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GEOMEMBRANE CONTAINMENT BARRIERS FOR LANDFILLS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Furnishing, installation, quality control, and testing of a HDPE geomembrane.

B. Related Specification Sections include but are not necessarily limited to:
   1. Division 00 - Procurement and Contracting Requirements.
   2. Division 01 - General Requirements.
   3. Section 31 23 00 - Earthwork.
   4. Section 31 38 40 – Final Soil Barrier.
   5. Final Cover Quality Control Plan.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. ASTM International (ASTM):
      a. D413, Standard Test Methods for Rubber Property-Adhesion to Flexible Substrate.
      b. D638, Standard Test Method for Tensile Properties of Plastics.
      c. D792, Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
      d. D882, Standard Test Method for Tensile Properties of Thin Plastic Sheeting.
      e. D1004, Standard Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting.
      f. D1505, Standard Test Method for Density of Plastics by the Density-Gradient Technique.
      g. D1603, Standard Test Method for Carbon Black Content in Olefin Plastics.
      h. D3895, Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry.
      i. D4218, Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique.
      j. D4437/D4437M, Standard Practice for Nondestructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes.
      k. D4833/D4833M, Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products.
      l. D4873/D4873M, Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples.
      m. D5199, Standard Test Method for Measuring the Nominal Thickness of Geosynthetics.
      n. D5397, Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test.
      o. D5596, Standard Test Method For Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
      p. D5641/D5641M, Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.
      q. D5721, Standard Practice for Air-Oven Aging of Polyolefin Geomembranes.
      r. D5820, Standard Practice for Pressurized Air Channel Evaluation of Dual-Seamed Geomembranes.
      s. D5885/D5885M, Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry.
      t. D5994/D5994, Standard Test Method for Measuring Core Thickness of Textured Geomembranes.

u. D6392, Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.
v. D7238, Standard Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus.
w. D7466/D7466M, Standard Test Method for Measuring Asperity Height of Textured Geomembranes.

2. Environmental Protection Agency (EPA):
   a. 530/SW-91/051, Inspection Techniques for the Fabrication of Geomembrane Field Seams.
   b. 600/R-93/182, Quality Assurance and Quality Control for Waste Containment Facilities.
3. Geosynthetic Research Institute (GRI):
   a. GM6, Pressurized Air Channel Test for Dual Sound Geomembranes.
   b. GM10, The Stress Crack Resistance of HDPE Geomembrane Sheet.
   c. GM11, Accelerated Weathering of Geomembranes Using a Fluorescent UVA Device.
   d. GM12, Asperity Measurement of Textured Geomembranes Using a Depth Gage.
   e. GM13, Test Methods, Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes.
   f. GM14, Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes.
   g. GM20, Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts.

B. Quality Assurance:
1. The Owner or Engineer's representative will conduct independent testing to support construction quality assurance program and to provide documentation of such to appropriate regulatory agencies.
   a. Facilitate and provide opportunities as required.
2. Unless specifically superseded by these Contract Documents or approved plans submitted by the Contractor, the geosynthetic materials shall be manufactured, stored, placed, seamed, tested and protected as described in EPA 600/R-93/182 and EPA 530/SW-91/051.
   a. This specifically includes:
      1) Material Composition.
      2) Manufacturing.
      3) Handling and Packaging.
      4) Shipment.
      5) Storage (Manufacturer and Site).
      6) Placement:
         a) Seaming and Joining.
         b) Destructive and Nondestructive Testing.
         c) Protection, Backfilling and Covering.
      7) Conformance Testing.
      8) Anchoring and Anchor Trenches.
      9) Access Roads/Ramps.

C. Qualifications:
1. Each manufacturing and fabricating firm shall demonstrate five years continuous experience with a minimum of 10,000,000 SQFT of HDPE geomembranes.
2. Installer:
   a. Demonstrate five years continuous experience with a minimum 10,000,000 SQFT of HDPE geomembranes.
   b. Trained and certified by at least one of the named manufacturers in this Specification (not necessarily the manufacturer supplying materials for this Project).
   c. Geomembrane Installer Personnel:

1) Installation Superintendent shall have worked in a similar capacity on at least five HDPE geomembrane liner jobs similar in size and complexity to the project described in the Contract Documents.
2) The Master Welder shall have completed a minimum of 5,000,000 SQFT of HDPE geomembrane seaming work using the type of seaming apparatus proposed for use on this Project.
3) Other welders shall have seamed a minimum of 1,000,000 SQFT of HDPE geomembrane.

3. Inspectors:
   a. Demonstrate three years continuous experience with a minimum 5,000,000 SQFT in similar geosynthetic materials installation.
   b. Remain on the project throughout the entire construction and covering of the HDPE geomembrane.
4. Independent Testing Laboratory shall demonstrate three years of continuous experience in similar geosynthetic materials testing.

D. Certifications:
1. Certifications are required for various aspects of the project related to the HDPE geomembrane system construction.

1.3 DEFINITIONS

A. Manufacturer:
1. Manufacturer producing geomembrane sheets from resin and additives.

B. Installer:
1. The Installers is the company actually performing the hands-on work in the field.

C. Inspector:
1. Inspectors of HDPE geomembrane are the individuals responsible for observing field installation of the geosynthetic materials and providing the Manufacturer, Fabricator, Installer and Owner with verbal and written documentation of the compliance of the installation with this specification and with written procedures manuals prepared by the Manufacturer or Installer.

D. Independent Testing Laboratory:
1. The firm hired to perform destructive testing of the HDPE geomembrane.
2. Firm shall be acceptable to Engineer and Owner.

1.4 SUBMITTALS

A. Shop Drawings:
1. Submit for Engineer's approval Shop Drawings, including:
   a. Manufacturer's certification that raw materials and sheet materials comply with required materials, mil thickness, and material properties.
      1) Original certificates are required.
   b. Manufacturer/Fabricator/Installer quality control requirements.
   c. Qualifications and experience of key personnel involved in installation/inspection of the geosynthetic materials and geosynthetic system.
   d. HDPE Geomembrane layout plan with proposed size, number, position and sequencing of panels and showing the location and direction of all field or factory joints.
      1) Proposed details for connecting the geosynthetic materials to appurtenances.
      2) Proposed methods of welding, seaming or jointing geosynthetic materials.
      3) Proposed method and sequencing for placement of drainage layer on top of the HDPE geomembrane.
      4) Proposed method of testing HDPE geomembrane and other geosynthetic materials, joints and connections at appurtenances for continuity.
      5) Location and configuration of haul roads and access points.

6) Proposed details for anchor trench if different than included in Contract Documents.

B. Informational Submittals:
1. Test results:
a. Resin test, tests of sheet material and factory seam tests at frequency specified in respective quality control manuals.
1) Results shall include or bracket the rolls delivered for use in the Work.
b. Daily test seam results.
c. Daily results of production seam testing.
2. Warranties
3. Submit written certifications that:
a. The HDPE geomembrane material delivered to site meets the requirements of this Specification.
b. The HDPE geomembrane were received and accepted in undamaged condition from shipper.
c. The subgrade has been properly prepared and acceptable for the placement of the HDPE geomembrane.
d. The HDPE geomembrane was installed in accordance with this Specification and with approved Shop Drawings.
e. The HDPE geomembrane joints were inspected, tested for strength and continuity, and passed all inspections, tests, or retests.
1) Incorporate all test and inspection data into this certification.
f. The drainage layer, geotextiles and protective soil cover layer on top of the HDPE geomembrane was placed properly and carefully.
4. Manufacturer/Installer's Field Installation Procedures Manual shall clearly identify and exceptions take to the specified execution of the Work.
5. Record Drawings: Submit reproducible drawings of record showing changes from the approved installation drawings. The record drawings shall include the identity and location of each repair, cap strip, penetration, boot, and sample taken from the installed geosynthetic for testing. The record drawings shall show locations of each type of material, anchor trenches and the construction baseline.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Handle and store HDPE geomembrane shall be stored in accordance with the manufacturer's recommendations and ASTM D4873.

B. Label each roll with the manufacturer's name, type, lot number, roll number, and roll dimensions (length, width, gross weight).
1. HDPE geomembrane or plastic wrapping damaged as a result of storage or handling shall be repaired or replaced, as directed.
2. HDPE geomembrane shall not be exposed to temperatures in excess of 60 DEGC (140 DEGF) or less if recommended by the Manufacturer.

C. No hooks, tongs or other sharp instruments shall be used for handling the HDPE geomembrane.
1. Rolls shall not be lifted by use of cables or chains in contact with the HDPE geomembrane.
2. HDPE geomembrane shall not be dragged along the ground.

1.6 PROJECT/SITE CONDITIONS

A. When the weather is of such a nature as to endanger the integrity and quality of the installation whether this is due to rain, high winds, cold temperatures, or other weather elements, the installation shall be halted until the weather conditions are satisfactory.

B. Ensure that adequate dust control methods are in effect to prevent the unnecessary accumulation of dust and dirt on surfaces which hamper efficient field seaming or performance.

C. Maintain surface water drainage diversions around the work area and provide for the disposal of water which may collect in the work area directly from precipitation falling within the area or from inadequate diversion structures or practices.

D. Coordinate the installation of leachate collection lines which shall be in accordance with HDPE geomembrane Manufacturer's recommendation and as specified in the Contract Documents and shown on the Drawings.

E. Vehicles, other than those specifically approved, will not be allowed on HDPE membrane unless at least 18 IN of protective soil cover have been placed over these materials.
   1. No vehicle shall access the completed Work unless it can be demonstrated that its weight, movement or activities will not damage the Work.
   2. When damage is suspected, uncover area, repair damage if required, and recover area at no cost to Owner.
   3. Suspect areas may be identified by Owner or Engineer.

1.7 WARRANTY

A. Written warranties addressing HDPE geomembrane material and installation workmanship shall be furnished by the Contractor and shall be made to the Owner.

B. Submit material samples and warranties prior to shipment.

C. Suitability of geosynthetic system shall be subject to Owner approval of warranty.

A. Standard Warranty: The special warranty specified in this Article shall not deprive Owner of other rights or remedies Owner may otherwise have under the Contract Documents and shall be in addition to, and run concurrent with, other warranties made by Contractor under the Contract Documents. The obligations of Contractor under the Contract Documents shall not be limited in any way by the provisions of the specified standard warranty and special warranty.

B. Special Warranty on geomembrane:
   1. Furnish manufacturer’s written warranty, running to benefit of Owner, agreeing to correct, or at option of warranty beneficiary, replace materials and equipment indicated in this Specifications section found to be defective during a period of three years after the date of Substantial Completion certified by Engineer.
   2. The Installer's warranty shall state that the materials were properly installed, properly (field and factory) welded, seamed and jointed and will not fail within two years of the installation under similar conditions.
      a. Warranty shall not be prorated.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
   1. HDPE Geomembrane:
      a. AGRU America, 500 Garrison Road, Georgetown, SC 29440.
      b. Solmax, 19103 Gundle Rd., Houston, Texas 77073.
      c. Poly-Flex, Inc., 2000 West Marshall Drive, Grand Prairie, Texas 75051.

2.2 MATERIALS

A. HDPE Geomembrane:
   1. Consist of unreinforced polyethylene.
      a. Thickness: 60 MILS.
      b. Manufactured from virgin, first quality resin designed and formulated specifically for liquid containment in hydraulic structures.

c. Reclaimed polymer shall not be added to the resin; except use of polymer recycled during the manufacturing process shall be allowed provided that recycled polymer shall be clean and shall not exceed 2 PCT by weight.
d. No additives or fillers may be added to the resin prior to or during manufacture of the HDPE geomembrane.

2. Manufactured to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter.
   a. Any such defects shall be cause for rejection of the material.
   b. Minor defects may be repaired in accordance with Manufacturer's recommendations if approved by the Engineer.
3. Manufactured as seamless rolls or as prefabricated panels.
   a. Minimum width: 15 FT as delivered to the site.
   b. All factory seams shall be inspected and tested for strength and continuity prior to delivery to the site.
4. Specifications:
   a. Textured HDPE geomembrane shall possess properties which meet or exceed the following minimum requirements (per GRI GM13):

PROPERTY	TEST METHOD	TEST VALUE
Thickness (min ave.) - lowest indiv. for 8 out of 10 values - lowest indiv. for any of the 10 values	ASTM D5994	60mils nom. (-5 PCT) -10 PCT -15 PCT
Asperity Height (min. ave.)	ASTM D7466	16 MIL
Density (min. ave.)	ASTM D1505/ ASTM D792	0.940 G/cc
Tensile Properties (min. ave.) (1)Type IV - yield stress - break stress - yield elongation - break elongation	ASTM D638	 126 LB/IN 90 LB/IN 12 PCT 100 PCT
Tear Resistance (min. ave.)	ASTM D1004	42 LB
Puncture Resistance (min. ave.)	ASTM D4833	90 LBS
Stress Crack Resistance (2)	ASTM D5397 (App.)	500 HR
Carbon Black Content (range)	ASTM D4218	2.0-3.0 PCT
Carbon Black Dispersion	ASTM D5596	note (3)
Oxidative Induction time (OIT) (min. ave.)(4) (a) Standard OIT or (b) High Pressure OIT	 ASTM D3895 ASTM D5885	 100 min 400 min
Oven Aging at 85 DEGC (4), (5) (a) Standard OIT (min. ave.) or (b) High Pressure OIT (min. ave.) PCT retained after 90 days	ASTM D5721 ASTM D3895 ASTM D5885	 55 PCT 80 PCT
UV Resistance (6) (a) High Pressure OIT (min ave) PCT retained after 1600 HRS (7)	ASTM D7238 ASTM D5885	 50 PCT

(1) Machine direction (MD) and cross machine direction (XMD) average values shall be on the basis of 5 test specimens each direction:
   (a) Yield elongation is calculated using a gage length of 1.3 IN.
   (b) Break elongation is calculated using a gage length of 2.0 IN.
(2) The SP-NCTL test shall be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
   (a) The yield stress used to calculate the applied load for the SP-NCTL test shall be the manufacturer's mean value via MQC testing.
(3) Carbon black dispersion for 10 different views:
   (a) Minimum 8 of 10 IN Categories 1 or 2.
   (b) All 10 IN Categories 1, 2, or 3.
(4) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(5) It is also recommended to evaluate supplies at 30 and 60 days to compare with the 90 day response.
(6) The condition of the test should be 20 HR UV cycle at 75 DEGC followed by 4 HR condensation at 60 DEGC.
(7) UV resistance is based on percent retained valve regardless of the original HP-OIT value.

5. Extrusion rod shall be manufactured from resin identical to that used in geomembrane manufacture. Manufactured extrusion rod shall be tested for carbon black content and dispersion, specific gravity, and melt index at a frequency of not less than one test per batch.

2.3 EQUIPMENT AND ACCESSORIES

A. Welding and Seaming Equipment:
   1. Equipped with gages showing temperatures at the nozzle (extrusion welder) or at the wedge (wedge welder).
   2. Maintained in adequate numbers to avoid delaying work.
   3. Supplied by a power source capable of providing constant voltage under a combined-line load.
   4. Electric generator shall not be placed on the HDPE geomembrane.

B. Field Tensiometer:
   1. Provide a tensiometer for on-site shear and peel testing of HDPE geomembrane seams.
      a. Tensiometer shall be in good working order.
      b. Built to ASTM specifications.
      c. Accompanied by evidence of calibration of equipment and gages within the past six months.
      d. Motor driven.
      e. Jaws capable of traveling a measure rate of 2 IN per minute.
      f. Equipped with a gauge that measures the force in unit pounds exerted between the jaws.
      g. Digital readout.

C. Punch Press:
   1. Provide a punch press for the onsite preparation of specimens for testing.
   2. Capable of cutting specimens in accordance with ASTM D4437.

D. Vacuum Box:
   1. Provide a vacuum box for onsite testing of HDPE geomembrane seams in accordance with ASTM D5641.

E. Equipment necessary to perform "Pressurized Air Channel Evaluation of Dual Seamed Geomembranes" in accordance with ASTM D5820.

F. Gages:
   1. Calibrated within past six months.
   2. Specified test values reading near mid-range of the gage scale.

2.4 FABRICATION

A. Produce geomembrane sheet which complies with this Specification Section.

B. Provide resin and additive quality control:
   1. Test raw resin and additives to ensure compliance with the Manufacturer's specifications and with this Specification Section.
   2. Test sheet material to ensure compliance with Manufacturer's specification and this Specification Section.
   3. Provide certification of the raw materials and finished sheet demonstrating compliance with this Specification Section.
   4. Provide certification of Fabricator's and Installer's training (unless Installer is certified by other acceptable manufacturer list herein), experience and methods for welding, seaming, jointing and inspecting geosynthetic materials installations in compliance with Manufacturer's standards and with Quality Assurance requirements of this Specification Section.

C. Fabricated Specials:
   1. Subject to same level of manufacturer's quality control.
   2. Fabricated from project rolls.
      a. Provide traceability of resin and roll stock.

PART 3 - EXECUTION

3.1 GEOSYNTHETIC SYSTEM

A. Geomembrane Subgrade:
   1. Protect subgrade at all times from damage until such time as the placement of HDPE geomembrane and other components of the geosynthetic system are complete.
   2. The subgrade shall be prepared in a manner consistent with proper subgrade preparation techniques for the installation of HDPE Geomembrane.
      a. The subgrade shall be properly compacted so as not to settle and cause excessive strains in the HDPE Geomembrane or other synthetic materials.
      b. Prior to installation, ensure a surface free of debris, roots, or angular stones larger than 1/2 IN.
      c. In addition, ensure that the subgrade has been rolled to provide a uniform surface.
      d. During installation, ensure that rutting or raveling is not caused by installation equipment or weathering.

B. Anchor Trenches:
   1. Geosynthetic materials placed on side slopes shall be anchored into trenches as detailed on the Contract Drawings.
   2. Excavation, backfill and compaction shall be in accordance with Specification Section 31 23 00.

