Prepared for

ENERGY • WATER • COMMUNITY SERVICES

Lower Colorado River Authority (LCRA)
P.O. Box 220
Austin, Texas 78767

COMPOSITE LINER DESIGN AND OPERATING CRITERIA REPORT

COMBUSTION BYPRODUCT LANDFILL FAYETTE POWER PROJECT FAYETTE COUNTY, TEXAS

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1/22/2022

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REFERENCE DRAWINGS

Drawing 1 Overall Site Plan
(Drawing 1 from Geosyntec Consultants (2021). "Run-On and Run-Off Control System Plan for Combustion Byproduct Landfill, Registration No. 31575, LCRA Fayette Power Project, Fayette County, Texas," prepared for LCRA, July. [Run-On and Run-Off Control Plan])

Drawing 2 Existing Site Conditions
(Drawing 2 from Run-On and Run-Off Control Plan (Geosyntec, 2021))

Drawing 4 Subcells 2A and 2D Base Grading Plan
(Drawing 4 from Run-On and Run-Off Control Plan (Geosyntec, 2021))

Drawing B-C-00G-164 Top of Subgrade and Underdrain Plan (Geosyntec, 2022b)
Drawing B-C-00G-165 Leachate Collection System Plan (Geosyntec, 2022b)
Drawing B-C-00G-166 Final Cover Grading Plan (Geosyntec, 2022b)
Drawing B-C-00G-172 Landfill Cross Sections (Geosyntec, 2022b)
Drawing B-C-00G-177 Liner System Details (Geosyntec, 2022b)
Drawing B-C-00G-180 Leachate Collection System Details I (Geosyntec, 2022b)

Drawing B-C-00G-181 Leachate Collection System Details II (Geosyntec, 2022b)

APPENDICES

Appendix A Certification by a Qualified Professional Engineer
Appendix B Construction Quality Assurance Plan
Appendix C HELP Model Output

1/22/2022

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1. INTRODUCTION

1.1 Purpose and Scope

This report presents information on the design, construction, and operation of the Combustion Byproduct Landfill (CBL) at the Lower Colorado River Authority (LCRA) Fayette Power Project (FPP). The design and construction information presented herein demonstrates that the CBL complies with Chapter 352, Subchapter F (Design Criteria) of Title 30 of the Texas Administrative Code (TAC) (i.e., 30 TAC §352, Subchapter F). These regulations for the design of new coal combustion residuals (CCR) landfills and lateral expansions of existing CCR landfills, were adopted by reference to Section 257.70 of Part 257, Subpart D of Title 40 of the Code of Federal Regulations (CFR) (i.e., 40 CFR §257.70). The operational information summarized herein demonstrates that the CBL complies with run-on and run-off control and inspection requirements of 30 TAC 352, Subchapter G. These requirements were adopted by reference to 40 CFR §257.81 and §257.84, respectively.

1.2 Organization of Report

The remainder of this Report is organized as follows:

- Section 2 summarizes the design, construction, and operational characteristics of the CBL;
- Section 3 describes how the composite liner component of the liner system proposed for the future lateral expansion cells of the CBL has been designed to meet the specification and performance requirements of 40 CFR §257.70(b);
- Section 4 describes how the leachate collection and removal system (LCRS) component of the liner system proposed for the future CBL cells has been designed to meet the performance requirements of 40 CFR §257.70(d);
- Section 5 describes how the CBL complies with the run-on and run-off control system requirements of 40 CFR §257.81;
- Section 6 describes how the CBL complies with the inspection requirements of CFR §257.84; and
- Section 7 provides a list of references cited in the report.

2. SUMMARY OF CBL CHARACTERISTICS

The FPP is a coal-fired power plant located east of La Grange in Fayette County, Texas (FPP site). CCR generated at FPP and small amounts of related Class 2 nonhazardous industrial wastes are disposed in the CBL, a CCR landfill located south of the power plant and north of the railroad that borders FPP (**Drawing 1**).

At final buildout, the CBL will consist of Cells 1 to 3 with approximate areas of 30 acres, 41 acres, and 29 acres, respectively (**Drawing 2**). Cell 1 and Subcell 2D are constructed, and the remainder of the CBL will be developed in phases (**Drawing 2**). Depending on the rates of CCR production and beneficial use, all cells may not be needed for CCR disposal and the final CBL footprint could be smaller than that shown in **Drawing 2**.

The CBL is primarily an above-grade landfill. The maximum below-grade depth of the liner system is typically 20 ft, but reaches up to 30 ft where there are localized topographic highs at natural ground level (**Drawings B-C-00G-164 and B-C-00G-172**). The future expansion area will be developed with a base (i.e., subgrade) that is located no less than 5 ft above the upper limit of the uppermost aquifer, the Intermediate Sand (Geosyntec Consultants (Geosyntec), 2022c). The maximum design elevation of the CBL is 470 feet mean sea level (ft msl) (**Drawing B-C-00G-166**), resulting in a maximum above-grade fill height of approximately 130 ft, which occurs in Cell 3.

Cell 1 and Subcell 2D are existing CCR landfill areas as defined by 30 TAC §352.3(a), which adopts by reference 40 CFR §257.53. Cell 1 was constructed in 1988 at natural grade with a recompacted clay liner installed over natural clay subgrade. This liner is equivalent to the liner recommended at that time in Texas Water Commission (TWC) Technical Guideline No. 3 for Class II industrial waste landfills: a 2-ft thick (minimum) recompacted clay-rich liner or 3 ft of in-place soil exhibiting a permeability less than 1×10^{-7} centimeter/second (cm/s) (TWC, 1988). TCEQ reviewed and approved the design of Cell 1 and its construction in in a letter dated January 18, 1988. A clay perimeter berm was constructed around the west, north, and east sides of the cell, and a clay cell separation berm was constructed along the south boundary of the cell (Geosyntec, 2013). In, 1992, the northern slope of Cell 1 was closed with final cover consisting of a 2-ft thick compacted clay layer with a hydraulic conductivity no greater than 1×10^{-7} cm/s overlain by 1 ft of general fill and at least 1 ft of topsoil. The limits of the final cover are shown on **Drawing 2**.

From October 2014 to May 2015, Subcell 2D was constructed below grade with a 3-ft thick compacted clay liner with a hydraulic conductivity less than 1×10^{-7} cm/s, which met the recommendations of TCEQ Technical Guideline No. 3 (2015) for Class 2 monofills of consistent, well characterized waste. TCEQ reviewed and approved the design of Subcell 2D and its construction in in a letter dated January 18, 1988, and acknowledged the revisions to the CBL design in letters dated June 14, 2012 and June 12, 2013. Subcell 2D currently includes a contact water retention pond (herein referred to as the Subcell 2D Contact Water Retention Pond)

(**Drawing 2**) lined with a 60-mil thick high density polyethylene (HDPE) geomembrane/2-ft thick compacted clay composite liner. Details of the constructed liner system of Subcell 2D and the Contact Water Retention Pond are included in the Construction Quality Assurance Certification Report (CQA Report) for Subcell 2D (Geosyntec, 2015). Subcell 2D is being used as a waste storage/product preparation area during CCR operations in Cell 1 and future Subcells 2A, 2B and 2C. As Cell 2 is filled and waste disposal transitions into Cell 3, a waste staging area may be developed in Cell 3 (Geosyntec, 2013).

The remainder of Cells 2 and 3 will be constructed with a liner system that meets the requirements of 40 CFR §§257.70(b) and (d), which includes a leachate collection system and underlying geomembrane/compacted clay composite liner.

Runoff from active areas in Cell 1 of the CBL currently drains to the Runoff Retention Pond via the runoff channel (**Drawing 2**). Contact water from the Subcell 2D Contact Water Retention Pond is managed through a pumping system which routes flow to the runoff channel. The Runoff Retention Pond is permitted under LCRA's Texas Pollutant Discharge Elimination System (TPDES) Permit No. WQ0002105000 and is designated as the "CBL Pond" in the permit. The permit allows water in the Runoff Retention Pond to be managed by conveying it to the FPP Reclaim Pond or, if effluent limitations are met, by discharging via Outfall 004. The Runoff Retention Pond will be used for management of contact water from the active area until the Leachate Evaporation Pond is constructed, which will occur prior to disposal of CCR in Subcell 2A (**Drawing 4**).

Stormwater run-off from the existing final cover system of the CBL flows into drainage channels along the perimeter of the CBL that primarily discharge south of the CBL, but also discharges to a drainage ditch north of the CBL. When CCR disposal operations are initiated in Cell 2 and later in Cell 3, the majority of stormwater run-off from the final cover system will flow into a proposed stormwater pond south of Cell 2 prior to being discharged from the site (**Drawing 4**).

3. COMPOSITE LINER DESIGN FOR FUTURE EXPANSION CELLS

3.1 Overview

In accordance with 30 TAC §352.701, which adopts by reference 40 CFR §257.70, new CCR landfills and any lateral expansion must be designed, constructed, operated, and maintained with a composite liner that meets the requirements of 40 CFR §257.70(b) or an alternative composite liner that meets the requirements of 40 CFR §257.70(c). There are no liner design requirements for existing CCR landfill areas in 30 TAC §352.701. Therefore, the liners for Cell 1 and Subcell 2D are not addressed in this section.

3.2 Liner Requirements

In accordance with 40 CFR §257.70(b), the standard composite liner must consist of two components:

- 30-mil (minimum) thick geomembrane liner (60-mil [minimum] thickness if an HDPE geomembrane is used) installed in direct and uniform contact with the underlying compacted soil; and
- 2-ft thick compacted soil liner with a hydraulic conductivity of no more than 1×10^{-7} cm/s.

The composite liner must also be:

- constructed of materials that are chemically compatible with the CCR and have sufficient strength and thickness to prevent failure due to pressure gradients, physical contact with CCR or leachate, climatic conditions, and stresses exerted during installation and operation;
- constructed of materials that provide appropriate interface shear resistance between the geomembrane and compacted soil layer to prevent sliding of the geomembrane;
- placed upon a stable foundation capable of preventing failure of the liner due to settlement, compression, or uplift; and
- installed to cover all ground surface likely to be in contact with CCR or leachate.

3.3 Liner Design

The liner system for the future expansion cells consists of the following components, from top to bottom (see Detail 14 on **Drawing B-C-00G-177**):

- 2-ft thick soil protective cover layer;
- geocomposite drainage layer consisting of an HDPE geonet core with a needlepunched non-woven geotextile bonded to its top and bottom surfaces (i.e., a double-sided geocomposite); and
- composite liner consisting of a 60-mil thick textured HDPE geomembrane overlying a 2-ft thick compacted clay liner with a hydraulic conductivity no greater than 1×10^{-7} cm/s.

The composite liner included in this liner system is consistent with the configuration of the standard composite liner of 40 CFR §257.70(b). The composite liner will be installed over the floor and sideslopes of the proposed expansion area and will be anchored at the top of the sideslopes beyond the limit of waste (see Detail 16 on **Drawing B-C-00G-177**). Therefore, the liner will cover all ground surface likely to be in contact with CCR or leachate. Further, the Construction Quality Assurance Plan (CQA) for the CBL (Geosyntec, 2022a) requires that the surface of the compacted clay liner be rolled with a flat wheel roller to create a smooth uniform surface for geomembrane placement and that the geomembrane be placed in a manner that minimizes geomembrane wrinkles.

The CQA Plan includes procedures for developing a stable foundation for liner construction. It requires that prior to construction of the compacted clay liner, the liner subgrade be inspected to verify that it is free of debris, organic matter, standing water, or excess moisture, It also requires that the subgrade be proof rolled to confirm that there is not excessive pumping, rutting, or deflection that could adversely affect the stability of the subgrade (and overlying liner).

The composite liner will be constructed with materials that are chemically compatible with CCR. HPDE geomembranes are nearly chemically inert under most exposure conditions because of their semi-crystallinity and relatively inert molecular structure. HDPE generally does not react with most chemicals because it does not have reactive sites. This is supported by the results of numerous chemical compatibility and HDPE aging tests presented in the technical literature (Dudzik and Tisinger, 1990; Tisinger and Giroud, 1993; Sangam and Rowe, 2002; Rowe et al., 2010).

The selected geomembrane is the most common type of geomembrane used for landfill liner and cover systems. It has sufficient thickness and strength to prevent failure due to stresses caused during installation, when concentrated stresses on the geomembrane should be the highest. The specified thickness and strength of the geomembrane is included in the CQA Plan (Geosyntec, 2022a). After installation, the geomembrane will be protected from construction stresses by the placement of the overlying double-sided geocomposite and 2-ft thick soil protective cover layer. Further, the CQA Plan includes construction provisions designed to protect the geomembrane during construction, such as limiting the ground pressure of equipment trafficking over the geomembrane unless there is a sufficient thickness of soil cover over the geomembrane. During operation, the geomembrane will be protected from concentrated stresses by the overlying liner system and waste materials.

The liner system will be constructed of materials that provide appropriate interface shear resistance between the geomembrane and compacted soil layer to prevent sliding of the geomembrane. The selected geomembrane is textured to enhance this interface strength. Further, the slope stability analysis of the CBL conducted by Geosyntec (2022c) indicated that the calculated factors of safety exceed the minimum value of 1.5 recommended by TCEQ (2020) for CCR landfills under typical conditions.

4. LCRS DESIGN FOR FUTURE EXPANSION CELLS

4.1 Overview

In accordance with 30 TAC §352.701, which adopts by reference 40 CFR §257.70, new CCR landfills and any lateral expansion must be designed, constructed, operated, and maintained with a leachate collection and removal system (LCRS) that meets the requirements of 40 CFR §257.70(d). There are no LCRS requirements for existing CCR landfill areas in 30 TAC §352.701. Therefore, LCRSs for Cell 1 and Subcell 2D are not addressed in this section.

4.2 LCRS Requirements

In accordance with 40 CFR §257.70(d), the LCRS for the CBL must be designed, constructed, operated, and maintained to collect and remove leachate from the landfill during the active life and post-closure period. The LCRS must be:

- designed to maintain less than a 12-inch (30-cm) depth of leachate over the composite liner;
- constructed of materials that are chemically compatible with the CCR and have sufficient strength and thickness to prevent failure due to pressure gradients, physical contact with CCR or leachate, and stresses exerted during installation and operation; and
- designed and operated to minimize clogging during the active life and post-closure care period.

4.3 LCRS Design

The LCRS for the expansion area includes the double-sided geocomposite components of the liner system (see Detail 14 on **Drawing B-C-00G-177**) and associated 6-in. diameter standard dimension ratio (SDR)-11 HDPE piping (**Drawings B-C-00G-165, B-C-00G-180, and B-C-00G-181**). For each subcell, liquids collected in the geocomposite drainage layer and chimney drains will be conveyed to a leachate header pipe, leachate corridor pipe, and then subsurface drain pipe that flows to a leachate evaporation pond located south of the CBL (**Drawing B-C-00G-177)**. The floor of the subcells will be graded with at a slope of approximately 2.2%, and the piping will have a minimum slope of 1%.

The geocomposite and leachate piping will be constructed with materials that are chemically compatible with CCR. As previously mentioned HPDE is nearly chemically inert because of their semi-crystallinity and relatively inert molecular structure. Further, a polypropylene geotextile was selected for the geocomposite because of its excellent chemical resistance.

The selected geocomposite has sufficient thickness and strength to prevent failure due to stresses caused during installation, when concentrated stresses on the geomembrane should be the highest. The specified thickness of the geonet component of the geocomposite is included in the CQA Plan (Geosyntec, 2022a). In addition, the geotextile component of the geocomposite was specified with strength parameters that meet installation survivability criteria of Geosynthetic Research Institute (GRI) Standard GT-13 (GRI, 2012). After installation, the geocomposite will be protected from construction stresses by the placement of the 2-ft thick soil protective cover layer and then overlying CCR. Further, the CQA Plan includes construction provisions designed to protect the liner system geosynthetics during construction, such as limiting the ground pressure of equipment trafficking over the geocomposite unless there is a sufficient thickness of soil cover over the geocomposite. During operation, the geocomposite will be protected from concentrated stresses by the overlying liner system and waste materials.

Consistent with standard practice and as recommended by TCEQ guidance (2020), the geocomposite drainage layer is designed to keep the calculated liquid levels within the thickness of the geocomposite (i.e., within the 0.2 in. thick geonet). The leachate collection rate and maximum leachate head on the floor of the liner system were calculated for four operational scenarios expected in the future subcells of the landfill (i.e., initial, intermediate, final, and final conditions after installation of the final cover system) using the Hydrologic Evaluation of Landfill Performance (HELP) computer model, Version 3.07, developed by the U.S. Environmental Protection Agency (USEPA) (Schroeder, 1994a,b). The hydrologic processes considered in the HELP model include precipitation, surface-water evaporation, runoff, infiltration, plant transpiration, soil water evaporation, soil water storage, vertical drainage (saturated and unsaturated), lateral drainage (saturated), vertical drainage (saturated) through compacted soil liners, and leakage through geomembranes. The HELP model output for the four operational scenarios are included in Appendix C. For all evaluated scenarios, the peak daily average head on the geomembrane liner (i.e., level of liquid within the geocomposite) is less than the thickness of the geocomposite.

The design hydraulic conductivity of the geocomposite drainage layer was calculated for each operation case by varying hydraulic conductivity of the layer until the peak daily average head on the geomembrane liner was approximately equal to the thickness of the geosynthetic drainage layer. Then, the hydraulic conductivities were used to evaluate the critical geocomposite transmissivity to specify in the CQA Plan using the design methodologies presented in Giroud et al. (2000) and GRI-GC8 (2013). To account for the potential long-term reduction of transmissivity of the geocomposite drainage layer due to chemical clogging, reduction factors were used to calculate the minimum required in-plane hydraulic conductivity and equivalent transmissivity of the geocomposite drainage layer.

To minimize clogging, the geotextile component of the geocomposite was selected to meet filtration criteria with the clayey on-site soil that is anticipated to be used for protective cover. For this, the geotextile was evaluated with respect to a retention criterion, a permeability criterion, a porosity criterion, and a thickness criterion based on methods proposed by Holtz et al. (1998) and Giroud (2010).

The hydraulic capacity and structural stability of the leachate pipes were evaluated using the calculated peak daily leachate flow rates and estimated applied loads, respectively. The hydraulic analysis indicated that the 6-in. diameter pipes have sufficient capacity to convey the peak daily flows estimated by the HELP model. The results of the structural stability analysis indicate that the specified flexible pipes have sufficient strength to withstand the applied loads when the landfill is at its final grades. The potential failure mechanisms that were evaluated include: (i) wall crushing; (ii) wall buckling; (iii) excessive ring deflection; and (iv) excessive bending strain.

5. RUN-ON AND RUN-OFF CONTROLS

In accordance with 30 TAC §352.811, which adopts by reference 40 CFR §257.81, the run-on and run-off control systems for the CBL must be designed, constructed, operated, and maintained to prevent flow onto the active portion of the CBL and collect and control flow from the active portion of the CBL during the peak discharge from a 25-year, 24-hour storm event. In addition, run-off from the active portion of the CBL must be handled in accordance with the surface waste requirements of 40 CFR §257.3-3.

A Run-on and Run-off Control System Plan (Plan) was previously prepared for the CBL by Geosyntec (2021) and certified by a qualified professional engineer to document that the CBL complies with 40 CFR §257.81(a) and (b), 30 TAC §352.821, and TCEQ guidance (TCEQ, 2020). The Plan has been added to the facility's operating record and uploaded to the facility's publicly-accessible website (Fayette Power Project CCR Rule Compliance Data and Information - LCRA), and TCEQ has been notified that these steps have been taken.

6. INSPECTION

In accordance with 30 TAC §352.841, which adopts by reference 40 CFR §257.84, the CBL must be examined by a qualified person at intervals not exceeding seven days for appearance of actual or potential structural weakness and other conditions which are disrupting or have the potential to disrupt the operation of safety of the CCR unit. In addition, the CCR must be inspected annually by a qualified professional engineer to ensure that the design, construction, operation, and maintenance of the CCR unit is consistent with recognized and generally accepted engineering standards.

Weekly inspections for the CBL are being conducted LCRA qualified staff. The results of the weekly inspections are added to the facility's operating record. Annual inspections of the of the CBL by a qualified professional engineer are being conducted in accordance with 40 CFR §257.84(b). The annual inspection reports are being added to the facility's operating record and uploaded to the facility's publicly-accessible website (Fayette Power Project CCR Rule Compliance Data and Information - LCRA), and TCEQ has been notified that these steps have been taken.

