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OCT 31 2008
BY: BSHW

October 30, 2008
File No. 09207049.02

Mr. Richard Tedder
Director of the Division of Waste Management
Florida Department of Environmental Protection (FDEP)
2600 Blair Stone Road
Twin Tower Office Building
Tallahassee, Florida 32399-2400

Subject: Request for Approval of Alternate Procedure
Landfill Sideslope Subbase Design
Citrus County Central Landfill Phase 3 Expansion

Dear Mr. Tedder:

On behalf of Citrus County, SCS Engineers (SCS) has prepared and submitted to the FDEP Southwest District Office, a permit application to construct the Citrus County Central Landfill Phase 3 Expansion. This letter was prepared in order to request approval for the landfill side slope sub-base design, in accordance with the criteria set forth in Rule 62-701.310(2), Florida Administrative Code, FAC. A fee of $2,000 in accordance with Rule 62-701.310(6), FAC, is also attached.

SIDESLOPE SUBBASE DESIGN REQUIREMENT

The criteria set forth in Rule 62-701.310(2), FAC, for approval of an alternate design is summarized in the following table and addressed in more detail in subsequent sections.

Rule	Criteria	Response
62-701.310(2)(a), FAC	Specific facility for which an exception is sought.	Citrus County Central Landfill Phase 3 Expansion
62-701.310(2)(b), FAC	Specific provisions from which an exception is sought	6-inch thick liner sub-base for a double geomembrane liner Rule 62-701.400(3)(c)(1), FAC
62-701.310(2)(c), FAC	Basis for the exception	The required liner sub-base is not practical due to benefit comparisons and construction issues.
62-701.310(2)(d), FAC	Alternate procedure sought and demonstration that the alternate procedure provides an equal degree of protection for the public and environment	Construction of lower geomembrane liner on sideslopes of prepared, naturally occurring, sub-grade soils. Alternative provides an equal degree of protection.

Rule	Criteria	Response
62-701.310(2)(e), FAC	Demonstration of effectiveness of proposed alternate procedure	Estimated leachate flow through sideslopes of Phase 3 Expansion is negligible.

Prior to addressing the criteria in detail for an alternate side slope sub-base design for Phase 3 at the Citrus County Central Landfill, SCS would like to note that on February 13, 1996, CH_2M HILL submitted a letter report to FDEP requesting an alternate side slope sub-base design for the Phase 1A Expansion at the Citrus County Central Landfill, which was subsequently approved by FDEP. On August 14, 2002, SCS submitted a letter report to FDEP also requesting an alternate side slope sub-base design for the Phase 2 Expansion at the Citrus County Central Landfill, which was subsequently approved by FDEP. A copy of the CH_2M HILL letter report was submitted in support of the request for an alternate side slope sub-base design for the Phase 2 Expansion.

It should be noted that the proposed liner profile for the side slope is similar to that of Phases 1A and 2, except that a bi-planar geocomposite (as opposed to a triplanar geocomposite) is proposed for the secondary leachate collection system.

Rule 62-701.310(2)(a), FAC – Facility for Which Exception is Sought

This exception is sought for the Citrus County Central Landfill Phase 3 Expansion in Lecanto, Florida.

Rule 62-701.310(2)(b), FAC – Provisions for Which Exception is Sought

The proposed lining system base plan and typical cross-sections for the Citrus County Central Landfill Phase 3 Expansion are shown on construction drawings included in the pending permit application. A detail for both the sideslopes and bottom liner systems of the Phase 3 Expansion are also shown on the enclosed Figure 1.

In accordance with Rule 62-701.400(3)(c), FAC, a double liner system consisting of upper and lower 60-mil geomembranes is proposed for this expansion. The exception is being sought for the lining sub-base criteria set forth in Rule 62-701.400 (3)(c)(1), FAC for the side slope liner portion only. This rule states that the lower geomembrane shall be placed directly on a sub-base which is a minimum of 6-inches thick, is free of sharp materials or any material larger than one-half inch, and has a saturated hydraulic conductivity of less than or equal to 1×10^{-5} cm/sec. SCS' proposed design does not include preparing a six-inch sub-base on the sideslopes of the Phase 3 Expansion. Rather, the side slope lower liner will be placed on prepared, in-place naturally occurring, sub-grade soils as shown in the lining detail on Figure 1.

Rule 62-701.310(2)(c), FAC – Basis for the Exception

The exception is based on whether it is practical to prepare a 6-inch thick lining sub-base on the side slopes for the proposed Phase 3 Expansion. In SCS' opinion, both from constructability and benefit considerations, the six-inch thick lining sub-base is not practical.

Constructability

SCS designed the sides of the proposed Phase 3 Expansion to have a slope of 2 horizontal to 1 vertical, in order to stay within the site constraints of the landfill, but still maximize the amount of highly desirable air space. With this consideration in mind, it is not practical to prepare a 6-inch thick lining sub-base in accordance with Rule 62-701.400(3)(c)(1), FAC. Due to slope considerations, it is unlikely, even if attempted, that the liner sub-base could be installed and compacted to meet the required permeability values.

Benefit Considerations

The provisions for a 6-inch thick liner sub-base set forth in Rule 62-701.400(3)(c)(1), FAC, are intended to help in containing leaks through the secondary liner that could cause pollution of underlying groundwater aquifers by the leaking leachate. In accordance with Rule 62-701.400(3)(c)(1), FAC, a geosynthetic clay liner with a hydraulic conductivity not greater than 1×10^{-7} cm/sec may be used in place of the six inch thick sub-base layer provided it is placed on a prepared subgrade which will not damage the geosynthetic clay liner. For the purposes of the proposed Phase 3 Expansion, the increased protection provided by a geosynthetic clay liner sub-base does not give a practical added benefit. The following site-specific conditions support this conclusion:

- The proposed leachate collection design includes a tri-planar geocomposite drainage layer for the primary leachate collection layer and a bi-planar geocomposite for the secondary leachate collection layer. This design, in conjunction with a side slope of 2 horizontal to 1 vertical, allows leachate that encounters the collection layers to drain to the landfill sump very quickly. The efficient transmission of leachate down the slope results in a minimal hydraulic head on the liner. With these two components, the incidence of significant leakage into the soil, induced through liner perforations, are substantially reduced.

