Attachment 2 - Specification KIF-0-TS-02622

ATTACHMENT 2 TO KINGSTON FOSSIL PLANT DREDGE CELL LATERAL EXPANSION QA/QC PLAN

SPECIFICATION KIF-0-TS-02622

REVISION 0

FOR

GEOCOMPOSITE DRAINAGE LAYER CONSTRUCTION QUALITY ASSURANCE

SECTION JOHN-0-TS-02622

GEOCOMPOSITE CONSTRUCTION QUALITY ASSURANCE

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GEOCOMPOSITE DRAINAGE LAYER CONSTRUCTION QUALITY ASSURANCE

1.0 GEOCOMPOSITES

See Specification 02621 for installation requirements for geocomposite drainage layer.

1.1 MANUFACTURING

The Geocomposite Manufacturer shall provide the Construction Manager with a list of guaranteed properties for the type of geocomposite to be supplied. The Geocomposite Manufacturer shall provide the Construction Manager with a written certification signed by a responsible party that the geocomposite actually delivered have properties that meet or exceed the guaranteed properties. In addition, the manufacturer shall perform the testing required by Table 2 and submit the results along with the delivery of the materials. Also, the manufacturer for the specified geocomposite shall submit for approval a MQA/MQC Plan prior to supplying any geocomposite.

The CQA Consultant will examine all of the manufacturer's certifications and test results to ensure that the property values listed on the certifications meet or exceed those specified. Any deviations will be reported to the Construction Manager.

1.2 LABELING

The Geocomposite Manufacturer shall identify all rolls of geocomposite with at least the following information:

a. Manufacturer's name.

b. Product identification.

c. Lot number.

d. Roll number.

e. Roll dimensions.

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

1.3 SHIPMENT AND STORAGE

Geocomposite cleanliness is essential to their performance and geocomposite rolls shall be wrapped in polyethylene sheets or otherwise protected against dust and dirt during shipping and storage.

The wrapping shall be removed less than one hour before placement. The CQA Consultant will verify that geocomposites are free of dirt and dust just before installation. The CQA Consultant will report the outcome of this verification to the Construction Manager, and if the geocomposites are judged dirty or dusty, they shall be washed by the Installer prior to installation.

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The CQA Consultant will observe washing operations and improper washing operations will be reported to the Construction Manager.

1.4 CONFORMANCE TESTING

1.4.1 Tests

Upon delivery of the rolls of geocomposite, the CQA Consultant will ensure that samples are removed and forwarded to the Geosynthetic CQA Laboratory for testing, at the frequency indicated on Table 3, to ensure sufficient conformance to both the Specifications and the list of guaranteed properties.

1.4.2 Sampling Procedures

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

1.4.3 Test Results

The CQA Consultant will examine all results from laboratory conformance testing and will report any nonconformance to the Construction Manager. The minimum standards for the geocomposite are provided in the construction specifications.

1.4.4 Conformance Test Failure

The following procedure will apply whenever a sample fails a conformance test that is conducted by the Geosynthetics CQA Laboratory.

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

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

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

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

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

1.5 HANDLING AND PLACEMENT

The Installer shall handle all geocomposites in such a manner as to ensure they are not damaged and shall comply with the following requirements:

a. On slopes, the geocomposites shall be secured in the anchor trench and then rolled down the slope in such a manner as to continually keep the geocomposite sheet in tension. If necessary, the geocomposite shall be positioned by hand after being unrolled to minimize wrinkles.

b. In the presence of wind, all geocomposites shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during placement and shall remain until replaced with overlying material.

c. Unless otherwise specified, geonet shall not be welded to geomembranes. Geonet shall be heat-bonded by the manufacturer to the geotextiles where indicated on the construction Drawings. No burn through geotextiles shall be permitted. No glue or adhesive shall be permitted.

d. The Installer shall take any necessary precautions to prevent damage to the underlying layers during placement of the geocomposite.

e. During placement of geocomposites, care shall be taken not to entrap in the geonet dirt or excessive dust that could cause clogging of the system, and/or stones that could damage the geomembrane. If dirt or excessive dust is entrapped in the geonet, it shall be hosed clean prior to placement of the next material on top of it. In this regard, care shall be taken with the handling of sandbags to prevent rupture or damage of the sandbag.

The CQA Consultant will note any non-compliance and report it to the Construction Manager.

1.6 JOINING

Adjacent geocomposites shall be joined according to the construction Drawings and specifications. As a minimum, the following requirements shall be met:

a. The geonet shall be placed with the long dimension parallel with the slope direction (up and down the slope, not sideways).

b. Adjacent roll edges of geonets shall be overlapped a minimum of 3-inches. The roll ends of geonets shall be overlapped a minimum of 6-inches.

c. All overlaps shall be joined by tying with plastic fasteners or polymeric braid. Metallic ties or fasteners are not allowed.

d. Tying devices shall be white or yellow, as contrasted to the black geonet, for ease of visual inspection.

e. Tie intervals along the roll edges shall be every 5-feet. Tie intervals along the roll ends and in anchor trenches shall be every 6-inches.

f. Where the geonet is bonded to geotextile(s), edges shall be seamed in accordance with the above requirements and item g. Where the geonet is bonded to geotextile(s), ends shall be seamed in accordance with the above requirements, and a geotextile cap shall be heat-bonded over the completed seam. The geotextile cap shall cover the open end of the geonet, the ties, and at least 6 inches of geotextile beyond the ties or geonet end. Heat bonding shall be performed with the utmost of care to prevent damage to any portion of the liner system. No burn through the geotextiles shall be permitted.

g. All geotextiles (top layer of geocomposite) shall be continuously sewn together with a single lock-type stitch seam. The Installer shall pay particular attention at seams to ensure that no protective cover material could inadvertently inserted beneath the geotextiles. Sewing shall be done using polymeric thread.

The CQA Consultant will note any non-compliance and report it to the Construction Manager.

1.7 REPAIR

Any holes or tears in the geocomposite shall be repaired by placing a patch extending 2 ft. beyond edges of the hole or tear. The patch shall be secured to the original geonet by tying every 6 in. If the hole or tear width across the roll is more than 50% the width of the roll, the damaged area shall be cut out and the two portions of the geonet shall be joined.

Where the geonet is bonded to geotextile(s), any holes or tears in the geonet shall be repaired by removing and replacing the damaged section of geocomposite across the full width of the roll.

Where the geonet is bonded to geotextile(s), any holes or tears in the geotextile up to 18 inches in diameter shall be repaired with a patch of the same geotextile. The patch shall be a minimum of 6 inches larger in all directions than the damaged area. The patch shall be heat bonded in place. Heat bonding shall be performed with the utmost of care to prevent damage to any portion of the liner system. No burn through the geotextiles will be permitted. Any holes or tears in the geotextile that are larger than 18 inches in any dimension shall be repaired by removing and replacing the damaged section of geocomposite across the full width of the roll. The CQA Consultant will observe any repair, note any non-compliance with the above requirements and report them to the Construction Manager.

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TABLE 1 – GEOCOMPOSITE MATERIAL REQUIREMENTS			
Characteristics	**Test Method**	**Units**	**Criteria (MARV)**
Resin			
Polymer Density	ASTM D 1505	g/cm^3	0.94
Melt Flow Index	ASTM D 1238	g/10 min	≤1.0
Geonet Test			
Carbon Black	ASTM D 1603	%	2.0
Tensile Strength, MD	ASTM D 5035	lbs/ ft	45
Density	ASTM D 1505	g/cm^3	0.94
Thickness	ASTM D 5199	mil	200
Geotextile Tests			
Mass per Unit Area	ASTM D 5261	oz/yd^2	6.0
Grab Tensile	ASTM D 4632	lbs.	170
Puncture	ASTM D 4833	lbs.	90
AOS, US Sieve	ASTM D 4751	mm	70
Water Flow Rate	ASTM D 4491	gpm/ft^2	110
UV Resistance	ASTM D 4355 (after 500 hours)	% retained	70
Geocomposite Tests			
Ply Adhesion	GRI GC-7	lbs/ in.	1.0
Transmissivity*	ASTM D 4716-00	m^2/sec	1×10^{-4}
Interface Friction Testing	ASTM D5321	degrees	22^0 and 24^0 (Residual)

TABLE 2 – MANUFACTURING QUALITY CONTROL TEST FREQUENCIES			
Characteristics	**Test Method**		**FREQUENCY**
Resin			
Polymer Density	ASTM D 1505		Once Per Lot
Melt Flow Index	ASTM D 1238		Once Per Lot
Geonet Test			
Carbon Black	ASTM D 1603		1/50,000 ft^2
Tensile Strength, MD	ASTM D 5035		1/50,000 ft^2
Density	ASTM D 1505		1/50,000 ft^2
Thickness	ASTM D 5199		1/50,000 ft^2
Geotextile Tests			
Mass per Unit Area	ASTM D 5261		1/90,000 ft^2
Grab Tensile	ASTM D 4632		1/90,000 ft^2
Puncture	ASTM D 4833		1/90,000 ft^2
AOS, US Sieve	ASTM D 4751		1/540,000 ft^2
Water Flow Rate	ASTM D 4491		1/540,000 ft^2
UV Resistance	ASTM D 4355 (after 500 hours)		Once per resin formulation
Geocomposite Tests			
Ply Adhesion	GRI GC-7		1/50,000 ft^2
Transmissivity	ASTM D 4716-00		1/540,000 ft^2

TABLE 3 - CQA TESTING FREQUENCY FOR GEOCOMPOSITES

PROPERTY	TEST METHOD	ACCEPTANCE CRITERIA (MINIMUM)	FREQUENCY
Resin Density, g/cm^3	ASTM D 1505	0.94	Every 80,000 $ft.^2$
Thickness, inch	ASTM D 5199	0.20	Every 80,000 $ft.^2$
Tensile Strength, lb./in.	ASTM D 5035	45	Every 80,000 $ft.^2$
Ply Adhesion, lb./in	GRI GC-7	1.0	Every 80,000 $ft.^2$
Interface Friction testing	ASTM D 5321	22^0 and 24^0 (Residual)	Two tests for each interface

END

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Attachment 3 – Fly and Bottom Ash Compaction Procedure

SUGGESTED PROCEDURE
DETERMINATION OF MOISTURE COMPACTION WINDOW FOR BOTTOM ASH AND FLYASH

1) Determine current, as-received moisture of material.

2) Run a Proctor point at 80% of Proctor Energy (20 blows/layer at 3 layers in 4-inch mold).

3) Determine density (wet and dry).

4) Evaluate compaction.

Wet Side

a) look for pumping
b) look for bleeding water
c) typically, the hammer sticks to the material if it is too wet

Dry Side

a) look for "fluffing" (i.e. non-compaction)
b) look at hammer penetration (i.e. deep penetration indicates energy absorption without compaction)
c) look for dust fluffs

5) Plot moisture vs density and correlate with observations to develop a moisture window.

APPENDIX J

Specifications for Placement of Geosynthetics

SPECIFICATION KIF-0-TS-02621

REVISION 0

FOR

GEOCOMPOSITE DRAINAGE LAYER

SECTION JOHN-0-TS-02621

GEOCOMPOSITE DRAINAGE LAYER

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PART 1 - GENERAL

1.1 SECTION INCLUDES

A. This Section covers technical requirements for furnishing and installing the geocomposite drainage layer.

B. This Section includes the following:

1. Geocomposite panel layout.

2. Furnishing and installing geocomposite.

3. Supervision of geocomposite installation by liner manufacturer's representative.

4. Construction of fill to be placed on geocomposite.

5. Submittal of data per Table 02621-1.

1.2 CODES AND STANDARDS

A. The latest edition and published addenda of the following publications in effect on the date of Contract Award are a part of this Section and, where referred to by title or by basic designation only, are applicable to the extent indicated by the specific reference:

1. American Society for Testing and Materials (ASTM):

a. D 1505, "Standard Test Method for Density of Plastics by the Density-Gradient Technique."

b. D 1603, "Standard Test Method for Carbon Black in Olefin Plastics."

c. D 4355, "Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus."

d. D 4491, "Standard Test Method for Water Permeability of Geotextiles by Permittivity."

e. D 4716, "Standard Test Method for Determining the (In-Plane) Flow Rate Per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head."

f. D 4751, "Standard Test Method for Determining Apparent Opening Size of a Geotextile."

g. D 4833, "Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products."

h. D 5035, "Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method)."

i. D 5199, "Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes."

j. D 5261, "Standard Test Method for Measuring the Mass per Unit Area of Geotextiles."

k. D 5321, "Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method."

2. Geosynthetic Research Institute (GRI), GC-7, "Determination of Adhesion and Bond Strength of Geocomposites."

B. Where the above referenced codes and standards contain recommendations in addition to requirements, the recommendations shall be considered requirements and shall be followed unless stated otherwise by this technical specification Section.

