7.6 Placement of Bottom Ash Drainage Layer

Placement of the bottom ash layer can proceed once grades for top of the fly ash base layer have been verified. Place the bottom ash layer in six-inch lifts and compact as described in Attachment 4.

7.7 Testing/Inspection

Density testing of the two-foot thick bottom ash layer is not required. No other testing is required. A technician shall be present to observe construction practices are in accordance with these requirements and the drawings, and to document that the thickness is in accordance with the drawings.

7.8 Placement of Filter Layer

The filter layer shall consist of a 50:50 mixture (by volume) of fly and bottom ash. After grades for the bottom ash drainage layer have been verified, place an additional six-inch thick lift of bottom ash. Place an additional six-inch layer of fly ash and mix using a rototiller as described in Section 6.2.1. The depth of the tiller shall be set such that the underlying fly ash layer shall remain undisturbed as practicable. The layer shall be compacted in accordance with requirements outlined in Attachment 3 under the supervision of the Certification Engineer. Work shall be accomplished in sections such that gradation testing can be performed to verify adequate mixing prior to installation over large areas. Laboratory hydraulic conductivity testing shall also be performed initially to ensure performance meets design parameters. Upon successful placement of the filter layer in an initial area, the additional layer shall be installed.

The bottom ash drainage and filter layers are highly erodable, and storm events can cause severe erosion depending upon the intensity of the rainfall. The construction of these layers can be performed in smaller segments, rather than in one large area as depicted on the drawings, in order to lessen the likelihood of erosion. Intermediate dikes can be constructed on the upslope side to divert stormwater around construction of the drainage and filter layers. Erosion of the fly ash base is more easily repaired than repair of the filter layers, although excessive erosion should be prevented.

7.9 Testing

Initially, perform gradation testing of four tests per acre (approximately 50,000 ft^2). Additionally, perform a laboratory hydraulic conductivity test for this area. If results are satisfactory to the Certification Engineer, continue testing at this rate for the next 50,000 ft^2. If testing yields satisfactory results, reduce gradation testing to four tests per acre (approximately one test per 10,000 ft^2). No additional hydraulic conductivity testing is required, unless otherwise directed by the Certifying Engineer.

8 STARTER DIKE CONSTRUCTION AND INSPECTION TESTING FOR DREDGE CELL EXPANSION

8.1 Materials Specification

Materials used to construct dikes for constructing the Phase 2 and 3 Dredge Cell Expansion shall be bottom ash obtained from KIF. At TVA's option, bottom ash may be imported from Bull Run Fossil Plant if needed for construction.

8.2 Pre-construction Testing

No preconstruction testing is required.

8.3 Placement

Ensure that the bottom ash dikes are being placed at the proper location in accordance with the drawings. Note that the bottom ash dikes will be placed to approximately elevation 775 for initial storage of gypsum. The dikes will eventually be covered with a layer of wet cast gypsum, and allowance must be made for the gypsum and eventual final cover placement.

Place bottom ash in accordance with requirements contained earlier in Section 6.2.1.

8.4 Testing

Perform testing as described in Section 6.2.2.

9 WET CAST GYPSUM DIKE CONSTRUCTION

9.1 Placement

Initially, gypsum will be sluiced from the scrubber facility to the Phase 2 area. It is important at this phase that the slope protection be properly constructed to ensure that the bottom ash filter layer does not erode initial filling of the diked area. After gypsum fills the area, a long-reach trackhoe will be utilized by the constructor/operator to wet-cast gypsum on the starter dike and create the rim ditch and inner berm. This method of rim ditch construction utilized the upstream method of dike construction. The rim ditch will be constructed to the lines and grades shown on the drawings.

The facility is designed such that there are at least two active gypsum areas for gypsum disposal. Once the rim ditch and inner dike are constructed, gypsum will continue to be sluiced and the outer dikes will be raised. Gypsum (or ash) can be used to subdivide the Phase 2 area as depicted on the drawings. This arrangement allows gypsum areas to be located along the outer dikes. It is important that gypsum be deposited in these areas without mixing with ash or other substances, so that only wet cast gypsum be utilized for outer dike construction.

Once rim ditch construction has been completed, and an area has been filled, the second area will begin to fill. During the inactive phase of the first area, dike raising can begin. Gypsum is excavated from the rim ditch using long-reach trackhoes and placed along the dike perimeter. Leveling, spreading, shaping, and compaction will be accomplished using a small dozer. Dikes will generally be raised in five-foot height increments, with individual lift thicknesses being approximately one to two feet thick. The individual lift thicknesses should be such that material can be placed, spread, shaped, and compacted to obtain a uniform consistency and be constructed to the lines and grades on the drawings. Perimeter drains shall be installed as shown on the drawings. It is important that elevations be checked during construction and adjustments made to avoid damage to the drains. The drawings contain instructions and

procedures to prevent this from occurring. Rim ditch grades are initially proposed at a slope of 0.25 percent (2.5 vertical feet per 1000 foot horizontal ditch length); however slopes can be adjusted to between 0.2 percent and 1 percent depending on the judgement of the Certification Engineer in concert with the facility operator.

After the dikes are successfully raised in the first area, the process is repeated for the second area, while filling is continued in the first area. Fly ash will also be sluiced into areas as designated on the drawings. It is important that the height of material in adjacent fly ash and gypsum areas be kept to within about 15 feet height difference, but no more than 20 feet, unless otherwise directed by the Certification Engineer. At a 0.25 percent rim ditch grade, the elevation difference at the entrance and outlet of the ditch is approximately 7-10 feet.

9.2 Inspection and Testing

Inspection and testing for wet cast dike construction will include the following activities:

- Inspection of initial dike construction is required to verify that material has the desired consistency, and is being placed, shaped, and compacted to the proper shape. It is anticipated that surveillance and inspection activities will be more frequent in the beginning, and will be reduced as successful operation is being demonstrated. The frequency of inspection will be determined by the Certification Engineer in concert with TVA FES.
- After initial dike construction is complete, and the area filled with gypsum, dike raising can begin for the second lift. The Technician shall take random samples at four locations along the rim ditch along the outer dike (not the interior dike or rim ditch) at approximate evenly spaced locations. Samples will be tested for grain size to determine variation in material. This information shall be reviewed by the Certification Engineer. Additionally, strength testing of material at the beginning and end points of the rim ditch along the outer dike (not the interior dike/rim ditch) may be performed to determine any variation in strength parameters. Operation of the rim ditch may be adjusted at the discretion of the Certification Engineer. This process can be repeated if determined necessary by the Certification Engineer in concert with TVA FES, but it is expected that as stack progression continues, the need for such testing will diminish over time if satisfactory results are obtained. This process may need to be repeated when Phase 3 construction begins, or if more frequent testing is deemed necessary by the Certification Engineer in concert with TVA FES.
- It is anticipated that quarterly inspections be performed by the Certification Engineer during dike raising activities as a minimum, and the frequency increased if necessary. The Technician should be present to inspect construction of the drains to ensure that the requirements on the drawings are being met. The frequency of these visits shall be determined by the Certification Engineer in concert with TVA FES.
- As stack construction progresses, TVA will perform surveys to determine the remaining life of the facility. These surveys will be reviewed by the Certification Engineer to ensure that grading is being adequately maintained on the side slopes.

10 FINAL COVER

10.1 Description

A compacted clay layer final cover is one option for final cover construction. It consists of: 12 inches of compacted soil with initial 12 inches being compacted low permeable select soil. KIF has soils on the

reservation that would meet the criteria for these soils. The uppermost 6 inches of compacted soil shall be random soil, and will be for installation of a 6-inch vegetative layer.

An alternate final cover consisting of a LLDPE geomembrane, geosynthetic drainage layer, and 18 inches of soil (6 inches for vegetation) as shown on Drawing 10W425-75 will be installed if determined by TVA FES. See Section 10.4 for material and installation QA/QC requirements.