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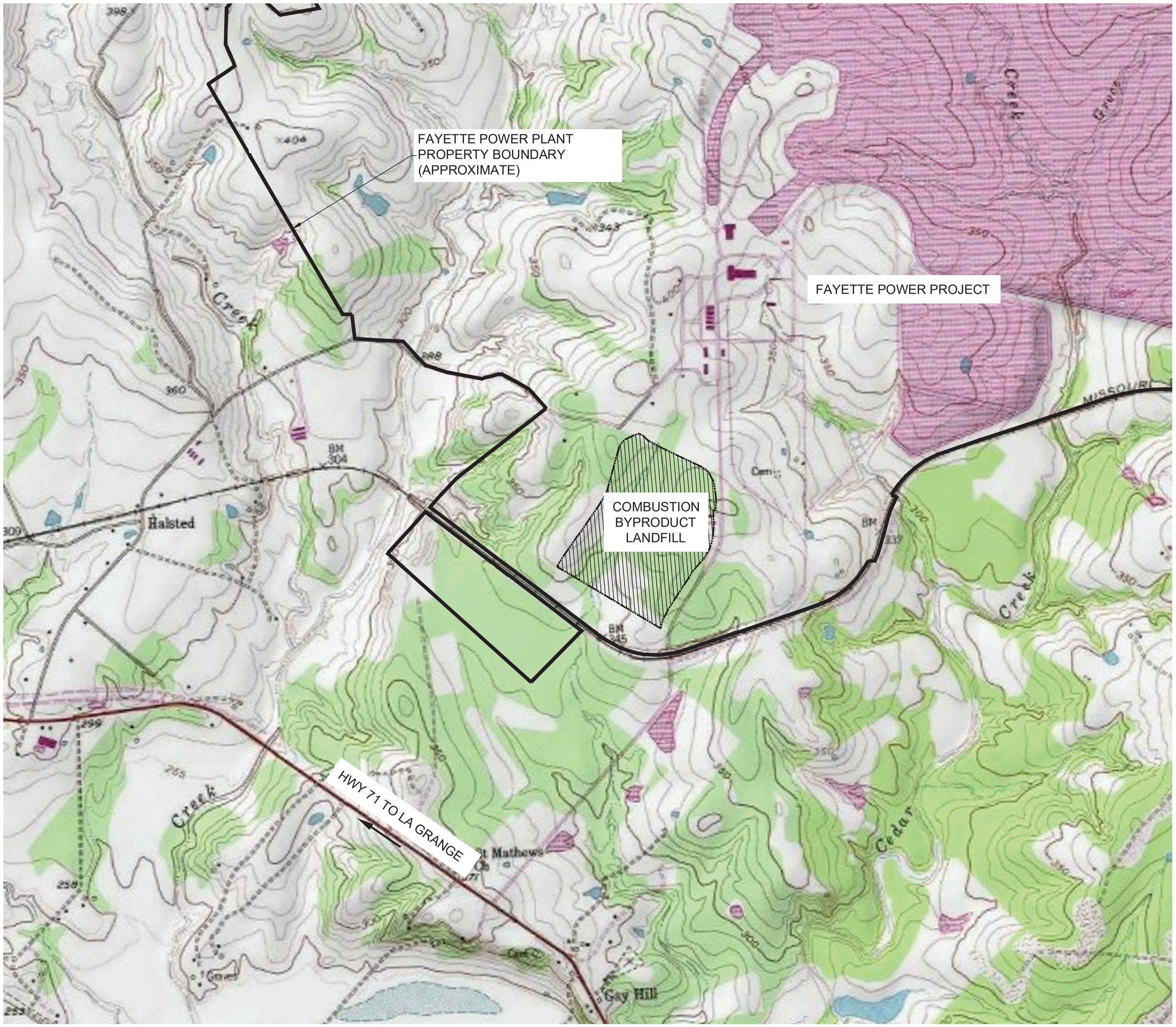
DRAWINGS



NOTE:

BASE MAP SOURCE: UNITED STATES GEOLOGIC SURVEY (USGS), 7.5 MINUTE SERIES QUADRANGLE (TOPOGRAPHIC) MAP OF LA GRANGE EAST, TEXAS 1957, REVISED 1981 AND FAYETTEVILLE, TEXAS 1958, REVISED 1981

0 800 1600
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

LCRA
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TITLE:
OVERALL SITE PLAN

PROJECT:
RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

SITE:
FAYETTE POWER PROJECT
COMBUSTION BYPRODUCT LANDFILL

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

Beth Gross
SIGNATURE
10.13.2016
DATE

STATE OF TEXAS
BETH ANN GROSS
79864
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DESIGN BY:	BG	DATE:	OCTOBER 2016
DRAWN BY:	JJV	PROJECT NO:	TXL0225.04
CHECKED BY:	BG	FILE:	TXL0225CCRR1
REVIEWED BY:	BG	DRAWING NO.:	
APPROVED BY:	BG	1 OF 8	

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LEGEND

Symbol	Description
350	EXISTING GROUND ELEVATION (FT,MSL) (NOTES 1,2)
(350)	EXISTING TOP OF CLAY LINER ELEVATION (FT,MSL) (NOTE 2)
	EXISTING ROAD
	EXISTING BUILDING
	EXISTING RAILROAD
	EXISTING VEGETATION / TREE
N 9949000 E 3428000	COORDINATE GRID (NOTE 2)
	EXISTING FENCE
	EXISTING LIMIT OF LANDFILL
	EXISTING LIMIT OF FINAL COVER
P P	EXISTING POWER POLE AND OVERHEAD POWER LINE
	EXISTING COMBUSTION WASTE FORCE MAIN
	PROPOSED PHASE BOUNDARY
	PROPOSED LIMIT OF WASTE

NOTES:

1. THE EXISTING CONTOUR BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING AN AERIAL SURVEY BASED ON PHOTOGRAPHY PERFORMED ON 23 NOVEMBER 2020 BY SKYVEYOR.
2. ELEVATIONS ARE IN FEET (FT) AS DEFINED BY THE NORTH AMERICAN VERTICAL DATUM (NAVD) OF 1988. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS CENTRAL ZONE (4203), NORTH AMERICAN DATUM 83 (NAD-83) 1983.
3. EXISTING COMBUSTION WASTE FORCE MAIN CONVEYS WATER FROM EXISTING RUNOFF RETENTION POND TO RECLAIM POND.

0 140 280
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

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GEOSYNTEC CONSULTANTS, INC.
TEXAS ENG. FIRM REGISTRATION NUMBER 1182
8217 SHOAL CREEK BLVD, SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: EXISTING SITE CONDITIONS

PROJECT: RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

SITE: FAYETTE POWER PROJECT
COMBUSTION BYPRODUCT LANDFILL

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

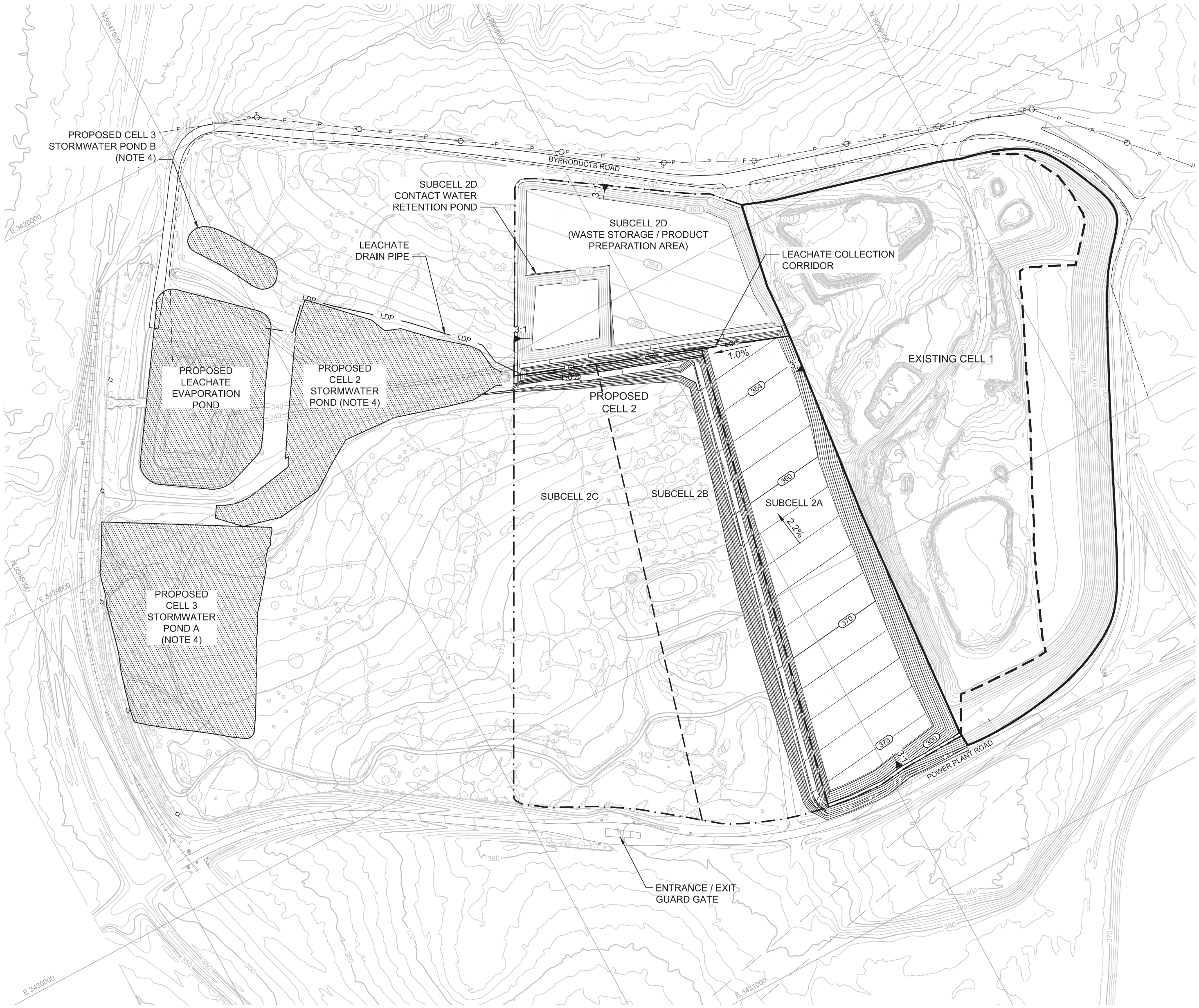
Beth Ann Gross
SIGNATURE
8/11/2021
DATE

STATE OF TEXAS
BETH ANN GROSS
79864
LICENSED PROFESSIONAL ENGINEER

DESIGN BY:	BG	DATE:	JULY 2021
DRAWN BY:	JJV	PROJECT NO.:	TXL0225.04
CHECKED BY:	BG	FILE:	TXL0225CCRR2
REVIEWED BY:	BG	DRAWING NO.:	
APPROVED BY:	BG	2 OF 8	

ENGINEERING DESIGN DRAWING

P:\CAD\PROJECTS\FAYETTE POWER PLANT\ENG DESIGN\CCR RULE COMPLIANCE (TXL0225.08)\RUN-OFF CONTROL PLANS\DRAWINGS\TXL0225CCRR2



LEGEND

Symbol	Description
350	EXISTING GROUND ELEVATION (FT,MSL) (NOTES 1,2)
(350)	EXISTING TOP OF LINER ELEVATION (FT,MSL))
	EXISTING ROAD
	EXISTING RAILROAD
	EXISTING COMBUSTION WASTE FORCE MAIN
P P	EXISTING POWER POLE AND OVERHEAD POWER LINE
	EXISTING VEGETATION / TREE
N 9949000 E 3428000	COORDINATE GRID (NOTE 2)
	EXISTING LIMIT OF LANDFILL
	EXISTING LIMIT OF FINAL COVER
	PROPOSED LIMIT OF WASTE
	PROPOSED PHASE BOUNDARY
(330)	PROPOSED TOP OF LINER ELEVATION (FEET) (NOTE 3)
LCC	PROPOSED LEACHATE COLLECTION CORRIDOR
LDP	PROPOSED LEACHATE DRAIN PIPE

NOTES:

1. THE EXISTING CONTOUR BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING AN AERIAL SURVEY BASED ON PHOTOGRAPHY PERFORMED ON 23 OCTOBER 2013 BY SURDEX CORPORATION AND LIDAR DATA PUBLISHED DECEMBER 2008 AND PROVIDED BY LCRA SURVEYING, MAPPING, AND GIS.
2. ELEVATIONS ARE IN FEET (FT) AS DEFINED BY THE NORTH AMERICAN VERTICAL DATUM (NAVD) OF 1988. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS CENTRAL ZONE (4203), NORTH AMERICAN DATUM 83 (NAD-83) 1983.
3. LANDFILL BASE GRADES MAY BE ADJUSTED BASED ON SUBSURFACE CONDITIONS.
4. STORMWATER PONDS TO BE CONSTRUCTED IN SEQUENCE WITH LANDFILL OPERATIONS. CELL 2 STORMWATER POND TO BE DECOMMISSIONED PRIOR TO CELL 3 LANDFILL CONSTRUCTION. CELL 3 STORMWATER POND MAY BE CONSTRUCTED IN LIEU OF CELL 2 STORMWATER POND.

0 150 300
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

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TEXAS ENG. FIRM REGISTRATION NUMBER 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: SUBCELLS 2A & 2D BASE GRADING PLAN

PROJECT: RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

SITE: FAYETTE POWER PROJECT
COMBUSTION BYPRODUCT LANDFILL

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

Beth Gross
SIGNATURE
10.13.2016
DATE

STATE OF TEXAS
BETH ANN GROSS
79864
LICENSED PROFESSIONAL ENGINEER

DESIGN BY:	BG	DATE:	OCTOBER 2016
DRAWN BY:	JJV	PROJECT NO.:	TXL0225.04
CHECKED BY:	BG	FILE:	TXL0225CCRR4
REVIEWED BY:	BG	DRAWING NO.:	
APPROVED BY:	BG	4 OF 8	

ENGINEERING DESIGN DRAWING

P:\CADD PROJECTS\FAYETTE POWER PLANT\ENG DESIGN\CCR RULE COMPLIANCE (TXL0225.08)\RUNON-OFF CONTROL PLANS\DRAWINGS\TXL0225CCRR4

LEGEND

Symbol	Description
350	EXISTING GROUND ELEVATION (FT, MSL) (NOTE 1)
	EXISTING ROAD
	EXISTING VEGETATION / TREE
N 9949000 E 3428000	COORDINATE GRID (NOTE 1)
	EXISTING FENCE
	EXISTING LIMIT OF LANDFILL
	EXISTING UNDERGROUND RUNOFF DISCHARGE PIPE
CBL	EXISTING GROUNDWATER MONITORING WELL
	PROPOSED LIMIT OF LINER
330	PROPOSED TOP OF LINER ELEVATION (FT, MSL)
LCC	PROPOSED LEACHATE COLLECTION CORRIDOR
	PROPOSED LEACHATE COLLECTION CHIMNEY DRAIN
	PROPOSED LEACHATE HEADER PIPE
LDP	PROPOSED LEACHATE DRAIN PIPE
	VALVE
	SUBCELL BERM

NOTE:

1. THE EXISTING CONTOUR BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING AN AERIAL SURVEY BASED ON PHOTOGRAPHY PERFORMED ON 23 OCTOBER 2020 BY SKYVEYOR AND LIDAR DATA PUBLISHED DECEMBER 2008 PROVIDED BY LCRA SURVEYING, MAPPING, AND GIS.

0 100' 200'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP
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TEXAS ENG. FIRM REGISTRATION NO. 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: LEACHATE COLLECTION SYSTEM PLAN

PROJECT: COMBUSTION BYPRODUCT LANDFILL EXPANSION

SITE: FAYETTE POWER PROJECT COMBUSTION BYPRODUCT LANDFILL

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

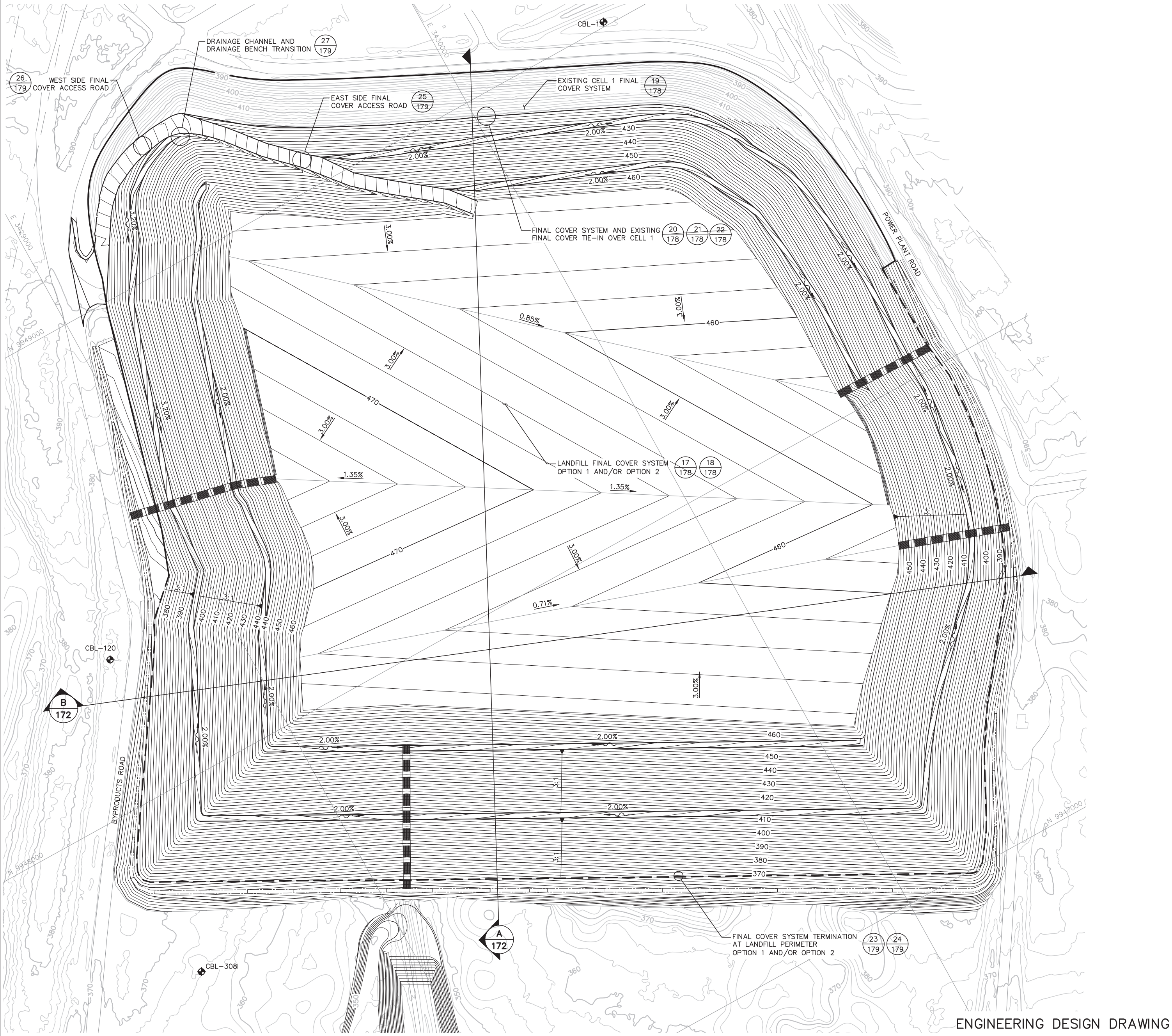
Beth Gross
SIGNATURE
1/12/2022
DATE

STATE OF TEXAS
BETH ANN GROSS
79864
LICENSED
PROFESSIONAL ENGINEER

DESIGN BY: MZI		DATE:	JANUARY 2022
DRAWN BY: JJV/KH		PROJECT NO.:	FL8518.01
CHECKED BY: MZI		FILE:	B-C-00G-164
REVIEWED BY: BG		DRAWING NO.:	
APPROVED BY: BG			B-C-00G-165

ENGINEERING DESIGN DRAWING

DRAWING: P:\CADD\Projects\F\Fayette Power Plant\ENG DESIGN\Expansion (TXL0225)\Drawings\B-C-00G-164.dwg PLOTTED: Jan 23, 2022 - 11:22pm



LEGEND

350	EXISTING GROUND ELEVATION (FT, MSL) (NOTE 1)
	EXISTING ROAD
	EXISTING VEGETATION / TREE
N 9949000 E 3428000	COORDINATE GRID (NOTE 1)
	EXISTING FENCE
	EXISTING UNDERGROUND RUNOFF DISCHARGE PIPE
CBL	EXISTING GROUNDWATER MONITORING WELL
	EXISTING LIMIT OF LANDFILL
	PROPOSED LIMIT OF LANDFILL
420	PROPOSED TOP OF FINAL COVER ELEVATION (FT, MSL)
	PROPOSED DRAINAGE DOWNCHUTE
	PROPOSED DRAINAGE TERRACE
	PROPOSED DRAINAGE BENCH
	PROPOSED PERIMETER DRAINAGE CHANNEL

NOTES:

1. THE EXISTING CONTOUR BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING AN AERIAL SURVEY BASED ON PHOTOGRAPHY PERFORMED ON 23 OCTOBER 2020 BY SKYVEYOR AND LIDAR DATA PUBLISHED DECEMBER 2008 PROVIDED BY LCRA SURVEYING, MAPPING, AND GIS.

0 100' 200'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP
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TEXAS ENG. FIRM REGISTRATION NO. 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: FINAL COVER GRADING PLAN

PROJECT: COMBUSTION BYPRODUCT LANDFILL EXPANSION

SITE: FAYETTE POWER PROJECT
COMBUSTION BYPRODUCT LANDFILL

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

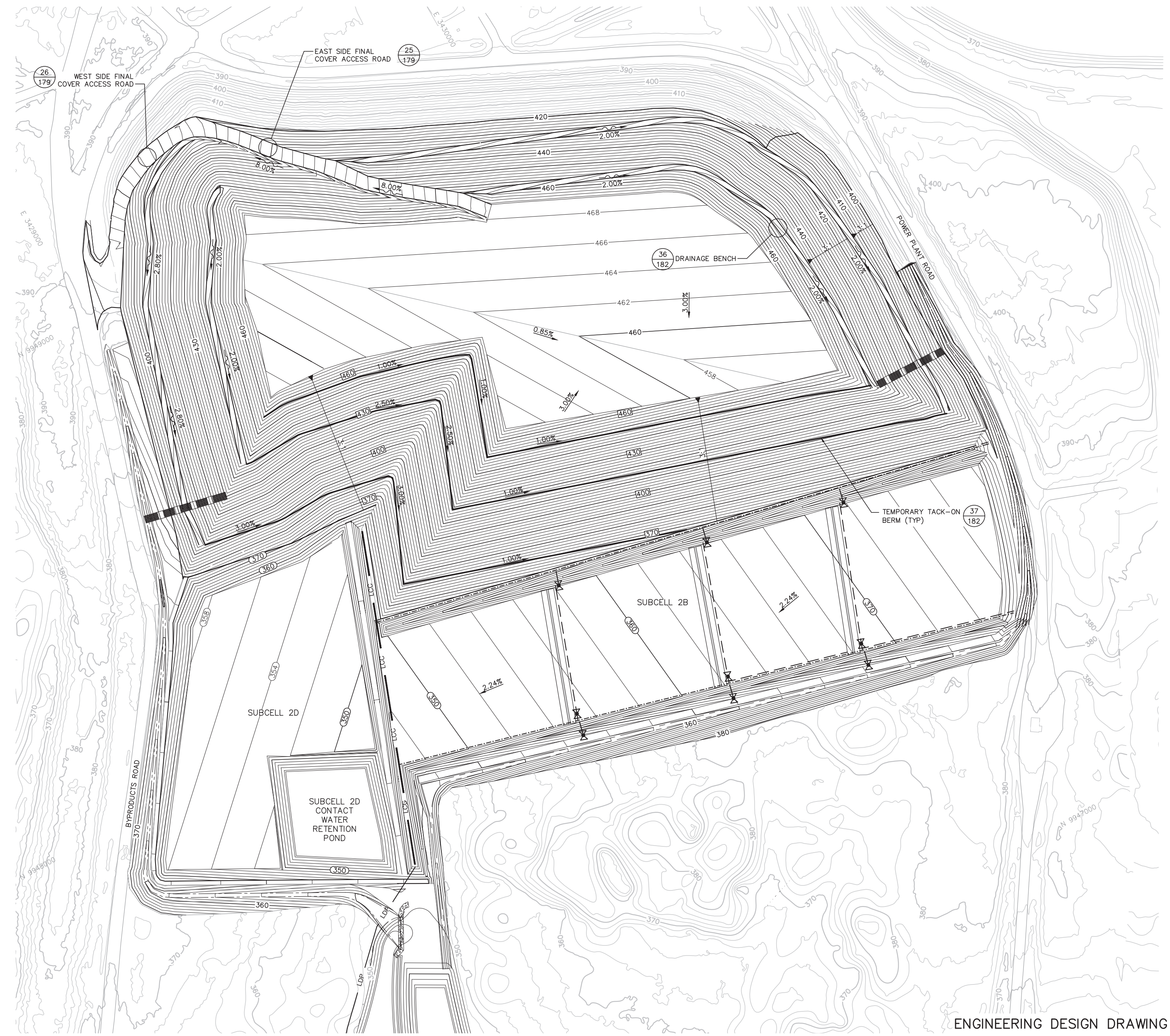
Beth Gross
SIGNATURE
1/12/2022
DATE

STATE OF TEXAS
BETH ANN GROSS
79864
LICENSED
PROFESSIONAL ENGINEER

DESIGN BY:	MZI	DATE:	JANUARY 2022
DRAWN BY:	JJV/KH	PROJECT NO.:	FL8518.01
CHECKED BY:	MZI	FILE:	B-C-00G-165
REVIEWED BY:	BG	DRAWING NO.:	
APPROVED BY:	BG		B-C-00G-166

ENGINEERING DESIGN DRAWING

DRAWING: P:\CADD\Projects\F\Fayette Power Plant\ENG DESIGN\Expansion (TXL0225)\Drawings\B-C-00G-165.dwg PLOTTED: Jan 23, 2022 - 11:23pm



LEGEND

350	EXISTING GROUND ELEVATION (FT, MSL) (NOTE 1)
	EXISTING ROAD
	EXISTING VEGETATION / TREE
N 9949000 E 3428000	COORDINATE GRID
330	PROPOSED FINISHED GROUND ELEVATION (FT, MSL)
(350)	PROPOSED TOP OF CLAY ELEVATION (FT, MSL)
[460]	PROPOSED INTERIM WASTE ELEVATION (FT, MSL)
LCC	LEACHATE COLLECTION CORRIDOR
LDP	LEACHATE COLLECTION DRAIN PIPE
	PROPOSED DOWNCHUTE
	PROPOSED DRAINAGE BENCH
	PROPOSED TEMPORARY TACK-ON BERM
	PROPOSED DRAINAGE TERRACE

NOTES:

1. THE EXISTING CONTOUR BASE MAP SHOWN ON THIS DRAWING WAS COMPILED USING AN AERIAL SURVEY BASED ON PHOTOGRAPHY PERFORMED ON 23 OCTOBER 2020 BY SKYVEYOR AND LIDAR DATA PUBLISHED DECEMBER 2008 PROVIDED BY LCRA SURVEYING, MAPPING, AND GIS.

