CORRESPONDENCE

TRC *Environmental Solutions Inc.*

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Irvine, California 92718
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October 18, 1996

Project No. 95-284

Catherine R. Pool, P.E.
State of Nevada
Division of Environmental Protection
RCRA Facilities Branch
Bureau of Waste Management
333 West Nye Lane
Carson City, NV 89710

Transmittal
Response to Notice of Deficiency (NOD)
Dated September 13, 1996

Dear Ms. Pool:

On behalf of U.S. Ecology, Inc., we are submitting the attached responses to comments received from the Nevada Division of Environmental Protection (NDEP) on the report entitled "Cell 12 Design Report, Volumes I and II", dated March 1996; supplemental information transmitted on Minimum Technology Requirements (MTR) dated April 4, 1996; and a letter from American Ecology Corporation to NDEP transmitted on July 9, 1996, regarding base liner configuration revisions.

The responses are intended to address the issues raised by NDEP. Calculation, Design Report, and Drawing, and Final Specifications and Construction Quality Assurance Plan documents will be submitted under separate cover. To assure that the revised and supplemental documents are developed to be consistent with NDEP's requirements, it is suggested that a meeting be scheduled at the earliest possible date to discuss the comment responses and resolve outstanding issues (if any). At the conclusion of that meeting, a schedule will be agreed to for submittal the above-mentioned documents.

If you have any questions, please call Zaki Naser at 702-553-2203.

Sincerely,

Scott M. Brown
Project Director

Richard D. Ellison, Ph.D., P.E.
President

SMB/RDE/GR:lmd
Enclosures

cc: Zaki Naser, U.S. Ecology, Inc.
Zia Qureshi, American Ecology Corporation
Miro Knezevic, TRC Environmental Solutions, Inc.

RESPONSE TO COMMENT NO. 17 REGARDING WASTE STRENGTH

The strength of hazardous waste has recently been investigated as part of a comprehensive study at the Operating Industries, Inc. (OII) Landfill Superfund Site in Monterey Park, California[1]. Waste strengths from large-scale direct shear tests were measured to be $\phi = 31°$ and c = 575 to 900 psf.

WASTE "C"

Supplemental slope stability analysis to be submitted under separate cover will use the previously assumed strength of $\phi = 27°$ and c = 300 psf and also a value of $\phi = 31°$ and c = 100 psf. Note that both of these values are less than the values measured at OII and are considered to be conservative.

RESPONSE TO COMMENT NO. 18 REGARDING COHESION OF NATIVE SOILS

Calculations shown in Exhibit C.3 indicate that a cohesion value of 1,000 psf must be achieved from soil reinforcement in the upper 9 to 19 feet of the existing native cohesionless soils in order to meet stability requirements. Since it is a requirement of the design to perform soil reinforcement (see Sheets 006, Note 1 and 007, Note 4), specifications will require that this cohesion value be achieved.

RESPONSE TO COMMENT NOS. 19 THROUGH 22 AND 25 REGARDING SLOPE STABILITY OF THE FINAL CONFIGURATION

Attachment A has been prepared to show how stability criteria is established for each type of temporary and permanent slope condition. Although it is general civil engineering practice to accept small amounts of permanent seismic induced deformation even for slippage planes along the liner system, Attachment A shows that a PSF of 1.0 or greater will be assumed at such critical potential failure surfaces. As a result, NDEP's requirement that the liner not be impacted due to a 0.42g earthquake will be adhered to.

Attachment A also discusses the criteria for less important failure surfaces, which do not have potential to damage the containment (liner) system. The maximum seismically induced permanent deformation for less important potential failure surfaces will be 6 inches. This amount of deformation is well within the range generally accepted in the landfill design practice as discussed in Seed and Bonaparte, 1992.

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(1) New Cure Inc. Seismicity, Settlement and Slope Stability Work Plan, Reports 1 through 10, Operating Industries Inc. Landfill, Monterey Park, California, August 1996.

Steve Wampler

rom:	Bob Marchand [BMARCHAND@usecology.com]
ent:	Thursday, September 27, 2007 10:56 AM
o:	Steve Wampler
Subject:	RE: Waste weight

Those numbers are included.

From: Steve Wampler [mailto:swampler@aquaeter.com]
Sent: Thursday, September 27, 2007 9:56 AM
To: Bob Marchand
Subject: RE: Waste weight

Are added materials, like clean soil (interim cover) or stabilization materials, included in the waste weight number? If not, in your opinion, is the amount those additives significant?

Steve Wampler
AquAeTer, Inc. - Denver
><>><>><>><>><>><>><>
swampler@aquaeter.com

7340 East Caley Avenue, #200
Centennial, CO 80111
======================================
'03-771-9150 / 303-349-1638 (cell) / 303-771-8776 (fax)

From: Bob Marchand [mailto:BMARCHAND@usecology.com]
Sent: Thursday, September 27, 2007 10:51 AM
To: Steve Wampler
Subject: RE: Waste weight

Steve:
The number is based on weights received vs. volume consumed as confirmed by survey.
Bob

From: Steve Wampler [mailto:swampler@aquaeter.com]
Sent: Thursday, September 27, 2007 9:03 AM
To: Bob Marchand
Subject: RE: Waste weight

Bob, can you provide a simple explanation of how this number is determined. We've used it (actually 100 PCF) in our revised calculations and should include a source for the Trench 11 number.

Steve Wampler
AquAeTer, Inc. - Denver
'<>><>><>><>><>><>><>
swampler@aquaeter.com

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==
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If you are not the intended recipient of this electronic message, please advise the sender immediately by return e-mail and delete this message.

From: Bob Marchand [mailto:BMARCHAND@usecology.com]
Sent: Monday, September 17, 2007 4:56 PM
To: Steve Wampler
Subject: RE: Waste weight

Our current estimate is 96.3 lbs/cubic foot based on historic receipts.
Bob

From: Steve Wampler [mailto:swampler@aquaeter.com]
Sent: Monday, September 17, 2007 3:18 PM
To: Bob Marchand
Subject: Waste weight

Bob – in the previous calculations, a pretty heavy weight was used for waste – 115 lbs/cubic foot. If the waste was all soil, it'd probably be 120-125 PCF. If all concrete, of course, much higher. But, we're thinking your average waste weight in the whole cell – all of Trench 11 – probably is lower. We note that the heaviest upper end unit weight we've seen for solid and hazardous waste is about 110 PCF at a closed hazwaste landfill in S. California. Do you have any way to estimate waste unit weight in the cell, with interim cover, etc. ?

(it could be significant in slope stability calculations as the waste weight is the driver toward stability/instability)

Steve Wampler
AquAeTer, Inc. - Denver
><>><>><>><>><>><>
swampler@aquaeter.com

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==
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LINER STRESSES (SIDEWALL LINER MATERIALS)

AquAeTer

optimizing environmental resources - water, air, earth

CALCULATION SUMMARY SHEET

PROJECT NUMBER: 073113

PROJECT NAME: USEN – Trench 12 Design, Supplemental Calculations

DATE: August 13, 2007

CALCULATION NUMBER: 5 Revision:

CALCULATION TITLE: Liner Stability on Trench 12 Side-Slopes

DESCRIPTION OF CALCULATION:

Determine liner materials stability on Trench 12 0.5:1.0 slopes. This calculation supplements a previous (1996) design calculation to incorporate the properties of liner materials that are available in 2007

REFERENCES USED: Number of Reference Pages Attached:

Previous calc: 1996 calculation by TRW titled "Liner Stresses"

Previous calc: 1997 calculation by HWA environmental titled "Side Slope Friction Forces"

Liner member manufacturer specifications

Koerner, "Designing with Geosynthetics" 1998.

REVIEW COMMENTS:

CALCULATION MADE BY: APM DATE: August 13, 2007

CALCULATION CHECKED BY: CAB DATE: August 13, 2007

CALCULATION REVISED BY: DATE:

CALCULATION REVIEWED BY: SLW DATE: 8/27/2007

CALCULATION
LINER STABILITY – TRENCH 12 SIDE SLOPES

Purpose of Calculation

Determine liner materials stability on Trench 12 0.5:1.0 slopes. Stability in this calculation refers to liner material strength and capacity to remain intact and functional under the loads that will be imposed by liner material weight (self weight of liner members and loading from overlying liner members) and resisted by liner strength and friction.

Method

This calculation supplements two previous liner design calculations including TRC Environmental Solutions March 1996 and HMW Environmental in January 1997. This calculation incorporates the properties of liner materials that are available in 2007. The previous calculations were part of the 1996 Trench 12 design that received conditional approval from NDEP. As such, this supplemental calculation is done in the same manner as the 'approved' 1996 calculations (and January 1997 supplement) and is changed only where 2007 liner materials and properties differ from those considered in the 1996 design.