C. HDPE Geomembrane:
   1. General:
      a. Installer of HDPE geomembranes is responsible for handling, fitting, welding, seaming, jointing and testing of geosynthetic materials sheets or blankets in the field.
      b. These responsibilities include but are not limited to:
         1) Acceptance (in writing) of the geosynthetic materials sheets or blankets from the transporter.
         2) Acceptance (in writing) of the soil or geosynthetic clay liner subgrade which will serve as a base for the HDPE geomembrane.
            a) This acceptance shall precede installation of the HDPE geomembrane.
            b) Shall state that the Installer has inspected the surface, and reviewed the Specifications for material and placement, and finds all conditions acceptable for placement of HDPE geomembrane.
            c) Shall explicitly state any and all exceptions to acceptance.

3) Handling, welding, seaming, jointing, testing and repair of HDPE geomembrane and other geosynthetic materials in compliance with this Specification and with written procedures manuals prepared by the Manufacturer or Fabricator.
    a) Manual shall be submitted to the Engineer together with Shop Drawings showing the layout of HDPE geomembrane within the facility.
        (1) Do not deviate from the procedures included in the manual.
    b) HDPE Geomembrane shall not be placed upon frozen foundation, standing water or other conditions which will result in deterioration of the foundation.
    c) HDPE Geomembrane materials shall be laid out according to plans previously approved by the Engineer.
    d) Adjacent rolls of HDPE geomembrane shall overlap a minimum of 3 IN, provided that greater overlap may be required to allow seaming in accordance with the Manufacturer's instructions.
4) Repair or replacement of defects in the geosynthetic materials as required by the Inspector or the Owner.
5) Installer and Manufacturer may be the same firm.

2. Panel deployment:
    a. Only those panel/sheets that can be seamed in one day shall be deployed.
    b. Place panels with minimal handling.
        1) Orient sheets to eliminate or minimize number of horizontal seams on side slopes.
        2) Protect panels from tear, puncture or abrasion.
        3) No seams will be permitted in the leachate collection trench.
    c. Equipment used to deploy the geomembrane shall not rut the recompacted clay liner, or damage the Geosynthetic Clay Liner.
        1) A rut is defined as a 1/4 IN depression over a 10 FT straight-edged length.
    d. No vehicular traffic is permitted on unprotected HDPE geomembrane.
    e. Minimize foot traffic.
        1) Do not allow personnel access to wet or slippery liners without adequate safety precautions.
    f. Ballast with sandbags to prevent wind uplift as recommended by Manufacturer and Fabricator and based on local climatic conditions.
        1) Remove and replace all wind damaged panels at no additional cost to Owner.
        2) If wind causes panels to be displaced, displaced panel may not be reused.
    g. Install HDPE geomembrane in stress free, tension free and relaxed condition.
        1) Account for temperature and weather-related impacts when deploying and covering.
        2) Stretching to fit and folding are not permitted.
    h. Do not allow HDPE geomembrane to bubble, fold, or create ripples as a result of deployment of drainage layer or protective soil cover placement.
        1) Except as noted on Contract Drawings no folds in HDPE geomembrane will be allowed.
    i. Any panel exhibiting stretching caused by placement, covering techniques, or wind shall be removed and may not be incorporated in the final construction.
    j. Field seaming:
        1) Field seaming shall be done in accordance with seaming recommendations furnished by the geomembrane Manufacturer and referenced EPA documents.
        2) Each piece of seaming equipment and each operator shall perform demonstration seams at the start of a shift, whenever equipment is switched on or seaming is interrupted for more than ten minutes, and at other times at the discretion of the Installer and Inspector.
        3) Demonstration seams shall use the same seaming materials and methods to be used in the actual construction.
        4) Surfaces to be seamed shall be clean and dry at the time of seaming.
            a) Precipitation and ponding of water on the HDPE geomembrane shall cause termination of seaming operations.

b) HDPE geomembrane shall not be seamed when ambient temperatures are below 41 DEGF or above 104 DEGF, without written consent of HDPE geomembrane Manufacturer or Fabricator, and Engineer.

5) HDPE geomembrane sheets shall be seamed continuously without fishmouths or breaks in the seam.
   a) Where fishmouths are unavoidable, the sheet shall be slit to a point such that the sheet lies flat and with no remaining wrinkle.
   b) The two edges of the slit shall be seamed together provided that the overlap for this seam shall be a minimum of 6 IN.
   c) Areas of the slit which do not achieve an overlap of 6 IN, including the terminus of the slit, shall be provided with a patch as discussed below.
6) All HDPE geomembranes shall be seamed by thermal fusion methods as recommended by the HDPE geomembrane Manufacturer.
   a) HDPE geomembrane seaming shall be double wedge weld unless otherwise approved or prohibited by construction.
7) Manufacturer's or Fabricator's seaming instructions shall specifically address subgrade preparation, seaming materials, temporary and permanent jointing, seaming temperatures including temperatures for seaming materials, seam finishing and curing.
8) A copy of Manufacturer's or Fabricator's seaming instructions shall be available on site at all times and shall not be deviated from without written approval of the Manufacturer and Engineer.
9) All panels/sheets should be overlapped a minimum of 3 IN.
   a) If horizontal seams are required on side slopes, the upper panel should be lapped over the lower panel.
10) Seaming shall not be conducted in the presence of standing water and/or soft subgrades.
   a) The seamed area shall be cleaned of dust, dirt and foreign material prior to and during the seaming operation.
11) Seaming shall extend to the outside edge of panels/sheets to be placed in anchor and/or drainage trenches.
12) Tack welds shall conform with manufacturers seaming techniques and shall not damage underlying membrane.

k. Patching:
   1) Defects in and damage to HDPE geomembrane sheets shall be repaired by seaming a patch over the defect.
      a) The patch material shall consist of an undamaged piece of HDPE geomembrane cut to provide a minimum of 6 IN of overlap in all directions from the defect.
      b) Round corners shall be utilized on all patches.
         (1) No bead or spot patching will be accepted.
      c) Torn or permanently twisted HDPE geomembrane shall be replaced at no expense to the Owner.
   2) Test all patch seams using one of the following nondestructive tests: Vacuum tests; spark tests; or ultrasonic tests.
      a) Test patch seams destructively at a frequency of ten percent or a minimum of one test per seaming personnel per day.
      b) This destructive testing may be accomplished using demonstration seams performed adjacent to the installation.

3.2 FIELD QUALITY CONTROL

A. Inspector shall not be a part of the installation program and shall not serve as a substitute for performing the duties or certification required of the Fabricator and Installer.
   1. Inspector’s responsibilities include, but are not limited to:
      a. Inspection of the material and the handling and field installation of the geomembranes.

1) Inspection of all welds, repairs and quality control test results.
b. All exceptions to material or installation shall be documented and furnished to the Engineer in writing within 48 HRS of discovery.
c. Inspection and Certification of HDPE geomembrane integrity until completion of placement of protective soil cover.

B. Trial Seam Testing:
1. Trial seams shall be made each half-day prior to production seaming.
a. The location of trial seam shall be in an area proposed for the day's production seaming.
b. Equipment, methods and personnel shall be the same as proposed for the day's seaming.
2. Samples shall be tested in accordance with ASTM D413 and ASTM D882.
a. To be acceptable, five of five replicate test specimens must meet specified seam strength requirements and failures shall be Film Tear Bond.
b. If the field tests fail to meet these requirements, the entire operation shall be repeated.
c. If the additional test seams fail, the seaming apparatus or seamer shall not be accepted or used for seaming until the deficiencies are corrected and two consecutive successful test seams are achieved.

C. Nondestructive Seam Testing:
1. All field seams shall be nondestructively tested over their full length.
a. Seam testing shall be performed as the seaming work progresses, not at the completion of field seaming.
b. All testing shall be documented.
1) Any seams which fail shall be repaired and documented.
2. Nondestructively test all field seams continuously using one of the following nondestructive seam tests: Vacuum box; ultrasonic tests; spark tests; and pressurized air channel test.

D. Destructive Seam Testing:
1. A minimum of one destructive test sample in each transverse field seam, and as many other samples as Engineer determines appropriate, shall be obtained at locations specified by the Engineer.
a. Sample locations shall not be identified prior to seaming.
b. The samples shall be a minimum of 12 IN wide by 48 IN long with the seam centered lengthwise.
c. Each sample shall be cut into three equal pieces with one piece retained by the Installer, one piece given to an Independent Testing Laboratory, and the remaining piece given to the Engineer for quality assurance testing and/or permanent record.
d. Each sample shall be numbered and recorded on the final panel layout record drawing, and cross-referenced to a field log which identifies:
1) Panel/sheet number.
2) Seam number.
3) Top sheet.
4) Date and time cut.
5) Ambient temperature.
6) Seaming unit designation.
7) Name of seamer.
8) Seaming apparatus temperature and pressures (where applicable).
2. A minimum of four, 1 IN wide replicate specimens shall be cut from the Installer's sample.
a. A minimum of two specimens shall be tested for shear strength and two for peel adhesion using an approved field quantitative tensiometer.
1) Jaw separation speed shall be 2 IN per minute.
b. To be acceptable, all replicate test specimens must meet the specified seam strength requirements and fail as Film Tear Bond.
3. If the field tests pass, five specimens shall be tested at the Independent Testing Laboratory for shear strength and five for peel adhesion in accordance with ASTM D4437.

a. To be acceptable, four out of five replicate test specimens must meet the specified seam strength requirements and fail as Film Tear Bond.

4. The minimum required seam strengths:

FAILURE MODE	TEST METHOD	VALUE(LBS/IN)
Shear	ASTM D6392	120
Peel (fusion)	ASTM D6392	91
Peel (extrusion)	ASTM D6392	78

5. If the field or laboratory tests fail, the seam shall be repaired in accordance with the Manufacturer's Quality Control manual.
6. In addition, all destructive seam sample holes shall be repaired the same day as cut.
7. Certified test results on all field seams shall be submitted to and approved by the Engineer prior to acceptance of the seam.
8. Ten percent of all repaired areas shall be destructively tested.
9. All repaired areas shall be nondestructively tested.
10. The Owner may separately conduct destructive testing for quality assurance.
    a. If samples tested by Owner fail, based on above criteria, seam will be classified as failed.
11. A map showing the locations, number and type of all patches shall be prepared and provided to the Owner.

3.3 GEOSYNTHETIC SYSTEM ACCEPTANCE

A. Retain all ownership and responsibility for the geosynthetic system until final acceptance by the Owner.
    1. Owner will accept the geosynthetic system installation when the installation is finished and all required warranties, test results, and documentation from the Contractor, Manufacturer, Inspector and Installer has been received and approved, and verification of the adequacy of all field seams and repairs, including associated testing, is complete.

3.4 SCHEDULE OF CERTIFICATIONS

A. The schedule of required certifications and signing parties follows the end of this Specification Section.

B. The certificates following the end of this Specification Section shall be completed and signed by the required parties, and the original certificates delivered to the Engineer's representative as a part of the completion of that particular phase of the geosynthetic system installation.

END OF SECTION

GIBBONS CREEK ENVIRONMENTAL REDEVELOPMENT GROUP
CCR Unit Closure

	CERTIFICATE	SIGNATURES REQUIRED
1.	Certification of Raw and Fabricated Material	Manufacturer Fabricator
2.	Certification of Material Acceptance from Shipper	Installer Contractor
3.	Certification of Acceptance of Subgrade	Installer Contractor
4.	Certification of Material Installation	Installer Contractor
5.	Certification of Material Joints	Installer Contractor
6.	Certification of Placement of Adjacent Liner Components	Installer Contractor

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CERTIFICATION OF RAW AND FABRICATED MATERIAL
(To Accompany Each Shipment) (Circle Material Type)

DATE:_____

MATERIAL DESCRIPTION:_____

_____
(include lot and roll/panel numbers)

WE THE UNDERSIGNED CERTIFY THAT THE RAW MATERIAL AND FINISHED HDPE GEOMEMBRANE MATERIAL, DRAINAGE COMPOSITE, AND GEOTEXTILES FURNISHED FOR GIBBONS CREEK ENVIRONMENTAL REDEVELOPMENT FROUP COMPLY WITH SPECIFICATIONS FOR CCR UNIT CLOSURE

_____
MANUFACTURER NAME

_____
MANUFACTURER SIGNATURE (Authorized Representative)

_____
FABRICATOR NAME

_____
FABRICATOR SIGNATURE (Authorized Representative, if different from Manufacturer)

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CERTIFICATION OF MATERIAL ACCEPTANCE FROM SHIPPER
(Per shipment; each roll or container) (Circle Material Type)

REPORT NO.:_____ DATE: _____

PANEL, ROLL, AND CONTAINER NUMBER REFERENCES_____

_____

WE THE UNDERSIGNED ACCEPT THE HDPE GEOMEMBRANE MATERIALS (ROLLS, SHEETS, BLANKETS), DRAINAGE COMPOSITE, AND GEOTEXTILES FROM THE TRANSPORTER. THESE MATERIALS WERE RECEIVED IN UNDAMAGED CONDITION BASED UPON OUR VISUAL INSPECTION.

_____
INSTALLER SIGNATURE

_____
CONTRACTOR SIGNATURE

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GIBBONS CREEK ENVIRONMENTAL REDEVELOPMENT GROUP
CCR Unit Closure

CERTIFICATION OF ACCEPTANCE OF SUBGRADE - Daily Certification
(Circle Material Type)

REPORT NO.:_____ DATE: _____

AREA REFERENCED:_____

_____

LINER PANEL NUMBERS INSTALLED OVER REFERENCED AREA THIS DATE:

_____

WE THE UNDERSIGNED CERTIFY THAT WE HAVE INSPECTED THE ENTIRE SURFACE, AND HAVE REVIEWED THE SPECIFICATION SECTION 31 35 26.17, FINAL COVER QUALITY CONTROL PLAN, AND RELATED SHOP DRAWINGS FOR MATERIAL AND PLACEMENT, AND FIND ALL CONDITIONS ACCEPTABLE FOR PLACEMENT OF THE HDPE GEOMEMBRANE LINER.

WE SPECIFICALLY TAKE THE FOLLOWING EXCEPTIONS TO THE ACCEPTANCE OF THE SUBGRADE ON THIS DATE:

_____

_____

_____

(Note: All exceptions shall be approved by Engineer prior to HDPE Geomembrane Liner deployment)

_____
INSTALLER SIGNATURE

_____
CONTRACTOR SIGNATURE

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CERTIFICATE OF MATERIAL INSTALLATION - Daily Certification
(Circle Material Type)

REPORT NO.:_____ DATE: _____

AREA REFERENCED:_____

_____

LINER PANEL NUMBERS INSTALLED THIS DATE:_____

_____

_____

WE THE UNDERSIGNED CERTIFY THAT THE HDPE GEOMEMBRANE LINER, DRAINAGE COMPOSITE, AND GEOTEXTILES WERE INSTALLED IN ACCORDANCE WITH THE SPECIFICATIOS AND WITH APPROVED SHOP DRAWINGS.

_____
INSTALLER SIGNATURE

_____
CONTRACTOR SIGNATURE

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GIBBONS CREEK ENVIRONMENTAL REDEVELOPMENT GROUP
CCR Unit Closure

CERTIFICATION OF MATERIAL JOINTS - Daily Certification Per Test
(As Shop Drawings and as a Compiled Report at the end of Project)
(Circle Material Type)

TEST REPORT NO.:_____ DATE: _____

FIELD LOG NO.:_____

LIST OF ALL DEFICIENCIES AND SUBSEQUENT REPAIRS, COPIES OF ALL FIELD AND FACTORY TESTS AND INSPECTION DATA INCLUDING RECORDS OF ALL NON-DESTRUCTIVE TESTING (FIELD LOGS) AND REPAIRS ARE ATTACHED.

WE THE UNDERSIGNED CERTIFY THAT THE HDPE GEOMEMBRANE AND ITS JOINTS WERE INSPECTED AND TESTED FOR STRENGTH AND CONTINUITY, DRAINAGE COMPOSITE SEAMS WERE INSPECTED FOR CONTINUITY, AND GEOTEXTILE SEAMS WERE INSPECTED FOR CONTINUITY AND PASSED ALL INSPECTIONS AND TESTS. WHERE FAILING TESTS OR DEFICIENCIES OCCURRED, THE AREA OF FAILURE WAS IDENTIFIED IN ACCORDANCE WITH THE APPROVED QUALITY CONTROL PROGRAM FOR THE PROJECT AND REPAIRED. THE AREAS OF FAILING TESTS, DEFICIENCIES AND THE SUBSEQUENT RETESTS OR TESTS TO DELINEATE THE LIMITS OF FAILURE ARE IDENTIFIED IN THE ATTACHED SEAM TESTS AND INSPECTION DATA.

_____
INSTALLER SIGNATURE

_____
CONTRACTOR SIGNATURE

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CERTIFICATION OF PLACEMENT OF ADJACENT LINER COMPONENTS –
Daily Certifications; Per Material and Location (Circle Material Type)

REPORT NO.:_____ DATE: _____

COMPONENT BEING PLACED:_____

SUBSTRATE:_____

LOCATION:_____

WE THE UNDERSIGNED CERTIFY THAT THE HDPE GEOMEMBRANE, GEOTEXTILE, AND DRAINAGE COMPOSITE ON TOP OF THE HDPE GEOMEMBRANE, GEOTEXTILE, AND DRAINAGE COMPOSITE, WAS CAREFULLY PLACED UNDER MY DIRECT SUPERVISION/OBSERVATION THIS DATE, AND WITHOUT KNOWINGLY DAMAGING ANY OF THE UNDERLYING OR ADJACENT SUBSTRATE.

