

LN_V ENGINEERING
engineers & consultants

November 29, 2007

Dr. Richard Carmichael
Municipal Solid Waste Permits Section
Waste Permits Division
Texas Commission on Environmental Quality
P.O. Box 13087
Austin, Texas 78711-3087

RE: Municipal Solid Waste - Angelina County
Angelina County Waste Management Center- MSW Permit No. 2105A
Request for Permit Modification

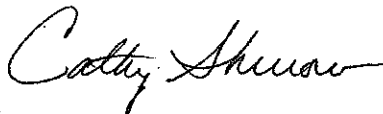
Dear Dr. Carmichael:

In accordance with §305.70(l) and on behalf of Angelina County Waste Management Center, we hereby request a permit modification to the above referenced permit.

The purpose of this permit modification is to revise the Site Development Plan (SDP), Attachment 12, Final Closure Plan to allow for an alternative final cover design. An "Alternative Final Cover Demonstration" and a "Final Closure Quality Control Plan (FCQCP)" are included as appendices to Attachment 12.

Please note that the enclosed SDP Attachment 12, Final Closure Plan will fully replace the current SDP Attachment 12, therefore we request review as an entirely new document. An original plus two (2) copies of this modification request along with the Part I Application (Form TCEQ-0650), the landowner's map and landowner's list, and the \$150.00 application fee are enclosed. Also, in accordance with 30 TAC §305.44, please find enclosed the signed "APPLICANT'S CERTIFICATION AND NOTICE OF APPOINTMENT." If you have any questions regarding this permit modification or require any additional information, please feel free to contact me at (361) 883-1984.

Sincerely,



Catherine A. Skurow, P.E.
Vice President of Environmental Services

Enclosures

cc: TCEQ Region 10 Office, Beaumont, Texas

**ANGELINA COUNTY
WASTE MANAGEMENT CENTER**
TCEQ Permit No. MSW-2105A

**SDP Attachment 12
Final Closure Plan**

prepared by:



November 20, 2007



Catherine A. Skurow 11/20/07
FOR PERMITTING PURPOSES ONLY

SDP ATTACHMENT 12

Final Closure Plan
Angelina County Waste Management Center
Type 1 MSW Landfill
TCEQ Permit No. MSW-2105A

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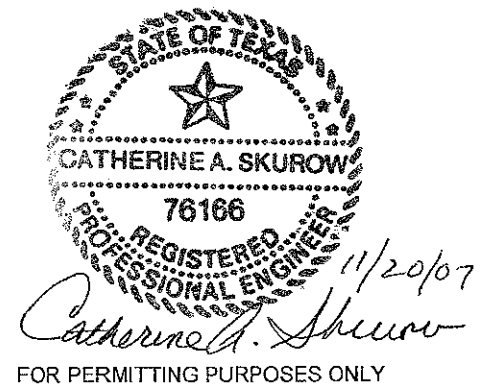


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SDP ATTACHMENT 12

**Final Closure Plan
Angelina County Waste Management Center
Type 1 MSW Landfill
TCEQ Permit No. MSW-2015A**

1 INTRODUCTION

This plan has been prepared to fulfill the requirements of 30 TAC Subchapter J, §§330.457, 330.459, and 330.461 regarding closure requirements for all Municipal Solid Waste (MSW) landfill units. As stated in the regulations, the required final closure system for each MSW landfill unit is determined by the date which the MSW landfill unit stops receiving waste and by the underlying bottom liner system for the unit. All MSW landfill units at the Angelina County Waste Management Center received waste after October 9, 1993. This document details the requirement for final closure of all MSW landfill units at the Angelina County Waste Management Center.

2 FINAL COVER SYSTEM REQUIREMENTS

2.1 MSW Landfill Units with Synthetic Bottom Liners

2.1.1 Subtitle D Final Cover System

30 TAC §330.457(a)(1) states that the final cover system for a MSW landfill unit with a synthetic bottom liner must have a synthetic membrane that has permeability less than or equal to the permeability of any bottom liner system overlain by a clay rich cover layer consisting of a minimum of 18 inches of earthen material with a coefficient of permeability no greater than 1×10^{-5} cm/sec.

The synthetic membrane currently permitted for the Angelina County Waste Management Center consists of 40 mil linear low density polyethylene. The synthetic membrane will be smooth on the gently sloping top sections of the cap and textured on the 4-horizontal:1-vertical side slopes.

2.1.2 Alternative Final Cover System

In accordance with 30 TAC §330.457(d), the executive director may approve an alternative final cover design that achieves an equivalent reduction in infiltration as the clay-rich soil layer detailed in 30 TAC §330.457(a)(1) and provides equivalent protection from wind and water erosion as detailed in 30 TAC §330.457(a)(3).

As detailed in the August 1, 2006 TCEQ rule interpretation of §330.457(d) regarding alternative final cover systems, the infiltration of the standard Subtitle D design must be modeled on the basis of its soil layer and synthetic membrane together. Additionally, if a permit specifies a design with more stringent final cover specifications than in §330.457(a)(1) or (2), the alternative must be compared against the more stringent design.

As detailed in the Alternative Final Cover Demonstration (Appendix 5.3 of this plan), the currently permitted final cover system is more stringent than the requirements of §330.457(a)(1) and (3), therefore an alternative final cover has been designed that achieves an equivalent or greater reduction in infiltration and provides equivalent protection from wind and water erosion as the currently permitted design.

An alternative final cover system (AFCS) has been designed for the MSW landfill units with synthetic bottom liners and consists of replacing the clay-rich soil layer component in the site's currently permitted final cover system with a geosynthetic clay liner (GCL). The GCL will be overlain with a 40 mil LLDPE geomembrane. The synthetic membrane will be textured on the 4-horizontal:1-vertical side slopes and smooth on lesser top slopes. The alternative final cover system will be used on all areas with a synthetic bottom liner.

2.1.3 Drainage Layer

A geocomposite drainage layer will be placed over the synthetic membrane. The geocomposite drainage layer will consist of a 200 mil geonet heat-fused to 10 oz geotextile filter fabric (single-sided for top slopes, double-sided for the 4-horizontal:1-vertical side slopes).

2.2 MSW Landfill Units With No Synthetic Liner

30 TAC §330.457(a)(2) states that the final cover system for a MSW landfill unit with no synthetic bottom liner must have a clay-rich cover soil layer consisting of a minimum of 18 inches of earthen material with a coefficient of permeability less than or equal to the permeability of any constructed bottom liner or natural subsoil present. The coefficient of permeability of the infiltration layer shall in no case exceed 1×10^{-5} cm/sec, even though the coefficient of permeability of the constructed bottom liner or natural subsoil is greater than 1×10^{-5} cm/sec or no data exist for the value(s) of the coefficient of permeability of the constructed bottom liner or natural subsoil.

Approximately 6.9 acres are underlain with pre-Subtitle D compacted clay liners with no synthetic bottom liners. Prior to initiating final closure of this area, an average of the permeabilities for the underlying compacted clay liner system will be calculated to determine the pre-construction permeability criteria for the final cover system.

The final cover for the MSW landfill unit with no synthetic bottom liner will be constructed with an infiltration layer consisting of a minimum of 18 inches of compacted clay with an average coefficient of permeability less than or equal to the pre-construction permeability criteria as discussed above or 1×10^{-5} cm/sec, whichever is less. Additionally, no more than 5% of the measured infiltration layer permeabilities from individual tests will be greater than 1×10^{-7} cm/sec, with no individual results greater than 5.0×10^{-7} cm/sec.

2.3 Erosion Layer

In accordance 30 TAC §330.457(a)(3), all final cover systems must include an erosion layer consisting of a minimum of six inches (6") of earthen material that is capable of sustaining native plant and must be seeded or sodded in order to minimize erosion.

The erosion layer for the Angelina County Waste Management Center will consist of 24 inches of earthen material with the top six inches (6") being capable sustaining native plant growth and will be seeded or sodded to minimize erosion.

3 QUALITY CONTROL TESTING

In accordance with 30 TAC §330.457(c), quality control testing shall be performed and documented on the 18 inches of compacted clay-rich soil cover for its coefficient of permeability at a frequency of no less than one test per surface acre of final cover. Permeability data shall be submitted to the executive director.

Quality control/quality assurance testing and documentation procedures for each final cover system installed will be in accordance with the site's Final Cover Quality Control Plan (FCQCP). A copy of the FCQCP can be found in Appendix 5.4 of this document.

4 LARGEST AREA REQUIRING FINAL COVER

The largest area requiring final cover is based upon the largest active area at any given time during the active life of the landfill. At the present time, approximately 36 acres have been developed. Of the 36 acres, one (1) acre was closed in 1995 and 35 acres are active. Therefore, 35 acres represent the largest area of the landfill requiring final cover. The executive director will be notified if the largest area requiring final cover exceeds 35 acres.

5 MAXIMUM INVENTORY OF WASTES

As detailed in the site development plan, the maximum inventory of waste that will ever be on-site during the active life of the landfill is estimated to be approximately 8,000,000 cubic yards.

6 IMPLEMENTATION OF FINAL CLOSURE PLAN

Implementation of the final closure plan for the Angelina County Waste Management Center will be as follows:

- No later than 45 days prior to initiation of final closure activities for each MSW landfill unit, written notice of the intent to close the unit will be submitted to the executive director and the notice of intent will be placed in the site's operating record.
- Upon notification to the executive director of the intent to close, a minimum of one (1) sign will be placed at the main entrance and all other frequently used points of access for the facility notifying all persons who may utilize the facility of the date of closing for the entire facility and the prohibition against further receipt of waste material after the stated date. Suitable barriers will be installed at all gates or

access points to adequately prevent the unauthorized dumping of solid waste at the closed facility.

- No later than 90 days prior to the initiation of final facility closure, a public notice of facility closure which will be placed in the newspaper of largest circulation in the vicinity of the facility. The notice will provide the name, address and physical location of the facility, the permit number and the last date of intended receipt of waste. An adequate number of copies of the approved final closure and post-closure plans will be available for public access and review.
- Final closure activities will begin no later than 30 days after the date the MSW landfill unit receives known last receipt of wastes. If there is remaining capacity and there is a reasonable likelihood that the unit will receive additional wastes, final closure activities will begin no later than one year after the most recent receipt of wastes.
- Final closure activities for each MSW landfill unit will be completed in accordance with this approved Final Closure Plan within 180 days following initiation of final closure activities.
- Following completion of all final closure activities for each MSW landfill unit, a documented certification, signed by an independent registered professional engineer, verifying that final closure has been completed in accordance with the approved Final Closure Plan will be submitted to the executive director for review and approval.
- Within 10 days after completion of final closure activities, a certified copy of an "affidavit to the public" will be submitted to the executive director in accordance with 30 TAC §330.19 regarding Deed Recordation. A copy of the affidavit will be placed in the operating record. In addition, a certified notation on the deed to the facility that will in perpetuity notify any potential purchaser of the property that the land has been used as a landfill facility and use of the land is restricted according to the provisions specified in 30 TAC §330.465 regarding Certification of Completion of Post-Closure Care. Within 10 days after completion of final closure activities, a certified copy of the modified deed will be submitted to the executive director and a copy will be placed in the site's operating record.

Following receipt of the required final closure documents, as applicable, and an inspection from the agency's regional office verifying proper closure of the MSW landfill facility according to the final approved closure plan, the executive director may acknowledge the termination of operation and closure of the MSW landfill unit and deem it properly closed.

Post-closure care maintenance will begin immediately upon the date of final closure of each MSW landfill unit as approved by the executive director.

7 FINAL CONTOUR MAP

The Angelina County Waste Management Center consists of two fill sectors, Tract 1 and Tract 2. Final contours for each tract consist of 4-horizontal:1-vertical side slopes with top slopes ranging from 2 percent to 6 percent. Intermediate plateaus will be built along portions of the side slopes as shown in Exhibit 4.5, Sheets 1 and 2 of 2.

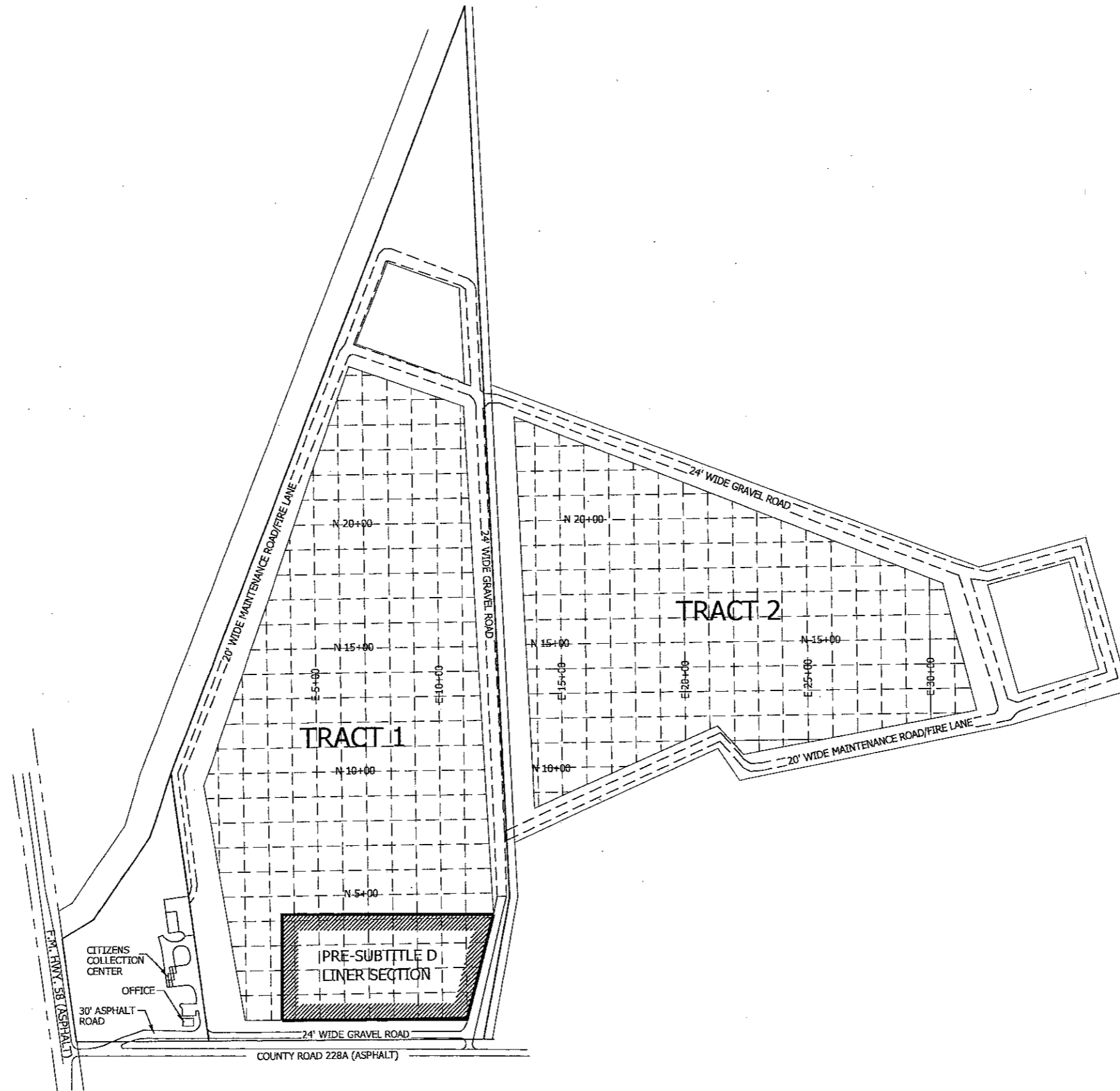
8 SOIL EROSION LOSSES COMPUTATIONS

Soil erosion losses computations can be found in Appendix 5.1.

9 SLOPE STABILITY ANALYSIS

Slope stability analysis for the final cover can be found in Appendix 5.2.

Exhibits



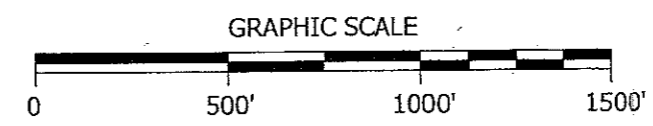
Catherine A. Skurow 11/20/07
 FOR PERMITTING PURPOSES ONLY
 REVISION 1

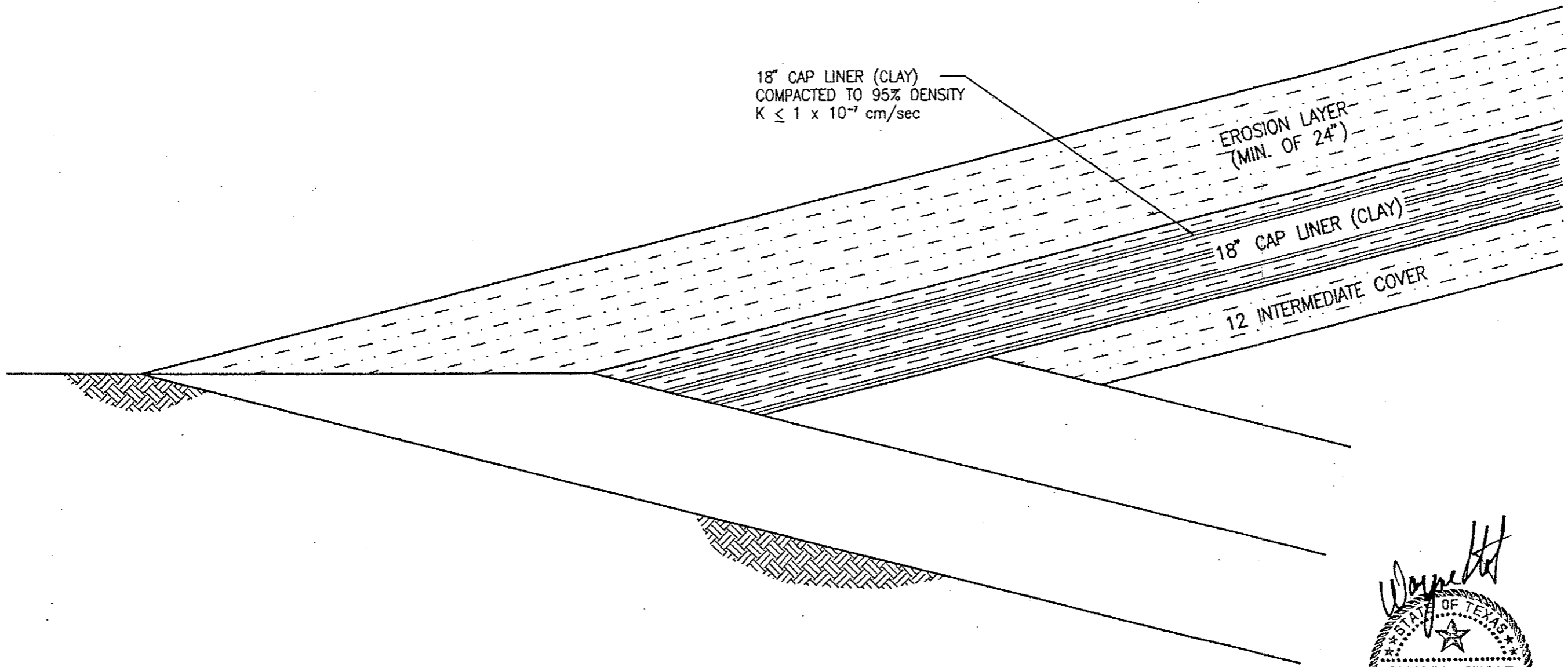
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2			
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NO.	DATE	DESCRIPTION	BY

EXHIBIT 4.1
 SITE PLAN
 ANGELINA COUNTY
 WASTE MANAGEMENT CENTER



Date	11/20/07	Dwg Name	\\070021\SITE PLAN.dwg
Scale as Shown	Drawn by JNP	Approved by CAS	Sheet 1 of 1