C. In the event of any conflict between codes, or Technical Specifications and codes, the more stringent regulation shall apply.

1.3 SUBMITTALS

Submittals shall be as required in Table 02621-1.

1.4 PACKAGING AND DELIVERY

All geocomposites shall be covered during shipment. The geocomposite shall be supplied in rolls, labeled with at least the following information:

Manufacturer's Name

Product Identification

Roll Number

Roll Weight

Roll Dimensions

Date of Manufacture

Geotextile Types

Geotextile Bonding

1.5 HANDLING, STORAGE, AND PROTECTION

A. The geocomposite rolls shall be stored on pallets in a secured area, away from dirt, dust, water, and extreme heat. The storage space shall be protected from theft, vandalism, animals, passage of vehicles, and be adjacent to the area to be lined. Stack geocomposite drainage layer material to a height not exceeding four (4) rolls high. The Contractor

shall be responsible for unloading and storing the geocomposite in accordance with the manufacturer's recommendations.

B. Upon arrival at the jobsite, the installer shall conduct a surface inspection of all rolls for defects and damage. This inspection shall be conducted without unrolling or unpacking unless defects or damages are found or suspected. The Contractor shall notify the Owner of any defects or damages.

PART 2 – PRODUCTS

2.1 MATERIALS

A. Manufacturer Requirements

1. The manufacturer of the geocomposite materials shall have had at least 10,000,000 square feet of its material installed for drainage and shall be approved by the Owner.

2. The geocomposite installation shall be performed under the supervision of the manufacturer's field representative or an installer approved by the manufacturer. The method of installation shall be approved by the manufacturer and authorized in writing, and submitted for approval before work begins to ensure that all warranties remain valid.

B. General Requirements

1. Geonet shall be manufactured by extruding two sets of polyethylene strands to form a three dimensional structure to provide planer water flow.

2. The geonet shall contain stabilizers to prevent ultraviolet light degradation.

3. The drainage layer shall be provided as a geocomposite manufactured by heat bonding 6 oz/yd^2 nonwoven geotextiles (both top and bottom) to the geonet. The bond shall be continuous with no unbonded areas. No burn through the geotextiles will be permitted. Glue and adhesives shall not be used.Geocomposite shall be FabriNet as manufactured by GSE Lining Technology, Inc. or approved equivalent. The geocomposite shall meet the following properties:

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Characteristics	Test Method	Units	Criteria (MARV)
Resin			
Polymer Density	ASTM D 1505	g/cm^3	0.94
Melt Flow Index	ASTM D 1238	g/10 min	≤1.0
Geonet Test			
Carbon Black	ASTM D 1603	%	2.0
Tensile Strength, MD	ASTM D 5035	lbs/ ft	45
Density	ASTM D 1505	g/cm^3	0.94
Thickness	ASTM D 5199	mil	200
Geotextile Tests			
Mass per Unit Area	ASTM D 5261	oz/yd^2	6.0
Grab Tensile	ASTM D 4632	lbs.	170
Puncture	ASTM D 4833	lbs.	90
AOS, US Sieve	ASTM D 4751	mm	70
Water Flow Rate	ASTM D 4491	gpm/ft^2	110
UV Resistance	ASTM D 4355 (after 500 hours)	% retained	70
Geocomposite Tests			
Ply Adhesion	GRI GC-7	lbs/ in.	1.0
Transmissivity*	ASTM D 4716-00	m^2/sec	1×10^{-4}
Interface-Friction Tests			
Geocomposite/ Cover Soil	ASTM D 5321	degrees	22 (Residual)
Geocomposite/Geomemeb.	ASTM D 5321	degrees	24 (Residual)

*Water at 20° C with a gradient of 0.1 and a load of 10,000 psf between two steel plates for 15 min.

4. Where required on the drawings, geocomposite manufactured with the bottom (ash side) having a woven calendered geotextile heat bonded to the geonet. The upper geotextile shall be a nonwoven geotextile per No. 3 above.

C. Manufacturing Quality Control

1. The geocomposite shall be manufactured in accordance with the Manufacturer's Quality Control Plan submitted to and approved by the Owner.

2. The geocomposite shall be tested according to the test methods and frequencies listed below:

Manufacturing Quality Control Test Frequencies			
Characteristics	**Test Method**		**FREQUENCY**
Resin			
Polymer Density	ASTM D 1505		Once Per Lot
Melt Flow Index	ASTM D 1238		Once Per Lot
Geonet Test			
Carbon Black	ASTM D 1603		1/50,000 ft^2
Tensile Strength, MD	ASTM D 5035		1/50,000 ft^2
Density	ASTM D 1505		1/50,000 ft^2
Thickness	ASTM D 5199		1/50,000 ft^2
Geotextile Tests			
Mass per Unit Area	ASTM D 5261		1/90,000 ft^2
Grab Tensile	ASTM D 4632		1/90,000 ft^2
Puncture	ASTM D 4833		1/90,000 ft^2
AOS, US Sieve	ASTM D 4751		1/540,000 ft^2
Water Flow Rate	ASTM D 4491		1/540,000 ft^2
UV Resistance	ASTM D 4355 (after 500 hours)		Once per resin formulation
Geocomposite Tests			
Ply Adhesion	GRI GC-7		1/50,000 ft^2
Transmissivity	ASTM D 4716-00		1/540,000 ft^2
Interface-Friction Tests*			
Geocomposite/ Cover Soil	ASTM D 5321		two tests
Geocomposite/Geomemb.	ASTM D 5321		two tests

* See NOTE under Table 02621-1 herein.

PART 3 – EXECUTION

3.1 INSTALLER REQUIREMENTS

A. An installer that has previously installed a minimum of 2,000,000 square feet of geocomposite shall perform the installation.

B. The installer's or manufacturer's field representative shall be in attendance full time during the GCL installation.

C. The GCL installer's or manufacturer's field representative shall certify in writing that all materials and shop drawings regarding panel placement, and construction techniques are

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in compliance with the manufacturer's recommendations and other accepted QA/QC procedures.

3.2 GEOCOMPOSITE DRAINAGE LAYER INSTALLATION

A. General Requirements:

1. The Contractor shall be responsible for the design of the geocomposite panel layout. Panels shall be placed with seams running up and down slopes, not horizontally.

2. The fabricator of the geocomposite panels used in the work shall prepare shop drawings with a proposed panel layout to cover the area shown on the Drawings. These drawings shall be submitted for approval prior to fabrication of the geocomposite. The drawings shall be provided in a reproducible hard copy or electronic format.

3. Written specifications for the manufacture, fabrication, installation, and quality assurance/quality control for the geocomposite shall be approved by the Owner prior to start of liner fabrication.

B. Installation Requirements:

1. The geocomposite shall be placed with the long dimension parallel with the slope direction (up and down the slope, not sideways).

2. For long, steep slopes, special care shall be taken so that only full-length rolls are used at the top of the slope.

3. Adjacent roll edges of geocomposite shall be overlapped a minimum of 3-inches. The roll ends of geonets shall be overlapped a minimum of 6-inches.

4. All overlaps shall be joined by tying with plastic fasteners or polymeric braid. Metallic ties or fasteners are not allowed.

5. Tying devices shall be white or yellow, as contrasted to the black geonet, for ease of visual inspection.

6. Tie intervals along the roll edges shall be every 5-feet. Tie intervals along the roll ends shall be every 6-inches.

7. The geocomposite edges shall be seamed in accordance with the above requirements and sewn together. Roll ends shall be seamed in accordance with the above requirements and a geotextile cap shall be heat-bonded over the completed seam. The geotextile cap shall cover the open end of the geonet, the ties, and at least 6 inches of geotextile beyond the ties or geonet end. Heat bonding shall be performed with the utmost of care to prevent damage to any portion of the liner system. No burn through the geotextiles will be permitted.

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8. The geocomposite shall be protected at all times during construction from contamination resulting from surface runoff. Any geocomposite so contaminated or otherwise damaged shall be removed and replaced.

9. In the presence of wind, all geocomposites shall be weighted down with sandbags or the equivalent. Such sandbags shall be used during placement and remain until replaced with cover material.

10. The geocomposite shall be properly anchored in the anchor trench to resist sliding. Anchor trench compaction equipment shall not come into contact with the geocomposite.

11. Install anchor trench in accordance with Specification 02778, LLDPE Geomembrane Construction Quality Assurance (Attachment 2 to QA/QC Plan).

3.3 COVER PLACEMENT

A. Cover soils shall be free of angular stones or other foreign matter, which could damage the geocomposite. Cover soils shall be approved by the Owner with respect to particle size, uniformity and chemical compatibility.

B. Soil cover shall be placed over the geocomposite using construction equipment that minimizes stresses on the geocomposite. A minimum of 1 foot of cover shall be maintained between the equipment tires/tracks and the geocomposite at all times during the covering process. This thickness recommendation does not apply to frequently trafficked areas or roadways, for which a minimum thickness of 2 feet shall be required.

C. Soil cover shall be placed in a manner that prevents the soil from entering the geocomposite overlap zones. Cover soil shall be pushed up slopes, not down slopes, to minimize tensile forces on the geocomposite.

D. Although direct vehicular contact with the geocomposite is to be avoided, lightweight, low ground pressure vehicles (such as 4-wheel, all-terrain vehicles) may be used to facilitate the initial placement of cover soil. The geocomposite supplier shall be contacted with specific recommendations on the appropriate procedures in this situation.

3.4 REPAIR

A. Prior to covering the deployed geocomposite, each roll shall be inspected for damage resulting from construction.

B. Any rips, tears or damaged areas on the deployed geocomposite shall be removed and patched. The patch shall be secured to the original geonet by tying every 6 inches with the approved tying devices. If the area to be repaired is more than 50 percent of the width of the panel, the damaged area shall be cut out and the two portions of the geocomposite shall be cut out and the two portions of the geocomposite shall be joined together in accordance with Section 3.3.

3.5 INTERFACE-FRICTION TESTING

TVA-00002278

A. Laboratory interface friction testing on the geocomposite/cover-soil and geocomposite/geomembrane interfaces shall be performed in accordance with ASTM D5321. Testing shall be performed with representative samples of geocomposite, geomembrane and Random Fill soil that will be compacted to 90% standard Proctor maximum dry density and used for construction of the final cover. For the geocomposite/cover-soil test, the substratum shall be the top surface of the geocomposite and the superstratum shall be the cover soil. For the geocomposite/geomembrane test, the superstratum shall be the geocomposite bottom surface and the substratum shall be the geomembrane top surface. A normal-stress range 0.1 tsf to 1.0 tsf shall be used. The compacted soil sample shall be saturated with water and both the geocomposite and geomembrane surfaces shall be wetted prior to shearing during the test. Both peak and residual shear stresses under each normal stress shall be recorded and friction angle interpreted separately for both peak and residual shear strength.

B The report for the testing shall consist, at a minimum, of sample size, sample origin, sample lot number, illustration of equipment used, summary of test methods employed, strain rate used during shear, shear stress-versus-displacement, normal stress-versus-peak stress and residual stress, peak and residual strength envelope plots. All stress versus displacement tests and all calculations performed to determine the angles of friction shall be corrected for machine resistance.

TABLE 02621-1 - DATA REQUIREMENTS AND SUBMITTAL SCHEDULE

Paragraph - Submittal Requirements		With Proposal	For Approval		For Record	
			Date	Copies	Date	Copies
All	Alternative Materials or Procedures	Yes	-	-	-	-
2.1 A	Manufacturer & Specification Sheet	Yes	-	-	-	-
2.1 B	Material Certification	No	2 Weeks prior to delivery	3	-	-
2.1 C	Manufacturing QC Testing	No	-	-	With delivery of rolls	3
3.1 A	Geocomposite Manufacturer's Experience	Yes	-	-	-	-
3.2 A	Manufacturer's Representative and Installation Requirements	No	2 Weeks prior to delivery	3	-	-
3.2 A	Shop Drawings for Geocomposite Installation	No	2 Weeks prior to Work	3 Prints	-	-
3.1 C	Final Documentation	No	-	-	Within 2 weeks after Work	3 Prints
3.5	Interface Friction Testing	No	*	-	-	-

* NOTE: Interface-friction testing shall be performed by CQA Consultant and the results will be used for approval prior to procurement. Geocomposite and geomemebrane samples shall be provided by the manufacturer(s) and loose soil sample will be provided by TVA.