0 100' 200'
SCALE IN FEET

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TEXAS ENG. FIRM REGISTRATION NO. 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: LANDFILL FILLING PLAN – SUBCELL 2A

PROJECT: COMBUSTION BYPRODUCT LANDFILL EXPANSION

SITE: FAYETTE POWER PROJECT COMBUSTION BYPRODUCT LANDFILL

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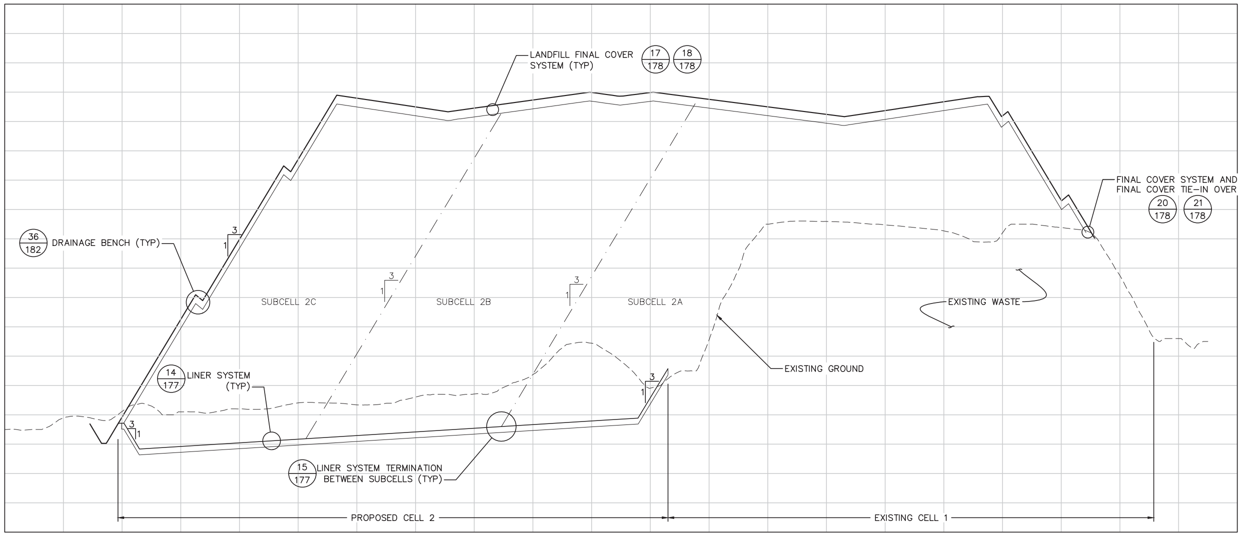
Beth Gross
SIGNATURE
1/12/2022
DATE

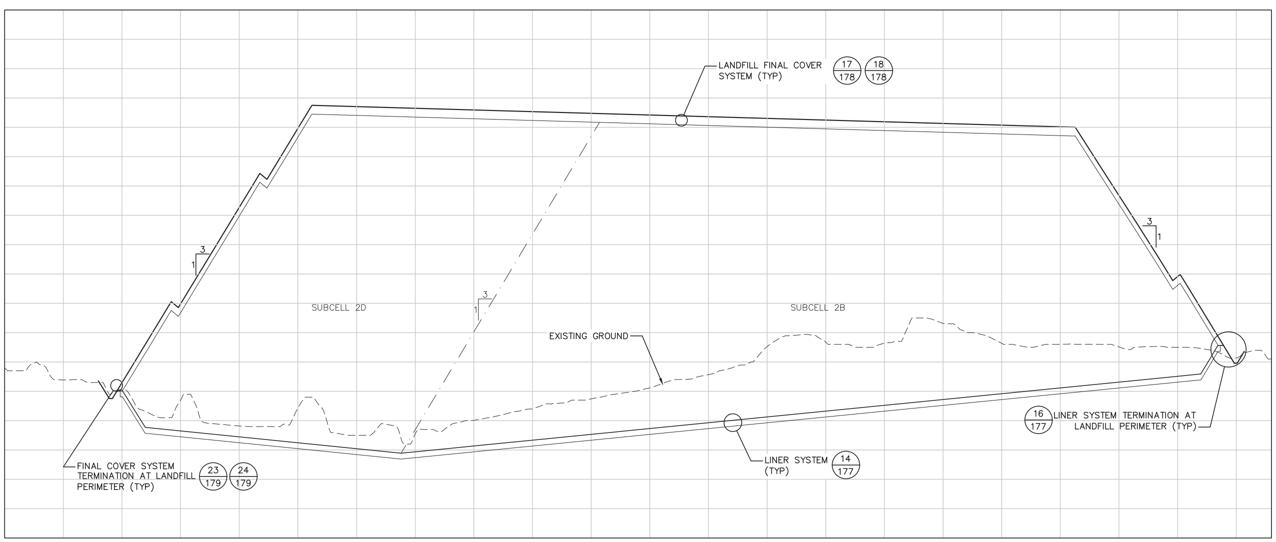
STATE OF TEXAS
BETH ANN GROSS
79864
LICENSED
PROFESSIONAL ENGINEER

DESIGN BY:	MZI	DATE:	JANUARY 2022
DRAWN BY:	JJV/KH	PROJECT NO.:	FL8518.01
CHECKED BY:	RN	FILE:	B-C-00G-166
REVIEWED BY:	BG	DRAWING NO.:	
APPROVED BY:	BG		B-C-00G-168

DRAWING: P:\CADD\Projects\F\Fayette Power Plant\ENG DESIGN\Expansion (TXL0225)\Drawings\B-C-00G-166.dwg PLOTTED: Jan 23, 2022 - 11:27pm



A/164 SECTION A
SOUTH–NORTH FINAL CROSS–SECTION



B/164 SECTION B
WEST–EAST FINAL CROSS–SECTION

ENGINEERING DESIGN DRAWING

VERTICAL SCALE IN FEET: 0, 20', 40'
HORIZONTAL SCALE IN FEET: 0, 100', 200'

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8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: LANDFILL CROSS SECTIONS

PROJECT: COMBUSTION BYPRODUCT LANDFILL EXPANSION

SITE: FAYETTE POWER PROJECT
COMBUSTION BYPRODUCT LANDFILL

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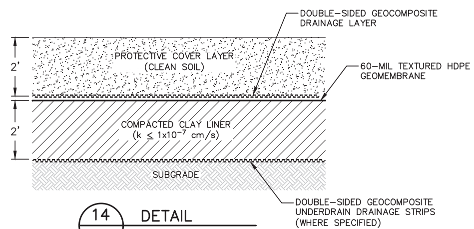
Beth Gross
SIGNATURE
1/12/2022
DATE

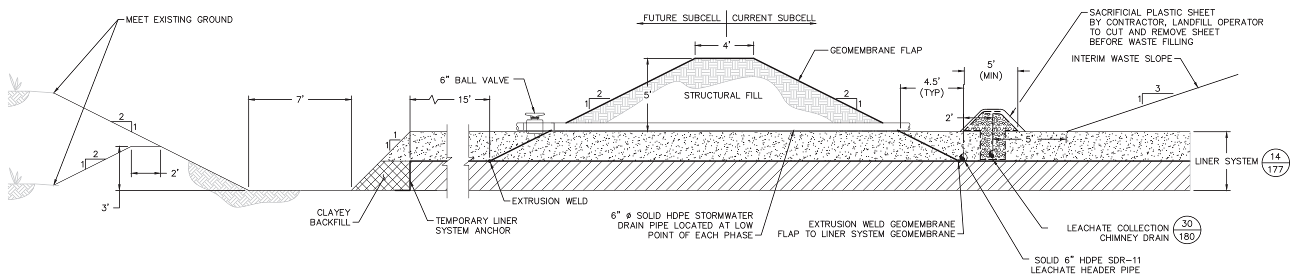
STATE OF TEXAS
BETH ANN GROSS
79864
LICENSED PROFESSIONAL ENGINEER

DESIGN BY: MZI	DATE: JANUARY 2022
DRAWN BY: JJV/KH	PROJECT NO.: FL8518.01
CHECKED BY: MZI	FILE: B-C-00G-170
REVIEWED BY: BG	DRAWING NO.:
APPROVED BY: BG	B-C-00G-172

DRAWING: P:\CADD\Projects\F\Fayette Power Plant\ENG DESIGN\Expansion (TXL0225)\Drawings\B-C-00G-170.dwg PLOTTED: Jan 23, 2022 - 11:10pm



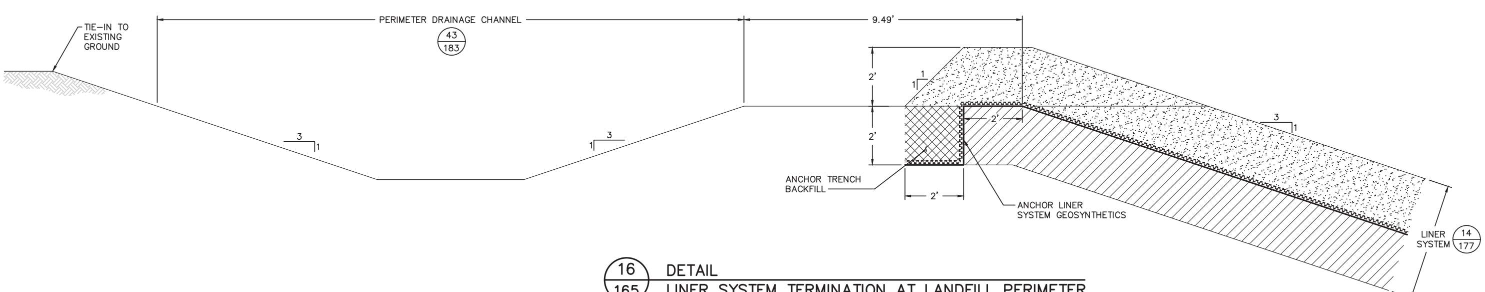
14/165 DETAIL
LINER SYSTEM
SCALE: 1" = 2'
0 2' 4'
SCALE IN FEET



15/167 DETAIL
LINER SYSTEM TERMINATION BETWEEN SUBCELLS
SCALE: 1" = 4'
0 4' 8'
SCALE IN FEET

NOTE:

1. DETAILS ARE DRAWN TO SCALE AS NOTED EXCEPT FOR GEOSYNTHETICS WHICH MAY BE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.



16/165 DETAIL
LINER SYSTEM TERMINATION AT LANDFILL PERIMETER
SCALE: 1" = 2'
0 2' 4'
SCALE IN FEET

ENGINEERING DESIGN DRAWING

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TEXAS ENG. FIRM REGISTRATION NO. 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: LINER SYSTEM DETAILS

PROJECT: COMBUSTION BYPRODUCT LANDFILL EXPANSION

SITE: FAYETTE POWER PROJECT
COMBUSTION BYPRODUCT LANDFILL

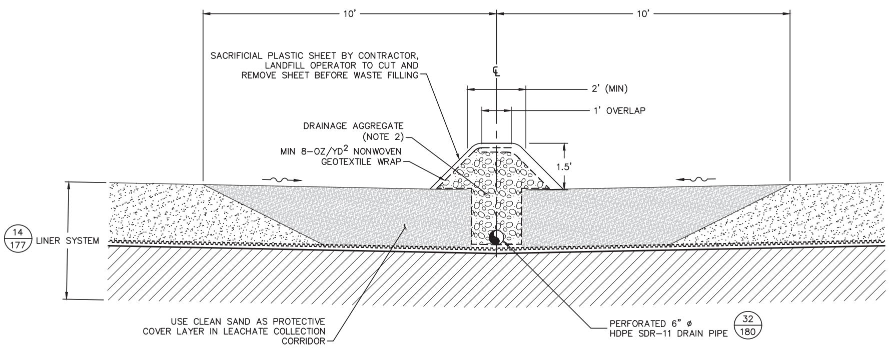
THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

Beth Gross
SIGNATURE
1/12/2022
DATE

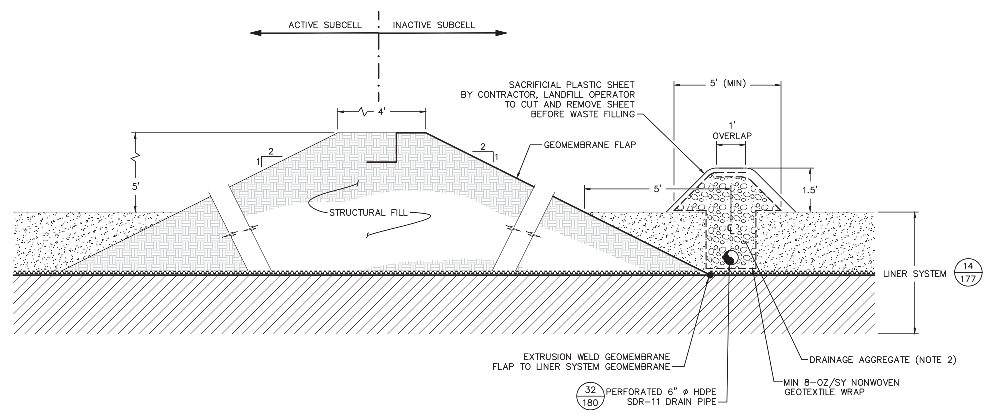
STATE OF TEXAS
BETH ANN GROSS
79864
LICENSED
PROFESSIONAL ENGINEER

DESIGN BY:	MZI	DATE:	JANUARY 2022
DRAWN BY:	JJV/KH	PROJECT NO.:	FL8518.01
CHECKED BY:	MZI	FILE:	B-C-00G-171
REVIEWED BY:	BG	DRAWING NO.:	
APPROVED BY:	BG		B-C-00G-177

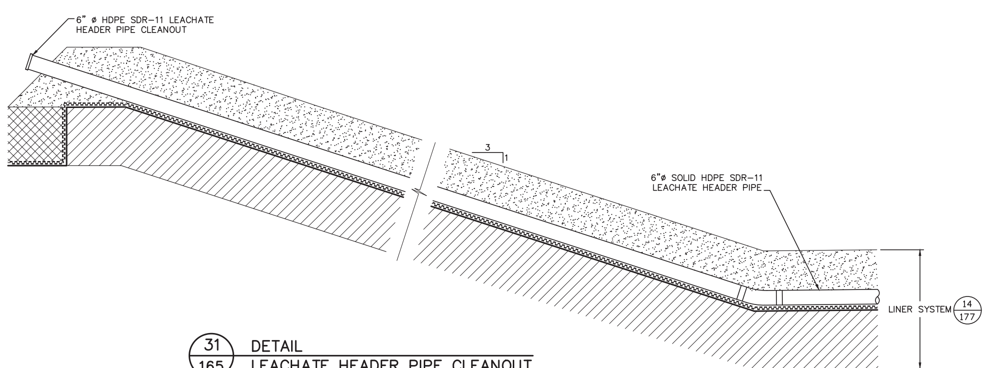
DRAWING: P:\CADD\Projects\F\Fayette Power Plant\ENG DESIGN\Expansion (TXL0225)\Drawings\B-C-00G-171.dwg PLOTTED: Jan 12, 2022 - 5:28pm



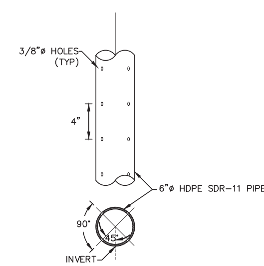
29/165 DETAIL
LEACHATE COLLECTION CORRIDOR AFTER SUBCELL 2D STORAGE AREA CONVERTED TO SUBCELL 2D LANDFILL
SCALE: 1" = 2'



30/165 DETAIL
LEACHATE COLLECTION CHIMNEY DRAIN
SCALE: 1" = 2'



31/165 DETAIL
LEACHATE HEADER PIPE CLEANOUT
SCALE: 1" = 2'



32/180 DETAIL
LEACHATE COLLECTION PIPE PERFORATIONS
SCALE: NOT TO SCALE

NOTES:

1. DETAILS ARE DRAWN TO SCALE AS NOTED EXCEPT FOR GEOSYNTHETICS WHICH MAY BE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. DRAINAGE AGGREGATE SHALL BE AASHTO #57 STONE CONSISTING OF NATURAL STONE OR GRAVEL, SUBROUNDED TO SUBANGULAR. FREE OF SHALE, CLAY, ORGANICS, FOREIGN OBJECTS FRIABLE MATERIALS, AND DEBRIS.

REV	DATE	DESCRIPTION	DRN	APP
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8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: LEACHATE COLLECTION SYSTEM DETAILS I

PROJECT: COMBUSTION BYPRODUCT LANDFILL EXPANSION

SITE: FAYETTE POWER PROJECT COMBUSTION BYPRODUCT LANDFILL

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

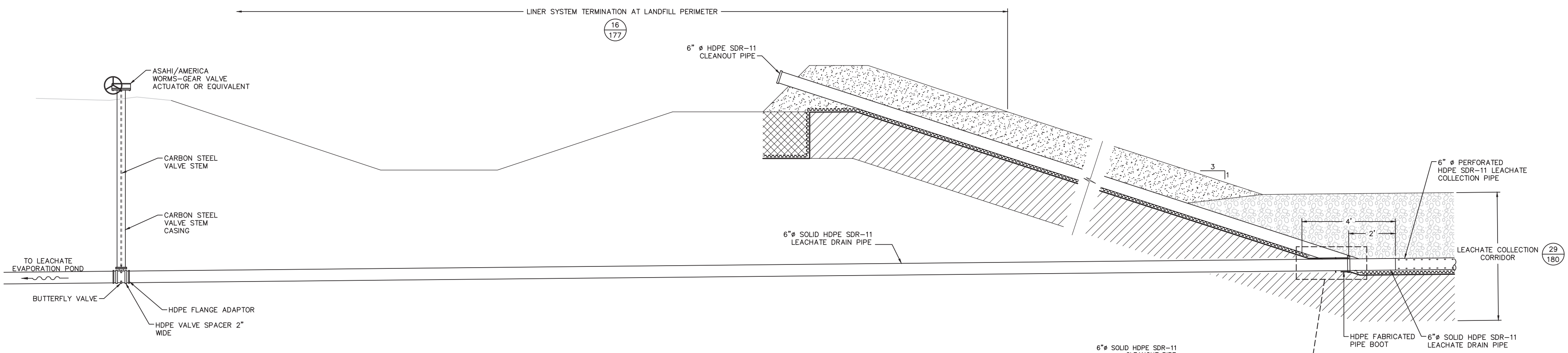
Beth Gross
SIGNATURE
1/12/2022
DATE

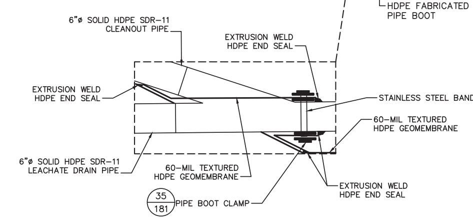
STATE OF TEXAS BETH ANN GROSS 79864 LICENSED PROFESSIONAL ENGINEER

DESIGN BY:	MZI	DATE:	JANUARY 2022
DRAWN BY:	JJV/KH	PROJECT NO.:	FL8518.01
CHECKED BY:	MZI	FILE:	B-C-00G-174
REVIEWED BY:	BG	DRAWING NO.:	
APPROVED BY:	BG	B-C-00G-180	

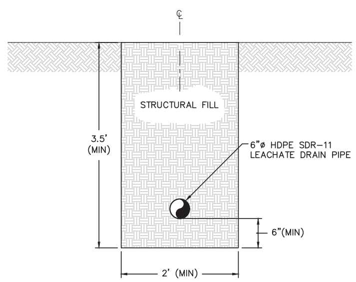
ENGINEERING DESIGN DRAWING

DRAWING: P:\CADD\Projects\F\Fayette Power Plant\ENG DESIGN\Expansion (TXL0225)\Drawings\B-C-00G-174.dwg PLOTTED: Jan 12, 2022 - 5:31pm

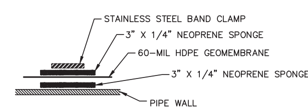




33/165 DETAIL
LEACHATE COLLECTION PIPE AT LANDFILL PERIMETER
SCALE: 1" = 2'
0 2' 4'
SCALE IN FEET



34/165 DETAIL
LEACHATE DRAIN PIPE TRENCH
SCALE: 1" = 1'
0 1' 2'
SCALE IN FEET



35/181 DETAIL
PIPE BOOT CLAMP
SCALE: NOT TO SCALE

NOTE:

1. DETAILS ARE DRAWN TO SCALE AS NOTED EXCEPT FOR GEOSYNTHETICS WHICH MAY BE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.

REV	DATE	DESCRIPTION	DRN	APP
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TEXAS ENG. FIRM REGISTRATION NO. 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: LEACHATE COLLECTION SYSTEM DETAILS II

PROJECT: COMBUSTION BYPRODUCT LANDFILL EXPANSION

SITE: FAYETTE POWER PROJECT COMBUSTION BYPRODUCT LANDFILL

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

Beth Gross
SIGNATURE
1/12/2022
DATE

STATE OF TEXAS
BETH ANN GROSS
79864
LICENSED PROFESSIONAL ENGINEER

DESIGN BY: MZI		DATE:	JANUARY 2022
DRAWN BY: JJV/KH		PROJECT NO.:	FL8518.01
CHECKED BY: MZI		FILE:	B-C-00G-175
REVIEWED BY: BG		DRAWING NO.:	
APPROVED BY: BG		B-C-00G-181	

ENGINEERING DESIGN DRAWING

DRAWING: P:\CADD\Projects\F\Fayette Power Plant\ENG DESIGN\Expansion (TXL0225)\Drawings\B-C-00G-175.dwg PLOTTED: Jan 12, 2022 - 5:32pm

APPENDICES

APPENDIX A

Certification by a Qualified Professional Engineer

CERTIFICATION BY A QUALIFIED PROFESSIONAL ENGINEER

The report was prepared by Geosyntec under the direction of Dr. Beth Ann Gross, P.E., a qualified professional engineer, in accordance with 30 TAC §352.231(d) and 30 TAC §352.4.

I certify that the design of the composite liner for the Combustion Byproduct Landfill at the Fayette Power Project (FPP) meets the liner design criteria of 40 CFR §257.70(b) and (d).

