, INSPECTION AND INSPECTION

The Soil QAC shall observe the procedures used by the Earthwork Contractor during placement of the drainage material to ensure that the materials are placed at the specified thickness. The thickness of the drainage layer shall be verified by survey on a 50-grid pattern across cell base area by the LSM following completion of the drainage layer placement.

In-place samples will be taken at a frequency of one sample per 1,000 yd^3. The in-place samples will be tested for particle size (to conform to maximum of 5% passing number 200 sieve) and hydraulic conductivity. The frequency of in-place samples to be tested for hydraulic conductivity may be increased to one per 5,000 yd^3 by the CQA Engineer and CWM Project Manager based on the results of the pre-qualification, conformance and in-place particle size testing for each source.

The Soil QAC shall prepare a certificate of acceptance for the drainage layer to be submitted to the Project Manager.

5.5 DEFECTS AND REPAIRS

If a defect is discovered in the final drainage blanket product, the Soil QAC shall determine the extent and the nature of the defect. If the defect is indicated by an unsatisfactory test result, the Soil QAC shall determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the Soil QAC deems appropriate.

5.5.1 Notification

After determining the extent and nature of the defect, the Soil QAC shall promptly notify the Project Manager and the Earthwork Contractor. A work deficiency meeting shall be held as needed between the Earthwork Contractor, the Soil QAC, and the Project Manager to assess the problem, review alternative solutions, and implement an action plan.

5.5.2 Repairs and Retesting

The Earthwork Contractor shall correct all deficiencies to the satisfaction of the Soil QAC. If a project specification criteria cannot be met, or unusual weather conditions hinder work, the Soil QAC shall develop and suggest solutions to the Project Manager for his approval.

The Soil QAC shall schedule appropriate retests when the work defect has been corrected. All retests by the Soil QAC shall verify that the defect has been corrected before any additional work is performed by the Earthwork Contractor in the area of the deficiency.

6.0 PROTECTIVE SOIL COVER

6.1 DESCRIPTION AND APPLICABILITY

Protective soil covers generally consist of soils used to protect the geosynthetic components of the lining systems and of the geosynthetic clay liner (GCL) final cover system. This cover prevents direct contact between the liner system and the waste materials, the leachate collection system and the waste materials, and provides physical protection for the geosynthetics in the GCL final cover system. The protective soil cover shall not have a particle size or have sharp edges that may damage a geosynthetic component. If necessary, processing may be required to remove oversized particles.

Where protective soil cover is used in conjunction with the baseliner system, the percentage of material finer than #200 sieve shall be evaluated to ensure that the protective material has a hydraulic conductivity large enough not to prevent free drainage of the landfill leachate into the leachate collection system. This requirement may not be necessary for protective soil cover that is placed on side slopes or for a GCL final cover system.

6.2 PREQUALIFICATION SOURCE TESTING

Prior to construction of the protective soil cover layer, tests to confirm the adequacy of the protective soil materials shall be performed on specimens procured from each borrow source area. The Soil QAC shall verify that the grain-size distribution (via ASTM D422 and, if appropriate, ASTM D1140) of the protective layer material meets the requirements of the project specifications.

For cohesive protective layer materials, the Soil QAC shall obtain the moisture content of the material at the source as specified in the project specifications to evaluate its workability. The Atterberg Limits tests shall be performed on these materials at the frequency specified in the project specifications.

Prior to construction of the protective soil layer in the GCL final cover system, the source material shall be tested for permeability (ASTM D5084) and compaction characteristics (ASTM D698 and ASTM D1557) to determine the range of in-place soil density and moisture content that meets the specified minimum value contained in the project specifications. These test results shall be used to develop the acceptable zone for compaction as described in Appendix C. The acceptable zone of compaction specifies the range of moisture content and dry unit weight that will allow the soil to achieve an in-place hydraulic conductivity that is less than or equal to the maximum allowable value contained in the project specifications. Once the acceptable zone of compaction is determined from laboratory test results, a test pad shall be constructed to verify that the actual equipment and compaction methods to be used by the Earthwork Contractor to construct the protective soil layer for the GCL final cover system can attain field soil densities and moisture contents that are within the acceptable zone for compaction. The test fill shall be constructed and tested as described in Appendix A.

All required testing shall be performed by the Soil QAL or another laboratory approved by the Project Manager. The Earthwork Contractor shall submit to the Project Manager the results of source evaluation tests. The material shall be accepted or rejected by the Project Manager based on the laboratory testing results. If identification of additional soil sources becomes necessary during construction, the same material qualification and testing procedures shall apply for each new source.

6.3 CONFORMANCE TESTING

Conformance testing of the protective soil material shall be performed to ensure the consistency of the material's physical properties and to verify that the material continues to comply with the specified requirements. The Soil QAC shall conduct onsite particle size tests at the frequency of one per 5,000 yd^3 of protective layer soil before placement. For cohesive soil used to construct the protective layer on the side slopes and the protective layer in the GCL final cover system, the Soil QAC shall obtain the moisture content of the protective layer soil at the time of placement at the frequency specified in the project specifications.

The Soil QAC shall report any nonconformance to the Project Manager. The Project Manager shall accept or reject the material based on this review and the requirements of the project specifications prior to construction.

6.4 CONSTRUCTION OBSERVATION AND INSPECTION

During construction of the GCL final cover protective soil layer, the Soil QAC shall perform in-situ moisture/density testing of the compacted material at a frequency of nine tests per acre per lift. The Soil QAC shall verify that all moisture/density test results are within the acceptable zone for compaction established by prequalification testing. The Soil QAC shall notify the Project Manager of any unacceptable moisture/density test results and the area shall be recompacted and retested until acceptable moisture/density test results are obtained.

The Soil QAC shall also collect Shelby tubes from the constructed GCL final cover protective soil layer for laboratory permeability testing. Shelby tubes shall be collected from the upper 12 inches of the 18-inch-thick layer and at a frequency of 4 per acre per lift. The Soil QAC shall verify that all laboratory-measured permeabilities are less than or equal to the maximum allowable value contained in the technical specifications. The Soil QAC shall notify the Project Manager of any failing permeability test results and the associated area shall be re-compacted and retested until acceptable permeability test results are obtained.

The Soil QAC shall verify the protective layer thickness by spot checks and direct measurements after placement. The Soil QAC shall also observe the placement of any geosynthetic the protective soil may come in contact with. The Soil QAC shall prepare a certificate of acceptance for the protective layer to be submitted to the Project Manager.

6.5 DEFECTS AND REPAIRS

If a construction defect is discovered in the protective layer, the Soil QAC shall determine the extent and the nature of the defect. If the defect is indicated by an unsatisfactory test result, the Soil QAC shall determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the Soil QAC deems appropriate.

6.5.1 Notification

After determining the extent and nature of the defect, the Soil QAC shall promptly notify the Project Manager and Earthwork Contractor. A work deficiency meeting shall be held as needed between the Earthwork Contractor, the Soil QAC, and the Project Manager to assess the problem, review alternative solutions, and implement an action plan.

6.5.2 Repairs and Retesting

The Earthwork Contractor shall correct all deficiencies to the satisfaction of the Soil QAC. If a project specification cannot be achieved, or unusual weather conditions hinder work, the Soil QAC shall develop and present to the Project Manager suggested solutions for his approval.

The Soil QAC shall schedule appropriate retests when the work defect has been corrected. All retests by the Soil QAC must verify that the defect has been corrected before any additional work is performed by the Earthwork Contractor in the area of the deficiency.

7.0 VEGETATIVE COVER

7.1 DESCRIPTION AND APPLICABILITY

Vegetative cover material generally consists of medium textured soils capable of supporting vegetative growth. Establishment of vegetation will:

- Protect the soil and/or geosynthetic cover against damage due to frost and excessive temperatures.
- Reduce cover erosion due to water and wind.
- Enhance the appearance of the landfill for aesthetic reasons.

Medium-textured soils (loam) have the best characteristics for seed germination and plant development. Site-specific top layer criteria shall be given in the project specifications.

Alternative cover designs prepared on site-specific basis in certain climatic regions may not require a vegetative soil cover. In such cases, the site-specific project specifications are to be used in lieu of the contents of this section as a guide for construction quality assurance purposes.

7.2 QUALITY CONTROL DOCUMENTATION

Prior to the construction of a vegetative layer, the particle size distribution of soil from each source (one test per source) shall be determined by the Soil QAC. All testing shall be performed by the Soil QAL.

7.3 CONSTRUCTION OBSERVATION AND INSPECTION

The vegetative cover layer shall be compacted moderately and uniformly to the specified thickness. The firmness of the compacted vegetative cover varies with the type of vegetation specified for the cover, and should be indicated in the project specifications.

The Soil QAC shall:

1. Verify the actual thickness of the vegetative cover after compaction by direct measurements. The thickness of the top layer of soil should be at least equal to, preferably greater than, the depth required for the protection of the compacted soil liner against frost. The vegetative layer final grades will be verified by surveying.
2. Ensure that care is taken in the vicinity of protrusions to prevent physical damage by the construction equipment.
3. Observe the quantity and the uniformity of any soil amendment incorporated within the tilled depth before seeding.
4. Ensure that the seeding application equipment is appropriate for the job. The rate of seed and mulch application, amount and uniformity of coverage, and watering instructions as provided in the construction specifications shall be closely observed.

5. Examine the perimeter areas to ensure that no bare spots are left.
6. Continue to inspect the cover until the vegetative cover has been established.

If erosion protection is to be achieved through the use of coarse materials (cobbles, riprap) instead of a vegetative cover, the Soil QAC shall verify that the particle-size distribution of the protective layer is as specified in the project specifications.

Upon completion of the vegetative cover layer placement, the Soil QAC shall prepare a certificate of acceptance for the vegetative layer to be submitted to the Project Manager. The Soil QAC shall report any non-conformance to the Project Manager.

7.4 DEFECTS AND REPAIRS

If a defect is discovered in the vegetation layer, the Soil QAC shall determine the extent and the nature of the defect. If the defect is indicated by an unsatisfactory test result, the Soil QAC shall determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the Soil QAC deems appropriate. If the vegetative layer has been subject to adverse weather conditions during construction, the Soil QAC shall reinspect the vegetative layer for possible damage in overly wet or desiccated areas.

7.4.1 Notification

After determining the extent and nature of the defect, the Soil QAC shall promptly notify the Project Manager and the Earthwork Contractor. A work deficiency meeting shall be held as needed between the Earthwork Contractor, the Soil QAC, and the Project Manager to assess the problem, review alternative solutions, and implement an action plan.

7.4.2 Repairs and Retesting

The Earthwork Contractor shall correct all deficiencies to the satisfaction of the Soil QAC. If a project specification criteria cannot be met, or unusual weather conditions hinder work, the Soil QAC shall develop and present to the Project Manager suggested solutions for his approval.

The Soil QAC shall schedule appropriate retests when the work defect has been corrected. All retests by the Soil QAC must verify that the defect has been corrected before any additional work is performed by the Earthwork Contractor in the area of the deficiency.

8.0 GENERAL EARTHFILL

8.1 DESCRIPTION AND APPLICABILITY

General earthfill consists of random, granular or cohesive material taken from on-site, approved off-site excavations or stockpiles used for non-critical applications. Soil used as general earthfill consists of a broad range of soils relatively free of organics, trash, or other deleterious matter.

This section does not identify specific tests to determine the suitability of earth materials for use in general earthfill. Testing and/or material qualification requirements specified for the general earthfill material in site-specific project specifications shall override the minimum qualifications given in this section.

8.2 QUALITY CONTROL DOCUMENTATION

The general earthfill sources shall be evaluated to determine acceptance with the project specifications. The visual examination and laboratory direct shear testing of the general earthfill soil shall be performed and documented by the Soil QAC. If required, the general fill material shall be processed such that it does not contain particles exceeding the maximum size established in the project specifications. The Project Manager shall accept or reject the material.

8.3 CONSTRUCTION OBSERVATION AND INSPECTION

The Soil QAC shall verify the requirements of the project specifications are met. In summary, a minimum of one Modified Proctor per source per year and minimum field density testing of one per 600 cubic yards is required. The CQA Engineer may request more frequent testing if needed. The Soil QAC shall report all non-conformances to the Project Manager.

8.4 DEFECTS AND REPAIRS

If a defect is discovered in the finished general earthwork, the Soil QAC shall determine the extent and the nature of the defect. If the defect is indicated by an unsatisfactory test result, the Soil QAC shall determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the Soil QAC deems appropriate. Defected soil is identified as damage to any compacted lift at any time during the construction, such as from weather or rutting under the loads imposed by earth moving equipment.

8.4.1 Notification

After determining the extent and nature of the defect, the Soil QAC shall promptly notify the Project Manager and the Earthwork Contractor. A work deficiency meeting shall be held as needed between the Earthwork Contractor, the Soil QAC, and the Project Manager to assess the problem, review alternative solutions, and implement an action plan.

8.4.2 Repairs and Retesting

The Earthwork Contractor shall correct all deficiencies to the satisfaction of the Soil QAC. If a project specification criteria cannot be met, or unusual weather conditions hinder work, the Soil QAC shall develop and present to the Project Manager suggested solutions for his approval.

The Soil QAC shall schedule appropriate retests, if any required, when the work defect has been corrected. All retests by the Soil QAC must verify that the defect has been corrected before any additional work is performed by the Earthwork Contractor in the area of the deficiency.

9.0 GEOMEMBRANES

9.1 DESCRIPTION AND APPLICABILITY

Geomembranes are low hydraulic conductivity barriers used in lining systems. This section is applicable to smooth HDPE, roughened HDPE, and coextruded polyethylene geomembranes. This section is not applicable to other geomembrane materials including Hypalon, PVC, and VLDPE.

9.2 MANUFACTURING PLANT INSPECTION

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

The manufacturing plant inspection shall include:

1. Verification that properties guaranteed by the Manufacturer meet all project specifications.
2. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.
3. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.
4. Review of handling, storage, and transportation procedures, and verification that these procedures will not damage the geomembrane.
5. Verification that roll packages have a label indicating the name of the manufacturer, type of geomembrane, thickness, roll number, and roll dimensions.
6. Verification that extrusion rods and/or beads are produced from the same base resin type as the geomembrane.

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

9.3 QUALITY CONTROL DOCUMENTATION

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

1. The origin (supplier's name and production plant) and identification (brand name and number) of the resin.
2. Copies of dated quality control certificates issued by the resin supplier.
3. Results of tests conducted by the Manufacturer to verify that the resin used to manufacture the geomembrane meets the project specifications for melt flow index and density.
4. A statement indicating that the amount of reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness and did not exceed 2% by weight.

5. A list of the materials which comprise the geomembrane, expressed in the following categories as percent by weight: polyethylene, carbon black, other additives.
6. A specification for the geomembrane which includes all properties contained in the project specifications measured using the appropriate test methods.
7. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.
8. Quality control certificates, signed by a responsible party employed by the Manufacturer. Each quality control certificate shall include roll identification numbers, testing procedures, and results of quality control tests. At a minimum, results shall be given for.

    a. Density (ASTM D1505 or D792).
    b. Carbon black content (ASTM D1603, D4218).
    c. Carbon black dispersion (ASTM D5596).
    d. Thickness (ASTM D5994).
    e. Tensile properties (ASTM D6693 Type IV).
    f. Tear strength (ASTM D1004).

    These quality control tests shall be performed in accordance with the test methods specified in the project specifications for every 40,000 ft^2 (4,000 m^2) of geomembrane produced.

    The manufacturers shall provide a certification letter which will provide data for puncture, environmental stress, low temperature, and burial.

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

1. Manufacturer's name.

2. Product identification.

3. Thickness.

4. Roll number.

5. Roll dimensions.

The LGM shall review and approve in writing, these documents and shall report any discrepancies with the above requirements to the Project Manager. The LGM shall verify that:

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

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

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

4. Rolls are appropriately labeled.

5. Certified minimum properties meet the project specifications.

9.4 CONFORMANCE TESTING

Upon delivery of the rolls of geomembrane, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geomembrane. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance to the project.

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

The following conformance tests shall be conducted:

1. Density.
2. Carbon black content.
3. Carbon black dispersion.
4. Thickness.
5. Tensile characteristics.

These conformance tests shall be performed in accordance with the test methods specified in the project specifications.

9.4.1 Sampling Procedures

The rolls to be sampled shall be selected by the Geosynthetic QAC. Samples shall be taken across the entire width of the roll and shall not include the first 3 ft (1 m). Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow.

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

Samples shall be taken at a rate of one per lot, at a minimum or one test per 100,000 ft^2 (10,000 m^2) of geomembrane.

9.4.2 Test Results

All conformance test results shall be reviewed, approved in writing, and material accepted or rejected by the LGM prior to the deployment of the geomembrane.

The LGM shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager. The LGM shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question

be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. The Manufacturer may have the same sample retested at two different CWM approved Geosynthetic QALs. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager.

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

9.5 SUBGRADE PREPARATION

9.5.1 Surface Preparation

The Earthwork Contractor shall be responsible for preparing the supporting soil for geomembrane placement. The Project Manager shall coordinate the work of the Earthwork Contractor and the Installer so that the requirements of the project specifications and the project QAM are met.

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

1. A qualified land surveyor has verified all lines and grades.
2. A qualified geotechnical engineer has verified that the supporting soil meets the criteria specified in the project specifications.
3. The surface to be lined has been rolled, compacted, or handworked so as to be free of irregularities, protrusions, loose soil, and abrupt changes in grade.
4. The surface of the supporting soil does not contain stones which may be damaging to the geomembrane.
5. There is no area excessively softened by high water content.
6. There is no area where the surface of the soil contains desiccation cracks with dimensions exceeding those allowed by the project specifications.
7. All temporary geomembranes, geotextiles, or other materials are removed.

The Installer shall certify in writing that the surface on which the geomembrane will be installed is acceptable. A certificate of acceptance shall be given by the Installer to the Geosynthetic

QAC prior to commencement of geomembrane deployment in the area under consideration. The Project Manager shall be given a copy of this certificate by the Geosynthetic QAC.