END

SPECIFICATION KIF-0-TS-02777

REVISION 0

FOR

LLDPE GEOMEMBRANE LINER

KIF-0-TS-02777-R0

LLDPE GEOMEMBRANE LINER

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LIST OF TABLES

1.0 PART 1 – GENERAL

1.1 SECTION INCLUDES

This section includes technical requirements for furnishing and installing the geomembrane liner. The geomembrane liner shall be textured Linear Low Density Polyethylene (LLDPE). This section includes the following:

A. Submittals.

B. Geomembrane liner panel layout.

C. Material conformance testing.

D. Furnishing, installing, sampling, testing, and repairing geomembrane liner and seams, and other incidental items required for installation.

1.2 REFERENCES

A. The latest edition and published addenda of the following publications in effect on the date of the Contract Award are a part of this Section and, where referred to by title or by basic designation only, are applicable to the extent indicated by the specific reference:

1. American Society for Testing and Materials (ASTM):

a. D 1004, "Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting."

b. D 1204, "Standard Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature."

c. D 1238, "Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer."

d. D 1505, "Standard Test Method for Density of Plastics by the Density-Gradient Technique."

e. D 3895, "Standard Test Method for Oxidative-Induction Time of Polyolefin by Differential Scanning Calorimetry."

f. D 4218, "Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique."

g. D 4833, "Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products."

h. D 5199, "Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes."

i. D 5321, "Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear

Method."

j. D 5397, "Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Tests."

k. D 5596, "Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black Polyolefin Geosynthetics."

l. D 5641, "Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber."

m. D 5820, "Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes."

n. D 5994, "Standard Test Method for Measuring Core Thickness of Textured Geomembranes."

m. D 6365, "Standard Practice for the Nondestructive Testing of Geomembrane Seams using the Spark Test."

o. D 6392, "Standard Test Method for Determining the Integrity of Non-Reinforced Geomembrane Seams Using Thermo-Fusion Methods."

p. D 6693, "Standard Test Method for Determining Tensile Properties of Non-Reinforced Polyethylene and Non-Reinforced Flexible Polypropylene Geomembranes."

2. Geosynthetic Research Institute (GRI), GM12, "Asperity Measurement of Textured Geomembranes Using a Depth Gauge."

3. United States Environmental Protection Agency (EPA) Method 9090 "Compatibility Test for Wastes and Membrane Liners."

B. Where the above referenced codes and standards contain recommendations in addition to requirements, the recommendations shall be considered requirements and shall be followed unless stated otherwise by this technical specification Section.

C. In the event of any conflict between codes, manufacturer's recommendations, or Technical Specifications and codes, the more stringent regulation shall apply.

1.3 SUBMITTALS

A. Data requirements and submittal schedule are as shown in Table 1.

B. Within two (2) weeks of project completion, the Contractor shall submit a report to the Project Manager. The report shall include at least the following items:

1. ALL manufacturer certifications and testing

2. ALL conformance, installation, sampling, laboratory and field testing records for the entire project as described herein.

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3. ALL information addressed in Table 1.

4. The signed warranty

5. Written certification that the liner has been installed in accordance with the Specifications and Drawings.

1.4 DESIGN REQUIREMENTS

A. The Contractor shall prepare shop drawings with the proposed panel and seam layout and shop details of the pipe connections. These drawings shall be submitted for approval prior to fabrication of the liner. The drawings shall be provided in both hardcopy and .pdf format at a minimum scale of 1"= 20'.

B. Written specifications for the manufacture, fabrication, installation, and QA/QC for the geomembrane liner shall be submitted to the Project Manager and approved by the Engineer prior to installation of the liner.

1.5 MARKING AND IDENTIFICATION

Each shipping roll or pallet shall be identified properly with the name of manufacturer, product type and thickness, manufacturer batch code, date of manufacture, physical dimensions, panel number, and directions for unfolding.

1.6 PACKAGING AND DELIVERY

All geomembrane liners shall be covered during shipment.

1.7 HANDLING, STORING, AND PROTECTION

The geomembrane liner panels shall be stored on pallets in a secured area, away from dirt, dust, water, and extreme heat. Rolls of panels shall not be stacked more than four (4) high. The storage space shall be protected from theft, vandalism, animals, passage of vehicles, and be adjacent to the area to be lined. The Contractor shall be responsible for unloading and storing the geomembrane liner.

2.0 PART 2 – PRODUCTS

2.1 MATERIAL REQUIREMENTS

A. GENERAL REQUIREMENTS

1. Liner compound shall be specifically designed for buried and for hydraulic liner installations and be chemically compatible with the anticipated water. The liner shall have been demonstrated by prior use to be suitable and durable for such purposes.

2. The liner shall be produced so as to be free of holes, undispersed raw materials, blisters, or any sign of delamination. Any such defect shall be repaired in accordance with the manufacturer's recommendations and/or Article 3.2.G.

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3. The lining material shall be uniform in color, thickness, and size. The liner shall be white to minimize elongation during sunny weather.

4. The liner accessories shall be obtained from manufacturers who have shown their materials to be compatible with the intended use and durability criteria, as well as chemically compatible with the anticipated water.

5. The Contractor shall submit with the proposal the name of the LLDPE liner manufacturer and indicate that the material meets the physical properties as specified herein.

6. Prior to geomembrane liner fabrication, the Contractor shall provide material certification from the liner manufacturer that its liner meets the physical and chemical requirements specified herein. Liner chemical compatibility with the water shall be based on EPA Method 9090 or other documented data.

B. LINEAR LOW DENSITY POLYETHYLENE (LLDPE) GEOMEMBRANE LINER

1. The raw materials for Linear Low Density Polyethylene (LLDPE) Liner manufacture shall be first quality resins containing no more than 2% clean recycled polymer by weight and a maximum of 1% by weight of additives, extenders, and fillers (not including carbon black).

2. The liner shall consist of 40 mil-thick LLDPE, textured similarly on both top and bottom surfaces..

3. The LLDPE lining material shall be manufactured with a minimum 15-ft seamless width. There shall be no factory seams.

4. The LLDPE liner material shall meet the physical property characteristics listed in Table 2. All values are minimum average roll values, unless noted otherwise.

C. CAULK:

Caulk shall be Sika Flex 1A, as manufactured by Sika Corporation or approved equal.

D. MANUFACTURER REQUIRMENTS:

1. The manufacturer of the lining material shall have had at least 10,000,000 square feet of its material installed for linings and shall be approved by the Engineer.

2. The manufacturer shall guarantee in writing that the liner materials and field seam materials will be free of defects for 20 years after delivery to the liner installation location. The workmanship shall be guaranteed for one (1) year.

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3.0 PART 3 – EXECUTION

3.1 INSPECTION AND PREPARATION

A. VISUAL INSPECTION

Upon arrival at the jobsite, the Contractor shall conduct a surface inspection of all rolls or pallets for defects and damage. This inspection shall be conducted without unrolling or unpacking unless defects or damages are found or suspected.

B. CONFORMANCE TESTING

Conformance testing will be performed in accordance with the "Geomembrane Construction Quality Assurance" specification.

3.2 INSTALLATION REQUIREMENTS

A. Contractor REQUIREMENTS

1. The full-time supervisor overseeing the LLDPE liner installation shall have 2,000,000 square feet of supervisory liner experience. All field technicians shall have over 1,000,000 square feet of seaming experience.

2. The full-time supervisor shall be certified by the manufacturer. Alternatively, a manufacturer's representative shall be in attendance full-time during the geomembrane liner installation.

3. The supervisor or manufacturer's field representative shall certify in writing that all materials and shop drawings regarding panel placement, seaming locations, and construction techniques are in compliance with the manufacturer's recommendations and other accepted QA/QC procedures and that all field seams are free of defects.

B. GENERAL REQUIREMENTS

1. The Contractor shall inspect the complete subgrade prior to installation of the liner assembly and submit to the Project Manager in writing, prior to commencement of the liner installation, acceptance of the subbase preparation.

2. The Contractor shall be responsible for the field layout of the geomembrane liner panels. Panels shall be placed with seams running up and down slopes, not horizontally.

3. The Contractor shall label each field panel with an "identification code" (number or letter-number) consistent with the layout plan. Each panel shall be marked with the original roll number, and a table or chart showing correspondence between roll numbers and field panel identification codes shall be established by the Contractor. The field panel identification code shall be used for all QA/QC records.

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C. LINER INSTALLATION REQUIREMENTS

1. The geomembrane liner shall be placed over the prepared surface to be lined in such a manner as to insure minimum handling and shall be installed in accordance with the manufacturer's recommendations. The prepared subgrade shall be maintained in a smooth, uniform, and compacted condition during installation.

2. The liner shall be installed in a relaxed condition and shall be free of tension and stress upon completion of the installation. The liner shall not be stretched to fit. The liner shall be spread out so there are no folds or bends in the liner.

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

4. Materials, equipment, or other items shall not be dragged across the surface of the liner or be allowed to slide down slopes on the lining. Personnel walking upon the lining material shall wear soft-sole shoes. Any portion of the liner damaged during installation by any cause shall be removed or repaired by using an additional piece of liner.

5. The amount of liner placed shall be limited to that which can be seamed on the same day.

6. Repair of damaged liner panels and test strip removal areas shall conform to the manufacturer's recommendations. Any tear, puncture, obvious stress point, seam failure, or hole created by sampling or testing procedures shall be overlaid with liner material of the same type used for liner panel fabrication and seamed as specified herein. No loose panel edges, bubbles, or wrinkles will be permitted in the patches. Each patch seam shall be tested as specified herein.

7. Install anchor trench in accordance with Specification 02778, LLDPE Geomembrane Construction Quality Assurance (Attachment 2 to QA/QC Plan).

D. FIELD SEAMING REQUIREMENTS

1. General Requirements:

   a. The seam area shall be clean and free of moisture, dust, dirt, oils, greases, foreign material, and debris of any kind.

   b. No "fish mouths" shall be allowed within the seam area. Where "fish mouths" do occur, the material shall be cut, lapped, seamed together in the lapped area, and patched in accordance with the manufacturer's requirements.

   c. Seam areas of panels shall be wiped clean to remove all dirt, moisture, or other foreign material in accordance with the material manufacturer's requirements.

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d. Individual panels of liner material shall be laid out and overlapped by a minimum of four inches for both double fusion welding (hot wedge weld) and extrusion welding. Typically, all sheeting shall be welded together using the hot wedge welding assembly, except for the areas where this method is not practical. For extrusion welding all sheeting shall be welded together by means of integration of the extrudate bead with the lining material. The composition of the extrudate shall be identical to the lining material.

2. Equipment Requirements:

The welding equipment used shall be capable of continuously monitoring and controlling the temperatures in the zone of contact where the machine is actually fusing the lining material so as to ensure that changes in the environmental conditions will not affect the integrity of the weld.

3. Weather Conditions for Seaming:

a. No seaming shall be attempted at an ambient temperature below 50°F or above 104°F. Below 50°F, panels shall be warmed artificially with hot air guns, radiant heaters, heat lamps, space heaters, etc.

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

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

d. The ambient temperatures shall be measured above the geomembrane surface. The Contractor shall demonstrate that these weather conditions are fulfilled.

e. Weather conditions at the time of all installation, seaming, sampling, and testing shall be recorded on the respective QA/QC documents.

E. INSPECTION AND TEST REQUIREMENTS

1. Trial Seams

a. Trial seams shall be made on fragment pieces of geomembrane liner to verify that seaming conditions are adequate. Such trial seams shall be made at the beginning of each seaming period, and at least once every five hours, for each seaming apparatus used in the seaming period. A trial seam also shall be made in the event that the ambient temperature varies more than 18°F since the last passing trial seam. Also, each seamer or seamer crew shall make at least one trial seam each seaming

period, or each 1,000 feet of seam. If any seaming apparatus is turned off for any reason, a new passing trial seam shall be completed for that specific seaming apparatus.

b. Trial seams shall be made under the same conditions as actual seams. The trial seam sample shall be at least 3 ft. long by 1 ft. (after seaming) with the seam centered lengthwise.

c. The Contractor shall provide the tensiometer required for shear and peel testing in the field. The tensiometer shall be automatic and shall have a direct digital readout.

d. The tensile strength of the seams shall be greater than the panel tensile strength. The seam failure shall be by Film Tear Bond (FTB) type.

e. Four specimens of field seams shall be taken initially by the Contractor and tested. Two specimens shall be tested in shear and two in peel using a field tensiometer, and they should not fail in the seam. Minimum strength requirements for field seams are provided on Table 2. In each type of test, a maximum of one non-FTB failure out of five tests is acceptable provided that the strength requirement is met on that sample. If a specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus will not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful full trial seams are achieved.

f. All trial seams shall be in accordance with Table 4.