18" CAP LINER (CLAY)
 COMPACTED TO 95% DENSITY
 $K \leq 1 \times 10^{-7}$ cm/sec

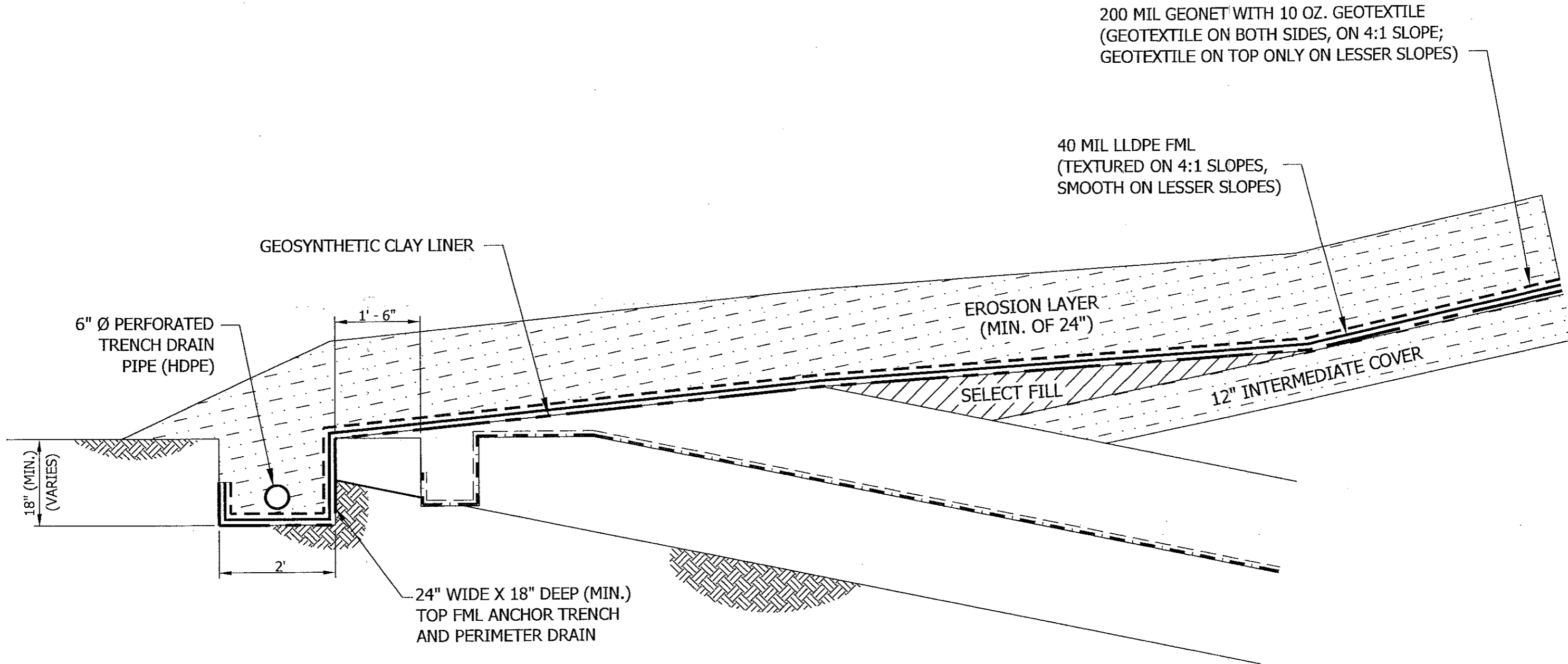
EROSION LAYER
 (MIN. OF 24")

18" CAP LINER (CLAY)

12" INTERMEDIATE COVER

Wayne Stolz
 STATE OF TEXAS
 WAYNE STOLZ
 43356
 REGISTERED PROFESSIONAL ENGINEER
 10/19/96

 ENGINEERS - SURVEYORS EVERITT GRIFFITH, JR. & ASSOCIATES, INC. 408 North Third Street Lufkin, Texas	ANGELINA COUNTY WASTE MANAGEMENT CENTER EXHIBIT A.2 TYPICAL COVER SECTION PRE-SUBTITLE D AREA		DRAWING OR JOB No. E A-62
	DESIGNER: JRG CHECKER: JRG DATE: 08-25-96	DRAWN BY: JRG CHECKER: JRG DATE: 08-25-96	SCALE: 1" = 2' SHEET NO.: 1 OF: 1



200 MIL GEONET WITH 10 OZ. GEOTEXTILE
(GEOTEXTILE ON BOTH SIDES, ON 4:1 SLOPE;
GEOTEXTILE ON TOP ONLY ON LESSER SLOPES)

40 MIL LLDPE FML
(TEXTURED ON 4:1 SLOPES,
SMOOTH ON LESSER SLOPES)

GEOSYNTHETIC CLAY LINER

6" Ø PERFORATED
TRENCH DRAIN
PIPE (HDPE)

1' - 6"

EROSION LAYER
(MIN. OF 24")

SELECT FILL

12" INTERMEDIATE COVER

18" (MIN.)
(VARIES)

2'

24" WIDE X 18" DEEP (MIN.)
TOP FML ANCHOR TRENCH
AND PERIMETER DRAIN



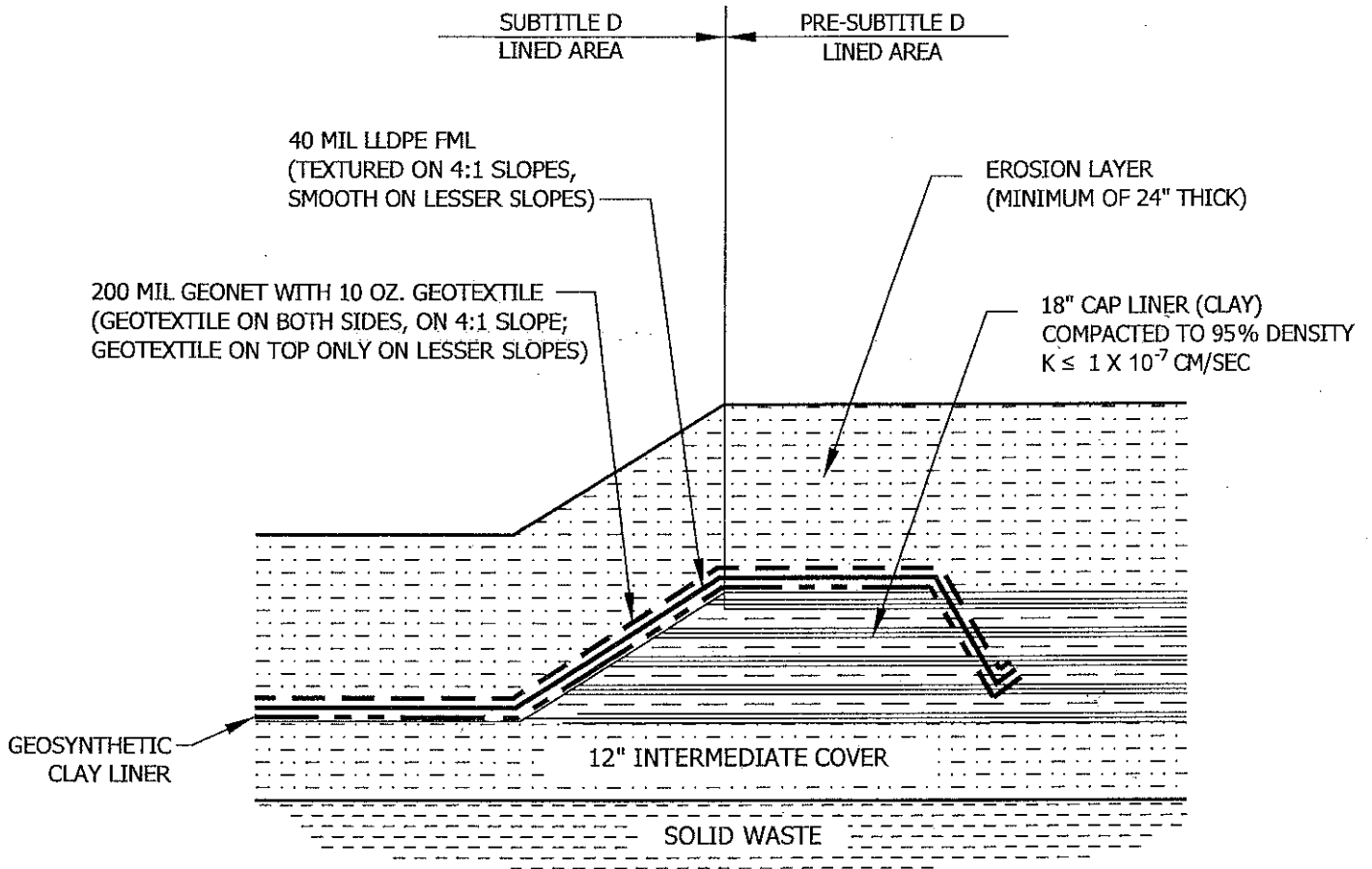
Catherine A. Skurow 11/20/07
FOR PERMITTING PURPOSES ONLY

EXHIBIT 4.3
TYPICAL COVER SECTION
SUBTITLE D AREA
WASTE MANAGEMENT CENTER
ANGELINA COUNTY



801 NAVIGATION, SUITE 300 CORPUS CHRISTI, TEXAS 78408
PH. (361) 883-1984 FAX (361) 883-1986 WWW.LNVINC.COM

Date	11/20/07	Dwg Name	070021.00\TYP COVER SECTION.dwg
NOT TO SCALE	Drawn by CMP	Approved by CAS	Sheet 1 OF 1



11/20/07

Catherine A. Skurow

FOR PERMITTING PURPOSES ONLY

EXHIBIT 4.4
FINAL COVER TIE-IN DETAIL
WASTE MANAGEMENT CENTER
ANGELINA COUNTY

LNV ENGINEERING
 engineers & consultants

801 NAVIGATION, SUITE 300 CORPUS CHRISTI, TEXAS 78408
 PH. (361) 883-1984 FAX (361) 883-1986 WWW.LNVINC.COM

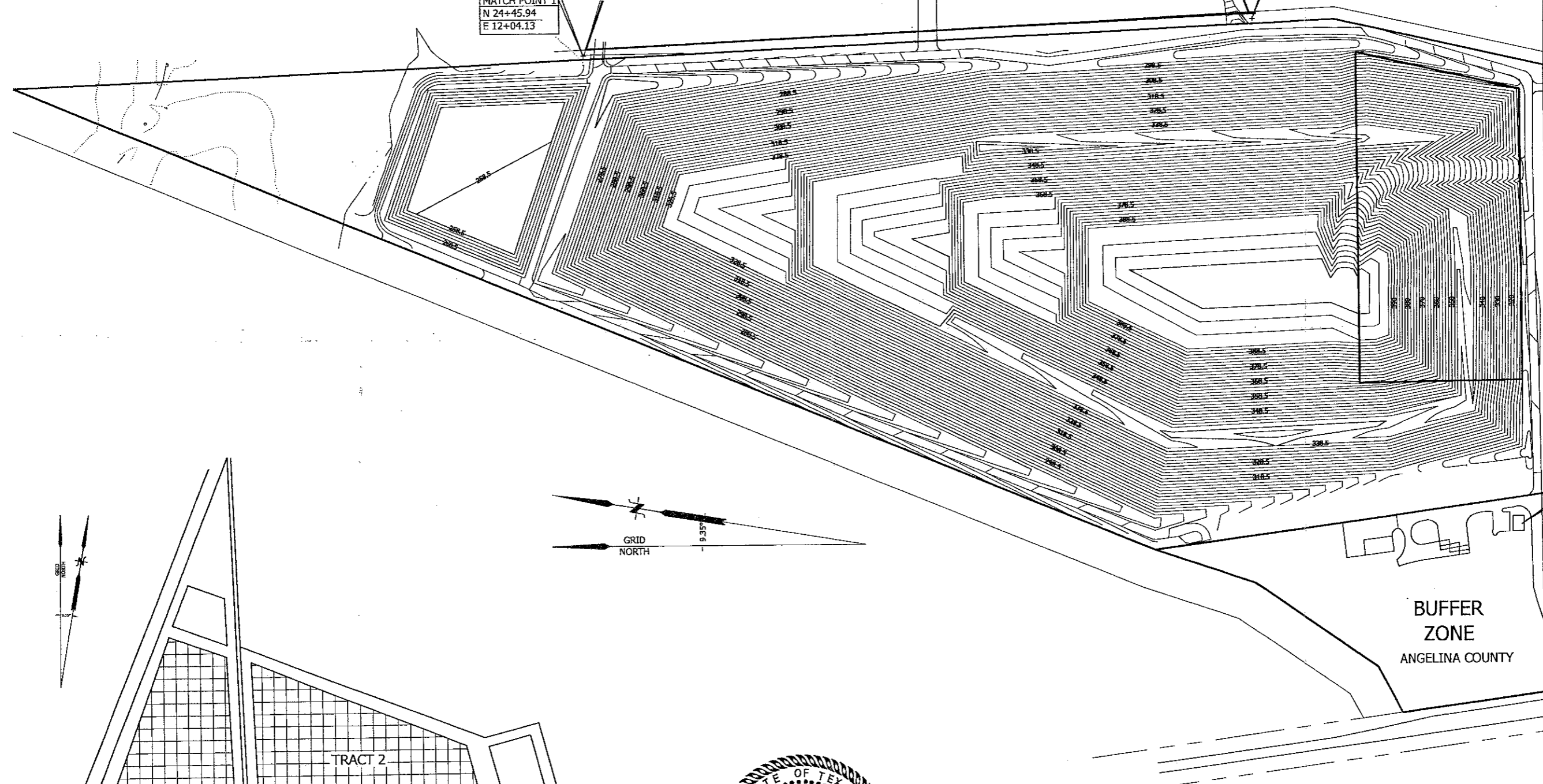
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E 12+34.57

OLD LANDFILL SITE (PERMIT No. 1281)

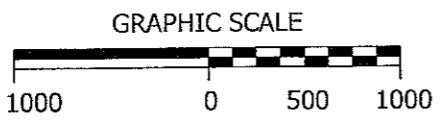
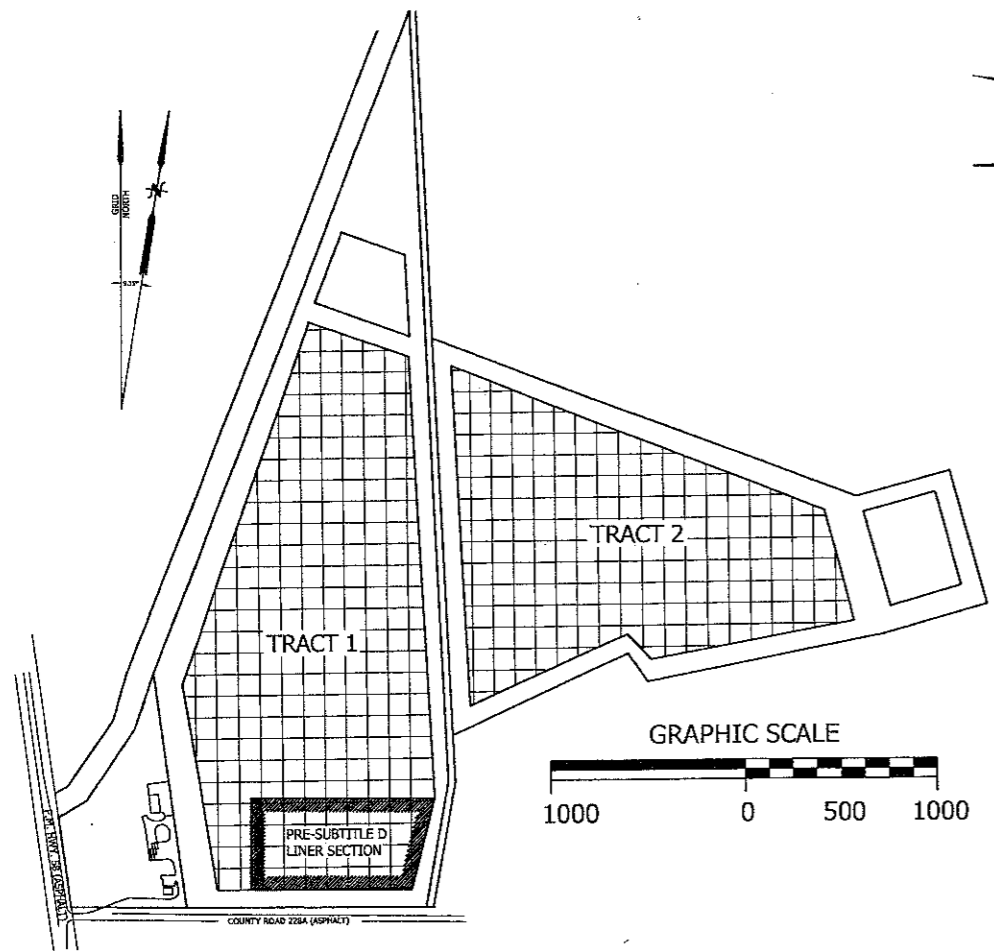
MATCH POINT 1
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E 12+04.13



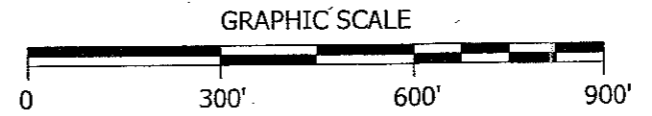
N 00+00.00
E 00+00.00

BUFFER ZONE
ANGELINA COUNTY

F.M. HWY. No. 58



Catherine A. Skurow 11/20/07
FOR PERMITTING PURPOSES ONLY
REVISION 1



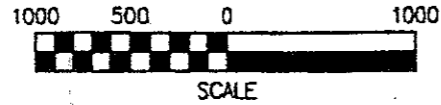
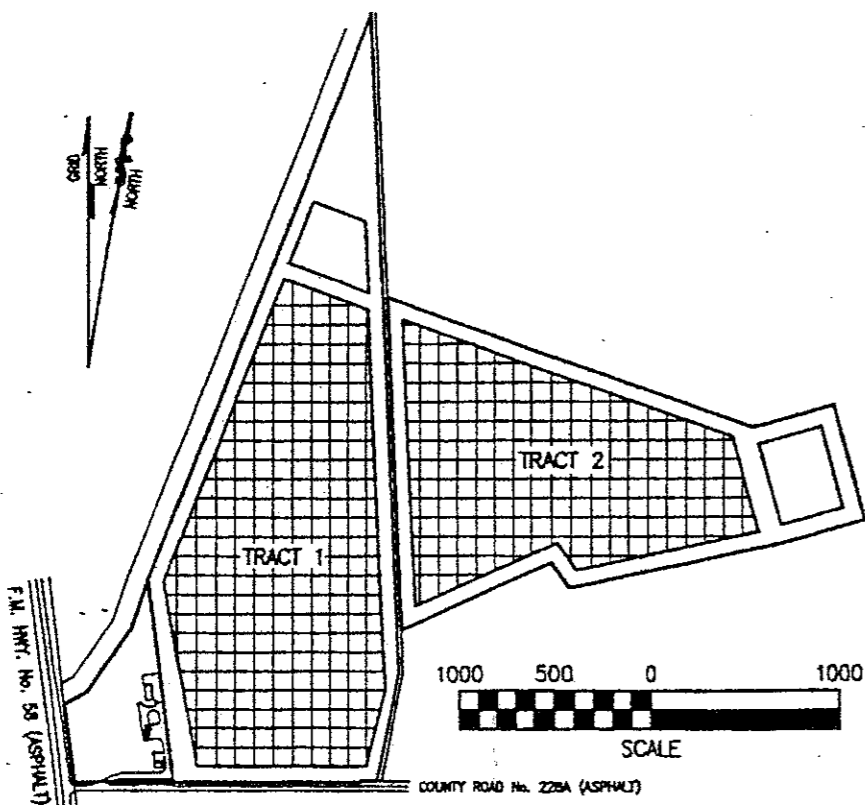
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2			
1	11/07	REVISE CONTOURS	LNV
NO.	DATE	DESCRIPTION	BY
EXHIBIT 4.5 FINAL CONTOUR MAP ANGELINA COUNTY WASTE MANAGEMENT CENTER			
LNV ENGINEERING engineers & consultants			
<small>801 NAVIGATION, SUITE 300 CORPUS CHRISTI, TEXAS 78408 PH. (361) 883-1984 FAX (361) 883-1986 WWW.LNVINC.COM</small>			
Date	11/20/07	Dwg Name	070021\Final Cover Contour Map_revised.dwg
Scale as Shown	Drawn by JNP	Approved by CAS	Sheet 1 of 2