_____
INSTALLER SIGNATURE

_____
CONTRACTOR SIGNATURE

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SECTION 31 37 00
CONCRETE REVETMENT

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Fabric-formed Concrete Revetment Mat

B. Related Sections include but are not necessarily limited to:
   1. Division 0 - Bidding Requirements, Contract Forms, and Conditions of the Contract.
   2. Division 1 - General Requirements.
   3. Section 31 23 00 - Earthwork.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. American Society for Testing and Materials International (ASTM):
      a. C31, Standard Practice for Making and Curing Concrete Test Specimens in the Field.
      b. C33, Standard Specification for Concrete Aggregates.
      c. C39, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.
      d. C150, Standard Specification for Portland Cement.
      e. C260, Standard Specification for Air-Entraining Admixtures for Concrete.
      f. C494, Standard Specification for Chemical Admixtures for Concrete.
      g. C618, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete.
      h. C939, Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
      i. D2256, Standard Test Method for Tensile Properties of Yarns by the Single-Strand Method.
      j. D4491, Standard Test Methods for Water Permeability of Geotextiles by Permittivity.
      k. D4533, Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
      l. D4595, Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method.
      m. D4632, Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
      n. D4751, Standard Test Method for Determining Apparent Opening Size of a Geotextile.
      o. D4873, Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples.
      p. D4884, Standard Test Method for Strength of Sewn or Thermally Bonded Seams of Geotextiles.
      q. D5199, Standard Test Method for Measuring the Nominal Thickness of Geosynthetics.
      r. D5261, Standard Test Method for Measuring Mass per Unit Area of Geotextiles.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See Section 01 33 00.
   2. Product technical data including:
      a. Acknowledgement that products submitted meet requirements of standards referenced.
      b. Material and method of installation and details for completed system.
      c. Manufacturer's construction and quality control manual.
      d. Concrete mix design.

3. The Contractor shall submit a manufacturer's certificate that the supplied fabric forms meet the criteria of these Specifications, as measured in full accordance with the test methods and standards referenced herein.
    a. The certificates shall include the following information about each fabric form delivered:
        1) Manufacturer's name and current address,
        2) Full product name,
        3) Style and product code number,
        4) Form number(s),
        5) Composition of yarn, and
        6) Manufacturer's certification statement.
4. Fabric form layout plan with proposed size, type, number, position, and sequencing of fabric form panels.
    a. Show the location and direction of all field and factory seams.
    b. Show proposed details for making field connections of the fabric forms.
    c. Show proposed details for connecting the fabric forms to appurtenances.
5. Submit all tests and certification in a single coordinated submittal.

1.4 DELIVERY, STORAGE AND HANDLING

A. See Section 01 65 50.

B. The fabric forms shall be kept dry and wrapped such that they are protected from the elements during shipping and storage.

C. If stored outdoors, the fabric forms shall be elevated and protected with a waterproof cover that is opaque to ultraviolet light.

D. Fabric forms labeling: per ASTM D 4873.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Fabric-formed Concrete Revetment Mat:
1. Subject to compliance with the Specifications, the following are approved fabric-formed concrete revetment mat manufacturers:
    a. Hydrotex, Atlanta, GA, (800) 253-0561.
    b. Other approved manufacturer.

2. The fabric form shall be uniform section lining, with the following typical dimensions and weights:
    a. Average thickness: 4.0 IN.
    b. Mass per unit area: 45 LB/FT^2.
    c. Drop point spacing: 3 x 4 IN.
    d. Concrete coverage: 75 FT^2/YD^3.
    e. Shear resistance: 18 LB/FT^2.
3. The uniform section fabric shall possess properties which meet or exceed the following minimum average roll values:

4.

Property	Test Method	Minimum Average Roll Value
Physical		
Composition of yarns		Nylon or polyester
Mass per unit area (double-layer), oz/yd^2	ASTM D 5261	12
Thickness, mils	ASTM D 5199	25
Mill width, in		76
Mechanical		
Wide-width strip tensile strength, lb/in	ASTM D4595	
- machine		140
- cross		110
Elongation at break, %	ASTM D4595	
- machine		20
- cross		30
Trapezoidal tear strength, lb	ASTM D 4533	
- machine		150
- cross		100
Hydraulic		
Apparent opening size (AOS), U.S. Standard Sieve	ASTM D4751	40
Flow rate, gal/min/ft^2	ASTM D 4491	90

5. The fabric forms shall be composed of synthetic yarns formed into a woven fabric.
   a. Yarns used in the manufacture of the fabric shall be composed of nylon and/or polyester.
   b. Forms shall be woven with a minimum of 50% textured yarns (by weight) to improve adhesion to fine aggregate concrete and to improve filtration.
   c. Partially-oriented, drawn-textured, and/or staple yarns shall not be used in the manufacture of the fabric.
   d. Each layer of fabric shall conform to the physical, mechanical and hydraulic requirements referenced herein.
   e. The fabric forms shall be free of defects and flaws that significantly affect their physical, mechanical, or hydraulic properties.
6. Fabric forms shall consist of double-layer woven fabric joined together by spaced, interwoven cords of uniform length to form a concrete lining with a finished average thickness and nominal mass per unit area listed in part 2.1A.2.
   a. Cord minimum breaking strength: Minimum 160 lb when tested in accordance with ASTM D 2256.
   b. After the form has been filled with fine aggregate concrete, the cords' drop points shall be spaced as listed in part 2.1A.2.
   c. The cords shall connect the two layers of fabric to form a comparatively uniform surface appearance.
7. Mill widths of fabric shall be as listed in part 2.1A.3.
   a. Each selvage edge of the top and bottom layers of fabric shall be reinforced for a width of not less than 1.35 inches by adding a minimum of 6 warp yarns to each selvage construction.

b. Mill width rolls shall be cut to the length required, and the double-layer fabric separately joined, bottom layer to bottom layer and top layer to top layer, by means of sewing thread, to form multiple mill width panels with sewn seams on not less than 72-inch centers.

8. All factory-sewn seams shall be downward facing.
   a. All seams sewn in the factory: Minimum 90 lb/in when tested in accordance with ASTM D 4884.
   b. All sewn seams and zipper attachments shall be made using a double line of U.S. Federal Standard Type 401 stitch.
   c. All stitches shall be sewn simultaneously and be parallel to each other, spaced between 0.25 inches to 0.75 inches apart.
   d. Each row of stitching shall consist of 4 to 7 stitches per inch.
   e. Thread used for seaming shall be nylon and/or polyester.
9. Baffles shall be installed at predetermined mill width intervals to regulate the distance of lateral flow of fine aggregate concrete.
   a. The baffle material shall be non-woven filter fabric.
10. Whenever plastic weep tubes for the relief of hydrostatic uplift pressure are required, they shall be inserted through the fabric forms at locations specified in the Contract Documents.
   a. The lower ends of the weep tubes shall be securely covered by filter fabric, or the fabric forms shall be placed over filter fabric.
11. Fine aggregate concrete:
   a. Mix Portland cement, fine aggregate and water to provide a readily pourable slurry.
      1) The consistency of the fine aggregate concrete delivered to the concrete pump shall be proportioned and mixed as to have an efflux time of 9 – 12 seconds when passed through the 0.75-inch orifice of the standard flow cone (ASTM C 939).
      2) Ready mix from plant which is certified by the National Ready-Mix Concrete Association. Field mixes subject to approval.
         a) Portland cement: ASTM C150, Type I or Type II.
         b) Fine aggregate: ASTM C33.
         c) Water: Clean, free from injurious amounts of oil, acid, salt, alkali, organics or other impurities.
         d) Pozzolan: ASTM C618, Class F.
         e) Plasticizing admixture: ASTM C 494, if used.
         f) Air entraining admixture: ASTM C 260, if used.
   b. Pozzolan grade fly ash shall be substituted for cement to the maximum percentage allowed by the manufacturer.
   c. Admixtures may be used with Engineer's approval.
   d. Hardened fine aggregate concrete compressive strength: Minimum 2000 psi at 28 days when specimens are made and tested in accordance with ASTM C31 and ASTM C39.

2.2 SOURCE QUALITY CONTROL

A. Perform all tests required to demonstrate source and material specifications are satisfied.

B. Contractor shall test all Fine Aggregate Concrete delivered to the site for compressive strength and air content, and provide test results to Owner and Engineer.

PART 3 - EXECUTION

3.1 FOUNDATION PREPARATION

A. General: Areas on which fabric forms are to be placed shall be constructed to the lines and grades shown on the Contract Drawings and to the tolerances specified in the Contract Documents, and approved by the Engineer.

B. Grading:

1. Grade slope to a smooth plane surface to provide intimate contact between the slope face and the interface surface of the fabric forms.
    a. All slope deformities, roots, grade stakes and stones which project normal to the local slope face must be regraded or removed.
    b. No holes, "pockmarks", slope board teeth marks, footprints, or other voids greater than 1 IN in depth normal to the local slope face shall be permitted.
    c. No grooves or depressions greater than 0.5 IN in depth normal to the local slope face with a dimension exceeding 1 FT in any direction shall be permitted.

2. Correction:
    a. Defective areas shall be brought to grade by placing nominally compacted homogeneous material.
    b. The slope and slope face shall be uniformly compacted.
    c. Depth of layers, homogeneity of soil and amount of compaction shall be as specified in Section 31 23 00.

3.2 INSTALLING FABRIC-FORMED CONCRETE REVETMENT MAT

A. General: Placed within the specified lines and grades shown on the Contract Drawings.

B. Placement on adjoining geosynthetic:
    1. Place on the geosynthetic in such a manner as to produce a smooth plane surface in intimate contact with the geosynthetic.

C. Prior to fine aggregate concrete injection, position the fabric at its approximate design location, making appropriate allowance for the contraction of the fabric in each direction which will occur as a result of fine aggregate concrete injection.
    1. Anchoring of the fabric forms shall be accomplished through the use of anchor trenches.
    2. Panels of fabric are to be factory assembled in predetermined sizes and jointed together side-by-side at the jobsite by means of a sewn seam or zipper closures attached to the upper and lower layers of fabric.
        a. Avoid field seaming to the extent possible.
        b. Machine sew seams shall be made with two lines of U.S. Federal Standard Type 101 stitches.
        c. The two (2) top layers of fabric and the two (2) bottom layers of fabric shall be separately joined so as to ensure full block thickness.
        d. Grab tensile strength of sewn seams shall be a minimum 100 LBS/IN per ASTM D4632.
        e. Face all sewn seams downward.
        f. Field seaming will only be allowed to join factory assembled panels together.
        g. There shall be no gaps in the seaming.
    3. Place fabric forms immediately following slope preparation.
    4. When conventional joining of fabric forms is impractical or where called for in the Contract Documents, adjacent forms may be overlapped a minimum of three (3) feet to form a lap joint.
        a. The lap joint shall be constructed as recommended in the manufacturers construction and quality control manual.
        b. Based on the predominant flow direction, the downstream edge of the form shall overlap the upstream edge of the next form.
        c. In no case shall simple butt joints between forms be permitted.
    5. Immediately prior to filling with fine aggregate concrete, the assembled fabric forms shall be inspected by the Engineer.
        a. No fine aggregate concrete shall be pumped into the fabric forms until their placement has been approved.
        b. At no time shall the fabric forms be exposed to ultraviolet light (including direct sunlight) for a period exceeding five (5) days.

D. Following placement and seaming of the fabric, inject fine aggregate concrete between the top and bottom layers of fabric to the specified dimensions.
   1. Tightly wrap injection pipe at injection point while pumping.
   2. Inject fine aggregate concrete in such a way that the fabric form is fully inflated and excessive pressure on the fabric forms and cold joints are avoided.
      a. A cold joint is defined as one in which the pumping of the fine aggregate concrete into a given form is discontinued or interrupted for an interval of forty-five (45) minutes or more.
      b. Repair damage to the fabric form caused by over-inflation to the satisfaction of the Engineer and at no cost to the Owner.
   3. After pumping, minimize spillage of the fine aggregate concrete on the surface of the fabric.
   4. Sequence injection of fine aggregate concrete such as to insure complete filling of the fabric form to the thickness specified.
   5. Holes in the fabric forms left by the removal of the filling pipe shall be temporarily closed by inserting a piece of nonwoven fabric or similar material.
      a. The nonwoven fabric shall be removed when the concrete is no longer fluid.
      b. The concrete surface at the hole shall be cleaned and smoothed by hand.

E. Do not permit foot traffic on the freshly pumped mat when such traffic will cause permanent indentations in the mat surface.
   1. Use walk boards where necessary.
   2. Clean up excessive fine aggregate concrete that has been inadvertently spilled on the mat surface.
   3. Do not permit the use of a water hose to remove spilled fine aggregate concrete from the surface of freshly pumped mat.

F. The backfilling and compaction of anchor and terminal trenches shall proceed in not less than one hour behind the concrete filling of the fabric formed mat.
   1. Backfilling and compaction shall be as specified in Section 31 23 00.
   2. Trenches shall be backfilled and compacted to the top of the mat.
   3. The trenches of completed sections of mats shall be backfilled and compacted by the end of the work day.

G. Measure block thickness during fine aggregate concrete injections.
   1. Reject any block measuring less than 90 percent of the average of all thickness measurements until acceptable thickness has been attained.
      a. Average must be 4 IN or greater.

3.3 MANUFACTURER'S REPRESENTATIVE

A. A manufacturer's representative shall be present for a minimum of 10 percent of the installation of the fabric form unless the Contractor can prove adequate experience in this technology.

END OF SECTION

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SECTION 31 38 40
FINAL SOIL BARRIER

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Soils used in the construction of the barrier component of a landfill cap system.

B. Related Sections may include but are not necessarily limited to:
   1. Division 01 - General Requirements.
   2. Section 31 23 00 - Earthwork.
   3. Final Cover Quality Control Plan.

1.2 QUALITY STANDARDS

A. Reference Standards:
   1. ASTM International (ASTM):
      a. D75/D75M, Standard Practice for Sampling Aggregates.
      b. D422, Standard Test Method for Particle-Size Analysis of Soils (Withdrawn 2016).
      c. D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft3 (600 kN-m/m3)).
      d. D1140, Standard Test Methods for Determining the Amount of Material Finer than 75-μm (No. 200) Sieve in Soils by Washing.
      e. D1556/D1556M, Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.
      f. D1557, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3 (2,700 kN-m/m3).
      g. D2216, Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.
      h. D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).
      i. D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).
      j. D2937, Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method.
      k. D4318, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
      l. D4767, Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils.
      m. D5084, Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.
      n. D5321/D5321M, Standard Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear.
      o. D6938, Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).
   2. Environmental Protection Agency (EPA):
      a. 600/R-93/182, Technical Guidance Document: Quality Assurance and Quality Control for Waste Containment Facilities, September, 1993.
   3. American Society of Civil Engineers (ASCE):
      a. Paper No. 25333, Water Content – Density Criteria for Compacted Soil Liners (Daniel et at, 1990), Published in the ASCE Journal of Geotechnical Engineering.
      b. Paper No. 23827, In-Site Hydraulic Conductivity for Compacted Clay (Daniel et al, 1989).

1.3 SUBMITTALS

A. See Section 01 33 00 for requirements for the mechanics and administration of the submittal process.

B. Shop Drawings:
   1. Certification that the proposed material conforms to the Specifications along with copies of the test results (from a qualified commercial testing laboratory).
   2. Borrow Source Characterization Study (BSCS) for each material and /or source proposed for the work.

C. Test Reports:
   1. Narrative.
   2. Field density test results.
   3. Permeability test results.
   4. Map of all field test (density, permeability, thickness, etc.) locations.
   5. Sealed by a licensed professional.

D. As-built drawings.
   1. Sealed topographic survey of subgrade prior to soil barrier placement.
   2. Sealed topographic survey of soil barrier to confirm thickness and record permeability test locations.

E. Information Submittals:
   1. Soil samples for independent testing as requested by Owner's representative.
   2. A written certification, by the contractor installing the materials, that lists and states that the work was performed to the specifications and tolerances. This document complements the set of sealed surveys.

1.4 JOB CONDITIONS

A. Verify conditions of subgrade prior to commencing work.

B. The work area is on a landfill which may pose risks to personnel. The contractor should be aware of and take precautions to protect personnel from potential safety issues which may include:
   1. Hazardous levels of gas (H2S and other gases),
   2. Airborne particulate hazards (coal ash or other dust).
   3. Waste sludges.
   4. Pathogens.

1.5 TOLERANCES

A. The barrier soil system must meet the following tolerances:
   1. The saturated hydraulic permeability of the barrier soil must be equal to or less than 1E-5 CM/sec, as determined by ASTM D5084.
   2. The work should be constructed to lines, grades, and control points indicated on the Drawings, and shall be controlled and documented with survey methods.
   3. The thickness of the barrier soil must be equal to or greater than 12 IN, with any excess beyond the grading tolerance located below the design subgrade (on the bottom of the layer).
   4. The grading tolerance for the finished surface of barrier soil (including control points and lines) in relation to the design elevation for the completed surface shall be as follows:
      a. All Areas: 0 to .1 FT above.

B. Global positioning system (GPS) based survey systems are required for grading.

C. All field test locations shall be documented by survey, GPS or other approved method demonstrated to be accurate to within 10 FT horizontally.

1.6 DELIVERY, STORAGE AND HANDLING

A. Materials may be stockpiled on-site in designate areas approved by the Engineer. Each type of material shall be stockpiled separately. Removal and placement of material shall be done in a manner to prevent contaminating stockpiled soils with soils adjacent to and beneath the stockpile that do not meet the specifications.

B. The bentonite storage sites should be cleared and level. Bentonite material shall be contained and covered to preserve the fitness and quality of the material.

1.7 QUALIFICATIONS

A. The work shall be managed by personnel that have demonstrated experience in processing and installation of a compacted barrier soil.

PART 2 - PRODUCTS

2.1 MATERIALS

A. All soils must be approved for use by the Engineer prior to use in the Work. See borrow soil characterization study (BSCS) requirements.