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

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

9.5.2 Anchor Trench

The Geosynthetic QAC shall verify that the anchor trench has been constructed according to the design drawings and project specifications.

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

Slightly rounded corners shall be provided in the trench so as to avoid sharp bends in the geomembrane. Excessive amounts of loose soil shall not be allowed to underlie the geomembrane in the anchor trench.

The anchor trench shall be adequately drained to prevent ponding or softening of the adjacent soils while the trench is open. The anchor trench shall be backfilled and compacted as outlined in the project specifications.

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

9.6 GEOMEMBRANE DEPLOYMENT

9.6.1 Panel Nomenclature

A field panel is defined as a unit of geomembrane which is to be seamed in the field, i.e., a field panel is a roll or a portion of a roll cut in the field.

It shall be the responsibility of the Geosynthetic QAC to ensure that each field panel is given an identification code (number or letter-number) consistent with the layout plan. This identification code shall be agreed upon by the Project Manager, Installer and Geosynthetic QAC. This field panel identification code shall be as simple and logical as possible. In general,

it is not appropriate to identify panels using roll numbers since roll numbers established in the manufacturing plant are usually cumbersome and are not related to location in the field. The Geosynthetic QAC shall establish a table or chart showing correspondence between roll numbers and field panel identification codes. The field panel identification code shall be used for all quality assurance records.

The Geosynthetic QAC shall verify that field panels are installed at the approximate locations indicated on the Installer's layout plan, as approved by the Project Manager.

9.6.2 Panel Deployment Procedure

The Geosynthetic QAC shall review the panel deployment progress of the Installer (keeping in mind issues relating to wind, rain, clay liner desiccation, and other site-specific conditions) and advise the Project Manager on its compliance with the approved panel layout drawing and its suitability to the actual field conditions. Once approved, only the Project Manager can authorize changes to the panel deployment procedure. The Geosynthetic QAC shall verify that the condition of the supporting soil does not change detrimentally during installation.

The Geosynthetic QAC shall record the identification code, location, and date of installation of each field panel.

Temporary hold down will be used during geomembrane installation and particularly against wind damage by sandbagging, tires, or other means as approved by the Project Manager. The selected method will not damage or cause leakage on liner surfaces or other materials (i.e., clay liner). Sand used in sandbags shall be well graded, clean sand with a maximum particle size of 0.25 inches (visual inspection). Source of sand will be approved by the Project Manager. In these matters, monitors will report such incidence to the LGM for cleaning.

9.6.3 Deployment Weather Conditions

Geomembrane deployment shall not be undertaken if weather conditions will preclude material seaming following deployment. (See Section 9.7.6)

The Geosynthetic QAC shall verify that the above conditions are fulfilled. Ambient temperature shall be measured by the Geosynthetic QAC in the area in which the panels are to be deployed. The Geosynthetic QAC shall inform the Project Manager of any weather related problems which may not allow geomembrane placement to proceed.

9.6.4 Method of Deployment

Before the geomembrane is handled on site, the Geosynthetic QAC shall verify that handling equipment to be used on the site is adequate and does not pose risk of damage to the geomembrane. During handling, the Geosynthetic QAC shall observe and verify that the Installer's personnel handle the geomembrane with care.

The Geosynthetic QAC shall verify the following:

1. Any equipment on the liner used does not damage the geomembrane by handling, excessive heat, leakage of hydrocarbons, or other means.
2. The prepared surface underlying the geomembrane has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement.
3. Any geosynthetic elements immediately underlying the geomembrane are clean and free of debris.
4. All personnel do not smoke or wear damaging shoes while working on the geomembrane, or engage in other activities which could damage the geomembrane.
5. The method used to unroll or adjust the panels does not cause excessive scratches or crimps in the geomembrane and does not damage the supporting soil.
6. The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels).
7. Adequate temporary loading and/or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent uplift by wind. In case of high winds, continuous loading, e.g., by sand bags, is recommended along edges of panels to minimize risk of wind flow under the panels.
8. Direct contact with the geomembrane is minimized, and the geomembrane is protected by geotextiles, extra geomembrane, or other suitable materials, in areas where excessive traffic may be expected.

The Geosynthetic QAC shall inform the Project Manager if the above conditions are not fulfilled.

9.6.5 Damage and Defects

Upon delivery to the site, the Geosynthetic QAC shall conduct a surface observation of all rolls for defects and for damage. This inspection shall be conducted without unrolling rolls unless defects or damages are found or suspected. The Geosynthetic QAC shall advise the Project Manager, in writing, of any rolls or portions of rolls which should be rejected and removed from the site because they have severe flaws, and/or minor repairable flaws.

The Geosynthetic QAC shall inspect each panel, after placement and prior to seaming, for damage and/or defects. The Geosynthetic QAC shall advise the Project Manager which panels, or portions of panels, should be rejected, repaired, or accepted. Damaged panels, or portions of damaged panels, which have been rejected shall be marked and their removal from the work area recorded by the Geosynthetic QAC. Repairs shall be made using procedures described in Section 9.10.

9.6.6 Writing on the Liner

To avoid confusion, the Installer and the Geosynthetic QAC shall each use different colored markers that are readily visible for writing on the geomembrane. The markers used must be semi-permanent and compatible with the geomembrane. The Installer shall use a white marker to write on the geomembrane. The Geosynthetic QAC shall use a yellow marker.

9.7 FIELD SEAMLNG

9.7.1 Seam Layout

Before installation begins, the Installer shall provide the Project Manager and the Geosynthetic QAC with a panel layout drawing, i.e., a drawing of the facility to be lined showing all expected seams. The LGM shall review the panel layout drawing and verify that it is consistent with accepted state-of-practice. No panels may be seamed without the written approval of the panel layout drawing by the Project Manager. In addition, panels not specifically shown on the panel layout drawing may not be used without the Project Manager's prior approval.

In general, seams should be oriented parallel to the line of maximum slope, i.e., oriented along not across, the slope. Seams are allowed on slopes which are less than or equal to 10H:1V. In corners and odd-shaped geometric locations, the number of seams should be minimized. No horizontal seam should be less than 5 ft (1.5 m) from the toe of the slope, or areas of potential stress concentrations, unless otherwise authorized by the Project Manager.

For the final cover geomembrane, extrusion welding the textured to textured seams will be the preferred welding method for the diagonal seam location at the corners. One full destructive test must be performed at each seam location. Seams will be welded diagonally on the panels that occur in corner locations and will be staggered at a minimum distance of 30 feet apart. One seam will be allowed between final cover benches on the slope.

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

9.7.2 Accepted Seaming Methods

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

Temporary bonding by leistering will be performed in accordance with Appendix F, Leister Bond Procedures.

9.7.2.1 *Extrusion Process*

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

The Geosynthetic QAC shall verify that:

1. The Installer maintains on-site the number of spare operable seaming apparatus decided upon at the pre-construction meeting.
2. Equipment used for seaming is not likely to damage the geomembrane.
3. Prior to beginning a seam, the extruder is purged until all heat-degraded extrudate has been removed from the barrel.
4. Clean and dry welding rods or extrudate pellets are used.
5. The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.

6. Grinding shall be completed no more than 1 hour prior to seaming.
7. A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage such that no damage occurs.
8. The geomembrane is protected from damage in heavy traffic areas.
9. Exposed grinding marks adjacent to an extrusion weld shall be minimized. In no instance shall exposed grinding marks extend more than 1/4 in. from the finished seamed area.
10. In general, the geomembrane panels are aligned to have a nominal overlap of 3 in. (75 mm) for extrusion welding. In any event, the final overlap shall be sufficient to allow peel tests to be performed on the seam.
11. No solvent or adhesive is used.
12. The procedure used to temporarily bond adjacent panels together does not damage the geomembrane; in particular, the temperature of hot air at the nozzle of any temporary welding apparatus is controlled such that the geomembrane is not damaged.

9.7.2.2 *Fusion Process*

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

The Geosynthetic QAC shall also verify that:

1. The Installer maintains on-site the number of spare operable seaming apparatus decided upon at the pre-construction meeting.
2. Equipment used for seaming is not likely to damage the geomembrane.
3. For cross seams, the edge of the cross seam is ground to an incline prior to welding.
4. The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.
5. A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage such that no damage occurs.
6. The geomembrane is protected from damage in heavy traffic areas.
7. A movable protective layer is used as required by the Installer directly below each overlap of geomembrane that is to be seamed to prevent buildup of moisture between the sheets and prevent debris from collecting around the pressure rollers.
8. In general, the geomembrane panels are aligned to have a nominal overlap of 5 in. (125 mm) for fusion welding. In any event, the final overlap shall be sufficient to allow peel tests to be performed on the seam.
9. No solvent or adhesive is used.

9.7.3 Seam Preparation

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

9.7.4 Trial Seams

Trial seams shall be made on fragment pieces of geomembrane liner to verify that conditions are adequate for production seaming. Such trial seams shall be made at the beginning of each seaming period, and at least once each five hours, for each production seaming apparatus used that day. Each seamer shall make at least one trial seam each day. Trial seams shall be made under the same conditions as actual seams. At the discretion of the Geosythetics QAC, trial seams may be Destructive Seam Tested as described in Section 9.9 in place of actual welded seams at the primary to secondary geomembrane seam locations in the anchor trench.

The trial seam sample shall be at least 5 ft (1.6 m) long by 1 ft (0.3 m) wide (after seaming) with the seam centered lengthwise. Seam overlap shall be as indicated in Section 9.6.2.

Two specimens shall, be cut from the sample with a 1 in. (25 mm) wide die. The specimens shall be cut by the Installer at locations selected randomly along the trial seam sample by the Geosynthetic QAC. The specimens shall be tested in peel using a field tensiometer. The tensiometer shall be capable of maintaining a constant jaw separation rate of two inches per minute. They should not fail in the seam as described in Section 9.9.5. If a specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus and seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial welds are achieved. The Geosynthetic QAC shall observe all trial seam procedures.

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

If agreed upon between the Project Manager and the LGM, and documented by the LGM in his daily report, the remaining portion of the trial seam sample can be subjected to destructive testing as indicated in Section 9.9.6. If a trial seam sample fails a test conducted by the Geosynthetic QAL, then a destructive seam test sample shall be taken from each of the seams completed by the seamer during the shift related to the subject trial seam. These samples shall be forwarded to the Geosynthetic QAL and, if they fail the tests, the procedure indicated in Section 9.9.7 shall apply. The conditions of this paragraph shall be considered satisfied for a given seam if a destructive seam test sample has already been taken.

9.7.5 General Seaming Procedures

During general seaming, the Geosynthetic QAC shall be cognizant of the following:

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

2. Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut fishmouths or wrinkles shall be seamed and any portion where the overlap is inadequate shall then be patched with an oval or round patch

of the same geomembrane extending a minimum of 6 in. (150 mm) beyond the cut in all directions.
3. If seaming operations are carried out at night, adequate illumination shall be provided.
4. Seaming shall extend to the outside edge of panels placed in the anchor trench.
5. All cross seam tees should be extrusion welded to a minimum distance of 4 in. (100 mm) on each side of the tee.
6. No field seaming shall take place without the Master Seamer being present.

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

9.7.6 Seaming Weather Conditions

9.7.6.1 *Normal Weather Conditions*

The normal required weather conditions for seaming are as follows:

1. Ambient temperature between 32°F (0°C) and 104°F (40°C) or sheet temperature less than 122°F (50°C) unless otherwise authorized by owner.
2. Dry conditions, i.e. no precipitation or other excessive moisture, such as fog or dew.
3. No excessive winds (excessive winds exceed 20 mph).

The LGM shall verify that these weather conditions are fulfilled and notify the Project Manager in writing if they are not. Ambient temperature shall be measured by the Geosynthetic QAC in the area in which the panels are to be placed. The Project Manager will then decide if the installation is to be stopped or special procedures are to be used.

9.7.6.2 *Cold Weather Conditions*

To ensure a quality installation, if seaming is conducted when the ambient temperature is below 32°F (0°C), the following conditions shall be met:

1. Geomembrane surface temperatures shall be determined by the Geosynthetic QAC at intervals of at least once per 100 ft of seam length to determine if preheating is required. For extrusion welding, preheating is required if the surface temperature of the geomembrane is below 32°F (0°C).
2. Preheating may be waived by the Project Manager based on a recommendation from the LGM, if the Installer demonstrates to the LGM's satisfaction that welds of equivalent quality may be obtained without preheating at the expected temperature of installation.
3. If preheating is required, the Geosynthetic QAC shall inspect all areas of geomembrane that have been preheated by a hot air device prior to seaming, to ensure that they have not been overheated.
4. Care shall be taken to confirm that the surface temperatures are not lowered below the minimum surface temperatures specified for welding due to winds or other adverse conditions. It may be necessary to provide wind protection for the seam area.

5. All preheating devices shall be approved prior to use by the Project Manager.
6. Additional destructive tests (as described in Section 9.9) shall be taken at an interval between 500 ft and 250 ft of seam length, at the discretion of the LGM.
7. Sheet grinding may be performed before preheating, if applicable.
8. Trial seaming, as described in Section 9.7.4, shall be conducted under the same ambient temperature and preheating conditions as the actual seams. Under cold weather conditions, new trial seams shall be conducted if the ambient temperature drops by more than 10°F from the initial trial seam test conditions. Such new seams shall be conducted upon completion of seams in progress during temperature drop.

9.7.6.3 Warm Weather Conditions

At sheet temperatures above 122°F or ambient temperature above 104°F, no seaming of the geomembrane shall permitted unless the Installer can demonstrate to the satisfaction of the Project Manager that geomembrane seam quality is not compromised.

Trail seaming, as described in Section 9.7.4, shall be conducted under the same ambient temperature conditions as the actual seams.

At the option of the Geosynthetic QAC, additional destructive tests (as described in Section 9.9) may be required for any suspect areas.

9.8 NONDESTRUCTIVE SEAM TESTING

9.8.1 Concept

The Installer shall nondestructively test all field seams over their full length using a vacuum test unit, air pressure test (for double fusion seams only), or other approved method (which shall be chosen by the Contractor and approved by the CQA Engineer and the NYSDEC prior to its use). Vacuum testing and air pressure testing are described in Sections 9.8.2 and 9.8.3, respectively. The purpose of nondestructive tests is to check the continuity of the seams. It does not provide quantitative information on seam strength. Nondestructive testing shall be carried out as the seaming work progresses, not at the completion of all field seaming.

For all seams, the Geosynthetic QAC shall:

1. Observe nondestructive testing procedures.
2. Record location, data, test unit number, name of tester, and outcome of all testing.
3. Visually inspect all tests.
4. Inform the Installer and Project Manager of any required repairs.

Any seams that cannot be nondestructive tested shall be cap-stripped with the same geomembrane.

The cap-stripping operations shall be observed by the Geosynthetic QAC and Installer for uniformity and completeness

The spark test method may be used for nondestructive testing of extrusion welds associated with HDPE pipe boots.

9.8.2 Vacuum Testing

The following procedures are applicable to vacuum testing.

1. The equipment shall consist of the following:

   a. A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, a porthole or valve assembly, and a vacuum gauge.
   b. A pump assembly equipped with a pressure controller and pipe connections.
   c. A rubber pressure/vacuum hose with fittings and connections.
   d. A soapy solution.
   e. A bucket and wide paint brush, or other means of applying the soapy solution.

2. The following procedures shall be followed:

   a. Energize the vacuum pump and reduce the applied pressure to approximately 5 psi (10 in. of Hg/35 kPa) gauge.
   b. Wet a strip of geomembrane approximately 12 in. by 48 in. (0.3 m by 1.2 m) with the soapy solution.
   c. Place the box over the wetted area.
   d. Close the bleed valve and open the vacuum valve.
   e. Ensure that a leak-tight seal is created.
   f. For a period of not less than 10 seconds, apply vacuum and examine the geomembrane through the viewing window for the presence of soap bubbles.
   g. If no bubble appears after 10 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 3 in. (75 mm) overlap, and repeat the process.
   h. All areas where soap bubbles appear shall be marked and repaired in accordance with Section 9.10.3.

9.8.3 Air Pressure Testing

The following procedures are applicable to double fusion welding which produces a double seam with an enclosed space.

1. The equipment shall consist of the following:

   a. An air pump (manual or motor driven), equipped with pressure gauge capable of generating and sustaining a pressure between 24 and 35 psi (200 and 233 kPa) and mounted on a cushion to protect the geomembrane.
   b. A rubber hose with fittings and connections.
   c. A sharp hollow needle, or other approved pressure feed device.

2. The following procedures shall be followed:

   a. Seal both ends of the seam to be tested.
   b. Insert needle or other approved pressure feed device into the air channel created by the fusion weld.
   c. Insert a protective cushion between the air pump and the geomembrane.

d. Pressurize the air channel to a pressure of approximately 30 psi (200 kPa). Close valve, allow 2 minutes for pressure to stabilize, and sustain pressure for at least 5 minutes. See Technical Specifications Sections 02400 and 02401 Part 304(C).
e. If loss of pressure exceeds the maximum permissible pressure differential as outlined in the project specifications or does not stabilize, locate faulty area and repair in accordance with Section 9.10.3.
f. Cut opposite end of tested seam area once testing is completed to verify continuity of the air channel. If air does not escape, locate blockage and retest unpressurized area. Seam the cut end of the air channel.
g. Remove needle or other approved pressure feed device and seal the hole in the geomembrane.

9.8.4 Test Failure Procedures

The Installer shall complete any required repairs in accordance with Section 9.10. For repairs, the Geosynthetic QAC shall:

1. Observe the repair and testing of the repair.
2. Mark on the geomembrane that the repair has been made.
3. Document the repair procedures and test results.

9.9 DESTRUCTIVE SEAM TESTING

9.9.1 Concept

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

9.9.2 Location and Frequency

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

1. A minimum frequency of one test location per 500 ft (150 m) of seam length performed by each welder. This minimum frequency is to be determined as an average taken throughout the entire facility.
2. Test locations shall be determined during seaming at the Geosynthetic QAC's discretion. Selection of such locations may be prompted by suspicion of overheating, contamination, offset welds, or any other potential cause of imperfect welding.