- According to the geotechnical investigation conducted on November 15, 2001 by Universal Engineering Sciences, the groundwater elevation at the site is approximately 5 feet NGVD and approximately 120 feet below ground surface. (A copy of the Universal Report was included as Attachment B in the request for approval of alternate procedure landfill side slope sub-base design and horizontal separation to property line for the Phase 2 Expansion). These measurements put the groundwater at approximately 50 feet below the lowest point of the Phase 2 Expansion side slopes. In addition, the geotechnical investigation describes the soil profile found in the footprint of the existing Phase 2 area and proposed Phase 3 Area.

When the soil profile of the Phase 3 Expansion is compared with the soil profile at the Phase 2 and Phase 1A Expansion, they are essentially the same. With this in mind, the average hydraulic conductivity of $3.0x10^{-5}$ cm/sec for the soil presented in CH_2M HILL's alternate procedure letter for the Phase 1A Expansion is appropriate to use for the Phase 3 Expansion.

Rule 62-701.310(2)(d), FAC – Alternate Procedure for Which the Approval is Sought and Demonstration that the Alternate Procedure Provides an Equal Degree of Protection for the Public and Environment

The alternate procedure being sought is to place the lower geomembrane side slope liner of the Phase 3 Expansion on prepared in-place, naturally occurring sub-grade soils instead of on a 6-inch thick prepared liner sub-base with a saturated hydraulic conductivity of less than or equal to $1x10^{-5}$ cm/sec or a GCL. The degree of protection of the proposed alternate procedure and the required lining sub-base can be evaluated by considering the calculated leakage rate through each alternative bottom layer.

The flow through a prescriptive GCL and, alternatively, in place soils was evaluated using the HELP Model (v.3). The HELP Model analysis uses site specific parameters including: thickness, transmissivity, and material characteristics of the geocomposite drainage layers, and site specific climatological data.

The HELP Model analysis is included in Attachment A and summarized below:

- Five years of actual on-site rainfall data collected at the facility including the worst case annual rainfall year and worst case daily rainfall event recorded.

- The expected flow area through a GCL sub-base layer in accordance with Rule 62-701.400(3)(c)(1), F.A.C. is 0.001 cubic feet per year per acre, which is negligible. (Refer to the HELP Model Analysis with GCL, Annual Average Values for Years 2003 through 2007, percolation/leakage through layer 12).

- The expected flow for the in-place subgrade soils is 0.003 cubic feet per year per acre, which is also negligible. (Refer to the HELP Model Analysis No GCL, Annual Average Values for Years 2003 through 2007, percolation/leakage through layer 11).

The calculation of the flow of leachate through the soil underlying the proposed Phase 3 Expansion sideslopes is de minimus as it relates to a potential impact to groundwater, thereby demonstrating the effectiveness of the proposed alternative procedure for the lining sub-base. Therefore, the potential flow through the proposed alternative design provides an equal degree of protection for the public and the environment.

Rule 62-701.310(2)(e), FAC – Demonstration of the Effectiveness of the Proposed Alternate Procedure

The effectiveness of the proposed alternate procedure is demonstrated by the ability of the proposed Phase 3 Expansion side slope liner system to contain leachate. The HELP Model analysis was used for this evaluation included in Attachment A. Results are summarized below:

- Based on the slope of the lining properties of the primary leachate collection layer, a 300-mil triplanar geocomposite, the maximum expected head on the primary lining is 0.036 inches.

- Using this head, the expected size of potential lining defects, and the properties of the underlying secondary collection layer; the maximum expected flow through the primary lining into the secondary leachate collection layer at each potential lining defect is expected to be 9.17 ft^3/day/ac.

- Based on the slope of the lining properties of the secondary leachate collection layer, a 250-mil biplanar geocomposite, the maximum expected head on the secondary lining is 0.037 inches.

- The calculated leakage rate through the proposed liner system on the side-slopes is de minimus, therefore, providing an equal level of effectiveness to the prescriptive design.

Based upon the HELP Model results and the assumptions made in the modeling, the leachate collection and detection system will maintain the leachate head to be within the thickness of the geocomposite layer, and will provide an equal level of environmental protection as the prescriptive liner design.

Additional calculations related to the liner stress on a 2:1 side slope are included in Attachment B. The enclosed calculations for the liner system stress were submitted with the Phase 2 Expansion Construction Application and are applicable to the Phase 3 Expansion Area. The use of the geogrid on the 2:1 sideslope will provide an additional factor of safety. The resulting calculations show that no stress is applied to any of the geosynthetic liner system materials. The geogrid specified can withstand the downward force calculated using methods prescribed by Koerner plus the addition of the landfill compactor and maintain at least a 1.5 factor of safety with only 5 percent strain on the material. A portion of the downward force is transferred to the bottom interface due to frictional forces within the liner system layers. The friction angles of the interface between the geogrid and the geocomposite, geocomposite and textured 60-mil HDPE geomembrane, and the textured geomembrane and the bottom soils will be measured with the actual materials to be used on the project. The resulting values will be compared to the values used in these calculations and the factor of safety will be verified.