Beth Ann Gross
Printed Name of Licensed Professional Engineer

Signature

January 22, 2020
Date

Geosyntec Consultants, Inc.
Texas Registered Engineering Firm
No. F-1182

APPENDIX B

Construction Quality Assurance Plan

Prepared for

ENERGY • WATER • COMMUNITY SERVICES

Lower Colorado River Authority
P.O. Box 220
Austin, Texas 78767

CONSTRUCTION QUALITY ASSURANCE PLAN

COMBUSTION BYPRODUCT LANDFILL
FAYETTE POWER PROJECT
FAYETTE COUNTY, TEXAS

Beth Ann Gross

STATE OF TEXAS
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1. INTRODUCTION

1.1 Purpose

This Construction Quality Assurance Plan (CQA Plan) establishes the material requirements; construction installation requirements; quality control (QC) program; and quality assurance (QA) monitoring, testing, documentation, and reporting procedures that will be used during construction of the soils and geosynthetics components of the liner system for Cells 2 (Subcells A-C) and 3 of the Combustion Byproduct Landfill (CBL) at the Lower Colorado River Authority (LCRA) Fayette Power Project (FPP) site (Site). Specifically, this CQA Plan addresses the structural fill, compacted soil liner, geomembrane liner, geocomposite drainage layer, leachate collection system aggregate, and protective cover layer components of the work.

This CQA Plan was developed in general accordance with the Texas Commission on Environmental Quality (TCEQ) guidance for CQA of liner systems for municipal solid waste landfills ("Guidance for Liner Construction and Testing for a Municipal Solid Waste Landfill", RG-534, TCEQ Waste Permits Division, September 2017) and also considers the technical guidance presented by the U.S. Environmental Protection Agency (EPA) for CQA of waste containment facilities ("Quality Assurance and Quality Control for Waste Containment Facilities," EPA/600/R-93/182, October 1993).

1.2 Definitions of Quality Assurance and Quality Control

In the context of this document, it is important to distinguish between CQA and construction QC (CQC). These terms are defined as follows:

- CQA refers to methods and actions employed by CQA personnel to provide confidence that an item or service meets the conformance requirements for a liner system component and installation described in this CQA Plan, contractual and regulatory requirements, and construction-level project plans, and will perform satisfactory in service. CQA is provided by a third-party consultant, hired by the Owner, who is independent from production and installation (i.e., independent of the Earthwork Contractor, Geosynthetics Manufacturer, Geosynthetics Installer, and any other material suppliers).

- CQC refers to those actions which provide a means to measure and control the characteristics of an item or service to meet contractual and regulatory requirements. Thus, CQC refers to those actions taken by the Earthwork Contractor, Geosynthetics Installer, and Geosynthetics Manufacturer to ensure that the materials and the workmanship meet the requirements of the construction-level project plans and specifications. In the case of soils, CQC is often combined with CQA and provided by the CQA Consultant. In the case of geosynthetics, CQC is provided by the manufacturers and installers of the various geosynthetics.

1.3 Description of Project Parties

The project parties who may be involved in the construction of the liner system for CBL Cells 2 (Subcells A-C) and 3 are described below.

- Owner. The Owner owns and/or is responsible for overall management of the Site and is responsible for complying with the provisions of the registration and of applicable state and federal regulations.

- Project Manager. The Project Manager is the official representative of the Owner. A key role of the Project Manager is to oversee CQA and CQC, hire CQA/CQC consultants and surveyors, manage contractor bidding and procurement, and review/approve project expenditures. Typically, the Project Manager also serves as a liaison between all parties involved in construction, to help ensure that lines of communication are maintained.

- Design Engineer. The Design Engineer is a Texas licensed Professional Engineer (P.E.) responsible for the design of the liner system. The Design Engineer may also be responsible for preparation of the construction-level project plans and specifications.

- Earthwork Contractor. The Earthwork Contractor (Contractor) is responsible for the preparation of the subgrade and placement of the soils components of the liner system and associated facilities.

- Supplier. The Supplier is responsible for supplying any man-made liner system material.

- Geosynthetics Manufacturer. The Geosynthetics [e.g., Geomembrane, Geotextile, and Geocomposite (i.e., bonded geonet-geotextile combination)] Manufacturer (Manufacturer) is responsible for the production of materials such as the geomembrane and geonet rolls from resin, geotextile rolls from fiber, and geocomposite rolls (bonding of geotextile and geonet).

- Geosynthetics Installer. The Geosynthetics Installer (Installer) is responsible for field handling, storing, placing, seaming, loading (against wind), and other aspects of the geosynthetics installation. The Installer may also be responsible for transportation of these materials to the site and for construction of the anchor trenches.

- Soils CQA Consultant. The Soils CQA Consultant is a party, independent from the Owner, Contractor, Manufacturer, and Installer, that is responsible for observing, testing and documenting activities related to the CQA of the earthworks at the site. The Soils CQA Consultant includes the Soils CQA Engineer, a Texas licensed P.E. who is responsible for issuing a signed and sealed CQA Certification Report for soils.

- Geosynthetics CQA Consultant. The Geosynthetics CQA Consultant is a party, independent from the Owner, Contractor, Manufacturer, and Installer, that is responsible for observing, testing, and documenting activities related to the CQA of the geosynthetics. The Geosynthetics CQA Consultant includes the Geosynthetics CQA Engineer, a Texas licensed P.E. who is responsible for issuing a signed and sealed CQA Certification Report for geosynthetics. Soils CQA services and Geosynthetics CQA services may be provided by the same firm.

- Soils CQA Laboratory. The Soils CQA Laboratory is a party, independent from the Owner, Contractor, Manufacturer, and Installer, that is responsible for conducting tests in the field and/or in the laboratory on samples of soils.

- Geosynthetics CQA Laboratory. The Geosynthetics CQA Laboratory is a third-party, independent from the Owner, Contractor, Manufacturer, and Installer, that is responsible for conducting tests in the field and/or in the laboratory on samples of geosynthetics. The Geosynthetics CQA Laboratory must be capable of providing geomembrane seam test results within 24 hours of receipt of samples.

- CQA Surveyor. The CQA Surveyor is a party, independent from the Owner, Contractor, Manufacturer, and Installer, that is responsible for conducting field surveys to collect data to verify the as-built locations of the work. The CQA Surveyor includes the Texas licensed Professional Land Surveyor, who is responsible for issuing signed and sealed final record drawings.

Each of the construction activities could be carried out by separate project parties selected by the Owner.

1.4 Manufacturer, Supplier, Contractor, and Installer Responsibilities

It is the responsibility of the Manufacturer, Supplier, Contractor, and Installer (as appropriate for various aspects of the work) to provide materials meeting the physical specifications provided in the Construction Documents. It is also the responsibility of the Contractor and Installer to be aware of the CQA testing and evaluation activities required for this project.

1.5 CQA Personnel Roles and Responsibilities

1.5.1 CQA Consultant

1.5.1.1 CQA Engineer

Each phase of the soil and liner evaluation will be conducted by the CQA Engineer or a qualified representative (described subsequently) working under the direct supervision of the CQA Engineer. The CQA Engineer will be a professional engineer (P.E.) registered in Texas, independent from the Owner, Contractor, and Installer, and experienced in geotechnical engineering and soils testing. The CQA Engineer must also be familiar with the use of soils and/or geosynthetics for liner construction. It is the responsibility of the CQA Engineer to oversee implementation of the CQA Plan during construction to verify that the liner system (materials, construction activities, and QA/QC activities) is constructed in accordance with the site-specific design.

The general responsibilities of the CQA Engineer include the following:

- review relevant construction-level project plans and specifications;
- be familiar with other site-specific documentation, including bid documents, proposed layouts, soils and groundwater investigation reports if relevant, and Manufacturer's and Installer's literature as relevant;
- attend appropriate project meetings (e.g., Pre-Construction Meeting, select Progress Meetings);
- administer the CQA program (i.e., assign and manage CQA technicians, check CQA field reports, and provide engineering review of CQA related issues);
- conduct periodic site visits as construction progresses to be fully knowledgeable of the construction methods and performance;
- review changes to the design, plans, and specifications;
- review Record Drawing(s) and related as-built information provided by the CQA Surveyor (e.g., thickness verifications, slopes, etc.); and
- oversee preparation of and sign and P.E. seal the CQA Certification Report.

1.5.1.2 CQA Technician

A properly qualified CQA Technician may work under the direct supervision of the CQA Engineer to monitor, test, and document construction. The CQA Technician will have one of the following minimum levels of experience: (i) a minimum of two years of directly related liner construction experience (or experience with similar low permeability liner and containment applications); or (ii) for an engineer or geologist with a bachelor of science degree, a minimum of six months of directly related experience. If there is more than one CQA Technician on-site at the same time on a project, a Lead CQA Technician will be designated, who will meet the above CQA Technician requirements.

The general responsibilities of the CQA Technician include the following:

- act as the on-site (resident) representative of the CQA Engineer;
- review relevant construction-level project plans and specifications;

- be familiar with other site-specific documentation, including bid documents, proposed layouts, soils and groundwater investigation reports if relevant, and Manufacturer's and Installer's literature as relevant;
- attend CQA-related meetings (i.e., Pre-Construction, Progress, and Problem or Work Deficiency Meetings);
- review the qualifications of the Contractor's equipment operators to ensure that care is taken to protect other portions of the work;
- review the Installer's personnel qualifications for conformance with those pre-approved for work on site;
- review all Supplier, Manufacturer, and Installer certifications and documentation and make appropriate recommendations;
- verify the calibration documentation and condition of on-site CQA equipment;
- periodically check stockpile or borrow pit sources for variability of the soils and ensure that conformance testing is carried out;
- monitor construction activities, including:
  - soils delivery, dumping, and placement;
  - soils moisture content and moisture conditioning, if required;
  - compaction of soils and in-situ testing of compacted density and moisture content;
  - collection of soil samples for laboratory testing for moisture/density relationships, permeability, and other testing as outlined in the specifications;
  - operations to protect completed areas before the covering materials are placed;
  - measurement of loose and compacted lift thickness;
  - verification of bonds between lifts;
  - compaction equipment type, number of passes, and equipment contact pressure;
  - condition of the soil surface for signs of excessive wetting, desiccation, or other disturbance prior to placement of any cover materials;
  - scarification, rewetting, recompaction, or proof rolling required to repair deteriorated areas;
  - geosynthetic material delivery;
  - unloading and on-site transport and storage of geosynthetics;
  - sampling for conformance testing by the Geosynthetics CQA Laboratory;
  - all geosynthetics placement operations;
  - condition of geosynthetics panels as placed;
  - all geosynthetic joining and/or seaming operations, including geomembrane trial seams, seam preparation, seaming, nondestructive seam testing, sampling for destructive testing, field tensiometer testing, laboratory sample marking, and repair operations;
- prepare soils and geosynthetics CQA logs;
- assign locations for testing and sampling;
- oversee collection and shipping of all laboratory test samples;

- review results of laboratory testing and make appropriate recommendations;
- note any on-site activities that could result in damage to the geosynthetics;
- oversee ongoing preparation of Record Drawing(s) and related as-built information provided by the CQA Surveyor (e.g., thickness verifications, slopes, etc.);
- prepare a brief daily field report that includes date, project name, weather conditions, equipment and personnel in the work area, activities planned and performed, a summary of the locations where construction and installation occurred, observations made of activities, names of parties to any discussions and discussion outcomes, off-site materials received, constraints or suggestions, concerns or potential problems including when the issue was identified and how it was corrected, decisions made regarding acceptance of units or work and/or corrective actions to be taken in instances of substandard quality, and signature of CQA personnel who authored the report;
- maintain a photographic record of work progress;
- report relevant observations and any unresolved deviations from the Plan to the CQA Engineer; and
- assist the CQA Engineer with preparation of the CQA Certification Report.

1.5.2 CQA Surveyor

The CQA Surveyor will be an independent third-party professional land surveyor (P.L.S.) registered in Texas.

1.6 Construction Timing and Full-Time CQA

Liner system soil and geosynthetics components should be constructed in a systematic and timely manner. Once construction is started, delays should be avoided unless adverse weather conditions prevent construction progress. Work areas for liner construction should be selected, sized, and sequenced so that each day’s work can be protected from adverse weather conditions. Furthermore, the selection of size and shape of work areas should be consistent, so that uniform construction/installation techniques and equipment can be selected.

Full-time CQA will be provided during construction and installation of the liner system soil and geosynthetics components by the CQA Engineer or his/her qualified representative(s) serving as CQA Technicians as described above. In the remainder of this document, the term “CQA personnel” refers collectively to either the CQA Engineer or to the CQA Technician(s) working on-site under direct supervision of the CQA Engineer.

2. SITE AND PROJECT CONTROL

2.1 Pre-Construction Meeting

Prior to initiating construction activities at the site, a Pre-Construction Meeting will be held at the site. The meeting will be attended by the Project Manager, Contractor, Installer, CQA Engineer, CQA Technician, and CQA Surveyor, as appropriate for the construction activity. If desired, a separate Soils Pre-Construction Meeting and Geosynthetics Pre-Construction meeting may be held, each to be attended by the appropriate parties.

The purpose of this meeting is to begin planning for coordination of tasks, to present the schedule and sequence of work, to discuss anticipated problems that might cause difficulties and delays in construction, and present the procedures for review and approval of clarifications and changes to the project documents.

The following scope should be considered for the Pre-Construction Meeting:

- communicate to all parties any relevant documents;
- review the project-specific CQA Plan;
- make any appropriate modifications to the CQA Plan;
- review critical design details of the project;
- review the responsibilities of each party;
- review lines of authority and communication;
- establish work area security and safety protocol;
- review methods for documenting and reporting, and for distributing documents and reports;
- select testing equipment and review protocols for testing and placement of soil and geosynthetics materials;
- establish protocols for handling deficiencies, repairs, and retesting;
- review the time schedule for all operations;
- establish soil stockpiling locations;
- review precautions to be taken against clay deterioration, due to wetting or desiccation;
- 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 fusion welding apparatus;
- establish procedures for use of the extrusion welding apparatus;
- finalize field cutout sample sizes;
- review seam testing procedures;
- review repair procedures; and

- conduct a site tour after the meeting to review the project features, clarify site conditions, and review material storage locations.

Items discussed during the Pre-Construction Meeting will be documented by a person designated at the beginning of the meeting, and the meeting minutes will be distributed to all relevant parties.

2.2 Progress Meetings

A weekly progress meeting will be held between the Project Manager, Contractor, Installer, CQA Technician, and any other concerned parties. The purpose of this meeting is to discuss current progress, planned activities for the next week, and any CQA issues, concerns, new business, or revisions to the work. The meeting will be documented by a person designated at the meeting, and minutes will be transmitted to affected parties. Any matter requiring action which is raised in this meeting will be reported to the appropriate parties.

Informal daily progress meetings may be held between select CQA personnel and the Contractor and/or Installer prior to the start of work or following the completion of work. The purpose of these informal meetings is to review the previous day's activities, review the upcoming day's activities, and identify any needs or potential construction problems. Major items discussed during these meetings will be documented in the CQA Technician’s daily field reports.

2.3 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 the Project Manager, Contractor, and CQA Technician. If the problem involves geosynthetics or may require a design modification, the Installer or Design Engineer, respectively, should also be available. The purpose of these meetings will be 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 a person designated at the meeting and minutes will be transmitted to affected parties.

2.4 Project Control Visits

Periodically, the construction site will be visited by the CQA Engineer. Project-specific plant visits for the manufacture and fabrication of the geomembrane are optional. These plant visits will be carried out at the discretion of the Owner, by the Owner or his designated alternate.

2.5 Drawing, Specification, and Plan Clarifications and Changes

Clarifications and/or changes to the design (drawings, specifications, and/or Plan) may be necessary during construction. In such cases, the CQA personnel will notify the CQA Engineer, who will in turn notify the Project Manager. After discussion between these parties about the need to consider a clarification or change, the CQA personnel will prepare written information describing the proposed change and rationale for the request. The Project Manager will determine whether the changes are relatively minor changes, or whether they are more substantial changes.

For minor changes to the design, the Project Manager and Design Engineer will consider the change and will then notify the CQA personnel of their acceptance or rejection of proposed change. The minor change will then be documented in the CQA Certification Report (e.g., narrative description, as-built detail, etc., as appropriate). Examples of minor changes include revisions to specified test methods (e.g., ASTM, GRI) and material properties to reflect the current industry standard and state of practice.

More substantial design changes will be made only with the written agreement of the Project Manager and Design Engineer. After the change is approved, the change as implemented will be documented in the CQA Certification Report (e.g., narrative description, as-built detail, etc., as appropriate).

3. STRUCTURAL FILL

3.1 Overview

This section addresses the specifications and CQA program to be implemented for structural fill. The following is discussed in the remainder of this section:

- Structural Fill Specifications;
- Pre-Construction Evaluation of Material Sources;
- Material Conformance Testing During Construction;
- Field Evaluation/Monitoring During Construction;
- Field Testing of Work Product; and
- Deficiencies, Problems, and Repairs.

3.2 Structural Fill Specifications

3.2.1 Structural Fill Material Specifications

Material requirements for the structural fill are presented in Table 3-1.

3.2.2 Structural Fill Target Compaction Criteria

Each lift of structural fill will be compacted to within the required range of moisture contents and densities defined by the pre-construction CQA testing program described subsequently in Section 3.3. Compaction criteria may be developed based on one of the following methods depending on the compaction equipment used and soil moisture conditions:

Standard Proctor Compaction Criteria. When "light" weight equipment (CAT 815-series compactors or equivalent) is used, the compaction criteria for structural fill are ≥95% of the maximum dry density and within 1 percentage point dry to 4 percentage points wet of optimum as determined from the Standard Proctor compaction test (ASTM D 698).

Modified Proctor Compaction Criteria. When "heavy" weight equipment (CAT 835-series compactors or equivalent) is used, the compaction criteria for structural fill are ≥90% of the maximum dry density and within 2 percentage points dry to 3 percentage points wet of optimum as determined from the Modified Proctor compaction test (ASTM D 1557).

Alternative Compaction Criteria. Alternative compaction criteria within the zone bounded by Standard and Modified Compaction Criteria may also be used.

3.3 Pre-Construction Evaluation of Material Sources

3.3.1 Sampling and Testing

Prior to placement of structural fill, CQA personnel will obtain a soil sample from the proposed source(s). Each source will be evaluated for potential use as structural fill by performing the pre-construction laboratory tests presented in Table 3-2 and comparing the results of the tests, where applicable, to the material specifications presented in Table 3-1.

3.3.2 Establishment of Target Compaction Criteria

The CQA Engineer will use the results of the pre-construction testing program to develop target compaction criteria for construction of the structural fill.

3.4 Material Conformance Testing During Construction

When soil from the borrow/stockpile area is easily distinguished and consistent with the soil characterized during pre-construction testing, additional ongoing laboratory conformance testing beyond the initial pre-construction tests is not required. Any time the soil material being used becomes variable, or soils vary or appear inappropriate or questionable compared to the results from the initial pre-construction test program, additional material conformance testing of the tests and methods outlined in Table 3-2 should be performed.

3.5 Field Evaluation/Monitoring During Construction

CQA personnel will be on-site when structural fill installation is ongoing so that all relevant activities can be observed and documented. The CQA Engineer will visit the site periodically as construction progress warrants. Such visits will be frequent enough so that the CQA Engineer is fully knowledgeable of the construction methods and performance, so that the CQA Engineer can determine that quality control monitoring and testing activities are adequate to meet the terms and intent of this CQA Plan. CQA personnel will visually monitor and document that construction of the structural fill is in accordance with the specifications and requirements set forth previously in this CQA Plan. These observations will include, but not be limited to:

- visual inspection of the subgrade for evidence that it is free of debris, organic matter, standing (ponded) water, and excessive moisture;

- visual inspection during subgrade proof-rolling for evidence (e.g., lack of excessive pumping, rutting, deflection) that the subgrade provides a sufficient foundation to place and compact structural fill;

- over-excavation of unsuitable subgrade and replacement of the unsuitable material with structural fill so that the affected area provides a firm foundation and ties into surrounding areas with acceptable proof-roll results or properly placed structural fill;
- scarifying of the subgrade surface prior to placing the first lift of structural fill, with scarification accomplished by tracking with a dozer, making a pass with the compactor, or similar means as approved by the CQA Engineer;
- moisture content and distribution, particle size, and other physical properties of the soil during processing, placement, and compaction;
- type and level of compactive effort, including type and weight of compactor, drum size and foot length, and number of passes;
- thickness of the loosely-placed soil lift for evidence that the loose lift thickness is no greater than 9 inches and no greater than the pad/prong length of the compactor so that complete bonding with the top of the previous lift is achieved;
- action of compaction equipment on soil surface (i.e., foot penetration, rolling, pumping, or shearing);
- thickness of the compacted soil lift for evidence that the lift thickness is approximately 6 inches;
- soil processing to achieve breakdown of soil structure;
- method of bonding lifts together, with each lift constructed on a scarified surface;
- soil moisture conditioning as needed to adjust the in-place moisture content to within specified limits;
- visual inspection for stones or other inclusions which may adversely affect compaction, lift bonding, and in-place testing;
- areas where damage due to excess moisture, insufficient moisture, or freezing may have occurred.

3.6 Field Testing of Work Product

3.6.1 Routine Field Testing

Field testing (e.g., in-situ density and moisture content testing) of placed structural fill will be performed by CQA personnel during construction to evaluate the Contractor's work product with respect to the requirements of the specifications. The test methods and frequencies for routine CQA field testing of the structural fill are given in Table 3-3. Test locations will be selected by CQA personnel.

3.6.2 Special Testing

A special testing frequency will be implemented at the discretion of CQA personnel when observations indicate potential problems, or as requested by the Owner. Additional testing for suspected areas will be considered when:

- the compactor rollers slip during rolling operations;
- the lift thickness is greater than specified;
- the material is at improper and/or highly variable moisture content;
- fewer than the anticipated number of roller passes are made;
- dirt-clogged rollers are used to compact the material;
- the fill materials differ substantially from those specified; or
- the degree of compaction is doubtful.

During construction, the frequency of testing may also be increased in the following situations:

- adverse weather conditions;
- breakdown of equipment;
- at the start and finish of grading;
- if the material fails to meet specification requirements;
- the work area is reduced; or
- as otherwise requested by the Owner.

3.6.3 Perforations

Perforations are holes in the structural fill that should be filled, and may include nuclear density test probe locations or sand cone test locations. Small perforations in the structural fill created during testing will be backfilled with structural fill material and the fill will be tamped in-place with a rod by CQA personnel.

3.7 <u>Deficiencies, Problems, and Repairs</u>

If a deficiency or noncompliance in the structural fill is discovered, CQA personnel will promptly evaluate the extent and nature of the defect. The extent of the deficient area will be evaluated by additional tests, observations, a review of records, or other means deemed appropriate.

Sections of structural fill that do not pass the required field tests will be reworked as appropriate (e.g., water added, additional compaction passes, etc.) and retested until the section in question does pass. If a failure occurs, the failing area will be defined. This will be accomplished by performing additional tests between the failed test and the nearest adjacent passing test locations. If those additional tests pass, then the area between the failed test and the additional passing tests must be reworked and retested until passing. If the additional tests fail, then additional tests must be performed halfway between the initial additional tests and the adjacent passing tests to further define the failing area. This procedure must be repeated until the failing area is defined, reworked, and retested with passing results. All field moisture-density results will be reported in the CQA Certification Report whether they indicate passing or failing values.

TABLE 3-1
MATERIAL SPECIFICATIONS FOR STRUCTURAL FILL

PROPERTY	QUALIFIER	UNITS	SPECIFIED VALUES	TEST METHOD(1)
Unified Soil Classification	Classification	--	SC, CL	ASTM D 2487
Percent Passing 3-inch Sieve	Minimum	Percent	100	ASTM D 422

Notes:

(1) CQA testing frequencies are provided in Tables 3-2 and 3-3.