MATCH POINT 1
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 E 12+04.13

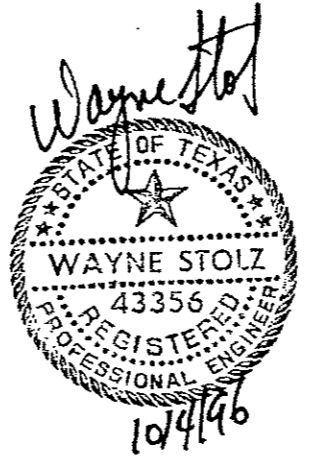
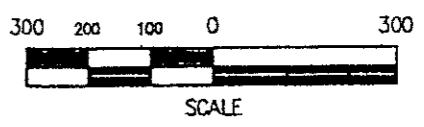
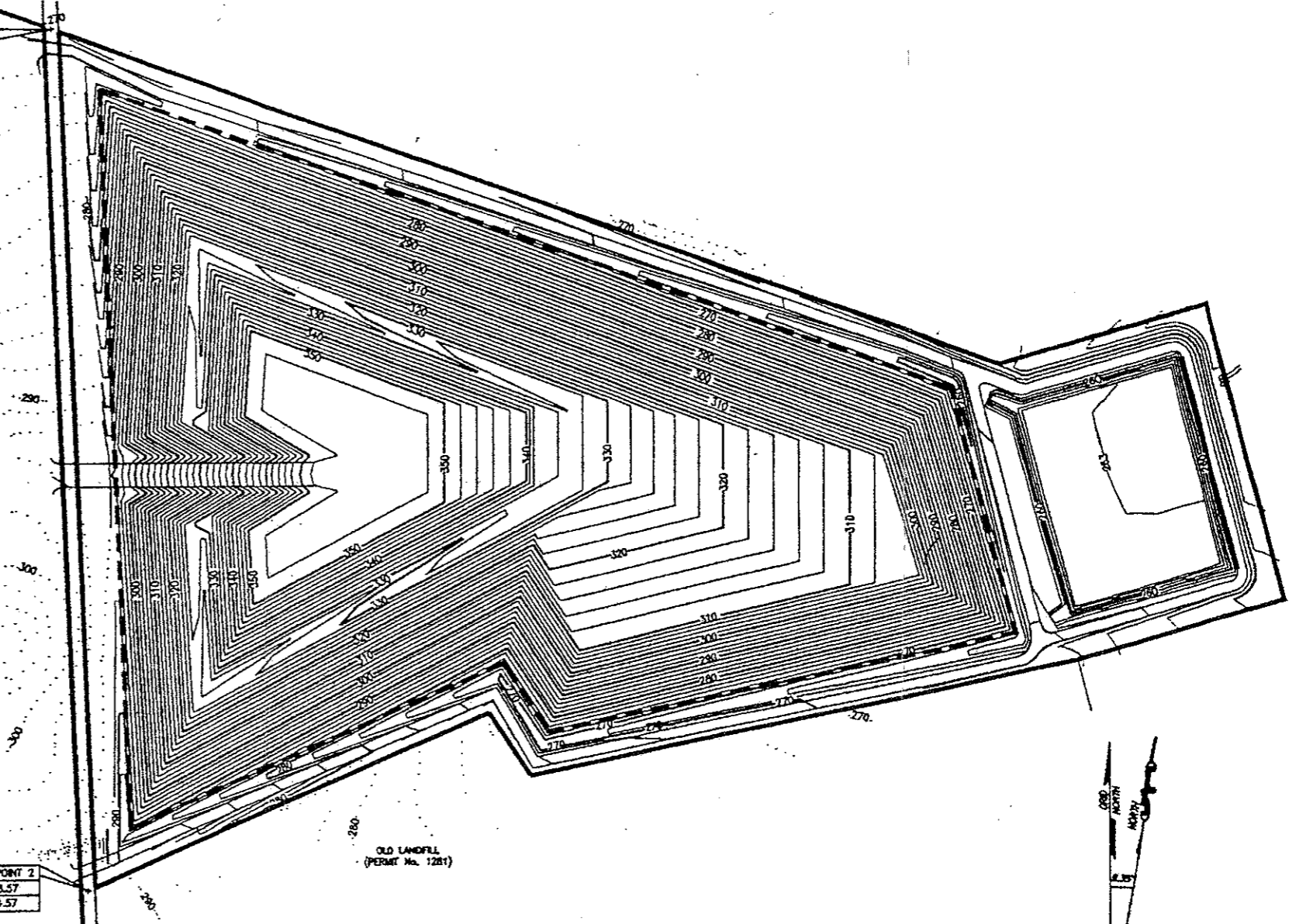
TRACT No. 1 - 81.56 ACRE SITE

MATCH POINT 2
 N 07+08.57
 E 12+84.57

OLD LANDFILL
 (PERMIT No. 1281)



SITE PLAN



 ENGINEERS - SURVEYORS EVERETT GRIFFITH, JR. & ASSOCIATES, INC. 408 North Third Street Lufkin, Texas	DESIGNED BY: WY	DRAWN BY: DGT/PHM	SCALE: 1"=200'	EXHIBIT OF JOB No. E A-62 SHEET 2 OF 2
	CHECKED BY: SA	DESIGNED BY: WY	DATE: 9-20-96	

Appendix 5.1
Soil Erosion Losses Computations

5.1 SOIL EROSION LOSSES COMPUTATIONS

Universal Soil Loss Equation $A = RKLSCP$

- Where: A = the computed soil loss in tons per acre per year, obtained by multiplication of the remaining factors
- R = the rainfall and runoff factor (400 for Angelina County)
- K = the soil erodibility factor (0.13 for sandy clay, 2% organic content)
- LS = the topographic factor or the slope-steepness factor (see below)
- C = the cover and management factor (Angelina County will utilize commercially available erosion mats on all slopes in excess of 10%, therefore use 0.003)
- P = the support practice factor (0.50 for 2 - 6% slopes)(0.90 for 25% slopes)

For flatter portions of final cover (2 - 6% slopes)

Given: 6% slope (3.4°)

λ = slope length (1,290 feet)(east end of Tract 2)

m = 0.5 for slopes 5% and steeper

$$LS = (\lambda / 72.6)^m (65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065)$$

$$= (1,290/72.6)^{0.5} (65.41 \sin^2 3.4^\circ + 4.56 \sin 3.4^\circ + 0.065)$$

$$= 2.4$$

$$A = RKLSCP$$

$$= (400)(0.13)(2.4)(0.003)(0.50)$$

$$= 0.19 \text{ tons/acre/year}$$

For steeper portions of final cover (25% slopes)

Given: 25% slope (14.5°)

λ = slope length (290 feet)(northwest side of Tract 1)

m = 0.5 for slopes 5% and steeper

$$LS = (\lambda / 72.6)^m (65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065)$$

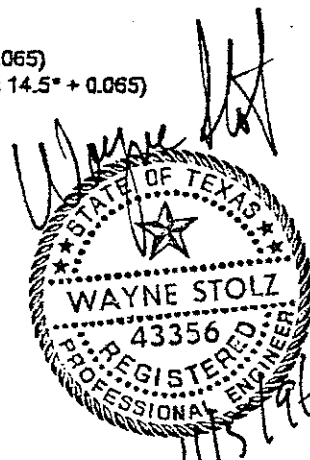
$$= (290/72.6)^{0.5} (65.41 \sin^2 14.5^\circ + 4.56 \sin 14.5^\circ + 0.065)$$

$$= 10.6$$

$$A = RKLSCP$$

$$= (400)(0.13)(10.6)(0.003)(0.90)$$

$$= 1.5 \text{ tons/acre/year}$$



Appendix 5.2
Slope Stability Analysis

**ANGELINA COUNTY
WASTE MANAGEMENT CENTER**
TCEQ Permit No. MSW-2105A

**SDP Attachment 12, Appendix 5.2
Slope Stability Analysis**

prepared by:



November 20, 2007



Catherine A. Skurow 11/20/07
FOR PERMITTING PURPOSES ONLY

SDP ATTACHMENT 12, APPENDIX 5.2

**Slope Stability Analysis
Angelina County Waste Management Center
Type 1 MSW Landfill
TCEQ Permit No. MSW-2105A**

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ATTACHMENT A Slope Stability Charts for Infinite Slopes

FOR PERMITTING PURPOSES ONLY

SDP ATTACHMENT 12, APPENDIX 5.2


Slope Stability Analysis
Angelina County Waste Management Center
Type 1 MSW Landfill
TCEQ Permit No. MSW-2105A

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ATTACHMENTS

ATTACHMENT A Slope Stability Charts for Infinite Slopes


Catherine A. Skurow 11/20/07
FOR PERMITTING PURPOSES ONLY

**Slope Stability Analysis
Angelina County Waste Management Center
Type 1 MSW Landfill
TCEQ Permit No. MSW-2105A**

1 INTRODUCTION

This documentation will show that the alternative final cover system that has been designed for the Angelina County Waste Management Center is stable with regards to sliding failure and tensile stresses on the side slopes.

2 STABILITY ANALYSIS

2.1 Sliding Failure Analysis

Failures related to interface friction angles are commonly referred to as sliding failure. The infinite slope stability analysis method was used to verify the stability of the alternate final cover system against sliding failure. The factor of safety (FS) for slope stability is determined using the following equation:

$$FS = A * [(\tan \phi) / (\tan \beta)] + B * [c / (\gamma * H)]$$

where, ϕ = interface friction angle (degrees)
c = cohesion between different components (psf)
 β = angle of slope (degrees)
A = parameter (see Attachment A)
B = parameter (see Attachment A)
 γ = unit weight of soil (pcf)
H = soil load along slope (ft)

To determine the critical interface friction angle (ϕ), the following component interfaces were considered:

- Compacted Clay and GCL Interface;
- GCL and 40 mil textured LLDPE Interface;
- 40 mil textured LLDPE and Geocomposite Interface; and
- Geocomposite and Erosion Layer Interface.

A summary of the friction angles for the component interfaces are as follows:

Component Interface	Friction Angle, ϕ (degrees)
Compacted Clay and GCL	19
GCL and 40 mil textured LLDPE	28
40 mil textured LLDPE and Geocomposite	26
Geocomposite and Erosion Layer Soil	26

The critical interface friction angle of the alternate final cover system is the friction angle between the GCL and the underlying compacted clay soil ($\phi = 19$ degrees). This critical interface will be used to determine the factor of safety for the slope stability of alternate final cover system against sliding failure.

For the critical interface,

$$\begin{aligned}\phi &= 19 \\ c &= 50 \\ \beta &= 14 \\ A &= 1 \\ B &= 4.3 \\ \gamma &= 120 \\ H &= 2\end{aligned}$$

Angle of slope, β , is based upon the steepest side slope of 4-horizontal:1-vertical. Parameters A and B are determined from slope stability charts for infinite slopes based upon slope ratio b ($\cot \beta$) and pore pressure ratio (r_u). For the worst case scenario for the critical interface, $r_u = 0$, therefore parameter $A = 1$. Stability charts are provided in Attachment A of this Appendix.

Substituting the values for the critical interface into the equation above yields a factor of safety (FS) for the stability of the alternate final cover system against sliding failure.

$$FS = 2.3$$

2.2 Tensile Stress Analysis

Tensile stresses for the static condition are induced in the liner due to self weight and overlying material weight. For the dynamic condition, the tensile stress are induced by the self weight and overlying material weight plus the weight of equipment operating on the liner system. The tensile stresses are resisted by the friction between the liner components. The tensile stresses are determined by calculating the shear forces in the liner system.

For the static condition, the shear force (P) on liner due to the self weight of liner and overlying erosion layer is:

$$P_s = W_s * \sin \beta$$

where, β = angle of slope (degrees)

W_s = weight of geocomposite (W_{COMP}) plus weight of geomembrane (W_{GEO}) plus weight of GCL (W_{GCL}) plus weight of soil erosion layer (W_{SOIL}) (lbs)

Given a slope length of 100 ft,

$$\begin{aligned}W_{COMP} &= [0.94 \text{ g/cm}^3 * (1 \text{ lb}/453.59 \text{ g}) * (16.387 \text{ cm}^3/\text{in}^3) * (1,728 \text{ in}^3/\text{ft}^3) \\ &\quad * (0.2 \text{ in}) * (1 \text{ ft}/12 \text{ in}) * 1 \text{ ft} * 100 \text{ ft}] + [[10 \text{ oz}/\text{yd}^2 * (1 \text{ lb}/16 \text{ oz}) \\ &\quad * (1 \text{ yd}^2/9 \text{ ft}^2) * 1 \text{ ft} * 100 \text{ ft}] * 2] = 111.7 \text{ lbs}\end{aligned}$$

$$W_{GEO} = 0.94 \text{ g/cm}^3 * (1 \text{ lb} / 453.59 \text{ g}) * (16.387 \text{ cm}^3/\text{in}^3) * (1,728 \text{ in}^3/\text{ft}^3) * (0.04 \text{ in}) * (1 \text{ ft}/12 \text{ in}) * 1 \text{ ft} * 100 \text{ ft} = 19.6 \text{ lbs}$$

$$W_{GCL} = 0.89 \text{ lb/ft}^2 * 1 \text{ ft} * 100 \text{ ft} = 89 \text{ lbs; and}$$

$$W_{SOIL} = 120 \text{ pcf} * 2 \text{ ft} * 1 \text{ ft} * 100 \text{ ft} = 24,000 \text{ lbs}$$

Summing the weights of each liner component results in a weight (W_s) of approximately 24,220.3 lbs. Therefore, the shear force (P_s) for the static condition is 5,859.4 lbs.

For the dynamic condition, the shear force (P_D) on liner due to the self weight of liner, weight of overlying erosion layer and weight of equipment is:

$$P_D = W_D * \sin \beta + F_b$$

where, β = angle of slope (degrees)

W_D = weight of geocomposite (W_{COMP}) plus weight of geomembrane (W_{GEO}) plus weight of GCL (W_{GCL}) plus weight of soil erosion layer (W_{SOIL}) plus weight of equipment (W_E) (lbs)

$$\text{where, } W_{COMP} = 111.7 \text{ lbs}$$

$$W_{GEO} = 19.6 \text{ lbs}$$

$$W_{GCL} = 89 \text{ lbs}$$

$$W_{SOIL} = 24,000 \text{ lbs; and}$$

$$W_E = 70,000 \text{ lb} / 12 \text{ ft} * 1 \text{ ft} = 5,833 \text{ lbs}$$

$$F_b = \text{breaking force of equipment (lbs)}$$

$$\text{where, } F_b = 0.3 * \text{Equipment Weight} = 1,750 \text{ lbs}$$

Summing the weights of each liner component results in a weight (W_D) of approximately 30,053.3 lb. Therefore, the shear force (P) for the static condition is 9,020.6 lb.

The resisting forces (F) as a result of friction between liner components are calculated by the following equation:

$$F = N * \tan \phi$$

where, ϕ = interface angle (degrees)

N = normal force on liner

where, $N = W_s * \cos \beta$ for the static condition

$N = W_D * \cos \beta$ for the dynamic condition

The factor of safety (FS) is calculated as follows:

$$FS = F / P$$

where, F = resisting force of component interface
 P = shearing force on liner system

The interface friction angles provided in the table above are used to calculate the resisting force for each component interface. The resisting forces and factors of safety (FS) are summarized in the table below.

Component Interface	Static Condition		Dynamic Condition	
	Resisting Force, F_s (lbs)	Factor of Safety, FS	Resisting Force, F_D (lbs)	Factor of Safety, FS
Compacted Clay and GCL	8,091.9	1.38	10,040.8	1.11
GCL and 40 mil textured LLDPE	12,495.6	2.13	15,504.9	1.72
40 mil textured LLDPE and Geocomposite	11,462.1	1.96	14,222.6	1.57
Geocomposite and Erosion Layer Soil	11,462.1	1.96	14,222.6	1.57

The shear force (P) is less than the resistance (F) of the compacted clay and GCL, therefore the GCL is stable on the compacted clay.

The shear force (P) is less than the resistance (F) of the GCL and 40 mil textured LLDPE interface, therefore the 40 mil LLDPE is stable on the GCL.

The shear force (P) is less than the resistance (F) of the 40 mil textured LLDPE and geocomposite interface, therefore the geocomposite is stable on the 40 mil LLDPE.

The shear force (P) is less than the resistance (F) of the geocomposite and erosion layer soil interface, therefore the erosion layer is stable on the geocomposite.

3 CONCLUSION

The alternate final cover system, as designed, is stable against sliding failure and tensile stresses.

A stability analysis should be performed using test data from actual materials to be used for final cover construction. Test results should verify that actual interface friction values can be achieved that exceed the values used in this analysis.

Attachment A

Slope Stability Charts for Infinite Slopes

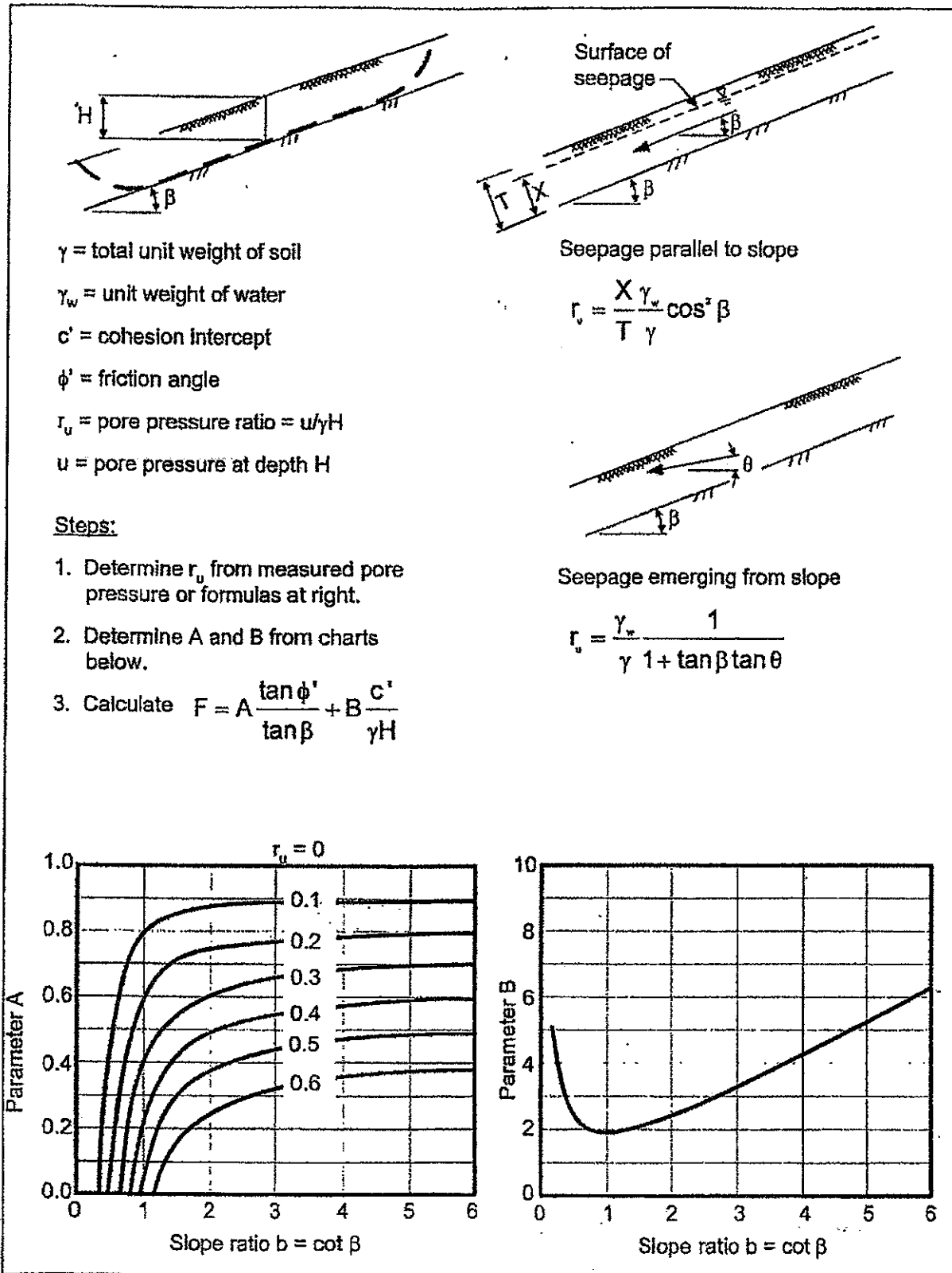


Figure E-7. Slope stability charts for infinite slopes (after Duncan, Buchianani, and DeWet 1987)

Appendix 5.3
Alternative Final Cover Demonstration

**ANGELINA COUNTY
WASTE MANAGEMENT CENTER
TCEQ Permit No. MSW-2105A**

**SDP Attachment 12, Appendix 5.3
Alternative Final Cover Demonstration**

prepared by:



November 20, 2007



Catherine A. Skurow 11/20/07
FOR PERMITTING PURPOSES ONLY

SDP ATTACHMENT 12, APPENDIX 5.3

**Alternative Final Cover Demonstration
Angelina County Waste Management Center
Type 1 MSW Landfill
TCEQ Permit No. MSW-2105A**

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1 INTRODUCTION	1
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3 ALTERNATIVE FINAL COVER PERFORMANCE CRITERIA	2
4 ALTERNATIVE FINAL COVER MODEL	2
5 CONCLUSION	3

ATTACHMENTS

ATTACHMENT A	Currently Permitted Final Cover System HELP Model Simulation
ATTACHMENT B	Subtitle D Final Cover System HELP Model Simulation
ATTACHMENT C	Alternative Final Cover System HELP Model Simulation



Catherine A. Skurow 11/20/07

FOR PERMITTING PURPOSES ONLY

**Alternative Final Cover Demonstration
Angelina County Waste Management Center
Type 1 MSW Landfill
TCEQ Permit No. MSW-2105A**

1 INTRODUCTION

In accordance with 30 TAC §330.457(d), the executive director may approve an alternative final cover design that achieves an equivalent or greater reduction in infiltration as the clay-rich soil layer detailed in 30 TAC §330.457(a)(1) and provides equivalent protection from wind and water erosion as detailed in 30 TAC §330.457(a)(3).