2. Non-destructive Seam Continuity Testing:

a. Non-destructive testing shall be performed on ALL field seams over their full length. Fillet-extrusion welds shall be tested with a vacuum chamber in accordance with ASTM D 5641. Double fusion (hot wedge) welds shall be pressure tested, pressurizing the gap created by the split face design of the hot wedge in accordance with ASTM D 5820. A spark test shall be used for all boots (in accordance with ASTM D 6365). Probe test methods shall not be used. The purpose of non-destructive tests is to check the continuity of seams. It does not provide any information on seam strength. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming. Non-destructive testing shall not be permitted before sunrise or after sunset.

b. The Contractor shall complete any required repairs in accordance with Article 3.2.G.

c. All non-destructive test results for each seam shall be documented.

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3. Destructive Testing

   a. The purpose of destructive testing is to evaluate seam strength. Seam strength testing shall be conducted as the seaming work progresses, not at the completion of all field seaming. Care shall be taken to properly cure all seams and samples according to test procedure requirements.

   b. Destructive testing shall be in accordance with ASTM D 6392 at a minimum frequency of one test per 2,000 feet of seam length. All field seams shall satisfy the requirements of Table 4.

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

   d. The installer shall cut samples as the seaming progresses in order to have laboratory test results before the geomembrane is covered by another material. Sampling shall be in accordance with Article 3.2.F.

   e. The destructive testing for conformance will be the responsibility of the CQA Consultant.

F. SAMPLING PROCEDURE

1. An identification number shall be assigned to each sample. Samples shall be marked accordingly (with the locations recorded on the layout drawing), and the date, ambient temperature, and welding machine number recorded.

2. The reason for the chosen sample location shall be stated (e.g., statistical routine, suspicious feature of the geomembrane).

3. Two types of samples shall be taken at each sample location.

4. The first type of sample shall be 1 in. wide by 12 in. long, with the seam centered parallel to the width. Two of these samples shall be taken at a distance of 42 in. apart. Each sample shall be tested using field tensiometer equipment for peel and shear failure, and shall not fail in the seam.

5. If any field test fails, the procedure outlined in Article 3.2.F.8 shall be followed. If the each test passes, the seam location qualifies for lab testing.

6. The second type of sample (for laboratory testing) shall be located between the two specimens for field testing, provided that the two surrounding field tests pass. The lab sample shall be 12 in wide by 42 in. long with the seam centered lengthwise. The sample shall be cut into three parts. One part (12 in x 12 in) shall be retained by the Contractor for laboratory testing, another part (12 in x 12 in) shall be retained for the Owner for archive storage, and a third part (12 in. x 18 in.) shall be retained for independent laboratory testing by the CQA Consultant.

7. Lab test samples shall meet the requirements set forth in Table 4. The testing lab shall provide test results no more than 24 hours after they receive the

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samples to allow liner installation to be adjusted as required.

8. In the event of any failing test; the Contractor shall do either of the following:

   a. Reconstruct the seam between any two passed destructive seam test locations.

   b. Trace the seam path to an intermediate location (10 ft. minimum each direction) and take small sample for an additional field test. If this test and the subsequent lab tests pass, the seam shall be reconstructed between these locations by capping. If either fails, the process shall be repeated to establish the zone over which the seam shall be reconstructed.

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

G. DEFECTS AND REPAIRS

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

2. Each suspect location both in seam and non-seam areas shall be non-destructively tested using the methods described in Article 3.2.E.2 as appropriate. Each location that fails the non-destructive testing shall be marked and repaired.

3. Any portion of the geomembrane exhibiting a flaw, or failing a destructive or non-destructive test shall be repaired. Several procedures exist for the repair of these areas. The available procedures include:

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

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

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

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

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

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4. In addition, the following provisions shall be satisfied:

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

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

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

   d. The repair procedures, materials, and techniques shall be approved in advance of the specific repair.

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

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

5. Each repair shall be non-destructively tested using the methods described in Article 3.2.E.2 as appropriate. Repairs that pass the non-destructive test will be taken as an indication of an adequate repair. Large caps (over 150 feet) shall require additional destructive testing. Work shall not proceed with any materials that will cover a repaired location until laboratory test results with passing values are available. Failed tests shall require the repair to be redone and retested until a passing test result is obtained.

H. LINER COVERING REQUIREMENTS

No field seam shall be covered or buried until tested and accepted by the CQA Consultant. Liner penetration attachments shall not be covered until inspected and accepted by the CQA Consultant.

3.3 INTERFACE-FRICTION TESTING

A. Refer to the requirements stated in TS-02621 with respect to geocomposite/geomembrane interface-friction testing.

TABLE 1 – DATA REQUIREMENTS AND SUBMITTAL SCHEDULE

Paragraph - Submittal Requirements		With Proposal	For Approval		For Record	
			Date	Copies	Date	Copies
All	Alternative Materials or Procedures	Yes	-	-	-	-
1.4.B	QA/QC Specifications for Liner	No	2 Weeks prior to liner fab.	3	-	-
2.1.A	Material Certification & Chemical Compatibility Tests	No	2 Weeks prior to liner fab.	3	-	-
2.1.B	LLDPE Liner Manufacturer	Yes	-	-	-	-
2.1.B	LLDPE Liner Physical Property Characteristics	Yes	-	-	2 Weeks prior to Work	3
2.1.C	Caulk – Manufacturer and Type	No	-	-	2 Weeks prior to Work	3
2.1.E	Liner Manufacturer's Experience	Yes	-	-	-	-
2.1.F	Liner Warranty	No	2 Weeks prior to fab.	3	-	-
3.1.A	Report on Inspection of Liner Goods	No	-	-	Within 1 day	3
3.2.A	Installer's Experience or Fabricator's Field Representative (Resumes)	Yes	-	-	-	-

TABLE 1 – DATA REQUIREMENTS AND SUBMITTAL SCHEDULE (CONT.)

Paragraph - Submittal Requirements		With Proposal	For Approval		For Record	
			Date	Copies	Date	Copies
3.2.A	Installer's or Manufacturer's Field Representative Certification of Shop drawings/panel placement	No	2 Weeks prior to Work	3	-	-
3.2.B	Written Acceptance of Subgrade	No	-	-	Within 1 day	3
3.2.A	Field Technical Experience (LLDPE)	No	-	-	2 Weeks prior to Work	3
3.2.E	LLDPE Testing Equipment - Manufacturer & Type	No	-	-	2 Weeks prior to Work	3
3.3	Geocomposite/Geomembrane Interface-Friction Testing	No	Prior to procurement	-	-	-
Attached	Sample QA/QC forms	No	-	-	2 Weeks prior to Work	3

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

TABLE 3 – CONFORMANCE TESTING FREQUENCY (By CQA Consultant)		
PROPERTY	TEST METHOD	TEST FREQUECY
Thickness	ASTM D 5994	1 TEST PER 50,000 SQUARE FT OF MATERIAL
Tensile Properties	ASTM D 6693	
Tear Resistance	ASTM D 1004	
Puncture Resistance	ASTM D 4833	
Asperity Height	GRI GM-12	
Friction Angle between Geomembrane and Geocomposite Net	ASTM D 5321	Two tests

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

END

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ATTACHMENT

Sample QA/QC Forms

LINER PROJECT QA/QC LOG

PROJECT NAME: _____

PROJECT NUMBER: _____ _____ INSTALLATION DATE: _____

PROJECT LOCATION: _____

PROJECT Owner: _____

ADDRESS: _____

CONTACT: _____ _____ PHONE: _____

PROJECT Engineer: _____

ADDRESS: _____

CONTACT: _____ _____ PHONE: _____

GENERAL Contractor: _____

ADDRESS: _____

CONTACT: _____ PHONE: _____

SPECIFIED LINER MATERIALS: _____ THICKNESS & TYPE: _____

SUPPLIER OF LINER MATERIALS: _____

ADDRESS: _____

CONTACT: _____ PHONE: _____

MATERIAL CERTIFICATION RECEIVED: _____

DATE: _____ ACCEPTED: _____

FABRICATOR OF MATERIAL: _____

INSTALLER OF MATERIAL: _____

QA/QC INSPECTION FIRM: _____

ADDRESS: _____

CONTACT: _____ PHONE: _____

LINER TESTING LABORATORY: _____

ADDRESS: _____

CONTACT: _____ PHONE: _____

SUBGRADE SURFACE ACCEPTANCE
(One per area)

PROJECT NAME: _____

DATE: _____ PROJECT NUMBER: _____

GENERAL Contractor: _____

ADDRESS: _____

CITY: _____ STATE: _____ ZIP: _____

SUPERINTENDENT OF PROJECT: _____ PHONE: _____

GEOMEMBRANE INSTALLER: _____

ADDRESS: _____

CITY: _____ STATE: _____ ZIP: _____

SUPERINTENDENT OF PROJECT: _____ PHONE: _____

CERTIFICATE OF ACCEPTANCE OF SUBBASE SOIL BY INSTALLER

I, the Undersigned, duly authorized representative of _____ do hereby accept the soil surface as being acceptable for the placement of a Geomembrane liner.

Name _____ Signature _____

Title _____ Date _____

Certificate Accepted by Inspector - Company: _____

Name _____ Signature _____

Title _____ Date _____

QA/QC INSPECTOR: _____

SITE SUPERVISOR: _____

INSTALLING SUPERVISOR: _____

RECEIVING QA/QC LOG
(One per truck)

PROJECT NAME: _____

DATE: _____ TIME: _____ PROJECT NUMBER: _____

TRUCKER'S ID: _____

NUMBER OF PIECES ON BOARD: _____

AGREE WITH PACKING LIST? _____

CONDITION OF PACKAGING: _____

VERIFY PROPER MATERIALS: _____

VERIFY PROPER THICKNESS: _____

IDENTIFY PANEL NUMBERS: _____

IDENTIFY ACCESSORIES: (ADHESIVE, BATTENS, BOOTS, ETC.): _____

_____

IDENTIFY DAMAGED ITEMS: _____

TYPE OF UNLOADING EQUIPMENT USED: _____

CONDITION: _____

OPERATOR: _____

COMMENTS: _____

STORAGE AREA

CONDITION (SURFACE): _____

LOCATION OF PLACEMENT AREA: _____

MATERIAL PROPERLY COVERED: _____

WEATHER CONDITIONS: _____ TEMPERATURE: _____

QA/QC INSPECTOR: _____

SITE SUPERVISOR: _____

PERSONNEL QA/QC LOG

(Installation and Field Seaming Personnel)
(One sheet per mobilization or change of personnel)

PROJECT NAME: _____

DATE: _____ PROJECT NUMBER: _____

SAFETY MEETING CONDUCTED ON MATERIALS HANDLING: _____

GIVEN BY: _____ DATE: _____

SUPERINTENDENT OF INSTALLATION: _____

SEAMING CREW PERSONNEL

#1 Crew Leader: _____ Helper: _____

#2 Crew Leader: _____ Helper: _____

#3 Crew Leader: _____ Helper: _____

#4 Crew Leader: _____ Helper: _____

#5 Crew Leader: _____ Helper: _____

#6 Crew Leader: _____ Helper: _____

#7 Crew Leader: _____ Helper: _____

#8 Crew Leader: _____ Helper: _____

OTHER CREW MEMBERS

NAME: _____ NAME: _____

NAME: _____ NAME: _____

NAME: _____ NAME: _____

NAME: _____ NAME: _____

SIGNED: _____
QA/QC INSPECTOR

DAILY PANEL PLACEMENT QA/QC LOG
(Placement of panels for seaming)
(One sheet per day of placement)

PROJECT NAME: _____

DATE: _____ PROJECT NUMBER: _____

WEATHER: TEMPERATURE - BEGINNING: _____ MID DAY: ____ENDING:_____

CONDITION: RAIN SNOW CLOUDY SUNNY _____

ACTUAL HOURS WORKED: _____

NUMBER OF CREW: _____ CREW LEADER: _____

OTHER ACTIVITIES: (Placement of sand bags, etc.) _____

TYPE OF PLACEMENT EQUIPMENT: _____

OPERATOR: _____

CONDITION: _____

NUMBER OF PANELS PLACED: _____ TOTAL S.F. PLACED: _____

PANEL I.D. NUMBERS: _____

_____

_____

_____

COMMENT ON SITE CONDITION: _____

_____

LINEAL FEET OF ANCHOR TRENCH DUG: _____

ACCEPTED: _____

SIGNED: _____

SEAMING QA/QC LOG
(Field seaming of panels)
(One sheet per seaming crew per day)

PROJECT NAME: _____

DATE: _____ PROJECT NUMBER: _____

WEATHER: TEMPERATURE - BEGINNING:____MID DAY:____ENDING:_____

CONDITION: RAIN SNOW CLOUDY SUNNY _____

NUMBER OF CREW _____ CREW LEADER: _____

TOTAL LINEAL FEET OF FIELD SEAM SEALED: _____

SEAMS WIDTH MINIMUM: 2" BOND AREA: _____

HARD WORKING SURFACE: _____

TOTAL LINEAL FEET OF FIELD SEAM TESTED: (NONDESTRUCTIVE) - METHOD:

_____

NUMBER OF SEAM REPAIRS REQUIRED (LIST LOCATION HERE AND ON AS-BUILT):

_____

_____

NUMBER OF OTHER REPAIRS REQUIRED (LIST LOCATIONS HERE AND ON AS-BUILT):

_____

_____

NUMBER OF SEAM SAMPLES MADE OR CUT FOR DESTRUCTIVE TESTING: (LIST LOCATIONS HERE AND ON AS-BUILT):

_____

_____

DESCRIPTION OF OTHER WORK PERFORMED TODAY: (BOOTS & BATTENS, ETC.):

_____

_____

SIGNED: _____
QA/QC INSPECTOR

DAILY QA/QC REPORT - FIELD SEAM SAMPLES
(Field seam test samples)
(One Sheet per sample)

PROJECT NAME: _____

DATE: _____ TIME: _____ PROJECT NUMBER: _____

TIME SAMPLE MADE AND/OR CUT: _____

CREW IDENTIFICATION (CREW LEADER): _____

SAMPLE IDENTIFICATION: _____

LOCATION OF SEAM: _____

WELD TYPE (FUSION/EXTRUSION/CHEMICAL/ADHESIVE): _____

MACHINE TEMPERATURE: _____

WEATHER AT TIME SEAM SAMPLE WAS MADE: TEMPERATURE: _____

CONDITION: RAIN SNOW CLOUDY SUNNY _____

HAS A TEST SAMPLE BEEN RETAINED FOR RETESTING? _____

TEST REQUIRED OF THIS SAMPLE (SHEAR & PEEL):

SHEAR RESULTS:	PEEL RESULTS:
#1 _____	#1 _____
#2 _____	#2 _____
#3 _____	#3 _____
#4 _____	#4 _____
#5 _____	#5 _____

CONSTRUCTION QA MONITOR ID: _____

RETURN RESULTS TO: _____

_____

SIGNED: _____
QA/QC INSPECTOR

QA/QC REPORT - PROTECTIVE COVER
(Placement of Cover)
(One sheet per day)

PROJECT NAME: _____

DATE: _____ PROJECT NUMBER _____

WEATHER: TEMPERATURE - BEGINNING: _____ MID DAY: _____ ENDING: ____

CONDITION: RAIN SNOW CLOUDY SUNNY _____

ACTUAL HOURS WORKED: _____ START: _____ STOP: _____

TYPE OF EQUIPMENT USED FOR HAULING: _____

TYPE OF EQUIPMENT USED FOR SPREADING: _____

CONDITION OF FILL: _____

COMMENTS: _____

_____

DAMAGE TO LINER REPORT

LOCATION: _____ SIZE: _____

CAUSED BY: _____

REPAIRED BY: _____

TESTED BY: _____

LOCATION: _____ SIZE: _____

CAUSED BY: _____

REPAIRED BY: _____

TESTED BY: _____

QA/QC INSPECTOR: ____

APPENDIX K

Seepage Analysis of Existing Dredge Cell Dikes

TABLE OF CONTENTS

DREDGE CELL SEEPAGE ANALYSES

1. INTRODUCTION

The seepage analyses performed in this calculation package deal with the conditions that caused the blow out that around November through December of 2003. It determines the causes of this blow out and graphically shows through diagrams of hydraulic pressures how this failure occurred. The excessive seepage gradient resulted from the raised phreatic surface inside the ash stack as a result of inadequate drainage of both the storm water and water drained from the wet stacking operations. These analyses support the conclusion that the failure was due not to the slope stability but to the piping or the excessive seepage gradient.

Suggestions for corrections are also provided through a series of analyses. In addition, this calculation package reviews what additional seepage pressures would be imposed on the Dredge Cells area following the construction stages shown in Drawing 10W426-1. Drawing 10W426-1 shows the proposed Phase 1, 2 and 3 construction plans for the Dredge Cell Area. The Dredge Cell Area consists of Cells 1, 2 and 3, where ash has been deposited to-date to Elevation (El.) of about **810'**.

This calculation plan is organized as follows:

- SITE HISTORY AND PERTINENT DATA
- SUBSURFACE EXPLORATIONS
- CRITICAL CROSS SECTIONS FOR SEEPAGE EVALUATIONS
- STRATIGRAPY FOR SEEPAGE ANALYSES
- FINITE ELEMENT PROGRAM FOR SEEPAGE ANALYSES
- DESIGN MATERIAL/SOIL PROPERTIES
- SEEPAGE EVALUATION
- RESULTS OF THE SEEPAGE EVALUATION
- CONCLUSION & RECOMMENDATIONS

The sections below describe each of the items above in succeeding order.

2. SITE HISTORY AND PERTINENT DATA

Currently, a new cell area is being created between Dredge Cell Area and Ash Pond Area, located inside Ash Pond Area, where a Stage 1 dike to El. 780' is being

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constructed. This area is called Phase 1, where ash will be temporarily deposited and later raised to be even with Dredge Cell Area elevation (810').

The original topography of the ash site may be assumed as shown in the Drawing 10N400, Section F (Ref 1.). This drawing shows that the original ground surface (GS) in the eastern half of Cell Area was approximately at El. 730', and dipped gently to El. 724' at its western edge. In Ash Pond Area, the GS dipped gently westward from El. 735' at its east edge to 724' or lower at its western edge. The GS varied from El. 745' to 730' in Stilling Basin Area.

The proposed plan is first to stack ash to Elevation as high as **868 feet** in Dredge Cell Area (i.e., raise the area further by 58 **feet**). Second, stack gypsum and fly ash both to an Elevation of approximately **970 feet** in the Ash Pond Area (i.e., raise the area there further by **210 feet**) as shown on Drawings 10N400 (Section F, Ref 1) and 10W425-34C (Ref. 2). Both ash and gypsum will be placed wet primarily (sluiced in from the plant) until the year 2019 and gypsum will be placed dry thereafter.

3. SUBSURFACE EXPLORATIONS

No deep borings were drilled in the interior cell and ash pond areas during the past investigations. Therefore, an additional subsurface exploration under Parsons direction was undertaken in March 2004 (Mactec, 2004) that consisted of the following:

- Twelve borings (B-1 through B-12),
- Eleven cone-penetrometer (CPT) soundings (CPT-1, 1A, 4, 6, 8, 9, 10, 11, 12A, DN and DS) with pore-water pressure measurement located adjacent to selected boring locations,
- Field permeability testing (at the blowout location), and
- Laboratory testing of disturbed and undisturbed ash and soil samples collected from the borings.

The exploration investigated the subsurface conditions of ash and natural subsoil in the interior areas and attempted to verify those obtained from the past explorations. The data obtained from the 2004 exploration (Mactec, 2004) gives the primary design conditions for the seepage analyses, although the data from the past explorations have been used as appropriate.

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4. CRITICAL SECTIONS FOR SEEPAGE EVALUATION

The critical section through existing Dredge Cell Area lies at the "blowout" location as shown in Figure 1. Figure 1 gives a simplified visualization of the stratigraphy based on interpretations of CPT and boring data from the Mactec 2004 report and drawings in Reference 1. These simplifications are needed because of bandwidth difficulties introduced with sharp corners in development of a finite element mesh for the seepage model. The critical section illustrated in Figure 1 will be called the Case 1 analysis.

The critical section for the Stages C, D, and E will be combined into a single Case 2 analysis. Drawing 10W425-6 gives the details of these stages. Figure 2 gives a simplified visualization of the stratigraphy based on similar interpretations of field data and available drawings.

5. STRATIGRAPHY FOR SEEPAGE ANALYSES

We performed an extensive review of data from all past and recent borings and CPT soundings to determine a representative subsurface stratigraphy near the "blowout" for use in a seepage analysis. Generally, data from the past borings matched the subsurface conditions revealed from the investigation performed in 2004. However, unlike the past investigations, the 2004 investigation included CPT soundings. The continuous record of data obtained from these soundings gave a more detailed profile of changes in the stratigraphy. In addition, the CPT probes provided critical data on hydraulic conductivity with depth. Consequently, CPT data were the determining factor in choosing the design profile.

The seepage model for the interior of the existing cells and the stratigraphy at the blowout location uses data from the borings and CPT soundings within Dredge Cell Area; specifically data from B-1 through B-5 and CPT-1, 4 and 6, and Monitoring Wells (MWs) 1, 2, 3, 4B, 6A, 13B, and 16A. The simplified Case 1 blowout seepage model of existing cells for this location is given in Table 1 as follows:

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Table 1. Soil Properties for Each Soil Zone.

Soil Zone	Elevation Range	General description
1	810'+ to 771'	Outer Dike - Mixture Rolled & Compacted Fly Ash (FA) and Bottom Ash (BA)
2	810' to 770'	Loose FA
3	770' to 763'	Medium dense to dense FA + BA
4	770' to 763	Outer Dike Dense Compacted FA + BA
5	763' to 725'	Loose FA + BA, Interior
6	763' to 725'	Natural Clay, soft to stiff (CL) at Toe
7	725' to 718'	Natural Clay, soft to stiff (CL)
8	718' to 703'	Clayey Silty Sand, Residuum (SC-SM)
9	Below 703'	Bedrock (Soft Shale)

For the Case 2 analyses where the dredge cells are raised to Elevations 826 and 842 in Stages D and E (See Drawing 10W425-6), the seepage analysis assume that Soil Zones 1 and 2 extend up accordingly.

6. FINITE ELEMENT PROGRAM FOR SEEPAGE ANALYSES

The seepage evaluation uses the TIMES two-dimensional finite element fate and transport model. TIMES is a 32-bit windows program, coded entirely in the object oriented programming language C++. The mesh module is a full feature, interactive, variable density 2D density mesh generator that can generate high quality triangular and quadrilateral elements easily around complex geometry, stress objects such as perimeter wells, funnel and gate systems, blanket drains, etc. TIMES models unsaturated flow, non-aqueous phase liquids (NAPL) flow, vacuum extraction wells, and all boundary conditions can be time dependent. TIMES has four methods for assigning nodal values: uniform, gradient, kriging, and user drawn contours. TIMES's transport module simulates solute transport with absorption and first order decay. •

7. DESIGN MATERIAL/SOIL PROPERTIES

The data for the hydraulic conductivity for the seepage analyses come from CPT hydraulic conductivity measurements with depth at soundings CPT 1, 1A and 4. Freeze and Cherry (Ref. 4) (1979, Pg. 37, Equations 2.31 and 2.32) describe how to calculate equivalent horizontal and vertical hydraulic conductivities for the layers shown in Figure 2. Note that zones of low conductivity will control the vertical conductivity and lead to lower values as in the smallest diameter pipe would control flow through a series of connected pipes. By contrast, the most conductive layers will dominate horizontal flow, as most flow will shift toward these layers as toward the large pipes in a parallel pipe network. Table 2 summarizes the soil properties used in the TIMES model for each of the soil zones. The Ratio K_h / K_v describes how much larger the horizontal hydraulic conductivity is than the vertical hydraulic conductivity. The residual saturation gives the moisture content when unsaturated conditions exist. The final column give the assumed van Genuchten model parameters for the wetting front as water infiltrates in from the pond and by surface infiltration due to rainfall through unsaturated material toward the water table.

Table 2. Design Soil Properties for Use in TIMES Model for Seepage Analyses

Zone	Hydraulic Conductivity		Ratio K_h / K_v	Residual Saturation n	Assumed van Genuchten Model Parameters	
	ft/day	cm/sec			VG alpha 1/ft	VG n
1	16.2	0.0057	35.8	0.15	3.5	1.5
2	20.6	0.0071	222.5	0.15	3.5	1.5
3	7.7	0.0027	700	0.2	3.5	1.5
4	7	0.0025	100	0.2	3.5	1.5
5	31.3	0.0110	439	0.35	3.5	1.5
6	.0028	1.0E-06	10	0.35	3.5	1.5

Note that the seepage model will assume that Soil Zones 7, 8, and 9 combine to represent a vertical no flow boundary because of their low hydraulic conductivities.

8. SEEPAGE EVALUATION

The seepage evaluation examines two main cases:

Case 1. Conditions that exist at the time of the blowout with the stack at Elevation 810 feet (Stage C, that is, Stage 1).

Case 2. Steady state conditions at Stage C to E (Stage 1 to 3) or from Stack Elevation of 810 to 842 feet.

In both of these cases, the model is run in transient mode until a steady state condition is reached. Recommendations are given to reduce the seepage forces within the slope as necessary.