TABLE 3-2
PRE-CONSTRUCTION TESTING REQUIREMENTS FOR STRUCTURAL FILL

TEST	METHOD	MINIMUM FREQUENCY OF TESTING(1)
Particle Size (Sieve) Analysis	ASTM D 422	1 per source of consistent material and 1 test per 5,000 yd^3
Atterberg Limits	ASTM D 4318	1 per source of consistent material and 1 test per 5,000 yd^3
Unified Soil Classification	ASTM D 2487	1 per source of consistent material and 1 test per 5,000 yd^3
Natural (as-received) Moisture Content	ASTM D 2216	1 per source of consistent material and 1 test per 5,000 yd^3
Standard Proctor Compaction	ASTM D 698, if "light" weight compactor to be used(2)	1 per source of consistent material and 1 test per 5,000 yd^3 (select either Standard or Modified Proctor Compaction Test based on weight of compactor to be used)
Modified Proctor Compaction	ASTM D 1557, if "heavy" weight compactor to be used(2)	

Notes:

(1) The testing frequency of one per source refers to a relatively consistent and distinguishable soil type at a borrow source location based on visual observations and field classification procedures. If the same borrow source is utilized for the soil supply of more than one liner area project, results from previous pre-construction tests may continue to be used. The minimum testing frequency can be reduced from 1 test per 5,000 yd^3 of consistent material after a sufficient database of pre-construction test results has been developed for the Site as determined by the CQA Engineer.

(2) The compaction test method will be selected to be representative of the type of compaction equipment planned for use by the Contractor. For reference, CAT 815 series compactors or equivalent are considered "light" weight equipment, representative of Standard Proctor Compaction Tests; and CAT 825 series compactors or equivalent are considered "heavy" weight equipment, representative of Modified Proctor Compaction Tests.

TABLE 3-3
FIELD CQA TESTING REQUIREMENTS FOR
STRUCTURAL FILL

TEST	METHOD	MINIMUM FREQUENCY OF TESTING
In-Place Density and In-Place Moisture Content (Nuclear Gauge)	ASTM D 6938	1 per 1,000 yd^3 of placed fill (minimum 2 tests per lift)
Oven Moisture Content	ASTM D 2216	As necessary to verify nuclear gauge density results
In-Place Density (Sand Cone or Drive Cylinder Method)	ASTM D 1556 or ASTM 2937	As necessary to verify nuclear gauge density results

4. COMPACTED SOIL LINER

4.1 Overview

This section addresses the specifications and CQA program to be implemented for the compacted soil liner. The following is discussed in the remainder of this section:

- Compacted Clay Liner Specifications;
- Pre-Construction Evaluation of Material Sources;
- Material Conformance Testing During Construction;
- Field Evaluation/Monitoring During Construction;
- Field Testing of Work Product;
- Deficiencies, Problems, and Repairs; and
- Thickness Verification.

4.2 Compacted Soil Liner Specifications

4.2.1 Compacted Soil Liner Material Specifications

Material requirements for the structural fill are presented in Table 4-1.

4.2.2 Compacted Soil Liner Compaction Criteria

Each lift of compacted soil liner will be compacted to within the required range of moisture contents and densities defined by the pre-construction CQA testing program described subsequently in Section 4.3.2. The pre-construction CQA testing program will establish the target compaction criteria (i.e., Acceptable Permeability Zone (APZ)) for construction of the recompacted clay liner. The APZ, developed in the laboratory, represents a range of moisture contents and dry unit weights that yields the required hydraulic conductivity for the anticipated range of compactive efforts (representative of compaction equipment type) to be used during construction. The APZ will be further defined by the following minimum standards for target compaction:

Standard Proctor Compaction Criteria. When “light” weight equipment (CAT 815-series compactors or equivalent) is used, the compaction criteria for compacted clay liner are ≥95% of the maximum dry density and within 0 to 4 percentage points wet of optimum as determined from the Standard Proctor compaction test (ASTM D 698).

Modified Proctor Compaction Criteria. When “heavy” weight equipment (CAT 835-series compactors or equivalent) is used, the compaction criteria for structural fill are ≥90% of the maximum dry density and within 1 percentage points dry to 3 percentage points wet of optimum as determined from the Modified Proctor compaction test (ASTM D 1557).

Alternative Compaction Criteria. Alternative compaction criteria within the zone bounded by Standard and Modified Compaction Criteria may also be used.

4.3 Pre-Construction Evaluation of Material Sources

4.3.1 Sampling and Testing

Prior to construction of the compacted soil liner, CQA personnel will obtain a soil sample from the proposed source(s). Each source will be evaluated for potential use as compacted soil liner by performing the pre-construction laboratory tests presented in Table 4-2 and comparing the results of the tests, where applicable, to the material specifications presented in Table 4-1.

4.3.2 Establishment of Target Compaction Criteria

The CQA Engineer will use the results of the pre-construction testing program to develop target compaction criteria [i.e., Acceptable Permeability Zone (APZ)] for construction of the compacted soil liner. The APZ, developed in the laboratory, represents a range of moisture (i.e., water) contents and dry unit weights that yields the desired hydraulic conductivity for the anticipated range of compactive efforts used during construction. The APZ will be further defined by the following minimum standards for target compaction:

Standard Approach. Pre-construction hydraulic conductivity samples will be remolded to the moisture and density conditions set forth in Table 4-2. These points should represent reasonable “worst case” conditions for hydraulic conductivity results on appropriately compacted soils. Thus, if the results pass, the largest possible APZ is then defined to be the range of moisture contents and dry densities that are wetter and denser than the pre-construction test. If higher moisture contents or dry densities are used for the hydraulic conductivity tests, then the higher values will be used for field control during placement. However, if lower moisture or density values are used and confirmed to achieve acceptable hydraulic conductivities, the APZ will still be based on the minimum compaction requirements provided in Table 4-2. In any case, when the APZ is based on the Standard Proctor compaction test, the maximum moisture content for compaction is 4 percentage points wet of optimum. When the APZ is based on the Modified Proctor compaction test, the maximum moisture content for compaction is 3 percentage points wet of optimum.

Alternate Approach. If requested by the Owner to further define a more detailed APZ, or if deemed necessary by the CQA Engineer based on material variability or equipment variability, an alternate approach may be used to develop the APZ. This alternate approach provides a rational method for accepting or disapproving compaction results when more than one type of compactor or compaction effort is used or when variations in Proctor relationships make choosing the most appropriate curve difficult. More specifically, the "line of optimums" approach may be used as the basis in field control. Under this alternative procedure, 80 percent of the field densities must lie on or above the line of optimums. The line of optimums approach is described in the following reference:

Benson, C.H. and Boutwell, G.P., "*Compaction Control and Scale-Dependent Hydraulic Conductivity of Clay Liners*", Proceedings, Fifteenth Annual Madison Waste Conference, Univ. of Wisconsin-Madison, Madison, Wisconsin, pp. 62-83, 1992.

The line of optimums approach as described by Benson and Boutwell (1992) is essentially a line drawn through the points corresponding to the optimum moisture content/maximum dry density on the moisture/density relationship curves for the modified proctor test, the standard proctor test, and a third compaction test using a reduced energy from the standard proctor test. If this procedure is used, those field density points that do not lie above the line of optimums must not be concentrated in any specific lift or section of fill.

4.3.3 Use of Results

The APZ is borrow-source soil specific. Thus, the APZ may be used from project-to-project when the same borrow source is used and when the borrow soil properties remain consistent with those used to develop the APZ. In some cases, soils in the borrow source may be variable. If the soils can be distinguished in the borrow source or at the construction area, separate APZs can be developed and applied in the field by CQA personnel. If the soils are not easily distinguishable, a composite APZ can be developed by overlaying the APZs and using the range determined from these values.

4.4 Material Conformance Testing During Construction

When soil from the borrow/stockpile area is easily distinguished and consistent with the soil characterized during pre-construction testing, additional ongoing laboratory conformance testing beyond the initial pre-construction tests is not required. Any time the compacted soil liner material being used becomes variable, or soils vary or appear inappropriate or questionable compared to the results from the initial pre-construction test program, additional material conformance testing of the tests and methods outlined in Table 4-2 should be performed.

4.5 Field Evaluation/Monitoring During Construction

CQA personnel will be on-site at all times when compacted soil liner construction is ongoing so that all relevant activities can be observed and documented. The CQA Engineer will visit the site periodically as construction progress warrants. Such visits will be frequent enough so that the CQA Engineer is fully knowledgeable of the construction methods and performance, so that the CQA Engineer can determine that quality control monitoring and testing activities are adequate to meet the terms and intent of this CQA Plan. CQA personnel will visually monitor and document that construction of the compacted soil liner is in accordance with the specifications and requirements set forth previously in this CQA Plan. These observations will include, but not be limited to:

- visual inspection of the subgrade for evidence that it is free of debris, organic matter, standing (ponded) water, and excessive moisture;
- visual inspection during subgrade proof rolling for evidence (e.g., lack of excessive pumping, rutting, deflection) that the subgrade provides a sufficient foundation for installation of compacted soil liner;
- scarifying of the subgrade surface prior to placing the first lift of compacted soil liner, with scarification accomplished by tracking with a dozer, making a pass with the compactor, or similar means as approved by the CQA Engineer;
- moisture content and distribution, particle size, and other physical properties of the soil during processing, placement, and compaction;
- type and level of compactive effort, including roller type and weight, drum size and foot length, and number of passes;
- thickness of the loosely-placed soil lift for evidence that the loose lift thickness is no greater than 9 inches and no greater than the pad/prong length of the compactor so that complete bonding with the top of the previous lift is achieved;
- action of compaction equipment on soil surface (i.e., foot penetration, rolling, pumping, or shearing);
- thickness of the compacted soil lift for evidence that the lift thickness is approximately 6 inches;
- soil processing to yield a relatively uniform soil matrix devoid of large clods or macrostructural features;
- method of bonding lifts together and making liner tie-ins, with each lift constructed on a scarified surface;
- soil moisture conditioning as needed to adjust the in-place moisture content to within specified limits;

- visual inspection for stones or other inclusions which may damage the overlying geomembrane liner or adversely affect compaction, lift bonding, and in-place testing/sampling;

- areas where damage due to excess moisture, insufficient moisture, or freezing may have occurred; and

- preparation and maintenance of the top surface of the soil liner for proper conditions for geomembrane liner deployment.

4.6 Field Testing of Work Product

4.6.1 Routine Field Testing

Field testing (e.g., in-situ density and moisture content testing and undisturbed tube sampling) of placed/compacted soil liner will be performed by CQA personnel during construction to evaluate the Contractor's work product with respect to the requirements of the specifications and requirements set forth in this CQA Plan. The test methods and frequencies for routine CQA field testing of the compacted soil liner are given in Table 4-3. Sampling and test locations will be selected by CQA personnel.

4.6.2 Special Testing

A special testing frequency will be implemented at the discretion of CQA personnel when observations indicate potential problems, or as requested by the Owner. Additional testing for suspected areas will be considered when:

- the compactor rollers slip during rolling operations;
- the lift thickness is greater than specified;
- the material is at improper and/or highly variable moisture content;
- fewer than the anticipated number of roller passes are made;
- dirt-clogged rollers are used to compact the material;
- the fill materials differ substantially from those specified; or
- the degree of compaction is doubtful.

During construction, the frequency of testing may also be increased in the following situations:

- adverse weather conditions;
- breakdown of equipment;
- at the start and finish of grading;
- if the material fails to meet specification requirements;
- the work area is reduced; or

- as otherwise requested by the Owner.

4.6.3 Perforations

Perforations are holes in the compacted soil liner that must be filled, and may include, but are limited to, the following:

- nuclear density test probe locations;
- undisturbed hydraulic conductivity test tube locations; and
- sand cone test locations or other density verification test methods.

All perforations in the compacted soil liner created during any sampling or testing will be backfilled using a mixture of at least 20% bentonite mixed with compacted soil liner material and compacted, or using an appropriate bentonite grout. Small perforations in the structural fill caused by nuclear density and sand cone test probe locations or other perforations of similar size will be backfilled and the fill will be tamped in-place with a rod by CQA personnel. Perforations in the compacted soil liner caused by sand cone test or tube sample locations will be backfilled and compacted by the Contractor to the satisfaction of the CQA Consultant.

4.7 Deficiencies, Problems, and Repairs

If a deficiency or noncompliance in the compacted soil liner is discovered, CQA personnel will promptly evaluate the extent and nature of the defect. The extent of the deficient area will be evaluated by additional tests, observations, a review of records, or other means deemed appropriate. If the defect is related to adverse site conditions, such as overly wet soils or surface desiccation, the CQA Consultant will define the limits and nature of the defect.

Sections of compacted soil liner that do not pass the required field tests will be reworked as appropriate (e.g., water added, additional compaction passes, etc.) and retested until the section in question does pass. If a failure occurs, the failing area will be defined. This will be accomplished by performing additional tests between the failed test and the nearest adjacent passing test locations. If those additional tests pass, then the area between the failed test and the additional passing tests must be reworked and retested until passing. If the additional tests fail, then additional tests must be performed halfway between the initial additional tests and the adjacent passing tests to further define the failing area. This procedure must be repeated until the failing area is defined, reworked, and retested with passing results. All field moisture-density results will be reported in the CQA Certification Report whether they indicate passing or failing values.

4.8 Thickness Verification

The CQA Surveyor will verify all lines and grades of compacted soil liner subgrade prior to liner construction and the top surface of the compacted soil liner. Compacted soil liner thickness verification will be determined by instrument survey method only; no test probes that create holes will be allowed. The verification points provided in the Construction Drawings will be used for record purposes. The verification points will be the same for both beginning and finished elevations of the soil liner, so that minimum thicknesses can be calculated and verified.

TABLE 4-1
MATERIAL SPECIFICATIONS FOR COMPACTED SOIL LINER

PROPERTY	QUALIFIER	UNITS	SPECIFIED VALUES	TEST METHOD[1]
Percent Passing 1-inch Sieve[2]	Minimum	Percent	100	ASTM D 422
Percent Passing #200 Sieve	Minimum	Percent	30	ASTM D 422
Liquid Limit	Minimum	Percent	30	ASTM D 4318
Plasticity Index	Minimum	Percent	15	ASTM D 4318
Unified Soil Classification	Classification	--	SC, CL, CH	ASTM D 2487
Hydraulic Conductivity	Maximum	cm/s	$\leq 1 \times 10^{-7}$	ASTM D 5084[3]

Notes:

(1) CQA testing frequencies are provided in Tables 4-1 and 4-2.
(2) Compacted clay liner material must also not contain rocks or stones that total more than 10% by weight.
(3) Refer to Table 4-3 for additional hydraulic conductivity testing requirements.

TABLE 4-2
PRE-CONSTRUCTION TESTING REQUIREMENTS FOR COMPACTED SOIL LINER

TEST	METHOD	MINIMUM FREQUENCY OF TESTING[1]
Particle Size (Sieve) Analysis	ASTM D 422	1 per source of consistent material and 1 test per 10,000 yd^3
Atterberg Limits	ASTM D 4318	1 per source of consistent material and 1 test per 10,000 yd^3
Unified Soil Classification	ASTM D 2487	1 per source of consistent material and 1 test per 10,000 yd^3
Natural (as-received) Moisture Content	ASTM D 2216	1 per source of consistent material and 1 test per 10,000 yd^3
Standard Proctor Compaction	ASTM D 698, if “light” weight compactor to be used[2]	1 per source of consistent material and 1 test per 10,000 yd^3 (select either Standard or Modified Proctor Compaction Test based on weight of compactor to be used)
Modified Proctor Compaction	ASTM D 1557, if “heavy” weight compactor to be used[2]	
Remolded Hydraulic Conductivity	ASTM D 5084[3][4][5]	1 per source of consistent material and 1 test per 10,000 yd^3

Notes:

(1) The testing frequency of one per source refers to a relatively consistent and distinguishable soil type at a borrow source location based on visual observations and field classification procedures. If the same borrow source is utilized for the soil supply of more than one liner area project, results from previous pre-construction tests may continue to be used. The minimum testing frequency can be reduced from 1 test per 10,000 yd^3 of consistent material after a sufficient database of pre-construction test results has been developed for the Site as determined by the CQA Engineer.

(2) The compaction test method will be selected to be representative of the type of compaction equipment planned for use by the Contractor. For reference, CAT 815 series compactors or equivalent are considered “light” weight equipment, representative of Standard Proctor Compaction Tests; and CAT 825 series compactors or equivalent are considered “heavy” weight equipment, representative of Modified Proctor Compaction Tests.

(3) Hydraulic conductivity testing will be performed using tap water or a 0.05N solution of $CaSO_4$. Use effective stress of 20 psi. Distilled or deionized water will not be used. The permeant should be deaired. Testing procedures in Appendix VII of the Corps of Engineers Manual EM 1110-2-1906 may be used as an alternative method.

(4) Perform remolded hydraulic conductivity test as appropriate for the type of compaction equipment planned for use, on either: (i) a remolded sample that is compacted greater than or equal to 95% of the maximum dry density and at the optimum moisture content as determined from the Standard Proctor Compaction test; or (ii) a remolded sample that is compacted greater than or equal to 90% of the maximum dry density and at one percentage point dry of optimum as determined from the Modified Proctor Compaction Test.

(5) Additional hydraulic conductivity tests may be performed during the preconstruction testing program if authorized by the Owner, in order to develop a more detailed, alternative acceptable permeability zone (APZ) that may broaden the range of allowable moisture-density target compaction criteria or define allowable conditions for use of soil blends. See Section 4.3.2. of this CQA Plan for a discussion of this approach.

TABLE 4-3
FIELD CQA TESTING REQUIREMENTS FOR COMPACTED SOIL LINER

TEST	METHOD	MINIMUM FREQUENCY OF TESTING
In-Place Density and In-Place Moisture Content (Nuclear Gauge)	ASTM D 6938	1 per 8,000 ft^2 of surface area per lift (minimum 3 tests per lift) for parallel lifts 1 per each 100 lineal feet per each 12 inches of thickness for horizonal lifts
Percent Passing #200 Sieve	ASTM D 422 or ASTM D 1140	1 per 100,000 ft^2 of surface area per lift (minimum 1 test per lift) 1 per each 2,000 lineal feet per each 12 inches of thickness for horizonal lifts
Atterberg Limits	ASTM D 4318	1 per 100,000 ft^2 of surface area per lift (minimum 1 test per lift) 1 per each 2,000 lineal feet per each 12 inches of thickness for horizonal lifts
Undisturbed Hydraulic Conductivity	ASTM D 5084(1)	1 per 100,000 ft^2 of surface area per lift (minimum 1 test per lift) 1 per each 2,000 lineal feet per each 12 inches of thickness for horizonal lifts
Oven Moisture Content	ASTM D 2216	As necessary to verify nuclear gauge density results.
In-Place Density (Sand Cone or Drive Cylinder Method)	ASTM D 1556 or ASTM 2937	As necessary to verify nuclear gauge density results
Layer Thickness Verification	Instrument Survey Measurements with As-Built Signed by Registered Surveyor	Minimum of 1 verification point per 5,000 ft^2 of surface area (minimum of 2 points).

Notes:
(1) Undisturbed hydraulic conductivity tests will be obtained using thin-walled push tube sampler (e.g., Shelby tube), and will be tested using tap water or a 0.05N solution of $CaSO_4$. Use effective stress of 20 psi. Distilled or deionized water will not be used. The permeant should be deaired.

5. GEOMEMBRANE LINER

5.1 Overview

This section addresses the specifications and CQA program to be implemented for the 60-mil textured high-density polyethylene (HDPE) geomembrane liner. The following is discussed in the remainder of this section:

- Geomembrane Liner Specifications;
- Pre-Installation Qualification of Material Sources;
- Material Conformance Testing;
- Field Evaluation/Monitoring During Installation;
- Field Testing of Work Product; and
- Deficiencies, Problems, and Repairs.

5.2 Geomembrane Liner Specifications

5.2.1 Geomembrane Material Specifications

A. Material requirements for the geomembrane are presented in Table 5-1.

B. The geomembrane resin properties will meet the requirements set forth in the Geosynthetics Research Institute (GRI) Test Method GM-13 (current industry standard), including a resin density generally in the range of 0.932 g/cc or higher, and a melt flow index of less than 1.0 g/10 min. Test standards for measuring resin density and melt flow index are given in GRI GM-13.

5.2.2 Manufacturing Quality Control (MQC)

A. The Geomembrane Manufacturer willl implement a manufacturing quality control (MQC) program for materials related to geomembrane manufacturing, which will include MQC sampling and testing to demonstrate the geomembrane quality and suitability for use.

B. The required MQC tests, methods, and frequencies are presented in Table 5-1.

C. Prior to shipping, the Geomembrane Manufacturer will provide CQA personnel with the required MQC information listed in Section 5.3, including results of the required MQC tests. Any sample that does not comply with the requirements will result in rejection of the roll from which the sample was obtained.

5.3 Pre-Installation Qualification of Material Sources

Prior to installation of the geomembrane, the Manufacturer will provide CQA personnel with manufacturer's certification statements and quality control information, including the following:

- Written certification, signed by a responsible party employed by the Manufacturer. The Manufacturer will guarantee the specified roll values are met for physical, mechanical, and environmental properties corresponding to the test procedures for the required geomembrane properties listed in the specifications.

- Manufacturer's quality control (MQC) certificates with test results signed by a responsible party employed by the Manufacturer. Each quality control certificate will include date, roll identification numbers, testing procedures, and results of quality control tests performed using the methods specified and at the required frequencies given in the specifications.

- Certification statement from the resin supplier stating that the resin properties are met for the specified test procedures and properties listed in the specifications.

- Copies of dated quality control certificates issued by the resin supplier for the resin density and melt flow index at the minimum frequency of one per each resin lot for the resin used in geomembrane production.

CQA personnel will examine all Manufacturer's certifications to verify that the property values listed on the certifications meet or exceed the specifications shown in Table 5-1 and that proper and complete documentation has been provided for all geomembrane to be used at the site. CQA personnel will report any deviations from the above requirements to the Project Manager and Installer prior to installation of the geomembrane. Any sample that does not comply with the requirements will result in rejection of the roll from which the sample was obtained and additional testing of rolls from the same lot or batch until a pattern of acceptable test results is established.

5.4 Material Conformance Testing

Conformance testing will be performed by the Geosynthetics CQA Laboratory. As a minimum, the geotextile, geonet, and geocomposite conformance tests listed in Table 5-2 will be performed by the Geosynthetics CQA Laboratory. Conformance sampling may be performed either at the manufacturing plant or upon delivery of rolls to the site, as requested by the Project Manager. Conformance samples will be taken across the entire roll width. All conformance test results will be reviewed by CQA personnel prior to deployment of the material. Any nonconformance will be immediately reported to the Project Manager. When a sample fails a conformance test, the material from the lot represented by the failing test should be considered out-of-specification and rejected.

5.4.1 Sampling Procedure

Samples will be taken across the entire width of the roll and will not include the first 3 ft. Unless otherwise specified, samples shall consist of one section 3 ft long by the roll width. The required minimum geomembrane conformance sampling frequencies are provided in Table 5-2. The CQA Consultant shall affix a label, tag, or otherwise mark each sample with the following information:

- date sampled;
- project number;
- lot/batch number and roll number;
- conformance sample number; and
- CQA personnel identification.

The geomembrane rolls which are sampled shall be immediately rewrapped in their protective coverings to the satisfaction of the CQA Consultant.