This calculation first compares the liner material specified in the 1996 design to materials currently available regarding liner weight and strength properties. The calculation secondly looks at the tension/elongation of the design slope liner system to predict if rupture or damage to the liner system could be caused by gravity, thermal expansion/contraction, wind uplift, seismic deformation, or waste settlement.

Comparison of Liner Material Properties

The following tabulations compare the properties of liner system materials considered in the 1996 Trench 12 design and the properties of materials considered in the 2007 design.

Table 1: Liner Properties Considered in 1996 Design

Liner Material (reference for product data)	Unit Weight (lbs/ft^2)	Self Weight* (lbs/ft)	Accumulated Weight (lbs/ft)
Non-woven Geotextile (Trevira Spunbond 1125)	0.052	4.5	4.5
Geonet (Poly-Net PN-3000)	0.180	15.1	19.6
100-mil HDPE (Textured Hyperflex) smooth upper/textured lower	0.54	45	65
Geocomposite (Texnet TN 3002/1125)	0.26	22	87
80-mil HDPE (Textured Hyperflex) textured upper/textured lower	0.44	37	124
GCL (Claymax 600 SP)	1.22	85.7	210

Note:
* Self Weight = Unit Weight*Slope Length (Slope Length = 84 feet)

Table 2: Liner Properties Considered in 2007 Design

Liner Material (reference for product data)	Unit Weight (lbs/ft^2)	Self Weight (lbs/ft)	Accumulated Weight (lbs/ft)
Non-woven Geotextile (GSE NW10; GEO 1008002)	0.069	5.8	5.8
Geonet (GSE HyperNet XL4000N004)	0.17	14	20
80-mil HDPE (GSE HST 080G000 - textured on one side)	0.37	31	51
Double-sided Geocomposite (GSE Fabrinet with double sided 6 ounce/yd^2 geotextile)	0.25	21	72
60-mil HDPE (GSE HD 060G000 –textured both sides)	0.28	24	96
GCL (CETCO Bentomat DN)	1.22	103	198

The 2007 design geonet weight was obtained from a phone conversation with the manufacturer's technical representative. Geonets are not commonly measured for unit weight.

Table2: Material Strengths

Material (reference for product data)	Yield Strength (lb/in) 1996 Design	Yield Strength (lb/in) 2007 Design
Geotextile	150	140[1]
Geonet	50	45
100-mil HDPE/80-mil HDPE	240	168
Geocomposite	Not Reported	78[1]
80-mil HDPE/60-mil HDPE	192	126
GCL	37.5	50

1 Yield strength obtained in phone conversation with manufacturer's representative

This calculation analyzes strength for liner materials proposed for use in Trench 12 at US Ecology's Beatty, Nevada facility. Stresses and strains on liner materials are estimated from the self weight of the liners, thermal expansion, seismic deformation, and settlement of the waste fill. The total induced stress from these factors is compared to estimated allowable stresses on the liner materials from estimated factors of safety that are assumed to be conservative.

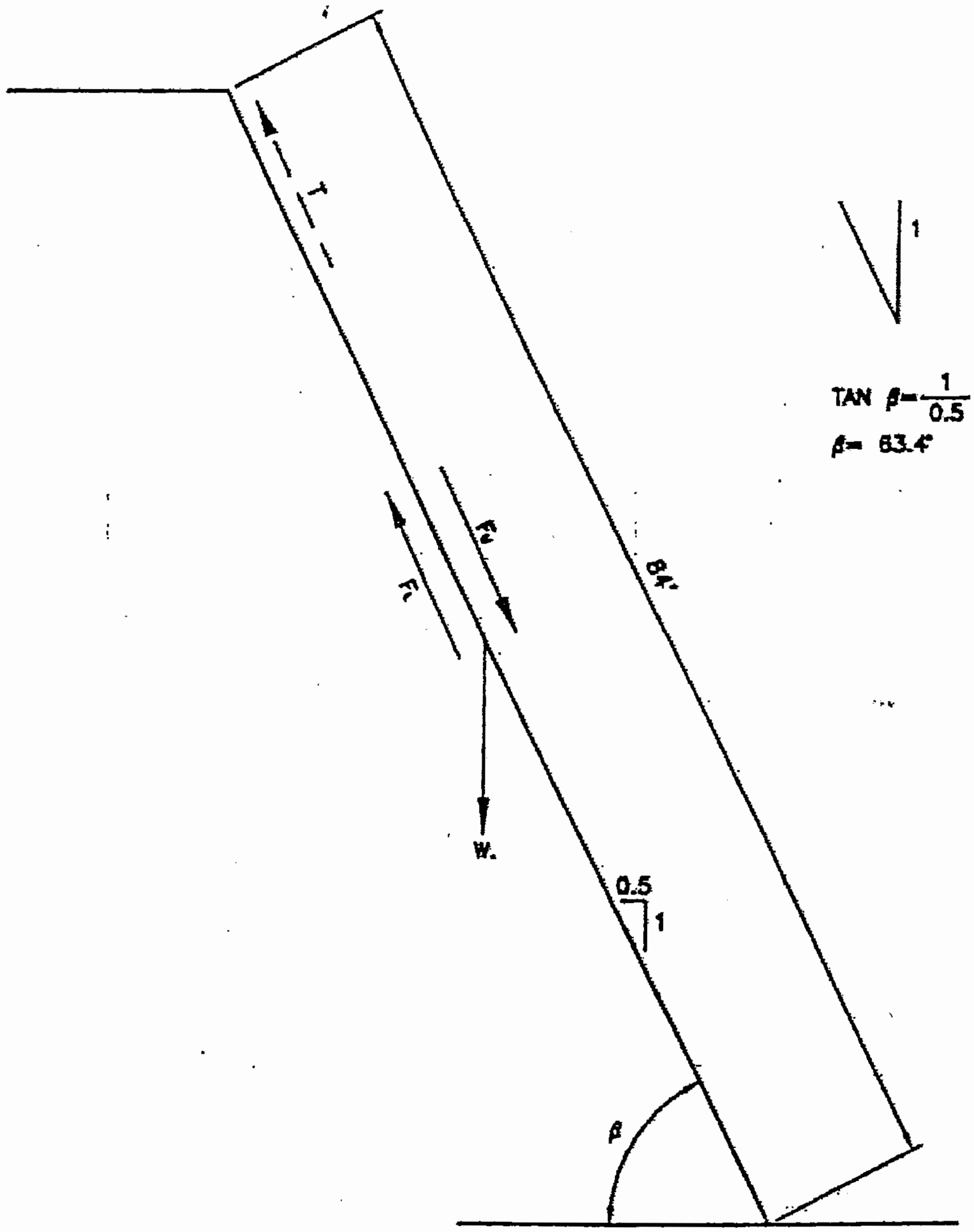
The liner materials will be placed on a 0.5:1 slope (an angle of 63.4° below horizontal). The trench will be 75 feet deep resulting in a slope length of 84 feet.

Self Weight Forces on Liner Members and Tensile Loads

Assuming stable slopes, the load due to gravity (tensile load) on the liners is due to self weight (shown in the tables above). The weight on the liner members accumulates for underlying liner members.