10.2 Material Specifications for Compacted Clay Final Cover

10.2.1 Compacted Select Soil

The first 12 inches of soil on top of the ash is the compacted select soil layer. The soil material utilized shall be CL or CH determined by ASTM D-2487. Clay soils shall possess a plasticity index (PI) greater than 10 in accordance with ASTM D 4318, and amount of fines (defined as dry-weight percentage passing the No. 200 sieve) is greater than or equal to 30% in accordance with ASTM D 1140. Clay soil materials shall be free of rock fragments larger than 2 inches in any dimension, topsoil, roots, and any other deleterious materials.

10.2.2 Compacted Random Soil

The material utilized for construction of the random soil layer shall be CL, CH, ML, or MH as determined by ASTM D-2487, and have a plasticity index (PI) less than 30 in accordance with ASTM D 4318. Material shall be free of rock fragments larger than two inches in any dimension, topsoil, roots, and any other deleterious materials.

10.2.3 Vegetative Layer

The soil to be utilized for establishing the vegetative cover shall be capable of sustaining a healthy stand of vegetation, and shall consist soil reasonably free from subsoil, noxious weeds, stones larger than two inches in diameter, or other deleterious matter that would prevent the formation of a suitable seed bed.

10.3 Pre-construction Testing

All soil to be used for construction of the clay soil liner will be inspected by the Certification Engineer to ensure that proper soils are being used. The Quality Assurance tests specified below in Table 1 will be performed on clay source material at the specified frequencies, and whenever a change in material occurs.

TABLE 1

QUALITY ASSURANCE TESTS FOR SOIL MATERIALS USED IN CLAY LINER CONSTRUCTION

Parameter	Test Method	Minimum Testing Frequency
Percent Fines	ASTM D 1140 (Note 1)	1 per 1,000 cubic yards (Note 2)
Percent Gravel	ASTM D 422 (Note 3)	1 per 1,000 cubic yards (Note 2)
Liquid and Plastic Limits	ASTM D 4318	1 per 1,000 cubic yards
Water Content	ASTM D 4643 (Note 4)	1 per 200 cubic yards
Water Content	ASTM D 2216 (Note 5)	1 per 1,000 cubic yards
Moisture/Density	ASTM D 698/ASTM D 1557	1 per 5,000 cubic yards or 1 per soil change
Permeability (Remolded)	ASTM D 5084 (Note 6)	1 per soil type

Notes:

1. Percent fines is defined as percent passing the Number 200 sieve.

2. In addition, at least one test should be performed each day that soil is excavated and transported to the site, and additional tests should be performed on any suspect or change in material observed by QA personnel.

3. Percent gravel is defined as percent retained on the Number 4 sieve.

4. This is a microwave oven drying method. Other methods may be used, if more appropriate.

5. Microwave oven drying, and other speedy methods, may involve systematic errors. Conventional oven drying (ASTM D 2216) is recommended on every fifth sample taken for rapid measurement. The intent is to document any systematic error in rapid water content measurement.

6. ASTM D 5084 is a laboratory procedure for determining hydraulic conductivity of soil materials.

The moisture/density/hydraulic conductivity relationship to control actual field placement of the clay liner and cover will be established as follows:

a. Samples of the source material will be taken for laboratory testing.
b. The soils will be prepared and compacted using Standard Proctor (ASTM D 698) and Modified Proctor (ASTM D 1557) procedures at varying moisture contents to develop compaction curves (dry unit weight vs. molding water content).
c. The compacted specimens are then subjected to permeability tests (ASTM D 5084), using care to ensure that standard permeation procedures are followed, and 2 psi is used for the maximum confining stress. The measured hydraulic conductivity is then plotted as a function of the molding water content.
d. The dry unit weight/water content points are then replotted to represent compacted specimens that have hydraulic conductivity greater than and less than 1×10^{-6} cm/sec. An "acceptable zone" is then

constructed to encompass the data points representing test results meeting or exceeding the hydraulic conductivity criteria.

e. The acceptable zone shall be limited to soil having a moisture content range at optimum to +3% of optimum moisture content (either standard or modified proctor compaction).
f. Moisture contents up to 5% above optimum may be allowed if direct shear testing of soils within this range indicate acceptable shear strength, based on shear strength values used in the analysis (see Appendix F of the Operations Manual).

Further explanation and testing procedures to establish the above relationship are presented in the report, *Water Content-Density Criteria for Compacted Soil Liners* [1].

Soils not meeting the above testing criteria are unsuitable and will not be used in clay soil liner construction.

10.4 Placement of Compacted Clay Final Cover

10.4.1 Compacted Select Soil

Prior to placement of compacted select soil, ensure that the ash fill and/or gypsum has been final graded. For the initial lift, the select soil shall be placed and spread over the ash or gypsum and compacted. For subsequent lifts, the previous lift shall be scarified to a depth of one to two inches to ensure adequate bond between the previous lift and the lift being installed. For all lifts, the soil shall be tilled as necessary to promote blending, adjust moisture content, and attain a nominal clod size of two inches or less. During tilling, the soil shall be visually checked to ensure that it does not contain rock fragments or gravel larger than two inches nominal size. Rock fragments or gravel larger than two inches nominal size shall be removed and placed in areas as directed by the Construction Manager.

The select soil shall be compacted using a suitable non-vibratory, footed compactor. The foot length of the compactor shall be a minimum four inches.

Fill material shall be placed in uniformly thick lifts not exceeding 6-inches in compacted thickness. Compaction requirements for select soil layer shall be governed by the moisture-density-permeability relationship of soils. Acceptance of a lift requires that results meet the moisture-density requirements as defined by construction of the "acceptable zone" as defined in Item 10.3. Perform testing in accordance with Section 10.5 prior to placement of subsequent layers of final cover. All test results must be satisfactory and accepted by the Certification Engineer prior to beginning the next layer.

10.4.2 Compacted Random Soil

Ensure that the select soil layer has been placed and is ready to receive the random soil layer. The random soil material shall be placed in uniformly thick lifts not exceeding 6-inches in compacted thickness. Compaction shall be a minimum of 90% of the maximum dry density at +/- 3% of the optimum moisture content in accordance with ASTM D 698.

In-place moisture and density testing in accordance with ASTM D 3017 and D 2922 respectively, shall be conducted after each lift is placed at a frequency of 5 tests per acre per lift. The location of the density tests shall be selected randomly by the Certification Engineer.

10.4.3 Vegetative Layer

Verify that random soil layer grades and elevations are correct before placing the vegetative layer. Place and spread the initial lift of vegetative layer in a manner that prevents damage to the underlying soil cap. Subsequent lifts shall be placed in a manner that prevents over-compaction such that vegetative growth is hindered. The top surface of the vegetative layer shall be roughened or scarified to an approximate depth of 2 inches to promote acceptance of seed and fertilizer.

Do not place vegetative layer until seeding and fertilization can be accomplished promptly after placement.

10.5 Field Testing

The Certification Engineer will visually inspect clay soil being placed during construction accordance with Item 10.3.

Field Testing of the clay soil liner will be performed to assure that construction meets requirements outlined in Table 2.

TABLE 2

TESTING FOR LOW PERMEABLE CLAY LAYER IN FINAL COVER

Parameter	Test Method	Minimum Testing Frequency
Water Content (Note 1)	ASTM D 3017 Nuclear Density of ASTM D 4643 microwave	5/acre/lift (Note 2)
Water Content (Note 3)	ASTM D 2216	1/acre/lift (Note 3)
Density (Note 4)	ASTM D 2922	5/acre/lift (Note 2)
Density (Note 5)	ASTM D 1556	1 acre lift (Note 5)
Permeability (Note 6)	ASTM D 5084	1/3 acres/lift or 1/ soil change
Construction Oversite	Visual Observation	Continuous

Notes:

1) ASTM D 3017 is a nuclear method and D 4643 is microwave oven drying.
2) In addition, at least one test should be performed each day soil is compacted and additional tests should be performed in areas for which the Certification Engineer has reason to suspect inadequate compaction.
3) Every fifth sample tested with ASTM D 3017 or D 4643 should also be tested by direct oven drying (ASTM D 2216) to aid in identifying any significant, systematic calibration errors with D 3017 or D 4643.
4) ASTM D 2922 is a nuclear method.
5) The sand cone (ASTM D 1556) is required in the event that the liner is to be constructed with soils having more than 20% retained on the number four sieve.