As detailed in the August 1, 2006 TCEQ rule interpretation of §330.457(d) regarding alternative final cover systems, the infiltration of the standard Subtitle D design must be modeled on the basis of its soil layer and synthetic membrane together. Additionally, if a permit specifies a design with more stringent final cover specifications than in §330.457(a)(1) or (2), the alternative must be compared against the more stringent design.

One alternative final cover system (AFCS) has been designed for the MSW landfill units with synthetic bottom liners and consists of replacing the clay-rich soil layer component in the site's currently permitted final cover system with a geosynthetic clay liner (GCL).

This documentation will show that the alternative final cover system that has been designed for the Angelina County Waste Management Center meets the requirements of 30 TAC §330.457(d).

2 MODELING APPROACH

All modeling for this demonstration was performed utilizing the Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3.07 (1 November 1997).

The simulations were performed with the HELP model using the program's synthetic weather data generation capabilities for Houston, Texas, with temperature and precipitation data adjusted with monthly normals from 1971-2000, obtained from the National Climatic Data Center (NCDC). Data was generated for a thirty year period to correspond with the post-closure care period for the facility. The runoff curve was generated by the model using a slope of 5% and a length of 200 feet. The slope length of 200 feet and a slope of 5% represents conservative runoff parameters in the final cover system. Run-off was allowed from the area modeled. The latitude of the landfill was estimated as 31.337°, the coordinates for the City of Lufkin, Texas.

An evaporative zone depth of 22 inches was assumed. This depth was suggested by the model as a fair value for corresponding to the presence of fair vegetative cover. This should be a fair assumption considering that vegetation will be promoted on the final cover system to limit erosion and the low permeability soils in the final cover will hold water and promote evapotranspiration in addition to reducing infiltration.

3 ALTERNATIVE FINAL COVER PERFORMANCE CRITERIA

In order to determine the most stringent final cover design and to establish performance criteria for an alternative final cover system, as required by the previously discussed TCEQ rule interpretation, the currently permitted design was modeled and compared to the final cover design specified in §330.457(a)(1) (Subtitle D final cover system) and §330.457(a)(3) (Erosion Layer).

The currently permitted final cover system was modeled using four layers; a 24-inch erosion layer, a 200 mil geonet drainage layer, a 40 mil linear low density polyethylene, and an 18-inch barrier layer of compacted clay with a hydraulic conductivity not exceeding 1×10^{-5} cm/sec. For simulation purposes, geomembrane manufacturer defects (pinholes) were assumed at one per acre and field installation defects were assumed at two per acre with a placement factor of 3 (good).

As calculated by the HELP model using the currently permitted final cover system design parameters, the peak daily percolation/leakage through layer 4 for years 1 to 30 is 5.85021 cubic feet, as shown on page 6 of 7 of the HELP model output for this analysis (Attachment A of this Appendix).

The Subtitle D final cover system was modeled using three layers; a 6-inch erosion layer, an 18-inch barrier layer of compacted clay with a hydraulic conductivity not exceeding 1×10^{-5} cm/sec and a geomembrane layer consisting of 40 mil linear low density polyethylene. For simulation purposes, geomembrane manufacturer defects (pinholes) were assumed at one per acre and field installation defects were assumed at two per acre with a placement factor of 3 (good).

As calculated by the HELP model using the Subtitle D final cover system parameters, the peak daily percolation/leakage through layer 3 for years 1 to 30 is 15.51400 cubic feet, as shown on page 5 of 5 of the HELP model output for this analysis (Attachment B of this Appendix).

The HELP model results indicate that the currently permitted design is more stringent than the final cover design specified in §330.457(a)(1) and (3), therefore the alternative final cover design must achieve an equivalent reduction in infiltration and provide equivalent protection from wind and water as the currently permitted design.

4 ALTERNATIVE FINAL COVER MODEL

The alternative cover system was modeled using four layers; a 24-inch erosion layer, a 200 mil geonet, 40 mil linear low density polyethylene and a 0.24-inch bentonite GCL with a hydraulic conductivity of 5.0×10^{-9} cm/sec which was modeled as a barrier layer.

As calculated by the HELP model, the peak daily percolation/leakage through layer 4 of the alternative final cover system, for years 1 to 30, is 0.05090 cubic feet, as shown on page 6 of 6 of the HELP model output for this analysis (Attachment C of this Appendix).

5 CONCLUSION

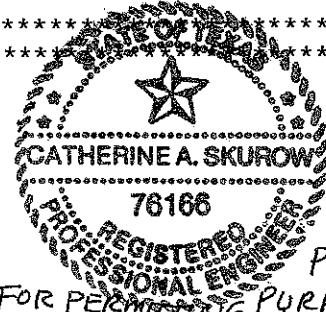
The HELP model simulations performed for this demonstration show that the alternative final cover design proposed for the Angelina County Waste Management Center will achieve an equivalent or greater reduction in infiltration and provides equivalent protection from wind and water erosion as the currently permitted final cover design which is more stringent than the final cover design specifications detailed in 30 TAC §330.457(a)(1) and in 30 TAC §330.457(a)(3).

Attachment A

**Currently Permitted Final Cover System
HELP Model Simulation**

 **
 **
 ** 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:\HELP3\ANGELINA.D4
 TEMPERATURE DATA FILE: C:\HELP3\ANGELINA.D7
 SOLAR RADIATION DATA FILE: C:\HELP3\ANGELINA.D13
 EVAPOTRANSPIRATION DATA: C:\HELP3\ANGELINA.D11
 SOIL AND DESIGN DATA FILE: C:\HELP3\ANGCLAY.D10
 OUTPUT DATA FILE: C:\HELP3\ANGCLAY.OUT



PAGES 1-7

FOR PERMANENT PURPOSES ONLY

TIME: 10:02 DATE: 10/29/2007

 TITLE: Angelina County Waste Management Center-Currently Permitted

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 10

THICKNESS	=	24.00	INCHES
POROSITY	=	0.3980	VOL/VOL
FIELD CAPACITY	=	0.2440	VOL/VOL
WILTING POINT	=	0.1360	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3135	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.119999997000E-03	CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 3.00
 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
 MATERIAL TEXTURE NUMBER 20

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	=	0.0117	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000	CM/SEC
SLOPE	=	5.00	PERCENT
DRAINAGE LENGTH	=	200.0	FEET

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 36

THICKNESS	=	0.04	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.	=	0.399999993000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	2.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3	- GOOD

LAYER 4

TYPE 3 - BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	18.00	INCHES
POROSITY	=	0.4000	VOL/VOL
FIELD CAPACITY	=	0.3660	VOL/VOL
WILTING POINT	=	0.2880	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999975000E-05	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 200. FEET.

SCS RUNOFF CURVE NUMBER	=	86.30	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	138.300	ACRES
EVAPORATIVE ZONE DEPTH	=	22.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	6.936	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	8.756	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.992	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	14.726	INCHES
TOTAL INITIAL WATER	=	14.726	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HOUSTON TEXAS

STATION LATITUDE	=	31.34 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	31
END OF GROWING SEASON (JULIAN DATE)	=	362
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	74.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	76.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	77.00 %

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

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
-----	-----	-----	-----	-----	-----
4.45	3.17	3.53	3.13	5.29	4.18
2.60	3.08	4.08	4.13	4.54	4.44

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

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
-----	-----	-----	-----	-----	-----
48.60	52.90	59.80	66.20	73.70	79.70
82.60	82.20	77.30	67.70	57.70	50.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR HOUSTON TEXAS
AND STATION LATITUDE = 31.34 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	4.83 2.91	3.29 2.99	3.27 4.09	2.87 3.65	4.23 5.36	3.67 3.91
STD. DEVIATIONS	2.78 1.39	1.90 1.77	2.12 1.70	1.75 2.64	2.50 2.94	3.50 1.93
RUNOFF						

TOTALS	0.714 0.074	0.219 0.132	0.240 0.210	0.218 0.430	0.654 0.971	0.456 0.415
STD. DEVIATIONS	1.018 0.158	0.302 0.274	0.497 0.262	0.370 0.637	0.885 0.903	0.923 0.512
EVAPOTRANSPIRATION						

TOTALS	1.555 2.935	2.123 2.771	2.912 3.253	3.432 1.931	3.387 1.179	3.105 0.860
STD. DEVIATIONS	0.124 1.240	0.203 1.242	0.676 1.132	1.161 0.626	1.284 0.162	1.903 0.125
LATERAL DRAINAGE COLLECTED FROM LAYER 2						

TOTALS	2.7158 0.0457	1.6207 0.0004	0.6930 0.0881	0.2322 0.4815	0.2018 2.1126	0.2927 2.4352
STD. DEVIATIONS	1.7906 0.1108	1.3332 0.0009	0.9510 0.3212	0.3943 1.0229	0.4931 1.9471	0.8463 1.5885
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

 AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0065	0.0041	0.0016	0.0005	0.0005	0.0008
	0.0001	0.0000	0.0002	0.0012	0.0059	0.0058
STD. DEVIATIONS	0.0046	0.0034	0.0022	0.0009	0.0011	0.0022
	0.0003	0.0000	0.0008	0.0025	0.0062	0.0041

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

	INCHES		CU. FEET	PERCENT
	-----	-----	-----	-----
PRECIPITATION	45.09	(6.729)	22633980.0	100.00
RUNOFF	4.732	(1.9622)	2375605.00	10.496
EVAPOTRANSPIRATION	29.442	(2.8668)	14780673.00	65.303
LATERAL DRAINAGE COLLECTED FROM LAYER 2	10.91978	(3.91620)	5482048.000	24.22043
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00006	(0.00002)	29.378	0.00013
AVERAGE HEAD ON TOP OF LAYER 3	0.002	(0.001)		
CHANGE IN WATER STORAGE	-0.009	(0.9239)	-4379.04	-0.019

PEAK DAILY VALUES FOR YEARS	1 THROUGH	30
	(INCHES)	(CU. FT.)
PRECIPITATION	4.62	2319374.000
RUNOFF	2.570	1290291.3700
DRAINAGE COLLECTED FROM LAYER 2	1.13242	568505.81200
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000012	5.85021
AVERAGE HEAD ON TOP OF LAYER 3	0.246	
MAXIMUM HEAD ON TOP OF LAYER 3	0.196	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.8 FEET	
SNOW WATER	2.21	1109642.2500
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.3468
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.1360

*** 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	7.2618	0.3026
2	0.0020	0.0100
3	0.0000	0.0000
4	7.2000	0.4000
SNOW WATER	0.000	

Attachment B

**Subtitle D Final Cover System
HELP Model Simulation**

 **
 **
 ** 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:\HELP3\ANGELINA.D4
 TEMPERATURE DATA FILE: C:\HELP3\ANGELINA.D7
 SOLAR RADIATION DATA FILE: C:\HELP3\ANGELINA.D13
 EVAPOTRANSPIRATION DATA: C:\HELP3\ANGELINA.D11
 SOIL AND DESIGN DATA FILE: C:\HELP3\MAR06_2.D10
 OUTPUT DATA FILE: C:\HELP3\MAR06_2.OUT



TIME: 15:22 DATE: 10/29/2007

PAGES 1-5
 FOR PERMITTING PURPOSES ONLY
Catherine A. Skurow 10/20/07

 TITLE: Angelina County Waste Management Center - Subtitle D

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 10
 THICKNESS = 6.00 INCHES
 POROSITY = 0.3980 VOL/VOL
 FIELD CAPACITY = 0.2440 VOL/VOL
 WILTING POINT = 0.1360 VOL/VOL
 INITIAL SOIL WATER CONTENT = 0.3935 VOL/VOL
 EFFECTIVE SAT. HYD. COND. = 0.119999997000E-03 CM/SEC
 NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 3.00
 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 3 - BARRIER SOIL LINER
 MATERIAL TEXTURE NUMBER 0
 THICKNESS = 18.00 INCHES
 POROSITY = 0.4000 VOL/VOL
 FIELD CAPACITY = 0.3660 VOL/VOL
 WILTING POINT = 0.2880 VOL/VOL
 INITIAL SOIL WATER CONTENT = 0.4000 VOL/VOL
 EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 36

THICKNESS	=	0.04	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.	=	0.399999993000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	2.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3	- GOOD

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	86.30	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	138.300	ACRES
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.361	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.388	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.816	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	9.561	INCHES
TOTAL INITIAL WATER	=	9.561	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HOUSTON TEXAS

STATION LATITUDE	=	31.34	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	31	
END OF GROWING SEASON (JULIAN DATE)	=	362	
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	7.80	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	76.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	77.00	%

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

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.45	3.17	3.53	3.13	5.29	4.18
2.60	3.08	4.08	4.13	4.54	4.44

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

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
48.60	52.90	59.80	66.20	73.70	79.70
82.60	82.20	77.30	67.70	57.70	50.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR HOUSTON TEXAS
AND STATION LATITUDE = 31.34 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	4.83	3.29	3.27	2.87	4.23	3.67
	2.91	2.99	4.09	3.65	5.36	3.91
STD. DEVIATIONS	2.78	1.90	2.12	1.75	2.50	3.50
	1.39	1.77	1.70	2.64	2.94	1.93
RUNOFF						
TOTALS	3.295	1.544	0.925	0.528	1.384	1.077
	0.221	0.252	0.743	1.444	3.462	2.800
STD. DEVIATIONS	2.727	1.705	1.495	0.893	1.731	2.128
	0.500	0.553	0.971	1.906	2.731	1.886

EVAPOTRANSPIRATION

TOTALS	1.633	2.106	2.676	2.707	2.801	2.681
	2.669	2.734	3.121	1.914	1.352	1.010
STD. DEVIATIONS	0.135	0.212	0.816	1.237	1.079	1.742
	1.090	1.297	1.035	0.703	0.174	0.136

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.0009	0.0007	0.0005	0.0003	0.0003	0.0002
	0.0001	0.0002	0.0004	0.0005	0.0008	0.0009
STD. DEVIATIONS	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002
	0.0001	0.0002	0.0002	0.0003	0.0001	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	4.8281	3.6270	2.0208	1.0868	0.8999	0.7521
	0.3767	0.4717	1.3458	1.9225	4.0608	5.0734
STD. DEVIATIONS	0.8822	1.2763	1.3105	0.8747	0.6934	0.9074
	0.5173	0.5550	0.8830	1.2998	1.1654	0.6656

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	45.09	(6.729)	22633980.0	100.00
RUNOFF	17.674	(5.6196)	8872666.00	39.201
EVAPOTRANSPIRATION	27.405	(2.4051)	13757950.00	60.784
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.00579	(0.00052)	2908.033	0.01285
AVERAGE HEAD ON TOP OF LAYER 2	2.205	(0.240)		
CHANGE IN WATER STORAGE	0.001	(0.2595)	454.53	0.002

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	4.62	2319374.000
RUNOFF	4.211	2114166.5000
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.000031	15.51400
AVERAGE HEAD ON TOP OF LAYER 2	6.000	
SNOW WATER	2.21	1109642.2500
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.3980
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.1360

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	2.3880	0.3980
2	7.2000	0.4000
3	0.0000	0.0000
SNOW WATER	0.000	

Attachment C

**Alternative Final Cover System
HELP Model Simulation**

 **
 **
 ** 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:\HELP3\ANGELINA.D4
 TEMPERATURE DATA FILE: C:\HELP3\ANGELINA.D7
 SOLAR RADIATION DATA FILE: C:\HELP3\ANGELINA.D13
 EVAPOTRANSPIRATION DATA: C:\HELP3\ANGELINA.D11
 SOIL AND DESIGN DATA FILE: C:\HELP3\ANGALT.D10
 OUTPUT DATA FILE: C:\HELP3\ANGALT.OUT



PAGES 1-6

TIME: 9:11 DATE: 10/29/2007

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Catherine A. Skurow 11/20/07

 TITLE: Angelina County Waste Management Center-Alternative Final Cover

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 10

THICKNESS	=	24.00	INCHES
POROSITY	=	0.3980	VOL/VOL
FIELD CAPACITY	=	0.2440	VOL/VOL
WILTING POINT	=	0.1360	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3135	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.119999997000E-03	CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 3.00
 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
 MATERIAL TEXTURE NUMBER 20

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	=	0.0117	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000	CM/SEC
SLOPE	=	5.00	PERCENT
DRAINAGE LENGTH	=	200.0	FEET

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 36

THICKNESS	=	0.04	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.	=	0.39999993000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	2.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3	- GOOD

LAYER 4

TYPE 3 - BARRIER SOIL LINER

MATERIAL TEXTURE NUMBER 0

THICKNESS	=	0.24	INCHES
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.49999997000E-08	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
 SOIL DATA BASE USING SOIL TEXTURE #10 WITH A
 FAIR STAND OF GRASS, A SURFACE SLOPE OF 5.%,
 AND A SLOPE LENGTH OF 200. FEET.