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

9.9.3 Sampling Procedures

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

1. Observe sample cutting.
2. Assign a number to each sample, and mark it accordingly.
3. Record sample location on layout drawing.
4. Record reason for taking the sample at this location (e.g., statistical routine, suspicious feature of the geomembrane).
5. Examine samples for holes, grooves, melt through, wavering welds, unusual weld width, and any other unusual characteristics.

All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in Section 9.10.3. The continuity of the new seams in the repaired area shall be tested according to Section 9.8.2.

9.9.4 Sample Dimensions

At each sampling location, two types of samples shall be taken by the Installer. First, two samples for field testing should be taken. Each of these samples shall be cut with a 1 in. (25 mm) wide die, with the seam centered parallel to the width. The distance between these two samples shall be 42 in. (1.1 m). If both samples pass the field test described in Section 9.9.5, a sample for laboratory testing shall be taken.

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

1. One portion to the Installer for optional laboratory testing, 12 in. by 12 in. (0.3 m by 0.3 m)
2. One portion for Geosynthetic QAL testing, 12 in. by 18 in. (0.3 m by 0.5 m) and
3. One portion to the Project Manager for archive storage, 12 in. by 12 in. (0.3 m by 0.3 m).

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

9.9.5 Field Testing

The two 1 in. (25 mm) wide strips mentioned in Section 9.9.4 and Section 9.7.4 shall be tested in the field using a tensiometer for peel adhesion and shall not fail according to the criteria in the project specifications. The tensiometer shall be capable of maintaining a constant jaw separation rate of two inches per minute. If the test passes in accordance with this section, the sample qualifies for testing in the laboratory. If it fails, the seam should be repaired in accordance with Section 9.9.7. Final judgement regarding seam acceptability, based on the failure criteria, rests with the LGM.

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

9.9.6 Laboratory Testing

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

Testing shall include "Seam Shear Strength" and Peel Adhesion". These terms along with minimum acceptable values shall be defined in the project specifications. At least five specimens shall be tested in each shear and peel. Specimens shall be selected alternately by test from the samples (i.e., peel, shear, peel, shear . . .). A passing test shall meet the minimum acceptable values in at least four of the five specimens tested for each method.

The Geosynthetic QAL shall provide verbal test results no more than 24 hours after they receive the samples. The LGM shall review laboratory test results as soon as they become available, and make appropriate recommendations to the Project Manager.

9.9.7 Destructive Test Failure Procedures

The following procedures shall apply when a sample fails a destructive test, whether that test is conducted by the geosynthetic QAL, or by field tensiometer. The Installer has two options:

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

All acceptable repaired seams shall be bound by two locations from which samples passing laboratory destructive tests have been taken. Passing laboratory destructive tests taken as indicated in Section 9.9 may be used as a boundary for the failing seam. In cases exceeding 150 ft (50 m) of repaired seam, a sample taken from the zone in which the seam has been repaired must pass destructive testing. Repairs shall be made in accordance with Section 9.10.3.

The Geosynthetic QAC shall document all actions taken in conjunction with destructive test failures. No installation of material above the HDPE geomembrane shall be done until

destructive testing for that section is completed and accepted by the geosynthetic QAC and test results delivered to NYSDEC engineer.

9.10 DEFECTS AND REPAIRS

9.10.1 Identification

All seams and non-seam areas of the geomembrane shall be examined by the Geosyntheric QAC for identification of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of examination. The geomembrane surface shall be cleaned by the Installer if the Geosynthetic QAC determines that the amount of dust or mud inhibits examination.

9.10.2 Evaluation

Each suspect location both in seam and non-seam areas shall be nondestructively tested using the methods described in Section 9.8. Each location which fails the nondestructive testing shall be marked by the Geosynthetic QAC and repaired by the Installer. All defects found during testing shall be numbered and marked immediately after detection. Work shall not proceed with any materials which will cover locations which have been repaired until appropriate nondestructive and laboratory test results with passing values are available.

9.10.3 Repair Procedures

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

1. The repair procedures available include:

    a. Patching, used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter.
    b. Patching, used to repair small tears, pinholes (less than or equal to 1/16"), or other minor, localized flaws.
    c. Capping, used to repair large lengths of failed seams.
    d. Extrusion welding the flap shall not be allowed.
    e. Removing bad seam and replacing with a strip of new material welded into place.

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

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

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

c. All seaming equipment used in repairing procedures shall meet the requirements of the project QAM.
d. Patches or caps shall be of the same geomembrane thickness and numbered. Extend at least 6 in. (150 mm) beyond the edge of the defect. All corners of patches shall be rounded with a radius of approximately 3 in. (75 mm).

9.10.4 Repair Verification

The Geosynthetic QAC shall observe all nondestructive testing of repairs and shall record the number of each repair, date, and test outcome. Each repair shall be nondestructively tested using the methods described in Section 9.8 as appropriate. Repairs which pass the nondestructive test shall be taken as an indication of an adequate repair. Repairs more than 150 ft (50 m) long require destructive test sampling, at the discretion of the LGM. Failed tests indicate that the repair shall be redone and retested until a passing test results.

9.10.5 Large Wrinkles

When seaming of the geomembrane is completed, and prior to placing overlying materials, the LGM shall indicate to the Project Manager which wrinkles should be cut and reseamed by the Installer. Also, LGM shall indicate to the Project Manager which areas are in tension (bridging or trampoline effect) should be cut and repaired by the Installer. The number of wrinkles and trampolines to be repaired should be kept to an absolute minimum. Therefore, wrinkles and trampolines should be located during the coldest part of the installation period, while keeping in mind the forecasted weather to which the uncovered geomembrane may be exposed. Wrinkles are considered to be large when the geomembrane can be folded over on to itself. This is generally the case for a wrinkle that extends 12 inches from the subgrade. Trampolines are considered for repair when the geomembrane is 9 inches above the clay liner. Seams produced while repairing wrinkles or trampolines shall be tested as outlined above.

When placing overlying material on the geomembrane, every effort must be made to minimize wrinkle development. If possible, cover should be placed during the coolest weather available. In addition, small wrinkles should be isolated and covered as quickly as possible to prevent their growth. The placement of cover materials shall be observed by the Geosynthetic QAC to ensure that wrinkle formation is minimized.

9.11 GEOMEMBRANE PROTECTION

The quality assurance procedures indicated in this Section are intended only to assure that the installation of adjacent materials does not damage the geomembrane. No installation of materials above the geomembrane shall proceed until all geomembrane testing has been completed for that segment. The quality assurance of the adjacent materials themselves are covered in separate sections of this manual.

9.11.1 Soils

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

1. Placement of soils on the geomembrane shall not proceed at an ambient temperature below 32°F (0°C) nor above 104°F (40°C) unless written approval is obtained from Project Manager.
2. Placement of soil on the geomembrane should be done during the coolest part of the day to minimize the development of wrinkles in the geomembrane.
3. A geotextile or other cushion approved by the Designer is generally required between aggregate and the geomembrane.
4. Equipment used for placing soil shall not be driven directly on the geomembrane.
5. A minimum thickness of 1 ft (0.3m) of soil is specified between a light dozer or equipment wheel pressure of 5 psi (or lighter) and the geomembrane.
6. In any areas traversed by any vehicles other than low ground pressure vehicles approved by the Project Manager, the soil layer shall have a minimum thickness of 3 ft (0.9 m). This requirement may be waived if provisions are made to protect the geomembrane through an engineered design. Drivers shall proceed with caution when on the overlying soil and prevent spinning of tires or sharp turns.

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

9.11.2 Concrete

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

9.11.3 Sumps and Appurtenances

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

1. Installation of the geomembrane in sump and appurtenant areas, and connection of geomembrane to sumps and appurtenances have been made according to specifications.

2. Extreme care is taken while welding around appurtenances since neither non-destructive nor destructive testing may be feasible in these areas.
3. The geomembrane has not been visibly damaged while making connections to sumps and appurtenances.
4. A representative of the Geosynthetic QAC shall be present at all times when the installer is welding geomembrane to appurtenant structures.

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

10.0 GEOTEXTILES

10.1 DEFINITION AND APPLICABILITY

Geotextiles are used in cushioning and filtering applications in lining systems. This section does not describe procedures for other applications such as erosion control or reinforcement.

This section is applicable to nonwoven geotextiles made of polyester or polypropylene and not applicable to nonwoven geotextiles made of other materials or woven geotextiles.

10.2 MANUFACTURING PLANT INSPECTION

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

The manufacturing plant inspection shall include:

1. Verification that properties guaranteed by the Manufacturer meet all CWM and/or project specifications.
2. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.
3. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.
4. Review of packaging, handling, storage, and transportation procedures and verification that these procedures will not damage the geotextile.
5. Verification that roll packages have a label indicating the name of the manufacturer, type of geotextile, roll number, and roll dimensions.
6. Verification that the geotextiles are inspected continuously for the presence of needles using a metal detector.

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

10.3 QUALITY CONTROL DOCUMENTATION

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

1. The origin (resin supplier's name and resin production plant) and identification (brand name and number) of the resin used to manufacture the geotextile.
2. Copies of dated quality control certificates issued by the resin supplier.
3. Reports on tests conducted by the Manufacturer to verify that resin used to manufacture the geotextile meets the Manufacturer's resin specifications.

4. Reports on quality control tests conducted by the Manufacturer to verify that the geotextile manufactured for the project meets the project specifications.
5. Documentation shall be provided to prove that the reclaimed polymer added less than or equal to 2%, to the resin during manufacturing was done with appropriate cleanliness.
6. A list of the materials which comprise the geotextile, expressed in the following categories as percent by weight: base polymer, carbon black, other additives.
7. A specification for the geotextile, which includes all properties published by the Manufacturer, measured using the appropriate test methods.
8. Written certification that minimum roll values given in the specification are guaranteed by the Manufacturer.
9. For non-woven geotextiles, written certification that the Manufacturer has continuously inspected the geotextile for the presence of needles and found the geotextile to be needle-free.
10. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificates shall include roll identification numbers, testing procedures and results of quality control tests. At a minimum, results shall be given in accordance with the Technical Specifications for:

a. Mass per unit area (ASTM D3776, D5261).
b. Grab strength (ASTM D4632).
c. Trapezoidal tear strength (ASTM D4533).
d. Burst strength (ASTM D3786).
e. Puncture strength (ASTM D4833).
f. UV resistance (ASTM D4355).
g. Filtration (ASTM D4751).
h. Permeability (ASTM D4491).

Quality control tests listed above as a, b, c, d, & e shall be performed for at least every 100,000 ft^2 (10,000 m^2) of geotextile produced. Only Manufacturer quality control certificates that include roll testing procedures and results of quality control tests are required for tests listed above as f, g, & h.

The Manufacturer shall identify all rolls of geotextiles with the following:
1. Manufacturer's name.
2. Product identification.
3. Roll number.
4. Roll dimensions.
5. Mark rolls with special instructions when required (i.e., this side up, etc.)

The LGM shall review and approve in writing these documents and shall report any discrepancies with the above requirements to the Project Manager. The LGM shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.

4. Roll packages are appropriately labeled.
5. Certified minimum roll properties meet the project specifications.
6. Verify that project specifications were submitted by the Project Manager to the Installer.
7. Certification of less than 2% reclaimed polymer added.

10.4 CONFORMANCE TESTING

Upon delivery of the rolls of geotextiles, the Geosynthetic QAC shall visually ensure that conformance test samples are obtained for the geotextile. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance with the project specifications.

At a minimum, the following conformance tests shall generally be performed on geotextiles:

1. Mass per unit area.
2. Grab strength.
3. Trapezoidal tear strength.
4. Burst strength.
5. Puncture strength.
6. Filtration.
7. Permeability.

These conformance tests shall be performed in accordance with the test methods specified in the project specifications. Other conformance tests may be required by the Designer.

10.4.1 Sampling Procedures

The rolls to be sampled shall be selected by the Geosynthetic QAC. Samples shall be taken across the entire width of the roll and shall not include the first complete revolution of fabric on the roll. Samples shall not be taken from any portion of a roll which has been subjected to excess pressure or stretching. Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow. All lots of material and the particular test sample that represents each lot should be defined before the samples are taken.

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

Samples shall be taken at a rate of one per lot, or at a minimum of one conformance test per 100,000 ft^2 (10,000 m^2) of geotextile.

10.4.2 Test Results

All conformance test results shall be reviewed and material accepted or rejected by the LGM prior to the deployment of the geotextile.

The LGM shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager. The LGM shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications. Materials and rolls which are in non-compliance shall be rejected.

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

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

10.5 GEOTEXTILE DEPLOYMENT

During shipment and storage, the geotextile shall be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions. Geotextile rolls shall be shipped and stored in relatively opaque and watertight wrappings. Wrappings shall be removed shortly before deployment.
The Geosynthetic QAC shall observe rolls upon delivery at the site and any deviation from the above requirements shall be reported to the Project Manager.

The Installer shall handle all geotextiles in such a manner as to ensure they are not damaged in any way, and the following shall be complied with:

1. On slopes, the geotextiles shall be securely anchored and then rolled down the slope in such a manner as to continually keep the geotextile sheet in tension.
2. In the presence of wind, all geotextiles shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material. Project Manager will approve source of sand used (well graded clean sand).

3. Geotextiles shall be cut using a geotextile cutter (hook blade) only. If in place, special care shall be taken to protect other materials from damage, which could be caused by the cutting of the geotextiles.
4. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geotextile.
5. During placement of geotextiles, care shall be taken not to entrap in or beneath the geotextile: stones; excessive dust; or moisture that could damage the geomembrane or may cause clogging of drains or filters or hamper subsequent seaming.
6. A visual examination of the geotextile shall be carried out over the entire surface, after installation, to ensure that no potentially harmful foreign objects, such as needles, are present.
7. Geotextile shall be placed and anchored in the manner and locations shown on the drawings. Any modifications to geotextile placement must be approved by the Project Manger.
8. The geotextile shall be protected at all times during construction from contamination by surface runoff and any fabric so contaminated shall be removed and replaced with uncontaminated fabric.

The Geosynthetic QAC shall note any non-compliance and report it to the Project Manager.

10.6 SEAMING PROCEDURES

Geotextiles shall be overlapped a minimum of 3 in. (75 mm) prior to seaming. In general, no horizontal seams shall be allowed on side slopes greater than 10H:1V (i.e., seams shall be along, not across, the slope), except as part of a patch.

All geotextiles shall be continuously sewn. Spot sewing is not allowed.

The Installer shall pay particular attention at seams to ensure that no earth cover material could be inadvertently inserted beneath the geotextile, if applicable.

Securing pins will not be used in geotextile installation. Sewing shall be done using polymeric thread with chemical and ultraviolet light resistance properties equal to or exceeding those of the geotextile. Sewing shall be done using machinery and stitch types specified in the project specifications or as approved in writing by the Project Manager and the LGM.

As an option, the geotextile may be overlapped and heat leistered in limited areas approved by the CQA Engineer and NYSDEC. When the Contractor has demonstrated sewing is not feasible based on field conditions, an alternative method will be to overlap the existing geotextile onto the new geotextile a minimum of 12 inches and continuously heat leister the two pieces together. If any burn holes are detected, the burn hole will have to be patched with a minimum overlap of 12 inches and continuously heat leistered.

10.7 DEFECTS AND REPAIRS

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

On slopes, a patch made from the same geotextile shall be sewn into place in accordance with the project specifications. Should any tear exceed 10% of the width of the roll, that roll shall be removed from the slope and replaced.

On non-slope areas, a patch made from the same geotextile shall be sewn into place with a minimum of 12-inch overlap in all directions.

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

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

10.8 GEOTEXTILE PROTECTION

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

1. The geotextile and underlying lining materials are not damaged.
2. Minimal slippage of the geotextile on underlying layers occurs.
3. No excess tensile stresses occur in the geotextile.

Granular materials shall be placed on geotextiles over the prepared area. During backdumping and spreading, a minimum depth of 1-foot of granular material shall be maintained at all times between the fabric and wheels of trucks or spreading equipment. All equipment used in spreading or traveling on the 1-foot layer for any reason shall exert a pressure of less than 63 psi to the underlying geotextile using a 2(H):1(V) stress distribution. Dozer blades, etc. shall not make direct contact with the fabric; however, if tears occur in the fabric during the spreading operation, the granular material shall be cleared from the fabric and the damage area repaired as previously described.

Large fabric wrinkles which may develop during the spreading operations shall be folded and flattened in the direction of the spreading.

Unless otherwise specified by the Designer, all lifts of soil material shall be in conformance with the guidelines given in Section 9.11.1.

Any noncompliance shall be noted by the Geosynthetic QAC and reported to the Project Manager.

11.0 GEONETS

11.1 DEFINITION AND APPLICABILITY

Geonets consist of drainage nets used in lining systems. This section is applicable to geonets made of HDPE, including "foamed" HDPE products and is not applicable to geonet made of other polymers.

11.2 MANUFACTURING PLANT INSPECTION

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

The manufacturing plant inspection shall include:

1. Verification that properties guaranteed by the Manufacturer meet all project specifications.
2. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.
3. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.
4. Review of packaging, handling, storage, and transportation procedures and verification that these procedures will not damage the geonet.
5. Verification that roll packages have a label indicating the name of the manufacturer, type of geonet, roll number, and roll dimensions.

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

11.3 QUALITY CONTROL DOCUMENTATION

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

1. The origin (supplier's name and production plant) and identification (brand name and number) of the resin.
2. Copies of dated quality control certificates issued by the resin supplier.
3. Results of tests conducted by the Manufacturer to verify that the resin used to manufacture the geonet meets the project specifications for melt flow index and density.
4. A certification indicating that the amount of reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness and for geonet used for leachate collection applications, did not exceed 2% by weight.
5. A list of the materials which comprise the geonet, expressed in the following categories as percent by weight: polyethylene, carbon black, other additives.