In addition to the liner stress analysis anchor trench calculations are included in Attachment C. The anchor trench calculations utilized the weakest interface angle of the liner system and the specified yield stress for the geomembrane (126 lb/inch width). The anchor trench calculations results in a recommended horizontal anchor of 3 feet runout length with a depth of 2 feet.

Please do not hesitate to contact SCS if you have any questions or need additional information to assist in your review process.

Sincerely,

Dominique H. Bramlett, P.E.
Senior Project Engineer

John A. Banks, P.E.
Project Director
SCS ENGINEERS

DHB/JAB:dhb

cc: Susan Pelz, P.E., FDEP Tampa
Susan Metcalfe, P.G., Citrus County

Attachments

Application Fee

Figure 1	Liner System Details
Attachment A	HELP Model Analysis
Attachment B	Liner Stress Analysis
Attachment C	Anchor Trench Calculations

10/30/08

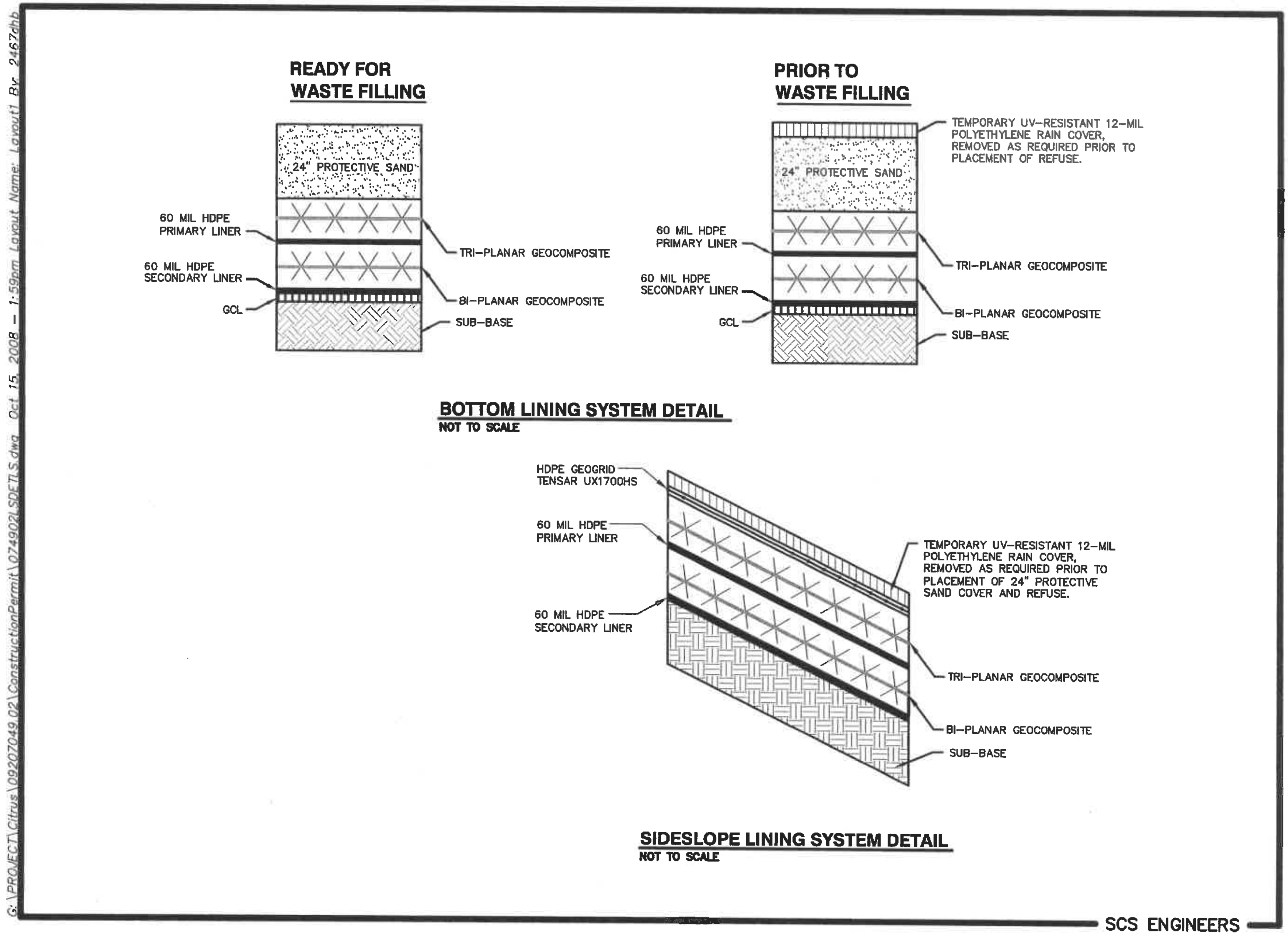

Figure 1. Liner System Details

ATTACHMENT A

HELP MODEL ANALYSIS

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


PRECIPITATION DATA FILE:     P:\HELP\CITRUS.D4
TEMPERATURE DATA FILE:       P:\HELP\CITRUS.D7
SOLAR RADIATION DATA FILE:   P:\HELP\CITRUS.D13
EVAPOTRANSPIRATION DATA:     P:\HELP\CITRUS.D11
SOIL AND DESIGN DATA FILE:   p:\HELP\CIT35ALN.D10
OUTPUT DATA FILE:            P:\HELP\cit35aln.OUT


TIME:  10:48     DATE:  10/28/2008


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

     TITLE:  Citrus County Alternate Procedure Request

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


                                   LAYER  1    (6-inch daily cover)
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   5
          THICKNESS                       =      6.00   INCHES
          POROSITY                        =      0.4570 VOL/VOL
          FIELD CAPACITY                  =      0.1310 VOL/VOL
          WILTING POINT                   =      0.0580 VOL/VOL
          INITIAL SOIL WATER CONTENT      =      0.0554 VOL/VOL
          EFFECTIVE SAT. HYD. COND.       =   0.100000005000E-02 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2 (10 ft waste)