B. Low Permeability Soil - General:
   1. Provide natural, fine-grained soil or bentonite amended soil that is capable of being worked to produce a soil layer of thickness shown on the Drawings that meets the hydraulic conductivity requirements.
   2. The soil shall be relatively homogeneous in color and texture and shall be free from roots, stones, foreign objects, and other deleterious materials.
   3. Some soils not meeting the requirements for Natural Fine-Grained Soil items 1 and 4 below, may be acceptable for use in the Work at the sole discretion of the Engineer. To gain approval for soils not meeting the definition of Natural Fine-Grained Soil, the Contractor must submit data on soils for the Engineer's review. The submittal should contain: A statement signed by a qualified professional engineer that the proposed soils will meet the grain size and hydraulic conductivity requirements and are otherwise suitable for use in the Work; and supporting geotechnical test data and results.

C. Natural Fine-Grained Soil:
   1. Classification: Natural fine-grained soil shall have a classification of SC, SM, CH, CL, MH, or ML as determined by ASTM D2487.
   2. Grain sizes shall be within the following gradation:

Sieve Size	Percent Passing by Weight
3/4 IN	100
No. 4	>90
No. 200	>20

   3. Hydraulic Conductivity: The saturated hydraulic conductivity of the natural fine-grained soil shall meet the stated tolerances, when compacted in accordance with requirements established by the CQC Consultant and Contractor on the basis of the barrier soil test strip as specified herein.
   4. Other Barrier soil Properties:
      a. The liquid limit shall be at least 30 as measured by ASTM D4318.
      b. The plasticity index shall be at least 10 and less than 35 as measured by ASTM D4318.

D. Bentonite Amended Soil (where applicable):

1. Hydraulic conductivity of constructed bentonite amended soil shall meet the tolerances when compacted in accordance with requirements established by the CQC Consultant on the basis of test results from the barrier soil test strip and the BSCS.
2. Soil used in the bentonite amended soil shall be free from roots, organic matter, debris, particles larger than 3/4 IN, and other deleterious material. All soil used in the bentonite amended soil shall be taken from a borrow area approved by the CQA Consultant and Engineer.
3. Unless approved otherwise by the CQA Consultant, the soil used in the bentonite amended soil shall meet the following washed sieve gradation:

Sieve Size	Percent Passing by Weight
3/4 IN	100
No. 4	55-100
No. 20	45 - 75
No. 200	10 - 40

4. Bentonite:
   a. Bentonite shall be free-flowing, powdered, high-swelling, sodium montmorillonite clay free of additives.
   b. Acceptable bentonite manufacturers are:
      1) Bentonite Performance Minerals LLC (281) 871-7900.
      2) CETCO (847) 851-1800.
      3) WYO-BEN, (800) 548-7055.
      4) Approved equal.

E. Permeability Test:
1. Laboratory permeability tests (ASTM D5084) shall be conducted in constant head, triaxial type permeameters. The specimens shall be consolidated under an isotropic effective consolidation stress not to exceed 10 PSI. The inflow to and outflow from the specimens shall be monitored with time and the coefficient of permeability calculated for each recorded flow increment. The test shall continue until steady state flow is achieved and relatively constant values of coefficient of permeability are measured.

F. Interface Friction Tests:
1. Test materials using ASTM D5321.
2. This material is part of a system. The entire system must meet the requirements before any component material is deemed acceptable.
3. Any retesting or other additional testing required to demonstrate compliance with the Specifications shall be at no additional cost to the Owner.

2.2 BARRIER SOIL MATERIAL ACCEPTANCE

A. General:
1. Notify the CQA Consultant at least 24 HRS prior to sampling so that they may observe the sampling procedures.
2. All tests necessary for the Contractor to locate and define acceptable sources of materials shall be made by the CQC Consultant.
3. Contractor to furnish samples to CQA/Engineer upon request without charge.
4. All samples required in this Section shall be representative and be clearly marked to show the source of the material and the intended use on the project. Sampling of the material source shall be done by the CQC Consultant in accordance with ASTM D75.
5. Tentative acceptance of the material source shall be based on an inspection of the source by the CQA Consultant and the certified test results of the Borrow Source Characterization

Study (BSCS) as submitted by the Contractor. No imported materials shall be delivered to the site until the proposed source and materials tests have been accepted in writing by the CQA Consultant and or Engineer.

6. Final acceptance of any material will be based on results of tests made on material samples taken from the completed barrier soil test strip, combined with the results of the BSCS. If tests conducted by the CQC Consultant or the CQA Consultant indicate that the material does not meet Specification requirements, material placement will be terminated until corrective measures are taken. Material which does not conform to the Specification requirements and is placed in the work shall be removed and replaced at the Contractor's sole expense.
7. Be solely responsible for obtaining all permits required to obtain acceptable sources of materials for use in the work.

B. Sampling and testing required herein shall be done at the Contractor's sole expense.

C. Borrow Source Characterization Study:
1. CQC Consultant shall complete one BSCS study per source of natural fine-grained soils or of soil that will be used in bentonite amended soils.
2. The Contractor will be responsible for all processing and screening of the barrier soil material at their own cost to meet the requirements of the Specifications. The Contractor will be responsible for the erosion protection of the stockpile and borrow area during his operation. Coordinate all aspects of this operation with the Engineer, CQC Consultant, CQA Consultant, and Project Manager.
3. Conduct tests, including particle size, Atterberg limits, moisture-density, and hydraulic conductivity tests, as necessary to locate an acceptable source of material.
4. Once a potential source of material has been located, the CQC Consultant shall develop and undertake a testing program to demonstrate the acceptability of the proposed material. Certified results of all tests shall be submitted to the CQA Consultant upon completion of tests. Tentative acceptance of the borrow source by the CQA Consultant will be based upon the results of the study. The testing program shall include the following elements, at a minimum:
   a. An excavation plan for the borrow source indicating proposed surface mining limits and depths of samples to be taken for testing.
   b. Test pits for borrow source sampling shall be appropriately spaced to reflect site geomorphology and sampled at depth intervals appropriate to the proposed excavation methods.
5. Test Parameters and Reporting:
   a. Test natural soils from each proposed borrow area.
   b. Where applicable, test the bentonite amended soil product for acceptance in addition to the borrow area tests.
   c. Test frequency: a minimum of five samples or one per 20,000 cubic yards of estimated in-place quantity, whichever is greater per location/material.
   d. Testing:

Parameter	Test Method.
Particle Size (sieve plus hydrometer)	ASTM D422
Atterberg Limits	ASTM D4318
Standard Proctor	ASTM D698
Hydraulic Conductivity(1)	ASTM D5084

(1) Hydraulic conductivity tests shall be performed on recompacted samples of the proposed material compacted according to criteria developed by the CQC Consultant using data from tests conducted in accordance with ASTM D698.

6. Develop an Acceptable Window: Determine an acceptable zone of moisture contents and dry unit weights for which permeabilities are less than or equal to the specified value in general accordance with ASCE paper 25333, which is generally outlined below and other pertinent criteria.
    a. Compact five or six different specimens in the laboratory; each with modified, standard, and reduced Proctor compaction procedures and plot on a moisture-density curve.
    b. Permeate compacted specimens to determine their hydraulic conductivity.
    c. On the graph of dry density vs. moisture content, identify the samples which have hydraulic conductivities less than or equal to 1.0×10^{-5} CM/s.
    d. Draw an "acceptable zone" of water content and dry density around the samples with hydraulic conductivities less than or equal to the maximum acceptable value.
    e. Perform Internal Shear Tests (ASTM D4767) and Interface Shear Tests (ASTM D6321) on specimens and plot the friction angles (internal and interface with the textured synthetic liner) as a function of molding water content.
    f. Modify the acceptable zone based on other considerations e.g. Shear strength, interface friction, shrink/ swell potential and other appropriate considerations.
    g. Provide the test data and graphs for review.
7. Bentonite Amended Soil Testing (where applicable):
    a. For acceptance of a source for soils to be used in bentonite amended soils, perform a Design Mix Analysis and submit certifications for the imported bentonite material as described below.
    b. Design Mix Analysis:
        1) Collect two of the coarsest samples of the soil taken from the approved borrow area (based on percent retained on #200 sieve). Soil samples for testing shall be at least 100 LBS each.
        2) Trial mix samples shall be prepared by mixing each soil sample with three trial application rates of bentonite. Compact each trial mix sample to a dry density equal to 95 PCT relative compaction and at a moisture content within the range of optimum to optimum plus 3 PCT (ASTM D698) for the unamended soil.
        3) Test the hydraulic conductivity of the trial mix samples using ASTM D5084 and report all data to CQA Consultant. Graph measured hydraulic conductivity vs. percent bentonite.
        4) Select a minimum bentonite content needed to consistently achieve the required in-place hydraulic conductivity.
    c. Bentonite: CQC Consultant shall submit certifications from the supplier of the bentonite material that it meets the requirements specified under PART 2 - PRODUCTS.

D. Soils Conformance Testing:
1. Following acceptance of a borrow source for natural fine-grained soils and soils for bentonite amendment, perform the following tests on samples taken from the production material using the methods and at the frequencies indicated below:

Test	Test Method	Minimum Frequency
Percent Fines	ASTM D1140	1 per 10,000 CUYD
Atterberg Limits	ASTM D4318	1 per 10,000 CUYD
Standard Proctor	ASTM D698	1 per 10,000 CUYD

2. When amended soils are used, conduct tests of the mixed bentonite amended soil, after it has been discharged from the pugmill and before this is placed in the work using the methods and at the frequencies indicated below:

Test	Method	Minimum Frequency
Standard Proctor	ASTM D698	1 per 10,000 CUYD

3. The Engineer may increase the frequency if results indicate more than 2 PCT of the material is not compliant to the BSCS criteria.
4. Any failing test by either CQC or CQA, shall be treated as a failure of the material to meet specifications.
5. If tests indicate material does not meet Specification requirements, Terminate material placement until corrective measures are taken.
6. Remove and replace material which does not meet Specification requirements at no additional cost to the Owner.

2.3 EQUIPMENT

A. Compaction Equipment:
1. The compaction equipment shall be of a suitable type, adequate to obtain the permeability specified, that provides a kneading action, such as a wobble-wheeled roller or a sheepsfoot roller having tines as long as the maximum loose lift thickness to ensure proper lift interface compaction free of voids.
2. The CQC Consultant shall confirm compaction equipment adequacy, and recommend changes if required, based on the barrier soil test strip. Such additional equipment will be provided by Contractor at no additional cost.
3. Hand-operated equipment shall be capable of achieving specified soil densities.
4. The finished surface of the final lift shall be rolled with a smooth steel drum roller or rubber-tired roller to eliminate tine or roller marks and provide a smooth, dense surface for geomembrane placement.

B. Moisture Control Equipment:
1. Equipment for applying water shall be of a type and quality adequate for the work, shall not leak, and shall be equipped with a distributor bar or other approved device to assure uniform application.
2. Equipment for mixing and drying out material shall consist of blades, discs, or other equipment defined by the CQC Consultant as approved by the CQA Consultant.
3. Mixing of natural fine-grained soils may also be required to get even distribution of moisture.
4. Allow sufficient time for adjustment of soil water content to fully saturate the lift prior to applying compaction effort, unless otherwise approved by CQA consultant.

C. Bentonite Amended Soil Mixing Equipment (where applicable):
1. Mix, process, and condition the bentonite amended soil in a pugmill prior to placing and compacting the mixture.
2. The pugmill shall have the capability to break up soil clumps and mix material to form a homogeneous blend. The pugmill shall have controls that allow a variable rate of discharge from it, to control the degree of mixing. The pugmill shall have automated controls to control the rate of feed of each material to within an accuracy of 2 PCT by weight.
3. The pugmill discharge shall be equipped with a batching bin having a drop outlet for loading hauling vehicles directly from the pugmill. Pugmill shall be positioned to allow direct discharge to hauling vehicles.
4. Do not store amended soil in a manner or for a length of time that will cause any degradation of the project or amended soil.

PART 3 - EXECUTION

3.1 BARRIER SOIL TEST PAD

A. Installation:

1. Prior to barrier soil production placement, a barrier soil test strip of a dimension no less than 100 FT long by 30 FT wide by the specified thickness shall be constructed by the Contractor over a compacted subgrade within the lined site.
2. The barrier soil test strip shall be constructed in 6 IN lifts. The final compacted thickness of each lift shall be a maximum of 6 IN. prior to placement of successive lifts, the surface of the lift in place shall be scarified or otherwise conditioned to eliminate lift interfaces.
3. The barrier soil test strip shall be constructed using the same equipment and construction procedures that are anticipated for use during actual installation.
4. During test strip installation, the Contractor in coordination with his CQC Consultant shall determine the field procedures that are best suited for his construction equipment to achieve the requirements specified herein. If subsequent testing invalidates the performance of the procedures the CQA Consultant may require that the Contractor establish new procedures.

B. Testing.
1. The CQC Consultant shall document that the subgrade of the barrier soil test strip is properly compacted to at least 95 PCT of the maximum dry density, as determined using the Standard Proctor test (ASTM D698) at a minimum of three test locations within the test strip area.
2. A minimum of five random samples of the barrier soil construction materials delivered to the site during test strip installation shall be tested by the CQC Consultant for moisture content (ASTM D2216), soil type (ASTM D2488) sieve analyses with hydrometer (ASTM D422) and Atterberg limits (ASTM D4318).
3. The CQC Consultant shall conduct at least one standard Proctor (ASTM D698), one modified Proctor (ASTM D1557) compaction test, and one 'reduced Proctor' (std. Proctor with 15 blows per lift) to establish the moisture-density relationship ranges needed to achieve the required hydraulic conductivity (see ASCE Paper No. 23827).
4. At least five field density measurements shall be performed by the CQC Consultant on each lift of the barrier soil test strip. Conduct field density tests by the same methods that will be used during production. The density measurement if performed by a nuclear gauge shall be verified through performance of one sand cone test (ASTM D1556) or drive tube test (ASTM D2937) at a location selected by the CQA Consultant. The moisture content measurement, if performed by a nuclear gauge shall be verified by recovering at least five samples for oven-dry testing (ASTM D2216) from the test location.
5. A composite sample will be taken from each lift for recompacted lab permeability (ASTM D5084).
6. Upon completion of the barrier soil test strip, the CQC Consultant, as observed by the CQA Consultant, shall measure the thickness of the test strip at a minimum of five random locations.
7. A minimum of one undisturbed sample shall be taken from each lift of the test strip by the CQC Consultant for laboratory hydraulic conductivity testing. The samples shall be taken within a 2 FT radius of the in-situ density and moisture tests. The CQA Consultant will also conduct at least one confirmatory in-situ hydraulic conductivity testing.

C. Acceptance/Rejection:
1. Upon receipt of the test data from the CQA Consultant and review of the results, the Project Manager shall inform the Contractor if the test strip can remain in-place as part of the barrier soil.
2. The test strip will be considered acceptable if the measured hydraulic conductivity of the test strip as determined by ASTM D5084 meets the requirements of the Specifications.
3. If field and laboratory test data indicate that the installed test strip meets the requirements of this Specification, it may be used as part of the barrier soil provided that it is adequately protected by the Installer from drying and equipment damage after installation. The Installer shall scarify the barrier soil material along the edge of the test strip. A minimum 2 FT overlap per lift is required for mixing and compaction between the test strip and the barrier soil.

4. If the test strip fails to achieve the desired results, the soil material of the test strip shall be completely removed, and additional mix designs (if bentonite amended) and/or test strips will be constructed until a test strip meets the requirements. No additional barrier soil may be placed until a test strip has been accepted by the Engineer.
5. The data gathered from the test strip(s) (i.e., field density, moisture, undisturbed samples, and in-situ hydraulic conductivity) shall be used along with the Proctor curves for the soil to modify the range of acceptable moisture and density test values, per ASCE Paper No. 25333 which are likely to be consistent with the required maximum permeability as recommended by ASCE Paper No. 23827. This range of moisture/density values will be established by the CQC Consultant and the CQA Consultant and will be added to the data from the BSCS and utilized as a means to establish Pass/Fail Criteria for the installation of the subject material.

3.2 INSTALLATION

A. Repair leachate seeps as required.

B. The subgrade shall be smooth and free of vegetation, sticks, roots, foreign objects, and debris. It shall be the responsibility of the Contractor to keep the receiving surfaces in the accepted condition until complete installation of the barrier soil is accomplished.

C. The barrier soil shall not be placed over areas deemed unacceptable by either the CQC or CQA Consultants based on proofroll observations or inadequate test results.

D. The barrier soil shall be installed in 6 IN compacted lifts. The material shall be placed consistent with criteria developed from construction of a satisfactory test strip.

E. When particles exceeding 1/2 IN are observed at the final lift surface, they shall be removed by the Contractor prior to final rolling of the surface.

F. For existing barrier soil remaining in place on the landfill, contractor shall scarify, blade, disc, moisture condition, and compact the top 12 IN of material to achieve the hydraulic conductivity specified in section 1.5.

G. Equipment shall be used such that bonding of the lifts will occur. Equipment shall have cleats or other protrusions of such length necessary to completely penetrate into the loose lift. Compaction shall be performed using appropriately heavy, properly ballasted, penetrating foot compactor making a minimum number of passes as approved by the CQC Consultant and CQA Consultant based on the barrier soil test strip.

H. Dry, blend, or wet material as required to maintain the barrier soil at suitable moisture content.

I. If desiccation and crusting of the lift surface occurs prior to placement of the next lift, this area shall be scarified to a minimum depth of 2 IN or until sufficiently moist materials are encountered, whichever is greater. After scarification, the superficial material should be reworked to obtain moisture content at least 2 PCT above optimum moisture content. Alternately, the drier superficial soil may be stripped and mixed with additional moist soil to achieve a moisture content satisfying the project requirements.

J. No frozen material shall be placed.

K. Material shall not be placed on a previous lift which is frozen. Frozen in-place material shall be removed prior to placement of additional soil material.

L. Material which has been subjected to a freeze/thaw cycle(s) shall be disked and recompacted prior to placement of subsequent lifts.