6) ASTM D 5084 is a laboratory permeability test that is to be performed on Shelby tube samples taken from the constructed liner. However, this test is not acceptable for soils with more than 20% retained on the number 4 sieve.

All voids left by test equipment shall be filled with bentonite, and hand tamped by the Subcontractor.

Additional tests may be performed as directed by the Certification Engineer based on the following conditions:

a. The clay soil or fill material appears to be at an improper moisture content or the moisture content is not uniform.
b. Fill materials appear to differ substantially from those specified or previously tested.
c. The degree of compaction is questionable or does not appear uniform.

10.6 Non-Conforming Test Results

Density and moisture content test locations that fail to meet or exceed construction criteria will require reworking. The boundaries of the area to be reworked will be defined by the closest test locations, which meet density and moisture content specifications. The non-conforming area will be reworked, dried or wetted as necessary, and retested. A non-conformance report will be prepared for areas, which do not meet construction specifications after reworking and retesting.

Laboratory permeability test results which demonstrate a permeability above 1×10^{-6} cm/sec will be immediately brought to the attention of the Certification Engineer. Non-conforming permeability test results may result in a review of previous test results, retesting, and/or a reevaluation of compaction criteria. After review and/or retesting areas which do not meet the specified permeability will require reworking.

All non-conformance reports will be brought to the attention of the Construction Manager by the Certification Engineer and will be documented in the Quality Assurance files.

10.7 Geocomposite Final Cover

10.7.1 Material and Installation Requirements

Attachments 2 and 3, Specifications KIF-0-TS-02778 and KIF-0-TS-02622 contain requirements for QA/QC for installing the geocomposite final cover.

11 CONSTRUCTION TOLERANCES

The minimum thickness of the compacted soil layer in the final cover shall be 18 inches. The top of the vegetative layer shall be such that the final grade provides a minimum 6 inches thickness for the vegetative layer. Other construction tolerances are as noted on the drawings.

12 SURVEYING

Surveying will be performed under this section to document as-built conditions, and will be the responsibility of the Constructor. The as-built survey will be performed by a Land Surveyor registered in

the state of Tennessee. Intermediate surveying for construction layout, slope staking, etc., may be performed by the Constructor's personnel.

The completed subgrade surface will be surveyed, before placement of any clay liner, to verify that grades and elevations are in accordance with the approved plans. At a minimum, survey points shall be established on a 100 ft. x 100 ft. grid, and at all slope changes along the subgrade. Survey grid points shall be located such that the same grid can be reused for subsequent as-built surveys as the completion of the ash fill progresses. In addition, cross sections shall also be surveyed at locations shown on the construction drawings.

The completed compacted fly ash surface will be surveyed, before placement of the overlying drainage layer, to verify that grades and elevations are in accordance with the approved plans. At a minimum, survey points shall coincide with the 100 ft x 100 ft grid established for the as-built survey of the subgrade, and at all slope changes. Cross sections shall also be surveyed at locations shown on the construction drawings.

Survey points for the starter dike shall be along the top, crest of slope, mid-point of slope, and bottom of each slope, sufficient to document the as-built condition of the starter dike. The completed ash fill surface shall be surveyed prior to placement of the compacted soil final cover, to verify and document grades, elevations, and thickness of the ash fill. At a minimum, survey points shall be located on the same 100 ft. x 100 ft. grid used for the as-built survey of the subgrade, and at all slope changes along the ash fill. Cross sections shall also be surveyed at locations shown on the construction drawings.

After completion of the compacted soil final cover, the completed cap surface shall be surveyed prior to placement of the vegetative layer, to verify and document grades, elevations, and. At a minimum, survey points shall be located on the same 100 ft. x 100 ft. grid used for the as-built survey of the ash fill, and at all slope changes. Cross sections shall also be surveyed at locations shown on the construction drawings.

The vegetative layer shall be surveyed after completion to verify and document grades, elevations, and thickness. At a minimum, survey points shall be located on the same 100 ft. x 100 ft. grid used for the as-built survey of the final cover, and at all slope changes along the ash fill. Cross sections shall also be surveyed at locations shown on the construction drawings.

The Certification Engineer may request additional survey information as required for certification.

13 REPORTING

13.1 Deficiencies

When deficiencies are discovered, the Certification Engineer shall immediately determine the nature and extent of the problem, notify the Constructor, and complete required documentation. In all cases, the Certification Engineer will notify the Constructor within one-half hour of discovering the deficiency. If the deficiency will cause construction delays of more than four hours or will necessitate substantial rework, the Certification Engineer shall also notify the Construction Manager.

The Constructor shall correct the deficiency to the satisfaction of the Certification Engineer. If the Constructor is unable to correct the problem, the Certification Engineer will prepare a nonconformance

report and will develop and present suggested solutions to the Construction Manager for approval. If the solution requires a design revision, the Owner shall also be contacted.

The corrected deficiency shall be retested before additional work is performed. All retests, and the steps taken to correct the problem, will be documented by the Certification Engineer.

13.2 Documentation

This QA/QC Plan depends on through monitoring and documentation of all construction activities. Therefore, the Certification Engineer shall document that all Quality Assurance requirements have been addressed and satisfied. Documentation shall consist of daily record keeping, construction problem resolutions, photographic records, design revisions, weekly progress reports, and a certification and summary report.

13.2.1 Daily Record Keeping

At a minimum, daily records shall consist of field notes, summaries of the daily meetings with the Constructor, observations and data sheets, and construction problems and resolution reports. This information shall be submitted to the Construction Manager for review and approval.

A Daily Meeting Report will be prepared each day, summarizing discussions held with the Constructor. This report will include the following items:

a. date, project name, and location;
b. names of parties involved in discussions;
c. data on weather conditions;
d. listing and location of construction activities underway during the time frame of the Daily Summary Report;
e. equipment present on-site;
f. descriptions of areas and/or activities being inspected and/or tested, and related documentation;
g. description of off-site materials received;
h. scheduled activities;
i. items discussed;
j. signature of the Certification Engineer.

13.2.2 Observation and Test Sheets

Observation and test data sheets shall include the following information:

a. date, project name, and location;
b. weather data;
c. reduced-scale site plan showing work areas, including sample and test locations;
d. description of ongoing construction;
e. summary of test results identified as passing, failing, or in the event of a failed test, retest;
f. calibration of test equipment;
g. summary of decisions regarding acceptance of the work and/or corrective actions taken;
h. signature of the Certification Engineer.

13.2.3 Construction Problem Reports

This report identifies and documents construction problems and resolutions. It is intended to document problems involving significant rework and is not intended to document items easily corrected unless the problems are recurring. At a minimum, this report shall include the following items:

a. detailed description of the problem;
b. location and cause of the problem;
c. how the problem was identified;
d. resolution of the problem;
e. personnel involved,
f. signature of the Certification Officer and Construction Manager.

13.2.4 Survey Control

The following procedures will be followed with respect to the as-built survey of the ash and gypsum fill components.

- The subgrade, ash dikes, starter dikes, wet cast gypsum dikes, completed ash and gypsum fill, compacted select soil and random soil layers, and vegetative layer will be surveyed to verify that grades and elevations are in accordance with the approved plans as described in Section 10.0. A comparison of the pre- and post-component construction surveys will be conducted to verify construction thickness.

- The Surveyor shall promptly submit results of each survey to the Construction Manager. Survey results shall include: copy of any field notes, electronic and hard copy of the survey point file, and electronic and hard copy of survey drawing.

- The Certification Engineer will certify that the components meet the requirements in the plans and will submit approval to the Construction Manager.

13.2.5 Design Changes

Design changes may be required during construction. In such cases, the Certification Engineer shall notify the Construction Manager, who will then notify the Owner. Design changes shall only be made with written agreement of the Construction Manager and Owner.