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 19

THICKNESS	=	120.00 INCHES
POROSITY	=	0.1680 VOL/VOL
FIELD CAPACITY	=	0.0730 VOL/VOL
WILTING POINT	=	0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0713 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 3 (10 ft waste)

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 19

THICKNESS	=	120.00 INCHES
POROSITY	=	0.1680 VOL/VOL
FIELD CAPACITY	=	0.0730 VOL/VOL
WILTING POINT	=	0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0730 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 4 (10 ft waste)

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 19

THICKNESS	=	120.00 INCHES
POROSITY	=	0.1680 VOL/VOL
FIELD CAPACITY	=	0.0730 VOL/VOL
WILTING POINT	=	0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0730 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 5 (5 ft waste)

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 19

THICKNESS	=	60.00 INCHES
POROSITY	=	0.1680 VOL/VOL
FIELD CAPACITY	=	0.0730 VOL/VOL

```
WILTING POINT                      =      0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT         =      0.0730 VOL/VOL
EFFECTIVE SAT. HYD. COND.          =  0.100000005000E-02 CM/SEC


                        LAYER  6    (24-inch drainage sand)
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   7
THICKNESS                          =     24.00    INCHES
POROSITY                           =      0.4730 VOL/VOL
FIELD CAPACITY                     =      0.2220 VOL/VOL
WILTING POINT                      =      0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT         =      0.2590 VOL/VOL
EFFECTIVE SAT. HYD. COND.          =  0.520000001000E-03 CM/SEC


                        LAYER  7    (300-mil triplanar geocomposite)
                        --------

          TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                          =      0.27    INCHES
POROSITY                           =      0.8500 VOL/VOL
FIELD CAPACITY                     =      0.0100 VOL/VOL
WILTING POINT                      =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT         =      0.0106 VOL/VOL
EFFECTIVE SAT. HYD. COND.          =   8.00000000000      CM/SEC
SLOPE                              =     45.00    PERCENT
DRAINAGE LENGTH                    =    140.0     FEET


                        LAYER  8    (60-mil HDPE geomembrane)
                        --------

          TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                          =      0.06    INCHES
POROSITY                           =      0.0000 VOL/VOL
FIELD CAPACITY                     =      0.0000 VOL/VOL
WILTING POINT                      =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT         =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.          =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY                =      0.50    HOLES/ACRE
FML INSTALLATION DEFECTS           =      1.00    HOLES/ACRE
FML PLACEMENT QUALITY              =  5 - BAD
```

LAYER 9 (250-mil biplanar geocomposite)

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	0.23	INCHES
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	2.50000000000	CM/SEC
SLOPE	=	45.00	PERCENT
DRAINAGE LENGTH	=	140.0	FEET

LAYER 10 (60-mil HDPE geomembrane)

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.50	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 11 (24-inch drainage sand)

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4570	VOL/VOL
FIELD CAPACITY	=	0.1310	VOL/VOL
WILTING POINT	=	0.0580	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4570	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.299999992000E-04	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 5 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 4.% AND

A SLOPE LENGTH OF 121. FEET.

SCS RUNOFF CURVE NUMBER	=	84.60	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.424	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	3.414	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.424	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	47.982	INCHES
TOTAL INITIAL WATER	=	47.982	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
TAMPA FLORIDA

STATION LATITUDE	=	27.58	DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00	
START OF GROWING SEASON (JULIAN DATE)	=	0	
END OF GROWING SEASON (JULIAN DATE)	=	367	
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	8.60	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	76.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TAMPA FLORIDA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
2.94	3.26	2.35	0.68	1.38	8.20
13.13	8.40	20.26	1.27	0.70	3.15

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TAMPA FLORIDA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
59.80	60.80	66.20	71.60	77.10	80.90
82.20	82.20	80.90	74.50	66.70	61.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TAMPA FLORIDA
AND STATION LATITUDE = 27.58 DEGREES

WARNING: TEMPERATURE FOR YEAR 1 USED WITH PRECIPITATION FOR YEAR 2003

WARNING: SOLAR RADIATION FOR YEAR 1 USED WITH PRECIPITATION FOR YEAR 2003

WARNING: TEMPERATURE FOR YEAR 2 USED WITH PRECIPITATION FOR YEAR 2004

WARNING: SOLAR RADIATION FOR YEAR 2 USED WITH PRECIPITATION FOR YEAR 2004

WARNING: TEMPERATURE FOR YEAR 3 USED WITH PRECIPITATION FOR YEAR 2005

WARNING: SOLAR RADIATION FOR YEAR 3 USED WITH PRECIPITATION FOR YEAR 2005

WARNING: TEMPERATURE FOR YEAR 4 USED WITH PRECIPITATION FOR YEAR 2006

WARNING: SOLAR RADIATION FOR YEAR 4 USED WITH PRECIPITATION FOR YEAR 2006

WARNING: TEMPERATURE FOR YEAR 5 USED WITH PRECIPITATION FOR YEAR 2007

WARNING: SOLAR RADIATION FOR YEAR 5 USED WITH PRECIPITATION FOR YEAR 2007

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 2003 THROUGH 2007

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.73	3.58	3.16	2.50	3.25	10.36
	10.75	6.83	6.87	3.18	1.88	3.01
STD. DEVIATIONS	1.00	1.67	2.61	2.89	2.97	8.03
	2.46	1.27	7.65	3.23	1.54	1.29