M. During construction, exposed finished lifts of the barrier soil material should be sprinkled with water to minimize desiccation, as necessary. The Contractor is responsible to protect the barrier soil from rain, drying, desiccation, erosion and freezing. All defective areas shall be repaired by the Contractor to the satisfaction of the CQC Consultant at no extra compensation.

N. At the end of each day's construction activities, completed lifts or sections of the compacted barrier soil should be sealed. Common sealing methods include rolling with a rubber tired or smooth-drum roller, back dragging with a bulldozer, or placement of temporary cover soil over the compacted barrier soil. The compacted barrier soil should be sprinkled with water, as needed.

O. If testing shows that a lift is significantly thicker than 6 IN, the top of the lift will be shaved off so that the lift is approximately 6 IN thick.

3.3 FIELD QUALITY CONTROL AND QUALITY ASSURANCE

A. Refer to the CQA Plan and EPA publication 600/R-93/182.

B. Soil CQC testing will be performed by JBS Engineering and Environmental.

C. Confirm specified thickness by survey at a frequency of 1 per 5,000 square feet or fraction thereof.

D. The following field and laboratory quality control tests shall be performed during barrier soil construction:

Test	Method	Minimum Frequency	Acceptable Criteria
Field Density	ASTM D2937	1/10,000 SQFT/lift	≥95 PCT of ASTM D698
Atterberg Limits	ASTM D4318	1/acre/lift	BSCS Criteria
Fines Content	ASTM D1140	1/acre/lift	BSCS Criteria
Hydraulic Conductivity	ASTM D5084	1/acre/lift	$\leq 1 \times 10^{-5}$ CM/SEC
Laboratory Moisture Density Relationship	ASTM D698	1/5,000 CUYD of placed material	NA

E. Testing and results shall conform to criteria above, unless Engineer accepts a modification per Paragraph 3.1.C.5. of Barrier Soil Test Strip.

F. Test frequencies may be modified by the Engineer. If there are indications of declining or failing test results, frequencies may be increased. If hydraulic conductivity test results are well above acceptable, the frequency for Atterberg limit and fine content testing may be waived by the Engineer.

G. The acceptable criteria may be modified by the CQA Consultant if supported by the test strip results and approved by the Engineer.

H. Holes in the compacted barrier soil, such as those created as a result of destructive testing (e.g. thin-walled Shelby tube sampling and nuclear gauge, field density determinations), shall be backfilled and tamped by rod, uniformly in 2 IN thick lifts. The backfill material shall be the same material or hydrated bentonite powder, if approved by the CQA Consultant. On the surface, the backfill material shall extend slightly beyond the holes to make sure that a good tie-in with the surrounding barrier soil is achieved. Repaired areas shall be observed and documented by the CQC Consultant.

I. Give minimum of 24 HR advance notice to CQA Consultant when ready for soil testing and inspection in completed area of the barrier soil.

J. For areas not meeting field and laboratory testing criteria, scarify the full depth of the lift or replace the material as needed. The material shall be reworked, moisture conditioned, and compacted to the specified density. Areas not meeting the thickness requirements shall be augmented with additional materials. The added materials shall be reworked with the soil layer to ensure homogeneity and proper bonding. This may be done by scarification of the surface

prior to addition of new material. The repaired area shall be properly documented, and field and laboratory quality control testing shall be performed to ensure the repaired barrier soil section meets the requirements specified herein.

K. Pay for all costs associated with corrective work and retesting resulting from failing tests. The CQA Consultant shall be informed immediately of all failing tests.

L. Plot all field density test locations by lift on an electronic drawing and provide engineers or surveyors certification of the accuracy of the locations.

M. Field density test locations not accurately documented or precisely located may not be counted towards the required testing frequency.

END OF SECTION

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SECTION 32 91 13
TOPSOILING AND FINISHED GRADING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Topsoiling and finished grading.

B. Related Specification Sections include but are not necessarily limited to:
   1. Division 00 - Procurement and Contracting Requirements.
   2. Division 01 - General Requirements.
   3. Section 31 10 00 - Site Clearing.
   4. Section 31 23 00 - Earthwork.
   5. Section 31 25 00 - Soil Erosion and Sediment Control.
   6. Section 32 92 00 - Seeding, Sodding and Landscaping.

C. Location of Work: All areas within limits of grading and all areas outside limits of grading which are disturbed in the course of the work.

1.2 SUBMITTALS

A. Shop Drawings:
   1. See Specification Section 01 33 00 for requirements for the mechanics and administration of the submittal process.
   2. Project Data: Test reports for furnished topsoil.

1.3 SITE CONDITIONS

A. Verify amount of topsoil stockpiled and determine amount of additional topsoil, if necessary to complete work.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Topsoil:
   1. Original surface soil typical of the area.
   2. Existing topsoil stockpiled under Specification Section 31 10 00.
   3. Friable, loamy soil capable of supporting native plant growth.

2.2 TOLERANCES

A. Finish Grading Tolerance: ±0.1 FT from required elevations.

PART 3 - EXECUTION

3.1 PREPARATION

A. Correct, adjust and/or repair rough graded areas.
   1. Cut off mounds and ridges.
   2. Fill gullies and depressions.
   3. Perform other necessary repairs.
   4. Bring all sub-grades to specified contours, even and properly compacted.

B. Loosen surface to depth of 2 IN, minimum.

C. Remove all stones and debris over 2 IN in any dimension.

3.2 ROUGH GRADE REVIEW

A. Reviewed by Engineer in Specification Section 31 10 00.

3.3 PLACING TOPSOIL

A. Do not place when subgrade is wet or frozen enough to cause clodding.

B. Spread and lightly compact to a depth of 6 IN for all disturbed earth areas.

C. If topsoil stockpiled is less than amount required for work, furnish additional topsoil at no cost to Owner.

D. Provide finished surface free of stones, sticks, or other material 1 IN or more in any dimension.

E. Provide finished surface smooth and true to required grades.

F. Restore stockpile area to condition of rest of finished work.

3.4 ACCEPTANCE

A. Upon completion of topsoiling, obtain Engineer's acceptance of grade and surface.

B. Make test holes where directed to verify proper placement and thickness of topsoil.

END OF SECTION

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SECTION 32 92 00
SEEDING, SODDING AND LANDSCAPING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Seeding, sodding and landscape planting:
      a. Soil preparation.

B. Related Specification Sections include but are not necessarily limited to:
   1. Division 00 - Procurement and Contracting Requirements.
   2. Division 01 - General Requirements.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. American Nursery and Landscape Association/American National Standards Institute (ANLA/ANSI):
      a. Z60.1, American Standard for Nursery Stock.
   2. AOAC International (AOAC).
   3. ASTM International (ASTM):
      a. D2028, Standard Specification for Cutback Asphalt (Rapid-Curing Type).
      b. D5276, Standard Test Method for Drop Test of Loaded Containers by Free Fall.

B. Quality Control:
   1. Fertilizer:
      a. If Engineer determines fertilizer requires sampling and testing to verify quality, testing will be done at Contractor's expense, in accordance with current methods of the AOAC.
      b. Upon completion of Project, a final check of total quantities of fertilizer used will be made against total area seeded.
      c. If minimum rates of application have not been met, Contractor will be required to distribute additional quantities to make up minimum application specified.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See Specification Section 01 33 00 for requirements for the mechanics and administration of the submittal process.
   2. Layout drawings:
      a. Scaled site plan (scale 1 IN = 20 FT or equal to scale of Project site plan Drawing) on reproducible Drawing to show:
   3. Product technical data including:
      a. Acknowledgement that products submitted meet requirements of standards referenced.
      b. Manufacturer's installation instructions.
      c. Signed copies of vendor's statement for seed mixture required, stating botanical and common name, place of origin, strain, percentage of purity, percentage of germination, and amount of Pure Live Seed (PLS) per bag.
      d. Type of herbicide to be used during first growing season to contain annual weeds and application rate.
   4. Certification that each container of seed delivered will be labeled in accordance with Federal and State Seed Laws and equals or exceeds Specification requirements.

1.4 SEQUENCING AND SCHEDULING

A. Installation Schedule:
   1. Show schedule of when lawn type and other grass areas are anticipated to be planted.

2. Indicate anticipated dates Engineer will be required to review installation for initial acceptance and final acceptance.

B. Pre-installation Meeting:
   1. Meet with Engineer and other parties as necessary to discuss schedule and methods, unless otherwise indicated by Engineer.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Native Grass Seeding: Certified seed of locally adapted strains.

B. Application:
   1. Broadcast seeding.
   2. Apply as hydro-mulch mixture.

C. Water:
   1. Water free from substances harmful to grass or sod growth.
   2. Provide water from source approved prior to use.

D. Acceptable seeding rates:
   1. Spring: March - September (Combination of Bermuda and Bahia)
      a. Bahia Seed – 20lb/acre
      b. Bermuda Seed "hulled" – 25 lb/acre
      c. Fertilizer – 600 lb/acre
   2. Fall: October – February
      a. Rye (use in critical areas that require a quick growing time) – 20 lb/acre
      b. Wheat – 120 lb/acre
      c. Fertilizer – 400 lb/acre

PART 3 - EXECUTION

3.1 SOIL PREPARATION

A. General:
   1. Limit preparation to areas which will be planted soon after.
   2. Provide facilities to protect and safeguard all persons on or about premises.
   3. Protect existing trees designated to remain.
   4. Verify location and existence of all underground utilities.
      a. Take necessary precaution to protect existing utilities from damage due to construction activity.
      b. Repair all damages to utility items at sole expense.

B. Preparation for Seeding:
   1. Loosen surface to minimum depth of 4 IN.
   2. Remove stones over 1 IN in any dimension and sticks, roots, rubbish, and other extraneous matter.
   3. Prior to applying fertilizer, loosen areas to be seeded with a double disc or other suitable device if the soil has become hard or compacted.
   4. Correct any surface irregularities in order to prevent pocket or low areas which will allow water to stand.
   5. Distribute fertilizer uniformly over areas to be seeded according to manufacturer's directions.
   6. Incorporate fertilizer into soil to a depth of at least 2 IN by disking, harrowing, or other approved methods.
   7. Remove stones or other substances from surface which will interfere with turf development or subsequent mowing operations.

8. Grade to a smooth, even surface with a loose, uniformly fine texture.
    a. Roll and rake, remove ridges and fill depressions, as required to meet finish grades.
    b. Limit fine grading to areas which can be planted soon after preparation.
9. Restore areas to specified condition if eroded or otherwise disturbed after fine grading and before planting.

3.2 INSTALLATION

A. Pasture Seeding:
1. Do not use seed which is wet, moldy, or otherwise damaged.
2. Perform seeding work from April 20 to May 15 for spring planting, and August 1 to September 15 for fall planting, unless otherwise approved by Engineer.
3. Employ satisfactory methods of sowing using mechanical power-driven drills or seeders, mechanical hand seeders, or other approved equipment.
4. Distribute seed evenly over entire area with 50 percent sown in one direction, and the remainder at right angles sown to first sowing.
5. Stop work when work extends beyond most favorable planting season for species designated, or when satisfactory results cannot be obtained because of drought, high winds excessive moisture, or other factors.
    a. Resume work only when favorable conditions develop.
6. Lightly rake seed into soil followed by light rolling or cultipacking.
7. Immediately protect seeded areas against erosion by mulching.
    a. Spread mulch in continuous blanket using 1-1/2 tons per acre to a depth of 4 or 5 straws. Use a tacking method over the mulched area.
8. Protect seeded slopes against erosion with erosion netting or other methods approved by Engineer.
    a. Protect seeded areas against traffic or other use by erecting barricades and placing warning signs.

3.3 MAINTENANCE AND REPLACEMENT

A. General:
1. Begin maintenance of planted areas immediately after each portion is planted and continue until final acceptance or for a specific time period as stated below, whichever is the longer.
2. As required provide and maintain temporary piping, hoses, and watering equipment to convey water from water sources and to keep planted areas uniformly moist for proper growth.
3. Protection of new materials:
    a. Provide barricades, coverings or other types of protection necessary to prevent damage to existing improvements indicated to remain.
    b. Repair and pay for all damaged items.
4. Replace unacceptable materials with materials and methods identical to the original specifications unless otherwise approved by the Engineer.

B. Seeded Areas:
1. Maintain seeded areas for a minimum of 90 days, minimum, after installation and acceptance of entire project area to be planted.
2. Maintenance period begins at completion of planting and establishment of at least 70% coverage as determined by Engineer.
3. Engineer will review seeded area after installation for initial acceptance.
4. Maintain seeded area by watering, fertilizing, weeding, mowing, trimming, and other operations such as rolling, regrading, and replanting as required to establish a smooth, uniform area, free of weeds and eroded or bare areas.
5. Lay out temporary watering system and arrange watering schedule to avoid walking over muddy and newly seeded areas.
    a. Use equipment and water to prevent puddling and water erosion and displacement of seed or mulch.

6. Mow seeded area as soon as there is enough top growth to cut with mower set at recommended height for principal species planted.
    a. Repeat mowing as required to maintain height.
    b. Do not delay mowing until grass blades bend over and become matted.
    c. Do not mow when grass is wet.
    d. Time initial and subsequent mowings as required to maintain a height of 1-1/2 to 2 IN.
    e. Do not mow lower than 1-1/2 IN.
7. Remulch with new mulch in areas where mulch has been disturbed by wind or maintenance operations until disturbed areas have been sufficiently covered.
    a. Anchor as required to prevent displacement.
8. Unacceptable plantings are those areas that do not meet the quality of the specified material, produce the specified results, or were not installed to the specified methods.
9. Replant bare areas using same materials specified.
10. Engineer will review final acceptability of installed areas at end of maintenance period.
11. Maintain repaired areas until remainder of maintenance period or approved by Engineer, whichever is the longer period.

END OF SECTION

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SECTION 33 40 00
STORM DRAINAGE SYSTEM

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Storm drainage systems.
   2. Storm drainage pipe.
   3. Inlets, headwalls, flumes and flared end sections.

B. Related Specification Sections include but are not necessarily limited to:
   1. Division 00 - Procurement and Contracting Requirements.
   2. Division 01 - General Requirements.
   3. Section 31 23 33 - Trenching, Backfilling, and Compacting for Utilities.

1.2 QUALITY ASSURANCE

A. Referenced Standards:
   1. American Association of State Highway and Transportation Officials (AASHTO):
      a. M36, Standard Specification for Corrugated Steel Pipe, Metallic-Coated, for Sewers and Drains (Equivalent ASTM A760/A760M).
      b. M190, Standard Specification for Bituminous-Coated Corrugated Metal Culvert Pipe and Pipe Arches.
   2. ASTM International (ASTM):
      a. A760/A760M, Standard Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains.
      b. C14, Standard Specification for Nonreinforced Concrete Sewer, Storm Drain, and Culvert Pipe.
      c. C76, Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe.
      d. C361, Standard Specification for Reinforced Concrete Low-Head Pressure Pipe.
      e. F2510/F2510M, Standard Specification for Resilient Connectors Between Reinforced Concrete Manhole Structures and Corrugated Dual- and Triple-Wall Polyethylene and Polypropylene Pipes.
      f. F2648/F2648M, Standard Specification for 2 to 60 IN (50 to 1500 MM) Annular Corrugated Profile Wall Polyethylene (PE) Pipe and Fittings for Land Drainage Applications.
   3. Texas Department of Transportation Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges 2014:
      a. Standard Details and Specifications.

1.3 SUBMITTALS

A. Shop Drawings:
   1. See Specification Section 01 33 00 for requirements for the mechanics and administration of the submittal process.
   2. Product technical data including:
      a. Acknowledgement that products submitted meet requirements of standards referenced.
   3. Certifications.
   4. Test reports.
   5. Submit all tests and certification in a single coordinated submittal.
      a. Partial submittals will not be accepted.

B. Submit schedules and details for structures and joints.

1.4 WARRANTY

A. Warrant that the infiltration will not exceed the amount specified in the Exfiltration Test paragraph in the FIELD QUALITY CONTROL Article in PART 3 of this Specification Section during the one year correction period.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Reinforced Concrete Pipe (RCP):
   1. Reinforced concrete culvert, storm drain and sewer pipe: ASTM C76, Classes III, IV, and V.

B. RCP Joint Sealer:
   1. Rubber gasket: ASTM C361.

C. Flared End Sections:
   1. Conform to TxDOT Specifications.
   2. Bituminous coated: AASHTO M190, Type A.
   3. Jointing: Same as pipe.

D. Corrugated Metal Pipe (CMP):
   1. AASHTO M36 (ASTM A760/A760M), 16 GA.
   2. Bituminous coated: AASHTO M190, Type A.
   3. Jointing: Connecting bands of same base metal coated as pipe.

E. High Density Polyethylene Pipe (HDPE):
   1. ASTM F2648/F2648M.
   2. ASTM F2510/F2510M.

F. CMP Joint Sealer:
   1. Cold applied asphalt joint compound.
   2. Preformed flexible pipe joint sealing compound.
   3. Rubber gasket: ASTM C361.

G. Concrete and Reinforcement for Headwalls, and Flumes:
   1. Comply with TxDOT specifications, Drawings, and Details.

PART 3 - EXECUTION

3.1 PREPARATION

A. Comply with Specification Section 31 23 33.

3.2 INSTALLATION

A. Install products in accordance with manufacturer's instructions.

B. Comply with Specification Section 31 23 33.

3.3 FIELD QUALITY CONTROL

A. Verify and coordinate installation.

B. In case of conflict, do not relocate piping without prior approval from the Engineer.

END OF SECTION

Final Cover Quality Control Plan (FCQCP)

Gibbons Creek Steam Electric Station

Site A and Site F Landfill Closure

GCERG, Inc.

Grimes County, TX

July 2021

ISSUED FOR CONSTRUCTION

HDR Engineering, Inc.
Firm Registration No. F-754

17111 Preston Road, Suite 300
Dallas, Texas 75248
972-960-4400

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Table of Contents

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1 General

This Final Cover Quality Control Plan (FCQCP) has been prepared to provide the Owner, Engineer, and Construction Quality Assurance (CQA) Consultant the means to govern the construction quality and to document construction operations in accordance with the engineering drawings.