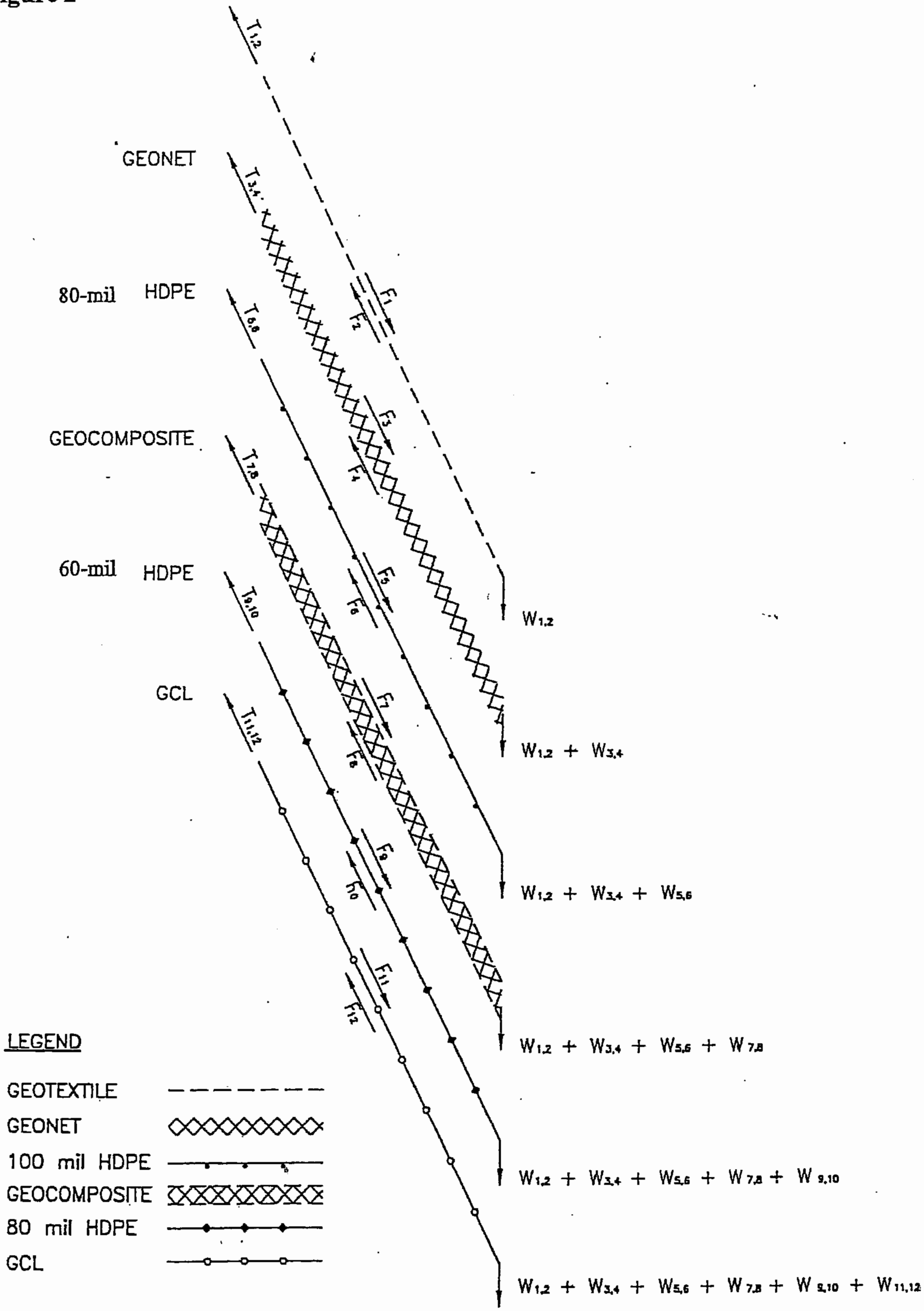
Self Weight = unit weight * slope length

Figure 1



FREE BODY DIAGRAM

Figure 2



EXPLODED VIEW OF THE SIDE SLOPE LINER SYSTEM

Self weight is the length of liner member (slope length = 84 feet) times the unit weight of the liner material, which is expressed in lbs per square feet. The unit weight of each liner material was obtained from specification sheets from liner member manufacturers. Tables 1 and 2 give the unit weight from the manufacturer, the self weight determined from the slope length of 84 feet for the 1996 design and 2007 design liner materials, and the accumulated weight accumulated for underlying liner members.

Friction forces acting on the upper side (F_U) of the liner and the forces acting on the lower side (F_L) of the liner were calculated using free body diagram analysis specific to runout calculations as shown in the 1996 TRW calculation and revisions provided in the 1997 HWA revision. F_U equals the friction force acting on the upper side of the liner member. This friction (F_U) is part of the total force that is tending to cause liner member failure. F_L is the component of the resultant force that resists failure as shown in Figure 1. F_L was derived in the HMA Environmental January 1997 detailed explanation of friction force F_L.

$F_L = AW * \cos(B) * \tan(d)$
$F_U = F_L$ of liner component above

Where:
AW = accumulated weight of liner members
d = friction angle between liner components
B = slope angle (i.e. 63.4° below horizontal)

Accumulated weight (AW) is tabulated in Table 2. Slope angle (B) is the angle of the slope (63.4°). Friction angle (d) is the residual friction angle which is dependent on the liner materials that are in contact with each other. A graphical representation of the liner members with frictional forces is attached as Figure 2. The tensile load due to self weight (T) is calculated using the HMA Environmental January 1997 detailed explanation of friction forces.

$T = ((SW * \sin(B)) + F_U - F_L)/(12\text{inch}/1\text{foot})$

Where:
SW = self weight of liner members

The friction forces and tensile load for each liner member are calculated in Table 4. The residual friction angles were obtained from phone conversations with liner material technical representatives and the 1997 calculation done by HMA Environmental.

Table 4: Tensile Load due to Self Weight

Liner Material (reference for product data)	d, Residual Friction Angle	F_U (lb/ft)	F_L (lb/ft)	T, Tensile Load Self Weight (lbs/in)
Non-woven Geotextile (GSE NW10; GEO 1008002)	19	0	0.89	0.36
Geonet (GSE HyperNet XL4000N004)	8*	0.89	1.26	1.03
80-mil HDPE (GSE HST 080G000 - textured on one side)	21	1.26	8.79	1.69
Double-sided Geocomposite (GSE Fabrinet with double sided 6 ounce/yd^2 geotextile)	21	8.79	12.4	1.26
60-mil HDPE (GSE HD 060G000 –textured both sides)	19	12.4	14.6	1.56
GCL (CETCO Bentomat DN)	36	14.6	64.2	3.49

* = Estimated from 1996 call to technical representative, no current reference.

The tensile load is given in lbs/in because the yield strength of the different liner members is expressed in lbs/in.

Summary of Liner Member Strengths and Strains

The following table summarizes the tensile strength at yield and percent strain at yield for each liner members. The tensile strength at yield is the strain at which the liner member deforms. Prior to the yield point the material will deform elastically and will return to its original shape when the applied stress is removed. The amount of elongation at yield also is known as the strain at yield and is reported as a percent. The information below was obtained from material specification sheets provided by the manufacturers.

Table 3: Yield Strength and Strain

Liner Material (reference for product data)	Tensile Strength at Yield (lbs/in)	Strain at Yield (%)
Non-woven Geotextile (GSE NW10; GEO 1008002)	140[1]	50
Geonet (GSE HyperNet XL4000N004)	45	23[2]
80-mil HDPE (GSE HST 080G000 - textured on one side)	168	12
Double-sided Geocomposite (GSE Fabrinet with double sided 6 ounce/yd^2 geotextile)	78[1]	50
60-mil HDPE (GSE HD 060G000 –textured both sides)	126	12
GCL (CETCO Bentomat DN)	50	15

1 = Obtained from phone conversation with GSE Tech. representative, see phone log dated 7/19/2007.

2 = The percent strain at yield for geonets are not normally computed and not listed on data sheets. The value of 23% is taken from the textbook Designing with Geosynthetics by Robert Koerner, Chapter 4, pg. 340, Tensile Strength of Geonets. In phone conversations with technical representatives, they recommend using the yield properties of the non-woven geotextile for the geocomposite layer.

Calculation of Strains

Four strains are considered on the liner members including strain due to 1) self weight, 2) thermal expansion, 3) seismic deformation, 4) settlement of waste fill. The calculation of each strain is described below.

Strain due to self weight is calculated by comparing the percent strain at yield of each member to the tensile load due to self weight. For example:

(Tensile load due to self weight (lbs./in))/(Tensile strength at yield (lbs./in)) = (Strain due to self weight(%))/(Strain at yield (%)) where strain due to self weight is the unknown.

Rearranging the equation:
Strain due to self weight (%) = Tensile load due to self weight (lbs./in)/Tensile strength at yield (lbs./in)*Strain at yield (%).

Example using the 60-mil HDPE where

Tensile load due to self weight = 1.51 lbs./in
Tensile strength at yield = 126 lbs./in
Strain at yield = 12%

Therefore, Strain due to self weight for the 60-mil HDPE = $\frac{1.51 lbs./in}{126 lbs./in} * 12\% = 0.14\%$

Strain due to thermal expansion is considered only for HDPE Geomembranes and Geonets. From a conversation with a liner technical representative, the coefficient of linear thermal expansion is 0.00012 cm/cm*degC. A temperature variation of 40 degC was assumed in the 1997 HMA calculation, and is assumed here. Therefore; the strain due to thermal expansion is 0.00012 cm/cm*degC * 40 degC, or 0.5%.

Seismic deformation during waste placement is expected to be small. The 1997 HMA calculation references a document by US Ecology stating the strain from seismic deformation is around 0.2%. This strain will only act on the first two liner members because the liner system is designed to allow slippage between the second and third liner members (Geonet and 60-mil HDPE) and seismic strain is not expected to be transferred below that interface.

Strain from waste fill settlement also was considered. A US Ecology document was referenced, but not included in the 1997 HMA calculation estimating strain from waste fill settlement at less than 4%. Strain due to waste settlement will again only act on the first two liner members because of the design slippage between the second and third liner members.