13.2.6 Weekly Progress Reports

The Certification Engineer shall prepare weekly progress reports summarizing construction and quality control activities. At a minimum this report, submitted to the Construction Manager, shall contain the following information:

a. date, project name, and location;
b. summary of work activities;
c. summary of deficiencies and/or defects and resolutions;
d. signature of Certification Engineer.

13.2.7 Certification Reports

The Certification Engineer will be required to submit the following certification reports. The first certification report will cover construction of ash dikes for the existing dredge cell and dike raising of Phase 1 ash dredge cells, the initial phase of construction for Phase 2, 3, construction of each stage of wet cast gypsum (or ash) dikes, and will be required prior to disposal of ash and/or gypsum. A certification report will also be required for final closure.

The final certification report will be required after the ash fill has been completed. This report will cover the capping phase of construction and will be required during closure of the facility. This report will address final ash-fill slopes, final cover, and vegetative layer.

At the completion of each phase of construction, the Certification Engineer shall submit a certification report to the Construction Manager. This report shall certify that the work has been performed in substantial compliance with the approved plans. At a minimum, this report shall contain the following information:

a. summary of all construction activities;
b. testing laboratory test results;
c. observation and test data sheets;
d. sampling and testing location plan;
e. description of significant construction problems and their resolution;
f. list of changes from the approved plans and the justification for these changes;
g. record drawings;
h. certification statement signed and sealed by the Certification Engineer.

14 REFERENCES

1. Daniel, D. E., and Benson, C. H., *Water Content-Density Criteria for Compacted Soil Liners*, Journal of Geotechnical Engineering, Vol. 116, December 1990.

Attachment 1 - Specification KIF-0-TS-02778

ATTACHMENT 1 TO KINGSTON FOSSIL PLANT DREDGE CELL LATERAL EXPANSION QA/QC PLAN

SPECIFICATION KIF-0-TS-02778

REVISION 0

FOR
LLDPE GEOMEMBRANE
CONSTRUCTION QUALITY ASSURANCE

SECTION JOHN-0-TS-02778

LLDPE GEOMEMBRANE CONSTRUCTION QUALITY ASSURANCE

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PART 1 – GENERAL - GEOMEMBRANE MANUFACTURE, FABRICATION, AND DELIVERY

1.0 GEOMEMBRANE MANUFACTURING

1.1 Raw Material - LLDPE Geomembrane

The raw materials for polyethylene (LLDPE) geomembrane manufacture shall be first-quality resins containing no more than 2% clean recycled polymer by weight and a maximum of 1% by weight of additives, extenders and fillers (not including carbon black), and meeting the minimum construction specifications.

1.2 General

Compliance testing shall be carried out by the Manufacturer to demonstrate that the product meets specifications. At the Owner's discretion and cost, the Geosynthetics CQA Laboratory for purposes of conformance may carry out additional testing. If the results of the Manufacturer's and the Geosynthetics CQA Laboratory's testing differ, the testing will be repeated by the Geosynthetics CQA Laboratory, and the Manufacturer will be allowed to monitor this testing. The results of this latter series of tests will prevail, provided that the applicable test methods have been followed.

Prior to the installation of any geomembrane material, the Manufacturer shall provide the Construction Manager and the CQA Consultant with the following information, as applicable for liner type:

a. The origin (Resin Supplier's name and production plant), identification (brand name, number) and production date of the resin.

b. A copy of the quality control certificates issued by the Resin Supplier.

c. Reports on the tests conducted by the Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the project. At a minimum, these tests should include density, melt flow index, and oxidative induction time.

d. A statement confirming that if polymer is recycled during the manufacturing process, it is done with appropriate cleanliness and does not exceed 2% by weight for the manufacture of LLDPE.

The CQA Consultant will review these documents and report any discrepancies with the above requirements to the Construction Manager.

1.3 Geomembrane Manufacturing

Prior to the installation, the Geomembrane Manufacturer shall provide the Construction Manager and the CQA Consultant with the following:

a. A properties sheet including, at a minimum, all specified properties, measured using test methods indicated in the Specifications, or equivalent.

b. A list of quantities and descriptions of materials other than the base polymer which comprise the geomembrane.

c. The sampling procedure and results of testing.

d. A certification that property values given in the properties sheet are minimum values and are guaranteed by the Geomembrane Manufacturer.

The CQA Consultant will verify that:

a. The property values certified by the Geomembrane Manufacturer meet all of the requirements of Table 1.

b. The measures of properties by the Geomembrane Manufacturer are properly documented and that the test methods used are acceptable.

1.4 Rolls

Prior to shipment, the Geomembrane Manufacturer shall provide the Construction Manager and the CQA Consultant with a quality control certificate for each roll of geomembrane provided. A responsible party employed by the Geomembrane Manufacturer, such as the production manager, shall sign the quality control certificate. The quality control certificate shall include at least the following information:

a. Roll numbers and identification.

b. Sampling procedures and results of quality control tests. As a minimum, results shall be in accordance with Table 2

The CQA Consultant will:

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

b. Review the quality control certificates and verify that the certified roll properties meet the specifications.

1.5 Conformance Testing

1.5.1 Tests: Upon delivery of the rolls of geomembrane, the CQA Consultant will ensure that samples are removed at the specified frequency and forwarded to the Geosynthetics CQA Laboratory for testing to ensure conformance to both the design specifications and the list of guaranteed properties.

As a minimum, the CQA laboratory will perform the tests listed in Table 3.

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

1.5.3 Test Results: The CQA Consultant will examine all results from laboratory conformance testing and will report any non-conformance to the Construction Manager. The minimum standards are given in Table 1.

1.5.4 Procedures for Conformance Test Failure: The following procedure will apply whenever a sample fails a conformance test that is conducted by the Geosynthetics CQA Laboratory.

Two (2) additional samples shall be taken from the roll of geomembrane that has failed the conformance test. The Geosynthetics CQA Laboratory shall perform two (2) identical retests of the failing test.

a. If both of the two (2) retests on the roll pass, the roll shall be deemed acceptable.

b. If either of the two (2) retests on the roll fail, the Installer shall replace the roll of geomembrane that is in non-conformance with the specifications with a roll that meets the specifications. In addition, the Installer shall remove conformance samples (for testing by the Geosynthetics CQA Laboratory) from the closest numerical roll on both sides of the failed roll. These two samples must both conform to the Specifications. If either one of these samples fail, every roll of geomembrane on site from the same lot and every roll delivered subsequently from the same lot must be tested by the Geosynthetics CQA Laboratory for conformance to the Specifications.

The retesting and additional conformance testing to address a test failure shall be at the expense of the Installer.

The CQA Consultant will document actions taken in conjunction with conformance test failures.

1.6 Delivery

Transportation and Handling: Transportation of the geomembrane is the responsibility of the Geomembrane Manufacturer, Installer, or other party as agreed upon. All handling on site is the responsibility of the Installer.

When the geomembrane arrives on-site, the CQA Consultant will verify that the installer supervisor has carefully checked the material for damage during shipment and will also make spot checks himself. Packing slips shall be checked to ensure delivery of the correct materials, and to verify type, thickness, and quality of material. All accessory materials such as solvents, adhesives, tapes, etc., shall be checked for damage and compatibility with material and project specifications. Shelf life shall be noted and not exceeded. A "Material Receiving Log" shall be completed for each delivery truck. All comments shall be recorded on that form.

The CQA Consultant will verify that:

a. Handling equipment used on the site is adequate and does not pose any risk of damage to the geomembrane. Typical equipment used to unload and handle liner rolls are forklifts, front-end loaders with forks, and cranes. The unloading equipment shall be of sufficient size and readily accessible to delivery vehicles (trucking and on-site transport and placement equipment).

b. The Installer's personnel shall handle the geomembranes with care. LLDPE is delivered in rolls weighing up to 5,000 pounds each and should be handled with appropriate equipment to avoid damage.