More specifically, this FCQCP addresses the components required to construct the closure system for the Site A and Site F Landfills. The common components of a closure system often include many of the following layers: soil subgrade, compacted soil liner, HDPE geomembrane, a drainage geocomposite, an infiltration layer and topsoil. As many of the components are the same or similar for both landfills, this CQA plan is organized by the components of the work. This plan is intended to be used for both closure systems; therefore it includes material components that may not be used on both projects.

The CQA Plan is divided into the following sections:

1 General
2 Soil Liner
3 Geomembrane Liner
4 Drainage Geocomposite
5 Earthen Drainage & Protective Components
6 Geotextile
7 High Density Polyethylene Pipe, Manholes, & Fittings
8 Surveying
9 Documentation

1.1 Scope of Construction Quality Assurance Plan

The scope of this FCQCP includes the CQA of the soils and geosynthetic components of the landfill closure systems. The CQA for the selection, evaluation, and placement of the soils is included in the scope. This document is intended to be used in concert with the CQC requirements presented in the project specifications.

1.2 Definitions

1.2.1 Construction Quality Assurance

In the context of this plan, construction quality assurance is defined as a planned and systematic program employed by the Owner to assure conformity of the constructed closure system with the design drawings and the project specifications. CQA is provided by the CQA Consultant as a representative of the Owner and is independent from the Contractor and all manufacturers. The CQA program is designed to provide adequate confidence that items or services meet contractual and regulatory requirements and will perform satisfactorily in service.

1.2.2 Construction Quality Control

Construction Quality Control refers to actions taken by manufacturers, fabricators, installers, or the Contractor to ensure that the materials and the workmanship meet the requirements of the

design plans and project specifications. For earthen components such as the compacted clay liner, the infiltration layer and topsoil, CQC will be provided by Owner's CQA Consultant. In the case of geosynthetic components, material quality control is provided by manufacturer certifications and the CQC for the installation of the various geosynthetics is provided by the Contractor's CQC Consultant. The manufacturer's specifications and quality control (QC) requirements are included in this CQA Plan by reference only.

1.2.3 Minimum Average Roll Value (MARV)

Geosynthetics are commonly specified on a minimum or maximum average roll value (MARV). The MARV is the value two standard deviations away from the average value for the product.

1.2.4 CQA/CQC Certification Document

At the completion of construction, a certification document will be prepared by the CQA Consultant and be submitted to the state regulatory agency. The certification report will include all QC testing performed by the Geosynthetics Manufacturers, all CQC testing performed by the CQC Consultant, or Geosynthetic Installers, and all CQA conformance testing performed by the CQA Consultant.

1.2.5 Units

In this CQA Plan, all properties and dimensions are expressed in U.S. units.

1.2.6 References

The CQA Plan includes references to the test procedures of the ASTM International (ASTM), and the "Geosynthetic Research Institute" (GRI).

1.3 Governance between Documents

The CQA Plan is intended to be a supporting document to improve the overall documentation of the Work. The CQA Plan is less specific than the project specifications, and conflicts may exist between the documents. The Contractor is instructed to bring all apparent discrepancies or conflicts to the attention of the Engineer or CQA Consultant for resolution. The Engineer has the sole authority to determine resolution of conflicts existing within the Contract Documents. The more stringent requirement shall control the resolution, unless otherwise determined by the Engineer.

1.4 Parties to Construction Quality Assurance

The lines of authority and communications between each of the parties involved in the CQA and CQC are illustrated in Figure 1.

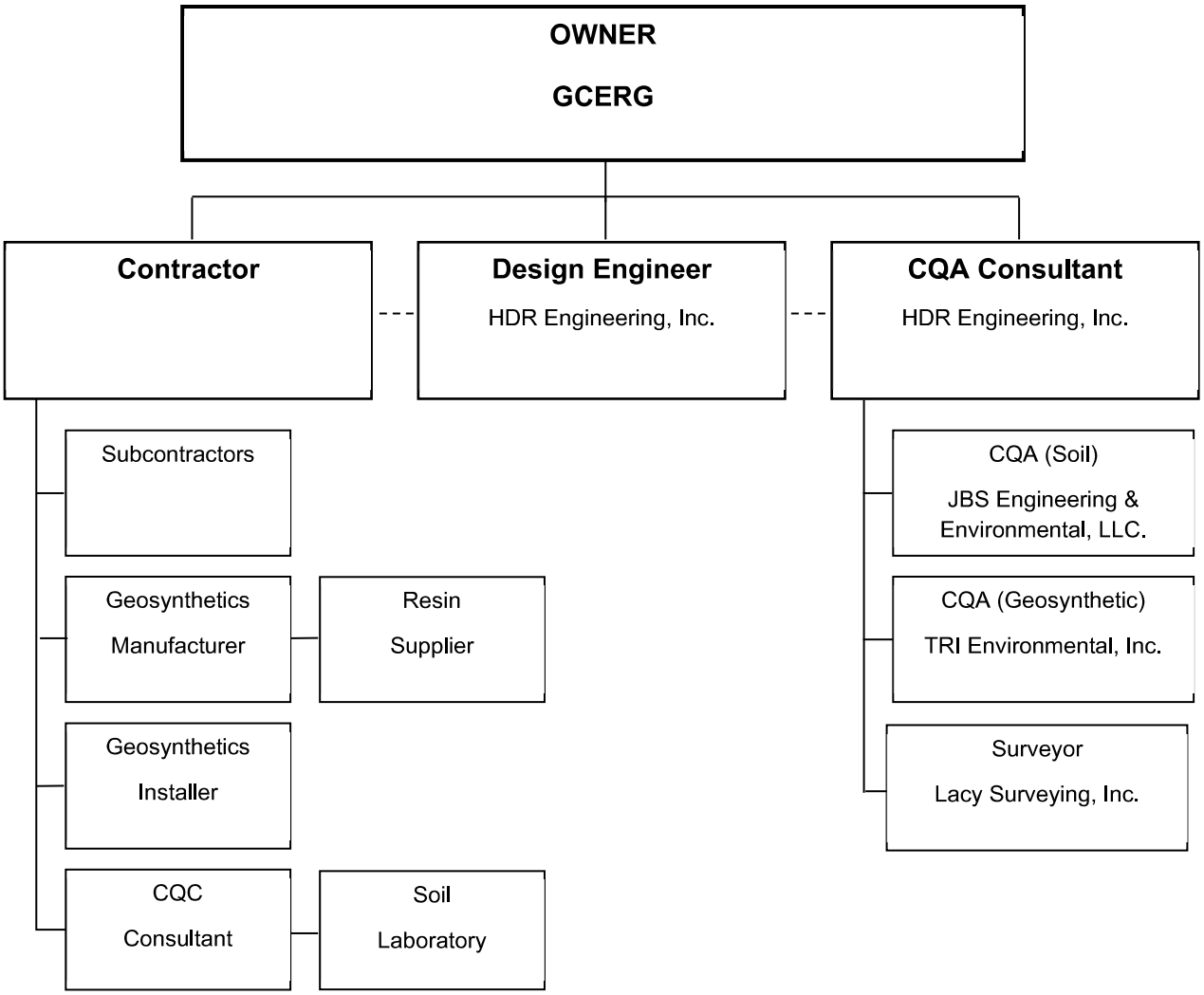

Figure 1 CQA/CQC Lines of Authority and Communication

1.4.1 Owner

The Owner is the Gibbons Creek Environmental Redevelopment Group (GCERG), who owns and/or is responsible for the facility.

1.4.2 Project Manager

The Project Manager is the official representative of the Owner. The Project Manager serves as communications coordinator for the project, initiating the resolution, preconstruction, and construction meetings outlined in this section. The Project Manager shall also be responsible for proper resolution of all quality issues that arise during construction.

1.4.3 Design Engineer

The Design Engineer is responsible for the engineering design, drawings, plans and project specifications for the liner system and protective cover system. The Design Engineer is HDR Engineering, Inc.

1.4.4 Contractor

The Contractor is responsible for the construction of the project and system components in accordance with contract specifications. The Contractor is responsible for all of their subcontractors. The Contractor is responsible for submittal coordination and the overall CQC on the project.

1.4.5 Geosynthetics Manufacturer

The Geosynthetics Manufacturer(s) is (are) responsible for the production of geomembranes, geonets, and geotextiles. The manufacturers are responsible for Quality Control (QC) during manufacture of the geosynthetic components, certification of the properties of the geosynthetic components, and field installation criteria.

1.4.6 Geosynthetics Installer

The Geosynthetics Installer(s) may be the Contractor or a subcontractor to the Contractor and is (are) responsible for field handling, storing, placing, seaming, protection of (against wind, etc.), and other aspects of the geosynthetics installations, including the geomembranes, and geotextiles. The Geosynthetics Installer may also be responsible for transportation of these materials to the site and for the preparation and completion of anchor trenches.

1.4.7 Construction Quality Assurance Consultant

The CQA Consultant, HDR Engineering, Inc., is a representative of the Owner and is responsible for observing, testing, and documenting activities related to the CQC/CQA of the earthworks at the site and the installation of the geosynthetic components of the closure system. The CQA Consultant is also responsible for issuing a facility certification report sealed by a registered professional engineer.

1.4.8 Geosynthetics Construction Quality Assurance Laboratory

The Geosynthetics CQA Laboratory is a party, independent from the Owner, which is responsible for conducting tests on conformance samples of geosynthetics used. The Geosynthetics CQA Laboratory service cannot be provided by any party involved with the manufacture, fabrication, or installation of any of the geosynthetic components. TRI Environmental, Inc. will be the Geosynthetics CQA Laboratory.

1.4.9 Soils Construction Quality Assurance Laboratory

The Soils Construction Quality Assurance Laboratory is a party, independent from the Owner, which is responsible for conducting geotechnical tests on conformance samples of soils used in the closure system. The Soils CQA Laboratory service cannot be provided by any party involved with the Contractor. JBS Engineering, Inc. will be the Soils CQA Consultant.

1.4.10 Construction Quality Control Consultant

The term CQC Consultant shall be used to designate the registered professional engineer in charge of the quality control work. The personnel of the CQC Consultant also include Quality Control Monitors who are also located at the site for construction observation and monitoring. The CQC Consultant is responsible for the timely conveyance of CQC testing results to the CQA Consultant.

1.4.10.1 EARTHWORK AND SOIL QUALITY CONTROL CONSULTANT

The Earthwork and Soil CQC consultant is a representative of the Owner and will be responsible for the earthwork and soil quality control sampling and testing. JBS Engineering, Inc. will be the Soils CQC Consultant.

1.4.10.2 GEOSYNTHETICS CONSTRUCTION QUALITY CONTROL

The Geosynthetics Installer will be responsible for the geosynthetics quality control testing and reporting during the field installation of geosynthetic material.

1.4.10.3 GEOSYNTHETICS CONSTRUCTION QUALITY CONTROL LABORATORY

The Geosynthetics CQC Laboratory is responsible for conducting conformance tests on samples of geosynthetics at the direction of the CQC Consultant.

1.4.10.4 SOILS CONSTRUCTION QUALITY CONTROL LABORATORY

The Soils Construction Quality Control Laboratory is responsible for conducting geotechnical tests on soil samples at the direction of the CQC Consultant.

1.5 Qualifications of the Parties

The following qualifications are required of all parties involved with the manufacture, fabrication, installation, transportation, and CQC/CQA of all materials for the project. Where applicable, these qualifications shall be submitted by the Contractor to the Project Manager for review and approval.

1.5.1 Contractor

Qualifications of the Contractor are specific to the construction contract and independent of this CQA Plan. A complete up to date version of each geosynthetic component manufacturer's QC Plan shall be incorporated into the Contractor's CQC Plan.

1.5.2 Geosynthetics Manufacturers

Each Geosynthetics Manufacturer must satisfy the qualifications presented in the project specifications and must be prequalified and approved by the Project Manager.

The physical properties of each geosynthetic product must be certified by the geosynthetics manufacturer. The properties certified must include, at a minimum, those identified in the project specifications. Manufacturer’s certification must be approved by the CQA Consultant before the product is used.

1.5.3 Geosynthetic Installer(s)

The Geosynthetic Installer(s) will be trained and qualified to install the geosynthetics components of the liner system. Each Geosynthetics Installer must meet the requirements of the project specifications and be approved by the Project Manager. The Geomembrane Installer must be approved by the Geomembrane Manufacturer.

1.5.4 Construction Quality Assurance Consultant

The CQA Consultant will act as the Owner's CQA representative and will report to the Project Manager. The CQA Consultant will perform conformance testing to satisfy the requirements of this CQA Plan, will observe the CQC work performed by the CQC Consultant, and will prepare

the certification document incorporating both CQA and CQC test data. The CQA Consultant will have experience in the CQC/CQA aspects of geomembrane system construction and soils testing, and be familiar with ASTM and other related industry standards. The activities of the CQA Consultant will be performed under the supervision of a registered professional engineer.

1.5.5 Construction Quality Control Consultant

The Earthwork and Soil CQC Consultant will be a subcontractor to the CQA Consultant. The Earthwork and Soil CQC Consultant will be experienced with soils, including soil liners, and geosynthetics, including geomembranes, geonets, and geotextiles. The Earthwork and Soil CQC Consultant will satisfy the requirements of the project specifications and be approved by the Project Manager. The activities of the CQC Consultant will be performed under the supervision of a registered professional engineer.

The Geosynthetic Installer will work for the Contractor and be experienced with geosynthetics, including geomembranes, geonets, geocomposites, and geotextiles. The Geosynthetic Installer will satisfy the requirements of the project specifications and be approved by the Contractor.

1.5.6 Geosynthetics Construction Quality Control Laboratory

The Geosynthetics CQC Laboratory is a subcontractor of the CQC Consultant and will have experience in testing geosynthetics and be familiar with ASTM, GRI, and other applicable test standards. The laboratory shall be accredited under the GAI-LAP program for all tests required for the project. The Geosynthetics CQC Laboratory will be capable of providing test results within 24 hours or a reasonable time after, as agreed to at the outset of the project, receipt of samples, and will maintain that standard throughout the installation.

1.6 Site and Project Control

To guarantee a high degree of quality during installation, clear, open channels of communication are essential. To that end, meetings are critical.

1.6.1 CQA/CQC Resolution Meeting

Prior to field mobilization by the Contractor, a Resolution Meeting will be held. This meeting will include all parties then involved, including the Project Manager, the CQA Consultant, the Engineer, the Contractor, and the CQC Consultant.

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

This meeting should include all of the following activities.

- Provide relevant documents to all involved parties.
- Review critical design details of the project.
- Review the seam layout drawing provided by the Geomembrane/Geosynthetic Installer.
- Review the site-specific CQA and CQC Plans and make any appropriate modifications to the plans to ensure that all necessary testing activities are specified.

- Reach a consensus on the CQA/CQC quality control procedures, especially on methods for determining acceptability of the soils and geosynthetics.
- Review the proposed closure system.
- Select testing equipment and review protocols for testing and placement of general earthwork materials.
- Confirm methods for the soil material selection testing, acceptable zone determinations, and test strip installation.
- Confirm the methods for documenting and reporting, and for distributing documents and reports, and confirm the lines of authority and communication.

The meeting will be documented by the Project Manager and minutes will be transmitted to all parties.

1.6.2 Liner Preconstruction Meeting

A Liner Preconstruction Meeting will be held at the site a minimum of one month prior to placement of the closure system. At a minimum, the meeting will be attended by the Project Manager, Engineer, the CQA Consultant, the Contractor, the CQC Consultant, and the Geosynthetic/Geomembrane Installation Superintendent.

Specific activities considered for this meeting include the following.

- Make any appropriate modifications to the CQA and CQC Plans.
- Review the responsibilities of each party.
- Review lines of authority and communication.
- Review methods for documenting and reporting, and for distributing documents and reports.
- Establish protocols for testing.
- Establish protocols for handling deficiencies, repairs, and retesting.
- Review the time schedule for all operations.
- Establish rules for writing on the geomembrane, i.e., who is authorized to write, what can be written, and in which color.
- Outline procedures for packaging and storing archive samples.
- Review panel layout and numbering systems for panels and seams.
- Establish procedures for use of the extrusion seaming apparatus, if applicable.
- Establish procedures for use of the fusion seaming apparatus, if applicable.
- Finalize field cutout sample sizes.
- Review seam testing procedures.
- Review repair procedures.
- Establish soil stockpiling locations (if any).

The meeting will be documented by the Project Manager and minutes will be transmitted to all parties. The Resolution Meeting and the Preconstruction Meeting may be held as one meeting or separate meetings, depending on the direction of the Project Manager.

1.6.3 Weekly Progress Meetings

A weekly progress meeting will be held between the Project Manager, the CQA Consultant, the Contractor, the CQC Consultant, the Geosynthetic/Geomembrane Installation Superintendent, and representatives from any other involved parties. This meeting will discuss current progress, planned activities for the next week, projected milestone dates for major activities, and any new business or revisions to the work. The CQA Consultant will log any problems, decisions, or questions arising at this meeting in his daily report. Any matter requiring action which is raised in this meeting will be reported to the appropriate parties.

Meeting frequency may be adjusted depending on the schedule of the project and the mutual agreement of all parties involved.

1.6.4 Problem or Work Deficiency Meetings

A special meeting will be held when and if a problem or deficiency is present or likely to occur. At a minimum, the meeting will be attended by all interested parties, the Contractor, the Project Manager, and the CQA Consultant. If the problem requires a design modification, the Engineer should also be present. The purpose of the meeting is to define and resolve the problem or work deficiency as follows:

- define and discuss the problem or deficiency;
- review alternative solutions; and
- implement an action plan to resolve the problem or deficiency.

The meeting will be documented by the Project Manager and minutes will be transmitted to affected parties.