Figure 3 gives the finite element mesh, boundary and initial conditions for Case 1. A pool elevation of four feet has been modeled as a pressure head elevation behind the 810-foot Stage C dike. The hydraulic conductivity of the top layer of soil has been assumed to be equal to 0.028 ft/day (or 1.0E-05 cm/sec). An average daily recharge rate of one sixth of this conductivity has been assumed for the infiltration rate into the surrounding soils and slopes. No flow boundaries have been assumed along the bottom and left sidesl. By contrast, the model assumes no change in heads at the vertical right side of the model from the initial conditions. A similar configuration will be used in Case 2, for the modeling from Stages C to E to a final elevation of 842 feet.

The water table or phreatic surface approximately follows the data given by MWs 1, 2, and 3 as measured in November through December 2003. This seepage model assumes that the initial phreatic surface varies from an Elevation of ~ 783 at MW-3 to over 791' at the left hand side of the grid; i.e., approximately 8 feet above that observed in the monitoring well MW-3 temporarily installed near boring B-3 during the April 2004 investigation. Figure 3 shows the profile and the phreatic surface along the slope based on the data from borings B-1, 2, 3 and monitoring wells MW-1, 2, 3. *(Note that the stack height used for this Case 1 evaluation corresponds to the recent condition under which the blowout occurred and not the future raised-stack condition.)*

9. RESULTS OF THE SEEPAGE EVALUATION

In the Case 1, the seepage analysis looks at taking the existing observed monitoring well conditions back in November and December 2003 to back out an assumed water table and combining that with an assumed pool elevation pressure head of four feet at the top of the dike. As the water seeps through the unsaturated dredged fly and bottom ash materials and moves toward the compacted outer dikes, one sees a rise in the water table pressure contours. Figure 4 shows the Case 1 pressure heads from 0 to 40 feet for the Stage C (Stage 1) Dike that goes up to about 810 feet after flow achieves steady state. By contrast, Figure 4A shows that the total head contours align perpendicularly to the pressure contours and that the flow lines are generally horizontal to the northwest (because on the anisotropic dominance of the horizontal conductivity). While the blow out that occurred in the field probably did not occur under conditions of steady state and we will never know the exact conditions at time of failure, Figures 4 and 4A illustrate conceptually how the failure occurred and why the clay bulge developed above Elevation 771 feet. Once the piping failure had occurred the seepage pressure was temporarily relived.

To reduce these seepage pressures, Figure 5 shows how the installation of slope under drains / bench drains and a composite geonet drainage layer from Elevation 783 to the ditch can solve the problem (See Drawing 10W425-73). The analysis placed the composite geonet drainage layers about 18 inches below the surface and assumed them to be calendered 100-120 AOS with the geotextile side facing down on top of the fly ash/bottom ash. The bench drains were assumed to be about 4 feet below the surface and consist of 6 inch perforated HDPE pipe.

In Case 2, the seepage analysis looks at what will happen when the dredge cells are raised from Stage C to E (from 1 to 3). Drawing 10W425-6 shows the addition of six more perimeter drains in raising the stack from Stage C to Stage E. Figure 6 shows the seepage analysis of Case 2 for the condition similar to the first Case 1 where no slope or bench drains and composite geonet drainage layers exist on the lower slope. Figure 6 illustrates conceptually how a similar piping failure can occur again with construction of Stages D and E should no measures be undertaken to reduce seepage forces below Elevation 794 feet.

Finally, Figure 7 show that with the installation of slope under / bench drains and composite geonet drainage layers below Elevation 794 down to the ditch reduces the pressure heads to zero at the surface and therefore controls the seepage exit gradients to acceptable levels.

10. CONCLUSIONS AND RECOMMENDATIONS

1. The seepage evaluation for the Stage C (Stage 1)/ Case 1 existing conditions case of the Dredge Cell Area finds that high water table conditions and related seepage forces likely caused the blow up on the northwest side of the dredge cell. Additional analyses suggest that to reduce these seepage forces that slope under drains / bench drains and composite geonets be placed along the slope to prevent the buildup of seepage forces.

2. Specifically, the slopes at and below Elevation 794 feet that have no perimeter drains should be retrofitted with under drains at the base of each slope no longer than 100 feet in length.

3. In addition, from Elevation 783 feet to 760 feet or the ditch, whichever is lower, the slope should be retrofitted with a composite geonet drainage layer to reduce seepage forces. The bottom of the composite geonet must be in contact with the fly ash and bottom ash and be covered with a minimum of soil with a plasticity index (PI) greater than 10, preferably in the range of 20 to 30. The geotextile of the composite geonet drainage layer to be placed against the fly ash and bottom ash must have an AOS greater than 100 and preferably greater than 120 and this geotextile must be calendered.

4. If the remedies are constructed as assumed in the model, the seepage analyses of Case 1 show that these remedies reduce the hydraulic pressures to an acceptable level.

5. Similarly, the seepage evaluation for the Stage E (Stage 3)/ Case 2 existing conditions case of the Dredge Cell Area finds that high water table conditions and related seepage forces would likely cause another blow out on the northwest side of the dredge cell. **Therefore, the succeeding stages must be constructed with the remedial measures described for Stage C (Case 1) as have been already implemented before further staging takes place.** Additional analyses suggest that to reduce these seepage forces that slope under drains / bench drains and composite geonets be placed along the slope to prevent the buildup of seepage forces.

END

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11. REFERENCES

1. Drawing Nos. 10W425-6 and 34C (showing proposed Phase 1, 2 and 3 plans).
2. TVA Drawing No. 10N400 – R6, dated 7-5-56 (showing original surface topography).
3. TIMES, TriHydro, 307-745-7474, Fax 307-745-7729, Email: TriHydro@lariat.com.
4. Freeze, R. A., and J. A. Cherry. Groundwater. Prentice-Hall, Inc. Englewood Cliffs, New Jersey 07632.
5. TVA report titled, *Hydro geologic Evaluation of Ash Pond Area*, dated June 1995.
6. Mactec report titled, *REPORT OF GEOTECHNICAL EXPLORATION, ASH DISPOSAL AREA,* dated May 4, 2004.
7. Drawing No. SK PR0637 C80 (showing locations of borings drilled prior to 2004).
8. Mactec report titled, *Laboratory Testing Results – Samples from Gypsum Pond at Cumberland Fossil Plant*, dated May 13, 2004.
9. Drawing No. 10425-73 (showing Existing Dredge Cell Under drain Installation on Existing Slope Elevation from the Ditch ~ 755 or 760 to 790.

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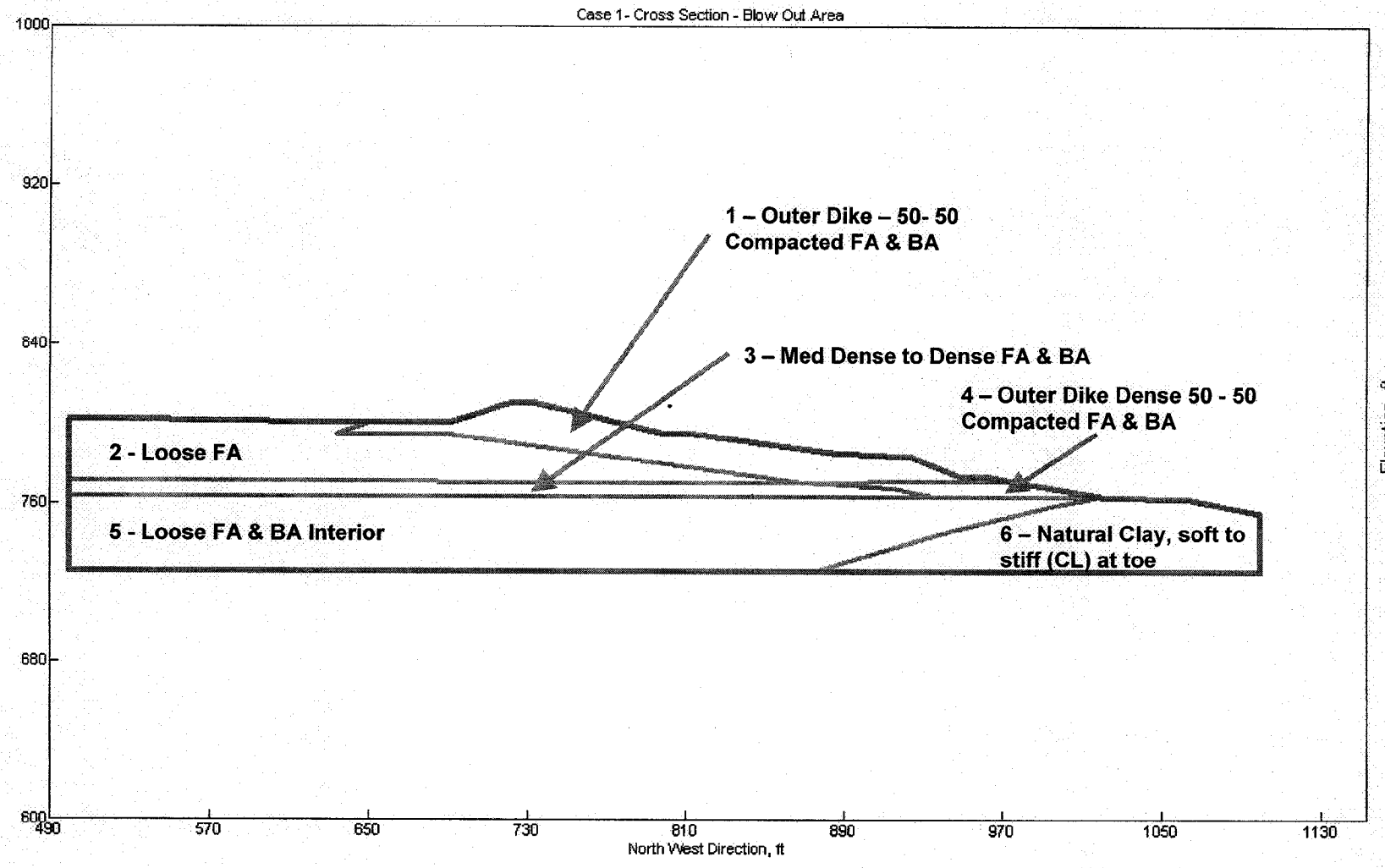

Figure 1. Soil Zones For Case 1 – Stage C at Elevation 810 feet Identified By Number and Brief Description.

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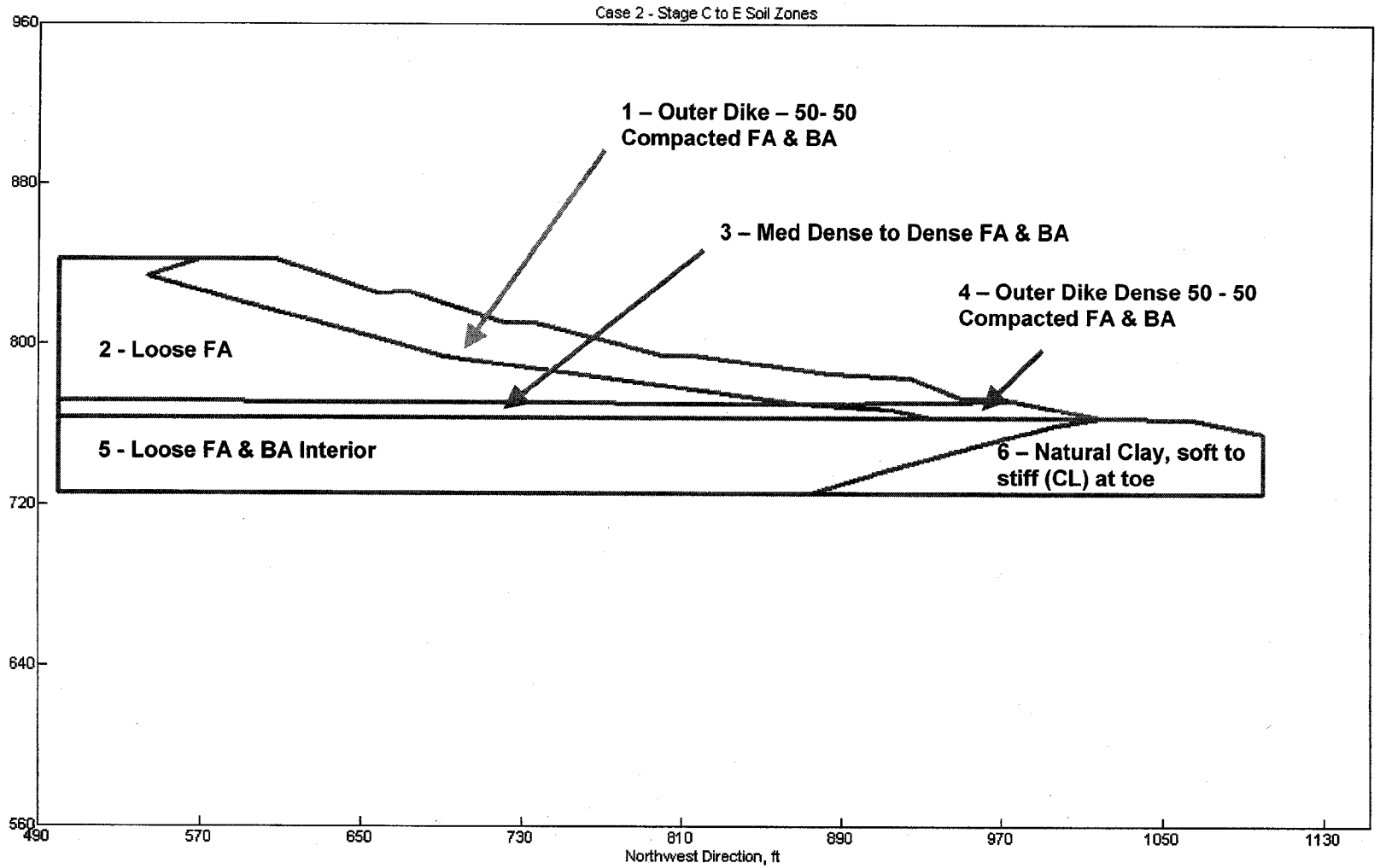

Figure 2. Soil Zones for Case 2 – Stage C to E at Elevation 842 feet Identified By Number and Brief Description.