RUNOFF

TOTALS	0.071	0.225	0.271	0.227	0.233	2.026
	1.360	0.368	1.860	0.215	0.167	0.107
STD. DEVIATIONS	0.158	0.234	0.332	0.486	0.436	3.256
	0.881	0.321	3.756	0.481	0.371	0.073

EVAPOTRANSPIRATION

TOTALS	1.303	1.663	1.788	1.318	1.437	4.160
	5.316	4.165	3.004	1.770	0.649	1.306
STD. DEVIATIONS	0.449	0.659	1.304	1.556	1.084	1.480
	0.790	0.703	0.950	1.214	0.464	0.813

LATERAL DRAINAGE COLLECTED FROM LAYER 7

TOTALS	1.1924	0.8924	1.4767	1.3908	1.1121	1.6498
	4.3406	3.8660	2.0324	1.9203	0.8394	0.9333
STD. DEVIATIONS	0.4865	0.3185	1.3986	1.4312	0.9319	1.2912
	2.5911	1.8751	1.7168	1.6257	0.6508	1.0348

PERCOLATION/LEAKAGE THROUGH LAYER 8

TOTALS	0.0169	0.0140	0.0180	0.0174	0.0154	0.0180
	0.0325	0.0317	0.0211	0.0206	0.0136	0.0136
STD. DEVIATIONS	0.0029	0.0024	0.0081	0.0078	0.0078	0.0074
	0.0105	0.0079	0.0080	0.0090	0.0063	0.0059

LATERAL DRAINAGE COLLECTED FROM LAYER 9

TOTALS	0.0169	0.0140	0.0180	0.0174	0.0154	0.0180
	0.0325	0.0317	0.0211	0.0206	0.0136	0.0136
STD. DEVIATIONS	0.0029	0.0024	0.0081	0.0078	0.0078	0.0074
	0.0105	0.0079	0.0080	0.0090	0.0063	0.0059

PERCOLATION/LEAKAGE THROUGH LAYER 11

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 8

AVERAGES	0.0003	0.0003	0.0004	0.0004	0.0003	0.0005

	0.0012	0.0010	0.0006	0.0005	0.0002	0.0002
STD. DEVIATIONS	0.0001	0.0001	0.0004	0.0004	0.0002	0.0004
	0.0007	0.0005	0.0005	0.0004	0.0002	0.0003

DAILY AVERAGE HEAD ON TOP OF LAYER 10

AVERAGES	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 2003 THROUGH 2007

	INCHES		CU. FEET	PERCENT
PRECIPITATION	57.11	(11.991)	207309.3	100.00
RUNOFF	7.129	(4.0139)	25879.55	12.484
EVAPOTRANSPIRATION	27.878	(4.8985)	101198.62	48.815
LATERAL DRAINAGE COLLECTED FROM LAYER 7	21.64618	(5.30189)	78575.648	37.90262
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.23291	(0.02785)	845.466	0.40783
AVERAGE HEAD ON TOP OF LAYER 8	0.000	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 9	0.23291	(0.02785)	845.463	0.40783
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.00000	(0.00000)	0.003	0.00000
AVERAGE HEAD ON TOP OF LAYER 10	0.000	(0.000)		
CHANGE IN WATER STORAGE	0.223	(1.4310)	810.02	0.391

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PEAK DAILY VALUES FOR YEARS 2003 THROUGH 2007

	(INCHES)	(CU. FT.)
PRECIPITATION	6.00	21780.000
RUNOFF	3.403	12352.9492
DRAINAGE COLLECTED FROM LAYER 7	0.61036	2215.59985
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.002526	9.17016
AVERAGE HEAD ON TOP OF LAYER 8	0.005	
MAXIMUM HEAD ON TOP OF LAYER 8	0.036	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 9	0.00253	9.17013
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 10	0.000	
MAXIMUM HEAD ON TOP OF LAYER 10	0.037	
LOCATION OF MAXIMUM HEAD IN LAYER 9 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	0.00	0.0000

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.2445

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0424

*** 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.

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FINAL WATER STORAGE AT END OF YEAR 2007

LAYER	(INCHES)	(VOL/VOL)
1	0.5392	0.0899
2	8.7295	0.0727
3	8.7600	0.0730
4	8.7600	0.0730
5	4.3800	0.0730
6	6.9554	0.2898
7	0.0032	0.0118
8	0.0000	0.0000
9	0.0023	0.0100
10	0.0000	0.0000
11	10.9680	0.4570
SNOW WATER	0.000	

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


PRECIPITATION DATA FILE:     P:\HELP\CITRUS.D4
TEMPERATURE DATA FILE:       P:\HELP\CITRUS.D7
SOLAR RADIATION DATA FILE:   P:\HELP\CITRUS.D13
EVAPOTRANSPIRATION DATA:     P:\HELP\CITRUS.D11
SOIL AND DESIGN DATA FILE:   p:\HELP\CIT35ALT.D10
OUTPUT DATA FILE:            P:\HELP\CIT35ALT.OUT


TIME:  10:53     DATE:  10/28/2008


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

     TITLE:  Citrus County Alternate Procedure Request

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


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


                                   LAYER  1    (6-inch daily cover)
                                   --------

                        TYPE 1 - VERTICAL PERCOLATION LAYER
                            MATERIAL TEXTURE NUMBER   5
          THICKNESS                    =       6.00    INCHES
          POROSITY                     =       0.4570 VOL/VOL
          FIELD CAPACITY               =       0.1310 VOL/VOL
          WILTING POINT                =       0.0580 VOL/VOL
          INITIAL SOIL WATER CONTENT   =       0.0554 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =   0.100000005000E-02 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2 (10 ft waste)