2 CCR Material Removal

Section 2 of the CQA Plan addresses the CQA activities associated with the CCR material removal during the decommissioning of the Scrubber Sludge Pond and Ash Ponds.

2.1 Excavation Monitoring

During the pre-construction meeting the Contractor, the Project Manager, and the CQA Officer will review the CCR excavation plans and specifications to ensure an understanding between all parties on the excavation requirements. The CQA Site Manager or CQA Monitor will observe excavation activities weekly. During periods of CCR excavation, a weekly summary report will be developed noting the following details:

- Map showing area(s) of active excavation
- Review and interpretation of monitoring data collected by the Contractor and actions taken

- Approximate volume of material excavated (truckloads or other approximations)
- General composition of material excavated (CCR, geomembrane, sand, clay, etc.)
- Any excavation problems or difficulties encountered, their location and solution
- Confirm CCR material, rocks and sediment is removed.

Prior to acceptance of the CCR removal as complete, the area will be visually inspected by the CQA Site Manager as exhibiting no visible signs of CCR material in the EAP.

3 Soil Liner

This section of the CQA Plan addresses the soil components of the closure system, and outlines the soils CQA program to be implemented with regard to materials confirmation, laboratory and field confirmation test requirements, overview and interfacing with the Contractor, and resolution of problems.

3.1 Soil Liner System

3.1.1 Soil Liner Subgrade

The subgrade material below the soil liner is composed of controlled fill, in situ soils, and/or CCR material. The subgrade shall be placed and compacted in accordance with project specifications. Testing will be conducted by the CQC/CQA Consultant (JBS Engineering & Environmental, LLC). The CQC/CQA Consultant shall conduct field density and moisture tests at the frequency presented in the project specifications.

Prior to the construction of the soil liner, the CQC/CQA Consultant will visually examine the surface of the subgrade to verify that any potentially deleterious materials have been removed.

3.1.2 Compacted Clay Material

The compacted clay material shall be placed and compacted in accordance with the project specifications. The CQC/CQA Consultant shall conduct field density and moisture tests at the frequency presented in the project specifications.

Hydraulic conductivity, Atterberg limits, and percent fines testing of the soil liner material shall be performed by the CQC/CQA Consultant in accordance with the project specifications.

Sealed topographic surveys shall be used to document thickness requirements. Interim thickness measurement shall be conducted in accordance with the project specifications by the CQC/CQA Consultant. Refer to Section 8 for surveying requirements.

3.2 Soils Testing

3.2.1 Test Methods

All testing used to evaluate the suitability or conformance of soils materials will be carried out in accordance with the project specifications.

3.2.2 Soils Testing Requirements

The soil CQC/CQA testing must comply with the minimum frequencies presented in the project specifications.

3.3 Soils Construction Quality Control and Assurance

CQC/CQA will be performed on all soil components of the liner construction. CQA evaluation will consist of: (1) monitoring the work; and (2) performing laboratory and field tests. Laboratory tests will be conducted on samples taken at the borrow source, stockpile, and during the course of the work prior to construction. Field tests will be conducted during the course of the work.

3.3.1 Monitoring

The CQC/CQA Consultant shall monitor and document the construction of all soil components. Monitoring the construction work for the subgrade soil and the soil component of the liner system, includes the following:

- performing CQC testing to determine the water content and other physical properties of the subbase and soil component of the liner system during compaction and compilation of the data;
- monitoring the loose thickness of lifts as placed;
- monitoring the action of the compaction and/or heavy hauling equipment on the construction surface (i.e., penetration, pumping, cracking. etc.); and
- monitoring the number of passes used to compact each lift.

3.3.2 Construction Quality Assurance Judgmental Testing

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

- the rollers slip during rolling operation;
- the lift thickness is greater than specified;
- the fill material is at an improper moisture content;
- fewer than the specified number of roller passes are made;
- dirt-clogged rollers are used to compact the material;
- the rollers may not have used optimum ballast;
- the fill materials differ substantially from those specified; or
- the degree of compaction is doubtful.

3.3.3 Perforations in Soil Liner

Perforations that must be filled will include, but not be limited to:

- soil density test locations;
- permeability sampling locations; and/or
- destructive thickness checks.

Unless otherwise noted, or as directed by the Project Manager, all perforations of the subbase by probes or sample tubes will be backfilled with soil in accordance with project specifications or

with bentonite. The CQC/CQA Consultant will observe and confirm that adequate procedures are being employed.

3.3.4 Deficiencies

If a defect is discovered in the earthwork product, the CQC/CQA Consultant will immediately determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQC/CQA Consultant will determine the extent of the deficient area by additional tests, observations, a review of records, or other appropriate means. If the defect is related to adverse site conditions, such as overly wet soils or surface desiccation, the CQC/CQA Consultant will define the limits and nature of the defect.

3.3.4.1 NOTIFICATION

After determining the extent and nature of a defect, the CQC/CQA Consultant will notify the Project Manager and Contractor and schedule appropriate retests when the work deficiency is corrected.

3.3.4.2 REPAIRS AND RETESTING

The Contractor will correct the deficiency to the satisfaction of the CQC/CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQC/CQA Consultant will develop and present suggested solutions to the Project Manager for approval.

The CQC/CQA Consultant must retest all areas represented by failing tests after they have been reworked by the Contractor. All retests performed by the CQC/CQA Consultant must verify that the defect has been corrected before the Contractor proceeds with additional work in the area of the deficiency. The CQC/CQA Consultant will verify that all installation requirements are met and that all submittals are provided.

4 Geomembrane Liner

4.1 Geomembrane Manufacturer's Certification

Compliance testing will be performed by the Geomembrane Manufacturer to demonstrate that the product meets the manufacturers' standards and the project specifications. The manufacturer shall submit a package of certifications and the quality control test results to the Contractor. The Contractor shall distribute the package upon receipt to the CQA consultant prior to the installation of any geomembrane material.

The quality control certificate will be signed by a responsible party employed by the Geomembrane Manufacturer, such as the production manager. In addition to the end product certifications and test results, the package should include the following information.

4.1.1 Raw Material

- Resin Supplier's name and resin production plant.
- Identification (brand name and number), and production date of the resin.
- Copies of the quality control certificates issued by the Resin Supplier.

- Reports on the tests conducted by the Geomembrane Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the project.
- A statement that the percentage of reclaimed polymer added to the resin is in accordance with the project specifications.

4.1.2 Rolls and Sheets

- Roll numbers and identification.
- Property sheets including, at a minimum, all specified properties, measured using test methods indicated in the project technical specifications, or equivalent.
- Sampling procedures and results of testing.

4.2 Conformance Testing

The CQA Consultant may perform additional testing for purposes of conformance evaluation. If the results of the Geomembrane Manufacturer's and the CQA Consultant's testing differ, the testing will be repeated by the CQA Consultant's laboratory, and the Geomembrane 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.

The CQA Consultant will review the manufacturers' documents and verify that:

- the reported property values certified by the Geomembrane Manufacturer meet all of the project technical specifications; and
- the measurements of properties by the Geomembrane Manufacturer are properly documented and that the test methods used are acceptable.

The CQA Consultant shall report any discrepancies with the above requirements to the Project Manager.

4.3 Handling, and Storage

4.3.1 Handling

The CQA Consultant will verify that:

- handling equipment used on the site is adequate, meets manufacturer's recommendations, and does not pose any risk of damage to the geomembrane; and
- the Geomembrane Installer's personnel handle the geomembranes with care.

Upon delivery at the site, the CQA Consultant will conduct a surface observation of all rolls and sheets for defects and damage. This examination will be conducted without unrolling rolls or unfolding sheets unless defects or damages are found or suspected.

The CQA Consultant will indicate to the Project Manager:

- any rolls or sheets, or portions thereof, that should be rejected and removed from the site because they have severe flaws; and
- any rolls or sheets that have minor repairable flaws.

4.3.2 Storage

The CQA Consultant will document that the Contractor's storage of the geomembrane provides adequate protection against moisture, dirt, shock, and other sources of damage or contamination and is in accordance with the project specifications.

4.4 Geomembrane Installation

4.4.1 Earthwork

4.4.1.1 SURFACE PREPARATION

The Contractor and Geomembrane Installer will certify in writing that the surface on which the geomembrane will be installed meets line and grade, and the surface preparation requirements of the project specifications. The certificate of acceptance will be given to the CQA Consultant prior to commencement of geomembrane installation in the area under consideration. The CQA Consultant will give a copy of this certificate to the Project Manager.

To ensure a timely covering of the soil liner surface, the Project Manager may allow subgrade acceptance in areas as small as one acre. After the supporting soil has been accepted by the Geomembrane Installer, it will be the Geomembrane Installer's responsibility to indicate to the Project Manager of any change in the supporting soil condition that may require repair work. If the CQA Consultant concurs with the Geomembrane Installer, then the Project Manager will ensure that the supporting soil is repaired.

4.4.1.2 ANCHORAGE SYSTEM

The CQA Consultant will verify that anchor trenches have been constructed according to project specifications and design drawings.

4.4.2 Geomembrane Placement

4.4.2.1 FIELD PANEL IDENTIFICATION

The CQA Consultant will document that the Geomembrane Installer labels each field panel with an "identification code" (number or letter-number consistent with the layout plan) agreed upon by the Geomembrane Installer and CQA Consultant at the CQA/CQC Preconstruction Meeting.

The Geomembrane Installer will establish a table or chart showing correspondence between roll numbers and field panel identification codes. This documentation shall be submitted to the CQA Consultant weekly for review and verification. The field panel identification code will be used for all quality control and quality assurance records.

4.4.2.2 FIELD PANEL PLACEMENT

4.4.2.2.1 Location

The CQA Consultant will verify that field panels are installed at the location indicated in the Geomembrane Installer's layout plan, as approved.

4.4.2.2.2 Installation Schedule

The CQA Consultant will evaluate every change in the schedule proposed by the Geomembrane Installer and advise the Project Manger on the acceptability of that change. The

CQA Consultant will verify that the condition of the supporting soil has not changed detrimentally during installation.

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

4.4.2.2.3 Placement of Geomembrane

The CQA Consultant will verify that project specification related restrictions on placement of geomembrane are fulfilled. Additionally, the CQA Consultant will verify that the supporting soil has not been damaged by weather conditions.

Wrinkles and folds shall be prevented to the extent possible and repaired when they are not prevented.

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

4.4.2.2.4 Damage

The Geomembrane Installer's CQC Inspector will visually observe each panel for damage after placement and prior to seaming. The CQC Inspector will advise the CQA Consultant which panels or portion of panels were rejected or marked for repair. Damaged panels, or portions of damaged panels, which have been rejected will be marked and their removal from the work area recorded by the CQA Consultant.

4.4.3 Field Seaming

4.4.3.1 SEAM LAYOUT

The Geomembrane Installer will provide the CQA Consultant with a seam layout drawing, i.e. a drawing of the facility to be lined showing all expected seams. The CQA Consultant and Engineer will review the seam layout drawing and verify that it is consistent with the accepted state of engineering practice and this CQA Plan. In addition, panels not specifically shown on the seam layout drawing may not be used without the Project Manager's prior approval.

A seam numbering system compatible with the panel numbering system will be agreed upon at the Resolution and/or Preconstruction Meeting. An on-going written record of the seams and repair areas shall be maintained by the Geomembrane Installer with weekly review by the CQA Consultant.

4.4.3.2 REQUIREMENTS OF PERSONNEL

The Geomembrane Installer will provide the CQA Consultant with a list of proposed seaming personnel and their experience records. This document will be reviewed by the Project Manager and the CQA Consultant for compliance with project specifications.

4.4.3.3 SEAMING EQUIPMENT AND PRODUCTS

Field seaming processes must comply with project specifications. Proposed alternate processes will be documented and submitted to the CQA Consultant for his approval. Only seaming apparatus which have been specifically approved by make and model will be used.

4.4.3.4 NONDESTRUCTIVE SEAM CONTINUITY TESTING

The Geomembrane Installer will nondestructively test all field seams over their full length using test methods approved by the project specifications. The CQA Consultant shall periodically observe the nondestructive testing to ensure conformance with this CQA Plan and the project specifications.

For approximately 10% of the noncomplying tests, the CQA Consultant will:

- observe continuity testing of the repaired areas performed by the Geomembrane Installer;
- confirm the record location, date, test unit number, name of tester, and compile the record of testing provided by the Geomembrane Installer;
- provide a walkthrough inspection of all impacted seam areas and verify that the areas have been tested in accordance with the CQA Plan and project specifications; and
- verify that the Geomembrane Installer has marked repair areas with the appropriate color-coded marking pencil.

4.4.3.5 DESTRUCTIVE SEAM TESTING

Destructive seam tests will be performed by the Geomembrane Installer's CQC inspector at locations and a frequency in accordance with the project specifications. The CQA Consultant will perform conformance tests on a minimum of 10% of the CQC destructive seam test samples obtained. Additional destructive seam tests may be required at the CQA Consultant's discretion. Selection of such locations may be prompted by suspicion of contamination, excessive grinding, off center and/or offset seams, or any other potential cause of imperfect seaming.

4.4.3.5.1 Geosynthetics CQA Laboratory Testing

Destructive test samples will be packaged and shipped by the CQA Consultant in a manner that will not damage the test sample. The Project Manager will be responsible for storing the archive samples. These procedures will be fully outlined at the Resolution and/or Preconstruction Meeting. Samples will be tested by the Geosynthetics CQA Laboratory.

Conformance testing will include "Seam Strength" and "Peel Adhesion" in accordance with project specifications. All geomembrane destructive test samples that fail to meet project specifications shall be saved and sent to the CQA Consultant for observation.

The Geosynthetics CQA Laboratory will provide preliminary 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.

4.4.3.5.2 Defining Extent of Destructive Seam Test Failure

All defective seam test failures must be bounded by seam tests from which destructive samples passing laboratory tests have been taken. The Geomembrane Installer's CQC Inspector will document repair actions taken in conjunction with all destructive seam test failures.

4.4.4 Defects and Repairs

All seams 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. Each suspected location, both in seam and non-seam areas, will be nondestructively tested using methods in accordance with the project specifications. Each location which fails the nondestructive testing will be marked by the Geomembrane Installer's CQC Inspector and repaired by the Geomembrane Installer. Repair procedures will be in accordance with project specifications or procedures agreed to by the Project Manager in the Preconstruction Meeting. The CQA Consultant will observe all repair procedures and advise the Project Manager of any problems.

4.4.5 Backfilling of Anchor Trench

Anchor trenches will be backfilled and compacted as outlined in the earthwork specifications. The soil used to backfill the anchor trench shall meet the specifications for soil liner and placed in a manner that does not stress or damage the geosynthetics. The CQA Consultant will review the backfilling operation and advise the Project Manager of any problems.

Liner edges that are constructed with run-out instead of anchor trenches (such as construction phase boundaries) will be protected with plywood sheets above the geosynthetics. Subsequent construction must always lap the prior certification limits such that all areas are certified to be in conformance with the plans and specifications. The CQA consultant shall review the procedures to excavate the plywood sheet prior to extending the liner section. The entire length of seam to previously constructed areas shall be thoroughly inspected for conformance. Any liner component (soil and geosynthetic) that is damaged, whether by excavation or other cause, shall be properly repaired and inspected by the CQA consultant. Any deficiencies noted such as, failing seams, shall be addressed to prevent reoccurrence in the new construction.

4.4.6 Materials in Contact with 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. Although protective geosynthetics and geotextiles have been incorporated into the liner system, all reasonable measures to protect the geomembrane and provide additional quality assurance procedures are necessary to assure that systems built with these materials will be constructed to ensure proper performance.

4.4.6.1 SOILS

Prior to placement, the CQA Consultant will visually confirm that all soil materials to be placed against the geomembrane comply with project specifications. The Geomembrane Installer will provide the CQA Consultant a written surface acceptance certificate. All soil materials shall be placed and compacted in accordance with project specifications.

4.4.6.2 CONCRETE STRUCTURES AND OTHER APPURTENANCES

The CQA Consultant will review:

- installation of the geomembrane in appurtenance areas, and connection of the geomembrane to appurtenances;
- that extreme care is taken while seaming around appurtenances since neither nondestructive nor destructive testing may be feasible in all of these areas;
- testing is conducted in all areas that are feasible;

- the geomembrane has not been visibly damaged while making connections to appurtenances;
- the installation of the geomembrane shall be exercised so as not to damage sumps; and

The CQA Consultant will inform the Project Manager if the above conditions are not fulfilled or observed to be in accordance with project specifications.

5 Drainage Geocomposite

5.1 Material Requirements

All HDPE drainage composite shall be manufactured in accordance with the project specifications.

5.2 Manufacturing

The drainage composite manufacturer will provide the Contractor and the CQC Consultant with a written certification, signed by a responsible party, that the drainage composites actually delivered have properties which meet or exceed the specified properties.

The CQA Consultant will examine all manufacturers' certifications to ensure that the property values listed on the certifications meet or exceed the project specifications. Any deviations will be reported to the Project Manager.

5.3 Labeling

The drainage composite manufacturer will identify all rolls of drainage composite in accordance with project specifications. The CQA Consultant will examine rolls upon delivery and any deviation from the above requirements will be reported to the Project Manager.

5.4 Shipment and Storage

Drainage composite cleanliness is essential to its performance; therefore, the shipping and storage of drainage composite must be in accordance with the project specifications. The CQA Consultant will examine rolls upon delivery and any deviation from the above requirements will be reported to the Project Manager.

The CQA Consultant will check that drainage composites are free of dirt and dust just before installation. The CQA Consultant will report the outcome of this review to the Project Manager; and, if the drainage composites are judged dirty or dusty, they will be washed by the drainage composite Installer prior to installation.

Washing operations will be observed by the CQA Consultant and improper washing operations will be reported to the Project Manager.

5.5 Handling and Placement

The drainage composite Installer will handle all drainage composites in a manner in accordance with the project specifications. The CQA Consultant will note any noncompliance and report it to the Project Manager.