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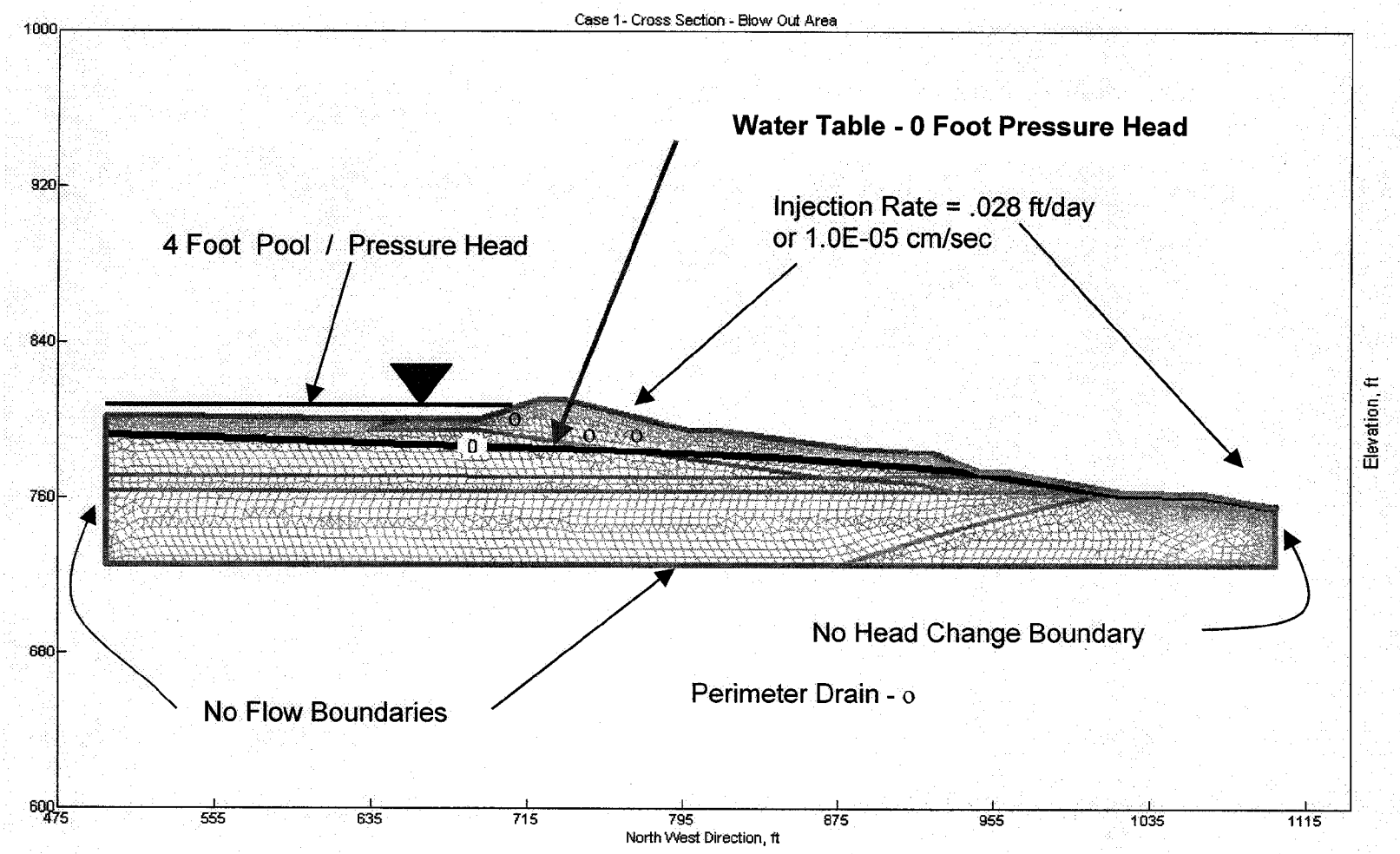

Figure 3. Case 1 Cross Section for Blow Out Area Showing Finite Element Mesh, Boundary and Initial Conditions.

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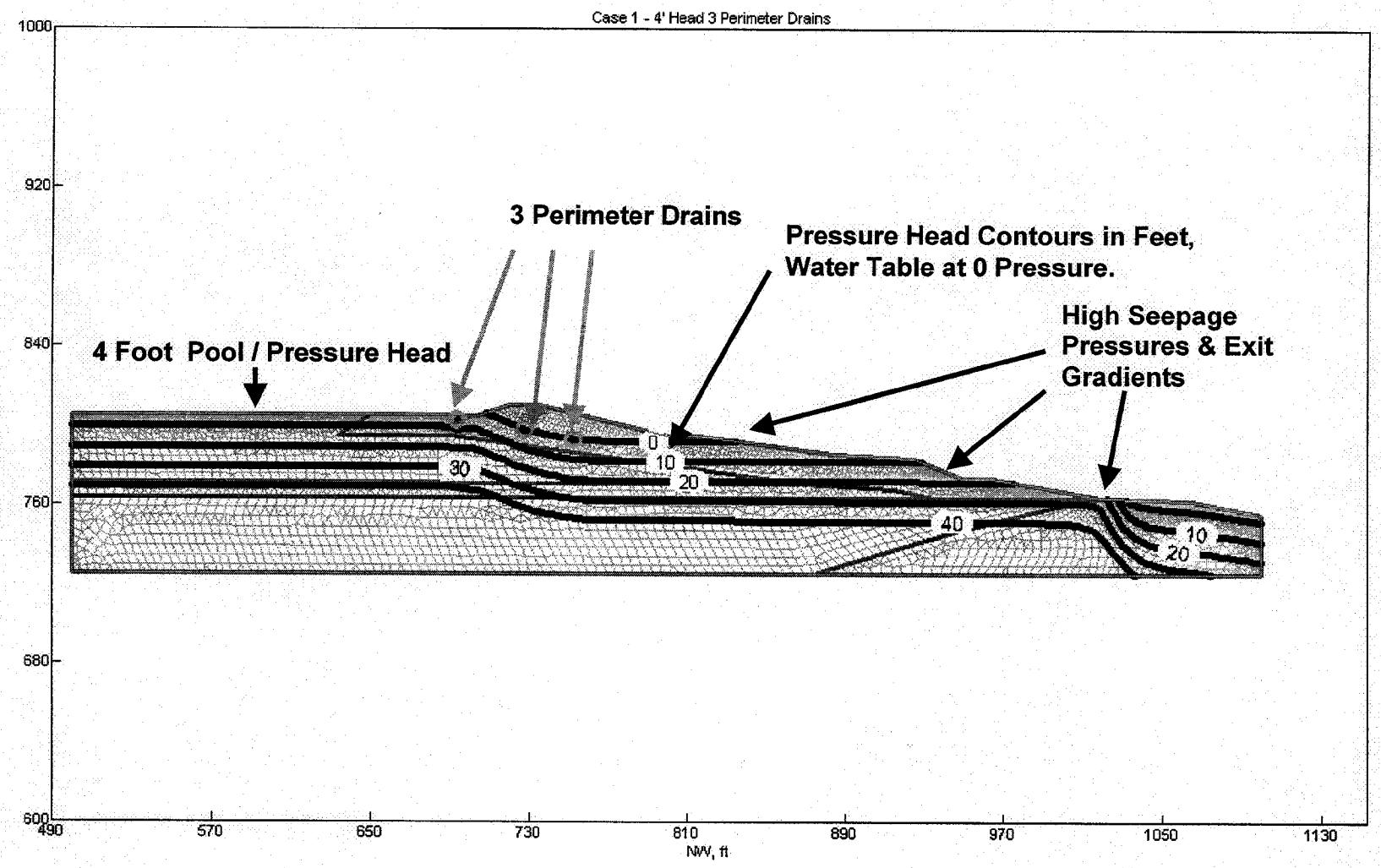

Figure 4. Case 1. Perimeter Drains for Stage C (Stage 1) Still Produce Large Exit Gradients At Steady State.

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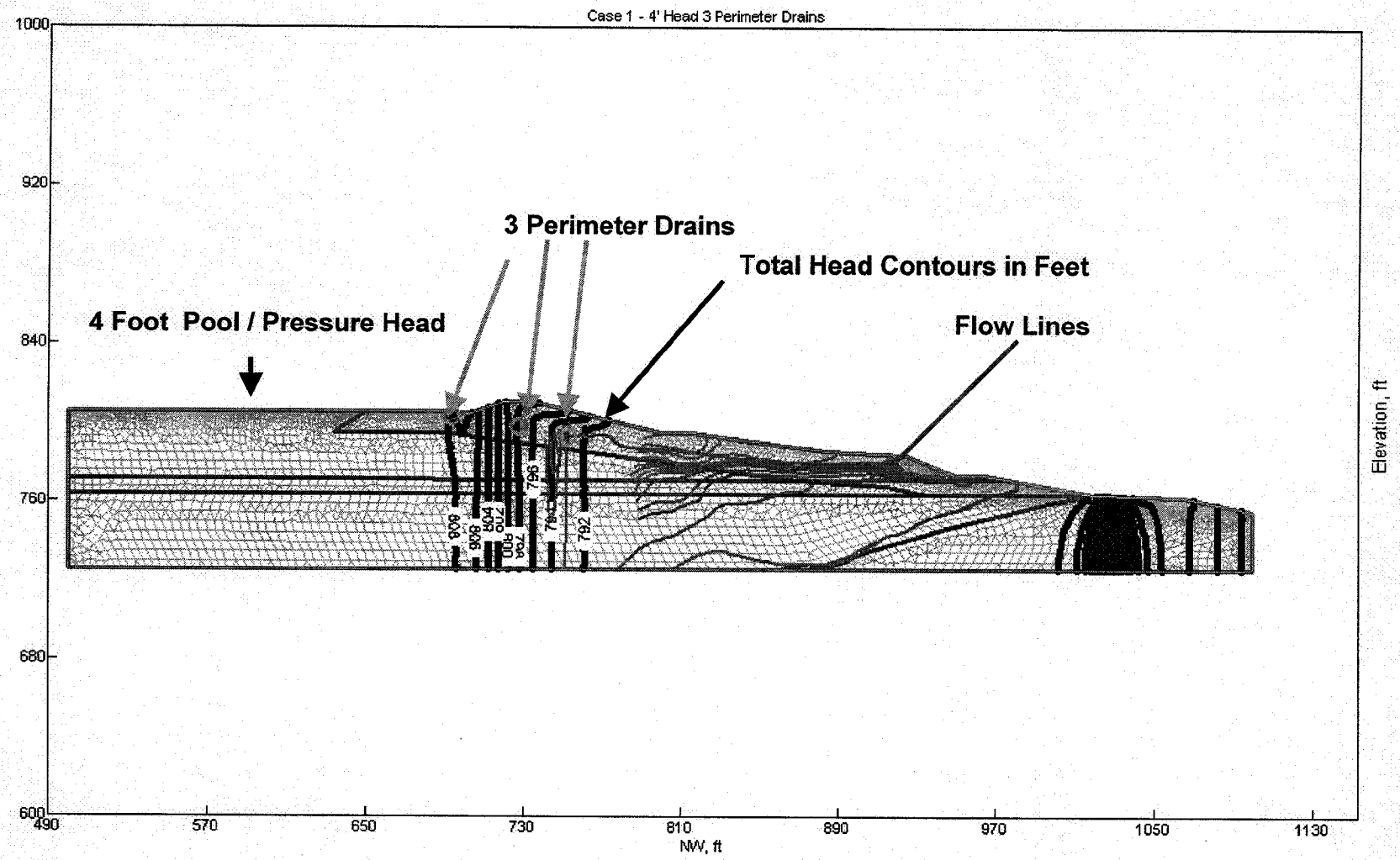

Figure 4A. Case 1. Perimeter Drains for Stage C (Stage 1) Total Heads at Steady State With Flow Lines.