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 19

THICKNESS	=	120.00 INCHES
POROSITY	=	0.1680 VOL/VOL
FIELD CAPACITY	=	0.0730 VOL/VOL
WILTING POINT	=	0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0713 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 3 (10 ft waste)

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 19

THICKNESS	=	120.00 INCHES
POROSITY	=	0.1680 VOL/VOL
FIELD CAPACITY	=	0.0730 VOL/VOL
WILTING POINT	=	0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0730 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 4 (10 ft waste)

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 19

THICKNESS	=	120.00 INCHES
POROSITY	=	0.1680 VOL/VOL
FIELD CAPACITY	=	0.0730 VOL/VOL
WILTING POINT	=	0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0730 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 5 (5 ft waste)

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 19

THICKNESS	=	60.00 INCHES
POROSITY	=	0.1680 VOL/VOL
FIELD CAPACITY	=	0.0730 VOL/VOL

```
WILTING POINT                  =     0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT     =     0.0730 VOL/VOL
EFFECTIVE SAT. HYD. COND.      =  0.100000005000E-02 CM/SEC


                         LAYER  6    (24-inch drainage sand)
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   7
THICKNESS                      =    24.00   INCHES
POROSITY                       =     0.4730 VOL/VOL
FIELD CAPACITY                 =     0.2220 VOL/VOL
WILTING POINT                  =     0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT     =     0.2590 VOL/VOL
EFFECTIVE SAT. HYD. COND.      =  0.520000001000E-03 CM/SEC


                         LAYER  7    (300-mil triplanar geocomposite)
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                      =     0.27   INCHES
POROSITY                       =     0.8500 VOL/VOL
FIELD CAPACITY                 =     0.0100 VOL/VOL
WILTING POINT                  =     0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT     =     0.0106 VOL/VOL
EFFECTIVE SAT. HYD. COND.      =   8.00000000000      CM/SEC
SLOPE                          =    45.00   PERCENT
DRAINAGE LENGTH                =   140.0    FEET


                         LAYER  8    (60-mil HDPE geomembrane)
                         --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
THICKNESS                      =     0.06   INCHES
POROSITY                       =     0.0000 VOL/VOL
FIELD CAPACITY                 =     0.0000 VOL/VOL
WILTING POINT                  =     0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT     =     0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.      =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY            =     0.50   HOLES/ACRE
FML INSTALLATION DEFECTS       =     1.00   HOLES/ACRE
FML PLACEMENT QUALITY          =  5 - BAD
```

LAYER 9 (250-mil biplanar geocomposite)

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	0.23	INCHES
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	2.50000000000	CM/SEC
SLOPE	=	45.00	PERCENT
DRAINAGE LENGTH	=	140.0	FEET

LAYER 10 (60-mil HDPE geomembrane)

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.50	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 11 (GCL)

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	0.25	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.	=	0.499999997000E-08	CM/SEC

LAYER 12 (sub-base)

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4570	VOL/VOL

FIELD CAPACITY	=	0.1310 VOL/VOL
WILTING POINT	=	0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1310 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.299999992000E-04 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 5 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 4.% AND A SLOPE LENGTH OF 121. FEET.

SCS RUNOFF CURVE NUMBER	=	84.60	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.424	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	3.414	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.424	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	40.345	INCHES
TOTAL INITIAL WATER	=	40.345	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM TAMPA FLORIDA

STATION LATITUDE	=	27.58	DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00	
START OF GROWING SEASON (JULIAN DATE)	=	0	
END OF GROWING SEASON (JULIAN DATE)	=	367	
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	8.60	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	72.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	78.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	76.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR TAMPA FLORIDA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

-------	-------	-------	-------	-------	-------
2.94	3.26	2.35	0.68	1.38	8.20
13.13	8.40	20.26	1.27	0.70	3.15

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TAMPA FLORIDA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
59.80	60.80	66.20	71.60	77.10	80.90
82.20	82.20	80.90	74.50	66.70	61.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR TAMPA FLORIDA
AND STATION LATITUDE = 27.58 DEGREES