5.6 Stacking and Joining

Adjacent drainage composites will be joined according to construction drawings and project specifications. The CQA Consultant will note any noncompliance and report it to the Project Manager.

When several layers of drainage composites are stacked, care should be taken to ensure that stacked drainage composites are placed in the same direction. A stacked drainage composite will never be laid in perpendicular directions to the underlying drainage composite unless otherwise specified by the Engineer. The CQA Consultant will observe the stacking of drainage composites and will note any noncompliance and report it to the Project Manager.

5.7 Repair

Any holes or tears in the drainage composite will be repaired and documented in accordance with project specifications. The CQA Consultant will observe any repair, note any noncompliance with the above requirements, and report them to the Project Manager. CQA Consultant shall report all holes, tears, damage and repairs to the Project Manager.

5.8 Placement of Soil Materials

All soil materials placed over the drainage composite should be placed in accordance with project specifications so as to ensure:

- the drainage composite and underlying geomembrane are not damaged;
- wrinkles and folds are prevented to the extent possible and repaired when not prevented;
- minimal slippage of the drainage composite on the underlying geomembrane occurs;
- the material is not exposed for longer than is allowed by the project specifications; and
- no excess tensile stresses occur in the drainage composite.

Any noncompliance will be noted by the CQA Consultant and reported to the Project Manager.

6 Earthen Drainage & Protective Components

6.1 Introduction

This section of the CQA plan addresses the earthen components of a cap system that will be placed above various geosynthetics. For cap systems these components include sand and gravel drains, “infiltrations layers” and topsoil (“erosion layers). This section outlines the CQA program to be implemented with regard to materials confirmation, laboratory and field test requirements, overview and interfacing with the Contractor, and resolution of problems.

6.2 General Placement

6.2.1 Wrinkles and Folds in Geosynthetics

All earthen materials placed directly above a geosynthetic shall be placed by the contractor in a manner that minimizes wrinkles and folds. The CQA Consultant shall monitor placement and document any areas in which folding occurs so that the Contractor can make repairs to the geosynthetics. It may be necessary to adjust the time of day or the method of placement in order to minimize wrinkling of the geosynthetics. Failure of the Contractor to control wrinkles shall be reported by the CQA consultant to the Project Manager for resolution.

6.2.2 Abrasion and Puncture of Geosynthetics

The CQA consultant shall be aware of activities during the placement of earthen materials above the geosynthetics that may result in abrasion or puncture. The CQA consultant shall investigate any activity that is a cause for concern and shall document all investigations. The documentation shall include a description of the activity that is causing concern; the location; a description of the damage to the geosynthetic (if any); a description of the repair; and preventative measures to be implemented to avoid future incidents of a similar nature.

Activities that may be cause for concern include:

- sharp turns;
- spinning of wheels or tracks;
- digging in placed material; and
- pushing material across a geosynthetic.

6.2.3 Equipment Separation

The CQC consultant shall check that the specified separation between equipment and geosynthetics is maintained. That CQA consultant shall observe and report any problems to the Project Manager.

6.2.4 Exposure

Some geosynthetics, especially geotextiles, degrade when exposed to ultraviolet light. The project specifications may require that these materials be covered within a certain number of days. The CQA consultant shall document when these materials are covered in a timely fashion. If current progress indicates that any materials will not be covered within the time defined in the project specifications the CQA consultant shall report that information to the Project manager and Contractor.

6.3 Soil and Gravel (granular) Drainage Material

The CQC/CQA Consultant will provide testing of the granular material at the frequency specified in the project specifications. The CQC/CQA Consultant will observe that placement of the granular material is done in a manner to protect the geomembrane.

6.4 Infiltration Layer Material

The infiltration layer shall be placed in accordance with the project specifications. The CQC/CQA Consultant will perform gradation and thickness testing of the material at the frequency specified in the project specifications. The CQC/CQA Consultant will observe that placement of the material is accomplished in a manner to protect the geomembrane. The

6.5 Erosion Layer (Topsoil) Material

The erosion layer will consist of topsoil placed in accordance with the project specifications. The CQC/CQA Consultant will provide nutrient and thickness testing of the material at the frequency specified in the project specifications. The CQC/CQA Consultant will observe that placement of the material is accomplished in a manner to protect the erosion layer.

6.6 Materials Testing

6.6.1 Test Methods

All testing used to evaluate the suitability or conformance of earthen materials will be carried out in accordance with the project specifications.

6.6.2 Material Testing Requirements

Laboratory CQA conformance tests may be conducted on samples taken at the borrow source, stockpile, and during the course of work prior to construction. Field conformance tests will be conducted by the CQC/CQA Consultant during the course of the work.

The material CQC testing must comply with the minimum frequencies presented in the project specifications.

6.7 Deficiencies

If a defect is discovered in the earthwork product, the CQC/CQA Consultant will immediately determine the extent and nature of the defect and report it to the CQA Consultant. If the defect is indicated by an unsatisfactory test result, the CQC/CQA Consultant will determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the CQA Consultant deems appropriate.

6.7.1 Notification

After determining the extent and nature of a defect, the CQC/CQA Consultant will notify the Project Manager and Contractor and schedule appropriate retests when the work deficiency is corrected.

6.7.2 Repairs and Retesting

The Contractor will correct the deficiency to the satisfaction of the CQC/CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQC/CQA Consultant will develop and present to the CQA Consultant and Project Manager suggested solutions for approval.

All retests recommended by the CQC/CQA Consultant must verify that the defect has been corrected before any additional work is performed by the Contractor in the area of the

deficiency. The CQC/CQA Consultant will verify that all installation requirements are met and that all submittals are provided.

7 Geotextile

7.1 Manufacturing

Compliance testing will be performed by the manufacturer to demonstrate that the product meets the manufacturers' standards and the project specifications. The manufacturer shall submit a package of certifications and the quality control test results to the Contractor. The Contractor shall distribute the package upon receipt to the CQA consultant prior to the installation of any material.

The quality control certificate will be signed by a responsible party employed by the Geosynthetics Manufacturer, such as the production manager.

The CQA Consultant will examine all manufacturer certifications to ensure that the property values listed on the certifications meet or exceed those specified for the particular type of geotextile. Any deviations will be reported to the Project Manager.

The inspection methods, handling techniques, and property values identified in the specifications for the filter geotextile shall also apply to geotextile portion of the geocomposite drainage media.

7.2 Labeling

The Geosynthetics Manufacturer will identify all rolls of geotextile in conformance with the project specifications. The CQA Consultant will examine rolls upon delivery and any deviation from the above requirements will be reported to the Project Manager.

7.3 Shipment and Storage

During shipment and storage, the geotextile will be protected as required by the manufacturer’s recommendations and the project specifications. The CQA Consultant will observe rolls upon delivery at the site and any deviation from the above requirements will be reported to the Project Manager.

7.4 Handling

The Geosynthetics Installer will handle all geotextiles in such a manner as required by the project specifications. Any noncompliance will be noted by the CQA Consultant and reported to the Project Manager.

7.5 Seams and Overlaps

All geotextiles will be seamed or overlapped in accordance with project specifications or as approved by the CQA Consultant and Engineer. The CQA consultant shall walk the material after placement to confirm that the proper methods have been used.

7.6 Repair

Any holes or tears in the geotextile will be repaired in accordance with the project specifications. The CQA Consultant shall observe any repairs and note any noncompliance with the above requirements and shall report them to the Project Manager.

7.7 Exposure

The CQA consultant shall document the placement time of the material and track the exposure time until the material has been covered. Any material that is exposed to UV radiation longer than the time allowed by the project specifications shall be reported to the Project Manager.

8 Surveying

8.1 Introduction

Lacy Surveying will perform the construction surveys for the purposes of record documentation of the project. The Contractor shall provide their own survey team to survey lines and grades on an ongoing basis during construction.

8.2 Goals

The survey component of the work has two major goals, to construct the work per the plans and specifications and to document the completed work for the CQA report.

8.3 Survey Control

Permanent benchmarks and baseline control points have been established at the site and are as indicated in the project drawings. All surveys should note the horizontal and vertical datums used for control.

8.4 Surveying Personnel

The Contractor's survey crew will consist of a senior surveyor and as many assistants as are required to satisfactorily undertake the work. All surveying personnel will be experienced in the provision of these services including supplying detailed, accurate documentation.

All record documentation surveying will be performed under the direct supervision of a licensed land surveyor (PLS) licensed in the state in which the project is located.

8.5 Precision and Accuracy

A wide variety of survey equipment is available to meet the requirements of this project. The survey instruments used for this work should be sufficiently precise and accurate to meet the needs of the project. All survey instruments should be capable of reading to a precision of 0.01 foot and with a setting accuracy of 20 seconds. (5.6×10^{-3} degrees).

The contour intervals and confidence level of all topographic drawings shall be clearly stated on the drawing and should be appropriate for the tolerances required by the specifications.

8.6 Lines and Grades

The subgrade, top of soil liner with final surfaces shall be surveyed to verify the lines and grades achieved during construction. The survey should at least include the following.

- One or more construction baselines.
- The edges of all surface breaks (ex. toes, crests, ridges and valleys).
- All structures.
- Invert elevation of and location of all HDPE piping at each lateral intersection and endpoint, and at least every 50 feet between the intersections and endpoints.
- Inverts of sumps, manholes and other appurtenances.
- Top/toe of all berms, roads, and channels.
- Location of edge of liner, anchor trenches tie-in seam to adjacent existing liner system (as applicable).
- Major patches of HDPE liner.

Laser planes or GPS systems are highly recommended for achieving the correct lines and grades during construction of each surface.

8.7 Thickness Measurements

Lacy Surveying, as a representative of the Owner, shall obtain top and bottom elevations of the soil liner and other components as required by the project specifications. Thickness verification may be done with a table or by electronic comparison of drawing files. The procedure for obtaining top and bottom elevations of the soil liner shall be agreed to by the CQA Consultant and Engineer prior to construction. The surveyor shall review the survey information with the Contractor to ensure that the survey demonstrates compliance with the project technical specifications. The Contractor is responsible for repair of any areas of non-compliance evidenced by the survey. The CQA Consultant and Contractor shall review the thickness measurements of the soil liner component prior to placement of the geomembrane liner. The CQA consultant should notify the Project Manager of areas the need to be corrected.

8.7.1 Tabular verification

A thickness verification table may be compiled containing the following information for each point.

- Proposed subgrade elevation.
- Actual subgrade elevation.
- Subgrade deviation.
- Proposed soil liner elevation.
- Actual soil liner elevation.
- Soil liner thickness.
- Elevation deviation.
- Proposed cover elevation.
- Actual cover elevation.
- Cover Thickness.

- Cover Elevation deviation.

Any deviations in elevation or thickness outside the tolerances allowed by specification shall be corrected.

8.7.2 Drawing verification

Electronically compare the surfaces for thickness verification. Supply the Engineer and/or the CQA Consultant with electronic files in agreed upon common format for comparison for review. These files may be for all or a portion of the work. The reviewer shall generate a drawing illustrating the areas of noncompliance and provide it to the Contractor for acquisition of additional data points or corrective action.

8.8 Tolerances

Except for liner components where no minus tolerances are acceptable, the following are maximum tolerances for survey points.

- On surfaces: the maximum tolerances shall be 0.25 foot. This tolerance must be set to the record elevation of the surface below it and not the design elevation.

8.9 Documentation

The results from the field surveys will be documented on a set of survey record (as-built) drawings by Lacy Surveying. The Contractor shall certify to the CQA Consultant and Engineer that the results of the survey demonstrates compliance with the contract documents. Sealed surveys depicting the information gathered shall be supplied to the Engineer and CQA Consultant in sufficient quantities. The surveys shall depict the information in a topographic format and illustrate actual data points.

9 Documentation

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

This CQA plan integrates the testing and inspection performed by the CQC Consultant in accordance with the project specifications with the CQA overview and conformance testing performed by the CQA Consultant in accordance with this CQA Plan.

The CQA Consultant will provide the Project Manager with the CQC Consultant's daily and weekly reports including signed descriptive remarks, data sheets, and logs to verify that all CQC monitoring activities have been carried out. The CQA Consultant will also provide the Project Manager with a weekly report summarizing CQA activities and identifying potential quality assurance problems. The CQA Consultant will also maintain a copy of this CQA plan and a complete file of plans, reports, project specifications, checklists, test procedures, daily logs, and other pertinent documents at the job site.

9.1 Recordkeeping

The CQC Consultant's reporting procedures will include preparation of a daily report which, at a minimum, will consist of:

a) field notes, including memoranda of meetings and/or discussions with the Contractor;
b) observation logs and testing data sheets; and
c) construction problem and solution data sheets.

The daily report must be completed at the end of each CQC Consultant's shift, prior to leaving the site. This information will be submitted weekly to and reviewed by the CQA Consultant.

The CQC Consultant's weekly reports must summarize the major events that occurred during that week. Critical problems that occur shall be communicated verbally to the Project Manager or CQA Consultant immediately as well as being included in the weekly reports. The CQC Consultant's weekly report must be submitted to the CQA Consultant no later than the Monday following the week reported.

The CQA Consultant's weekly report must summarize the CQC Consultant's weekly and daily reports, CQA conformance testing activities, construction problems that occurred, and the resolution of construction problems. The CQA Consultant's weekly report should identify all potential or actual compliance problems outstanding. The CQA Consultant's weekly report must be submitted to the Project Manager on the Wednesday following the week reported.

9.1.1 Memorandum of Discussion with CQC Consultant or Geosynthetic Installer

A report will be prepared summarizing each critical discussion between the CQA Consultant and the CQC Consultant or Geosynthetic Installer. At a minimum, the report will include the following information.

- Date, project name, location, and other identification.
- Name of parties to discussion at the time.
- Relevant subject matter or issues.
- Activities planned and schedule.
- Signature of the CQA Consultant.

9.1.2 CQA Observation Logs and Testing Data Sheets

CQA observation logs and conformance testing data sheets will be prepared by the CQA Consultant on a weekly basis. At a minimum, these logs and data sheets will include the following information.

- An identifying sheet number for cross referencing and document control.
- Date, project name, location, and other identifying information.
- Data on weather conditions.
- A scale site plan showing all proposed work areas and test locations.
- Descriptions and locations of ongoing construction.
- Descriptions and specific locations of areas, or units, of work being tested and/or observed and documented.
- Locations where tests and samples were taken.

- A summary of test results.
- Calibrations of test equipment, and actions taken as a result of recalibration.
- Off-site materials received, including quality verification documentation.
- Decisions made regarding acceptance of units of work, and/or corrective actions to be taken in instances of substandard quality.
- The CQA Consultant's signature.

9.1.3 CQA Construction Problem and Solution Data Sheets

CQA sheets describing special construction situations will be cross-referenced with specific CQA observation logs and testing data sheets, and must include the following information, where available.

- An identifying sheet number for cross referencing and document control.
- A detailed description of the situation or deficiency.
- The location and probable cause of the situation or deficiency.
- How and when the situation or deficiency was found or located.
- Documentation of the response to the situation or deficiency.
- Final results of any responses.
- Any measures taken to prevent a similar situation from occurring in the future.
- The signature of the CQA Consultant, and signature of the Project Manager indicating concurrence if required by this CQA Plan.

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

9.2 CQA Photographic Reporting Data Sheets

Photographic reporting data sheets, where used, will be cross-referenced with CQA observation logs and testing data sheets and/or CQA construction problem and solution data sheets. Digital photographs shall be taken at regular intervals during the construction process and in all areas deemed critical.

These photographs will serve as a pictorial record of work progress, problems, and mitigation activities. The file name for the digital photographs will contain the date and a description of the photograph (i.e. 20210712 Liner Installation Cell 1). These records will be presented to the Project Manager upon completion of the project.

In lieu of photographic documentation, digital video may be used to record work progress, problems, and mitigation activities. The Project Manager may require that a portion of the documentation be recorded by photographic means in conjunction with video.

9.3 Design and/or Project Technical Specification Changes

Design and/or project specification changes may be required during construction. In such cases, the CQA Consultant will notify the Project Manager and the Engineer. The Project Manager will then notify the appropriate agency, if necessary.

Design and/or project specification changes will be made only with the written agreement of the Project Manager and the Engineer, and will take the form of an addendum to the project specifications. All design changes shall include a detail (if necessary) and state which detail it replaces in the plans.

9.4 CQA Progress Reports

The CQA Consultant will prepare a summary progress report each week, or at time intervals established at the pre-construction meeting. As a minimum, this report will include the following information.

- A unique identifying sheet number for cross-referencing and document control.
- The date, project name, location, and other identifying information.
- A summary of work activities during progress reporting period.
- A summary of construction situations, deficiencies, and/or defects occurring during the progress reporting period.
- Summary of all test results, failures and retests, and signature of the CQA Consultant.
- A schedule update including projection of major milestone dates.

9.5 Signature and Final Report

At the completion of each major construction activity at the structural fill unit, the CQA Consultant will certify all required forms, observation logs, field and laboratory testing data sheets including sample location plans, construction problems and solution data sheets. The CQA Consultant will also provide a final report which will certify that the work has been performed in compliance with the plans and project technical specifications, and that the supporting documents provide the necessary information.

The CQA Consultant will also provide summaries of all the data listed above with the report. The Record Drawings will include scale drawings depicting the location of the construction and details pertaining to the extent of construction (e.g., depths, plan dimensions, elevations, soil component thicknesses, etc.). All surveying and base maps required for development of the record drawings will be done by the construction surveyor. These documents will be certified by the Contractor and CQC Consultant and delivered to the CQA Consultant and included as part of the CQA documentation (Certification) report.

It may be necessary to prepare interim certifications, as allowed by the regulatory agency to expedite completion and review.

9.6 Storage of Records

All handwritten data sheet originals, especially those containing signatures, will be stored by the Project Manager in a safe repository on site. Other reports may be stored by any standard method which will allow for easy access. All written documents will become property of the Owner.