Table 4 summarizes the strains on each liner member due to self weight, thermal expansion, seismic deformation, and settlement then totals the strains for each liner member.

As calculated above, total tensile load = 10.2 lbs/in
Since T_{allow} > total tensile load, the material is safe from failure.

HDPE

Upper HDPE
HDPE reducing factor values range from 10 to 100 times (Koerner, 1998). While the 1996 TRC calculation used a reducing factor of 40 in their analysis, they also indicated that the value was extremely conservative. A reducing factor of 10 is used in this analysis.

For the upper 80 mil HDPE, $T_{ultimate}$ = 168 lbs/in, therefore
T_{allow} = 168/10 = 16.8lbs/in

As calculated above, total tensile load = 8.7 lbs/in
Since T_{allow} > total tensile load, the material is safe from failure.

Lower HDPE
For the lower 60 mil HDPE, $T_{ultimate}$ = 126 lbs/in, therefore
T_{allow} = 126/10 = 12.6 lbs/in

As calculated above, total tensile load = 6.7 lbs/in
Since T_{allow} > total tensile load, the material is safe from failure.

Geocomposite

No recommended reducing factors were available for geonets; therefore, a reducing factor of 4 was used as done in the 1996 TRW calculation.
Inserting this reducing factor into the equation yields
$T_{allow} = T_{ultimate} /4.0$
For geonet, $T_{ultimate}$ = 78 pounds/inch, therefore
T_{allow} = 78/4 = 19.5 pounds/inch

As calculated above, total tensile load = 1.3 lbs/in
Since T_{allow} > total tensile load, the material is safe from failure.

GCL

No recommended reducing factors were available for GCLs; therefore, a reducing factor of 10 was used as done in the 1996 TRW calculation.
Inserting this safety factor into the equation yields
$T_{allow} = T_{ultimate} /10$
For GCL, $T_{ultimate}$ = 50 pounds/inch, therefore
T_{allow} = 50/10 = 5.0 pounds/inch

As calculated above, total tensile load = 3.5 lbs/in
Since T_{allow} > total tensile load, the material is safe from failure.

Table 5: Tensile Load Comparison

Liner Material (reference for product data)	Tensile Strength at Yield (lbs/in)	Safety Factor	Tensile Load Allowed (lbs/in)	Total Tensile Load (lbs/in)
Non-woven Geotextile (GSE NW10; GEO 1008002)	140	11.25	12.4	12.1
Geonet (GSE HyperNet XL4000N004)	45	4	11.3	10.2
80-mil HDPE (GSE HST 080G000 - textured on one side)	168	10	16.8	8.7
Double-sided Geocomposite (GSE Fabrinet with double sided 6 ounce/yd^2 geotextile)	78	4	19.5	1.3
60-mil HDPE (GSE HD 060G000 –textured both sides)	126	10	12.6	6.8
GCL (CETCO Bentomat DN)	50	10	5.0	3.5

CONCLUSIONS

Liner material stability on Trench 12 side slopes of 0.5:1.0 were evaluated for liner material strength and capacity to remain intact and function under the loads that will be imposed by liner material weight (self weight of liner members and loading from overlying liner members) and resisted by liner strength and friction.

The materials proposed for the 2007 design were compared to materials proposed in 1996. Geotextiles do not report yield strength therefore a straight comparisons of the materials was not made. Proposed Geonets and GCLs have similar yield strength properties. 80-mil (primary) and 60-mil (secondary) HDPE liners are proposed for the 2007 design and haves lower yield strength then the 1996 design using 100-mil (primary) and 80-mil (secondary) HDPE; however, the respective unit weights are less, resulting in lower total accumulated weight and lower yield strength requirements.

Four strains were considered on the liner members including strain due to 1) self weight, 2) thermal expansion, 3) seismic deformation, 4) settlement of waste fill. Stains on individual members were summed as a total strain of the liner system. The total strain was compared to the manufacturer's technical specification strains at yield. A reduction factor (conservative safety factor) was used with the manufacturer's data. None of the 2007 liner member's calculated strains exceed the stain at yield provided in technical specifications.

Slope
Liner
Members

GSE®

Product Data Sheet

GSE STANDARD PRODUCTS

GSE Nonwoven Geotextile

GSE Nonwoven Geotextiles is a family of polypropylene, staple fiber, nonwoven, needlepunched geotextiles. Manufactured using an advanced manufacturing and quality system, these products are the most uniform and consistent nonwoven, needlepunched geotextile currently available in the industry. GSE combines a fiber selection and approval system with in-line quality control and a state-of-the-art laboratory to ensure that every roll shipped meets customer specifications. The company has performed extensive performance testing to evaluate suitability of its nonwovens for various applications. GSE Nonwoven Geotextiles are available in a range of weights to meet your specific project needs. *These product specifications meet or exceed GRI GT12, GRI GT13 and AASHTO M288.*

Product Specifications

TESTED PROPERTY	TEST METHOD	FREQUENCY	NW4	NW6	NW8	NW10	NW12	NW16
Product Code			GEO 0408002	GEO 0608002	GEO 0808002	GEO 1008002	GEO 1208002	GEO 1608002
AASHTO M288 Class			3	2	1	>1	>>1	>>>1
Mass per Unit Area, oz/yd^2 (g/m^2)	ASTM D 5261	90,000 ft^2	4 (135)	6 (200)	8 (270)	10 (335)	12 (405)	16 (540)
Thickness	ASTM D 5199	1/90,000 ft^2	45 mil	70 mil	80 mil	~~100 mil~~	110 mil	155 mil
Grab Tensile Strength, lb (N)	ASTM D 4632	90,000 ft^2	120 (530)	170 (755)	220 (975)	260 (1,155)	320 (1,420)	390 (1,735)
Grab Elongation, %	ASTM D 4632	90,000 ft^2	50	50	50	50	50	50
Puncture Strength, lb (N)	ASTM D 4833	90,000 ft^2	60 (265)	90 (395)	120 (525)	165 (725)	190 (835)	240 (1,055)
Trapezoidal Tear Strength, lb (N)	ASTM D 4533	90,000 ft^2	50 (220)	70 (310)	95 (420)	100 (445)	125 (555)	150 (665)
Apparent Opening Size, Sieve No. (mm)	ASTM D 4751	540,000 ft^2	70 (0.212)	70 (0.212)	80 (0.180)	100 (0.150)	100 (0.150)	100 (0.150)
Permittivity, sec^{-1}	ASTM D 4491	540,000 ft^2	1.50	1.50	1.50	1.20	0.80	0.70
Permeability, cm/sec	ASTM D 4491	540,000 ft^2	0.22	0.30	0.30	0.30	0.29	0.27
Water Flow Rate, gpm/ft^2 (l/min/m^2)	ASTM D 4491	540,000 ft^2	120 (4,885)	110 (4,480)	110 (4,480)	85 (3,460)	60 (2,440)	50 (2,035)
UV Resistance (% retained after 500 hours)	ASTM D 4355	per formulation	70	70	70	70	70	70
Roll Length$^{(1)}$, ft (m)			600 (182)	600 (182)	600 (182)	300 (91)	300 (91)	300 (91)
Roll Width$^{(1)}$, ft (m)			15 (4.6)	15 (4.6)	15 (4.6)	15 (4.6)	15 (4.6)	15 (4.6)
Roll Area, ft^2 (m^2)			9,000 (836)	9,000 (836)	9,000 (836)	4,500 (418)	4,500 (418)	4,500 (418)

NOTES:

- The property values listed are in weaker principal direction. All values listed are Minimum Average Roll Values (MARV) except apparent opening size in mm and UV resistance. Apparent opening size (mm) is a Maximum Average Roll Value. UV is a typical value.
- $^{(1)}$Roll lengths and widths have a tolerance of ±1%.

YIELD STRENGTH ≥ 140 lbs/in FROM PHONE CONVERSATION w/ MANF. REP. SEE ATTACHED PHONE LOG

$$\frac{335\,g}{M^2} = \frac{0.052\ lbs}{ft^2}$$

DS037 NW R03/15/06

North America	GSE Lining Technology, Inc.	Houston, Texas	800 435 2008	281 443 8564	Fax: 281 230 8650
South America	GSE Lining Technology Chile S.A.	Santiago, Chile		56 2 595 4200	Fax: 56 2 595 4290
Asia Pacific	GSE Lining Technology Company Limited	Bangkok, Thailand		66 2 937 0091	Fax: 66 2 937 0097
Europe & Africa	GSE Lining Technology GmbH	Hamburg, Germany		49 40 767420	Fax: 49 40 7674234
Middle East	GSE Lining Technology-Egypt	The 6th of October City, Egypt		202 2 828 8888	Fax: 202 2 828 8889

AquAeTer

optimizing environmental resources - water, air, earth

TELEPHONE CONVERSATION AND MEETING RECORD

(X) Telephone call

(_) Meeting at ____________________

Persons Involved (*note who initiated the conversation*)

(_)
Name: Jimmy Youngblood
of: GSE

(_)
Name: Adam Musulin
of: **AquAeTer, Inc.**

Date: 7/19/2007

Time: 8:45

Telephone No: (281) 230-2523

Project Number: 073113

Conversation Subject: Geotextile Grab Tensile Strength

The Product Data Sheet from GSE for a non-woven geotextile reports the grab tensile strength in lbs. For the pupose of our liner calculation we would like the strength reported in lbs/in. APM spoke to Mr. Youngblood about the possibility of getting a number in lbs/in. The test method for geotextiles is ASTM D 4632, which reports the strength as a force (lbs.) on a 4-inch piece of fabric. Mr. Youngblood stated that you do not want to just divide the force number by the 4-inches of fabric used because the grips used in the test are not 4-inches wide.