WARNING: TEMPERATURE FOR YEAR 1 USED WITH PRECIPITATION FOR YEAR 2003

WARNING: SOLAR RADIATION FOR YEAR 1 USED WITH PRECIPITATION FOR YEAR 2003

WARNING: TEMPERATURE FOR YEAR 2 USED WITH PRECIPITATION FOR YEAR 2004

WARNING: SOLAR RADIATION FOR YEAR 2 USED WITH PRECIPITATION FOR YEAR 2004

WARNING: TEMPERATURE FOR YEAR 3 USED WITH PRECIPITATION FOR YEAR 2005

WARNING: SOLAR RADIATION FOR YEAR 3 USED WITH PRECIPITATION FOR YEAR 2005

WARNING: TEMPERATURE FOR YEAR 4 USED WITH PRECIPITATION FOR YEAR 2006

WARNING: SOLAR RADIATION FOR YEAR 4 USED WITH PRECIPITATION FOR YEAR 2006

WARNING: TEMPERATURE FOR YEAR 5 USED WITH PRECIPITATION FOR YEAR 2007

WARNING: SOLAR RADIATION FOR YEAR 5 USED WITH PRECIPITATION FOR YEAR 2007

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 2003 THROUGH 2007

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.73	3.58	3.16	2.50	3.25	10.36
	10.75	6.83	6.87	3.18	1.88	3.01
STD. DEVIATIONS	1.00	1.67	2.61	2.89	2.97	8.03
	2.46	1.27	7.65	3.23	1.54	1.29
RUNOFF						
TOTALS	0.071	0.225	0.271	0.227	0.233	2.026
	1.360	0.368	1.860	0.215	0.167	0.107
STD. DEVIATIONS	0.158	0.234	0.332	0.486	0.436	3.256
	0.881	0.321	3.756	0.481	0.371	0.073
EVAPOTRANSPIRATION						
TOTALS	1.303	1.663	1.788	1.318	1.437	4.160
	5.316	4.165	3.004	1.770	0.649	1.306
STD. DEVIATIONS	0.449	0.659	1.304	1.556	1.084	1.480
	0.790	0.703	0.950	1.214	0.464	0.813
LATERAL DRAINAGE COLLECTED FROM LAYER 7						
TOTALS	1.1924	0.8924	1.4767	1.3908	1.1121	1.6498
	4.3406	3.8660	2.0324	1.9203	0.8394	0.9333
STD. DEVIATIONS	0.4865	0.3185	1.3986	1.4312	0.9319	1.2912
	2.5911	1.8751	1.7168	1.6257	0.6508	1.0348
PERCOLATION/LEAKAGE THROUGH LAYER 8						
TOTALS	0.0169	0.0140	0.0180	0.0174	0.0154	0.0180
	0.0325	0.0317	0.0211	0.0206	0.0136	0.0136
STD. DEVIATIONS	0.0029	0.0024	0.0081	0.0078	0.0078	0.0074
	0.0105	0.0079	0.0080	0.0090	0.0063	0.0059
LATERAL DRAINAGE COLLECTED FROM LAYER 9						
TOTALS	0.0169	0.0140	0.0180	0.0174	0.0154	0.0180
	0.0325	0.0317	0.0211	0.0206	0.0136	0.0136
STD. DEVIATIONS	0.0029	0.0024	0.0081	0.0078	0.0078	0.0074
	0.0105	0.0079	0.0080	0.0090	0.0063	0.0059
PERCOLATION/LEAKAGE THROUGH LAYER 11						

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

PERCOLATION/LEAKAGE THROUGH LAYER 12

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 8

AVERAGES	0.0003	0.0003	0.0004	0.0004	0.0003	0.0005
	0.0012	0.0010	0.0006	0.0005	0.0002	0.0002
STD. DEVIATIONS	0.0001	0.0001	0.0004	0.0004	0.0002	0.0004
	0.0007	0.0005	0.0005	0.0004	0.0002	0.0003

DAILY AVERAGE HEAD ON TOP OF LAYER 10

AVERAGES	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 2003 THROUGH 2007

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.11 (11.991)	207309.3	100.00
RUNOFF	7.129 (4.0139)	25879.55	12.484
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PERCOLATION/LEAKAGE THROUGH LAYER 8	0.23291 (0.02785)	845.466	0.40783

AVERAGE HEAD ON TOP OF LAYER 8	0.000 (	0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 9	0.23291 (	0.02785)	845.466	0.40783
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.00000 (	0.00000)	0.001	0.00000
AVERAGE HEAD ON TOP OF LAYER 10	0.000 (	0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.00000 (	0.00000)	0.001	0.00000
CHANGE IN WATER STORAGE	0.223 (	1.4310)	810.02	0.391

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PEAK DAILY VALUES FOR YEARS 2003 THROUGH 2007

	(INCHES)	(CU. FT.)
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PERCOLATION/LEAKAGE THROUGH LAYER 8	0.002526	9.17016
AVERAGE HEAD ON TOP OF LAYER 8	0.005	
MAXIMUM HEAD ON TOP OF LAYER 8	0.036	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 9	0.00253	9.17016
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.000000	0.00000
AVERAGE HEAD ON TOP OF LAYER 10	0.000	
MAXIMUM HEAD ON TOP OF LAYER 10	0.037	
LOCATION OF MAXIMUM HEAD IN LAYER 9 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.000001	0.00433
SNOW WATER	0.00	0.0000

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.2445

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0424

*** 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.

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FINAL WATER STORAGE AT END OF YEAR 2007

LAYER	(INCHES)	(VOL/VOL)
1	0.5392	0.0899
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5	4.3800	0.0730
6	6.9554	0.2898
7	0.0032	0.0118
8	0.0000	0.0000
9	0.0023	0.0100
10	0.0000	0.0000
11	0.1875	0.7500
12	3.1440	0.1310
SNOW WATER	0.000	

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SCS ENGINEERS

SHEET ________ OF ________

CLIENT	PROJECT	JOB NO.
Citrus County	Phase 3 - Alternate Procedure	09207049.02

SUBJECT	BY	DATE
Transmissivity/Hydraulic Conductivity Calculations	DHB	10/21/2008
	CHECKED QR	DATE 10/27/08

OBJECTIVE:

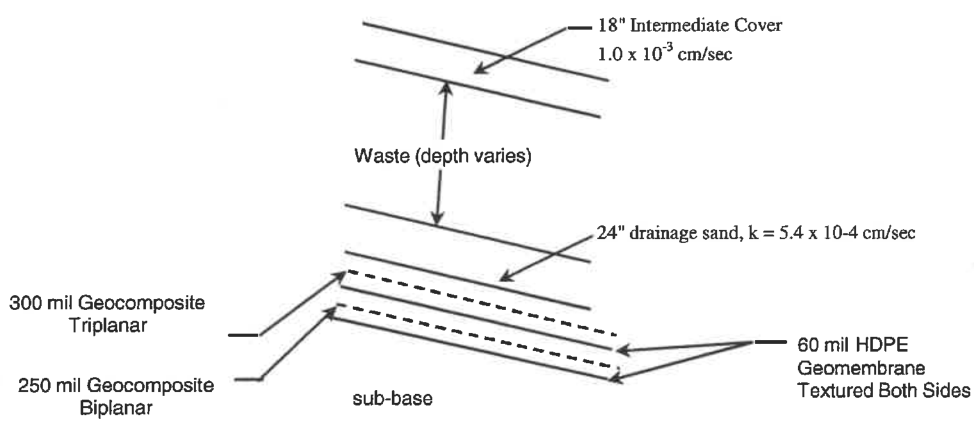
To determine the hydraulic conductivity for the geocomposite used in the leachate collection and removal system (LCRS) and leak detection system.