Upon delivery to the site, the Installer and the CQA Consultant will conduct a surface observation of all material for defects and for damage. This examination will be conducted without unrolling unless defects or damages are found or suspected. The CQA Consultant will indicate any problems to the Construction Manager and identify on the "Material Receiving Log":

a. Any rolls, or portions thereof, that should be rejected and removed from the site because they have severe flaws.

b. Any material that has minor repairable flaws.

c. All accessories will be inspected visually. The containers and labels shall show brand name, type of material, date of manufacture, proper method of application, and expiration date for shelf-life determination. All containers shall be properly sealed.

1.7 Storage

The Installer shall be responsible for the storage of the geomembrane on site. The Construction Manager will provide storage space in a location (or several locations) such that on-site transportation and handling are minimized. All areas will be of adequate size

for ease of handling and located near the placement area to minimize handling and travel. The storage area shall be level and smooth, free of rocks, holes or debris. If in a building, the area should be of a size suitable for material handling, accessibility and maneuverability. Storage space should protect the geomembrane from theft, vandalism, passage of vehicles, etc. Storage of geomembrane rolls at the site shall not exceed five (5) rolls high, as crushing of the core or flattening of the rolls may occur. Open areas should be fenced for security.

The CQA Consultant will document that storage of the geomembrane ensures adequate protection against dirt, shock, and other sources of damage. All liner materials shall be protected from the weather, either in enclosed areas, or as a minimum, pallets and crates shall be covered with tarpaulins or plastic to keep moisture, water, and sunlight from contact with the material. All accessory materials such as adhesives, cements, solvents, mastics, caulks and tape shall be stored inside a temperature-controlled shelter.

1.8 Reference Specifications

See Specification 02777 for geomembrane installation.

2.0 GEOMEMBRANE INSTALLATION

2.1 Subgrade and Subbase Layer Construction

2.1.1 Surface Preparation: The General Contractor shall be responsible for preparing the subgrade and the subbase layer according to the Specifications.

The CQA Consultant will document that:

a. A qualified Land Surveyor has verified all lines and grades.

b. The requirements for soil testing and inspection are satisfied.

The Installer shall certify in writing that the surface on which the geomembrane is to be installed is acceptable. The "Subgrade Surface Acceptance" form shall be completed, signed by the Installer and given to the Construction Manager prior to commencement of geomembrane installation in the area under consideration. The Construction Manager will give the CQA Consultant a copy of this form.

After the subbase has been accepted by the Installer, it shall be the Installer's responsibility to indicate to the Construction Manager any change in the subbase condition that may require repair work. If the CQA Consultant concurs with the Installer, then the Construction Manager will ensure that the subbase is repaired.

2.1.2 Anchorage System: Anchor trenches shall be excavated by the Contractor to the lines and widths shown on the design drawings, prior to geomembrane placement. The Geosynthetics CQA Consultant will verify that anchor trenches have been constructed according to design drawings.

Slightly rounded corners shall be provided in trenches where the geomembrane adjoins the trench so as to avoid sharp bends in the geomembrane. No loose soil shall underlie the geomembrane in the trenches.

2.2 Geomembrane Placement

2.2.1 Personnel: Liner installation shall be performed with a combination of large equipment and placement crews. Personnel shall have training and shall be supervised by a qualified Superintendent. Minimum training shall include the following items:

a. Brief instructions on purpose of lining installation.

b. Brief instructions on placement procedures.

c. Knowledge of safety procedures to be observed during geomembrane placement including, at a minimum:

1. Dismounting techniques from a geomembrane panel lifted several feet in the air.

2. Safe method of removing metal bands from geomembrane packaging.

3. Awareness of techniques to avoid over-stressing of arms, legs, and back during placement operations.

2.2.2 Clothing: All on-site personnel shall wear certain special clothing during lining placement. This includes:

a. Smooth-soled shoes. No shoes with indented patterns shall be worn since small rocks can be trapped in the void areas and inadvertently puncture and tear the lining.

b. Gloves - when handling/pulling lining into places, gloves should be worn to prevent abrasion or other damage to the worker's hands.

c. Each installer shall be inspected to ensure that his clothing and footwear will not damage either the geomembrane or the installer during placement.

2.2.3 Field Panel Identification: The CQA Consultant will document that the Installer labels each field panel with an "identification code" (number or letter-number) consistent with the layout plan. The Construction Manager, Installer, and CQA Consultant will agree upon this identification code. It shall be the responsibility of the Installer to ensure that each field panel placed is marked with the original roll number. The roll number shall be marked at a location agreed upon by the Construction Manager, Installer, and CQA Consultant.

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

2.2.4 Field Panel Placement: The "Daily Panel Placement Log" and "Daily Seaming Log" will be completed daily.

2.2.5 Location: The CQA Consultant will verify that field panels are installed at the location indicated on the Installer's layout plan, as approved or modified.

2.2.6 Installation Schedule: Field panels shall be placed one at a time unless otherwise approved by the CQA Consultant, and each field panel shall be seamed immediately after its placement (in order to minimize the number of unseamed field panels exposed to wind).

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

The CQA Consultant will evaluate every change in the schedule proposed by the Installer and advise the Construction Manager on the acceptability of that change. The CQA Consultant will verify that the condition of the subase has not changed detrimentally during installation.

The CQA Consultant will record the identification code, location, and date of installation of each field panel.

2.2.7 Weather Conditions: Geomembrane placement shall not proceed at an ambient temperature below 50°F or above 104°F unless authorized by the Construction Manager. In addition, the geomembranes shall not be unrolled unless the sheet temperatures are between 32°F and 122°F. If ambient conditions create sheet temperatures below 50°F then panels shall be warmed by artificial means (i.e. hot air guns, heat lamps, space heaters, etc.) prior to seaming. Geomembrane placement shall not be done during any precipitation, in an area of ponded water, or in the presence of excessive winds (i.e. conditions under which the liner may be blown around and/or raised off the ground with workers on the liner, or the liner edges may whip, shred, or rip).

The CQA Consultant will verify that the above conditions are fulfilled. Additionally, the CQA Consultant will verify that the supporting soil has not been damaged by weather conditions.

2.2.8 Method of Placement: The following is the responsibility of the Installer; the CQA Consultant will document that these conditions are satisfied:

a. All placement equipment is on-site and in working order.

b. Any equipment used does not damage the geomembrane by handling, traveling, excessive heat, leakage of hydrocarbons or other means. Utility knives have only hook-type blades. All necessary personnel are on-site.

c. The prepared surface underlying the geomembrane has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement.

d. Any geosynthetic elements immediately underlying the geomembrane are clean and free from debris.

e. All personnel working on the geomembrane shall not smoke, wear boots or shoes capable of damaging the geomembrane, or engage in other activities that could damage the geomembrane.

f. The method and equipment used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil.

g. The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels). The panels are installed in a relaxed condition, free of tension, stress, folds or bends, and not stretched to fit.

h. Adequate temporary loading and/or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, is placed to prevent uplift by wind (in case of high winds, continuous loading by adjacent sand bags is recommended along the edges of panels to minimize the risk of wind flow under the panels).

i. Direct contact with the geomembrane is minimized; i.e., the geomembrane is protected by geotextiles, extra geomembrane, or other suitable materials, in areas where excessive traffic may be expected. Materials, equipment and other items are not dragged, allowed to slide, or allowed to impact the geomembrane or other liner system components.

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

2.2.9 Damage: The CQA Consultant will visually observe every panel, after placement and prior to seaming, for damage. The CQA Consultant will advise the Construction Manager which panels, or portions of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels that have been rejected will be marked and their removal from the work area recorded by the CQA Consultant. Repairs will be made according to procedures described in Section 2.12.

As a minimum, the CQA Consultant will document that:

a. The panel is placed in such a manner that it is unlikely to be damaged.

b. Any tear, punctures, holes, thin spots, etc. are either marked for repair or the panel is rejected.

2.3 Field Seaming

The "Daily Seaming Log", "Trial Seam Report", "Field Destructive Test Log", and "Non-Destructive Test Log" will be completed for daily seaming operations.