5.4.2 Test Results

The CQA Consultant will review all laboratory conformance test results and assure compliance of the test results with the Technical Specifications prior to deployment of the geomembrane. Any non-conformance shall be reported to the Construction Manager.

5.4.3 Conformance Test Failure

In the case of failing test results, the Contractor may request that another sample from the failing roll be retested by the Geosynthetics CQA laboratory with the manufacturer's technical representative present during the test procedure. If the retest fails or if the option to retest is not exercised, then two isolation conformance samples shall be obtained by the CQA Consultant. These isolation samples shall be taken from rolls, which have been determined by correlation with the manufacturer's roll number, to have been manufactured prior to and after the failing roll. This method for choosing isolation rolls for testing should continue until passing tests are achieved. All rolls which fail numerically between the passing roll numbers shall be rejected. The CQA Consultant will assure that the Contractor has replaced all rejected rolls. The CQA Consultant shall document all actions taken in conjunction with geocomposite conformance test failures.

5.5 Field Evaluation/Monitoring During Installation

5.5.1 General

Prior to construction, CQA personnel and the Project Manager will review the proposed panel layout plan prepared by the Installer. The purpose of the review is to become familiar with the proposed orientation of the panels, the general installation sequencing, and the quantities of materials needed for the job, and to assess whether the proposed installation layout complies with the relevant specifications.

5.5.2 Transportation, Handling, and Storage

CQA personnel will monitor the transportation, handling, and storage of the geomembrane onsite. The Project Manager will designate a geomembrane storage location. During transportation, handling, and storage, the geomembrane must be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions.

Handling of the geomembrane rolls must be performed in a competent manner such that damage does not occur to the geomembrane or to its protective wrapping. Rolls of geomembrane must not be stacked upon one another to the extent that deformation of the roll occurs or to the point where accessibility can cause damage in handling. Furthermore, geomembrane rolls must be stacked in such a way that access for conformance sampling is possible.

Upon delivery to the Site, the Contractor, Installer, and CQA Consultant will conduct an inspection of the rolls for defects and damage. This inspection will be conducted without unrolling the materials unless defects or damages are found or suspected. The CQA Consultant will indicate to the Project Manager:

- rolls, or portions thereof, which should be rejected and removed from the Site because they have severe flaws; and
- rolls which include minor repairable flaws.

The CQA Consultant will also monitor that equipment used to handle the geomembrane onsite is adequate and does not pose any risk of damage to the geomembrane when used properly.

5.5.3 Condition of Geomembrane Subgrade

Prior to deployment of geomembrane, CQA personnel will observe the work area, and will verify that the surface on which geomembrane will be deployed has been fully approved. This includes, at a minimum the following requirements:

- keep surface of the subgrade soil free of sharp stones, stones larger than 3/8-inch, sticks, or other debris;

- finish soil subgrade surface by rolling with a flat wheel roller until a smooth uniform surface is achieved;

- protect soil subgrade from desiccation cracking, rutting, erosion, and ponding prior to and during placement of the geomembrane; and

- preserve subgrade by regular watering and proof rolling or by placing a temporary soil cover over subgrade, removing the temporary soil cover prior to geomembrane placement, and resurveying the soil subgrade surface prior to geomembrane placement.

It is the responsibility of CQA personnel to provide subgrade acceptance forms to the Installer and verify that they have been signed by CQA personnel and the Installer prior to deployment.

5.5.4 Field Panel Identification

Each field panel will be given an identification code, which will be used for CQA records. CQA personnel will monitor field panel placement and will record the field panel identification code, manufacturers roll number, location, date of installation, and dimensions of each field panel. CQA personnel will label each panel in the field with its panel identification number using a semi-permanent marker (e.g., paint stick).

5.5.5 Geomembrane Deployment

CQA personnel will continuously monitor geomembrane deployment and verify compliance with the geomembrane installation specifications, including:

- the wind is not excessive for deployment;

- any equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons or other means;

- the surface underlying the geomembrane has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement, without excessive moisture (e.g., dew, ponding, etc.);

- the anchor trench is of the proper dimensions and in suitable condition, without loose soils underlying the geomembrane;

- personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane;

- the method used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil;

- the method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels);

- adequate temporary loading and/or anchoring (e.g., sand bags) has been placed to prevent uplift by wind; and

- direct contact with the geomembrane is minimized in areas where excessive traffic may be expected (e.g., the geomembrane is protected by geosynthetics, extra geomembrane, or other suitable materials).

CQA personnel will advise the Installer which panels, or portions of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels which have been rejected will be marked and their removal from the work area will be recorded by CQA personnel.

5.5.6 Geomembrane Seaming

Field panel seaming will be continuously monitored by CQA personnel to verify and document compliance with the seaming specifications shown in Table 5-3, including:

- weather conditions for seaming are within the limits required by the specifications, unless authorized by the CQA Engineer;

- prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material;

- seams are overlapped a minimum of 3 inches or as recommended by the Manufacturer;

- if seam overlap grinding is required, the process is completed according to the Manufacturer's instructions and/or the specifications, whichever is the more stringent, prior to the seaming operation, and in a way that does not damage the geomembrane;

- the grind depth will not exceed 10 percent of the geomembrane thickness;

- grinding marks will not appear beyond the extrudate after it is placed; and

- seams are aligned with the fewest possible number of wrinkles and “fishmouths”.

For fusion welding, CQA personnel will:

- verify and document that the fusion-welding apparatus is a self-propelled device and that it is permanently marked with an identification number;
- verify that the fusion-welding apparatus is equipped with gauges giving the applicable temperatures and welding speed;
- verify that a suitable number of spare operable seaming apparatus are maintained on site;
- confirm that the electric generator is placed on a smooth base such that no damage occurs to the geomembrane;
- confirm that, for cross seams, the edge of the cross seam is ground to a smooth incline (top and bottom) prior to welding;
- verify that a smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and
- verify that a movable protective layer is used, as necessary, directly below each overlap of geomembrane that is to be seamed to prevent build-up of moisture between the sheets.

For extrusion welding, CQA personnel will:

- verify and document that the extrusion-welding apparatus is permanently marked with an identification number;
- verify that the extrusion-welding apparatus is equipped with gauges giving the temperature in the apparatus and at the nozzle;
- verify that the extrudate is comprised of the same resin as the geomembrane sheeting;
- monitor extrudate temperatures, ambient temperatures, and geomembrane sheet temperatures at appropriate intervals;
- verify that a suitable number of spare operable seaming apparatus are maintained on site;
- verify that the extruder is purged prior to beginning a seam until all heat-degraded extrudate has been removed from the barrel;
- confirm that the electric generator is placed on a smooth base such that no damage occurs to the geomembrane; and
- confirm that a smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage.

5.5.7 Placement of Soil Materials Over Geomembrane

CQA personnel will provide continuous monitoring during soil placement on the geomembrane liner to document that soil is being placed in a manner protective of the geomembrane and that the equipment placing the soil meets the ground pressure requirements.

5.6 Field Testing of Work Product

5.6.1 Trial Seams

Trial seam testing will be performed by the Installer. CQA personnel will observe and document the Installer's trial seam testing procedures and verify that they are in accordance with the specifications shown in Table 5-3. CQA personnel will document identification numbers of trial seam samples and record results. Each sample will also be marked with the date, time, machine temperature(s), setting(s), number of seaming unit, and name of seaming technician.

5.6.2 Nondestructive Seam Testing

Nondestructive field seam testing will be performed on all seams by the Installer to check the continuity of seams. During the Installer's nondestructive testing of field seams, CQA personnel will continuously monitor and confirm that seams are tested over their full length using either the vacuum test (for extrusion welds) or the air pressure test (for double fusion seams). CQA personnel will also continuously monitor nondestructive testing and document the results, including at a minimum the test location, date, test identification number, name of tester, and result of testing.

CQA personnel will notify the Installer of any required repairs and will observe and document that adequate repairs are made and retesting performed. The information collected for an initial test will also be collected for a retest.

5.6.3 Destructive Testing

Location and Frequency. CQA personnel will select all destructive seam test sample locations in order to accomplish the minimum average sampling and testing frequencies of 1 test per 500 ft of seam per seamer/welder combination. Sample locations will be established by CQA personnel according to the guidelines given below.

- Test locations will be determined during seaming at CQA personnel's discretion. Selection of such locations may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential cause of imperfect welding.

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

Sampling Procedures. The Installer will cut the destructive samples at the locations designated by CQA personnel, under observation of the CQA personnel when possible. CQA personnel will mark each sample accordingly and record the sample location. At a given sampling location, two types of samples will be taken: (i) field test samples; and (ii) laboratory test samples. A minimum of two field samples (i.e., test strips) should be taken for field testing. Each of these test strips should typically be 1 in. wide by 12 in. long, with the seam centered parallel to the width. The distance between these two specimens should typically be 42 in. If both specimens pass the field test described below, a full laboratory destructive sample will be taken for testing by the Geosynthetics CQA Laboratory, as follows:

- The full destructive sample should be located between the two field test strips. The sample should typically be 12 in. wide by 42 in. long with the seam centered lengthwise. The sample will be cut into three parts and distributed as follows:
  - one 12 in. by 12 in. portion to be retained by the Installer;
  - one 12 in. by 12 in. portion to be archived by CQA personnel; and
  - the remaining 12 in. by 18 in. portion to be forwarded immediately by CQA personnel to the Geosynthetics CQA Laboratory.

All holes in the geomembrane resulting from destructive seam test sampling will be immediately repaired by the Installer. The continuity of the new seams in the repaired area will be nondestructively tested.

Field Testing. The test strips will be tested in the field by the Installer, using a gauged tensiometer. CQA personnel will observe the field tests and mark all samples and portions of samples with their test number. CQA personnel will also document using the appropriate standardized field forms: the date, number of seaming unit, seaming technician identification, destructive sampling, and pass or fail description.

Laboratory Testing. Destructive test samples will be tested in peel and shear by the Geosynthetics CQA Laboratory. Results will be reviewed by CQA personnel for conformance with the specifications as soon as they become available. The CQA Engineer and Owner will be notified of any inconsistencies or nonconformances.

Procedures for Destructive Test Failure. The following procedures will apply whenever a sample fails a destructive test, whether that test was conducted in the field or by the Geosynthetics CQA Laboratory. CQA personnel will document that the Installer follows one of two options to repair the failed seam:

- The Installer may reconstruct the entire seams (e.g., remove the old seams and reseam) between any two passed destructive test locations.

- The Installer may trace the welding path to an intermediate location a minimum of 10 ft from the point of the failed test in each direction and take a small sample for an additional field testing in accordance with the destructive test procedure at each location. If these additional isolation samples pass the field test, then full laboratory samples are taken at both locations. If these laboratory samples meet the specified strength criteria, then the seam is reconstructed between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed.

In all cases, failed seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken or the entire seam is reconstructed and retested. In cases exceeding 150 ft of reconstructed seam, a sample taken from the zone in which the seam has been reconstructed must pass destructive testing. CQA personnel will document all actions taken in conjunction with destructive test failures.

5.7 Deficiencies, Problems, and Repairs

5.7.1 Inspection for Defects

All seams and non-seam areas of the geomembrane will be examined by CQA personnel for identification of defects, holes, blisters, undispersed raw materials and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane should be clean at the time of examination.

5.7.2 Repair Procedures

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

5.7.3 Verification of Repairs

Each repair will be numbered, logged, and non-destructively tested using approved methods. Repairs which pass the non-destructive test will be taken as an indication of an adequate repair. Large caps may be of sufficient extent to require destructive test sampling, at the discretion of CQA personnel or as previously specified. CQA personnel will observe all non-destructive testing of repairs and will record the number of each repair, date, and test outcome.

TABLE 5-1a

MATERIAL SPECIFICATIONS FOR GEOMEMBRANE LINER(11)

PROPERTIES	TEST METHOD	SPECIFIED VALUE	FREQUENCY
Thickness mils (min. ave.) - mils • lowest individual for 8 out of 10 values - % • lowest individual for any of the 10 values - %	D 5994	nom. – 5% -10 -15	per roll
Asperity Height mils (min. ave.) - mils	D 7466	16	every 2nd roll *(1)*
Formulated Density (min. ave.) - g/cc	D 1505/D 792	0.940	200,000 lb
Tensile Properties (min. ave.) *(2)* • yield strength - lb/in. • break strength - lb/in. • yield elongation - % • break elongation - %	D 6693 Type IV	 126 90 12 100	20,000 lb
Tear Resistance (min. ave.) - lb	D 1004	42	45,000 lb
Puncture Resistance (min. ave.) - lb	D 4833	90	45,000 lb
Stress Crack Resistance *(3)* - hr.	D 5397 (App.)	500	per GRI GM10
Carbon Black Content (range) - %	D 4218 *(4)*	2.0-3.0	20,000 lb
Carbon Black Dispersion	D 5596	note *(5)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(6)* (a) Standard OIT - min. — or — (b) High Pressure OIT - min.	 D 8117 D 5885	 100 400	200,000 lb
Oven Aging at 85°C *(6), (7)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 8117 D 5885	 55 80	per each formulation
UV Resistance *(8)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(10)*	D 7238 D 8117 D 5885	 N.R. *(9)* 50	per each formulation

Notes:
(1) Alternate the measurement side for double sided textured sheet
(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Yield elongation is calculated using a gage length of 1.3 inches. Break elongation is calculated using a gage length of 2.0 inches.
(3) SP-NCTL per ASTM D5397 Appendix is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should 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.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(4) Other methods such as ASTM D1603 (tube furnace) or D6370 (TGA) are acceptable if an appropriate correlation to D4218 (muffle furnace) can be established.
(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views: 9 in Categories 1 or 2 and 1 in Category 3.
(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(8) The condition of the test should be 20 hour UV cycle at 75C followed by 4 hour condensation at 60C.
(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic results for some of the antioxidants in the UV exposed samples.
(10) UV resistance is based on percent retained values regardless of the original HP-OIT value.
(11) This specification is based on the Geosynthetic Research Institute (GRI) GM-13 Specification, currently the industry standard.

TABLE 5-1b

MATERIAL SPECIFICATIONS FOR GEOMEMBRANE LINER INTERFACE SHEAR STRENGTH

PROPERTY	QUALIFIER	UNITS	SPECIFIED VALUE	TEST METHOD	CQA TESTING FREQUENCY (Minimum)
Interface Shear Strength (geomembrane to compacted clay liner)	Minimum	deg	15	ASTM D 5321[(1)]	Note 1
Interface Shear Strength (geomembrane to geocomposite)	Minimum	deg		ASTM D 5321[(1)]	Note 1

Notes:

(1) Interface shear strength testing will be performed by a qualified, independent third-party geosynthetics testing laboratory on the materials intended for use as the liner system side slope prior to shipping.

Interface shear tests will be performed at a range of normal stresses up to 15,000 psf (min) using fresh specimens for each test configuration, and using a maximum shear rate of 1 mm/minute for geosynthetic-to-soil interfaces and 5 mm/minute for geosynthetic-to-geosynthetic interfaces. Compacted clay material used for interface tests will be remolded in the laboratory to the critical compaction condition (e.g., the lowest density and highest moisture content specified for compaction).

Passing interface strength results for a particular interface are applicable from project-to-project at the site (e.g., for subsequent cell construction, next liner phases, etc.) and testing need not be repeated, provided that the geosynthetic type and soil source/properties proposed for use remains representative of those tested.

TABLE 5-1c

WELDED SEAM SPECIFICATIONS FOR GEOMEMBRANE LINER

PROPERTY	QUALIFIER	UNITS	VALUES(3, 4, 5) 60 mil HDPE	TEST METHOD(5)	CQA TESTING FREQUENCY
Fusion Seams					
Air Test	-	psi	30 psi pressure, 5 minute hold, pressure must not drop by 3 psi	ASTM D 5820	Observe Installer testing 100% of fusion seams
Shear Strength	Minimum	lb/in.	120	GRI GM-19 (using ASTM D 6392)	(1) and (2)
Shear Elongation at Break	Minimum	%	50		
Peel Strength	Minimum	lb/in.	91		
Peel Separation	Minimum	%	25		
Extrusion Seams					
Vacuum Test	-	psi	5 psi vacuum, 10 second hold	ASTM D 5641	Observe Installer testing 100% of extrusion seams
Shear Strength	Minimum	lb/in.	120	GRI GM-19 (using ASTM D 6392)	(1) and (2)
Shear Elongation at Break	Minimum	%	50		
Peel Strength	Minimum	lb/in.	78		
Peel Separation	Minimum	%	25		

Notes:

(1) Trial seams will be made at start of each day and at re-start after breaks, shift change, etc. Elongation/separation measurements may be eliminated for field testing.

(2) Destructive tests will be taken at a minimum frequency of one per 500 linear ft of welded production seam.

(3) For all destructive tests, 4 of 5 samples must meet or exceed the above values, and all samples must meet or exceed 80% of the above values for a test to pass.

(4) Locus-of-break patterns will meet the acceptable break codes given in GRI GM-19.

(5) The above specification is based on the GRI GM-19 Specification, currently the industry standard for welded geomembrane seams. Specified test methods and parameters may be modified by the CQA Engineer to be consistent with changes to the industry standard for geomembrane seams.

TABLE 5-2

MATERIAL CQA CONFORMANCE TESTING REQUIREMENTS FOR GEOMEMBRANE LINER

TEST	METHOD(1)	MINIMUM FREQUENCY OF CQA TESTING(3)
Thickness – Lab Measurement(2)	ASTM D 5994	1 per 50,000 ft^2
Sheet Density	ASTM D 1505/D 792	1 per 100,000 ft^2
Tensile Properties	ASTM D 6693 Type IV	1 per 100,000 ft^2
Carbon Black Content	ASTM D 4218	1 per 100,000 ft^2
Carbon Black Dispersion	ASTM D 5596	1 per 100,000 ft^2

Notes:

(1) Required Manufacturer's QC testing methods and frequencies are given in the geomembrane specifications for the applicable test items listed above, along with the required material properties.

(2) CQA testing frequency will also be at a minimum of one per resin lot.

(3) Specified test methods may be replaced with new ASTM or GRI methods by CQA Engineer as they become available, consistent with changes to the industry standard for HDPE geomembranes.

6. GEOCOMPOSITE DRAINAGE LAYER

6.1 Overview

This section addresses the specifications and CQA program to be implemented for the double-sided geocomposite drainage layer. The following is discussed in the remainder of this section:

- Geocomposite Drainage Layer Specifications;
- Pre-Installation Qualification of Material Sources;
- Material Conformance Testing During Installation; and
- Field Evaluation/Monitoring During Installation.

6.2 Geocomposite Drainage Layer Specifications

6.2.1 Geocomposite Material Specifications

A. Material requirements for the geocomposite drainage layer are presented in Table 6-1.

B. The resin of the geonet component of the geocomposite will have a resin density generally in the range of 0.932 g/cc or higher, and a melt flow index of less than 1.0 g/10 min.

6.2.2 Manufacturing Quality Control (MQC)

A. The Geocomposite Manufacturer will implement a manufacturing quality control (MQC) program for materials related to geocomposite manufacturing, which will include MQC sampling and testing to demonstrate the geomembrane quality and suitability for use.

B. The required MQC tests, methods, and frequencies are presented in Table 6-1.

C. Prior to shipping, the Geocomposite Manufacturer will provide CQA personnel with the required MQC information listed in Section 6.3, including results of the required MQC tests. Any sample that does not comply with the requirements will result in rejection of the roll from which the sample was obtained.

6.3 Pre-Installation Qualification of Material Sources

Prior to installation of the geomembrane, the Manufacturer will provide CQA personnel with manufacturer's certification statements and quality control information, including the following:

- Written certification, signed by a responsible party employed by the Manufacturer. The Manufacturer will guarantee the specified roll values are met for physical, mechanical, and environmental properties corresponding to the test procedures for the required geocomposite properties listed in the specifications.

- Manufacturer's quality control (MQC) certificates with test results signed by a responsible party employed by the Manufacturer. Each quality control certificate will include date, roll identification numbers, testing procedures, and results of quality control tests performed using the methods specified and at the required frequencies given in the specifications.

CQA personnel will examine all Manufacturer's certifications to verify that the property values listed on the certifications meet the specifications shown in Table 6-1 and that proper and complete documentation has been provided for all geocomposite to be used at the site. CQA personnel will report any deviations from the above requirements to the Project Manager and Installer prior to installation of the geocomposite. Any sample that does not comply with the requirements will result in rejection of the roll from which the sample was obtained and additional testing of rolls from the same lot or batch until a pattern of acceptable test results is established.

6.4 Material Conformance Testing

6.4.1 Testing Procedure

Conformance testing will be performed by the Geosynthetics CQA Laboratory. As a minimum, the geotextile, geonet, and geocomposite conformance tests listed in Table 6-2 will be performed by the Geosynthetics CQA Laboratory. Conformance sampling may be performed either at the manufacturing plant or upon delivery of rolls to the site, as requested by the Project Manager. Conformance samples will be taken across the entire roll width. All conformance test results will be reviewed by CQA personnel prior to deployment of the material. Any nonconformance will be immediately reported to the Project Manager. When a sample fails a conformance test, the material from the lot represented by the failing test should be considered out-of-specification and rejected.

Additional conformance samples may be taken to isolate the portion of the lot not meeting the specifications shown in Table 5-2. To isolate the out-of-specification material, two additional conformance samples should be taken from the closest numerical roll numbers to the failing sample. If both samples pass, only the initial failed roll will be rejected. If any one of the additional tests fails, then the entire lot will be rejected, and the procedure may be repeated with additional tests to further bracket the failing rolls within the lot.

6.4.2 Sampling Procedure

Samples will be taken across the entire width of the roll and will not include the first 3 ft. Unless otherwise specified, samples shall consist of one section 3 ft long by the roll width for geonet and geocomposite testing and one section 10 ft long cut 1 ft from the edge of the geonet for testing of the unbonded geotextiles. The required minimum geocomposite conformance sampling frequencies are provided in Table 6-2. The CQA Consultant shall mark the machine direction on the samples with an arrow and affix a label, tag, or otherwise mark each sample with the following information:

- date sampled;
- project number;
- lot/batch number and roll number;
- conformance sample number; and
- CQA personnel identification.

The geocomposite rolls which are sampled shall be immediately rewrapped in their protective coverings to the satisfaction of the CQA Consultant.

6.4.3 Test Results

The CQA Consultant will review all laboratory conformance test results and assure compliance of the test results with the Technical Specifications prior to deployment of the geocomposite. Any non-conformance shall be reported to the Construction Manager.

6.4.4 Conformance Test Failure

In the case of failing test results, the Contractor may request that another sample from the failing roll be retested by the Geosynthetics CQA laboratory with the manufacturer's technical representative present during the test procedure. If the retest fails or if the option to retest is not exercised, then two isolation conformance samples shall be obtained by the CQA Consultant. These isolation samples shall be taken from rolls, which have been determined by correlation with the manufacturer's roll number, to have been manufactured prior to and after the failing roll. This method for choosing isolation rolls for testing should continue until passing tests are achieved. All rolls which fail numerically between the passing roll numbers shall be rejected. The CQA Consultant will assure that the Contractor has replaced all rejected rolls. The CQA Consultant shall document all actions taken in conjunction with geocomposite conformance test failures.

6.5 Field Evaluation/Monitoring During Installation

6.5.1 Transportation, Handling, and Storage of Geocomposite

CQA personnel will monitor the transportation, handling, and storage of the geocomposite onsite. The Project Manager will designate a geocomposite storage location. During transportation, handling, and storage, the geocomposite must be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions.