Mr. Youngblood then provided some data for a wide width tensile strength test. For the 6 oz/yd^2 geotextile the wide width tensile strength was 78 lbs/in. For the 4 oz/yd^2 geotextile the wide width tensile strength was 72 lbs/in. Mr Youngblood stated that these numbers are averages of a few tests and not true specifications and are not garunteed to be met in the specifications. This is why these numbers are not reported on the product data sheets. Safety factors are used in the calculation to compensate for the uncertainty.

10 oz/yd² = 140 lbs/in

8 oz/yd² = 106 lbs/in

12 oz/yds² = 175 lbs/in

16 oz/yds² → 260 lbs/in

GSE®

Product Data Sheet

GSE STANDARD PRODUCTS

GSE HyperNet, HF, HS and UF Geonet

GSE HyperNet geonets are synthetic drainage materials manufactured from a premium grade high density polyethylene (HDPE) resin. The structure of the HyperNet geonet is formed specifically to transmit fluids uniformly under a variety of field conditions. HDPE resins are inert to chemicals encountered in most of the civil and environmental applications where these materials are used. GSE geonets are formulated to be resistant to ultraviolet light for time periods necessary to complete installation. GSE HyperNet geonets are available in standard, HF, HS, and UF varieties.

The table below provides index physical, mechanical and hydraulic characteristics of GSE geonets. Contact GSE for information regarding performance of these products under site-specific load, gradient, and boundary conditions.

Product Specifications

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE ROLL VALUE[b]			
			HyperNet	HyperNet HF	HyperNet HS	HyperNet UF
Product Code			XL4000N004	XL5000N004	XL7000N004	XL8000N004
Transmissivity[a], gal/min/ft (m^2/sec)	ASTM D 4716	1/540,000 ft^2	9.66 (2×10^{-3})	14.49 (3×10^{-3})	28.98 (6×10^{-3})	38.64 (8×10^{-3})
Thickness, mil (mm)	ASTM D 5199	1/50,000 ft^2	200 (5)	250 (6.3)	275 (7)	300 (7.6)
Density, g/cm^3	ASTM D 1505	1/50,000 ft^2	0.94	0.94	0.94	0.94
Tensile Strength (MD), lb/in (N/mm)	ASTM D 5035	1/50,000 ft^2	45 (7.9)	55 (9.6)	65 (11.5)	75 (13.3)
Carbon Black Content, %	ASTM D 1603, modified	1/50,000 ft^2	2.0	2.0	2.0	2.0
Roll Width[c], ft (m)			15 (4.6)	15 (4.6)	15 (4.6)	15 (4.6)
Roll Length[c], ft (m)			300 (91)	250 (76)	220 (67)	200 (60)
Roll Area, ft^2 (m^2)			4,500 (418)	3,750 (348)	3,300 (305)	3,000 (278)

NOTES:

- [a]Gradient of 0.1, normal load of 10,000 psf, water at 70° F (20° C), between steel plates for 15 minutes.
- [b]These are MARV values that are based on the cumulative results of specimens tested by GSE.
- [c]Roll widths and lengths have a tolerance of ±1%.

GEONET UNIT WEIGHT PROVIDED BY MANUFACTURER REP DURING PHONE CONVERSATION = 0.17 $\frac{lbs}{ft^2}$

DS017 HyperNet R01/13/06

North America	GSE Lining Technology, Inc.	Houston, Texas	800 435 2008	281 443 8564	Fax: 281 230 8650
South America	GSE Lining Technology Chile S.A.	Santiago, Chile		56 2 595 4200	Fax: 56 2 595 4290
Asia Pacific	GSE Lining Technology Company Limited	Bangkok, Thailand		66 2 937 0091	Fax: 66 2 937 0097
Europe & Africa	GSE Lining Technology GmbH	Hamburg, Germany		49 40 767420	Fax: 49 40 7674234
Middle East	GSE Lining Technology-Egypt	The 6th of October City, Egypt		202 2 828 8888	Fax: 202 2 828 8889

GSE®

Product Data Sheet

GSE STANDARD PRODUCTS

GSE HD Textured (Single-Sided)

GSE HD Textured is the textured version of GSE HD. It is a high quality, high density polyethylene (HDPE) geomembrane with one or two coextruded, textured surfaces, and consisting of approximately 97.5% polyethylene, 2.5% carbon black and trace amounts of antioxidants and heat stabilizers; no other additives, fillers or extenders are used. The resin used is specially formulated, virgin polyethylene and is designed specifically for flexible geomembrane applications. GSE HD Textured has excellent resistance to UV radiation and is suitable for exposed conditions. This product allows projects with greater slopes to be designed since frictional characteristics are enhanced. *These product specifications meet or exceed GRI GM13.*

$\frac{0.94\,g}{cm^3} = \frac{0.0021\,lbs}{cm^3} \cdot \frac{0.193\,cm\ \text{THICK}}{} = \frac{4.0\times10^{-4}\,lbs}{cm^2}$ OR $\frac{0.37\,lbs}{ft^2}$

Product Specifications

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM VALUE			
Product Code			HST 040G000	HST 060G000	HST 080G000	HST 100G000
Thickness, (minimum average) mil (mm)	ASTM D 5994	every roll	38 (0.96)	57 (1.45)	76 (1.93)	95 (2.41)
Lowest individual for 8 out of 10 values			36 (0.91)	54 (1.40)	72 (1.80)	90 (2.30)
Lowest individual for any of the 10 values			34 (0.86)	51 (1.30)	68 (1.73)	85 (2.16)
Density, g/cm³	ASTM D 1505	200,000 lb	0.94	0.94	0.94	0.94
Tensile Properties (each direction)[(1)]	ASTM D 6693; Type IV	20,000 lb				
Strength at Break, lb/in-width (N/mm)	Dumbell, 2 ipm		60 (11)	90 (16)	120(21)	150 (27)
Strength at Yield, lb/in-width (N/mm)			84 (15)	126 (22)	168 (29)	210 (37)
Elongation at Break, %	G.L. = 2.0 in (51 mm)		100	100	100	100
Elongation at Yield, %	G.L. = 1.3 in (33 mm)		12	12	12	12
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	28 (125)	42 (187)	56 (249)	70 (311)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	60 (267)	90 (400)	120 (534)	150 (667)
Carbon Black Content, %	ASTM D 1603	20,000 lb	2.0	2.0	2.0	2.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	+Note 1	+Note 1	+Note 1	+Note 1
Asperity Height	GRI GM 12	second roll	+Note 2	+Note 2	+Note 2	+Note 2
Notched Constant Tensile Load[(2)], hr	ASTM D 5397, Appendix	200,000 lb	300	300	300	300
REFERENCE PROPERTY	**TEST METHOD**	**FREQUENCY**	**NOMINAL VALUE**			
Oxidative Induction Time, min	ASTM D 3895, 200° C; O_2, 1 atm	200,000 lb	>100	>100	>100	>100
Roll Length[(3)] (approximate), ft (m)	Standard Textured		650 (198)	420 (128)	320 (98)	250 (76)
Roll Width[(3)], ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft² (m²)			14,625 (1,359)	9,450 (878)	7,200 (669)	5,625 (523)

NOTES:

- +Note 1: Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- +Note 2: 10 mil average. 8 of 10 readings ≥7 mils. Lowest individual ≥ 5 mils.
- GSE HD Standard Textured is available in rolls weighing about 3,000 lb (1,360 kg).
- [(1)]The combination of stress concentrations due to coextrusion texture geometry and the small specimen size results in large variation of test results. Therefore, these tensile properties are minimum average values.
- [(2)]NCTL for HD Textured is conducted on representative smooth membrane samples.
- All GSE geomembranes have dimensional stability of ±2% when tested with ASTM D 1204 and LTB of <-77° C when tested with ASTM D 746.
- [(3)]Roll lengths and widths have a tolerance of ± 1%.