2.3.1 Seam Layout: The Installer shall provide the Construction Manager and the CQA Consultant with a seam layout drawing for the facility, showing all expected seams. The CQA Consultant or the Engineer will review the seam layout drawing and verify that it is consistent with the accepted state of practice and this CQA Plan. No panels may be seamed in the field without the Construction Manager's approval. In addition, no panels not specifically shown on the seam layout drawing may be used without the Construction Manager's prior approval.

In general, field and factory seams should be oriented parallel to the line of maximum slope, i.e., oriented along, not across, the slope. In corners and odd-shaped geometric locations, the number of seams should be minimized. No horizontal seam should be within 10 ft. of the toe of slopes, or areas of potential stress concentrations, unless otherwise authorized.

The completed liner shall not exhibit any "trampolining" during any daylight hours (6:00 a.m. to 8:00 p.m.).

All parties will agree upon a seam numbering system compatible with the panel numbering system.

2.3.2 Requirements of Personnel: The seaming crew for liner installation typically consists of a minimum two-person crew. The project superintendent and all crew foremen shall meet minimum installation experience for linings. The project superintendent shall have installed 2,000,000 sq. ft. of liner. The master seamer shall have installed 1,000,000 sq. ft. of liner. All crew members shall have minimum safety training in handling liner materials.

All personnel performing polyethylene seaming operations will be qualified by experience. Seaming personnel must have seamed at least 10,000 ft. of polyethylene geomembrane seams using the same type of seaming apparatus to be used on this project.

2.3.3 Clothing: All seaming crews shall wear the following special clothing during seaming operations:

a. Smooth-soled shoes or boots - no indented patterns on the soles.

b. Gloves - Leather gloves will protect against hot equipment or other damage.

c. Goggles or suitable protective eyewear during seaming operations.

d. Kneepads - to protect the worker's knees.

2.3.4 Experience: The Installer shall provide the Construction Manager and the CQA Consultant with a list of proposed seaming personnel and their experience records. The Construction Manager and the CQA Consultant will review this document.

2.4 Seaming Equipment and Products

2.4.1 Field Seaming: Approved processes for field seaming of polyethylene are extrusion seaming and fusion seaming. Proposed alternate processes shall be documented and submitted to the Owner or his representative for his approval. Only apparatus that have been specifically approved by make and model shall be used. The Installer shall use a pyrometer to ensure that accurate temperatures are being achieved.

2.4.2 Polyethylene Seaming Techniques - Extrusion Process: The extrusion-seaming apparatus shall be equipped with gauges giving the relevant temperatures of the apparatus such as the temperatures of the extrudate, nozzle, and preheat. The Installer shall provide documentation regarding the extrudate to the Construction Manager and the CQA Consultant and shall certify that the extrudate is compatible with the Specifications, and in any event is comprised of the same resin as the geomembrane sheeting.

The CQA Consultant will log apparatus temperatures, extrudate temperatures, and ambient temperatures at appropriate intervals. Ambient temperatures will be measured 6 in. above the geomembrane surface.

The CQA Consultant will verify that:

a. The Installer maintains on-site a suitable number of spare operable seaming apparatus.

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

c. The extruder is purged prior to beginning a seam until all heat-degraded extrudate has been removed from the barrel.

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

e. A smooth insulating plate or fabric is placed beneath the hot seaming apparatus after usage.

f. The geomembrane is protected from damage in heavily trafficked areas.

2.4.3 Fusion Process: The fusion-seaming apparatus must be automated vehicular-mounted devices. The fusion-seaming apparatus shall be equipped with gauges giving the

applicable temperatures. The Installer prior to each seaming period shall verify pressure settings.

The CQA Consultant will log ambient temperatures, seaming apparatus temperatures, and speeds. Ambient temperatures will be measured 6 in. above the geomembrane surface.

The CQA Consultant will also verify that:

a. The Installer maintains on-site a suitable number of spare operable seaming apparatus.

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

c. For cross seams, the edge of the cross seam is ground to a smooth incline (top and bottom) prior to seaming.

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

e. A smooth insulating plate or fabric is placed beneath the hot seaming apparatus after usage.

f. The geomembrane is protected from damage in heavily trafficked areas.

g. Build-up of moisture between the sheets is prevented (a movable protective layer may be used as required directly below each overlap of geomembrane that is to be seamed to accomplish this end).

2.5 Seam Preparation

The CQA Consultant will verify that:

a. Prior to seaming, the seam area is clean and free of moisture, dust, dirt, oils, greases, debris of any kind, and foreign material.

b. If seam overlap grinding is required, the process is completed according to the Geomembrane Manufacturer's instructions within one hour of the seaming operation, and in a way that does not damage the geomembrane.

c. The abrading does not extend more than 0.5 in. on either side of the extrusion seam.

d. Seams are aligned with the fewest possible number of wrinkles and "fishmouths".

2.6 Weather Conditions for Seaming

The normally required weather conditions for seaming are as follows:

a. Unless authorized in writing by the Construction Manager, no seaming shall be attempted at an ambient temperature below 50°F or above 104°F. Below 50°F, panels shall be warmed artificially with hot air guns, radiant heaters, heat lamps, space heaters, etc.

b. The geomembrane shall be dry and protected from wind, rain, snow, heavy mist or fog, hail, high or low temperatures, dust, or other adverse environmental conditions.

c. The ambient temperatures shall be measured 6 in. above the geomembrane surface.

If the Installer wishes to use methods which may allow seaming at ambient temperatures below 50°F or above 104°F, the Installer shall demonstrate and certify that such methods produce seams which are entirely equivalent to seams produced at ambient temperatures above 50°F and below 104°F, and that the overall quality of the geomembrane is not adversely affected.

The CQA Consultant will verify that these weather conditions are fulfilled and will advise the Construction Manager if they are not. The Construction Manager will then decide if the installation will be stopped or postponed.

2.7 Overlapping and Temporary Bonding

The Installer shall ensure that, and the CQA Consultant will verify that:

a. The panels of geomembrane have a minimum finished overlap of 4 in. for extrusion and fusion seaming, but in any event sufficient overlap shall be provided to allow peel tests to be performed on the seam.

b. No solvent or adhesive shall be used unless the product is accepted in writing by the Owner (samples shall be submitted to the Owner for testing and evaluation).

c. The procedure used to temporarily bond adjacent panels together shall not damage the geomembrane (in particular, the temperature of hot air at the nozzle of any spot seaming apparatus is controlled such that the geomembrane is not damaged).

The CQA Consultant will log all overlapping and temporary bonding, and will log and report to the Construction Manager any non-compliance.

2.8 Trial Seams

Trial seams shall be made on fragment pieces of geomembrane liner to verify that seaming conditions are adequate. Such trial seams shall be made at the beginning of each seaming period, and at least once every five hours, for each seaming apparatus used in the seaming period. A trial seam also shall be made in the event that the ambient temperature varies more than 18°F since the last passing trial seam. The ambient temperature shall be measured 6 in. above the liner. Also, each seamer or seamer crew shall make at least one trial seam each seaming period, or each 1,000 feet of seam. Trial seams shall be made under the same conditions as actual seams. If any seaming apparatus is turned off for any reason, a new passing trial seam shall be completed for that specific seaming apparatus. The Installer shall provide the tensiometer required for shear and peel testing in the field. The tensiometer shall be automatic and shall have a direct digital readout.

The trial seam sample for polyethylene shall be at least 3 ft. long by 1 ft. (after seaming) with the seam centered lengthwise.

All sample seams shall be cured or aged properly before testing in accordance with the test procedure.

Four specimens of field geomembrane seams shall initially be taken by the Installer and tested. Two specimens shall be tested in shear and two in peel using a field tensiometer, and they should not fail in the seam. Minimum strength requirements for field seams are provided on Table 4. In each type of test, a maximum of one non-FTB failure out of five tests is acceptable provided that the strength requirement is met on that sample. If a specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus and seamer will not be accepted and will not be used for seaming until the deficiencies are corrected and two consecutive successful full trial seams are achieved.

The CQA Consultant will observe all trial seam procedures and record data on the "Trial Seam Report." The remainder of the successful trial seam sample will be assigned a number and marked accordingly by the CQA Consultant, who will also log the date, hour, ambient temperature, seaming unit number, name of seamer, and pass or fail description. The sample itself will be cut into two pieces, one to be retained in the Owner's archives and one to be given to the Installer.