6. A specification for the geonet which includes all properties contained in the project specifications measured using the appropriate test methods.
7. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.
8. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificates shall include roll identification numbers, sampling procedures and results of quality control tests. At a minimum, results shall be given for

    a. Density (ASTM D1505).
    b. Mass per unit area (ASTM D3776, D5261).
    c. Thickness (ASTM D1777, D5199).
    d. Carbon black content (ASTM D1603, D4218).
    e. Tensile Strength (ASTM D1682, D5035).
    f. Transmissivity (ASTM D4716).

Quality control tests shall be performed in accordance with the test methods specified in the project specifications for every 40,000 ft^2 (4,000 m^2) of geonet produced.

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

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

The LGM shall review and approve in writing these documents and shall report any discrepancies with the above requirements to the Project Manager. The LGM shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.
4. Roll packages are appropriately labeled.
5. Certified minimum properties meet the project specifications.

11.4 CONFORMANCE TESTING

Upon delivery of the rolls of geonet, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geonet. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance to the project specifications.

At a minimum, the following tests shall be performed:

1. Density.
2. Mass per unit area.
3. Thickness.

These conformance tests shall be performed in accordance with the test methods specified in the project specifications. Other conformance tests may be required by the project specifications. If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out of specification and rejected. Alternatively, at the option of the Project Manager, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out-of-specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

11.4.1 Sampling Procedures

The rolls to be sampled shall be selected by the Geosynthetic QAC. Samples shall be taken across the entire width of the roll and shall not include the first 3 ft (1 m). Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow.

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

Samples shall be taken at a rate of one per lot, or at a minimum of one conformance test per 100,000 ft^2 (10,000 m^2) of geonet.

11.4.2 Test Results

All conformance test results shall be reviewed and material accepted or rejected by the LGM prior to the deployment of the geonet.

The LGM shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager. The LGM shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present

during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different CWM approved Geosynthetic QALs at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager.

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

11.5 GEONET DEPLOYMENT

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

Geonet cleanliness is essential to its performance. Therefore, the geonet rolls should be protected against dust and dirt during shipment and storage.

The Geosynthetic QAC shall verify that the geonet is free of dirt and dust prior to installation. The Geosynthetic QAC shall report any rolls judged dirty to the Project Manager. If the geonet is judged dirty or dusty, it shall be washed by the Installer prior to installation. Washing operations shall be observed by the Geosynthetic QAC and improper washing operations shall be reported to the Project Manager.

The Installer shall handle all geonet in such a manner as to ensure that it is not damaged in any way, and the following shall be complied with:

1. On slopes, the geonet shall be secured and rolled down the slope in such a manner as to continually keep the geonet sheet in tension. If necessary, the geonet shall be positioned by hand after being unrolled to minimize wrinkles.
2. In the presence of wind, all geonet shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.
3. Unless otherwise specified, geonet shall not be welded to geomembrane.
4. Geonet shall only be cut using scissors, or other cutting tools approved by the Project Manager that will not damage the underlying geosynthetics. Care shall be taken not to leave tools in the geonet.

5. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geonet.
6. During placement of geonet, care shall be taken not to entrap dirt or excessive dust in the geonet that could cause clogging of the drainage system, and/or stones that could damage the adjacent geomembrane. If dirt or excessive dust is entrapped in the geonet, it should be washed clean prior to placement of the next material on top of it. In this regard, care shall be taken with the handling of sandbags, to prevent puncturing the sandbag. Wash water and sediment will be removed after washing to approval of Geosynthetic CQA.

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

11.6 SEAMS AND OVERLAPS

Adjacent geonet shall be joined according to construction drawings and specifications. At a minimum, the following requirements shall be met:

1. Adjacent rolls shall be overlapped by at least 4 in. (100 mm).
2. The geonet overlaps shall be tied with plastic fasteners. Tying devices shall be white or yellow for easy inspection. Metallic devices are not allowed.
3. Tying shall be every 5 ft (1.5 m) along the slope, every 6 in. (0.15 m) in the anchor trench and every 6 in. (0.15 m) along end-to-end seams on the base of the landfill.
4. In general, no horizontal seams shall be allowed on side slopes.
5. In the corners of the side slopes of rectangular landfills, where overlaps between perpendicular geonet strips are required, an extra layer of geonet shall be unrolled along the slope, on top of the previously installed geonet, from top to bottom of the slope.
6. When more than one layer of geonet is installed, joints shall be staggered.
7. When several layers of geonet are stacked, rolls shall be deployed in the same direction to prevent strands of one layer from penetrating the channels of the adjacent layer.

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

When several layers of geonet are stacked, care shall be taken to prevent strands of one layer from penetrating the channels of the next layer, thereby significantly reducing the transmissivity. This cannot happen if stacked geonet are placed in the same direction. A stacked geonet shall never be laid in perpendicular directions to the underlying geonet (unless otherwise specified by the Designer).

11.7 DEFECTS AND REPAIRS

If the hole or tear width is less than 50% of the width of the roll, the damaged area shall be repaired as follows:

1. A patch shall be placed extending 1 ft (0.3 m) beyond the edges of the hole or tear.
2. The patch shall be secured to the original geonet by tying every 6 in. (0.15 m). Tying devices shall be as indicated in Section 11.6.

If the hole or tear width across the roll is more than 50% of the width of the roll, the damaged area shall be repaired as follows:

1. On the base of the landfill, the damaged area shall be cut out and the two portions of the geonet shall be joined as indicated in Section 11.6.
2. On side slopes, the damaged geonet roll shall be removed and replaced.

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

11.8 GEONET PROTECTION

Soil should never be placed in direct contact with geonet. Soil materials near the geonet shall be placed in such a manner as to ensure:

1. The geonet and underlying lining materials are not damaged.
2. Minimal slippage of the geonet on underlying layers occurs.
3. No excess tensile stresses occur in the geonet.

Unless otherwise specified by the Designer, all lifts of soil material shall be in conformance with the guidelines given in Section 9.11.1.

Any noncompliance shall be noted by the Geosynthetic QAC and reported in writing to the Project Manager.

12.0 GEOTEXTILE/GEONET COMPOSITE

Geotextile/geonet composite are materials used as drainage and filter media in lining systems. This section is applicable to drainage geocomposites made of nonwoven geotextiles (polyester or polypropylene) and HDPE geonet. The geotextiles may be bonded to one side of the geonet or both, depending on the application. It is not applicable to composites made with other components.

12.1 DEFINITION AND APPLICABILITY

Geotextile/Geonet Composite (geocomposite) consists of a geotextile which is thermally bonded to geonet. The geotextile may be bonded to one side or both sides of the geonet. The geocomposite is used as a drainage component of lining systems.

12.2 MANUFACTURING PLANT INSPECTION

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

The manufacturing plant inspection shall include:

1. Verification that the proper quality control documentation has been received by the geocomposite manufacturer from the component manufacturers (Section 10.2, 11.2).
2. Verification that properties guaranteed by the Manufacturer meet all project specifications.
3. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.
4. Spot inspection of the rolls and verification that they are free of imperfections or contamination by foreign matter.
5. Review of packaging, handling, storage, and transportation procedures and verification that these procedures will not damage the geocomposite.
6. Verification that roll packages have a label indicating the name of the manufacturer, type of geocomposite, roll number, and roll dimensions.

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

12.3 QUALITY CONTROL DOCUMENTATION

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

1. The origin (supplier's name and production plant) and identification (brand name and number) of the geotextile and geonet used to fabricate the geocomposite.
2. Copies of dated quality control certificates issued by the geotextile and geonet supplier. These certificates shall contain the results of the quality control tests performed on the geocomposite components outlined in Section 10 and 11 of this QAM.
3. A specification for the geocomposite which includes all properties published by the Manufacturer measured using the appropriate test methods.
4. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.
5. Quality control certificates for the geocomposite, signed by a responsible party employed by the Manufacturer. The quality control certificates shall include roll identification numbers, testing procedures and results of quality control tests. At a minimum, results shall be given for:

    a. Mass per unit area (ASTM D3776, D5261).
    b. Thickness (ASTM D1777, D5199).
    c. Geotextile-geonet adhesion (ASTM D7005).
    d. Transmissivity Testing (ASTM D4716).

Quality control tests shall be performed for at least every 40,000 ft^2 (4,000 m^2) and transmissivity testing for at least every 100,000 ft^2 (10,000 m^2) of geocomposite produced.

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

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

The LGM shall review these documents, shall approve all documentation in writing, and shall report any discrepancies with the above requirements to the Project Manager. The LGM shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.
4. Roll packages are appropriately labeled.
5. Certified minimum roll properties meet the project specifications.
6. Project specifications were submitted by the Project Manager to the Installer.

12.4 CONFORMANCE TESTING

Upon delivery of the rolls of geocomposite, the Geosynthetic QAC shall visually ensure that conformance test samples are obtained for the geocomposite. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance with the project specifications.

At a minimum, the following conformance tests shall generally be performed on geocomposite as a unit:

1. Mass per unit area.
2. Thickness.
3. Geotextile-geonet adhesion.
4. Transmissivity test.

These conformance tests shall be performed in accordance with the test methods specified in the project specifications. Additional conformance tests may be required by the project specifications.

12.4.1 Sampling Procedures

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

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

Samples shall be taken at a rate of one per lot, or at a minimum of one conformance test per 100,000 ft^2 (10,000 m^2) of geocomposite.

12.4.2 Test Results

All conformance test results shall be reviewed and material accepted or rejected by the LGM prior to the deployment of the geocomposite.

The LGM shall examine all results from laboratory conformance testing and shall report any non-conformance to the Project Manager. The LGM shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present

during the testing. This retesting shall be done at the expense of the Manufacturer. The Manufacturer may have the same sample retested at two different CWM approved Geosynthetic QALs at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager.

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

12.5 GEOCOMPOSITE DEPLOYMENT

During shipment and storage, the geocomposite shall be protected from ultraviolet light exposure, moisture, mud, dirt, dust, puncture, cutting, or any other damaging conditions. Geocomposite rolls shall be shipped and stored in relatively opaque and watertight wrappings. The roll wrappings shall be removed shortly before deployment.

For one-sided geocomposite, the Geosynthetic QAC shall verify that the geonet is free of dirt and dust prior to installation. The Geosynthetic QAC shall identify any dirty rolls and report them to the Project Manager. If the geonet is judged to be dirty or dusty, it shall be washed by the Installer prior to installation. Washing operation shall be observed by the Geosynthetic QAC and improper washing operations shall be reported to the Project Manager.

The Geosynthetic QAC shall observe rolls upon delivery at the site and any deviation from the above requirements shall be reported to the Project Manager.

The Installer shall handle all geocomposite in such a manner as to ensure they are not damaged in any way, and the following shall be complied with:

1. On slopes, the geocomposite shall be securely anchored and then rolled down the slope in such a manner as to continually keep the geocomposite sheet in tension. If necessary, the geocomposite shall be positioned by hand after being unrolled to minimize wrinkles.
2. In the presence of wind, all geocomposites shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.
3. Unless otherwise specified, single sided geocomposite shall not be welded to the geomembrane.

4. Geocomposites shall be cut using a hook blade or other tool approved by the Project Manager. If in place, special care shall be taken to protect underlying geosynthetics from damage which could be caused by the cutting of the geocomposite. Care shall be taken not to leave the tools in the geocomposite.
5. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geocomposite.
6. During placement of geocomposite, care shall be taken not to entrap in or beneath the geocomposite, stones, or dirt that could damage the geomembrane, cause clogging of drains or filters, or hamper subsequent seaming. If dirt or excess dust is entrapped in the geonet of single sided geocomposite it should be washed clean prior to placement of the next material on top of it. Wash water and sediment removed after washing to approval of Geosynthetic CQA. In this regard, care shall be taken with the handling of sandbags, to prevent puncturing the sandbag.
7. A visual examination of the geotextile of the geocomposite shall be carried out over the entire surface, after installation, to ensure that no potentially harmful foreign objects, such as needles, are present.

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

12.6 SEAMING PROCEDURES

In general, no horizontal seams shall be allowed on side slopes greater than 10H:1V (i.e., seams shall be along, not across, the slope), except as part of a patch. Adjacent geocomposites shall be joined according to construction drawings and project specifications.

12.6.1 Geonet Seams

At a minimum, the following requirements shall be met

1. Adjacent geonet shall be overlapped by at least 4 in. (100 mm).
2. The geonet overlaps shall be tied with plastic fasteners. Tying devices shall be white or yellow for easy inspection. Metallic devices are not allowed.
3. Tying shall be every 5 ft (1.5 m) along the slope, every 6 in. (0. 15 m) in the anchor trench, and every 6 in. (0. 15 m) along end-to-end seams on the base of the landfill.
4. In the corners of the side slopes of rectangular landfills, where overlaps between perpendicular geonet strips are required, an extra layer of geonet shall be unrolled along the slope, on top of the previously installed geonet, from top to bottom of the slope.
5. When more than one layer of geonet is installed, joints shall be stagggered.
6. When several layers of geonet are stacked, rolls shall be deployed in the same direction to prevent strands of one layer from penetrating the channels of the adjacent layer.

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

12.6.2 Geotextiles Seaming

Perform geotextile seaming in accordance with Section 10.6.

12.7 DEFECTS AND REPAIRS

Any portion of the geocomposite exhibiting a flaw shall be repaired. Prior to acceptance of the geocomposite, the Installer shall locate and repair all damaged areas as directed by the Geosynthetic QAC. The Geosynthetic QAC shall observe any repair and report any noncompliance with the following requirements in writing to the Project Manager.

12.7.1 Small Defects

If in the Geosynthetic QAC's judgement, the defect is determined to be small, typically smaller than 3 ft by 3 ft, the geocomposite shall be repaired as follows:

12.7.1.1 If the geonet is judged to be undamaged but the geotextile is damaged, a patch of geotextile shall be placed. The geotextile patch shall be sewn in place with a minimum of 12-inch overlap in all directions.

12.7.1.2 If the geonet is judged to be damaged, the damaged geonet shall be removed. A section of geonet shall be cut to replace the removed section. The geonet shall be tied to the existing geonet using white plastic fasteners placed at least every 6 inches. A geotextile patch shall be placed over the repaired geonet section. The geotextile patch shall be sewn in place with a minimum of 12-inch overlap in all directions.

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

12.7.2 Large Defects

If in the Geosynthetic QAC's judgement, the defect is determined to be large, typically larger than 3 ft by 3 ft, the geocomposite shall be replaced.

12.8 PROTECTION

For single sided geocomposites soils should never be placed in direct contact with geonet. All soil materials located on top of the geocomposite shall be deployed in such a manner as to ensure:

1. The geocomposite and underlying lining materials are not damaged.
2. Minimal slippage of the geocomposite on underlying layers occurs.
3. No excess tensile stresses occur in the geocomposite.

Unless otherwise specified by the Designer, all lifts of soil material shall be in conformance with the guidelines given in Section 9.11.1.

Any noncompliance shall be noted by the Geosynthetic QAC and reported to the Project Manager.

PC/MODELCIT/MODELNEW

13.0 GEOSYNTHETIC CLAY LINERS

13.1 DEFINITIONS AND APPLICABILITY

Geosynthetic Clay Liners (GCLs) are geocomposite materials that consist of a low hydraulic conductivity montmorillonite-rich expansive clay (bentonite) core which is bonded to a geotextile backing. GCLs are used as barriers in lining systems.

13.2 MANUFACTURING PLANT INSPECTION

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

The manufacturing plant inspection shall include:

1. Verification that properties guaranteed by the Manufacturer are met and meet all project specifications.
2. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.
3. Spot inspection of the rolls and verification that they are free of imperfections or contamination by foreign matter.
4. Review of handling, storage, and transportation procedures, and verification that these procedures will not damage the GCL.
5. Verification that roll packages have a label indicating the name of the manufacturer, roll number, and roll dimensions.
6. Verification that overlap lines are printed on the rolls.

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

13.3 QUALITY CONTROL DOCUMENTATION

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

1. The origin (supplier's name and location of material source) and identification of the bentonite used for production of the GCL.
2. Copies of dated quality control information issued by the bentonite supplier.
3. Results of quality control tests conducted by the GCL Manufacturer to verify that the bentonite supplied met the GCL Manufacturer's specifications.
4. Copies of dated quality control information provided by the geotextile Manufacturer.

5. A specification for the GCL which includes all properties contained in the project specifications for GCLs.

6. Written certification that the minimum values given in the project specifications are guaranteed by the Manufacturer.

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

   a. Moisture content (ASTM D4643)
   b. Hydraulic conductivity (ASTM 5084, GRI GCL-2)
   c. Swell index (GRI GCL-1, ASTM D5890)
   d. Mass per unit area (ASTM D3776, D5261, D5993)

These quality control tests shall be performed in accordance with the test methods for at least every 10,000 ft^2 (1,000 m^2) for moisture content, swell index and mass per unit area. Hydraulic conductivity tests shall be performed in accordance with the test methods for at least every 100,000 ft^2 (10,000 m^2) of GCL produced.

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

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

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

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.
4. Rolls are appropriate labeled.
5. Certified minimum properties meet the project specifications.
6. Project specifications and the QAP were submitted by Project Manager to the Installer.
7. Manufacturer confirms a field drying shrinkage potential to allow proper seam overlap in the field.

13.4 CONFORMANCE TESTING

13.4.1 Sampling Procedures

Upon delivery of the rolls of GCL, the Geosynthetic QAC shall ensure that conformance test samples are obtained. The rolls to be sampled shall be selected by the Geosynthetic QAC.

Samples shall not be taken from any portion of a roll which has been damaged. Unless otherwise specified, samples shall be 1 ft (0.3 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing liner. Alternatively, a lot may be designated by the Geosynthetic QAC based on a review of all roll information including quality control documentation and manufacturing records. If the Project Manager desires, the Geosynthetic QAC can perform the conformance test sampling at the manufacturing plant. This may expedite the installation process for certain projects.