DS006s HDtexdss R03/09/06

North America	GSE Lining Technology, Inc.	Houston, Texas	800 435 2008	281 443 8564	Fax: 281 230 8650
South America	GSE Lining Technology Chile S.A.	Santiago, Chile		56 2 595 4200	Fax: 56 2 595 4290
Asia Pacific	GSE Lining Technology Company Limited	Bangkok, Thailand		66 2 937 0091	Fax: 66 2 937 0097
Europe & Africa	GSE Lining Technology GmbH	Hamburg, Germany		49 40 767420	Fax: 49 40 7674234
Middle East	GSE Lining Technology-Egypt	The 6th of October City, Egypt		202 2 828 8888	Fax: 202 2 828 8889

www.gseworld.com

GSE®

Product Data Sheet

GSE STANDARD PRODUCTS

GSE FabriNet Geocomposite (Double-Sided)

GSE FabriNet geocomposite consists of GSE HyperNet geonet heat-laminated on both sides with a GSE nonwoven needlepunched geotextile. GSE HyperNet is a 200 mil thick geonet manufactured from a premium grade high density polyethylene resin. For the purpose of lamination to geonets, GSE nonwoven needlepunched geotextiles are available in mass per unit area range of 6 oz/yd² (200 g/m²) to 16 oz/yd² (540 g/m²). GSE FabriNet geocomposites are designed and formulated to perform drainage function under a range of anticipated site loads, gradients and boundary conditions. Index properties for the product are provided in the table below. Please contact GSE for further information regarding performance under site-specific conditions.

Product Specifications YIELD STRENGTH VALUE ON ATTACHED PHONE LOG

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE ROLL VALUE[a]		
Geocomposite			6 oz/yd²	8 oz/yd²	10 oz/yd²
Product Code			F42060060S	F42080080S	F42100100S
Transmissivity[b], gal/min/ft (m²/sec)	ASTM D 4716	1/540,000 ft²	0.48 (1 x 10^{-4})	0.48 (1 x 10^{-4})	0.43 (9 x 10^{-5})
Ply Adhesion, lb/in (g/cm)	ASTM D 7005	1/50,000 ft²	1.0 (178)	1.0 (178)	1.0 (178)
Roll Width[c], ft (m)			14.5 (4.4)	14.5 (4.4)	14.5 (4.4)
Roll Length[c], ft (m)			230 (70.1)	200 (60.9)	190 (58.0)
Roll Area, ft² (m²)			3,335 (310)	2,900 (269)	2,755 (256)
Geonet core[d]					
Transmissivity,[b] gal/min/ft (m²/sec)	ASTM D 4716		9.66 (2 x 10^{-3})	9.66 (2 x 10^{-3})	9.66 (2 x 10^{-3})
Thickness, mil (mm)	ASTM D 5199	1/50,000 ft²	200 (5)	200 (5)	200 (5)
Density, g/cm³	ASTM D 1505	1/50,000 ft²	0.94	0.94	0.94
Tensile Strength (MD), lb/in (N/mm)	ASTM D 5035	1/50,000 ft²	45 (7.9)	45 (7.9)	45 (7.9)
Carbon Black Content, %	ASTM D 1603	1/50,000 ft²	2.0	2.0	2.0
Geotextile (prior to lamination)[d,e]					
Mass per Unit Area, oz/yd² (g/m²)	ASTM D 5261	1/90,000 ft²	6 (200)	8 (270)	10 (335)
Grab Tensile, lb (N)	ASTM D 4632	1/90,000 ft²	170 (755)	220 (975)	260 (1,155)
Puncture Strength, lb (N)	ASTM D 4833	1/90,000 ft²	90 (395)	120 (525)	165 (725)
AOS, US sieve (mm)	ASTM D 4751	1/540,000 ft²	70 (0.212)	80 (0.180)	100 (0.150)
Permittivity, (sec⁻¹)	ASTM D 4491	1/540,000 ft²	1.5	1.5	1.2
Flow Rate, gpm/ft² (lpm/m²)	ASTM D 4491	1/540,000 ft²	110 (4,480)	110 (4,480)	85 (3,460)
UV Resistance, % retained	ASTM D 4355 (after 500 hours)	once per formulation	70	70	70

NOTES:

- [a]These are MARV values that are based on the cumulative results of specimens tested and determined by GSE. AOS in mm is a maximum average roll value.
- [b]Gradient of 0.1, normal load of 10,000 psf, water at 70° F between steel plates for 15 minutes.
- [c]Roll widths and lengths have a tolerance of ±1%.
- [d]Component properties prior to lamination.
- [e]Refer to geotextile product data sheet for additional specifications.

2 LAYER OF GEOTEXTILE @ 200 g/m² OR $0.08\ \frac{lb}{ft^2}$ + PREVIOUSLY CALCULATED GEONET UNIT WEIGHT OF $0.17\ \frac{lbs}{ft^2} = 0.25\ \frac{lbs}{ft^2}$

DS018 Fabrinet R01/13/06

North America	GSE Lining Technology, Inc.	Houston, Texas	800 435 2008	281 443 8564	Fax: 281 230 8650
South America	GSE Lining Technology Chile S.A.	Santiago, Chile		56 2 595 4200	Fax: 56 2 595 4290
Asia Pacific	GSE Lining Technology Company Limited	Bangkok, Thailand		66 2 937 0091	Fax: 66 2 937 0097
Europe & Africa	GSE Lining Technology GmbH	Hamburg, Germany		49 40 767420	Fax: 49 40 7674234
Middle East	GSE Lining Technology-Egypt	The 6th of October City, Egypt		202 2 828 8888	Fax: 202 2 828 8889

GSE®

Product Data Sheet

GSE STANDARD PRODUCTS

GSE HD Textured

GSE HD Textured is the textured version of GSE HD. It is a high quality, high density polyethylene (HDPE) geomembrane with one or two coextruded, textured surfaces, and consisting of approximately 97.5% polyethylene, 2.5% carbon black and trace amounts of antioxidants and heat stabilizers; no other additives, fillers or extenders are used. The resin used is specially formulated, virgin polyethylene and is designed specifically for flexible geomembrane applications. GSE HD Textured has excellent resistance to UV radiation and is suitable for exposed conditions. This product allows projects with greater slopes to be designed since frictional characteristics are enhanced. *These product specifications meet or exceed GRI GM13.*

$\frac{0.94\,g}{cm^3} = \frac{0.0021\,lbs}{cm^3} \cdot \frac{0.145\,cm\ \text{THICK}}{1} = \frac{3.0\times10^{-4}\,lbs}{cm^2}$ or $\frac{0.28\,lbs}{ft^2}$

Product Specifications

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM VALUE				
Product Code			HDT 030G000	HDT 040G000	HDT 060G000	HDT 080G000	HDT 100G000
Thickness, (minimum average) mil (mm)	ASTM D 5994	every roll	29 (0.73)	38 (0.96)	57 (1.45)	76 (1.93)	95 (2.41)
Lowest individual for 8 out of 10 values			27 (0.69)	36 (0.91)	54 (1.40)	72 (1.80)	90 (2.30)
Lowest individual for any of the 10 values			26 (0.66)	34 (0.86)	51 (1.30)	68 (1.73)	85 (2.16)
Density, g/cm³	ASTM D 1505	200,000 lb	0.94	0.94	0.94	0.94	0.94
Tensile Properties (each direction)[1]	ASTM D 6693, Type IV	20,000 lb					
Strength at Break, lb/in-width (N/mm)	Dumbell, 2 ipm		45 (8)	60 (11)	90 (16)	120(21)	150 (27)
Strength at Yield, lb/in-width (N/mm)			63 (11)	84 (15)	126 (22)	168 (29)	210 (37)
Elongation at Break, %	G.L. = 2.0 in (51 mm)		100	100	100	100	100
Elongation at Yield, %	G.L. = 1.3 in (33 mm)		12	12	12	12	12
Tear Resistance, lb (N)	ASTM D 1004	45,000 lb	21 (93)	28 (125)	42 (187)	56 (249)	70 (311)
Puncture Resistance, lb (N)	ASTM D 4833	45,000 lb	45 (200)	60 (267)	90 (400)	120 (534)	150 (667)
Carbon Black Content, %	ASTM D 1603	20,000 lb	2.0	2.0	2.0	2.0	2.0
Carbon Black Dispersion	ASTM D 5596	45,000 lb	+Note 1	+Note 1	+Note 1	+Note 1	+Note 1
Asperity Height	GRI GM 12	second roll	+Note 2	+Note 2	+Note 2	+Note 2	+Note 2
Notched Constant Tensile Load[2], hr	ASTM D 5397, Appendix	200,000 lb	300	300	300	300	300

REFERENCE PROPERTY	TEST METHOD	FREQUENCY	NOMINAL VALUE				
Oxidative Induction Time, min	ASTM D 3895, 200° C; O_2, 1 atm	200,000 lb	>100	>100	>100	>100	>100
Roll Length[3] (approximate), ft (m)	Standard Textured		830 (253)	700 (213)	520 (158)	400 (122)	330 (101)
Roll Width[3], ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft² (m²)			18,674 (1,735)	15,750 (1,463)	11,700 (1,087)	9,000 (836)	7,425 (690)

NOTES:

- +Note 1: Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- +Note 2: 10 mil average. 8 of 10 readings ≥7 mils. Lowest individual ≥ 5 mils.
- GSE HD Standard Textured is available in rolls weighing about 4,000 lb (1,800 kg).
- [1]The combination of stress concentrations due to coextrusion texture geometry and the small specimen size results in large variation of test results. Therefore, these tensile properties are minimum average values.
- [2]NCTL for HD Textured is conducted on representative smooth membrane samples.
- All GSE geomembranes have dimensional stability of ±2% when tested with ASTM D 1204 and LTB of <-77° C when tested with ASTM D 746.
- [3]Roll lengths and widths have a tolerance of ± 1%.