2.9 General Seaming Procedure

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

a. All seaming shall commence from the center to the edges to minimize entrapment of large wrinkles that will require cutting and patching.

b. The working area shall be clean and smooth and have adequate room for maneuvering. A firm surface shall be provided by using a flat board or similar hard surface directly under the seam overlap to achieve proper support.

c. Prior to seaming a lining sheet or patch, all edges shall be free of defects such as blisters and tears. Once the seam is formed, it is desirable that there be no free edge on the upper lining that equipment or other items can catch or snag on, potentially damaging the seam in this location.

d. For fusion seaming of geomembrane, a movable protective layer of plastic may be required directly below each overlap of geomembrane that is to be seamed. This is to help prevent any moisture build-up between the sheets to be seamed.

e. Sandbags shall remain placed on the seaming edges of all sheets until the lining is formally seamed. Sandbags shall be spaced no more than 5 to 6 feet apart.

f. "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. beyond the cut in all directions.

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

h. Seaming shall extend to the outside edge of panels. No liner edge shall be buried within 30 feet of an "incomplete" field seam. This allows for re-tensioning to remove wrinkles along the seam area.

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

2.10 Non-destructive Seam Continuity Testing

Non-destructive testing of all field seams shall be done to check 100% of all seams. The "Non-Destructive Test Log" shall be completed relative to non-destructive testing. The Installer shall perform non-destructive tests on all field seams over their full length. Fillet-extrusion welds shall be tested with a vacuum chamber in accordance with ASTM D 5641. Hot wedge welds shall be pressure tested, pressurizing the gap created by the split face design of the hot wedge in accordance with ASTM D 5820. A spark test, in accordance with ASTM D 5820, shall be used for all boots. Probe test methods shall not be used. The testing shall be carried out to the accepted standards of the industry. The purpose of non-destructive tests is to check the continuity of seams. It does not provide any information on seam strength. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming. Non-destructive testing shall not be permitted before sunrise or after sunset unless the Installer demonstrates capabilities to do so.

The CQA Consultant will:

a. Observe all continuity testing.

b. Record location, date, test unit number, name of tester, and outcome of all testing.

c. Inform the Installer and Construction Manager of any required repairs.

The Installer shall complete any required repairs in accordance with Subsection 2.12.

The CQA Consultant will:

a. Observe the repair and retesting of the repair.

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

c. Document the results.

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

a. All such seams shall be cap-stripped with the same geomembrane.

b. If the seam is accessible to testing equipment prior to final installation, the seam shall be non-destructively tested prior to final installation.

c. If the seam cannot be tested prior to final installation, the seaming and cap-stripping operations shall be observed by the CQA Consultant and Installer for uniformity and completeness.

The seam number, date of observation, name of tester, and outcome of the test, or observation will be recorded by the CQA Consultant.

2.11 Destructive Testing

2.11.1 Concept: Destructive seam tests will be performed at locations selected by the CQA Consultant. The purpose of these tests is to evaluate seam strength. Seam strength testing will be done as the seaming work progresses, not at the completion of all field seaming. Care will be taken to properly cure all seams and samples according to test procedure requirements.

2.11.2 Location and Frequency: The CQA Consultant will select locations where seam samples will be cut out for laboratory testing. Those locations will be established as follows:

a. A minimum frequency of one test location per 2,000 ft. of seam length.

b. The Installer, Construction Manager, and CQA Consultant will agree upon a maximum frequency.

c. Test locations will be determined during seaming at the CQA Consultant's discretion.

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

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

a. Observe sample cutting.

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

c. Record the sample location on the layout drawing.

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

All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired. The continuity of the new seams in the repaired area shall be tested.

2.11.4 Size of Samples: At a given sampling location, the Installer shall take two types of samples. These specimen sizes may be changed at the advice or recommendation of the CQA Consultant.

First, two specimens shall be taken for field testing. Each of these specimens shall be 1 in. wide by 12 in. long, with the seam centered parallel to the width. The distance between these two specimens shall be 42 in. If both specimens pass the field test described in the next subsection, a sample for laboratory testing shall be taken.

The sample for laboratory testing shall be located between the two specimens for field testing. The destructive sample shall be 12 in wide by 42 in. long with the seam centered lengthwise. The sample shall be cut into three parts and distributed as follows:

a. One portion to the Installer for laboratory testing, 12 in. x 12 in.

b. One portion to the Owner for archive storage, 12 in. x 12 in.

c. One portion for Geosynthetics CQA Laboratory testing, 12 in. x 18 in.

2.11.5 Field Testing: The two 1 in. wide specimens mentioned in Subsection 2.11.4 will be tested in the field, by tensiometer, for peel and shear respectively, and should not fail in the seam. If any field test sample fails to pass, then the procedures outlined in Subsection 2.11.8 will be followed.

The CQA Consultant will witness all field tests and mark all samples and portions with their number. The CQA Consultant will also log the date and time, ambient temperature,

seaming unit number, name of technician, apparatus temperatures and speeds, and pass or fail description.

2.11.6 Geosynthetics Construction Quality Assurance Laboratory Testing: Destructive test samples will be packaged and shipped, if necessary, under the responsibility of the CQA Consultant in a manner that will not damage the test sample. The Construction Manager will be responsible for storing the archive samples. Test samples will be tested by the Geosynthetics CQA Laboratory. The Construction Manager will select the Geosynthetics CQA Laboratory.

Testing of polyethylene materials will include "Shear Strength" (ASTM D 6392) and "Peel Strength" (ASTM D 6392). At least 5 specimens will be tested for each test method. A maximum of one non-FTB failure is acceptable provided that strength requirements are met on that sample.

The Geosynthetics CQA Laboratory will provide test results no more than 24 hours after they receive the samples. The CQA Consultant will review laboratory test results as soon as they become available, and make appropriate recommendations to the Construction Manager.

Should field tensiometer testing be carried out, the following procedure should be followed: if the test passes, the sample qualifies for testing in the laboratory; if it fails, the seam should be repaired in accordance with Subsection 2.12.3.

2.11.7 Installer's Laboratory Testing: The Installer's laboratory test results shall be presented to the Construction Manager and the CQA Consultant for review.

2.11.8 Procedures for Destructive Test Failure: The following procedures will apply whenever a sample fails a destructive test, whether that test is conducted by the Geosynthetics CQA Laboratory, the Installer's Laboratory, or by field tensiometer. The Installer has two options:

The Installer can reconstruct the seam between any two passed destructive seam test locations.

The Installer can trace the seaming path to an intermediate location (at 10 ft. minimum from the point of the failed test in each direction) and take a small sample for an additional field test at each location. If these additional samples pass tensiometer testing, then full destructive laboratory samples shall be taken. If these destructive laboratory samples pass the tests, then the seam shall be reconstructed between these locations by capping. If either sample fails, then the process is repeated to establish the zone in which the seam shall be reconstructed.

If a fusion-type seam fails destructive testing and the Installer chooses to cap the seam, the only acceptable capping method is as described in Subsection 2.12.3. Applying topping is not an approved method of capping long lengths of seam.

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

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

2.12 Defects and Repairs

2.12.1 Identification: All seam and non-seam areas of the geomembrane will be examined by the CQA Consultant for identification of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of examination. The geomembrane surface shall be broomed or washed by the Installer if the amount of dust or mud inhibits examination. Water used for washing shall be directed to a sedimentation control structure prior to discharge.

2.12.2 Evaluation: Each suspect location both in seam and non-seam areas will be non-destructively tested using the methods described in Subsection 2.10 as appropriate. Each location, which fails the non-destructive testing, will be marked by the CQA Consultant and repaired by the Installer. Work shall not proceed with any materials that will cover a repaired location until laboratory test results with passing values are available.