SCS RUNOFF CURVE NUMBER	=	86.30	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	138.200	ACRES
EVAPORATIVE ZONE DEPTH	=	22.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	6.936	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	8.756	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.992	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	7.706	INCHES
TOTAL INITIAL WATER	=	7.706	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
HOUSTON TEXAS

STATION LATITUDE	=	31.34 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	31
END OF GROWING SEASON (JULIAN DATE)	=	362
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	74.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	76.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	77.00 %

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

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
-----	-----	-----	-----	-----	-----
4.45	3.17	3.53	3.13	5.29	4.18
2.60	3.08	4.08	4.13	4.54	4.44

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

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
-----	-----	-----	-----	-----	-----
48.60	52.90	59.80	66.20	73.70	79.70
82.60	82.20	77.30	67.70	57.70	50.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR HOUSTON TEXAS
AND STATION LATITUDE = 31.34 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	4.83	3.29	3.27	2.87	4.23	3.67
	2.91	2.99	4.09	3.65	5.36	3.91
STD. DEVIATIONS	2.78	1.90	2.12	1.75	2.50	3.50
	1.39	1.77	1.70	2.64	2.94	1.93
RUNOFF						

TOTALS	0.714	0.219	0.240	0.218	0.654	0.456
	0.074	0.132	0.210	0.430	0.971	0.415
STD. DEVIATIONS	1.018	0.302	0.497	0.370	0.885	0.923
	0.158	0.274	0.262	0.637	0.903	0.512
EVAPOTRANSPIRATION						

TOTALS	1.555	2.123	2.912	3.432	3.387	3.105
	2.935	2.771	3.253	1.931	1.179	0.860
STD. DEVIATIONS	0.124	0.203	0.676	1.161	1.284	1.903
	1.240	1.242	1.132	0.626	0.162	0.125
LATERAL DRAINAGE COLLECTED FROM LAYER 2						

TOTALS	2.7158	1.6207	0.6930	0.2322	0.2018	0.2927
	0.0457	0.0004	0.0881	0.4815	2.1127	2.4352
STD. DEVIATIONS	1.7906	1.3332	0.9510	0.3943	0.4931	0.8463
	0.1108	0.0009	0.3212	1.0229	1.9471	1.5885
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

 AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0065	0.0041	0.0016	0.0005	0.0005	0.0008
	0.0001	0.0000	0.0002	0.0012	0.0059	0.0058
STD. DEVIATIONS	0.0046	0.0034	0.0022	0.0009	0.0011	0.0022
	0.0003	0.0000	0.0008	0.0025	0.0062	0.0041

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	45.09	(6.729)	22617612.0	100.00
RUNOFF	4.732	(1.9622)	2373887.25	10.496
EVAPOTRANSPIRATION	29.442	(2.8668)	14769985.00	65.303
LATERAL DRAINAGE COLLECTED FROM LAYER 2	10.91984	(3.91622)	5478112.500	24.22056
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00000	(0.00000)	0.598	0.00000
AVERAGE HEAD ON TOP OF LAYER 3	0.002	(0.001)		
CHANGE IN WATER STORAGE	-0.009	(0.9239)	-4375.88	-0.019

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30		
	(INCHES)	(CU. FT.)
PRECIPITATION	4.62	2317696.750
RUNOFF	2.570	1289358.3700
DRAINAGE COLLECTED FROM LAYER 2	1.13243	568102.12500
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000000	0.05090
AVERAGE HEAD ON TOP OF LAYER 3	0.246	
MAXIMUM HEAD ON TOP OF LAYER 3	0.196	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.8 FEET	
SNOW WATER	2.21	1108839.8700
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.3468
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.1360

*** 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	7.2618	0.3026
2	0.0020	0.0100
3	0.0000	0.0000
4	0.1800	0.7500
SNOW WATER	0.000	

Appendix 5.4

Final Cover System Quality Control Plan

**ANGELINA COUNTY
WASTE MANAGEMENT CENTER**
TCEQ Permit No. MSW-2105A

**SDP Attachment 12, Appendix 5.4
Final Cover Quality Control Plan**

prepared by:



November 20, 2007



Catherine A. Skurow 11/20/07

FOR PERMITTING PURPOSES ONLY

**Final Cover Quality Control Plan
Angelina County Waste Management Center
Type 1 MSW Landfill
TCEQ Permit No. MSW-2105A**

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LIST OF ATTACHMENTS

ATTACHMENT A Geosynthetic Research Institute (GRI) Test Method GM17



**Final Cover Quality Control Plan
Angelina County Waste Management Center
Type 1 MSW Landfill
TCEQ Permit No. MSW-2105A**

1 INTRODUCTION

As per 30 TAC §330.457(e)(1), this Final Cover Quality Control Plan (FCQCP) was prepared to detail methods and procedures for the installation of final cover at the Angelina County Waste Management Center.

2 SCOPE

This Final Cover Quality Control Plan (FCQCP) has been prepared to provide materials, construction, and QA/QC (Quality Assurance/Quality Control) criteria for the various elements of the final cover system which includes:

- Soil infiltration layers
- Geosynthetic clay liners
- Infiltration layer geomembrane (as required)
- Drainage layers (as required), and
- Erosion layer

Materials, construction, and QA/QC criteria for the alternate final cover system are also included.

This plan also provides guidance necessary for testing and reporting evaluation procedures to the professional preparing the Final Cover System Evaluation Report (FCSER) describing the necessary procedures for implementation.

3 DEFINITIONS

The following list of definitions pertinent to the FCQCP is provided for reference:

ASTM: American Society for Testing and Materials - One of the largest, professionally recognized voluntary standards development systems in the world.

Atterberg Limits: (ASTM D4318) A series of six "limits of consistency" of fine-graded soils defined by Swedish soil scientist Albert Atterberg, two of which are frequently used today to establish a soil's physical boundaries dealing with its plasticity characteristics. These soil boundaries or limits used most frequently are based upon the numerical difference of the Liquid Limit and the Plastic Limit as defined below:

Liquid Limit (LL): The percentage of moisture in a soil, subjected to a prescribed test, that defines the upper point which is the soil's consistency changes from the plastic to the liquid state.

Plastic Limit (PL): The percentage of moisture in a soil, subjected to a prescribed test, that defines the lower point at which the soil's consistency changes from the plastic to the semi-solid state.

Plasticity Index (PI): The numerical difference between the LL and the PL of a fine-graded soil that denotes the soils plastic range. The larger the PI the greater a soil's plasticity ranger and the greater the plasticity characteristics.

Classification System: The soil classification system will be in accordance with the standard test method for classification of soils for engineering purposes (ASTM D2487).

Coefficient of Permeability: (aka Hydraulic Conductivity) The amount of flow per unit of time through soil under a unit of hydraulic gradient at standard temperature.

Compaction: The process of increasing the density or unit weight of soil by rolling, tamping, vibrating, or other mechanical means.

Compactive Effort: The amount of compaction energy held constant, and usually transferred into a soil sample with a compaction hammer device, used on soil samples in various laboratory test procedures to establish a soil's density at various moisture contents.

Constructed Soil Infiltration Layer: Soil infiltration layers constructed from reworked soils from a borrow source or bentonite-amended soils.

Construction Quality Assurance (CQA): A planned system of activities that provides the owner and permitting agency assurance that the facility was constructed as specified in the design (US EPA, 1993).

Construction Quality Control (CQC): A planned system of inspections that is used to directly monitor and control the quality of a construction project.

Density: Mass density of a soil is its weight per unit volume, usually reported in pounds per cubic foot.

Extrusion Weld: A bond between two linear low density polyethylene (LLDPE) materials which is achieved by extruding a bead of LLDPE over the leading edge of the seam between the upper and lower sheet using a hand-held apparatus. Extrusion welds will be used for patch repairs, destructive repairs, and in some tie-ins.

FCSER: Final Cover System Evaluation Report - A stand alone, quality control test report prepared in accordance with the methods and procedures contained in this FCQCP that details the installation and testing of the final cover system.

Film Tear Bond: A failure in the geomembrane sheet material on either side of the seam and not within the seam itself.

Fusion Weld: A bond between two LLDPE geomembrane materials which is achieved by fusing both surfaces in a homogeneous bond of the two surfaces using a power driven apparatus capable of heating and compressing the overlapped portions of the geomembrane sheets.

Geotechnical Engineering Professional (GEP): A Professional Engineer registered in the State of Texas who possesses professional experience in geotechnical engineering and testing.

Geomembrane Infiltration Layer: An essentially impermeable geosynthetic composed of one or more synthetic sheets.

GRI: Geosynthetic Research Institute - Located at Drexel University, the GRI conducts research with geosynthetic materials and develops industry testing standards for these materials. This institute is supported by many geosynthetic manufacturers, installers, and raw materials suppliers to the industry.

Independent Geosynthetics Laboratory (IGL): A qualified geosynthetics testing laboratory not affiliated with either the manufacturer or the owner.

LLDPE: Linear Low Density Polyethylene - An ethylene/ α -olefin copolymer having a linear molecular structure. The comonomers used to produce the resin can include hexane, octane, or methyl pentene. LLDPE resins have a natural density in the range of 0.915 to 0.926 g/ml (ref. Pate, T.J. Chapter 29 in Handbook of Plastic Materials and Technology, I.I. Rubin Ed., Wiley, 1990).

Moisture Content: Ratio of quantity of water in the soil (by weight) to the weight of the soil solids (dry soil), expressed in percentage; also referred to as water content.

Moisture/Density Relationship: A test in which soil samples are compacted in a known volumetric container at various moisture contents at a constant level of compactive effort and their corresponding densities are determined. The test procedures and compactive efforts used are those normally prescribed in ASTM D 698 and ASTM D 1157 (See Optimum Moisture Content).

Optimum Moisture Content (OMC): Moisture content corresponding to maximum dry density as determined in standard Proctor test (ASTM D 698) or modified Proctor (ASTM D 1557).

Project Representative: The on-site or designated representative of the Angelina County Waste Management Center.

Qualified Engineering Technician: A representative of the GEP who is represented to be NICET-certified in Geotechnical Engineering Technology at level 2 for soils and geomembrane testing, an engineering technician with a minimum of four years of directly related experience, or a graduate engineer or geologist with one year of directly related experience.

Secondary Structure: The macrostructure of a geologic stratum. Structural features in a soil or rock deposit which can be seen with little or no magnification, to include, but not limited to, pockets, lenses, layers, seams, or partings of varying soil types, slickensided fissures, laminated structure, and/or mineral concretions or staining.

Sieve Analysis: A laboratory soil test consisting of placing a known weight of soil sample through a series of wire mesh sieves stacked upon each other in successively smaller mesh size and used to determine the percentage size gradation of the sample.

Soil Borrow Source: Soils in which the Liquid Limit (LL) and Plasticity Index (PI) do not vary by 10 points or more. A soil that varies by 10 or more from the originally established

LL or PI is considered as a separate soil source for the purpose of this document and requires a separate soils test series.

TCEQ: Texas Commission on Environmental Quality and its successors.

4 SOIL INFILTRATION LAYER (PRE-SUBTITLE D AREA)

The soil infiltration layer of the final cover system will have continuous on-site inspection during construction and/or installation by the GEP or his/her Qualified Engineering Technician. The GEP or his/her Qualified Engineering Technician will perform all field sampling and testing, both during construction and/or installation and after completion of the infiltration layer construction or installation.

The requirements for constructed soil infiltration layer and soil infiltration layer materials are as follows:

<u>Property</u>	<u>Method</u>	<u>Required Value</u>
Atterberg limits	ASTM D 4318	Liquid Limit not less than 30 Plasticity Index not less than 15
Sieve Analysis	ASTM D 422	>30% passing #200 mesh sieve
Permeability	ASTM D 5084	As outlined in Final Closure Plan
Soil Classification	ASTM D 2487	N/A
Moisture Content	ASTM D 2216	N/A
Standard Proctor	ASTM D 698	See compaction curve for reference
Modified Proctor	ASTM D 1557	See compaction curve for reference
Thickness of infiltration and erosion layers	Survey methods	As outlined in Final Closure Plan

4.1 Preconstruction Testing - Soil Infiltration Layer

After identifying a potential soil infiltration layer material, characteristic tests will be conducted on representative samples of the material as follows:

1. Sieve analysis, Atterberg limits and soil classification will be conducted to determine if the soil meets the criteria outlined above. If the results of these tests indicate acceptable source material, a Proctor compaction test will be conducted to determine the maximum dry density and optimum moisture content. The type of ASTM Proctor compaction test, standard or modified, will be determined by the certifying engineer based on types of heavy equipment to be used in the field. Equipment capable of providing a minimum of 12,400 ft-lbf/ft³ will be used for compaction. If a modified Proctor is to be used, equipment capable of providing 56,000 ft-lbf/ft³ or greater compaction must be used.

2. Using the results from the standard Proctor test, a permeability test sample will be prepared at no less than 95% of the maximum dry density and at the optimum moisture content. If modified Proctor test is used as a reference, a permeability test sample will be prepared at no less than 90% of maximum dry density and at a moisture content 1% drier than the optimum moisture content.
3. Permeability tests will be conducted per the specified test method using tap water or 0.05N calcium sulfate solution as the permeant fluid. Distilled or deionized water is not acceptable for use as permeant fluid. The permeant fluid will be deaired.
4. If the permeability is less than the permeability outlined in the Final Closure Plan for a specific area of the landfill, soil infiltration layer construction may begin with that soil material over the specified area.
5. If the permeability test for the sample prepared at 95% of the maximum dry density and at the optimum moisture (see (4.1)(2) above if modified Proctor test method is used) content does not satisfy the permeability requirements outlined in the Final Closure Plan, permeability test(s) with increased dry density and/or increased moisture content will be required if the soil material is to be used for soil infiltration layer construction. Using systematic increases in compaction effort and moisture content, an additional permeability test sample(s) will be prepared and tested.
6. The minimum acceptable compaction criteria for soil infiltration layer construction will be based on the criteria used in the permeability test which met the permeability requirement outlined in the Final Closure Plan.
7. All permeability test data on soil materials which are used for a soil infiltration layer must be submitted regardless of test method used or test results.
8. If materials vary by more than 10 points in either the liquid limit or plasticity index from previous evaluated materials, a separate preconstruction evaluation will be conducted.
9. If multiple borrow sources are to be used, a separate preconstruction evaluation will be made for the different sources. If different soil layers or types are encountered in the same borrow area, a separate preconstruction evaluation will be performed for the different materials under consideration for use as soil infiltration layer.
10. A moisture-density compaction curve must be established prior to field testing. The moisture-density compaction curve will include a zero air voids line. It is required that the specific gravity used for the zero air voids line be included, but it may be estimated.
11. The maximum clod size of the soil infiltration layer soils will be approximately one inch (1") in diameter but in all cases soil clods will be reduced to the

smallest size necessary to achieve the coefficient of permeability reported by the testing laboratory and to destroy any macrostructure evidence after the compaction of the clods under density-controlled conditions.

12. The soil infiltration layer material will contain no rocks or stones larger than one inch in diameter or that total more than 10% by weight. One-hundred percent (100%) of the material used in the soil infiltration layer must pass the one inch (1") screen.

4.2 Soil Infiltration Layer Installation

A. General

1. The surface of the waste/intermediate cover should be compacted to the maximum possible density to prepare a working surface on which to place the first lift of final cover soil.
2. Infiltration layer soil will not be placed or compacted during sustained periods of temperatures below 30°F. Infiltration layer soil may be placed during early morning freezing temperatures with warming trends during the day.
3. Soil infiltration layer construction and testing should be completed in a systematic and timely fashion. Delays should be avoided in soil infiltration layer completion. There should not be more than a 14-day hiatus in construction unless adverse weather prevents construction progress.

B. Hydrating Infiltration Layer Soil

1. In order to ensure proper hydration of the infiltration layer soil, clod size reduction should be completed through discing, pulverizing, possibly screening, or other equivalent methods, prior to adding water.
2. A minimum of five (5) passes of a disk or three (3) passes of a pulverizer should be made at alternating right angles where space permits for soil processing. Additional passes should be performed if necessary to thoroughly break up and blend the infiltration layer soil prior to compacting.
3. After water is added, the soil must be thoroughly mixed and stockpiled, if necessary, to allow adequate time (usually overnight or longer) to hydrate. The higher the plasticity of the soil, the longer this mixing and hydration process will take.
4. Water used in the hydrating infiltration layer soils must be clean and will not have come into contact with waste or any objectionable material.

C. Placement

1. Approved soil infiltration layer material will be placed in uniform layers not exceeding nine inches (loose lift). If the pads of the compactor to be used will not penetrate into the top of the previously compacted lift, the thickness of the loose lift will be reduced to allow for full penetration by the compactor pads.
2. Compaction equipment will be maintained to avoid clogging of infiltration layer soil around the compactor pads. A minimum of one (1) lift for each six-inches (6") of soil infiltration layer will be used.

D. Compactive Effort

1. As each lift (approximately six inches (6") of compacted thickness) of infiltration layer has been completed, field density and moisture content tests will be performed at the frequency outlined.
2. Minimum field compaction criteria for a constructed soil infiltration layer is 95% (or as Section (4.1)(2) above if modified Proctor test method is used) of the maximum dry density at a moisture content at or above the optimum moisture content, or the compaction criteria established during preconstruction testing, whichever is more restrictive.
3. Soil infiltration layers will not be compacted with a bulldozer or any track-mobilized equipment unless it is used to pull a pad-footed roller. Compaction of soil infiltration layer material loose lifts will be performed with an appropriately heavy, properly ballasted, penetrating foot compactor such as a pad foot, prong-foot, or sheepsfoot compactor similar to a CAT 815 or equivalent.
4. A minimum of four passes are required, with a pass being defined as two applications of the compacting roller (i.e., for a one roller compactor, a pass is a trip forward and back, for a two-roller compactor, a pass is a trip forward). Additional passes may be required to achieve compaction requirements.
5. Within a construction area, each lift will be thoroughly compacted and satisfy moisture and density controls through field testing prior to placement of subsequent lifts.

E. Lift Bonding

1. The top of each lift should be roughened to a willow depth prior to placement of the next lift of soil for compaction.
2. No loose lifts will be thicker than the pads of the compactor so that complete bonding with the top of the previous lift is achieved.

3. During construction, finished lifts or sections may be sprinkled with water as needed to prevent drying and desiccation.
4. If desiccation and crusting of a lift surface occur before placement of the next lift, the area will be sprinkled with water, scarified, and tested for acceptable moisture content prior to placement of a subsequent lift.
5. Completed lifts or sections of compacted soil infiltration layer will be sealed by rolling with a rubber tired or smooth drum roller and sprinkled with water as needed.
6. The top surface of the completed soil infiltration layer must be proof rolled with a smooth-wheel roller prior to final infiltration layer-thickness surveying.
7. If possible, the surface of a soil infiltration layer will be proof rolled when construction is shut down for more than 24 hours to mitigate the effects of desiccation.

F. Infiltration Layer Tie-Ins

Soil infiltration layer section must not be constructed by "butting" the entire thickness of a new layer section to the previously constructed infiltration layer section. Either of the following methods must be followed:

1. The edge of the old section of infiltration layer must be cut back on a slope that the entire existing infiltration edge is tied to new construction without superimposed construction joints; or
2. The edge of the old section of infiltration layer will be cut back on one-foot (1') offset layers (stair steps) so that each foot of the existing infiltration layer edge is tied to new construction without superimposed construction joints. The length of the tie-in area should be at least 5 feet per foot of infiltration layer thickness.

G. Field Testing

Each constructed area developed as a separated segment (non-monolithically) must be considered as separately evaluated areas independent of each other for the purposes of calculating dimensions to determine the required number of samples.

1. Minimum requirements for field testing during construction of soil infiltration layer are as follows:
 - a. A field density and moisture content test will be conducted per every 8,000 square feet for each six inch (6") compacted lift, (but not less than three (3) tests per six inch (6") compacted lift).

- b. Sieve analysis will be performed at a frequency of one test per every 100,000 square feet or major fraction thereof. A minimum of one test per 6 inch compacted lift is required.
- c. Atterberg limits will be determined at a frequency of one test per every 100,000 square feet or major fraction thereof. A minimum of one test per 6 inch compacted lift is required.
- d. Permeability tests will be performed at a frequency of one test per every surface acre of final cover, or major fraction thereof, evenly distributed over the entire soil infiltration layer thickness with a minimum of one permeability test per each 6-inch compacted lift.

For an 18-inch infiltration layer constructed in three 6-inch lifts, for example, the regulatory requirement of one permeability test per surface acre of final cover should be met by testing each lift for permeability at a frequency of one (1) test per three (3) surface acres.

- e. Thickness verification will be performed by instrument survey methods only. A minimum of one verification point per 10,000 square feet of surface area is required. If the construction area is less than 10,000 square feet, a minimum of two verification points will be required. Reference locations with elevations will be noted on a drawing of the area evaluated. All elevation calculations necessary for thickness verification determination will be attached as part of the supporting documentation to the FCSEIR including corrections for true thicknesses measured perpendicularly to sidewalls.
2. When sampling for permeability tests, two Shelby tubes/drive cylinders will be retrieved. One tube/cylinder will serve as the primary test sample. The second tube/cylinder will serve as the backup sample in case of damage or sample disturbance in the first tube, or in case of a non-conforming permeability test.
 3. Care will be taken to reference field density tests to the correct Proctor curve for the material being used in construction.
 4. An increase in the frequency of field density testing does not require a corresponding increase in sieve analysis, Atterberg limits or permeability testing.
 5. If the frequency of field density testing is increased, the frequency of the other tests remains one test per 100,000 square feet per 6 inch compacted lift or major fraction thereof.
 6. Throughout construction of soil infiltration layer, test results will be reviewed. If the liquid limit or plasticity index of the soil varies more

than 10 points from the limits determined during preconstruction testing, a compaction test will be performed on the varying material. A laboratory permeability test will be performed on the varying material to ensure a permeabilities requirements, as outlined in the Final Closure Plan, will be achieved using the construction compaction criteria.

7. Sand cone tests, rubber balloon tests, or drive cylinder samples may be used to correlate dry density and moisture content measurements with those of the nuclear gauge. The results of these tests will be documented and reviewed to determine if re-calibration of the nuclear density gauge is necessary.
8. All sampling or testing locations will be backfilled with appropriate bentonite grout or a mixture of at least 20% bentonite-enriched infiltration layer soil and compacted by hand tamping. These locations include field density test locations, material sample locations, and tube sample locations, as well as any other infiltration layer penetration.
9. If used, field permeability testing of constructed soil infiltration layer will be in accordance with ASTM D 5093 or the Boutwell STEI two-stage field permeability test. Field permeability testing will be used only with the prior consent of the TCEQ.
10. All test results will be reported. In case of non-conforming test results, the steps taken to correct the nonconformity will be explained in the FCSEF following procedures outlined below.