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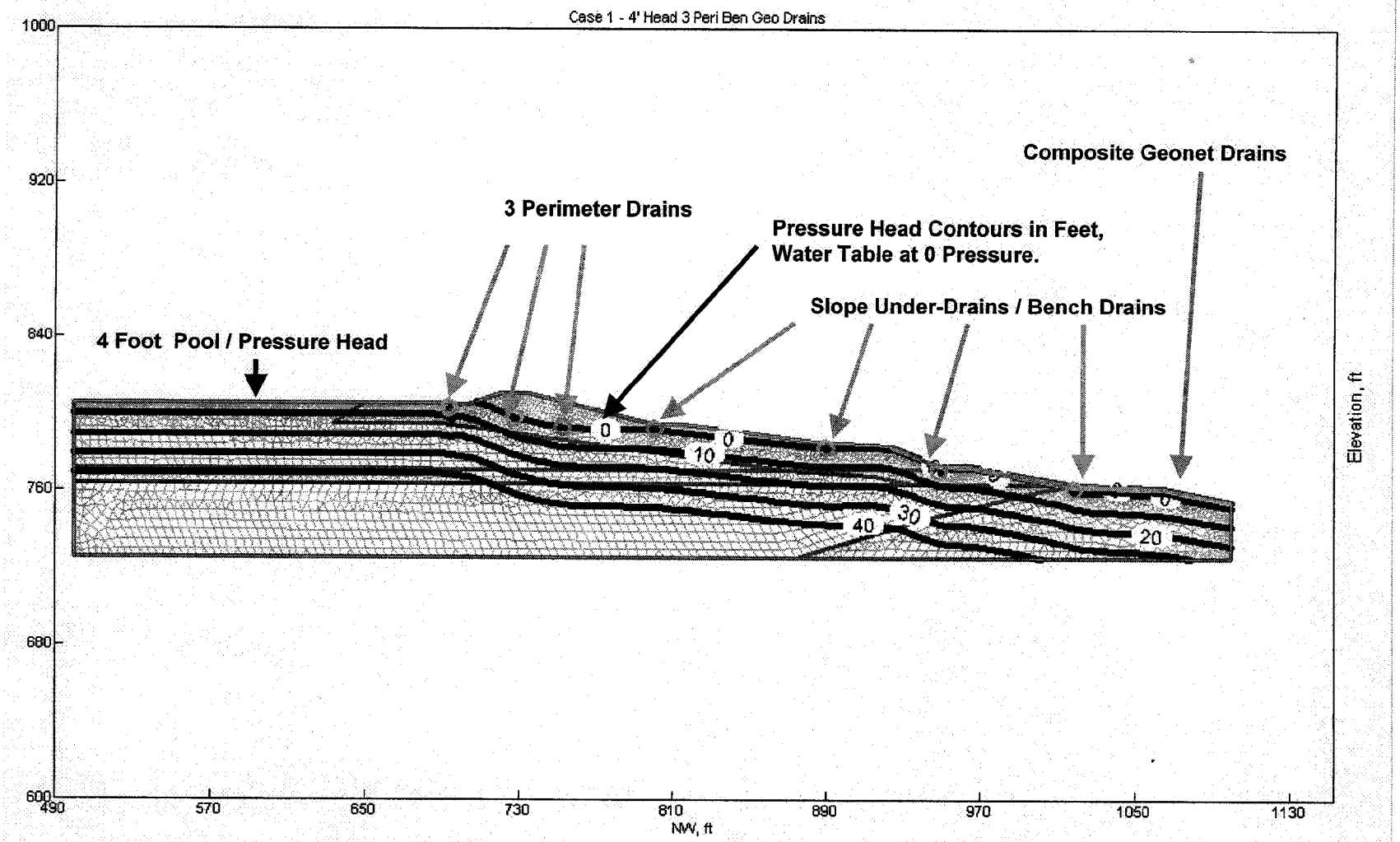

Figure 5. Case 1. Perimeter Drains for Stage C (Stage 1) Control Exit Gradients.

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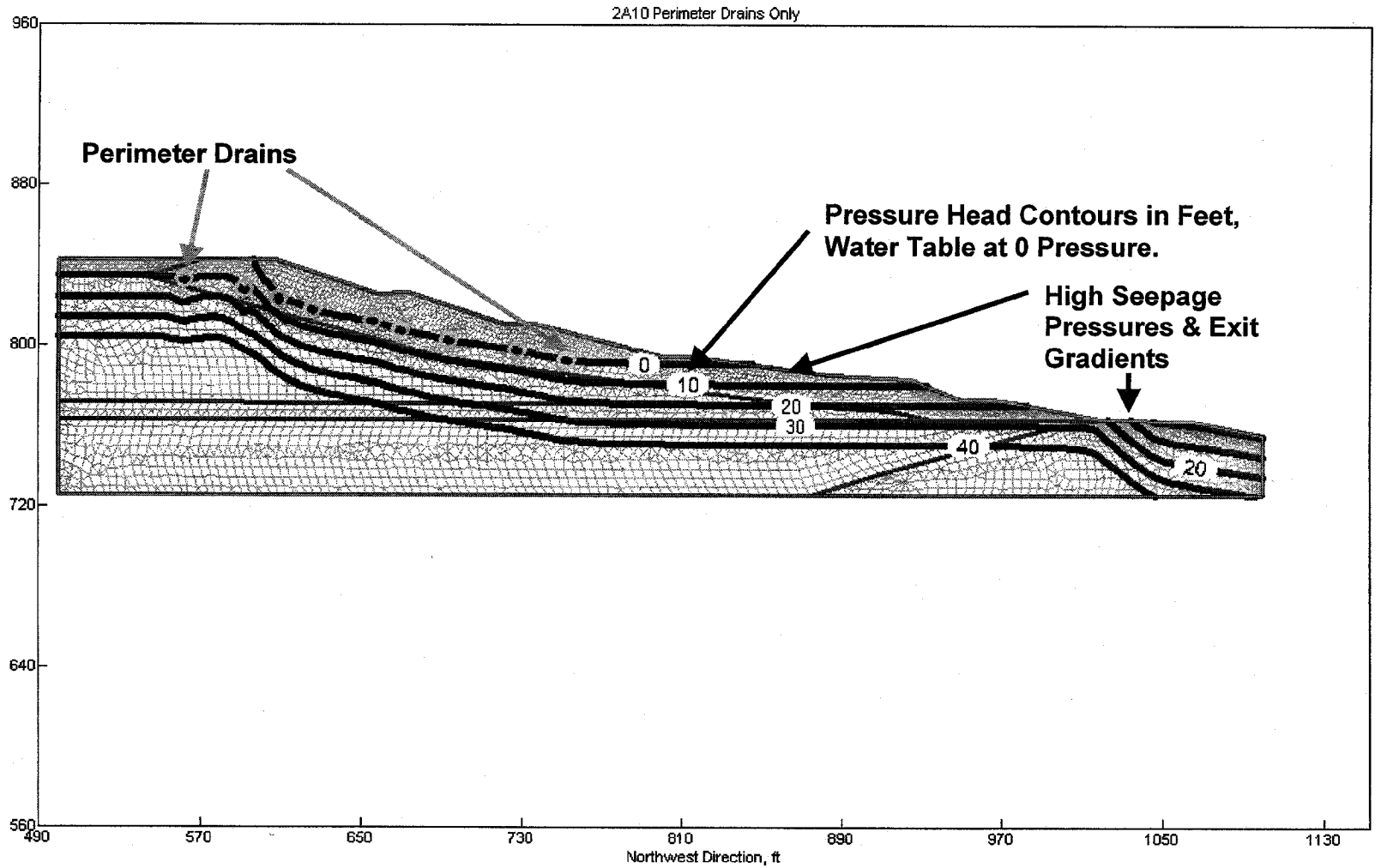

Figure 6. Case 2. Perimeter Drains for Stage E (Stage 3) Still Allow Large Exit Gradients At Steady State.

TVA-00002324

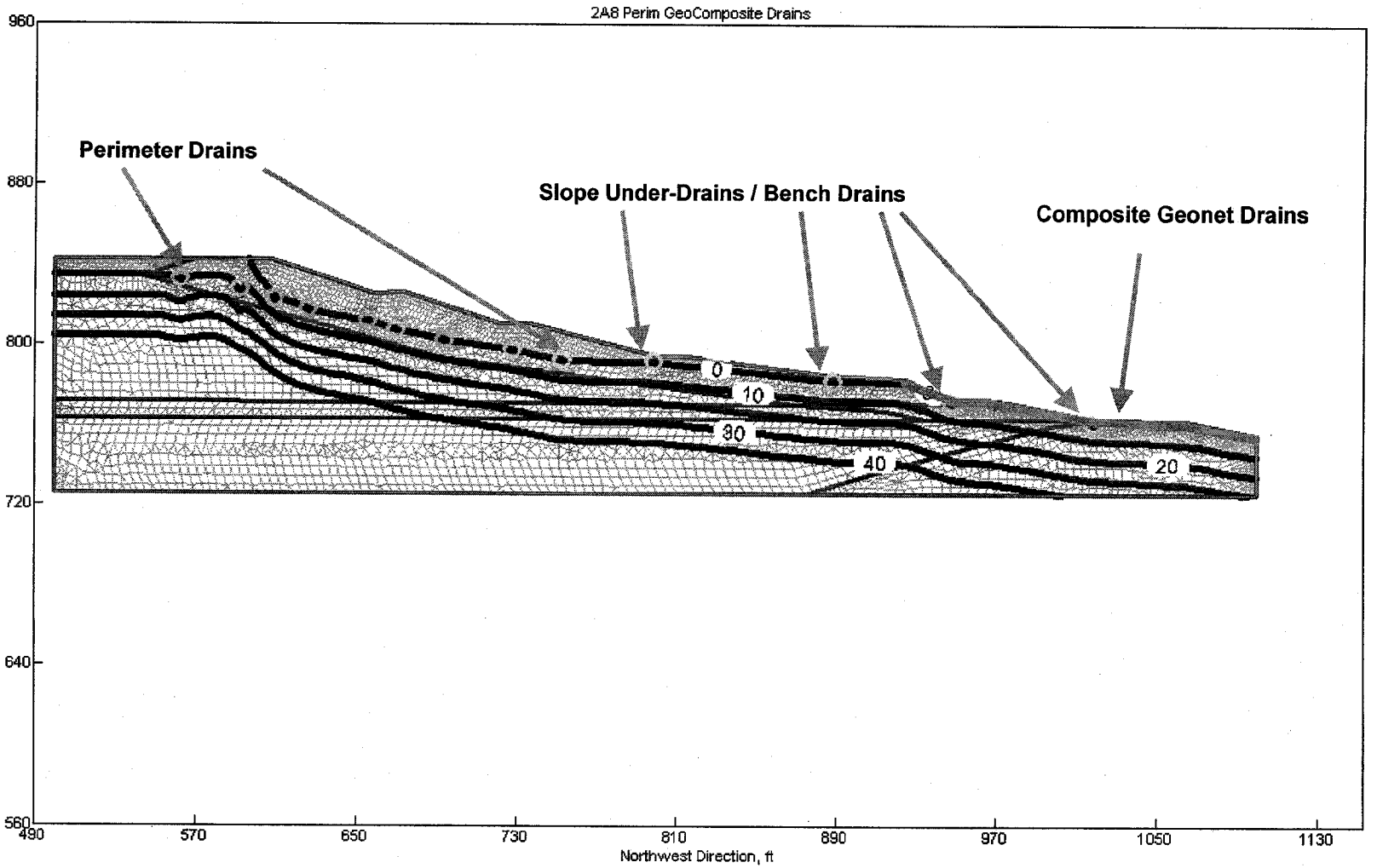

Figure 7. Case 2. Perimeter, Bench, and Composite Geonet Drains for Stage E (Stage E) Control Exit Gradients.

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