2.12.3 Repair Procedure: Any portion of the geomembrane exhibiting a flaw, or failing a destructive or non-destructive test, shall be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure will be agreed upon between the Construction Manager, Installer, and CQA Consultant. The procedures available include:

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

b. Grinding and reseaming, used to repair small sections of extruded seams.

c. Spot seaming, used to repair small tears, pinholes or other minor localized flaws.

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

e. Topping, used to repair areas of inadequate seams, which have an exposed edge.

In addition, the following provisions shall be satisfied:

a. Surfaces of the geomembrane that are to be repaired shall be abraded no more than one hour prior to the repair, if applicable.

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

c. All seaming material and equipment used in repairing procedures shall be approved.

d. The CQA Consultant and Installer shall approve the repair procedures, materials, and techniques in advance of the specific repair.

e. Patches or caps shall extend at least 6 in. beyond the edge of the defect, and all corners of patches shall be rounded with a radius of at least 3 in.

f. The geomembrane below large caps shall be appropriately cut to avoid water or gas collection between the two sheets.

2.12.4 Verification of Repairs: Each repair will be numbered and logged. Each repair shall be non-destructively tested using the methods described in Subsection 2.10 as appropriate. Repairs that pass the non-destructive test will be taken as an indication of an adequate repair. Large caps may be of sufficient extent to require destructive testing, at the discretion of the CQA Consultant. Failed tests will require the repair to be redone and retested until a passing test result is obtained. The CQA Consultant will observe all non-destructive testing of repairs and will record the date of the repair and test outcome.

2.12.5 Large Wrinkles: When seaming of the geomembrane is completed (or when seaming of a large area of the geomembrane is completed) and prior to placing overlying materials, the CQA Consultant will observe the geomembrane for wrinkles. The CQA Consultant will indicate to the Construction Manager which wrinkles should be cut and reseamed by the Installer. The seam thus produced will be tested like any other seam.

2.13 Backfilling of Anchor Trench

Anchor trenches shall be adequately drained, to prevent ponding or otherwise softening of the adjacent soils while the trench is open. Also, storm water shall not accumulate in the trenches and flow underneath any completed liner sections. Anchor trenches shall be backfilled in accordance with the construction drawings.

Care shall be taken when backfilling the trenches to prevent any damage to the geosynthetics.

The CQA Consultant will observe the backfilling operation and advise the of any problems.

2.14 Liner System Certification/Acceptance

The Installer and the Manufacturer shall retain all ownership and responsibility for the geosynthetics in the disposal site until acceptance by the Owner.

The liner system will be accepted by the Owner when:

a. The installation is finished.

b. Verification of the adequacy of all seams and repairs, including associated testing, is complete.

c. Installer's representative furnishes the Construction Manager with certification that the geomembrane was installed in accordance with the Manufacturer's recommendations as well as the plans and specifications.

d. All documentation of installation is completed, including the CQA Consultant's final report.

e. The Construction Manager has received certification, including Record Drawing (s), sealed by a Professional Engineer.

The CQA Consultant will certify that installation has proceeded in accordance with this CQA Plan for the project, except as noted to the Construction Manager.

2.15 Materials in Contact with the Geomembranes

The quality assurance procedures indicated in this Subsection are only intended to assure that the installation of these materials does not damage the geomembrane. Additional quality assurance procedures are necessary to assure that systems built with these materials will be constructed in such a way to enable proper performance.

2.15.1 Drainage Nets: The CQA Consultant will verify that the drainage nets are installed in accordance with the procedures described in "Geonet Construction Quality Assurance" specification. Extreme care shall be exercised so as not to damage the geomembrane during placement of the drainage nets and the materials overlying the drainage nets.

2.15.2 Appurtenances: A copy of the specifications prepared by the Engineer for appurtenances will be given by the Construction Manager to the CQA Consultant for review.

The CQA Consultant will verify that:

a. Installation of the geomembrane in appurtenant areas and connection of geomembrane to appurtenances have been made according to Specifications.

b. Extreme care is taken while seaming around appurtenances, since neither non-destructive nor destructive testing may be feasible in these areas.

c. The geomembrane has not been visibly damaged while making connections to appurtenances.

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

2.16 Liner System Protective Cover

2.16.1 The geomembrane shall be covered with protective materials as shown on the construction drawings.

2.16.2 Protective Cover Materials: Protective materials shall be placed on the geosynthetics to prevent damage to the liner. The cover materials shall be placed in accordance with the Drawings and shall be placed only after testing and approval by the Owner. Protective cover shall be placedacceptance of all seams and geomembrane placement.

2.16.3 Equipment: Light ground pressure equipment (less than 6 psi contact pressure) shall be operated in a minimum of 12 inches of cover and must not be driven on the geosynthetics. Heavy equipment and trucks shall operate on a minimum of 4 feet of cover.

2.16.4 The cover shall be placed so as not to cause any wrinkles, folds, or bends in the geosynthetics.

2.16.5 Leachate collection system piping shall be placed so that the pipe is in uniform contact with the bedding material.

2.16.6 Cover Procedure: If applicable, cover slopes from the bottom by pushing the cover material upward. This reduces tension on the membrane caused by material falling downhill.

2.16.7 Damage: The CQA Consultant will mark any areas of possible damage. Marked areas shall later be uncovered by hand for inspection and repaired, if necessary.

TABLE 1 – LLDPE MINIMUM MATERIAL REQUIREMENTS			
PROPERTY	TEST METHOD	UNITS	TEXTURED
Gage (nominal)	NA	mils	40
Thickness	ASTM D 5994	mils	40
Asperity Height	GRI GM-12	mils	10
Base Sheet Density	ASTM D 1505	g/cm^3	0.915
Resin – Melt Flow Index	ASTM D 1238	g/10 min.	° 1.0
Carbon Black - Content	ASTM D 4218	percent	2 to 3
Carbon Black - Dispersion	ASTM D 5596	rating	Category 1 or 2
Tensile Properties: Stress at Yield	ASTM D 6693	lb/inch	76
Stress at Break	ASTM D 6693	lb/inch	90
Strain at Yield	ASTM D 6693	percent	18
Strain at Break	ASTM D 6693	percent	450
Tear Resistance	ASTM D 1004	lbs.	22
Puncture Resistance	ASTM D 4833	lbs.	48
Oxidative Induction Time	ASTM D 3895	min.	100
Friction Angle between Geomemebrane and Geocomposite interface	ASTM D 5321	degrees	24 (Residual)

TABLE 2 – MANUFACTURER'S TESTING FREQUENCY IN ACCORDANCE WITH GIR GM-17 STANDARDS		
PROPERTY	TEST METHOD	FREQUENCY
Thickness	ASTM D 5994	Per Roll
Tensile Properties	ASTM D 6693	20,000 lb.
Carbon Black Content	ASTM D 4218	45,000 lb.
Carbon Black Dispersion	ASTM D 5596	45,000 lb.
Resin Density	ASTM D 1505	200,000 lb.
Resin Melt Flow Index	ASTM D 1238	Each Batch
Tear Resistance	ASTM D 1004	45,000 lb.
Puncture Resistance	ASTM D 4833	45,000 lb.
Standard OIT	ASTM D 3895	200,000 lb.
Asperity Height	GRI-GM 10	Per 2nd Roll

TABLE 3 – CQA CONFORMANCE TESTING FREQUENCY		
PROPERTY	TEST METHOD	FREQUENCY
Thickness	ASTM D 5994	Every 50,000 ft^2
Tensile Properties	ASTM D 638 (As modified in NSF54)	Every 50,000 ft^2
Tear Resistance	ASTM D 1004	Every 50,000 ft^2
Puncture Resistance	ASTM D 4833	Every 50,000 ft^2
Asperity Height	GRI GM-12	Every 50,000 ft^2
Interface-Friction Angle	ASTM D 5321	Two

TABLE 4 – LLDPE LINER MINIMUM WELD VALUES			
PROPERTY	TEST METHOD	UNITS	TEXTURED/SMOOTH
Shear Strength – Fusion and Extrusion	ASTM D 6392	lb/inch	56 and Film Tear Bond
Peel Strength – Fusion and Extrusion	ASTM D 6392	lb/inch	48 and Film Tear Bond

END