H. Non-Conforming Tests - Field Density and Moisture Tests

1. Sections of compacted soil infiltration layer which do not meet the density and moisture content requirements may be reworked and retested until the section does pass the criteria or the section of compacted soil infiltration layer may be removed and replaced to passing standards.
2. In the event of a failed moisture-density test, it is necessary to isolate the non-conforming area. Additional tests will be performed approximately half-way between the failed test and the nearest adjacent passing test locations. If the additional tests pass, the area bounded by passing tests will be reworked and retested. If the additional tests fail, a second set of additional tests will be performed between the failing additional tests and surrounding passing tests. This process will be repeated until the non-conforming area is defined. Once the non-conforming area is defined, it will be reworked and retested until compaction and moisture criteria are met.

3. In lieu of additional tests to define the non-conforming area, it is acceptable to rework entire area bounded by the initial surrounding passing tests.
4. If reworking consistently fails and the section does not pass the criteria, the non-conforming area will be removed and replaced.
5. All reworked areas will be tested and confirmed to satisfy the compaction criteria. The reporting of retests will clearly indicate the number and location of the non-conforming test and the subsequent conforming retest. Retests will be taken near the location of the original non-conforming test.

I. Non-Conforming Tests - Permeability Tests

1. In the event of a non-conforming permeability test, the test procedures and test sample will be reviewed for inconsistency in test procedure or flaw in the permeability test sample. A review of the associated soil characteristic tests and field density/moisture content tests will be performed to confirm that the appropriate compaction criteria was used.
2. A permeability sample will be prepared from the backup drive cylinder or Shelby tube sample and an additional permeability test will be performed on the backup sample.
3. If the backup sample provides an acceptable permeability result, the results of the first sample will be disregarded if it is determined that the first sample or test procedure was flawed. If the backup sample does not provide an acceptable permeability, a review of the required compaction criteria will be performed to determine if the compaction criteria require revision.
4. Additional permeability test samples will be retrieved between the non-conforming permeability location and the surrounding passing permeability test locations. The results from these additional permeability tests will be used to bound the area requiring rework or removal and replacement. The area to be reworked or removed and replaced will be bounded by passing permeability tests. In lieu of additional testing to define the nonconforming area, the area between the initial passing permeability tests may be reworked or removed and replaced.
5. If reworking consistently fails and the section does not pass the criteria, the non-conforming area will be removed and replaced.
6. All reworked areas will be tested and confirmed to satisfy the permeability criteria. The reporting of retests will clearly indicate the number and location of the non-conforming test and the subsequent conforming retest. Retests will be taken near the location of the original non-conforming test.

J. Survey Control

1. The as-built thickness of the soil infiltration layer will be determined by survey methods.
2. Prior to the placement of any soil infiltration layer, the prepared surface will be surveyed once per 10,000 square feet on a pre-established grid.
3. Upon completion of the soil infiltration layer, and prior to the installation of subsequent elements, the top of the soil infiltration layer will be surveyed to ensure the specified thickness of soil infiltration layer has been achieved.
4. Upon completion of the erosion layer the top of the layer will be surveyed to ensure the specified thickness has been placed.

5 GEOSYNTHETIC CLAY LINER (SUBTITLE D AREA)

Geosynthetic clay liner placement will have continuous on-site inspection during construction by the GEP or his/her Qualified Engineering Technician. All field sampling and testing, both during construction and after completion of geosynthetic clay liner placement, will be performed under the observation of the GEP or his/her Qualified Engineering Technician.

5.1 General Material Requirements

1. All proposed GCL will meet the specifications detailed in Table 1, below, and will be capable of retaining its structure during deployment. For each lining event, the manufacturer will provide recommended seaming procedures and supporting test documentation showing the GCL seams are no more permeable than the GCL itself at the confining pressure anticipated in the field.

Table 1 - GCL Properties

Material Property	Standard Test Method	Specified Value
Free Swell	ASTM D 5890 (or as amended)	24 ml. (min.)
Fluid Loss	ASTM D 5891 (or as amended)	18 ml. (max.)
Bentonite Mass/Area (@ 0% Moisture)	ASTM D 5993 (or as amended)	0.75 lb/ft ² (min.)
Grab Tensile	ASTM D 4632 (or as amended)	90 lbs. *75 lbs (min.)
Permeability/Index Flux	ASTM D 5887 (or as amended)	5 x 10 ⁻⁹ cm/sec (max)/ 1 x 10 ⁻⁹ m ³ /m ² sec (max.)
Hydrated Internal Shear Strength	ASTM D 5321 (or as amended)	500 psf. *50 psf (min.)

2. The GCL will be supplied in rolls with structurally sound cores and wrapped to protect from ultraviolet light exposure, moisture, excess humidity, puncture, cutting, and/or any other deleterious conditions.
3. GCL rolls will be marked or tagged with manufacturer's name, product id, roll number and roll dimension.

5.2 On-Site Storage and Handling

1. On-site handling will be performed with a front end-loader, backhoe, dozer, or other equipment with the spreader bar and core pipe or slings. Alternatively, a forklift with a "stinger" attachment may be used for on-site handling and, in certain cases, installation. A forklift without a stinger attachment should not be used to lift or handle the GCL rolls.
2. Rolls will be stored at the job site away from high traffic areas but sufficiently close to the active work area to minimize handling. The designated storage area should be flat, dry and stable. Moisture protection of the GCL is provided by its packaging; however, an additional tarpaulin or plastic sheet is recommended.
3. Rolls should be stacked in a manner that prevents them from sliding or rolling. (This can be accomplished by frequent choking of the bottom layer of rolls). The rolls should be stacked no higher than the height at which they can be safely handled by laborers (typically no higher than four layers or rolls). Rolls should never be stacked on end.
4. GCL rolls will be stored above ground (i.e., wooden pallets).

5.3 Source Quality Control - Preconstruction Testing

1. GCL testing will be performed by the supplier, manufacturer and the third-party independent laboratory to evaluate characteristics for quality control.
2. At a minimum, laboratory tests will be performed at the specified frequencies as detailed in Table 2 as follows:

Table 2 - GCL Testing Frequencies

Tester	Material	Material Property	Standard Test Method	Frequency of Testing
Supplier or GCL Manufacturer	Bentonite ^A	Free Swell	ASTM D 5890 (or as amended)	1 per 50 tons and every truck or trailer
		Fluid Loss	ASTM D 5891 (or as amended)	
GCL Manufacturer	GCL Product	Mass/Unit Area	ASTM D 5993 (or as amended)	1 per 40,000 ft ²
		Moisture Content	ASTM D 2216 (or as amended)	1 per 40,000 ft ²
		Grab Tensile Strength ^B	ASTM D 4632 (or as amended)	1 per 200,000ft ²
		Permeability/Index Flux ^{B, D}	ASTM D 5887 (or as amended)	1 per week for each production line ^C
Independent Laboratory (Conformance Testing)	GCL Product	Mass/Unit Area	ASTM D 5993 (or as amended)	1 per 40,000 ft ²
		Permeability/Index Flux ^{B, D}	ASTM D 5887 (or as amended)	1 per week for each production line ^C
		Hydrated Internal Shear Strength ^{D, E}	ASTM D 5321 (or as amended)	1 per GCL/adjoining material type

Notes:

- A Tests to be performed on bentonite before incorporation into GCL
- B Not applicable for geomembrane-backed GCL. Manufacturer of geomembrane-backed GCL must, however, certify that product will meet required permeability standards based on prior testing
- C Report last 20 permeability values, ending on production date of supplied GCL
- D Test at confining/consolidating pressures simulating field conditions
- E Not applicable for slopes of 7H:1V or flatter. Testing must be in hydrated state unless GCL is to include geomembrane on both sides of GCL

3. Samples not satisfying these specifications and manufacturer's specification will result in the rejection of applicable rolls.
4. Testing of needle-punched GCL will be performed by passing GCL directly over magnets to try to remove broken needles, and continuous testing with metal detectors to verify there are no broken needles.
5. The Geotechnical Quality Control Professional (GQCP) or their representative may request additional testing of individual rolls to more closely identify non-complying rolls and to qualify individual rolls at the discretion and expense of the GCL Manufacturer.
6. Samples of the GCL will be taken across the entire width of the roll but will not include the first 1 ft. Unless otherwise specified, size of the samples will be 1 ft long by the roll width. The samples will be identified by type, lot and roll numbers. The sampler will mark the machine direction on the samples with an arrow.
7. A lot will be defined as a group of consecutively numbered rolls from the same manufacturing line.

8. Samples will be taken at the rates specified in Table 2, above. These samples will then be forwarded to the Geosynthetic Quality Assurance Laboratory (QAL) for testing to ensure conformance to the project specifications.

5.4 Geosynthetic Clay Liner (GCL) Construction

All GCLs will have continuous on-site inspection during construction by the GQCP or their qualified representative. All field sampling and testing, both during construction and after completion of the GCL construction, will be performed under the observation of the GQCP or their qualified representative

A. Subgrade Preparation Procedures

1. Verify the subgrade surface is free of rocks which may damage the membrane, desiccation cracks which may affect the integrity of the clay liners, ruts, voids, etc.
2. Remove debris and rock particles greater than $\frac{3}{8}$ -inch in diameter from soil surface
3. Scarify, moisture condition, and compact the upper six (6) inches soil. Compaction will first be performed with a tamping-foot compactor and then the surface finished with a smooth drum roller.
4. Do not place GCL on an area that has become softened by precipitation or otherwise damaged.
5. Prior to GCL installation, the condition of the subgrade must be deemed suitable for GCL installation by the GQCP and the installer.
6. Provide required anchor trench at the liner perimeter to secure the GCL. Ensure loose soil underlying the GCL in the anchor trench is minimized.

B. Placement

1. Remove protective cover soil and prepare tie-in to existing liner(s).
2. On slopes, anchor GCL securely and deploy it down slope in a controlled manner to continually keep the GCL in tension. Unroll GCL panels onto the subgrade; do not drag panels across it.
3. Install GCL with the appropriate side of the material facing upward.
4. Ensure GCL panels lie flat on the underlying subgrade with no wrinkles or folds.
5. Cut GCL with a cutter (hook blade). Protect adjacent materials from potential damage due to cutting.

6. Provide temporary loading, such as sandbags, or equivalent, in presence of high wind that may dislocate panels. Do not remove loading until replaced with appropriately loaded cover material.
7. Prevent damage to underlying subgrade during placement of GCL. Do not use equipment to deploy the GCL that may cause excessive rutting (> 1") of the subgrade.
8. During deployment, do not entrap stones, excessive dust or moisture, in or beneath the GCL.
9. Prevent excess loss of bentonite on edges during installation.
10. Visually examine entire GCL surface and ensure no potentially harmful foreign objects are present. Remove foreign objects encountered or replace GCL.
11. Deploy GCL in such a manner so as to protect the GCL from moisture and precipitation during and after installation. Do not install GCL in standing water or during inclement weather such as rain or high winds.
12. Do not deploy more GCL material during any one working day than can be covered by the end of that day.
13. Maintain a correlation between panel numbers and roll numbers.
14. Position the edges of the upslope panels above the edges of the downslope panels in a shingle-like fashion.

C. Anchorage

1. If placed on a side slope, the end of the GCL roll should be placed in an anchor trench at the top of a slope. The front edge of the anchor trench should be rounded to eliminate any sharp corners that could cause excessive stress on the GCL. Loose soil should be removed or compacted into the floor of the anchor trench.
2. If a trench is used for anchoring the end of the GCL, soil backfill should be placed in the anchor trench to provide resistance against pullout.
3. Place GCL in the anchor trench such that it covers the entire anchor trench floor but does not extend up the rear anchor trench wall.

D. Seaming

1. Overlap GCL edges a minimum of 6 inches (150 mm). Apply a continuous bead of granular bentonite approximately 3 inches (75 mm) from the underlying edge of the GCL.

2. Overlap roll end-of-panel seams a minimum of 12 inches (300 mm).
3. Shingle overlapped seams so that the edge of the upslope panel is positioned above the downslope panel.
4. Do not use horizontal seams on side-slopes unless slope length exceeds roll length. In that case, place seams only in the lower half of slopes and stagger with end overlaps accomplished in accordance with manufacturer's recommendation.
5. With the exception of corners, when required, do not "Piece-in" an area with small panels. Plan for and provide sufficient material to avoid the use of repetitive small panels.
6. For reinforced GCL, add granular bentonite as supplied by the GCL manufacturer to seams at a rate equal to 1/4 pound per linear foot (0.4 kg/m) using a method or device approved by the GCL manufacturer.
7. Visually inspect seam continually to ensure:
 - a. GCL material entirely covers the subgrade;
 - b. Panel edges cover the 6 inch lap line printed on the upper surface of each panel;
 - c. Overlap zone is not contaminated with loose soil or other debris; and
 - d. Bentonite added to seams is continuous.

E. Defects & Repairs

1. Sections which have been prematurely hydrated will be removed and replaced.
2. Repair holes and tears in GCL as follows:
 - a. Place a piece of new material extending over the entire area of damage with a minimum 12 inch overlap in all directions.
 - b. Add powder or granular bentonite to patches as required by manufacturer's recommendations. Secure patches so that placement overlying layer does not dislodge the patch. Placing the patch beneath the damaged sheet generally eliminates this potential.

5.5 Geosynthetic Clay Liner (GCL) Protection

Operation of construction equipment on the GCL will be minimized to reduce the potential for damage or puncture. Vehicles, other than low contact pressure

vehicles, are not allowed on deployed GCL. Deployed GCL panels should contain no folds or excessive slack. The GQCP or their representative will verify that generators, tools, or supplies are not be stored directly on GCL. Deployed GCL must not be used as a work area unless a protective tarpaulin is placed over the GCL. Installation personnel must not smoke or wear damaging shoes when working on the GCL.

5.6 Interface with Geomembrane

Upon completion of GCL installation, the geomembrane should be installed as soon as possible. When deploying the geomembrane on top of the GCL, extra care must be taken to ensure that the GCL and underlying lining materials are not damaged, minimal slippage of GCL on underlying layers occurs, and no excess tensile stress occurs on the GCL.

Special precaution should be taken if textured geomembrane will be installed directly over the GCL. Because considerable friction may develop between the geomembrane and the GCL, it may be difficult to pull the geomembrane into position for welding to adjacent panels. A smooth "slip sheet" should be used to provide a low-friction sliding surface for the geomembrane until it is in position for welding.

6 GEOMEMBRANE INFILTRATION LAYER REQUIREMENTS (SUBTITLE D AREA)

Any geomembrane infiltration layers that are constructed as part of a composite final cover system will have continuous on-site inspection during construction by the GEP or his/her Qualified Engineering Technician. All field sampling and testing, both during construction and after completion of the infiltration layer construction, will be performed under the observation of the GEP or his/her Qualified Engineering Technician.

Geomembrane material will be LLDPE (linear low-density polyethylene), or other equivalent geomembrane material approved by TCEQ in the event LLDPE is no longer manufactured.

The geomembrane must have a minimum thickness of 40 mils. Approved geomembrane material used must overlay and be in direct contact with an approved subgrade soil or geosynthetic material.

6.1 LLDPE Material Requirements

1. Geomembrane infiltration layer material must be produced from virgin raw materials. Reground, reworked or trim materials from the same lot may be acceptable but recycled or reclaimed materials must not be used in the manufacturing process.
2. LLDPE material and required welding rods will contain between 2% and 3% carbon black and may contain no more than 1% other additives.
3. Geomembrane sheet must be free from pinholes, surface blemishes, scratches, or other defects (e.g., non-uniform color, streaking, roughness,

agglomerates of carbon black or other additives or fillers, visibly discernible regrind or rework, etc.).

4. The geomembrane used will meet, at a minimum, the standards included in the Geosynthetic Research Institute (GRI) Test Method GM-13, Revision 4 dated December 13, 2000.
5. Resin documentation, including density and melt flow index, will be submitted for resins used.
6. All LLDPE geomembrane material will be shipped in rolls. Folded or creased sections of panels are not acceptable and will not be used unless they are a normal part of the manufacturing process.
7. The GEP or his/her Qualified Engineering Technician will inspect the delivered materials for damage and defects. Pushing, sliding or dragging of rolls or pallets can cause damage and should be avoided.
8. Geomembrane material must be protected from soft or wet ground and rocky or rough ground. LLDPE geomembrane must not be stacked more than five (5) rolls high (or as recommended by the manufacturer) to avoid crushing the cores of the rolls. A sacrificial cover must be used to protect the geomembrane if store on-site for more than six (6) months. The rolls and pallets must be stored in such a manner to avoid shifting, abrasion, or other adverse movements that can damage the geomembrane infiltration layer material.

6.2 LLDPE Preconstruction Testing

The geomembrane manufacturer conducts many tests throughout the manufacturing process and after the geomembrane is produced. The manufacturer's test may include thickness, specific gravity, carbon black content, carbon black dispersion, tensile properties, tear and puncture resistance, oxidation induction time, oven aging, UV resistance, volatile loss, resistance to soil burial, stress cracking resistance, and dimensional stability.

1. All geomembrane sheets and seams will be tested and evaluated prior to acceptance. In general, testing of the geomembrane will be conducted by the manufacturer prior to shipping. Manufacturer testing will be performed in accordance with Table 3, on the following page.
2. The GEP or his/her Qualified Engineering Technician or IGL may perform additional testing as required by these detailed Specifications or as required in the judgement of the GEP or his/her Qualified Engineering Technician or to verify that the geomembrane sheet and seams meet the specifications. At a minimum, the GEP or his/her Qualified Engineering Technician or IGL, will perform conformance testing at the frequencies indicated in Table 3 and these specifications.

3. The Installer or supplier (manufacturer) will be required to submit his Quality Control results for each roll of geomembrane and each separate resin used in manufacturing to the GEP or his/her Qualified Engineering Technician.
4. As a minimum, the Installer will perform the tests at the frequencies given in Table 3.
5. Test results will be submitted to the GEP or his/her Qualified Engineering Technician, who will review and confirm the geomembrane material meets specifications prior to installation of a geomembrane sheet.

**TABLE 3
Standard Tests on LLDPE Geomembrane Material**

TEST	TYPE OF TEST	STANDARD TEST METHOD	FREQUENCY OF TESTING
Resin (LLPDE)	Density	ASTM D1505	1 test per 100,000 sq. ft. and every resin lot
	Melt Flow Index	ASTM D 1238 (90/2.16 and 190/21.6)	
Manufacturer's Quality Control	Testing per GRI Test Method GM 17 for LLDPE ¹		
Conformance Testing by Third Party Independent Laboratory	Thickness ²	ASTM D5199 (Smooth LLDPE), D5994 (Textured LLDPE)	1 test per 100,000 sq. ft. and every resin lot
	Specific Gravity/Density	ASTM D1505/D792 (LLDPE)	
	Carbon Black Content	ASTM D1603	
	Carbon Black Dispersion	ASTM D5596	
	Tensile Properties	ASTM D63832 Type IV	
Destructive Seam Field Testing	Shear and Peel	ASTM D4437	Varies for field, lab, and archive
Non-destructive Seam Field Testing	Air Pressure	GRI GM6	all dual-track fusion
	Vacuum (LLDPE)	ASTM D4337	all non-air pressure tested seam when possible

¹ GRI Test Method GM 17 can be found in Attachment B of this plan.

² Field thickness measurements for each panel must be conducted. Use ASTM D374/D5994 and perform 1 series of measurements along the leading edge of each panel, with individual measurements no greater than 5 feet apart. No single measurement shall be less than 10% (for LLDPE) below the required normal thickness in order for the panel to be acceptable.

³ Break Elongation calculated using 2-inch initial gauge length.

6.3 Geomembrane Installation

A. General

1. The geomembrane infiltration layer will be installed as soon as practical after completion of the soil infiltration layer and associated testing. Each sequential section of geomembrane will be secured

in an anchor trench and continuously welded to the adjacent sections.