DS006 HDtext R03/09/06

North America	GSE Lining Technology, Inc.	Houston, Texas	800 435 2008	281 443 8564	Fax: 281 230 8650
South America	GSE Lining Technology Chile S.A.	Santiago, Chile		56 2 595 4200	Fax: 56 2 595 4290
Asia Pacific	GSE Lining Technology Company Limited	Bangkok, Thailand		66 2 937 0091	Fax: 66 2 937 0097
Europe & Africa	GSE Lining Technology GmbH	Hamburg, Germany		49 40 767420	Fax: 49 40 7674234
Middle East	GSE Lining Technology-Egypt	The 6th of October City, Egypt		202 2 828 8888	Fax: 202 2 828 8889

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CETCO LINING TECHNOLOGIES

Bentomat® & Claymax® Panel & Roll Specifications

UNIT WEIGHT $\frac{2650 \text{ lbs}}{2175 \text{ ft}^2} = 1.22 \text{ lb/ft}^2$

Panel Specifications

PRODUCTS	DIMENSIONS Width x Length	AREA	EFFECTIVE AREA
BENTOMAT® ST	15 ft x 150 ft (4.6 m x 45.7 m)	2,250 ft^2 (209 m^2)	2,145 ft^2 (200 m^2)
BENTOMAT SDN	14.5 ft x 150 ft (4.4 m x 45.7 m)	2,175 ft^2 (202 m^2)	2,071 ft^2 (193 m^2)
BENTOMAT DN	14.5 ft x 150 ft (4.4 m x 45.7 m)	2,175 ft^2 (202 m^2)	2,071 ft^2 (193 m^2)
BENTOMAT YSDN	14.5 ft x 200 ft (4.4 m x 60.9 m)	2,900 ft^2 (270 m^2)	2,771 ft^2 (258 m^2)
BENTOMAT CL Lovell, WY Plant	15 ft x 150 ft (4.6 m x 45.7 m)	2,250 ft^2 (209 m^2)	2,145 ft^2 (200 m^2)
BENTOMAT CL Fairmount, GA Plant	14.5 ft x 150 ft (4.4 m x 45.7 m)	2,175 ft^2 (202 m^2)	2,071 ft^2 (193 m^2)
BENTOMAT CLT	15 ft x 150 ft (4.6 m x 45.7 m)	2,250 ft^2 (209 m^2)	2,145 ft^2 (200 m^2)
CLAYMAX® 200R	15 ft x 150 ft (4.6 m x 45.7 m)	2,250 ft^2 (209 m^2)	2,145 ft^2 (200 m^2)
CLAYMAX 600CL Lovell, WY Plant	15 ft x 150 ft (4.6 m x 45.7 m)	2,250 ft^2 (209 m^2)	2,145 ft^2 (200 m^2)
CLAYMAX 600CL Fairmount, GA Plant	14.5 ft x 150 ft (4.4 m x 45.7 m)	2,175 ft^2 (202 m^2)	2,071 ft^2 (193 m^2)

Roll Specifications

PRODUCTS	DIMENSIONS Length x Diameter (Avg.)	NOMINAL WEIGHT	ROLLS / TRUCKLOAD
BENTOMAT ST	16 ft x 24 in (4.9 m x 610 mm)	2,600 lbs (1180 kg)	16 rolls per truckload
BENTOMAT SDN	16 ft x 24 in (4.9 m x 610 mm)	2,650 lbs (1200 kg)	15 rolls per truckload
BENTOMAT DN	16 ft x 24 in (4.9 m x 610 mm)	2,650 lbs (1200 kg)	15 rolls per truckload
BENTOMAT YSDN	15 ft x 24 in (4.6 m x 600 mm)	2,500 lbs (1133 kg)	17 rolls per truckload
BENTOMAT CL	16 ft x 24 in (4.9 m x 610 mm)	2,650 lbs (1200 kg)	15 rolls per truckload
BENTOMAT CLT	16 ft x 26 in (4.9 m x 660 mm)	2,950 lbs (1340 kg)	15 rolls per truckload
CLAYMAX 200R	16 ft x 20 in (4.9 m x 510 mm)	2,750 lbs (1250 kg)	15 rolls per truckload
CLAYMAX 600CL	16 ft x 20 in (4.9 m x 510 mm)	2,825 lbs (1250 kg)	15 rolls per truckload

Unloading and handling equipment for all GCL products:

- Spreader bar and core pipe: Spreader bar 17 ft (5.2 m) long; core pipe 20 ft (6.1 m) long, nominal pipe size, XXH.
- Core Pipe for Bentomat YSDN: 16 ft (4.9 m); O.D. = 3.5 in (90 mm)
- A solid 3.5 in. (90 mm) O.D. x 14.5 ft (4.4 m) solid steel pipe stinger attachment for a forklift.
- Slings: 2 Polyester slings are required, approximately 12 ft (3.7 m) long x 2 in (50 mm) wide each.
- Vehicle needed: Front end loader or forklift (are typical).

Standard Roll Specifications:

- Packaging: U.V. resistant polyethylene sleeve.

CETCO LINING TECHNOLOGIES

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For the most up-to-date product information please visit our website, www.cetco.com
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Revised 9-03

geosynthetic clay liners • geosynthetic clay liners • geosynthetic clay liners

CETCO LINING TECHNOLOGIES

Certified Properties

BENTOMAT® DN CERTIFIED PROPERTIES

MATERIAL PROPERTY	TEST METHOD	TEST FREQUENCY $ft^2(m^2)$	REQUIRED VALUES
Bentonite Swell Index[1]	ASTM D 5890	1 per 50 tonnes	24 mL/2g min.
Bentonite Fluid Loss[1]	ASTM D 5891	1 per 50 tonnes	18 mL max.
Bentonite Mass/Area[2]	ASTM D 5993	40,000 ft^2 (4,000 m^2)	0.75 lb/ft^2 (3.6 kg/m^2) min
GCL Grab Strength[3]	ASTM D 6768	200,000 ft^2 (20,000 m^2)	50 lbs/in (88 N/cm) MARV
GCL Peel Strength[3]	ASTM D 6496	40,000 ft^2 (4,000 m^2)	3.5 lbs/in (6.1 N/cm) min
GCL Index Flux[4]	ASTM D 5887	Weekly	1×10^{-8} m^3/m^2/sec max
GCL Hydraulic Conductivity[4]	ASTM D 5887	Weekly	5×10^{-9} cm/sec max
GCL Hydrated Internal Shear Strength[5]	ASTM D 5321 ASTM D 6243	Periodic	500 psf (24 kPa) typ @ 200 psf

Bentomat DN is a reinforced GCL consisting of a layer of sodium bentonite between two nonwoven geotextiles, which are needlepunched together.

Notes

[1] Bentonite property tests performed at a bentonite processing facility before shipment to CETCO's GCL production facilities.
[2] Bentonite mass/area reported at 0 percent moisture content.
[3] All tensile strength testing is performed in the machine direction using ASTM D 6768. All peel strength testing is performed using ASTM D 6496. Upon request, tensile and peel results can be reported per modified ASTM D 4632 using 4 inch grips.
[4] Index flux and permeability testing with deaired distilled/deionized water at 80 psi (551kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressure. Reported value is equivalent to 925 gal/acre/day. This flux value is equivalent to a permeability of 5×10^{-9} cm/sec for typical GCL thickness. Actual flux values vary with field condition pressures. The last 20 weekly values prior the end of the production date of the supplied GCL may be provided.
[5] Peak values measured at 200 psf (10 kPa) normal stress for a specimen hydrated for 48 hours. Site-specific materials, GCL products, and test conditions must be used to verify internal and interface strength of the proposed design.