Handling of the geocomposite rolls must be performed in a competent manner such that damage does not occur to the geocomposite or to its protective wrapping. Rolls of geocomposite must not be stacked upon one another to the extent that deformation of the roll occurs or to the point where accessibility can cause damage in handling. Furthermore, geocomposite rolls must be stacked in such a way that access for conformance sampling is possible. Protective wrappings shall be removed less than one hour prior to unrolling the geocomposite. After unrolling, a geocomposite shall not be exposed to ultraviolet light for more than 14 calendar days.

Outdoor storage of geocomposite rolls must not exceed the Manufacturer's recommendations or longer than 6 months whichever is less. For storage periods longer than 6 months a temporary enclosure shall be placed over the rolls, or they shall be moved to an enclosed facility. The location of temporary field storage shall not be in areas where water can accumulate. The rolls shall be elevated off the ground to prevent contact with ponded water.

Upon delivery to the Site, the Contractor, Installer, and CQA Consultant will conduct an inspection of the rolls for defects and damage. This inspection will be conducted without unrolling the materials unless defects or damages are found or suspected. The CQA Consultant will indicate to the Project Manager:

- rolls, or portions thereof, which should be rejected and removed from the Site because they have severe flaws; and
- rolls which include minor repairable flaws.

The CQA Consultant will also monitor that equipment used to handle the geocomposites onsite is adequate and does not pose any risk of damage to the geocomposites when used properly.

6.5.2 Geocomposite Placement

The CQA Consultant shall monitor the placement of all geocomposites to assure they are not damaged in any way, and the following conditions are met.

- On slopes, the geocomposites shall be securely anchored in the anchor trench and then deployed down the slope in such a manner as to continually keep the geocomposites in tension.
- 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 earth cover material.
- Trimming of the geocomposites shall be performed using only a upward cutting hook

blade. Special care must be taken to protect other materials from damage which could be caused by the cutting of the geocomposites.

- The CQA Consultant shall monitor that the Installer is taking necessary precautions to prevent damage to underlying layers during placement of the geocomposite.
- During placement of geocomposites, care shall be taken not to entrap stones, soil, excessive dust, or moisture that could damage the geomembrane, generate clogging of drains or filters, or hamper subsequent drainage operations.
- A visual examination of the geocomposite shall be carried out over the entire surface, after installation, to ensure that no potentially harmful foreign objects, (e.g., stones, sharp objects, small tools, sandbags, etc.) are present.

6.5.3 Geocomposite Joining, Seams, and Overlaps

The components of the geocomposite (e.g., geotextile, geonet) shall be seamed, joined, and overlapped to like components in adjacent geocomposites. Lower geotextile components of the geocomposites shall be overlapped such that the component has a minimum overlap of 4 in. Adjacent edges of geonet component along the length of the geocomposite should be overlapped a minimum 2-3 in. and joined by tying the geonet together with white or yellow plastic fasteners or polymeric thread evenly spaced every 5 ft along slopes and every 10 ft along flat surfaces and slopes less than or equal to 2 percent grade. Geonet for adjoining geocomposite panels (end to end) along the roll width should be shingled down in direction of slope and overlapped a minimum of 12 in. and joined by tying the geonet together with white or yellow plastic fasteners or polymeric thread evenly spaced every 12 in. Upper geotextile components of the geocomposites shall be continuously sewn (i.e., spot sewing is not allowed). Geotextiles shall be overlapped 6 in. prior to sewing. No horizontal seams shall be allowed on side slopes that are steeper than 10 horizontal to 1 vertical (i.e., seams shall be along, not across, the slope), except as part of a patch.

Sewing of geotextiles shall be done using polymeric thread with chemical and ultraviolet resistance properties equal to or exceeding those of the geotextile. The seams shall be sewn using a single row type "401" two-thread chain stitch or similar approved by the CQA Managing Engineer. The CQA Consultant shall monitor the geotextile seaming and geonet tying procedures to assure that joining, seams, and overlaps are in accordance with the specifications described in this document.

6.5.4 Geocomposite Repair

The CQA Consultant shall monitor that any holes or tears in the geocomposite are repaired as follows:

- A patch made from the same geocomposite will be secured into place by tying fasteners through the bottom geotextile and the geonet of the patch, and through the top geotextile and geonet.

- The patch will extend at least 2 ft beyond the edges of the hole or tear.
- The patch will be secured every 6 in. and heat sealed to the top geotextile of the geocomposite needing repair.
- If the hole or tear is more than 50 percent of the width of the roll, the damaged area should be cut out and the two portions of the geocomposite will be joined.

Care will be taken to remove any soil or other material which may have penetrated the torn geocomposite component. The CQA Consultant will observe any repair and verify that any non-compliance with the above requirements is corrected.

6.5.5 Placement of Soil Materials Over Geocomposite

CQA personnel will provide continuous monitoring during placement of soil materials located on top of a geocomposite, to assure that:

- no damage occurs to the geocomposite;
- no shifting of the geocomposite from its intended position occurs and underlying materials are not exposed or damaged;
- excess tensile stress does not occur in the geocomposite; and
- equipment ground pressure on geocomposites overlying geomembranes does not exceed those specified in the material specifications.

Soil backfilling or covering of the geocomposite shall be completed within 14 days. On side slopes soil layers shall be placed over the geocomposite from the bottom of the slope upward.

TABLE 6-1
MATERIAL SPECIFICATIONS FOR GEOCOMPOSITE DRAINAGE LAYER

PROPERTY	QUALIFIER	UNITS	SPECIFIED VALUES(1)	TEST METHOD(1)	MINIMUM FREQUENCY OF MQC TESTING(2)
Nonwoven Geotextile Component					
Polymer Composition	minimum	percent	95% polypropylene	-	-
Mass Per Unit Area	minimum	oz/yd^2	8	ASTM D 5261	1 per 100,000 ft^2
Grab Tensile Strength	minimum	lbs	158	ASTM D 4632	1 per 100,000 ft^2
Trapezoidal Tear Strength	minimum	lbs	56	ASTM D 4533	1 per 100,000 ft^2
CBR Puncture Strength	minimum	lbs	320	ASTM D 6241	1 per 100,000 ft^2
Apparent Opening Size	minimum	sieve size	70	ASTM D 4751	1 per 500,000 ft^2
Permittivity	minimum	s^{-1}	0.02	ASTM D 4491	1 per 500,000 ft^2
UV Resistance	minimum	percent ret. @ 500 hrs	70	ASTM D 4355	per formulation
Geonet Component					
Polymer Composition	minimum	percent	95% polyethylene	-	-
Thickness	minimum	inch	0.20	ASTM D 1777	1 per 100,000 ft^2
Tensile Strength	minimum	lb/inch	40	ASTM D 5035	1 per 100,000 ft^2
Carbon Black Content	minimum	%	2.0	ASTM D 5035	1 per 100,000 ft^2
Density	minimum	g/cc	0.935	ASTM D 792 or ASTM D 1505	1 per 100,000 ft^2
Double-Sided Geocomposite					
Transmissivity(2)	minimum	m^2/s	3×10^{-4}	ASTM D 4716	1 per 500,000 ft^2

Notes:

(1) Specified test methods and parameters may be modified by the CQA Engineer to be consistent with changes to the industry standard ASTM or GRI methods as they become available.

(2) At least one test per resin lot.

(3) Index transmissivity test for liner system geocomposite will be performed at: applied stress of 14,000 psf (min.), gradient of 0.02, and load duration of 15 minutes. Test configuration between two steel plates.

TABLE 6-2
CQA CONFORMANCE TESTING REQUIREMENTS FOR GEOCOMPOSITE DRAINAGE LAYER

TEST	METHOD(1)	MINIMUM FREQUENCY OF CQA TESTING(2)
Geonet Component		
Thickness	ASTM D 1777	1 per 200,000 ft^2
Tensile Strength	ASTM D 5035	1 per 200,000 ft^2
Carbon Black Content	ASTM D 5035	1 per 200,000 ft^2
Density	ASTM D 792 or ASTM D 1505	1 per 200,000 ft^2
Geotextile Component		
Mass Per Unit Area	ASTM D 5261	1 per 200,000 ft^2
Grab Tensile Strength	ASTM D 4632	1 per 200,000 ft^2
Trapezoidal Tear Strength	ASTM D 4533	1 per 200,000 ft^2
CBR Puncture Strength	ASTM D 6241	1 per 200,000 ft^2
Apparent Opening Size	ASTM D 4751	1 per 200,000 ft^2
Water Permittivity	ASTM D 4491	1 per 200,000 ft^2
Geocomposite		
Transmissivity	ASTM D 4716	1 per 200,000 ft^2

Notes:
(1) Specified test methods may be replaced with new ASTM or GRI methods by CQA Engineer as they become available, consistent with changes to the industry standard for geocomposites.
(2) CQA testing frequency will also be at a minimum of one per resin lot.

General Note: Required material properties are given in Table 6-1 of this Plan.

7. LEACHATE COLLECTION SYSTEM AGGREGATE

7.1 Introduction

This section addresses the specifications and CQA program to be implemented for leachate collection system aggregate. The following is discussed in the remainder of this section:

- Leachate Collection System Aggregate Specifications;
- Pre-Construction Evaluation of Material Sources;
- Material Conformance Testing During Construction; and
- Field Evaluation/Monitoring During Construction.

7.2 Leachate Collection System Aggregate Specifications

7.2.1 Aggregate Material Requirements

Material requirements for the leachate collection system aggregate are presented in Table 7-1.

7.3. Pre-Construction Evaluation of Material Sources

Prior to placement of leachate collection system aggregate, CQA personnel will obtain a soil sample from the proposed source(s). Each source will be evaluated for potential use as protective cover by performing the pre-construction laboratory tests presented in Table 7-2 and comparing the results of the tests, where applicable, to the material specifications presented in Table 7-1.

7.4 Material Conformance Testing During Construction

Conformance testing shall be performed in accordance with the methods and frequencies given in Table 7-2.

7.5 Field Evaluation/Monitoring During Construction

CQA personnel will be on-site at all times when placement of leachate collection system aggregate is ongoing, so that all relevant activities can be observed and documented. CQA personnel will visually monitor and document that installation of the gravel is in accordance with the specifications and requirements set forth previously in this document. These observations will include, but not be limited to visual monitoring and documentation of:

- the thickness and dimensions of the material as loosely placed and spread for compliance with the drawings and engineering details;

- the granular material for consistency of particle size distribution, shape, color, and appearance with the material approved during the pre-construction qualifying process;

- the construction equipment used during placement of the material to verify that only low-ground pressure equipment traverses over geosynthetics-lined areas until the specified material thickness above the geosynthetics is attained:

Allowable Equipment Ground Pressure (psi)	**Minimum Thickness of Soil Overlying Geosynthetics (in.)**
<5	12
<10	18
<20	24
>20	36

  A greater thickness than 36-in. shall be maintained over geosynthetics in areas trafficked by loaded hauling trucks and trailers and for turning areas.

- wrinkles or excess tensile stresses to underlying geosynthetics are minimized.

TABLE 7-1
MATERIAL SPECIFICATIONS FOR
LEACHATE COLLECTION SYSTEM DRAINAGE AGGREGATE

PROPERTY	QUALIFIER	UNITS	SPECIFIED VALUES	TEST METHOD[(1)]
Largest Particle Size	Maximum	Inch	2 in.	ASTM D 422 OR ASTM C 136
Percent Passing 3/8-in. Sieve	Maximum	Percent	5%	ASTM D 422 OR ASTM C 136
Percent Passing #200 Sieve	Maximum	Percent	3%	ASTM D 422 OR ASTM C 136

TABLE 7-2
PRE-CONSTRUCTION AND CONFORMANCE TESTING REQUIREMENTS FOR LEACHATE COLLECTION SYSTEM AGGREGATE

TEST	METHOD	MINIMUM FREQUENCY OF TESTING[(1)]
Particle Size (Sieve) Analysis	ASTM D 422 or ASTM C136	Pre-construction: 1 per source Conformance: repeat every 3,000 yd^3

Notes:

(1) Results of Pre-Construction qualification tests may be counted towards the conformance testing frequency requirements, provided the results meet the specified material properties.

8. PROTECTIVE COVER LAYER

8.1 Introduction

This section addresses the specifications and CQA program to be implemented for protective cover. The following is discussed in the remainder of this section:

- Protective Cover Specifications;
- Pre-Construction Evaluation of Material Sources;
- Material Conformance Testing During Construction;
- Field Evaluation/Monitoring During Construction; and
- Thickness Verification.

8.2 Protective Cover Layer Specifications

8.2.1 Protective Cover Layer Material Requirements

Material requirements for the protective cover material are presented in Table 8-1.

8.2.2 Protective Cover Layer Target Compaction Criteria

Protective cover does not require compaction control; however, it should be stable for construction and subsequent disposal traffic.

8.3 Pre-Construction Evaluation of Material Sources

Prior to placement of protective cover, CQA personnel will obtain a soil sample from the proposed source(s). Each source will be evaluated for potential use as protective cover by performing the pre-construction laboratory tests presented in Table 8-2 and comparing the results of the tests, where applicable, to the material specifications presented in Table 8-1.

8.4 Material Conformance Testing During Construction

When soil from the borrow/stockpile area is easily distinguished and consistent with the soil characterized during pre-construction testing, additional ongoing laboratory conformance testing beyond the initial pre-construction tests is not required. Any time the soil material being used becomes variable, or soils vary or appear inappropriate or questionable compared to the results from the initial pre-construction test program, additional material conformance testing of the tests and methods outlined in Table 8-2 should be performed.

8.5 Field Evaluation/Monitoring During Construction

CQA personnel will be on-site at all times when protective cover layer construction is ongoing, so that all relevant activities can be observed and documented. CQA personnel will visually monitor and document that construction of the protective cover layer is in accordance with the specifications and requirements set forth previously in this document. These observations will include, but not be limited to visual monitoring and documentation of:

- the protective cover soil material to evaluate the visual material classification and check for the presence of deleterious materials that could damage the liner and leachate collection systems or impede their performance as designed;

- the thickness and dimensions of the material as loosely placed and spread for compliance with the drawings and engineering details;

- proper placement techniques (generally in the up-slope direction) for protective cover on sideslope areas;

- the construction equipment used during placement of the material to verify that only low-ground pressure equipment traverses over geosynthetics-lined areas until the specified material thickness above the geosynthetics is attained:

Allowable Equipment Ground Pressure (psi)	Minimum Thickness of Soil Overlying Geosynthetics (in.)
<5	12
<10	18
<20	24
>20	36

  A greater thickness than 36-in. shall be maintained over geosynthetics in areas trafficked by loaded hauling trucks and trailers and for turning areas.

- wrinkles or excess tensile stresses to underlying geosynthetics are minimized.

8.6. Thickness Verification

The CQA Surveyor will verify protective cover thickness. Protective cover thickness verification will be determined by instrument survey method. The verification points provided in the Construction Drawings will be used for record purposes. Verification points should be at a spacing (e.g., grid) not exceeding 5,000 square feet. The beginning survey will be the previously completed top of compacted soil liner survey. The finished elevations of the protective cover layer will be taken using the same horizontal survey locations, so that thicknesses can be calculated and verified.

TABLE 8-1
MATERIAL SPECIFICATIONS FOR PROTECTIVE COVER

PROPERTY	QUALIFIER	UNITS	SPECIFIED VALUES	TEST METHOD(1)
Percent Passing 2-inch Sieve	Minimum	Percent	100	ASTM D 422

Notes:

(1) CQA testing frequencies are provided in Table 8-2.

TABLE 8-2
PRE-CONSTRUCTION TESTING REQUIREMENTS FOR PROTECTIVE COVER

TEST	METHOD	MINIMUM FREQUENCY OF TESTING[1]
Particle Size (Sieve) Analysis	ASTM D 422	1 per source of consistent material

Notes:

(1) The testing frequency of one per source refers to a relatively consistent and distinguishable soil type at a borrow source location based on visual observations and field classification procedures. If the same borrow source is utilized for the soil supply of more than one liner area project, results from previous pre-construction tests may continue to be used.

9. DOCUMENTATION

Upon completion of all required liner construction and evaluation and before placing the lined area into service, the CQA Engineer will prepare and submit a CQA Certification Report to the Owner for review and retention. The CQA Certification Report will document that all QA requirements have been addressed and satisfied and will be signed and sealed by the CQA Engineer performing the evaluation. The report will include a narrative describing the work and testing programs required by the CQA Plan, "as-built" record drawings, and appendices of photographs, laboratory test results, and field data. Specifically, the CQA Certification Report will include the following:

- a narrative summary of the construction activities, including a discussion of required CQA and CQC testing (procedures, protocols, required and actual testing frequencies or number of tests, failed tests, procedures to correct failed areas, documentation of re-tests, etc.;

- a photographic log showing a chronological record of work progress;

- as-built record drawing(s) showing confirmation of compacted soil liner and protective cover elevations and thicknesses;

- as-built geomembrane panel layout record drawing(s), showing location of panels, destructive test samples, patches and repairs;

- supporting documentation, including reference to the following items in the narrative report or as attachments to the report, as appropriate:

    - provision of full-time CQA by CQA personnel during soil liner construction and geomembrane installation;
    - preconstruction and CQA conformance soil test results;
    - for compacted soil liner:
        - nuclear gauge calibration information;
        - summary of field moisture-density control test methods and results, with reference to the lift and location tested and indication of passing or failing test results with cross-reference to a corresponding repair and passing test;
        - summary of hydraulic conductivity test results, with reference to the lift and location where samples were taken and indication of passing or failing test results with cross-reference to a corresponding repair and passing test;
        - summary tables of laboratory tests, with comparison to the specifications and indication of passing or failing test results;

    - compacted soil liner construction practices for floor and sideslope sections;
    - compacted soil liner placement and processing methods;
    - observations of compacted soil liner conditions prior to and after construction, including soil structure, clod size and presence of inclusions;
    - compacted soil liner construction methods, equipment type, compactor weight and foot length, and typical number of passes;
    - compacted soil liner lift tie-in and bonding observations;
    - repair of failed and damaged lifts of compacted soil liner;
    - post-construction care of compacted soil liner;
  - geosynthetic roll shipment information (material inventory);
  - geosynthetic MQC certificates, documentation, and testing results for the required MQC tests and frequencies identified in this CQA Plan;
  - geosynthetic CQA conformance testing results for the required CQA tests and frequencies identified in this CQA Plan;
  - for geomembrane:
    - geomembrane liner subgrade acceptance;
    - geomembrane storage and handling procedures;
    - information on deployment of geomembrane panels (also addressing field panel identification and placement, panel wrinkles, fish-mouths, or manufacturing creases, and equipment placed on geomembrane);
    - weather and ambient temperature compared to seaming limits;
    - trial seaming documentation, including names of seamers and machines, trial test times and temperatures, and results;
    - production seam documentation, including preparation and orientation, names of seamers and machines, and seam times;
    - seam repair documentation, including preparation and orientation, names of seamers and machines, and seam times;
    - nondestructive testing documentation for 100% of seams, including methods, criteria, names of testers, test times, and results;
    - destructive seam testing methods, criteria, and results;
    - 100% visual inspection of geomembrane for defects, damage, etc.;
    - repair information, including preparation and procedures, failure delineation, patch size and shape, and retesting;
  - anchor trench preparation and backfilling; and
  - any deviations from the construction drawings and specifications.

APPENDIX C

HELP Model Output

Initial Condition (IN)

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                 HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    C:\PRECIP.D4
TEMPERATURE DATA FILE:      \TEMP.D7
SOLAR RADIATION DATA FILE:  \SOLAR.D13
EVAPOTRANSPIRATION DATA:    \ET_BARE.D11
SOIL AND DESIGN DATA FILE:  \IN.D10
OUTPUT DATA FILE:           \IN.OUT

TIME:  15:16     DATE:   8/ 4/2015

******************************************************************************

     TITLE:  LCRA Fayette Power Project - Initial Condition

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                                   LAYER  1
                                   --------

                        TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     60.00   INCHES
           POROSITY                   =      0.5010 VOL/VOL
           FIELD CAPACITY             =      0.2840 VOL/VOL
           WILTING POINT              =      0.1350 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2929 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.109000001000E-03 CM/SEC

                                   LAYER  2
                                   --------

                        TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  13
           THICKNESS                  =     24.00   INCHES
           POROSITY                   =      0.4300 VOL/VOL
           FIELD CAPACITY             =      0.3210 VOL/VOL
           WILTING POINT              =      0.2210 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.3599 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.330000003000E-04 CM/SEC

                                   LAYER  3
                                   --------

                          TYPE 2 - LATERAL DRAINAGE LAYER
                          MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      0.20   INCHES
           POROSITY                   =      0.8500 VOL/VOL
           FIELD CAPACITY             =      0.0100 VOL/VOL
           WILTING POINT              =      0.0050 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.7522 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.720000029000     CM/SEC
           SLOPE                      =      2.24   PERCENT
           DRAINAGE LENGTH            =    500.0    FEET

                                   LAYER  4
                                   --------

                          TYPE 4 - FLEXIBLE MEMBRANE LINER
                          MATERIAL TEXTURE NUMBER  35
           THICKNESS                  =      0.06   INCHES
           POROSITY                   =      0.0000 VOL/VOL
           FIELD CAPACITY             =      0.0000 VOL/VOL
           WILTING POINT              =      0.0000 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
           FML PINHOLE DENSITY        =      2.00   HOLES/ACRE
           FML INSTALLATION DEFECTS   =      2.00   HOLES/ACRE
           FML PLACEMENT QUALITY      =  4 - POOR

                                   LAYER  5
                                   --------

                        TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  16
           THICKNESS                  =     24.00   INCHES
           POROSITY                   =      0.4270 VOL/VOL
           FIELD CAPACITY             =      0.4180 VOL/VOL
           WILTING POINT              =      0.3670 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.4180 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000001000E-06 CM/SEC
```

```
           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

  NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

 SCS RUNOFF CURVE NUMBER            =      0.00
 FRACTION OF AREA ALLOWING RUNOFF   =      0.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
 EVAPORATIVE ZONE DEPTH             =     10.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE  =      1.951  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE =      5.010  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE =      1.350  INCHES
 INITIAL SNOW WATER                 =      0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS   =     36.391  INCHES
 TOTAL INITIAL WATER                =     36.391  INCHES
 TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR

             EVAPOTRANSPIRATION AND WEATHER DATA
             -----------------------------------

  NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
           AUSTIN                TEXAS

      STATION LATITUDE                        =  30.18 DEGREES
      MAXIMUM LEAF AREA INDEX                 =   0.00
      START OF GROWING SEASON (JULIAN DATE)   =     44
      END OF GROWING SEASON (JULIAN DATE)     =    346
      EVAPORATIVE ZONE DEPTH                  =  10.0  INCHES
      AVERAGE ANNUAL WIND SPEED               =   9.30 MPH
      AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  66.00 %
      AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  70.00 %
      AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  66.00 %
      AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  67.00 %

  NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR    AUSTIN              TEXAS

           NORMAL MEAN MONTHLY PRECIPITATION (INCHES)
```

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.60	2.49	1.68	3.11	4.19	3.06
1.89	2.24	3.60	3.38	2.20	2.06

```
  NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR    AUSTIN              TEXAS

      NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)
```

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
49.10	53.20	60.50	68.70	74.90	81.60
84.70	84.50	79.20	69.80	58.70	52.10