2. The geomembrane should not be placed during inclement weather such as rain, high winds or freezing temperatures.
3. No vehicular traffic will be allowed on the geomembrane prior to placement of the erosion or drainage layers. Only low-ground pressure equipment (e.g. golf carts, ATVs or other small rubber tired equipment with a ground pressure less than 5 psi and a total weight of less than 750 pounds) may be allowed to traverse the geomembrane.
4. If supporting equipment is operating on the geomembrane, it must be placed on a sacrificial surface or rub sheet in order to help protect the geomembrane. Personnel working on the geomembrane will not smoke, wear damaging shoes, or engage in any other activity likely to damage the geomembrane.

B. Preparation

1. Areas to receive geomembrane infiltration layer installation will be relatively smooth and even and free of rocks which may damage the membrane and/or desiccation cracks which may affect the integrity of the soil infiltration layer.
2. The surface of the subgrade must be finished by rolling with a flat wheel roller until a smooth uniform surface is achieved. Prior to geomembrane installation, the condition of the subgrade must be deemed suitable for geomembrane installation by the GEP or his/her Qualified Engineering Technician and the installer.
3. The soil subgrade must be protected from desiccation and cracking, rutting, erosion, and ponding prior to and during placement of the geomembrane. The condition of the subgrade must be preserved by regular watering and proof-rolling or by placing a minimum of twelve inches (12") of temporary soil cover which must be removed prior to geomembrane placement and the soil subgrade surface reassessed by the GEP or his/her Qualified Engineering Technician.

C. Placement

1. Installation of the geomembrane will be as follows:
 - a. Unroll only those sections, which are to be seamed together or anchored in one day. Panels will not be placed in inclement weather such as rain or high winds. Panels will be positioned with the overlap recommended by the manufacturer, but not less than 3 inches. The edge of the upslope sheet will be positioned above the edge of the downslope sheet. The geomembrane sections will be placed

in an anchor trench which is then backfilled with soil compacted to 90 percent of the maximum dry density as determined by the Standard Proctor Compaction Tests (ASTM D 698).

- b. After panels are initially in place, remove as many wrinkles as possible. Unroll several panels and allow the infiltration layer to "relax" before beginning field seaming. The purpose of this is to make the edges, which are to be bonded as smooth and free of wrinkles as possible. The number of rolls deployed ahead of seaming operations will be at the discretion of the Installer.
2. Thickness confirmation will be performed by the GEP or his/her Qualified Engineering Technician in the field on every roll of geomembrane to be installed. Field micrometer measurements will be performed in five feet increments along the leading edges of each geomembrane.

D. Trial Seams

1. Testing of trial seams will be conducted by the Installer under observation by the GEP or his/her Qualified Engineering Technician.
2. The Installer will maintain and use equipment and personnel at the site to perform testing of test seams.
3. A test seam will be made for each seaming apparatus to be used in field seaming. If more than one seaming technician uses the same apparatus, a separate test seam will be made for each apparatus/technician combination that will perform field welding. Test seams will be made each day prior to commencing field seaming. These seams will be made on fragment pieces of geomembrane infiltration layer to verify that seaming conditions are adequate. Time, tip temperature, and seamer name will be recorded for each trial seam.
4. Such test seams will be made at the beginning of each seaming period, such as morning start-up and after mid-day or lunch break. Tests seams will also be made for each occurrence of significantly different environmental condition such as temperature change, humidity, dust, etc., any time the machine is turned off for more than 30 minutes; and when seaming different geomembranes (tie-ins and smooth to textured) At the GEP's or his/her Qualified Engineering Technician's discretion, additional trial seams may be required. Each seamer will make at least one test seam each day.
5. The test seam sample will be at least 3-feet (0.91 meter) long by 1-foot wide (0.30 meter) with the seam centered lengthwise. Four (six when possible if using dual track fusion welding) adjoining 1-inch wide specimens will be die cut from the test seam sample. Two (2)

specimens will be tested in the field for shear and two (2) for peel (4 when possible if testing both inner and outer welds for dual track fusion welding).

6. The extensometer testing apparatus used for peel and shear tests must have an updated calibration certificate traceable to National Bureau of Standards (NBS).
7. Test seams will be tested by the Installer under observation of the GEP or his/her Qualified Engineering Technician. The specimens will not fail in the weld.
8. Failure criteria is the same as that for destructive seam testing outlined in Section 6.F.2.
9. If a test seam fails, the entire operation will be repeated. If the additional test seam fails, the seaming apparatus or seamer will not be accepted and will not be used for seaming until the deficiencies are corrected and two consecutive successful test seams are achieved.

E. Field Seaming

Field seaming (and repairs) will be performed in strict accordance with methods approved by the manufacturer. Strict attention to the details of seam preparation procedures recommended by the manufacturer is crucial in order to produce consistent seams that will not allow fluid leakage and will pass QA testing.

1. All foreign matter (dirt, water, oil, etc.) will be removed from the edges to be bonded. No solvents will be used to clean the geomembrane infiltration layer.
2. For extrusion-type welds, the bonding surfaces must be thoroughly cleaned by mechanical abrasion or alternate methods approved by the GEP or his/her Qualified Engineering Technician to remove surface cure and prepare the surfaces for bonding. The grinding will be performed so that grind marks are generally perpendicular to the edge of sheet.
3. Tack welds (if used) will use heat only; no double sided tape, glue, or other method will be permitted. The geomembrane will be seamed completely to the ends of all panels to minimize the potential of tear propagation along the seam. Excessive overgrind, as determined by the GEP or his/her Qualified Engineering Technician, will be repaired.
4. Field seaming may be performed by extrusion or fusion welding or a combination of these methods. Extrusion welding applies a molten bead of material to the leading edge of the seam between sheets of geomembrane. The fusion welding process heats the area to be

- joined to the melting point and then applies pressure to join the melted surfaces. Solvent welding is not acceptable.
5. The sheets should be positioned with the overlap recommended by the manufacturer, but not less than 3 inches for LLDPE.
 6. The seams will be oriented generally parallel to the line of maximum slope, i.e., oriented up and down, not across, the slope. In corners and odd shaped geometric locations, the number of field seams will be minimized.
 7. Seams on side slopes (steeper than 6H:1V) should be oriented parallel to the sideslip direction. Seams that join the side slopes and top or bottom sections should be located at least five feet (5') from the sideslip. In corners and odd-shaped geometric locations, the number of field seams should be minimized.
 8. No seaming will be attempted above 40°C (104°F) ambient air temperature. Below 5°C (41°F) ambient air temperature, preheating of the geomembrane will be required, unless it is demonstrated that this is not necessary (i.e., acceptable trial test (start-up) seams which duplicate, as closely as possible, actual field conditions). Preheating may be achieved by natural and/or artificial means (shelters and heating devices). Ambient temperature is measured 18 inches above the infiltration layer surface.
 9. A moveable protective layer of plastic may be required, as recommended by the GEP or his/her Qualified Engineering Technician, to be placed directly below each overlap of geomembrane that is to be seamed. This is to prevent any moisture build-up between the sheets to be welded.
 10. Seaming will extend to the outside edge of panels to be placed in anchor trenches.
 11. If required, a firm working surface will be provided by using a flat board, a conveyor belt, or similar hard surface directly under the seam overlap to achieve proper support.
 12. Seams at panel corners of 3 or 4 sheets will be completed with a patch having a minimum dimension of 24 inches, extrusion welded to the parent sheet.
 13. No folds, large wrinkles, or fish mouths will be allowed in the seam. Only normal factory-induced creasing from the blown film process may be acceptable. Where wrinkles or folds occur, the material will be cut, overlapped, and welded. This process should be accomplished in such a manner that constructed seams are not required to carry significant tensile loads. During wrinkle or fold repairs, adjacent geomembrane may not necessarily be required to

meet the 3 to 4-inch minimum overlap if approved by the GEP or his/her Qualified Engineering Technician.

14. All complete seams will be tightly bonded and sealed.

F. Field Testing - Geomembrane Infiltration Layer

All geomembrane seams will be tested and evaluated prior to acceptance. The GEP or his/her Qualified Engineering Technician will observe all production seam field test procedures. Testing of the seams will be conducted by the Installer under observation by the GEP or his/her Qualified Engineering Technician. At his discretion, the GEP or his/her Qualified Engineering Technician may have additional testing performed to verify that the geomembrane seams meet the specifications.

1. Non-Destructive Testing

Continuous, non-destructive testing will be performed on all seams by the installer. Air-pressure testing on dual-track fusion welds and vacuum-box testing on extrusion welds are the only acceptable methods for LLDPE geomembrane seams. All factory seams, in addition to field seams, should be non-destructively tested. All indicated leaks must be isolated and should be repaired by following the procedures described in Section 6.G, below.

- a. Air-Pressure Testing

The ends of the air channel of the dual-track fusion weld must be sealed and pressured to approximately 30 psi. The air pump must then be shut off and the air pressure observed after 5 minutes. A loss of less than 4 psi is acceptable if it is determined that the air channel is not blocked between the sealed ends. A loss equal to or greater than these pressure indicates the presence of a seam leak which must then be isolated and repaired by following the procedures described in Section 6.G, below. The GEP or his/her Qualified Engineering Technician should observe and record all pressure gauge readings.

- b. Vacuum-Box Testing

A suction value of approximately 3 to 5 inches of gauge volume must be applied to all extrusion welded seams that can be tested in this manner. Examples of extrusion welded seams that do not easily lend themselves to vacuum testing would be around boots, appurtenances, etc. The seam must be observed for leaks for at least 10 seconds while subjected to this vacuum. The GEP or his/her Qualified Engineering Technician must observe 100% of this testing.

c. Other Testing

Other non-destructive testing must have prior written approval from the TCEQ.

2. Destructive Testing

Destructive testing will be performed at least once within each 500 linear feet of production seam. The locations will be selected by the GEP or his/her Qualified Engineering Technician in such a manner as to representatively sample the geomembrane seam quality for the entire installation. Repairs greater than 10 feet in length must be counted in determining the total seam length for testing. At a minimum, a destructive test will be performed for each welding machine used for seaming or repairs.

A sufficient amount of the seam must be removed in order to conduct field testing, independent laboratory testing, and archiving of enough material in order to retest the seam when necessary. Field testing will include at least two (2) peel test specimens (four (4) when possible for testing both tracks on dual-track fusion welded seams). Independent laboratory testing will consist of five (5) shear test specimens and five (5) peel test specimens (10 when possible for both tracks of dual-track fusion seams). Destructive seam-testing locations will be cap-stripped and the cap completely seamed by extrusion welding LLDPE to the parent geomembrane. Capped sections will not be non-destructively tested. Additional destructive test samples may be taken if deemed necessary by the GEP or his representative.

a. Passing Criteria

Field-tested specimens from destructive-test location must pass in both shear and peel for the seam to be considered passing. Field-tested specimens are determined as passing if the specimen tested in peel fail in film tear bond (FTB) and all test specimens meet the criteria listed in this subsection. Independent laboratory testing must confirm these field results.

The minimum passing criteria for independent laboratory testing are as follows:

- At least 4 of 5 specimens tested in the peel mode must fail in FTB
- At least 4 of 5 specimens from each peel and sheer determination must meet the minimum specified values given in parts 1 and 2 of this subsection, below.

- The average value of the 5 specimens from each peel and shear determination must meet the minimum specified value given in parts 1 and 2 of this subsection, below.
 1. Shear Requirements - For LLDPE, the shear strength must meet the manufacturer's specifications and GRI or PGI Standards as applicable.
 2. Peel Requirements - For LLDPE, the peel strength must meet the manufacturer's specifications and GRI or PGI Standards as applicable.

The above criteria must be met by both tracks from each dual-track fusion welded seam before it is considered passing.

Test methods and frequency of testing for geomembrane are found in Table 1. It should be noted that geomembrane manufacturers may have differing values for their geomembrane sheets and, therefore, the specific values are not stated in this plan, only percentages. Consequently, the manufacturer's sheet-strength values must be provided to determine if the test results are passing.

b. Failing Criteria

If less than 4 of the 5 specimens from each destructive test pass, or if the average calculated from all 5 specimens is less than the specified values given in Table 2, or if more than one (1) specimen of LLDPE from the group of 5 specimens exhibits a non-FTB failure, the seam has failed.

If unresolved discrepancies exist between the GEP's or his/her Qualified Engineering Technician's and Installers's test results, the archived sample may be tested by the GEP or his/her Qualified Engineering Technician.

G. Non-Conforming Test Results

1. Samples, which do not pass the shear and peel tests will be re-sampled from locations at least 10 feet on each side of the original location. These two re-test samples must pass both shear and peel testing. If these two samples do not pass, then additional samples will continue to be obtained until the questionable seam area is defined.

2. If desired, it is acceptable to cap strip the non-conforming seam length with the cap strip extending the entire length between two passing seam tests.
3. Damaged and sample coupon areas of geomembrane will be repaired by the Installer by construction of a cap strip. The cap strip will extend a minimum of 6 inches in all direction from the area of concern.
4. No repairs will be made to seams by application of an extrusion bead to a seam edge previously welded by fusion or extrusion methods. Spot welding and extrusion beads may be used to repair surface flaws or irregularity.
5. Repaired areas will be non-destructive tested for seam integrity. At the discretion of the GEP or his/her Qualified Engineering Technician, destructive tests may be conducted on the repaired areas.

H. Anchor Trench and Backfilling

The anchor trench will be completed around all portions of the geomembrane where the leading edge(s) of the geomembrane will not be needed for a tie-in for the next area to receive final cover. The excavated anchor trench will have rounded corners in order to help protect the geomembrane. No loose soil will be allowed to underlie the geomembrane in the anchor trench. Excavation of the anchor trench will not be done too far in advance of geomembrane deployment.

The anchor trench will be backfilled and compacted to at least 90 percent of the density determined by the moisture/density compaction values detailed in Section 4 of this plan. Care should be used when backfilling and compacting the trench to prevent damage to the geomembrane. The anchor trench will be backfilled at the earliest practicable time following synthetics deployment. Results of the compaction testing need not be reported.

I. Survey Control

The edge locations of the geomembrane (interior upper edge of the anchor trench) will be documented by survey methods.

7 DRAINAGE LAYER REQUIREMENTS (SUBTITLE D AREA)

A geocomposite drainage layer will placed between the erosion layer and the geomembrane infiltration layer to reduce storm water infiltration into the waste and to enhance the overall stability of the final cover by removing water which percolates through the erosion layer. The geocomposite will consist of 200-mil HDPE drainage netting heat bonded to 10 oz geotextile filter fabric. Double-sided geocomposite will be placed on side slopes and single-sided geocomposite on top slopes.

All materials placed over the geomembrane should be placed during the coolest part of the day and deployed in "fingers" along the surface to control the amount of slack and minimize wrinkles and folds in the geocomposite. These materials must be deployed only up-slope on the side slopes so that stress imparted to the geomembrane is minimized. Full-time observation by the GEP or his/her Qualified Engineering Technician is required during deployment of the geocomposite drainage material.

Materials, placement procedures, and construction quality assurance for geocomposite will be in accordance manufacturer's recommendations.

8 EROSION LAYER REQUIREMENTS (ALL AREAS)

An erosion layer, consisting of a minimum of 24 inches of earthen material which is capable of sustaining native plant growth, will be placed over the soil infiltration layer. The erosion layer will be seed or sodded immediately after completion of the final cover. Temporary or permanent erosion control measures may be used to minimize erosion and aid establishment of vegetation.

The erosion layer will be placed using any appropriate equipment capable of accomplishing the work and should receive only the minimal compaction required for stability. The thickness of the erosion layer will be verified by survey methods at a frequency of one (1) verification point every 10,000 ft². Other quality assurance for the erosion layer should consist of continuous observation by the GEP or his/her Qualified Engineering Technician during construction, and performing additional tests felt necessary by the GEP to verify that the erosion layer has been constructed in accordance with the Final Closure Plan.

9 DOCUMENTATION

In accordance with 30 TAC, §330.253(e)(6), documented certification of closure must be submitted to the TCEQ upon completion of closure activities for a MSW site or MSWLF unit. The certification will be in the form of the Final Cover System Evaluation Report (FCSER) which must be signed by the GEP and must include all documentation necessary for certification of closure.

All final cover quality assurance/quality control testing must be performed in conformance with this plan. Data from all testing will be submitted in the FCSER.

Each FCSER submittal will include:

1. A discussion of construction of each of the final cover elements;
2. A clearly legible final cover placement map that depicts the site grid system, graphic scale, north arrow, area(s) covered by current submittal, and areas covered by all previous FCSER submittals with the dates of acceptance by the TCEQ;
3. All field and laboratory test documentation for soil infiltration layers including a sample location plot plan;
4. Manufacturer's certification, documentation of all manufacturer's and independent testing, seaming and repair records, and seam tests for any geomembrane used;

5. A geomembrane panel layout drawing showing locations of panels, repairs and tests for any geomembrane used;
6. Manufacturer's certification and testing documentation for any geosynthetic used; and
7. A GCL panel layout drawing locations of panels and repairs for any GCL used;
8. Manufacturer quality control test results and conformance test results for any GCL used;
9. All subgrade acceptance documentation;
10. Survey documentation detailing as-built subgrade elevations, thickness of soil infiltration layers and erosion layers.

All field and laboratory sampling and testing of components of the infiltration layer and its construction should be under the direct supervision of the GEP or his/her Qualified Engineering Technician. Any completed final cover area that fails to meet the minimum specified conditions of the required tests should be replaced (seam or liner flaw, etc. patched) or reworked, as appropriate, to achieve the required results. Inability to achieve the required results through reworking may be cause for rejection of the area in question. All reworked areas should be retested to prove adequacy to meet all applicable requirements.

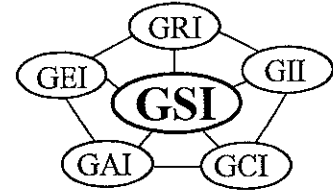
ATTACHMENT A

Geosynthetic Research Institute (GRI) Test Method GM17



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Revision schedule on pg. 14

GRI Test Method GM17*

Standard Specification for

"Test Properties, Testing Frequency and Recommended Warranty for
Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes"

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

- 1.1 This specification covers linear low density polyethylene (LLDPE) geomembranes with a formulated sheet density of 0.939 g/ml, or lower, in the thickness range of 0.50 mm (20 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.
- 1.2 This specification sets forth a set of minimum, maximum, or range of physical, mechanical and endurance properties that must be met, or exceeded by the geomembrane being manufactured.
- 1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

- 1.4 This standard specification is intended to ensure good uniform quality LLDPE geomembranes for use in general applications.

Note 2: Additional tests, or more restrictive values for the tests indicated, may be necessary under conditions of a particular application. In this situation, interactions with the manufacturers are required.

- 1.5 This specification also presents a recommended warranty which is focused on the geomembrane material itself.

- 1.6 The recommended warranty attached to this specification does not cover installation considerations which are independent of the manufacturing of the geomembrane.

Note 3: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

2. Referenced Documents

2.1 ASTM Standards

- D 792 Specific Gravity (Relative Density) and Density of Plastics by Displacement
- D 1004 Test Method for Initial Tear Resistance of Plastics Film and Sheeting
- D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
- D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
- D 1603 Test Method for Carbon Black in Olefin Plastics
- D 3895 Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis
- D 4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
- D 4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
- D 5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
- D 5323 Practice for Determination of 2% Secant Modulus for Polyethylene Geomembranes
- D 5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
- D 5617 Test Method for Multi-Axial Tension Test for Geosynthetics
- D 5721 Practice for Air-Oven Aging of Polyolefin Geomembranes
- D 5885 Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry
- D 5994 Test Method for Measuring the Core Thickness of Textured Geomembranes

D 6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes

2.2 GRI Standards

GM 11 Accelerated Weathering of Geomembranes using a Fluorescent UVA-Condensation Exposure Device

GM 12 Measurement of the Asperity Height of Textured Geomembranes Using a Depth Gage

2.3 U. S. Environmental Protection Agency Technical Guidance Document "Quality Control Assurance and Quality Control for Waste Containment Facilities," EPA/600/R-93/182, September 1993, 305 pgs.

3. Definitions

Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications.
ref. EPA/600/R-93/182

Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project.
ref. EPA/600/R-93/182

Linear Low Density Polyethylene (LLDPE), n – A ethylene/ α -olefin copolymer having a linear molecular structure. The comonomers used to produce the resin can include hexane, octane, or methyl pentene. LLDPE resins have a natural density in the range of 0.915 to 0.926 g/ml (ref. Pate, T. J. Chapter 29 in Handbook of Plastic Materials and Technology, I.I. Rubin Ed., Wiley, 1990).