Unless otherwise specified in the project specifications, samples shall be taken at a rate of one per lot, not to be less than one per 100,000 ft^2 (10,000 m^2) of GCL. Samples for hydraulic conductivity conformance tests shall be taken at least every 250,000 ft^2 (25,000 m^2). These samples shall be forwarded to the Geosynthetic QAL for testing to ensure conformance to the project specifications.

13.4.2 Conformance Tests

At a minimum, for the GCL to be used in the baseliner, the following conformance tests shall be conducted on the GCL as a unit:

1. Moisture content (ASTM-D4643)
2. Hydraulic conductivity (ASTM 5084)
3. Mass per unit area (ASTM D3776)

At a minimum, for the GCL to be used in the final cover, the following conformance tests shall be conducted on the GCL as a unit:

1. Moisture content (ASTM D4643)
2. Hydraulic conductivity (ASTM 5084)
3. Mass per unit area of bentonite (ASTM D5993)
4. Mass per unit area upper and lower layer geotextile (ASTM D5261)
5. Index flux of GCL (ASTM D5887)
6. Grab tensile strength of GCL (ASTM D4632)

Additional conformance tests may be required by the project specifications.

13.4.3 Test Results

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

If the Manufacturer has reason to believe the failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the manufacturer present during the testing. Alternatively, the Manufacturer may have the sample retested at two different Owner-approved Geosynthetic QALs. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original

Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to approval of the Project Manager.

If a test result is in non-conformance, all material from the lot represented by the failing test should be considered out-of-specification and rejected. Alternatively, at the option of the Project Manager, additional conformance test samples my be taken to "bracket" the portion of the lot not meeting specification (note that this procedures is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out-of-specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number or rolls within the lot.

13.5 GCL DEPLOYMENT

During shipment and storage, the GCL shall be protected from ultraviolet light exposure, moisture, excessive humidity, puncture, cutting, or any other damaging conditions. GCL rolls shall be shipped and stored in relatively opaque and watertight wrappings. GCL rolls shall be stored away from wet ground and be covered with a watertight tarp or under a roof to protect the stored rolls from hydration. The roll wrappings shall be removed shortly before deployment.

The Geosynthetic QAC shall observe rolls upon delivery and prior to deployment at the site and report any deviations from the above requirements to the Project Manager.

The Geosynthetic QAC shall review the GCL panel deployment progress and advise the Project Manager on its conformance with the actual field conditions. The Geosynthetic QAC shall verify that the Installer handles the GCL material in such a manner as to ensure that it is not damaged, and the following are complied with:

1. Final cover subgrade areas prepared for GCL deployment have been proof rolled and visually observed by the Geosynthetic QAC in accordance with the Technical Specifications.
2. The supporting soil surface for the GCL is smooth, firm, unyielding, and free of debris, vegetation, sticks, sharp rocks, void spaces, ice, abrupt elevation changes, standing water, or other materials that could damage the GCL. As determined by the geosynthetic QAC, all protrusions having the potential to damage the GCL must either be removed, crushed, or pushed into the surface with a smooth-drum compactor.
3. On slopes, the GCL rolls shall be securely anchored and the GCL material then deployed down the slope in such a manner as to keep the GCL panel in tension.
4. The GCL should be installed with the proper side of the material facing upward. The proper orientation of the material should be as specified by the project specification.
5. If the GCL is cut in place, special care shall be taken to protect underlying geosynthetic materials from damage, which could be caused by cutting of the GCL.
6. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the GCL.
7. During placement of the GCL, care shall be taken not to entrap beneath the GCL any stones, excessive dust, or moisture that could damage the GCL or any underlying geosynthetics.
8. After installation, a visual examination of the GCL shall be carried out over the entire surface to ensure that no potentially harmful foreign objects, contaminated soil, needles from the manufacturing process, or damaged areas are present.

9. Excess loss of bentonite on edges during deployment should be minimized.

The Geosynthetic QAC shall verify that the final cover subgrade surface for which GCL will be installed is not wet and meets the requirements of Technical Specification Section 02413-FC, Section 3.02, Paragraph D.1. During periods of obvious dry conditions, moisture testing of the subgrade may be waived by the Geosynthetics QAC.

The Geosynthetic QAC shall verify that no more GCL material is deployed during one working day than can be covered by the end of the day. Limited exceptions to this requirement may be given by the Project Manager if complete coverage of the GCL will be difficult to achieve by the end of a day and dry weather is forecast for several consecutive days. The Project Manager shall consider forecasted humidity levels prior to granting this approval.

GCL deployment shall not be undertaken during precipitation or when there is an immediate threat of precipitation. In the event that precipitation is imminent, the Geosynthetics Installer shall cease GCL installation activities and begin covering all deployed GCL with temporary tarps or other approved materials. Temporary covering shall be placed, or diversionary structures installed, in a manner to prevent runoff upslope of the exposed GCL from contacting the GCL. Temporary covering must be available on site at all times during the GCL installation, and no GCL shall be deployed such that the total area of exposed GCL exceeds the area of tarp or other approved temporary cover available at the site.

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

13.6 SEAMING PROCEDURES

13.6.1 Seam Overlap

Adjacent GCL panels shall be joined according to project plans and specifications. At a minimum, the Geosynthetic QAC shall verify the Installer complies with the following requirements:

1. Edge seam overlaps shall be a minimum of 6 in (150 mm).
2. Roll end seam overlaps shall be a minimum of 24 in (.6 m) or in accordance with manufacturer's recommendations and approved by the DESIGNER.
3. The addition of powdered bentonite to seam locations shall be in accordance with the manufacturer's recommendations.
4. End to end seams on slopes shall be minimized. If they are required, the Geosynthetic QAC shall contact the DESIGNER to verify the method used to attach the GCLs, has adequate tensile strength.

Prior to approval of the GCL by the Geosynthetic QAC, the following requirements should be visually verified by the QAC:

1. The required overlaps are provided. The overlap shall be continuously monitored since the panels may be subjected to shrinkage.
2. The amount of the powdered bentonite placed on the seam is in accordance with manufacturer's recommendations.

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

13.7 DEFECTS AND REPAIRS

Any portion of the GCL exhibiting flaws shall be repaired. Prior to acceptance of the installed GCL, the Installer shall locate and repair all damaged areas of the liner as directed by the Geosynthetic QAC. Defects or damage can be identified by either rips, tears, premature hydration of the GCL, or delamination of the geotextiles.

Rips and tears in the GCL shall be covered by another piece of GCL and repaired in accordance with the project specifications and manufacturer's recommendations.

Where the GCL has been exposed to moisture and has prematurely hydrated prior to placement of overlying material, the material shall be removed and replaced with material meeting the project specifications. The term "prematurely hydrated" shall not include minor partial hydration of the GCL material which may have been exposed to moisture within limited areas during construction. All defects and repairs shall be reported to the Project Manager.

13.8 GCL PROTECTION

All soil and/or geosynthetic materials located on top of the GCL shall be deployed in such a manner as to ensure:

1. The GCL and underlying liner materials are not damaged.
2. Slippage of the GCL on underlying layers is minimal.
3. No excess tensile stress occurs in the GCL.

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

APPENDIX A

TEST FILL PROGRAM FOR NEW CLAY AND GCL FINAL COVER PROTECTIVE SOIL SOURCES

Modified: 07/09

TEST FILL PROGRAM FOR NEW CLAY AND GCL FINAL COVER PROTECTIVE SOIL SOURCES

1.0 PURPOSE AND SCOPE

The purpose of the test fill is to establish a sequential and logical approach for the development of the placement and compaction procedures to be used during construction of compacted clay liners and geosynthetic clay liner (GCL) final cover protective soil layers that meets the required performance standard. The test fill program will allow the Earthwork Contractor, the Engineer or Project Manager, and the Soil Quality Assurance Consultant (QAC) to identify appropriate placement and compaction procedures. Once the construction procedures have been established by the test fill program, the Earthwork Contractor and the Soil QAC will monitor the compacted clay liner and GCL final cover protective soil layer construction procedures as an indicator that the performance standards are being achieved.

This test fill program documents the requirements for construction the test fill. The test fill program will include:

- Subgrade preparation.
- Construction of the test fill.
- Inspection and testing of the test fill.
- Sampling of portions of the test fill.

This test fill program may be modified with approval from the New York State Department of Environmental Conservation (NYSDEC).

2.0 TEST FILL MATERIAL

Feasibility testing of new clay and GCL final cover protective soil sources (not previously qualified) shall be performed prior to construction of the test fill. The material shall be evaluated in accordance with Sections 4.2 and 6.2 of the Quality Assurance Manual (QAM). These tests shall provide the basic relationship of permeability with varying density and moisture content. A typical representation of compaction and laboratory permeability test results for one clay source is shown on Figure 2.

3.0 CONSTRUCTION EQUIPMENT

The equipment to be used for the test fill shall be proposed by the Earthwork Contractor, and approved by the Soil QAC and Project Manager. The equipment to be used for the test fill shall be consistent with the equipment which will be used during actual layer construction. Variations may be approved by the Engineer provided that the equipment exhibits similar physical characteristics (e.g., weight, width, foot height, speed).

4.0 TEST FILL CONSTRUCTION

4.1 SUBGRADE PREPARATION

The area within the limits of the test fill shall be cleaned and grubbed of all trees, debris, brushes, stumps, roots, trash, and any other vegetation or objectionable material. Following clearing and

grubbing, the area shall be stripped of topsoil. Topsoil shall be stockpiled in an area designated by the Project Manager.

The surface of the subgrade shall be proof-rolled so as to be firm and free of irregularities, loose earth, and abrupt changes in grade. A drainage layer shall be installed on the subgrade. The drainage layer shall be firm, smooth and flat, shall have a hydraulic conductivity of a least two orders of magnitude higher than the expected hydraulic conductivity of the constructed test fill, and shall prevent fine particles of the test fill material from piping into the voids of the drainage layer. A layer of geotextile filter fabric may be placed between the drainage layer and test fill material, with the approval of the Engineer, to help prevent mixing of the materials. Upon the approval of the Engineer, the Earthwork Contractor may place a compacted sacrificial soil layer of 2 to 5 inches thick over the drainage layer prior to construction of the first test fill lift. This is to provide a layer of separation between the drainage layer and the first lift compaction and testing equipment. The subgrade, drainage layer, and test fill surfaces shall be sloped at a 2 percent grade. Line and grades shall be controlled by survey. No standing water or excessive moisture shall be allowed on the surface of the subgrade. The surface shall be inspected by the Soil QAC prior to beginning construction of the test fill.

4.2 TEST FILL REQUIREMENTS

The test fill shall be constructed and evaluated with the minimum criteria below. The requirements of Section 5 and general guidance from the NYSDEC presented in Appendix B will form additional requirements. In general, clay test fills will include multiple lifts, whereas GCL final cover protective soil test fills will include a single lift. In both cases, lift thicknesses will be comparable to those used in actual layer construction.

4.2.1 Lift Thickness for Clay Test Fills: In general, loose lift thickness shall not exceed length of the feet or pads as measured from the drum of the compactor prior to compaction or 9 inches, whichever is less. Refer to test fill construction procedure for thicknesses of the various test fill lifts.

4.2.2 Lift Thickness for GCL Final Cover Protective Soil Test Fills: Post-compaction lift thicknesses shall be approximately 18 inches to simulate the minimum allowable lift thickness used in actual construction.

4.2.3 Density: Dry density at or greater than 90 percent maximum modified proctor dry density.

4.2.4 Moisture Content:

1. At or greater than Optimum Moisture Content.
2. In-place moisture within acceptable compaction window.

4.2.5 Permeability Testing:

1. For clay test fills, conduct field hydraulic permeability testing by using the Sealed Double Ring Infiltrometer (SDRI) Test, Single Ring Infiltrometer (SRI), or Boutwell Two Stage Borehole Test as specified in Appendix B.

2. For both clay and GCL final cover protective soil test fills, obtain undisturbed samples by thin walled Shelby tube or block as indicated on the example test fill

configuration plan (Figure 1). Conduct constant head permeability testing on samples.

4.2.6 Permeability Testing: Collect samples for testing in accordance with requirements of Section 5. Inspect and conduct similar random testing as indicated on the example test fill configuration plan (Figure 1).

4.3 FILL PLACEMENT

The test fill shall be a rectangle approximately 60 feet long and at least 4 times wider than the widest piece of compaction equipment to be used in construction of a full scale facility (Figure 1). In no case shall the width be less than 20 feet.

The test fill shall be constructed in uniform horizontal lifts to a total thickness of at least 24 inches for compacted clay and approximately 18 inches for GCL final cover protective soil after compaction in accordance with the procedures specified below. The procedures, which vary with the lift considered, are intended to allow determination of a relationship between soil compaction criteria, which include density and moisture content, permeability, and compaction method parameters. Compaction method parameters include:

- Compactor characteristics.
- Thickness of compacted/uncompacted layers.
- Number of compactor coverages, and moisture content.

4.3.1 First Lift (Clay and GCL Final Cover Protective Soil Test Fills)

1. For both clay and GCL final cover protective soil test fills, the first lift shall be placed according to the thicknesses presented in Section 4.2

2. Soil moisture content shall be maintained at or above optimum water content determined by the Soil QAC. The Earthwork Contractor shall adjust the moisture content as necessary to obtain the specified density criteria.

3. The test fill material shall be compacted with coverages using the previously agreed compaction equipment.

4. The Earthwork Contractor shall permit the Soil QAC to performed in-place density tests and collect soil samples as specified in Section 5.3.1.

5. Holes left in the lift shall be repaired in accordance with methods outlined in the QAM. The repairs shall be made using procedures which have been shown to meet the required moisture and density criteria.

6. The test fill material shall be compacted a second time by applying two more one-way coverages with the selected compactor.

7. Steps 4 and 5 shall be repeated. Second series of tests shall be taken near the original tests.

8. The test fill material shall be compacted a third time by applying two more one-way coverages with the selected compactor.

9. Steps 4 and 5 shall be repeated. Third series of tests shall be taken near the first and second tests.

10. Steps 8 and 9, respectively, shall be repeated and continued until specified compaction criteria are obtained as identified by the Soil QAC.

4.3.2 Second Lift (Clay Test Fills Only)

1. The loose thickness of the second lift shall be such that the thickness of the lift will be 6 inches after compaction.

2. A competent bond with the first lift shall be achieved by the Earthwork Contractor and approved by the Soil QAC.

3. Steps 2 through 10 of Section 4.3.1 shall be repeated.

4.3.3 Remaining Lifts (Clay Test Fills Only)

1. The loose thickness of the remaining lifts shall be such that the thickness of the lifts will be 6 inches after compaction.

2. The procedures for compacting and testing the remaining lifts shall be those that have been tested and proven effective during the compaction of the second lift.

4.3.4 Final Surface Preparation (Clay Test Fills Only)

The surface of the test fill shall be rolled with a smooth steel drum or pneumatic roller so as to be free of irregularities, loose earth, and abrupt changes in grade. All stones larger than 1 inch shall be removed. Stones which are smaller than 1 inch and are judged to be detrimental to a geomembrane liner will be removed. One-half of the prepared soil surface shall be protected against damage with temporary plastic sheets. The sheets shall be placed immediately after the completion of surface preparation. Observations and documentation of desiccation cracking versus time shall be made on the uncovered section of the test fill.

5.0 **INSPECTION AND TESTING**

5.1 **TEST FILL MATERIAL**

The Soil QAC shall perform testing on the soil material prior to its use in the test fill. Testing will include at least the following:

- Soil density/moisture content relationship using the Standard Proctor Method (ASTM D698) and Modified Proctor compaction Method (ASTM D1557).
- Moisture content (ASTM D2216, D4643).
- Particle size distribution (ASTM D422).
- Atterberg limits (ASTM D4318).
- Soil Classification (ASTM D2487).
- Organic content (AASHTO T194).
- Hydraulic conductivity testing (ASTM D5084).

- Unconsolidated undrained triaxial shear test (ASTM D2850, clay source material only).

5.2 SUBGRADE PREPARATION

The Soil QAC shall observe the prepared subgrade for firmness, smoothness, and absence of abrupt changes in grade. The subgrade shall be surveyed to serve as the origin when determining thicknesses.

5.3 TEST FILL CONSTRUCTION

Test fill shall be constructed as described previously under Section 4.

5.3.1 Lift Compaction

For the first and second lifts (or, in the case of GCL final cover system protective soil, the only lift), the Soil QAC shall perform the following activities:

- Estimate the thickness of the loose lifts.

- Count the number of compactor coverages and observe compactor coverage of the test fill.

- Perform a minimum of eight nuclear gauge in-place density and moisture readings (ASTM D2292) at every two (2) coverages, and a minimum of two in-place density tests using the sand-come method (ASTM D1556), the rubber balloon method (ASTM D2167), or the drive cylinder method (ASTM D2937) to verify the nuclear gauge readings; compute degree of compaction (i.e., in-place dry density divided by the Modified Proctor maximum dry density); collect four additional soil samples for moisture content determination (ASTM D2216) and organic content (AASHTO T194).

- Observe the repair of holes left in the lift as a result of density testing and soil sample collection.

- Continue in-place density testing and moisture content determination to enable development of a curve giving in-place dry density versus number of compactor coverages for each lift thickness (Figure 3).

For each of the remaining lifts on clay test fills, the Soil QAC shall perform the following activities:

- Verify that the thickness of the loose lift does not exceed the loose thickness determined from testing of the second lift.

- Count the number of compactor coverages, determined from testing of the second lift, which are necessary to achieve the specified density and observe compactor coverage of the test till.

- Perform a minimum of eight nuclear density tests and two sand-cone density tests per lift to verify the adequacy of the construction procedures previously established.

The Soil QAC shall collect a minimum of six undisturbed Shelby tube samples or eight samples measuring 8 in. by 8 in. by 6 in. undisturbed block soil samples from varying depths of the completed test fill. The samples shall be waxed or otherwise protected to retain natural moisture and tested in the laboratory for the following:

- Hydraulic conductivity (permeability) using water as the permeant. (ASTM D5084).
- Soil density/moisture with Modified Proctor (ASTM D1557).
- Particle size distribution (ASTM D422).
- Atterberg limits (ASTM D4318).
- Soil classification (ASTM D2487).
- Soil moisture content (ASTM D2216, D4643).
- Organic content (AASHTO T194).