CETCO has developed an edge enhancement system that eliminates the need to use additional granular sodium bentonite within the overlap area of the seams. We call this edge enhancement, SuperGroove™, and it comes standard on both longitudinal edges of Bentomat® DN. It should be noted that SuperGroove™ does not appear on the end-of-roll overlaps and recommend the continued use of supplemental bentonite for all end-of-roll seams.

CETCO® LINING TECHNOLOGIES

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For the most up-to-date information please visit our website, www.cetco.com
A wholly owned subsidiary of AMCOL International

REFERENCE

KOERNER 1998

Fourth Edition

Designing with Geosynthetics

Robert M. Koerner, Ph.D., P.E.

H. L. Bowman Professor of Civil Engineering,
Drexel University and Director, Geosynthetic
Research Institute

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Upper Saddle River, New Jersey 07458

properties will sort out into their respective categories and uses, but most organizations are looking at the complete collection of tests as they were presented here.

Table 2.10 is a summary table of geotextile properties. The rapidly changing market and its demands make it difficult to give accurate values, but for typical commercially available geotextiles, Table 2.10 gives the range of current values. For the specific values of specific types of geotextiles, the respective manufacturers should be consulted.

2.4 ALLOWABLE VERSUS ULTIMATE GEOTEXTILE PROPERTIES

It is important to recognize that many of the preceding geotextile test properties represent idealized conditions and therefore result in the maximum possible numeric values when used directly in design; that is, they result in upper-bound values. In the design-by-function concept described in Section 2.1.3, the factor of safety was formulated around an allowable test value (Eqs. 2.2a and 2.2b). Thus, most laboratory test values cannot generally be used directly; they must be suitably modified for the in situ conditions. This could be done directly in the test procedure, for example, by conducting a completely simulated performance test; but in most cases this simply is not possible. Simulating installation damage, performing long-term creep testing, using site-specific liquids, reproducing in situ pore-water stresses, providing complete stress state modeling, and so on, are generally not feasible. To account for such differences between the laboratory measured test value and the desired performance value, two approaches can be taken:

1. Use an extremely high factor of safety at the end of a problem.
2. Use reduction factors on the laboratory-generated test value to make it into a site-specific allowable value.

The latter alternative of *reduction factors*‡ will be used in this book. By doing this, the usual value of the factor of safety can be used in the final analysis. Our approach will be to refer to the general laboratory-obtained value as an *ultimate* value and to modify it by reduction factors to an *allowable* value.

2.4.1 Strength-Related Problems

For problems dealing with geotextile strength, such as in separation and reinforcement applications, the formulation of the allowable values takes the following form. Typical values for reduction factors are given in Table 2.11. Note that these values, however, must be tempered by the site-specific considerations. If the laboratory test includes the mechanism listed, it appears in the equation as a value of 1.0.

$$T_{allow} = T_{ult}\left(\frac{1}{RF_{ID} \times RF_{CR} \times RF_{CD} \times RF_{BD}}\right) \tag{2.24a}$$

$$T_{allow} = T_{ult}\left(\frac{1}{\Pi RF}\right) \tag{2.24b}$$

‡In previous editions of this book, reduction factors were called partial factors of safety. This edition is changed to reflect the current trend in agency specifications and the more appropriate terminology.

TABLE 2.10 TYPICAL RANGE OF PROPERTIES FOR CURRENTLY AVAILABLE GEOTEXTILES

Physical Properties	
Specific gravity	0.9–1.7
Mass per unit area	135–1000 g/m^2
Thickness	0.25–7.5 mm
Stiffness	nil to 25,000 mg-cm
Mechanical Properties	
Compressibility	nil to high
Tensile strength (grab)	0.45–4.5 kN
Tensile strength (wide width)	9–180 kN/m
Confined tensile strength	18–180 kN/m
Seam strength	50–100% of tensile
Cyclic fatigue strength	50–100% of tensile
Burst strength	350–5200 kPa
Tear strength	90–1300 N
Impact strength	14–200 J
Puncture strength	45–450 N
Friction behavior	60–100% of soil friction
Pullout behavior	50–100% of geotextile strength
Hydraulic Properties	
Porosity (nonwovens)	50–95%
Percent open area (wovens)	nil to 36%
Apparent opening size (sieve size)	2.0 to 0.075 mm (#10 to #200)
Permittivity	0.02–2.2 s^{-1}
Permittivity under load	0.01–3.0 s^{-1}
Transmissivity	0.01 to 2.0 × 10^{-3} m^2/min
Soil retention: turbidity curtains	m.b.e.
Soil retention: silt fences	m.b.e.
Endurance Properties	
Installation damage	0–70% of fabric strength
Creep response	g.n.p if < 40% strength is being used
Confined creep response	g.n.p. if < 50% strength is being used
Stress relaxation	g.n.p. if < 40% strength is being used
Abrasion	50–100% of geotextile strength
Long-term clogging	m.b.e. for critical conditions
Gradient ratio clogging	m.b.e. for critical conditions
Hydraulic conductivity ratio	0.4–0.8 appear to be acceptable
Degradation Properties	
Temperature degradation	high temperature accelerates degradation
Oxidative degradation	m.b.e. for long service lifetimes
Hydrolysis degradation	m.b.e. for long service lifetimes
Chemical degradation	g.n.p. unless aggressive chemicals
Ratioactive degradation	g.n.p.
Biological degradation	g.n.p.
Sunlight (UV) degradation	major problem unless protected
Synergistic effects	m.b.e.
General aging	actual record to date is excellent

Abbreviations: m.b.e.—must be evaluated; g.n.p.—generally no problem.

TABLE 2.11 RECOMMENDED REDUCTION FACTOR VALUES FOR USE IN EQ. (2.24a)

Application Area	Range of Reduction Factors			
	Installation Damage	Creep*	Chemical Degradation	Biological Degradation
Separation	1.1 to 2.5	1.5 to 2.5	1.0 to 1.5	1.0 to 1.2
Cushioning	1.1 to 2.0	1.2 to 1.5	1.0 to 2.0	1.0 to 1.2
Unpaved roads	1.1 to 2.0	1.5 to 2.5	1.0 to 1.5	1.0 to 1.2
Walls	1.1 to 2.0	2.0 to 4.0	1.0 to 1.5	1.0 to 1.3
Embankments	1.1 to 2.0	2.0 to 3.5	1.0 to 1.5	1.0 to 1.3
Bearing capacity	1.1 to 2.0	2.0 to 4.0	1.0 to 1.5	1.0 to 1.3
Slope stabilization	1.1 to 1.5	2.0 to 3.0	1.0 to 1.5	1.0 to 1.3
Pavement overlays	1.1 to 1.5	1.0 to 2.0	1.0 to 1.5	1.0 to 1.1
Railroads (filter/sep.)	1.5 to 3.0	1.0 to 1.5	1.5 to 2.0	1.0 to 1.2
Flexible forms	1.1 to 1.5	1.5 to 3.0	1.0 to 1.5	1.0 to 1.1
Silt fences	1.1 to 1.5	1.5 to 2.5	1.0 to 1.5	1.0 to 1.1

*The low end of the range refers to applications which have relatively short service lifetimes and/or situations where creep deformations are not critical to the overall system performance.

where

T_{allow} = allowable tensile strength,
T_{ult} = ultimate tensile strength,
RF_{ID} = reduction factor for installation damage,
RF_{CR} = reduction factor for creep,
RF_{CD} = reduction factor for chemical degradation,
RF_{BD} = reduction factor for biological degradation, and
ΠRF = value of cumulative reduction factors.

Note that Eq. (2.24a) could have included additional site-specific terms, such as reduction factors for seams and intentionally made holes. It also could have been formulated with fractional multipliers (values ≤ 1.0) placed in the numerator of the equation or on the opposite side of the equation, as with the *load-factor design method.* It has been put in this form following other studies (e.g., Voskamp and Risseeuw [63]). While the equation indicates tensile strength, it can be applied to burst strength, tear strength, puncture strength, impact strength, and so on.

2.4.2 Flow-Related Problems

For problems dealing with flow through or within a geotextile, such as filtration and drainage applications, the formulation of the allowable values takes the following form. Typical values for reduction factors are given in Table 2.12. Note that these values must be tempered by the site-specific conditions, as in Section 2.4.1. If the laboratory test includes the mechanism listed, it appears in the equation as a value of 1.0.

$$q_{allow} = q_{ult}\left(\frac{1}{RF_{SCB} \times RF_{CR} \times RF_{IN} \times RF_{CC} \times RF_{BC}}\right) \tag{2.25a}$$

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