```
  NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR    AUSTIN              TEXAS
             AND STATION LATITUDE  =  30.18 DEGREES
```

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 1

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.65	2.56	0.82	0.03	1.74	0.00
	0.45	4.41	2.37	5.47	0.62	3.40
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.809	1.052	2.625	0.041	0.490	0.315
	0.288	4.208	1.795	2.973	1.642	2.518
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.6748	0.3552	0.5458	0.3889	0.2850	0.2612
	0.1239	0.0101	0.0090	0.0101	0.1120	0.9685
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ON TOP OF LAYER 4						
AVERAGES	0.1191	0.0694	0.0963	0.0709	0.0503	0.0476
	0.0219	0.0018	0.0016	0.0018	0.0204	0.1709
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	22.52 (0.000)	81747.6	100.00
RUNOFF	0.000 (0.0000)	0.00	0.000
EVAPOTRANSPIRATION	18.757 (0.0000)	68086.60	83.289
LATERAL DRAINAGE COLLECTED FROM LAYER 3	3.74434 (0.00000)	13591.942	16.62672
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00027 (0.00000)	0.972	0.00119
AVERAGE HEAD ON TOP OF LAYER 4	0.056 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00000 (0.00000)	0.000	0.00000
CHANGE IN WATER STORAGE	0.019 (0.0000)	69.04	0.084

PEAK DAILY VALUES FOR YEARS 1 THROUGH 1

	(INCHES)	(CU. FT.)
PRECIPITATION	1.56	5662.800
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 3	0.03609	131.02000
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000002	0.00864
AVERAGE HEAD ON TOP OF LAYER 4	0.197	
MAXIMUM HEAD ON TOP OF LAYER 4	0.389	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	6.9 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000000	0.00000
SNOW WATER	0.00	0.0000

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4285
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1350

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

FINAL WATER STORAGE AT END OF YEAR 1

LAYER	(INCHES)	(VOL/VOL)
1	17.5885	0.2931
2	8.6379	0.3599
3	0.1516	0.7578
4	0.0000	0.0000
5	10.0319	0.4180
SNOW WATER	0.000	

Intermediate Condition (INT)

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                   **
**               DEVELOPED BY ENVIRONMENTAL LABORATORY                      **
**                 USAE WATERWAYS EXPERIMENT STATION                        **
**           FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    C:\PRECIP.D4
TEMPERATURE DATA FILE:      \TEMP.D7
SOLAR RADIATION DATA FILE:  \SOLAR.D13
EVAPOTRANSPIRATION DATA:    \ET_BARE.D11
SOIL AND DESIGN DATA FILE:  \INT.D10
OUTPUT DATA FILE:           \INT.OUT

TIME:  15:23     DATE:   8/ 4/2015

******************************************************************************

     TITLE:  LCRA Fayette Power Project - Intermediate Condition

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                             LAYER  1
                             --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
     THICKNESS                  =    720.00   INCHES
     POROSITY                   =      0.5010 VOL/VOL
     FIELD CAPACITY             =      0.2840 VOL/VOL
     WILTING POINT              =      0.1350 VOL/VOL
     INITIAL SOIL WATER CONTENT =      0.2875 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  =  0.109000001000E-03 CM/SEC

                             LAYER  2
                             --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  13
     THICKNESS                  =     24.00   INCHES
     POROSITY                   =      0.4300 VOL/VOL
     FIELD CAPACITY             =      0.3210 VOL/VOL
     WILTING POINT              =      0.2210 VOL/VOL
     INITIAL SOIL WATER CONTENT =      0.3249 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  =  0.330000003000E-04 CM/SEC

                             LAYER  3
                             --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
     THICKNESS                  =      0.20   INCHES
     POROSITY                   =      0.8500 VOL/VOL
     FIELD CAPACITY             =      0.0100 VOL/VOL
     WILTING POINT              =      0.0050 VOL/VOL
     INITIAL SOIL WATER CONTENT =      0.0120 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  =  0.629999995000     CM/SEC
     SLOPE                      =      2.24   PERCENT
     DRAINAGE LENGTH            =    500.0    FEET

                             LAYER  4
                             --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
     THICKNESS                  =      0.06   INCHES
     POROSITY                   =      0.0000 VOL/VOL
     FIELD CAPACITY             =      0.0000 VOL/VOL
     WILTING POINT              =      0.0000 VOL/VOL
     INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
     FML PINHOLE DENSITY        =      2.00   HOLES/ACRE
     FML INSTALLATION DEFECTS   =      2.00   HOLES/ACRE
     FML PLACEMENT QUALITY      =  3 - GOOD


                             LAYER  5
                             --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  16
     THICKNESS                  =     24.00   INCHES
     POROSITY                   =      0.4270 VOL/VOL
     FIELD CAPACITY             =      0.4180 VOL/VOL
     WILTING POINT              =      0.3670 VOL/VOL
     INITIAL SOIL WATER CONTENT =      0.4180 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  =  0.100000001000E-06 CM/SEC
```

```
           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

  NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

 SCS RUNOFF CURVE NUMBER            =      0.00
 FRACTION OF AREA ALLOWING RUNOFF   =      0.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
 EVAPORATIVE ZONE DEPTH             =     10.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE  =      1.951  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE =      5.010  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE =      1.350  INCHES
 INITIAL SNOW WATER                 =      0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS   =    224.840  INCHES
 TOTAL INITIAL WATER                =    224.840  INCHES
 TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR

            EVAPOTRANSPIRATION AND WEATHER DATA
            -----------------------------------

  NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         AUSTIN                TEXAS

      STATION LATITUDE                        =  30.18 DEGREES
      MAXIMUM LEAF AREA INDEX                 =   0.00
      START OF GROWING SEASON (JULIAN DATE)   =     44
      END OF GROWING SEASON (JULIAN DATE)     =    346
      EVAPORATIVE ZONE DEPTH                  =  10.0  INCHES
      AVERAGE ANNUAL WIND SPEED               =   9.30 MPH
      AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  66.00 %
      AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  70.00 %
      AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  66.00 %
      AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  67.00 %


  NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    AUSTIN              TEXAS

         NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
-------    -------    -------    -------    -------    -------
  1.60       2.49       1.68       3.11       4.19       3.06
  1.89       2.24       3.60       3.38       2.20       2.06


  NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    AUSTIN              TEXAS

      NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
-------    -------    -------    -------    -------    -------
 49.10      53.20      60.50      68.70      74.90      81.60
 84.70      84.50      79.20      69.80      58.70      52.10


  NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    AUSTIN              TEXAS
           AND STATION LATITUDE  =  30.18 DEGREES
```

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.15	2.50	1.69	3.07	4.24	2.87
	2.10	2.84	3.09	2.84	2.07	2.03
STD. DEVIATIONS	0.76	1.44	0.99	1.85	2.40	2.46
	1.60	2.21	2.00	2.10	1.33	1.35
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.385	1.663	1.985	2.305	3.253	2.293
	1.886	2.280	2.273	2.200	1.656	1.634
STD. DEVIATIONS	0.662	0.777	1.049	1.106	1.466	1.668
	1.391	1.454	1.253	1.268	0.889	0.673
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.3521	0.4081	0.5221	0.4459	0.4678	0.4595
	0.3563	0.3757	0.4094	0.4678	0.4668	0.3852
STD. DEVIATIONS	0.2016	0.2044	0.2207	0.1768	0.2039	0.1657
	0.1763	0.1860	0.2189	0.1938	0.2081	0.2218
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001
	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
DAILY AVERAGE HEAD ON TOP OF LAYER 4						
AVERAGES	0.0710	0.0904	0.1053	0.0929	0.0943	0.0958
	0.0719	0.0758	0.0853	0.0944	0.0973	0.0777
STD. DEVIATIONS	0.0407	0.0454	0.0445	0.0368	0.0411	0.0345
	0.0356	0.0375	0.0456	0.0391	0.0434	0.0447

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	30.49 (6.254)	110681.1	100.00
RUNOFF	0.000 (0.0000)	0.00	0.000
EVAPOTRANSPIRATION	24.812 (4.1598)	90069.15	81.377
LATERAL DRAINAGE COLLECTED FROM LAYER 3	5.11674 (1.33101)	18573.770	16.78133
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00008 (0.00002)	0.284	0.00026
AVERAGE HEAD ON TOP OF LAYER 4	0.088 (0.023)		
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00008 (0.00018)	0.281	0.00025
CHANGE IN WATER STORAGE	0.561 (3.5121)	2037.93	1.841

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	8.49	30818.699
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 3	0.03186	115.64494
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000000	0.00165
AVERAGE HEAD ON TOP OF LAYER 4	0.199	
MAXIMUM HEAD ON TOP OF LAYER 4	0.392	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	7.2 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000464	1.68339
SNOW WATER	1.95	7072.4541

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.5010

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1350

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	222.8632	0.3095
2	8.6662	0.3611
3	0.1219	0.6095
4	0.0000	0.0000
5	10.0316	0.4180
SNOW WATER	0.000	

Final Condition – No Cover (FNC)

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**                                                                          **
**                                                                          **
**             HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                **
**               HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                 **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    C:\PRECIP.D4
TEMPERATURE DATA FILE:      \TEMP.D7
SOLAR RADIATION DATA FILE:  \SOLAR.D13
EVAPOTRANSPIRATION DATA:    \ET_BARE.D11
SOIL AND DESIGN DATA FILE:  \FNC.D10
OUTPUT DATA FILE:           \FNC.OUT

TIME:  16:33     DATE:   8/ 4/2015


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     TITLE:  LCRA Fayette Power Project - Final No Cover

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                               LAYER  1
                               --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =   1536.00   INCHES
           POROSITY                   =      0.5010 VOL/VOL
           FIELD CAPACITY             =      0.2840 VOL/VOL
           WILTING POINT              =      0.1350 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2857 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.109000001000E-03 CM/SEC

                               LAYER  2
                               --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  13
           THICKNESS                  =     24.00   INCHES
           POROSITY                   =      0.4300 VOL/VOL
           FIELD CAPACITY             =      0.3210 VOL/VOL
           WILTING POINT              =      0.2210 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.3244 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.330000003000E-04 CM/SEC

                               LAYER  3
                               --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      0.20   INCHES
           POROSITY                   =      0.8500 VOL/VOL
           FIELD CAPACITY             =      0.0100 VOL/VOL
           WILTING POINT              =      0.0050 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.0141 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.540000021000     CM/SEC
           SLOPE                      =      2.24   PERCENT
           DRAINAGE LENGTH            =    500.0    FEET

                               LAYER  4
                               --------

                    TYPE 4 - FLEXIBLE MEMBRANE LINER
                      MATERIAL TEXTURE NUMBER  35
           THICKNESS                  =      0.06   INCHES
           POROSITY                   =      0.0000 VOL/VOL
           FIELD CAPACITY             =      0.0000 VOL/VOL
           WILTING POINT              =      0.0000 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
           FML PINHOLE DENSITY        =      2.00   HOLES/ACRE
           FML INSTALLATION DEFECTS   =      2.00   HOLES/ACRE
           FML PLACEMENT QUALITY      =  3 - GOOD


                               LAYER  5
                               --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  16
           THICKNESS                  =     24.00   INCHES
           POROSITY                   =      0.4270 VOL/VOL
           FIELD CAPACITY             =      0.4180 VOL/VOL
           WILTING POINT              =      0.3670 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.4180 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000001000E-06 CM/SEC
```

```
           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

  NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

 SCS RUNOFF CURVE NUMBER            =      0.00
 FRACTION OF AREA ALLOWING RUNOFF   =      0.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
 EVAPORATIVE ZONE DEPTH             =     10.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE  =      1.951  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE =      5.010  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE =      1.350  INCHES
 INITIAL SNOW WATER                 =      0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS   =    456.590  INCHES
 TOTAL INITIAL WATER                =    456.590  INCHES
 TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR

             EVAPOTRANSPIRATION AND WEATHER DATA
             -----------------------------------

  NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
           AUSTIN                 TEXAS

      STATION LATITUDE                         =  30.18 DEGREES
      MAXIMUM LEAF AREA INDEX                  =   0.00
      START OF GROWING SEASON (JULIAN DATE)    =     44
      END OF GROWING SEASON (JULIAN DATE)      =    346
      EVAPORATIVE ZONE DEPTH                   =  10.0  INCHES
      AVERAGE ANNUAL WIND SPEED                =   9.30 MPH
      AVERAGE 1ST QUARTER RELATIVE HUMIDITY    =  66.00 %
      AVERAGE 2ND QUARTER RELATIVE HUMIDITY    =  70.00 %
      AVERAGE 3RD QUARTER RELATIVE HUMIDITY    =  66.00 %
      AVERAGE 4TH QUARTER RELATIVE HUMIDITY    =  67.00 %

  NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR    AUSTIN              TEXAS

           NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
-------     -------     -------     -------     -------     -------
  1.60        2.49        1.68        3.11        4.19        3.06
  1.89        2.24        3.60        3.38        2.20        2.06

  NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR    AUSTIN              TEXAS

      NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
-------     -------     -------     -------     -------     -------
 49.10       53.20       60.50       68.70       74.90       81.60
 84.70       84.50       79.20       69.80       58.70       52.10

  NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR    AUSTIN              TEXAS
             AND STATION LATITUDE  =  30.18 DEGREES
```

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.15	2.50	1.69	3.07	4.24	2.87
	2.10	2.84	3.09	2.84	2.07	2.03
STD. DEVIATIONS	0.76	1.44	0.99	1.85	2.40	2.46
	1.60	2.21	2.00	2.10	1.33	1.35
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.385	1.663	1.985	2.305	3.253	2.293
	1.886	2.280	2.273	2.200	1.656	1.634
STD. DEVIATIONS	0.662	0.777	1.049	1.106	1.466	1.668
	1.391	1.454	1.253	1.268	0.889	0.673
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.3013	0.3008	0.4501	0.4220	0.4066	0.4180
	0.3282	0.3207	0.3125	0.3872	0.4039	0.3423
STD. DEVIATIONS	0.1693	0.1850	0.2057	0.1579	0.2110	0.1603
	0.1787	0.1736	0.1901	0.1620	0.1795	0.1956
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0001	0.0001	0.0000	0.0001

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4						
AVERAGES	0.0709	0.0778	0.1059	0.1026	0.0957	0.1016
	0.0772	0.0755	0.0760	0.0911	0.0982	0.0805
STD. DEVIATIONS	0.0398	0.0480	0.0484	0.0384	0.0497	0.0390
	0.0421	0.0408	0.0462	0.0381	0.0437	0.0460

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	30.49 (6.254)	110681.1	100.00
RUNOFF	0.000 (0.0000)	0.00	0.000
EVAPOTRANSPIRATION	24.812 (4.1598)	90069.15	81.377
LATERAL DRAINAGE COLLECTED FROM LAYER 3	4.39356 (1.29441)	15948.622	14.40952
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00008 (0.00002)	0.284	0.00026
AVERAGE HEAD ON TOP OF LAYER 4	0.088 (0.026)		
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00008 (0.00018)	0.281	0.00025
CHANGE IN WATER STORAGE	1.285 (3.5344)	4663.09	4.213

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	8.49	30818.699
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 3	0.02707	98.25376
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000000	0.00164
AVERAGE HEAD ON TOP OF LAYER 4	0.197	
MAXIMUM HEAD ON TOP OF LAYER 4	0.389	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	6.6 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000464	1.68337
SNOW WATER	1.95	7072.4541

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.5010
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1350

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	476.2954	0.3101
2	8.6655	0.3611
3	0.1355	0.6777
4	0.0000	0.0000
5	10.0316	0.4180
SNOW WATER	0.000	

Final Cover (FC)

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                 **
**               DEVELOPED BY ENVIRONMENTAL LABORATORY                      **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:    C:\LCRA\DATA4.D4
TEMPERATURE DATA FILE:      C:\LCRA\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\LCRA\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\LCRA\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\LCRA\DATA10.D10
OUTPUT DATA FILE:           C:\LCRA\OUT.OUT

TIME:  15:25     DATE:  10/ 5/2016

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     TITLE:  LCRA Fayette Power Project - Final Cover

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
            COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                                   LAYER  1
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  11
          THICKNESS                 =     18.00   INCHES
          POROSITY                  =      0.4640 VOL/VOL
          FIELD CAPACITY            =      0.3100 VOL/VOL
          WILTING POINT             =      0.1870 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.3479 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.639999998000E-04 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.20
               FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

                                   LAYER  2
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  16
          THICKNESS                 =     36.00   INCHES
          POROSITY                  =      0.4270 VOL/VOL
          FIELD CAPACITY            =      0.4180 VOL/VOL
          WILTING POINT             =      0.3670 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.4186 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.100000001000E-06 CM/SEC

                                   LAYER  3
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
          THICKNESS                 =   1536.00   INCHES
          POROSITY                  =      0.5010 VOL/VOL
          FIELD CAPACITY            =      0.2840 VOL/VOL
          WILTING POINT             =      0.1350 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.2840 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.109000001000E-03 CM/SEC

                                   LAYER  4
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  13
          THICKNESS                 =     24.00   INCHES
          POROSITY                  =      0.4300 VOL/VOL
          FIELD CAPACITY            =      0.3210 VOL/VOL
          WILTING POINT             =      0.2210 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.3210 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.330000003000E-04 CM/SEC

                                   LAYER  5
                                   --------

                        TYPE 2 - LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER   0
          THICKNESS                 =      0.20   INCHES
          POROSITY                  =      0.8500 VOL/VOL
          FIELD CAPACITY            =      0.0100 VOL/VOL
          WILTING POINT             =      0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.0695 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.759999976000E-01 CM/SEC
          SLOPE                     =      2.24   PERCENT
          DRAINAGE LENGTH           =    500.0    FEET

                                   LAYER  6
                                   --------

                      TYPE 4 - FLEXIBLE MEMBRANE LINER
                        MATERIAL TEXTURE NUMBER  35
          THICKNESS                 =      0.06   INCHES
          POROSITY                  =      0.0000 VOL/VOL
          FIELD CAPACITY            =      0.0000 VOL/VOL
          WILTING POINT             =      0.0000 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.0000 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
          FML PINHOLE DENSITY       =      2.00   HOLES/ACRE
          FML INSTALLATION DEFECTS  =      2.00   HOLES/ACRE
          FML PLACEMENT QUALITY     =  3 - GOOD

                                   LAYER  7
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  16
          THICKNESS                 =     24.00   INCHES
          POROSITY                  =      0.4270 VOL/VOL
          FIELD CAPACITY            =      0.4180 VOL/VOL
          WILTING POINT             =      0.3670 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.4180 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.100000001000E-06 CM/SEC


                  GENERAL DESIGN AND EVAPORATIVE ZONE DATA
                  ----------------------------------------

     NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
            SOIL DATA BASE USING SOIL TEXTURE #11 WITH A
            GOOD STAND OF GRASS, A SURFACE SLOPE OF  1.%
            AND A SLOPE LENGTH OF 1600. FEET.

     SCS RUNOFF CURVE NUMBER            =    79.60
     FRACTION OF AREA ALLOWING RUNOFF   =   100.0    PERCENT
     AREA PROJECTED ON HORIZONTAL PLANE =     1.000  ACRES
     EVAPORATIVE ZONE DEPTH             =    18.0    INCHES
     INITIAL WATER IN EVAPORATIVE ZONE  =     6.262  INCHES
     UPPER LIMIT OF EVAPORATIVE STORAGE =     8.352  INCHES
     LOWER LIMIT OF EVAPORATIVE STORAGE =     3.366  INCHES
     INITIAL SNOW WATER                 =     0.000  INCHES
     INITIAL WATER IN LAYER MATERIALS   =   475.306  INCHES
     TOTAL INITIAL WATER                =   475.306  INCHES
     TOTAL SUBSURFACE INFLOW            =     0.00   INCHES/YEAR

                    EVAPOTRANSPIRATION AND WEATHER DATA
                    -----------------------------------

     NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
            AUSTIN               TEXAS

          STATION LATITUDE                        =  30.18 DEGREES
          MAXIMUM LEAF AREA INDEX                 =   3.00
          START OF GROWING SEASON (JULIAN DATE)   =    44
          END OF GROWING SEASON (JULIAN DATE)     =   346
          EVAPORATIVE ZONE DEPTH                  =  18.0  INCHES
          AVERAGE ANNUAL WIND SPEED               =   9.30 MPH
          AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  66.00 %
          AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  70.00 %
          AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  66.00 %
          AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  67.00 %

     NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
            COEFFICIENTS FOR    AUSTIN              TEXAS

            NORMAL MEAN MONTHLY PRECIPITATION (INCHES)
```

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.60	2.49	1.68	3.11	4.19	3.06
1.89	2.24	3.60	3.38	2.20	2.06

```
     NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
            COEFFICIENTS FOR    AUSTIN              TEXAS

          NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)
```

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
49.10	53.20	60.50	68.70	74.90	81.60
84.70	84.50	79.20	69.80	58.70	52.10

```
     NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
            COEFFICIENTS FOR    AUSTIN              TEXAS
            AND STATION LATITUDE  =  30.18 DEGREES

******************************************************************************

     AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH   30
```

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.15	2.50	1.69	3.07	4.24	2.87
	2.10	2.84	3.09	2.84	2.07	2.03
STD. DEVIATIONS	0.76	1.44	0.99	1.85	2.40	2.46
	1.60	2.21	2.00	2.10	1.33	1.35

RUNOFF

TOTALS	0.000	0.154	0.001	0.057	0.288	0.124
	0.061	0.052	0.047	0.154	0.098	0.212
STD. DEVIATIONS	0.000	0.313	0.002	0.126	0.839	0.326
	0.164	0.116	0.126	0.437	0.387	0.530

EVAPOTRANSPIRATION

TOTALS	1.681	1.683	2.320	3.841	4.326	2.898
	2.485	2.541	2.650	1.938	1.128	1.206
STD. DEVIATIONS	0.426	0.551	0.956	1.021	1.928	2.072
	1.908	1.623	1.529	0.842	0.305	0.340

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.0326	0.0262	0.0284	0.0275	0.0321	0.0386
	0.0496	0.0609	0.0666	0.0737	0.0640	0.0493
STD. DEVIATIONS	0.0158	0.0104	0.0120	0.0145	0.0163	0.0179
	0.0236	0.0274	0.0285	0.0322	0.0314	0.0274

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.0545	0.0480	0.0475	0.0474	0.0538	0.0667
	0.0829	0.1019	0.1151	0.1232	0.1106	0.0825
STD. DEVIATIONS	0.0263	0.0189	0.0201	0.0250	0.0272	0.0309
	0.0395	0.0458	0.0492	0.0538	0.0542	0.0458

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	30.49 (6.254)	110681.1	100.00
RUNOFF	1.248 (1.3388)	4528.62	4.092
EVAPOTRANSPIRATION	28.697 (4.4948)	104168.82	94.116
LATERAL DRAINAGE COLLECTED FROM LAYER 5	0.54953 (0.21445)	1994.790	1.80229
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00007 (0.00002)	0.256	0.00023
AVERAGE HEAD ON TOP OF LAYER 6	0.078 (0.030)		
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00006 (0.00016)	0.224	0.00020
CHANGE IN WATER STORAGE	-0.003 (2.0082)	-11.33	-0.010

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	8.49	30818.699
RUNOFF	4.404	15984.8096
DRAINAGE COLLECTED FROM LAYER 5	0.00380	13.78905
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00164
AVERAGE HEAD ON TOP OF LAYER 6	0.197	
MAXIMUM HEAD ON TOP OF LAYER 6	0.388	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	7.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000464	1.68375
SNOW WATER	1.95	7072.4541
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4640	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1870	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	6.1372	0.3410
2	15.0040	0.4168
3	436.2239	0.2840
4	7.7040	0.3210
5	0.1112	0.5562
6	0.0000	0.0000
7	10.0318	0.4180
SNOW WATER	0.000	