For clay test fills, the Soil QAC shall observe the test fill to verify the adequacy of the bonding between adjacent lifts. Such observation shall be exercised on the portion of the test fill which has been excavated to permit removal of undisturbed soil block samples and/or the sand-cone density testing.

5.3.2 Final Surface Preparation

The Soil QAC shall observe the prepared surface for firmness, smoothness, and absence of abrupt changes in grade. The final surface will be surveyed to verify the test fill thickness.

5.4 BULK FIELD HYDRAULIC CONDUCTIVITY (CLAY TEST FILLS ONLY)

One or more field bulk hydraulic conductivity test device(s) must be installed and performed in the area of the test fill that is prepared by the methods and controls that will be used in the actual construction. Acceptable field bulk hydraulic conductivity test devices include (but are not limited to) the following:

- Sealed Double Ring Infiltrometer (SDRI).
- Single Ring Infiltrometer (SRI).
- Boutwell two stage borehole.

Information from the field bulk hydraulic conductivity test must be used to confirm or deny that the soil, the methods of compaction, and the controls on compaction have produced a uniformly compacted soil with a bulk hydraulic conductivity of $1x10^{-7}$ centimeters per second (cm/s) or less. The results of the bulk field hydraulic conductivity test(s) should be submitted to the NYSDEC for review and approval at least 30 days prior to actual construction involving the soil material for which the test fill was performed.

6.0 DOCUMENTATION

The Soil QAC shall document activities associated with the construction, monitoring, and testing of the test fill and provide recommendations on placement and compaction procedures. Such documentation shall include daily reports of construction activities and oral communications with the Contractor. The following shall be documented for the specific sections listed below.

6.1 TEST FILL MATERIAL

The Soil QAC shall provide a moisture-density relationship for the test fill material and other test results as specified in Section 5.1

6.2 TEST FILL CONSTRUCTION

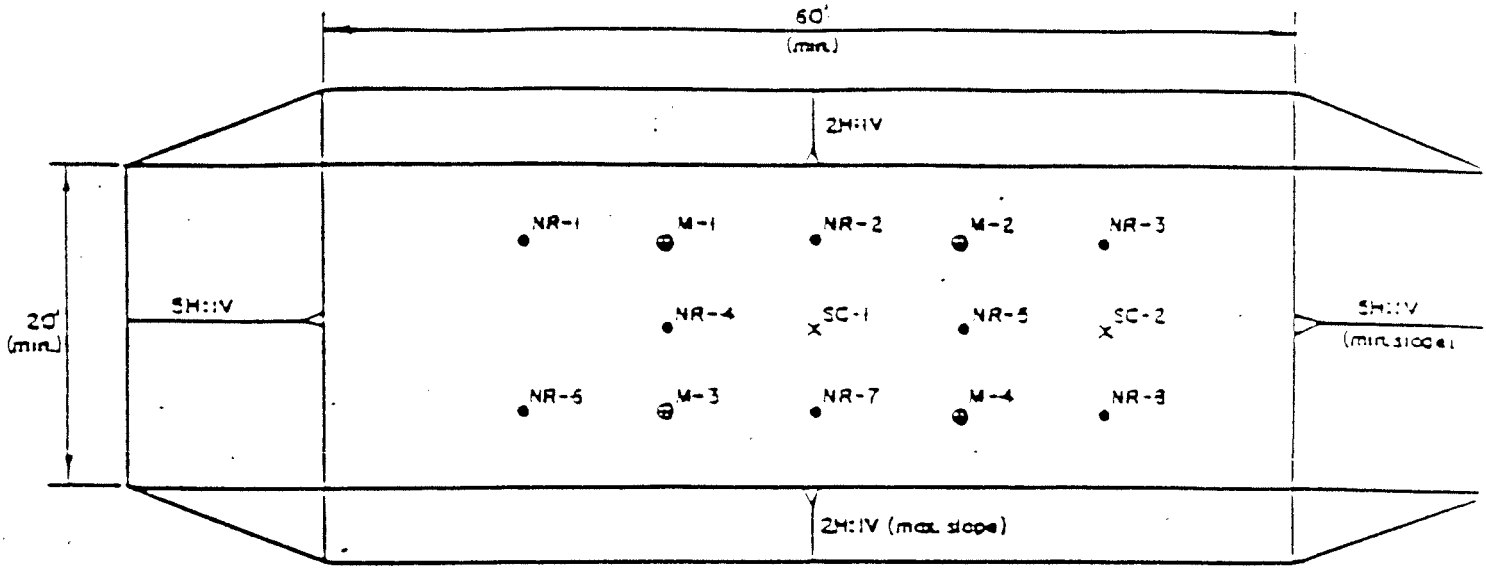
6.2.1 Subgrade Preparation

The Soil QAC shall document observations on subgrade preparation, as specified in Section 5.2.

6.2.2 Test Fill Construction

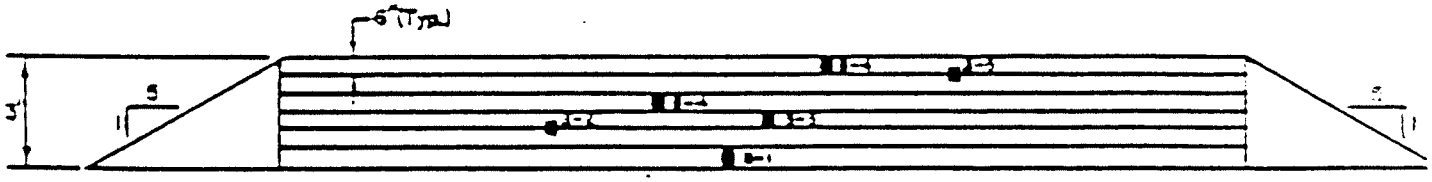
The Soil QAC shall document activities of the test fill construction, monitoring, and testing in a test fill summary report, which shall include but not be limited to:

- Record the compactor type, configuration, and weight; for sheepsfoot compactors, record the drum diameter and length, empty and ballasted weight, length and face area of feet, yoking arrangement, if any.
- Record thicknesses of lifts prior to and after compaction.
- Observe that construction equipment reaches normal operating speed before entering the area to be used for testing.
- Record density versus number of compactor coverages for each lift thickness, as specified in Section 5.3.1.
- Record the number of compactor coverages which will provide the specified degree of compaction and permeability.
- Record the procedure to bond lifts.
- Record results of moisture, in-place density and degree of compaction, as specified in Section 5.3.1.
- Document repair of holes left in the lift as a result of density testing and soil sample collection, as specified in Section 5.3.1.
- Record results of laboratory permeability testing and other soil properties tests performed on undisturbed soil samples.
- Include as-built drawing of the test fill and locations of all test samples for each lift.
- Include cross-section of the test fill showing number of lifts and lift thickness.
- Describe actual construction procedures.
- Observe test fill excavation for removal of undisturbed soil samples and observations of layer bonding, as specified in Section 5.3.1.



LEGEND

- NR-1 Nuclear guage reading on density and moisture (8 min./lift)
- SC-1 Sand cone test (2 min./lift)
- M-1 Moisture content sample (4 min./lift)
- B-1 Shelby tube or block sample for laboratory testing (6 min. at varying depths throughout test fill)



NOTES

1. The configuration and location of sample selection are included as an example only and may vary from test fill to test fill.
2. Sample locations shall be selected by the CQA engineer.

FIG. 1 SUGGESTED TEST FILL CONFIGURATION

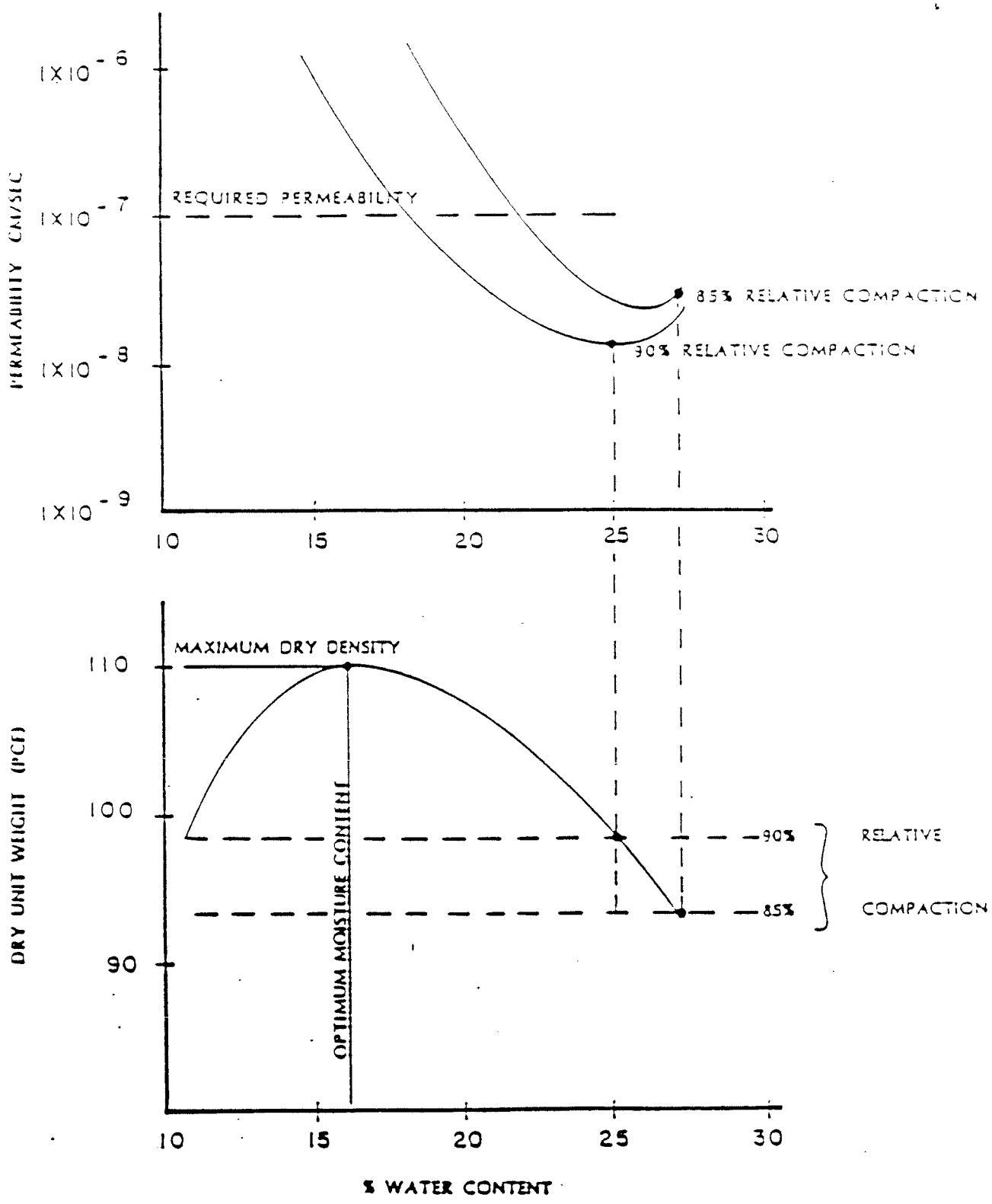


FIGURE NUMBER 2

PERMEABILITY, DENSITY AND MOISTURE CONDITION RELATIONSHIP

(ILLUSTRATIVE ONLY)

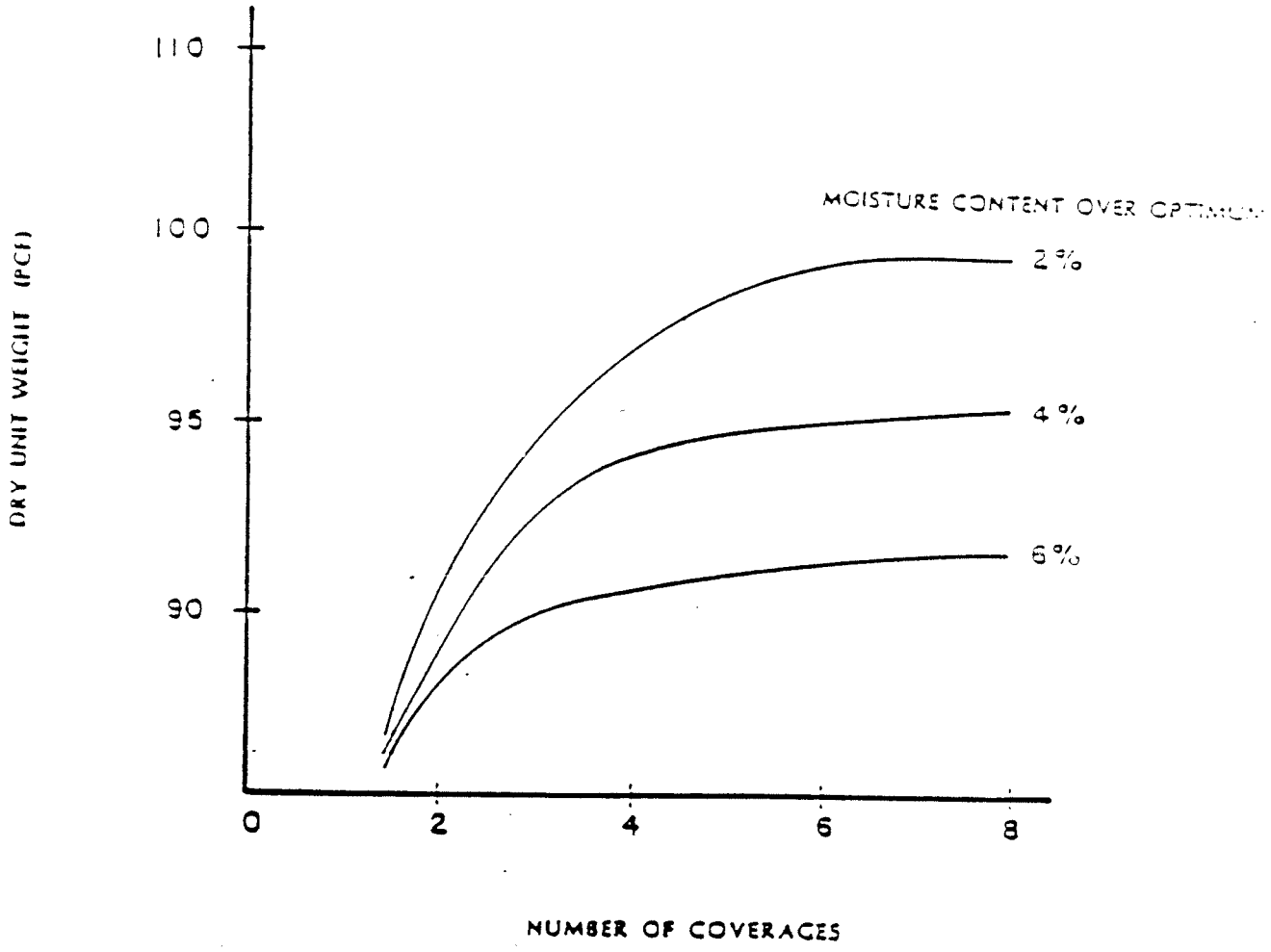


FIGURE NUMBER 3

MOISTURE/ DENSITY/ COMPACTIVE EFFORT RELATIONSHIP

APPENDIX B

GUIDANCE ON BULK HYDRAULIC CONDUCTIVITY (OR COEFFICIENT OF PERMEABILITY) TEST AND A TEST FILL (ATTACHMENT 1)

CWM
QAM

November 1992

Attachment 1

Guidance on Bulk Hydraulic Conductivity (or Coefficient of Permeability) Test and a Test Fill

Bulk Hydraulic Conductivity (or Coefficient of Permeability) Test

For decades engineers and others have taken small samples of compacted soil into the laboratory for hydraulic conductivity testing in order to verify that the intended hydraulic conductivity (or coefficient of permeability) has been achieved. This practice has been scrutinized in the past few years and has been found to occasionally produce misleading results. The bulk hydraulic conductivity of a soil barrier layer can be as much as several orders of magnitude greater than is indicated by the laboratory testing on samples of that same layer. Therefore, the use of a measure of in-field bulk hydraulic conductivity has been recognized as an important tool in determining soil barrier layer hydraulic conductivity.

Several means of measuring in-field bulk hydraulic conductivity exist: sealed double ring infiltrometer (SDRI), single ring infiltrometer, and Boutwell two stage borehole.

All of the in-field bulk hydraulic conductivity tests measure the hydraulic conductivity over a much larger area than the laboratory performed flexible wall permeameter test on undisturbed samples.

The SDRI measures the hydraulic conductivity over a relatively large cross-sectional area of about one square meter with a reasonable degree of confidence in 3 to 12 weeks.

The single ring infiltrometer generally utilizes a specially modified 55 gallon drum, and therefore, measures the hydraulic conductivity over a cross-sectional area of about one quarter of a square meter (Since the infiltration takes place in three dimensions, this estimate somewhat underestimates the area involved in the measurement). But since multiple tests can be set up in different locations in an area of interest, it is probable that 3 single ring infiltrometers will yield an equivalent estimate of the bulk field hydraulic conductivity in the area of interest as one SDRI test. Because a high standpipe can be used atop the single ring infiltrometer, this test can be somewhat quicker, yielding results in about 1 to 4 weeks.

The Boutwell two stage borehole measures the hydraulic conductivity over a relatively small area of 0.008 square meters for stage one, and of 0.064 square meters for stage two. Again, because multiple tests can be set up in different locations in an

area of interest, it is probable that five to ten Boutwell two stage boreholes yield an equivalent estimate of the bulk field hydraulic conductivity in the area of interest as one SDRI test. Because of the relatively high head that is used (4 to 7 feet), this test can be somewhat quicker than the SDRI, yielding results in about 1 to 3 weeks.