Formulation, n - The mixture of a unique combination of ingredients identified by type, properties and quantity. For linear low density polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

4. Material Classification and Formulation

- 4.1 This specification covers linear low density polyethylene geomembranes with a formulated sheet density of 0.939 g/ml, or lower. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.
- 4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.926 g/ml or lower, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min. This refers to the natural, i.e., nonformulated, resin.
- 4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be of the same formulation (or other approved formulation) as the parent material.
- 4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

5. Physical, Mechanical and Chemical Property Requirements

- 5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth LLDPE geomembranes and Table 2 is for single and double sided textured LLDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is "soft". It is to be understood that the tables refer to the latest revision of the referenced test methods and practices.

Note 4: The tensile strength properties in this specification were originally based on ASTM D 638 which uses a laboratory testing temperature of $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$. Since ASTM Committee D35 on Geosynthetics adopted ASTM D 6693 (in place of D 638), this GRI Specification followed accordingly. The difference is that D 6693 uses a testing temperature of $21^{\circ}\text{C} \pm 2^{\circ}\text{C}$. The numeric values of strength and elongation were not changed in this specification. If a dispute arises in this regard, the original temperature of $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ should be utilized for testing purposes.

Note 5: There are several tests sometimes included in other LLDPE geomembrane specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- Volatile Loss
- Dimensional Stability
- Coeff. of Linear Expansion
- Solvent Vapor Transmission
- Water Absorption
- Ozone Resistance

- Resistance to Soil Burial
- Low Temperature Impact
- ESCR Test (D 1693 and D 5397)
- Wide Width Tensile
- Water Vapor Transmission
- Hydrostatic Resistance
- Tensile Impact
- Small Scale Burst
- Various Toxicity Tests
- Field Seam Strength

Note 6: There are several tests which are included in this standard (that are not customarily required in other LLDPE geomembrane specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time
- Oven Aging
- Ultraviolet Resistance
- Asperity Height of Textured Sheet

Note 7: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

- Thickness of Textured Sheet
- Tensile Properties, incl. 2% Secant Modulus
- Puncture Resistance
- Axi-Symmetric Break Resistance Strain
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

Note 8: There are several GRI tests currently included in this standard. Since these topics are not covered in ASTM standards, this is necessary. They are the following:

- UV Fluorescent Light Exposure
- Asperity Height Measurement

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The various properties of the LLDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent, it must be followed in like manner.

Note 9: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively. Communication and interaction with the manufacturer is strongly suggested.

6. Workmanship and Appearance

- 6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties and hydraulic integrity of the geomembrane.
- 6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from such defects that would affect the specified properties and hydraulic integrity of the geomembrane.
- 6.3 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

7. MQC Sampling

- 7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.
- 7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.
- 7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

8. MQC Retest and Rejection

- 8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marketing

- 9.1 The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

9.2 Marking of the geomembrane rolls shall be done in accordance with the manufacturers accepted procedure as set forth in their quality manual.

10. Certification

10.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

11. Warranty

11.1 Upon request of the purchaser in the contract or order, a manufacturer's warranty of the quality of the material shall be furnished at the completion of the terms of the contract.

11.2 A recommended warranty for smooth and textured LLDPE geomembranes manufactured and tested in accordance with this specification is given in Appendix A.

11.3 The warranty in Appendix A is for the geomembrane itself. It does not cover subgrade preparation, installation, seaming, or backfilling. These are separate operations that are often beyond the control, or sphere of influence, of the geomembrane manufacturer.

Note 10: If a warranty is required for installation, it is to be developed between the installation contractor and the party requesting such a document.

Table 1(a) – Linear Low Density Polyethylene (LLDPE) Geomembrane (SMOOTH)

Properties	Test Method	Test Value										Testing Frequency (minimum) per roll
		20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils			
Thickness - mils (min. ave.)	D 5199	nom.	nom.	nom.	nom.	nom.	nom.	nom.	nom.	nom.	nom.	nom.
• lowest individual of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%
Density g/ml (max.)	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	200,000 lb
Tensile Properties (1) (min. ave.)	D 6693											20,000 lb
• break strength - lb/in.	Type IV	76	114	152	190	228	304	380	456			
• break elongation - %		800	800	800	800	800	800	800	800			
2% Modulus - lb/in. (max.)	D 5323	1200	1800	2400	3000	3600	4800	6000	7200			per formulation
Tear Resistance - lb (min. ave.)	D 1004	11	16	22	27	33	44	55	66			45,000 lb
Puncture Resistance - lb (min. ave.)	D 4833	28	42	56	70	84	112	140	168			45,000 lb
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	30	30	30	30	30	30	30			per formulation
Carbon Black Content - %	D 1603 (2)	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0			45,000 lb
Carbon Black Dispersion	D 5596	note (3)	note (3)	note (3)	note (3)	note (3)	note (3)	note (3)	note (3)			45,000 lb
Oxidative Induction Time (OIT) (min. ave.) (4)												
(a) Standard OIT	D 3895	100	100	100	100	100	100	100	100			200,000 lb
— or —												
(b) High Pressure OIT	D 5885	400	400	400	400	400	400	400	400			per formulation
Oven Aging at 85°C (5)												
(a) Standard OIT (min. ave.) - % retained after 90 days	D 5721 D 3895	35	35	35	35	35	35	35	35			per formulation
— or —												
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	60	60	60	60	60	60	60	60			per formulation
UV Resistance (6)												
(a) Standard OIT (min. ave.)	D 3895	N.R. (7)	N.R. (7)	N.R. (7)	N.R. (7)	N.R. (7)	N.R. (7)	N.R. (7)	N.R. (7)			per formulation
— or —												
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (8)	D 5885	35	35	35	35	35	35	35	35			per formulation

- (1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- (2) Break elongation is calculated using a gage length of 2.0 in. at 2.0 in./min.
- (3) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.
- (4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
 - 9 in Categories 1 or 2 and 1 in Category 3
- (5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
- (6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
- (7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
- (8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
- (9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 1(b) – Linear Low Density Polyethylene (LLDPE) Geomembrane (SMOOTH)

Properties	Test Method	Test Value										Testing Frequency (minimum) per roll	
		0.50 mm	0.75 mm	1.0 mm	1.25 mm	1.50 mm	2.00 mm	2.5 mm	3.0 mm				
Thickness - mm (min. ave.)	D 5199	nom.	nom.	nom.	nom.	nom.	nom.	nom.	nom.	nom.	nom.	nom.	
• lowest individual of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Density g/ml (max.)	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	90,000 kg
Tensile Properties (1) (min. ave.)	D 6693												9,000 kg
• break strength - N/mm	Type IV	13	20	27	33	40	53	66	80	80	80	80	
• break elongation - %		800	800	800	800	800	800	800	800	800	800	800	
2% Modulus - N/mm (max.)	D 5323	210	370	420	520	630	840	1050	1260				per formulation
Tear Resistance - N (min. ave.)	D 1004	50	70	100	120	150	200	250	300				20,000 kg
Puncture Resistance - N (min. ave.)	D 4833	120	190	250	310	370	500	620	750				20,000 kg
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	30	30	30	30	30	30	30				per formulation
Carbon Black Content - %	D 1603 (3)	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 kg
Carbon Black Dispersion	D 5596	note (3)	note (3)	note (3)	note (3)	note (3)	note (3)	note (3)	note (3)	note (3)	note (3)	note (3)	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) (4)													90,000 kg
(a) Standard OIT	D 3895	100	100	100	100	100	100	100	100	100	100	100	
— or —													
(b) High Pressure OIT	D 5885	400	400	400	400	400	400	400	400	400	400	400	
Oven Aging at 85°C (5)	D 5721												
(a) Standard OIT (min. ave.) - % retained after 90 days	D 3895	35	35	35	35	35	35	35	35	35	35	35	per formulation
— or —													
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	60	60	60	60	60	60	60	60	60	60	60	
UV Resistance (6)													
(a) Standard OIT (min. ave.)	D 3895	N. R. (7)	N. R. (7)	N. R. (7)	N. R. (7)	N. R. (7)	N. R. (7)	N. R. (7)	N. R. (7)	N. R. (7)	N. R. (7)	N. R. (7)	per formulation
— or —													
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (8)	D 5885	35	35	35	35	35	35	35	35	35	35	35	

- (1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- (2) Break elongation is calculated using a gage length of 50 mm at 50 mm/min.
- (3) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.
- (4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
 - 9 in Categories 1 or 2 and 1 in Category 3
- (5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
- (6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
- (7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
- (8) Not recommended since the high temperature of the Sid-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
- (9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 2(a) – Linear Low Density Polyethylene (LLDPE) Geomembrane (TEXTURED)

Properties	Test Method	Test Value										Testing Frequency (minimum) per roll	
		20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils				
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%)	nom. (-5%)	nom. (-5%)	nom. (-5%)	nom. (-5%)	nom. (-5%)	nom. (-5%)	nom. (-5%)	nom. (-5%)	nom. (-5%)	nom. (-5%)	Every 2 nd roll (2)
		-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Asperity Height mils (min. ave.) (1)	GM 12	10	10	10	10	10	10	10	10	10	10	10	200,000 lb
		-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%	
Density g/ml (max.)	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	20,000 lb	
Tensile Properties (3) (min. ave.) • break strength - lb/in. • break elongation - %	D 6693 Type IV	30	45	60	75	90	120	150	180	250	250	per formulation	
		250	250	250	250	250	250	250	250	250	250		
2% Modulus - lb/in. (max.)	D 5323	1200	1800	2400	3000	3600	4800	6000	7200			45,000 lb	
Tear Resistance - lb (min. ave.)	D 1004	11	16	22	27	33	44	55	66	88	110	45,000 lb	
Puncture Resistance - lb (min. ave.)	D 4833	22	33	44	55	66	88	110	132			per formulation	
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	30	30	30	30	30	30	30	30	30	45,000 lb	
Carbon Black Content - %	D 1603 (4)	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	45,000 lb	
Carbon Black Dispersion	D 5596	note (5)	note (5)	note (5)	note (5)	note (5)	note (5)	note (5)	note (5)	note (5)	note (5)	45,000 lb	
Oxidative Induction Time (OIT) (min. ave.) (6)												200,000 lb	
(a) Standard OIT	D 3895	100	100	100	100	100	100	100	100	100	100	per formulation	
--- or ---													
(b) High Pressure OIT	D 5885	400	400	400	400	400	400	400	400	400	400	per formulation	
Oven Aging at 85°C (7)	D 5721												
(a) Standard OIT (min. ave.) - % retained after 90 days	D 3895	35	35	35	35	35	35	35	35	35	35	per formulation	
--- or ---													
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	60	60	60	60	60	60	60	60	60	60	per formulation	
UV Resistance (8)													
(a) Standard OIT (min. ave.)	D 3895	N.R. (9)	N.R. (9)	N.R. (9)	N.R. (9)	N.R. (9)	N.R. (9)	N.R. (9)	N.R. (9)	N.R. (9)	N.R. (9)	per formulation	
--- or ---													
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (10)	D 5885	35	35	35	35	35	35	35	35	35	35	per formulation	

(1) Of 10 readings; 8 out of 10 must be ≥ 7 mils, and lowest individual reading must be ≥ 5 mils

(2) Alternate the measurement side for double sided textured sheet

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.

(4) Break elongation is calculated using a gage length of 2.0 in. at 2.0 in./min.

(5) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.

(6) Carbon black dispersion (only near spherical agglomerates) for 10 different views:

• 9 in Categories 1 or 2 and 1 in Category 3

(7) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(8) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(9) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(10) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(11) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 2(b) – Linear Low Density Polyethylene (LLDPE) Geomembrane (TEXTURED)

Properties	Test Method	Test Value										Testing Frequency (minimum) per roll
		0.50 mm	0.75 mm	1.0 mm	1.25 mm	1.50 mm	2.00 mm	2.5 mm	3.0 mm			
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	Every 2 nd roll (2)
Asperity Height mm (min. ave.) (1)	GM 12	10	10	10	10	10	10	10	10	10	10	90,000 kg
Density g/ml (max.)	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	9,000 kg
Tensile Properties (3) (min. ave.) • break strength - N/mm • break elongation - %	D 6693 Type IV	5 250	9 250	11 250	13 250	16 250	21 250	26 250	31 250	31 250	31 250	per formulation
2% Modulus - N/mm (max.)	D 5323	210	370	420	520	630	840	1050	1260	1260	1260	per formulation
Tear Resistance - N (min. ave.)	D 1004	50	70	100	120	150	200	250	300	300	300	20,000 kg
Puncture Resistance - N (min. ave.)	D 4833	100	150	200	250	300	400	500	600	600	600	20,000 kg
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	30	30	30	30	30	30	30	30	30	per formulation
Carbon Black Content - %	D 1603 (4)	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 kg
Carbon Black Dispersion	D 5596	note (5)	note (5)	note (5)	note (5)	note (5)	note (5)	note (5)	note (5)	note (5)	note (5)	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) (6)												90,000 kg
(a) Standard OIT	D 3895	100	100	100	100	100	100	100	100	100	100	per formulation
(b) High Pressure OIT	D 5885	400	400	400	400	400	400	400	400	400	400	per formulation
Oven Aging at 85°C (7)	D 5721											
(a) Standard OIT (min. ave.) - % retained after 90 days	D 3895	35	35	35	35	35	35	35	35	35	35	per formulation
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	60	60	60	60	60	60	60	60	60	60	per formulation
UV Resistance (8)												
(a) Standard OIT (min. ave.)	D 3895	N. R. (9)	N. R. (9)	N. R. (9)	N. R. (9)	N. R. (9)	N. R. (9)	N. R. (9)	N. R. (9)	N. R. (9)	N. R. (9)	per formulation
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (10)	D 5885	35	35	35	35	35	35	35	35	35	35	per formulation

(1) Of 10 readings; 8 out of 10 must be ≥ 0.18 mm, and lowest individual reading must be ≥ 0.13 mm

(2) Alternate the measurement side for double sided textured sheet

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.

(4) Break elongation is calculated using a gage length of 50 mm at 50 mm/min.

(5) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.

(6) Carbon black dispersion (only near spherical agglomerates) for 10 different views:

(7) 9 in Categories 1 or 2 and 1 in Category 3

(8) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(9) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(10) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(11) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(12) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Appendix "A"

Typical Linear Low Density Polyethylene (LLDPE) Geomembrane Warranty

Reviewed by: Donald J. Weiss, Esq.
General Council for GSI

ABC GEOMEMBRANE COMPANY LIMITED WARRANTY

Warranty No: _____
Project No: _____
Effective Date: _____

PURCHASER NAME: _____ PROJECT NAME: _____
ADDRESS: _____ ADDRESS/LOCATION: _____
CITY, STATE, ZIP, COUNTRY _____ CITY, STATE, ZIP, COUNTRY _____
GEOMEMBRANE TYPE/DESCRIPTION _____

ABC Geomembrane Company warrants each ABC geomembrane to be free from manufacturing defects (as defined by the contract's material specifications) and to be able to withstand normal weathering for a period of 5 years from the above effective date for normal use in approved applications.

This Limited Warranty does not include damages or defects in the ABC geomembrane resulting from acts of God, casualty or catastrophe including but not limited to: earthquakes, floods, piercing hail, tornadoes or force majeure. The term "normal use" as used herein does not include, among other things improper handling during transportation, unloading, storage or installation, the exposure of ABC geomembranes to harmful chemicals, atypical atmospheric conditions, weather abuse of ABC geomembranes by machinery, equipment or people; improper site preparation or covering materials, excessive pressures or stresses from any source or improper application or installation. ABC geomembrane material warranty is intended for commercial use only and is not in effect for the consumer as defined in the Magnuson Moss Warranty or any similar federal, state, or local statues. The parties expressly agree that the sale hereunder is for commercial or industrial use only.

Should defects or premature loss of use within the scope of the above Limited Warranty occur, ABC Geomembrane Company will, at its option, repair or replace the ABC geomembrane on a pro-rata basis at the then current price in such manner as to charge the Purchaser/User only for that portion of the warranted life which has elapsed since purchase of the material. ABC Geomembrane Company will have the right to inspect and determine the cause of any alleged defect in the ABC geomembrane and to take appropriate steps to repair or replace the ABC geomembrane if a defect exists which is covered under this warranty. This Limited Warranty extends only to ABC's geomembrane, and does not extend to the installation service of ABC Geomembrane Company or third parties nor does it extend to materials furnished or installed by others in connection with the intended use of the ABC geomembranes.

Any claim for any alleged breach of this warranty must be made in writing, by certified mail, to the President of ABC Geomembrane within ten (10) days of becoming aware of the alleged defect. Should the required notice not be given, the defect and all warranties are waived by the Purchaser, and Purchaser shall not have any rights under warranty. ABC Geomembrane Company shall not be obligated to perform repairs or replacements under this warranty unless and until the area to be repaired or replaced is clean, dry, and unencumbered. This includes, but is not limited to, the area made available for repair and/or replacement of ABC geomembrane to be free from all water, dirt, sludge, residuals and liquids of any kind. If after inspection it is determined that there is no claim under this Limited Warranty, Purchaser shall reimburse ABC Geomembrane Company for its costs associated with the site inspection.

In the event the exclusive remedy provided herein fails in its essential purpose, and in that event only, the Purchaser shall be entitled to a return of the purchase price for so much of the material as ABC Geomembrane Company determines to have violated the warranty provided herein. ABC Geomembrane Company shall not be liable for direct, indirect, special, consequential or incidental damages resulting from a breach of this warranty including, but not limited to, damages for loss of production, lost profits, personal injury or property damage. ABC Geomembrane Company shall not be obligated to reimburse Purchaser for any repairs, replacement, modifications or alterations made by Purchaser unless ABC Geomembrane Company specifically authorized, in writing, said repairs, replacements, modifications or alteration in advance of them having been made. ABC Geomembrane Company's liability under this warranty shall in no event exceed the replacement cost of the material sold to the Purchaser for the particular installation in which it failed.

ABC Geomembrane Company neither assumes nor authorizes any person other than the undersigned of ABC Geomembrane Company to assume for it any other or additional liability in connection with the ABC geomembrane made on the basis of the Limited Warranty. The Limited Warranty on the ABC geomembrane herein is given in lieu of all other possible material warranties, either expressed or implied, and by accepting delivery of the material, Purchaser waives all other possible warranties, except those specifically given. This Limited Warranty may only be modified by written document mutually executed by Owner and ABC Geomembrane Co.

Limited Warranty is extended to the purchaser/owner and is non-transferable and non-assignable; i.e., there are no third-party beneficiaries to this warranty.

Purchaser acknowledges by acceptance that the Limited Warranty given herein is accepted in preference to any and other possible materials warranties.

THIS LIMITED WARRANTY SHALL BE GOVERNED BY _____ (state) LAW AND VENUE FOR ALL LEGAL PROCEEDINGS IN CONNECTION WITH THIS LIMITED WARRANTY SHALL BE IN _____ (county, state). ABC GEOMEMBRANE COMPANY MAKES NO WARRANTY OF ANY KIND OTHER THAN THAT GIVEN ABOVE AND HEREBY DISCLAIMS ALL WARRANTIES, BOTH EXPRESSED OR IMPLIED, OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THIS IS THE ONLY WARRANTY THAT APPLIES TO THE MATERIALS REFERRED TO HEREIN AND ABC DISCLAIMS ANY LIABILITY FOR ANY WARRANTIES GIVEN BY ANY OTHER PERSON OR ENTITY, EITHER WRITTEN OR ORAL.

ABC GEOMEMBRANE COMPANY'S WARRANTY BECOMES AN OBLIGATION OF ABC GEOMEMBRANE COMPANY TO PERFORM UNDER THE WARRANTY ONLY UPON RECEIPT OF FINAL PAYMENT AND EXECUTION BY A DULY AUTHORIZED OFFICER OF ABC GEOMEMBRANE COMPANY.

I hereby state that I have read and understand the above and foregoing and agree to such by signing hereunder and agree that but for the warranties provided herein, no other warranties or representatives of ABC Co. have been made by agents or representatives of ABC Co. and this Limited Warranty supersedes all other documents or agreements concerning the warranty of the geomembrane.

PURCHASER NAME: _____ ABC GEOMEMBRANE COMPANY: _____

(President or Authorized Representative)
SIGNATURE: _____ DATE _____ SIGNATURE: _____ DATE _____
TITLE: _____ Sworn before me this _____ day of _____ 200_____