The time period involved and the need to isolate the measurement area from disturbance by construction equipment makes it impractical to perform these tests on the completed soil barrier layer in the land disposal unit. In addition to obstructing liner construction equipment, field bulk hydraulic conductivity measurement on a completed soil barrier layer would needlessly delay unit construction and expose the soil barrier to lengthy exposure to environmental conditions such as potential desiccation, water puddling or erosion, and freezing.

Instead of performing the test on the completed soil barrier layer, the field bulk hydraulic conductivity test should be conducted on a test fill in advance of construction of the compacted soil component. The test fill should be outside the construction zone, so that construction equipment damage is less likely, and longer term measurements can verify the hydraulic performance. In addition, hydraulic testing of a test fill section can be initiated very early in the permit application process, allowing accumulation of data which can provide increased confidence that design specifications can provide a sound structure.

In addition to demonstrating whether the specific construction materials and methods can produce a soil barrier layer with the necessary hydraulic conductivity, the results of the field bulk hydraulic conductivity test can have a direct effect on the type of moisture-density control that must be imposed during the actual construction. The results can be used to enlarge or decrease the range of permissible moisture-density points, termed the acceptable range, and consequently may modify the burden on the contractor during the construction of the compacted soil barrier layer in the cover.

The recommeded contents of a test fill plan follow.

Soil Test Fill

A soil test fill shall be constructed in a manner that is representative of the actual construction and using the same equipment and borrow soil that will be used in the actual construction in order to demonstrate that the field construction contractor can meet the material, construction, and product quality requirements of the waste management unit. One test fill shall be required per borrow soil/construction methodology. If there is a change in either, a new test fill is required.

At least sixty days prior to initiation of the test fill, the Department should be notified in writing of when the test fill will be conducted. Also, the notification shall specify the methods and procedures that will be used to construct and evaluate the test fill in accordance with these requirements. These procedures and methods must be accepted by the Department in writing before the test fill begins. The test fill construction should meet the following requirements:

(a) The soil used in the test fill shall be sampled and tested in a laboratory and be shown to meet the material specifications before use in the test fill. The same soil, a footed compactor with the same or lower weight per foot of roller width, and the exact same construction procedures, as will be used to construct the soil barrier layer shall be used in this test fill construction. Also the same monitoring requirements as will be used to construct the soil barrier layer shall be followed except for certain exceptions. The frequency of monitoring for certain parameters, such as hydraulic conductivity on Shelby tube or block samples, has to be increased to produce sufficient results to be meaningful.

(b) The subgrade for the test fill shall be firm, smooth and flat. A drainage layer shall be installed on the subgrade. The drainage layer shall be firm, smooth, flat, shall have a hydraulic conductivity several orders of magnitude higher than the expected hydraulic conductivity of the soil barrier layer, and shall not allow the fine particles of the soil to pipe into the voids of the drainage layer.

(c) The compacted soil in the test fill shall be at least 24 inches thick and shall be at least four lifts thick. Each lift should be soil compacted from a loose thickness of soil which complies with the requirements contained herein.

(d) The test fill should be constructed at least four times wider than the widest piece of equipment to be used in construction of the full scale facility.

(e) The test fill should be long enough to allow construction equipment to reach normal operating speed before entering the area to be used for testing.

(f) The resulting values of hydraulic conductivity in the field should be related to the following:

- the compactor specifications, such as total static weight, roller width, and foot length;
- number of passes of the compactor;
- screening method, mixing method and resulting maximum clod size;
- procedures for surface preparation;
- compaction equipment speed;
- uncompacted and compacted lift thickness; and,
- moisture content, and density. The relationship of moisture and density to hydraulic conductivity shall be used to select the appropriate moisture-density control that must be imposed.

Note: A clod is a lump of soil or clay which results from excavation, loading, unloading, spreading, and/or discing soils which have cohesive properties. Reducing hydraulic conductivity via compaction is thought to depend largely on the degree of removal of inter-clod voids.

(g) The following index properties should be used to monitor and document the construction quality obtained in the test fill.

- Hydraulic conductivity on subsamples from undisturbed (Shelby tube or block) samples, minimum one from each lift at random locations in the test fill. The undisturbed samples shall be taken in the wedge of soil between the end of the nuclear densitometer probe and the back of the gauge in order to allow the subsequent correlation of moisture and density with hydraulic conductivity.

- in place density and water contents;
- maximum clod size;
- particle size distribution; and
- Atterberg limits.

(h) One or more field bulk hydraulic conductivity test devices must be installed and performed in an area of the test fill that is prepared by the methods and controls that will be used in the actual construction. Acceptable field bulk hydraulic conductivity test devices include, but are not necessarily limited to, Boutwell Two Stage Borehole, Single Ring Infiltrometer, and Sealed Double Ring Infiltrometer.

Information from the field bulk hydraulic conductivity test must be used to confirm or deny

that the soil, the methods of compaction, and the controls on compaction have produced a uniformly compacted soil with a bulk hydraulic conductivity of $1x10^{-7}$ cm/sec or less.

(i) The results of the test fill should be submitted to the Department for review and approval at least 30 days prior to soil barrier installation.

APPENDIX C

REQUIREMENTS FOR DESIGNING ACCEPTABLE ZONE FOR COMPACTION CONTROL

REQUIREMENTS FOR DESIGNING ACCEPTABLE ZONE FOR COMPACTION CONTROL

1.0 INTRODUCTION

One of the most significant factors affecting the performance of compacted soil liners is controlling water content and dry unit weight during construction. A carefully written compaction specification can improve the likelihood of achieving low hydraulic conductivity while also satisfying other factors affecting performance such as strength, compressibility and desiccation resistance. Because a soil liner is meant to be a hydraulic barrier, low hydraulic conductivity (or hydraulic conductivity lower than a regulatory standard) should be the primary factor affecting the design of a compaction specification. The specification should then be tightened to meet other performance standards.

2.0 CONCEPT OF ACCEPTABLE ZONE

Figure 1 shows three compaction curves (Figure 1a) and three hydraulic conductivity curves (Figure 1b) that correspond to high compactive effort (Modified Proctor), moderate compactible effort (Standard Proctor), and low compactive effort (reduced Proctor). It is believed that these compactive efforts simulate the range of compactive efforts that can be achieved in the field (Benson and Daniel, 1990). A description of the procedure to achieve reduced Proctor compactive effort is included later in this document.

For each compaction curve shown in Figure 1, the lowest hydraulic conductivity is achieved for water contents in excess of optimum water content. Furthermore, similar water contents can yield radically different hydraulic conductivities if the compactive effort is changed. For example, at a water content of 11 percent, the hydraulic conductivity of this soil can be as low as 2×10^{-9} cm/sec and as high as 1×10^{-6} cm/sec. Hence, to ensure required hydraulic conductivities are achieved, a compaction specification should be designed that delineates a zone in the compaction plane which yields the desired hydraulic conductivity for the rate of compactive efforts that may be realized in the field. This zone of water contents and dry unit weights is called an "Acceptable Zone". For most cases, where the low hydraulic conductivity is desired, the acceptable zone will have a shape similar to the shaded region shown in Figure 1c.

3.0 DEVELOPING AN ACCEPTABLE ZONE

The procedure to develop an Acceptable Zone involves: (1) establishing a zone of water content and dry unit weight that yields the required hydraulic conductivity and (2) modifying the zone to account for other factors beside hydraulic conductivity.

A moisture and density control evaluation as outlined in Section 3.1 will be conducted as required by the NYSDEC and submitted to the NYSDEC for approval of an acceptable zone.

3.1 MOISTURE AND DENSITY CONTROL

Moisture and density control can be accomplished by meeting any of the three sets of requirements which are described as Case I, II, or III. The overall basis for these approaches can be found in a paper entitled, "Water Content-Density Criteria for Compacted Soil Liners," By D. E. Daniel and C. H. Benson in the *Journal of Geotechnical Engineering*, Vol. 116, No. 12, Pages 1811-1830, December 1990.

3.1.1 Case I

For this case, the following compaction control conditions have been proven to be necessary via the laboratory testing and the test fill.

1. The measured in-place moisture content immediately after soil compaction always shall be at, or greater than, the optimum moisture content form the most recent representative Modified Proctor curve developed on soil from the same borrow source.

2. The measured in-place dry density immediately after soil compaction shall be at or greater than 90 percent of the maximum Modified Proctor dry density from the most recent representative Modified Proctor curve developed on soil from the same borrow source.

3. The measured in-place moisture content and the measured in-place dry density immediately after soil compaction shall plot above the line of optimums on a plot of the most recent representative Modified and Standard Proctor curves. The line of optimums shall be a curve which passes through the maximums of both the Standard Proctor curve and the Modified Proctor curve and is parallel to the curve of zero air voids.

4. Compaction to the density required in (2) and (3), above, are waived at locations where any effort made to achieve this density would damage underlying flexible membrane liners, geonets, or geotextiles, or otherwise prevent them from achieving their intended function. One example is the lowest 6 inches of compacted soil in the upper composite liner on the sideslope of a double lined unit. Obviously, compaction of this soil with a footed compactor might adversely affect a component of the secondary leachate collection/detection system, such as a geonet, just beneath the soil, and might adversely affect the liner which is usually at the top of the secondary composite liner.

Requirements 1 through 3 of this case determine a bounded area on a plot of moisture and density which may be termed the "acceptable range."

Figure 1, "Acceptable Moisture-Density Plot for Soil for Case I" illustrates this acceptable range for moisture and density.

A Standard Proctor curve and a Modified Proctor curve are determined and plotted on the same figure. The line of optimums is a line which passes through the maximum point on both the Modified and Standard Proctor curves and is generally parallel to the curve of zero air voids. This line of optimums is one of the bounds of the acceptable range. The other is the horizontal line determined by 90 percent of the maximum value on the Modified Proctor curve.

3.1.2 Case II

For this case, compaction control to a density below 90 percent of the maximum Modified Proctor density has been proven in the laboratory and the test fill to be acceptable.

1. The measured in-place moisture content immediately after soil compaction always shall be at, or greater than, the optimum moisture content form the most recent representative Modified Proctor curve developed on soil from the same borrow source.

2. The measured in-place dry density immediately after soil compaction shall be at or greater than a density which corresponds to an alternate percent of the maximum Modified or Standard Proctor dry density from the most recent representative Modified Proctor curve developed on soil from the same borrow source. The density limit should be greater than 90 percent of the Standard Proctor density to prevent incomplete compaction of a very moist soil and the consequent creation of a structurally weak soil mass. The density limit shall be shown to meet the hydraulic conductivity limit of 1×10^{-7} cm/sec, maximum or less as demonstrated by remolded laboratory tested samples and by the field bulk hydraulic conductivity test on the test fill and shall be shown to have sufficient structural strength for the intended use.

3. The measured in-place moisture content and the measured in-place dry density immediately after soil compaction shall plot above the line of optimums on a plot of the most recent representative Modified and Standard Proctor curves. The line of optimums shall be a curve which passes through the maximums of both the Standard Proctor curve and the Modified Proctor curve and is parallel to the curve of zero air voids.

4. Compaction to the density required in (2) and (3), above, are waived at locations where any effort made to achieve this density would damage underlying flexible membrane liners, geonets, or geotextiles, or otherwise prevent them from achieving their intended function (see Case I above).

Requirements 1 through 3 of this case determine a bounded area on a plot of moisture and density which may be termed the "acceptable range." Figure 2, "Example Acceptable Moisture-Density Plot for Soil for Case II" illustrates one example of this acceptable range for moisture density.

A Standard Proctor curve and a Modified Proctor curve are determined and plotted on the same figure. Again, the line of optimums is one of the bounds of the acceptable range. In this second case, the other bound is the horizontal line determined by 90 percent of the maximum value on the Standard Proctor curve.

3.1.3 Case III

For this case, special compaction control below the line of optimums have been proven in the laboratory and the test fill to be acceptable.

1. The measured in-place moisture content immediately after soil compaction always shall be at, or greater than, the optimum moisture content form the most recent representative Modified Proctor curve developed on soil from the same borrow source.

2. The measured in-place dry density immediately after soil compaction shall be at or greater than 90 percent of the maximum Modified Proctor dry density from the most recent representative Modified Proctor curve developed on soil from the same borrow source.

3. The measured in-place moisture content and the measured in-place dry density immediately after soil compaction shall plot above an alternate line which is parallel to the line of optimums on a plot of the most recent representative Modified and Standard Proctor curves. The line of optimums is described in Case II above. The alternate line shall be offset by a certain percent moisture from the line of optimums. The offset is arrived at by demonstrating that the soil compacted to a moisture and density which plots above the alternate line has a hydraulic conductivity less than or equal to 1×10^{-7} cm/sec as demonstrated by remolded laboratory tested samples and by the field bulk hydraulic conductivity test on the test fill. The compacted soil shall have sufficient structural strength for the intended use as demonstrated by laboratory triaxial strength tests.

4. Compaction to the density required in (2) and (3), above, are waived at locations where any effort made to achieve this density would damage underlying flexible membrane liners, geonets, or geotextiles, or otherwise prevent them from achieving their intended function. One example is the lowest 6 inches of compacted soil in the upper composite liner on the sideslope of a double lined unit. Obviously, compaction of this soil with a footed compactor might adversely affect a component of the secondary leachate collection/detection system, such as a geonet, just beneath the soil, and might adversely affect the liner which is usually at the top of the secondary composite liner.

Requirements 1 through 3 of this case determine a bounded area on a plot of moisture and density which may be termed the "acceptable range."

Figure 3, "Example Acceptable Moisture-Density Plot for Soil for Case III" illustrates one example of this acceptable range for moisture and density.

A Standard Proctor curve and a Modified Proctor curve are determined and plotted on the same figure. Similar to Case I, the horizontal line determined by 90 percent of the maximum value on the Modified Proctor curve is one of the bounds. The other bound is now an alternate line which is parallel to the line of optimums but is offset by a certain percent moisture.

3.2 ADDITIONAL MOISTURE CONTROL DETAILS

The moisture content shall be maintained uniform throughout the lift. Whenever the moisture content of the soil at the borrow source is lower than the Modified Proctor optimum moisture content, then water shall be added and distributed within the soil sufficiently soon to ensure complete dispersion within the soil mass. Usually this means that water must be added before shipment of the soil to the site. If examination of the most recent representative Modified and

Figure 1. Acceptable Moisture–Density Plot for Case I

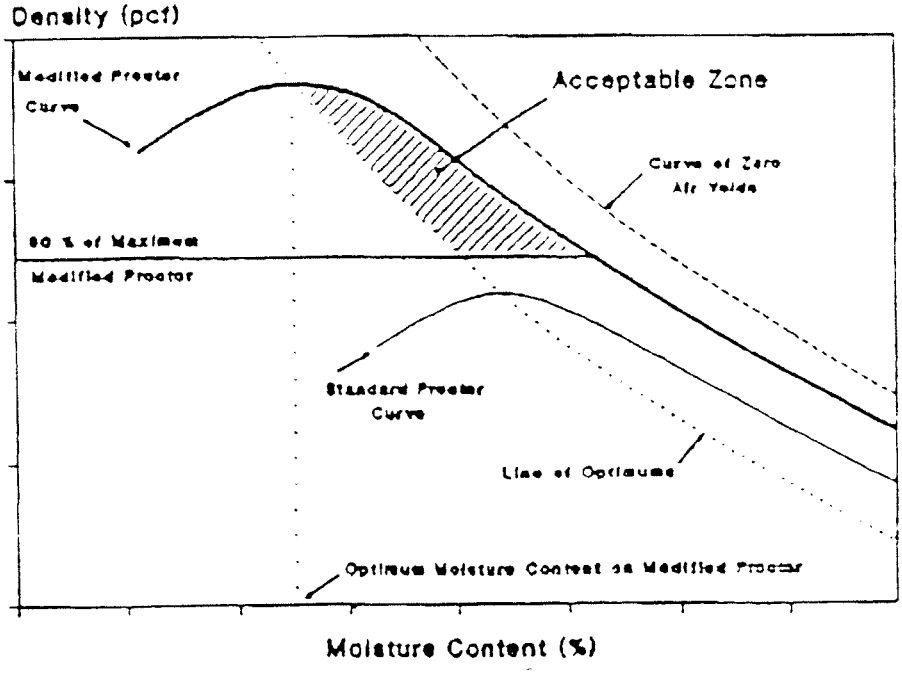


Figure 2. Acceptable Moisture–Density Plot for Case II

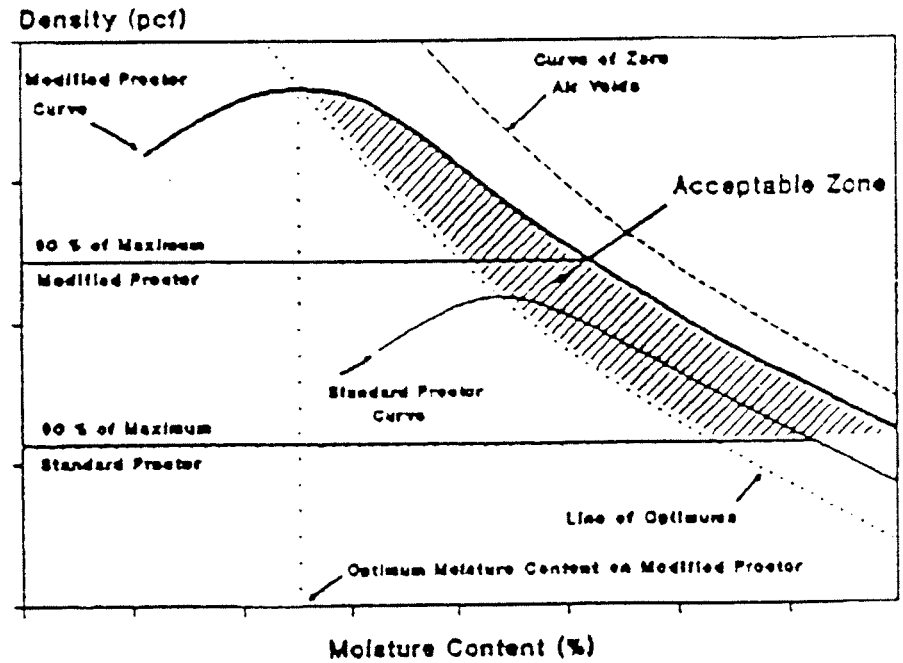
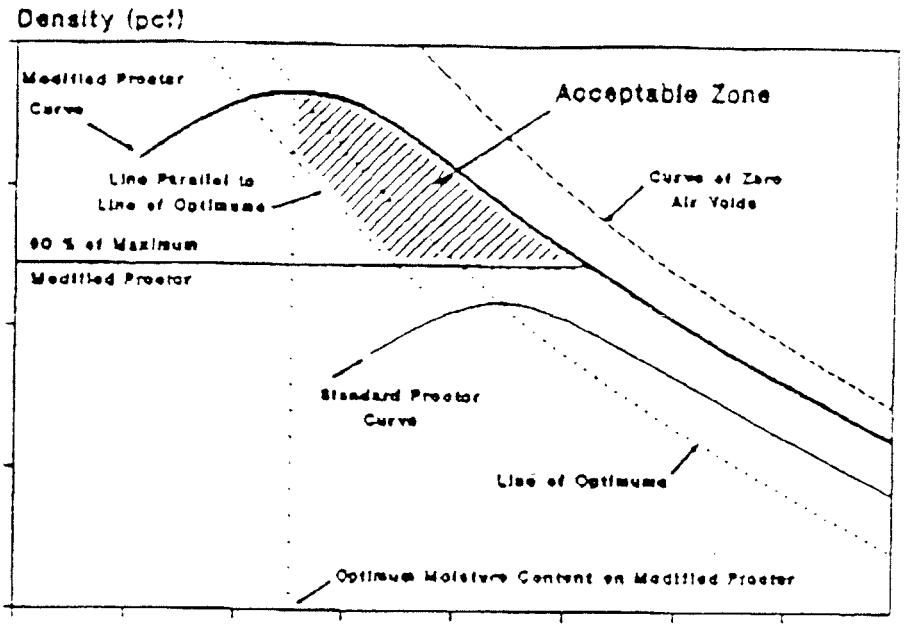


Figure 3. Acceptable Moisture–Density Plot for Case III



Standard Proctor curves indicates that the proper density can not be reached at its present moisture content, then the material will be dried before compaction. Drying will be accomplished by blading, discing, harrowing, or other aeration methods, to hasten the drying process. The affected soil will be mixed thoroughly within the loose lift or stockpile to ensure an even distribution of moisture within every loose lift prior to compaction.

If additional moisture must be added at the compaction site, then discing, watering, and discing again shall be conducted prior to compaction to ensure an even distribution of moisture within every lift.

4.0 VARIABLE SOIL PROPERTIES

In some cases, the borrow source may be so variable that different acceptable zones are needed to describe soils that have significantly different properties. If the soils can be easily distinguished in the borrow pit and/or the construction area, separate acceptable zones can be developed and supplied to field inspectors. If the soils are not easily distinguished, a composite acceptable zone can be developed by overlaying the acceptable zones (Figure 3). The intersection of the acceptable zones is then the composite Acceptable Zone.

5.0 USE OF THE ACCEPTABLE ZONE

The acceptable zone can be used directly in the field. Inspectors measuring water content and dry unit weight can plot the field data on the compaction curve. If the data falls in the acceptable zone and no visible defects are present, the compaction is deemed acceptable. Otherwise, the soil needs additional processing and compaction.

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APPENDIX D

ADDITIONAL CLAY BARRIER PLACEMENT REQUIREMENTS TO BE MONITORED

APPENDIX D

ADDITIONAL CLAY BARRIER PLACEMENT REQUIREMENTS TO BE MONITORED

The earthwork contractor will be responsible to conform to additional clay barrier construction requirements listed below. The soil CQA will verify through observation and documentation that these requirements are implemented.

1. Soil

Only natural soil material shall be utilized in the compacted soil barrier. this soil material must be free from roots; organic matter; frost; ice; frozen soil; trash; debris, rocks, or slag larger than 1-inch at the finish surface; and other deleterious materials.

If additional moisture must be added at the compaction site, then discing, watering, and discing again shall be conducted prior to compaction to ensure an even distribution of moisture within every lift.

2. Seal Rolling

Intermediate lifts shall be rolled to seal for protection from infiltration of precipitation. To prepare for subsequent lifts, sealed surface of intermediate lifts shall be scarified and, if necessary, shall be adjusted to a proper moisture content adequately in advance of subsequent soil placement to ensure a uniform moisture content in the intermediate lift and complete bonding of the lifts to one another.

3. Overworking

The soil shall not be overworked such that compaction and permeability requirements cannot be achieved, as indicated by test fill or recent actual construction standards. In no case shall an excessively compacted crust be formed on the top of a lift which is too smooth to bond to the next lift or is so brittle that it cracks.

4. Facility Sidewalls

Soil lifts used to build the facility sidewall liners shall be inclined at about the same angle as sideslope. Lift interfaces must not traverse the barrier layer, unless special actions are taken to be certain that these interfaces will be no more permeable than the core of lifts.

5. Contact Surfaces

A. Complete bonding of one placed volume of soil to another shall take place along any and all soil to soil contact surfaces. Contact surfaces include but are not limited to:

1) Berm soil placed over the floor soil which has been placed at a previous time.

2) Newly placed soil subject to desiccation including hot or freezing conditions.

3) Soil from one borrow source contacts soil from a different borrow source.

B. At a minimum, the previously placed soil shall be scarified and, if needed, adjusted to a proper moisture content. Frozen soil shall be removed from liner area. If differences in the soil types are encountered or if incomplete bonding, then contact surface shall be stepped and/or keyed.

C. Other contact surfaces as determined by the Soil OAC.

6. Final Surface

Final lift shall be seal rolled as soon as practical after final compaction to prevent moisture loss.

Areas lined with flexible membrane liner (FML) top surface of each completed soil barrier layer shall be smooth and the final surface shall be free of stones greater than 1-inch (25 mm) in diameter in its least dimension.

Surface to be lined with a FML shall be rolled with a smooth drum steel or pneumatic roller free of irregularities, loose earth, and abrupt changes in grade. Surface shall be maintained after certification of acceptance of surface by the geosynthetic installer and soil CQA.

To ensure a seal FML shall be installed as soon as practicable after soil barrier layer is judged acceptable by the Soil CQA. The soil surface shall be observed daily by the Engineer and FML Installer to check for soft areas or desiccation cracking.

No FML shall be placed in an area which has become softened by precipitation resulting in substandard strength requirements of 0.5 tsf.

The FML Installer shall provide written acceptance of surface preparation to the Engineer prior to any FML installation. Thereafter, Installer shall provide the Engineer with daily written acceptance of surface to be covered by FML in that day's operations.

7. Desiccation Crack Control and Repair

Daily or hourly observations shall ascertain effects of surface desiccation cracking upon integrity of soil barrier layer. Soil CQA shall indicate precautions for reducing the desiccation potential of final soil surface prior to installation of any FML or succeeding layer, (i.e., installation of a temporary FML cover, application or water, or prompt placement of succeeding layers).

A temporary FML cover such as a 10 mil polyethylene, or other available FML, may be used as temporary protection for soil. A temporary FML should be overlapped 1-foot and does not need to be seamed. Temporary FML must be removed prior to placement of the design FML or succeeding layer.

Minor soil barrier layer cracks from desiccation which are visible but too narrow to measure depth may be repaired by re-wetting, allowing sufficient time for crack healing.

In the event that measurable desiccation cracks develop on soil surface, following corrective procedures will be followed:

(i) For cracks measuring 2 inches in depth or less, dry powdered bentonite may be used for repairing, providing that cracks do not have sharp bends that would interfere with complete filling of the crack with bentonite. If dry powdered bentonite is used, the cracks should be completely filled with bentonite. If this procedure is not used, then the following procedure must be used. Alternatively, a water truck may apply water over the surface followed by smooth drum rolling.

(ii) Cracks deeper than 2 inches, but less than the depth of penetration of the discing blade (depth of penetration is defined as 75 percent of the distance measured from the axle to the edge of blade) are present, addition of bentonite will not be acceptable and surface shall be rewetted, disced, recompacted, and retested or the lift will be removed and the exposed soil will be scarified with a disc to the full depth of the cracks, if any remain, and recompacted in conformance with applicable requirements. If this procedure is not used, then the following procedure must be used.

(iii) Cracks deeper than the depth of penetration of the discing blade are observed, the lift shall be removed and exposed soil scarified with a disc to full depth of the cracks, and recompacted in conformance with the applicable requirements.

The method for measuring any crack depth shall be the insertion of a 20 gauge wire. This method will remain consistent throughout soil barrier layer construction. If cracks exhibit bends that interfere with or prohibit crack measurement, then hand shovels will be used to excavate soil that will assist in depth measurement. Any holes excavated with a hand shovel will be repaired by complete filling with dry powdered bentonite.

(iv) For cracks deeper than two inches in areas with limited access, an acceptable method for repairing cracks is as follows:

1. Open the crack with a hand shovel or pick to the depth of the crack;

2. Fill void with clay fines or a bentonite powder/clay mixture; and

3. Compact clay/bentonite mixture with hand tools.

APPENDIX E

PARTIES INVOLVED

Forms to be completed at

Pre-Construction Meeting by Project Manager.

OWNER:

Model City Facility
Chemical Waste Management of New York, Inc.
Balmer Road
Model City, NY

APPENDIX E

CONSTRUCTION PARTIES

1.2.1 Project Manager:

Name: _____
Title: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

1.2.2 Designer:

Representative: _____
Title: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

1.2.3 Geosynthetic Manufacturer:

Representative: _____
Title: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

1.2.4 Earthwork Contractor:

Contract Representative: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

Superintendent: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

1.2.5 Geosynthetic Installer:

Contract Representative: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____
Superintendent: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

Master Seamer: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

1.2.6 Soil Quality Assurance Consultant:

Representative: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

Managing Engineer: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

1.2.7 Geosynthetic Quality Assurance Consultant:

Representative: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____
Managing Engineer: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

1.2.8 Soil Quality Assurance Laboratory:

Representative: _____
Title: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

1.2.9 Geosynthetic Quality Assurance Laboratory:

Representative: _____
Title: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

QA CONSULTANT:

Representative: _____
Title: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

LAND SURVEYOR:

Representative: _____
Title: _____
Company Name: _____
Express Mail Address: _____
City, State Zip: _____
Phone: _____
Fax: _____

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APPENDIX F

LEISTER BOND PROCEDURES

APPENDIX F

QUALITY ASSURANCE MONITORING PLAN FOR LEISTER BOND PROCEDURE

RMU-1 Construction
CWM Chemical Services, Inc.
Model City Facility, New York

PURPOSE:

To establish a Quality Assurance (QA) plan for monitoring the Leister Bond method on HDPE geomembrane repairs. This plan is a supplement to the Quality Control (QC) Protocol submitted by Gundle for the Leister Bond method. Leister welds will be used to tack HDPE geomembrane sheets prior to extrusion welding in difficult areas such as the sumps and sideslopes.

Observance, by all parties, of a specific quality control protocol for the Leister bonding method, and assurance that no damage to the HDPE geomembrane occurs as a result of this process.

RESTRICTED USE:

Use of the Leister bonding method shall be restricted to seam lengths where the extrusion seaming method is used. Extrusion seams may occur at the following locations:

1. Patches and cap strips.

2. Areas where the use of a fusion welder is physically impossible or is cumbersome and impractical. Such areas might include sump areas or short seam lengths, or corner areas.

3. Penetration points such as boots around pipes.

The use of the Leister bonding method should be employed only in cases where the use of the extrusion seaming method is preferred over the fusion seaming method.

LEISTER BONDING PROCEDURES:

1. Direction of seaming on slopes shall be the most expedient direction for the type of seaming used. Seaming shall extend to the outside edge of panels to be placed or as otherwise approved in writing by the manufacturer and deemed acceptable by the Department.

2. Lap joints shall be used to seam factory-fabricated HDPE geomembrane sheets together in the field. All field joints shall be made on a supporting smooth surface.

3. Set air discharge temperature typically at 250° Celsius to 270° Celsius. This temperature may vary based on field conditions and on the adequacy of the temporary Leister bond. The

hot air discharge must always be below the true welding temperatures of 295° Celsius for 80 mil HDPE geomembrane.

4. Align HDPE geomembrane overlap with a minimum 3-inch overlap for seams and 6-inch overlap for patches and cap strips.

5. Insert air discharge nozzle between the overlap of the two HDPE geomembrane sheets, and manually progress the nozzle along the overlap while at the same time compressing the heated overlap surface. At no time should the Leister contact with a specific point on the FML exceed 10 to 15 seconds. (Estimated time for total burn through on 80 mil HDPE, at 250° Celsius, is 60 seconds.

6. The following criteria in regards to frequency of Leister or "tack" bonds shall be observed:

   A. Ordinary Circumstances.

      Under "ordinary" circumstances, patches or cap strips which are greater than 2 feet in length on any one side, the Leister bond spacing shall be a minimum of 2 feet in length and a maximum of four Leister bonds shall be allowed on each patch. Any Leister bonds which are used on a patch or cap strip shall at no time exceed 5 inches in length.

   B. Extra Ordinary Circumstances.

      Leister bonding of patches or cap strips in a continuous fashion is proposed for "extra ordinary" circumstances such as imminent bad weather or difficult HDPE geomembrane configurations.

This procedure shall provide a surface type "tack" bond to secure HDPE geomembrane overlaps prior to extrusion seaming.

QUALITY CONTROL PROCEDURES:

1. As part of the extrusion welding trial seam, the Leister bond method is typically used to secure the two remnant pieces of HDPE geomembrane. An approximate 6-inch portion of the trial seam will be left unwelded so as to allow direct observation of the Leister bond. On all trial seams, both the extrusion gun operator and the Leister operator will be recorded.

2. Shear specimens for the extrusion method trial seam can be biased so as to include a section of the trial seam that has been "Leistered" together. The field tensiometer is capable of reading load values. The load value for each shear test specimen can be recorded, with a minimum passing value being 160 psi; in peel, FTB must be achieved.

3. The surface of the lapped edges of any embossed and/or textured sheets shall be prepared as recommended by the manufacturer to provide a seam to equal or exceed the bonded seam strength requirement specified. The fusion weld shall have a 2-inch minimum width. The

extrusion welding process shall bond the exposed edge of the panel to the underlying HDPE geomembrane.

4. All Leister bonds in the field will be 100% visually observed for overheating by the master seamer and/or field superintendent. In addition, technicians will maximize, as is practical, the spacing between individual Leister "tacks".

5. When the Leister tool is not in use, the switch should be in the "off" position and care will be taken to avoid contact with FML by the nozzle until it has cooled.

6. It is not intended that the motor propelled Leister be used on this project.

The Geosynthetic QAC shall verify that:

1. The seaming personnel have the qualifications.

2. The overlaps meet requirements.

3. The seaming area is clean.

4. Subgrade is hard and no soft spots are present.

5. Seaming equipment is available on the site and meet the requirements.

6. Weather conditions for seaming are acceptable.

7. Seaming procedures are followed.

8. All cap-strips required in an earlier section are placed.

9. Equipment for testing seams is available on-site.

10. Panels are properly positioned to minimize wrinkling and wrinkled areas are seamed according to the procedures presented in the Quality Assurance Manual and Technical Specifications.

TESTING REQUIREMENTS:

1. For each extrusion weld trial seam, the Leister bond will be employed to secure the overlap prior to welding. Approximately 6 inches of the trial seam will be left unwelded to as to allow easy observation at the Leister bond. The Geosynthetic Quality Assurance Consultant (QAC) representative shall observe and document the condition of the Leister bond on the unwelded portion of the seam and record the name of the Leister operator.

   Extrusion weld trial seam coupons will be cur using a 1-inch wide die and removed from "Leistered" portions of the trial seam. The peel adhesion and shear strength criteria shall,

at a minimum, equal or exceed project technical specifications and criteria recommended in Table 4 of the National Sanitation Foundation (NSF) Standard No. 54-1991. Any trial seam test coupon which does not meet any of these test criteria will be considered a failure. Follow-up procedures for failed trial seams are stated in Section 9.10.

Additionally, the Geosynthetic QAC monitor shall determine if any failure in a test seam coupon was a result of the use of the Leister. If it is determined that the cause of failure was from the use of the Leister, then that Leister operator will be disqualified for the day.

2. Destructive testing of extrusion weld field seams that contain Leistered tack welds will be subjected to NSF Standard No. 54 test criteria. Any test coupons that fail to meet these criteria is considered a failure. If any more than one test coupon in the shear strength test fails to meet the NSF Standard No. 54 test criteria, then the test will be considered a failure and will be followed up as stated in Section 9.10.3 of the Quality Assurance Manual. In addition, the laboratory technician performing the test will observe the yield areas of all extrusion weld destructive test coupons and record if the yield originated in the Leistered area.

FIELD APPLICATIONS:

1. The operating temperature of each Leister tool in use will be recorded at least daily by the Geosynthetic QAC, and compared against the typical operating temperature.

2. The Geosynthetic QAC monitor shall periodically observe the field use of the Leister procedure and report cases of abuse.

3. If a particular Leister operator is abusive in the field or does not appear to be knowledgeable about Leistering procedures, the operator may be disqualified from Leistering on the recommendation of the Geosynthetic QAC monitor to the Owner.

4. In extraordinary cases such as anticipated events of rain or high winds or in areas such as the crest and toes of slopes, continuous Leister of patches may be allowed but only with supplemental approval from the Quality Assurance Officer. The Quality Assurance Officer shall document the circumstances of approval and consult the NYSDEC construction observer immediately if available or, if not available, at the next earliest time.

5. The Project manager shall be notified if installer does not follow the procedures outlined in the approved QC Protocol for the use of the Leister.

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