REFERENCES:

1. GRI Standard - GC8 Technical Release, April 17, 2001
2. Hydrologic Evaluation of Landfill Performance (HELP Model), ver 3.07
3. Triplanar Material Properties (Tendrain 770-2 Double sided Geocomposite)
4. Biplanar Material Properties (GSE 250 mil Double sided Composite)
5. "Table 4 - Default Soil, Waste, and Geosynthetic Characteristics" for HELP Model.

PROCEDURE:

1. Geocomposite properties are dependent on landfill load, landfill leachate and other conditions. Determine loads on geocomposite.
2. GRI Standard - GC8 is a way to determine geocomposite allowable flow rates based on specific landfill conditions.
3. Use Excel spreadsheet to calculate the downstream hydraulic conductivity (k) for various landfill conditions.
4. Use Table 4 - "Default Soil, Waste, and Geosynthetic Characteristics" for soil texture within the HELP Model.
5. Use calculated values in step 3 to run the HELP Model.



SCS ENGINEERS

SHEET ______ OF ______

CLIENT	PROJECT	JOB NO.	
Citrus County	Phase 3 - Alternate Procedure	09207049.02	
SUBJECT		BY:	DATE:
HELP Model Load Calculations		DHB	10/21/2008
		CHECKED:	DATE:
		DB	10/27/08

Open Cell, 35 ft waste

Material	Material Density (pcf)	Depth of material (ft)	Load (psf)
Sand	110	2.0	220
Solid Waste	60	35.0	2,100
Soil Cover	110	0.5	55
		Total	**2,375**

SCS ENGINEERS			
SHEET ______ OF ______			
CLIENT Citrus County	PROJECT Phase 3 - Alternate Procedure	JOB NO. 09207049.02	
SUBJECT Transmissivity/Hydraulic Conductivity Calculations	BY DHB	DATE 10/21/2008	
	CHECKED QB	DATE 10/27/08	

EQUATIONS:

From Attachment 2

$$T_{allow} = \frac{T_{ultimate}}{RF_{IN} * RF_{CC} * RF_{BC} * RF_{CR} * FS}$$

Where,

3. RF_{IN} = Intrusion reduction factors (accounted for in RF_{CR})
4. RF_{CC} = Chemical clogging reduction factor
5. RF_{BC} = Biological clogging reduction factor

RF_{CR} = Creep reduction factor

$$RF_{CR} = \left[\frac{(t'/t) - (1 - n_{original})}{(t_{CR}/t) - (1-n_{original})}\right]^3$$

Where,

t' = Thickness at 100 hours

t = Virgin thickness

HELP Model. Thickness at >> 100 hours

$n_{original}$ = Original porosity $= \frac{1 - \text{mass unit area}}{\text{density x thickness}}$

FS = Factor of Safety = 2 (Industry Standard)

$$k = \frac{T_{allow}}{t'}$$

Where,

k = Hydraulic conductivity, cm/sec

NOTE:

RF_{IN} accounts for the geotextile encroaching on the geonet under a constant loading. A 100-hour transmissivity test accounts for intrusion. After the 100-hour seat time, the geotextile has already begun to intrude into the geonet, therefore, the transmissivity value reflects the intrusion. The transmissivity values for these calculations are all based on the 100-hour test, therefore, RF_{IN} = 1.0.

TRIPLANAR (PRIMARY COLLECTION SYSTEM)

Purpose

Calculate the design transmissivity, k, of a 300-mil triplanar geocomposite under soil/geocomposite/geomembrane boundary conditions for various loading conditions.

From the TENAX technical department, the following Transmissivity (T) values are known:
(Based on TENDRAIN 770-2 geocomposite specifications). Refer to product specifications in HELP Model references.

@ 45% Gradient		(2H:1V)
Load (psf)	T (m^2/sec)	
2,500	2.00E-03	

Reduction Factors	thickness, t =	300 mil
RF-Intrusion, RF_{IN}		0.3 inches
RF-Chemical Clogging, RF_{CC}		0.762 cm
RF-Biological Clogging, RF_{BC}		
RF-Creep, RF_{CR}		
FS - Factor of Safety		

Equations

$$T_{allow} = \frac{T_{ultimate}}{RF_{IN} * RF_{CC} * RF_{BC} * RF_{CR} * FS}$$

$$t' = \frac{t}{RF_{CR}}$$

$$k = \frac{T_{allow}}{t'}$$

Leachate Collection System

Chemical Clogging RF_{CC} = 1.5 to 2.0
Biological Clogging RF_{BC} = 1.1 to 1.3

} Obtained from GRI Standard GC8 page GC8-9 provided in reference.

Leachate Detection System

Chemical Clogging RF_{CC} = 1.1 to 1.5
Biological Clogging RF_{BC} = 1.1 to 1.3

} Obtained from GRI Standard GC8 page GC8-9 provided in reference.

WASTE LOAD 2,500 PSF

Reduction Factors		thickness, t =	300 mil
RF_{IN} =	1.0		0.3 inches
RF_{CC} =	1.5		0.762 cm
RF_{BC} =	1.1		
RF_{CR} =	1.1		
FS =	2.0		

2H:1V					
Load (psf)	T (m^2/sec)	T_{allow} (m^2/sec)	T_{allow} (cm^2/sec)	t' (cm)	k (cm/sec)
2,500	2.00E-03	5.51E-04	5.5	0.693	8.0

t' = 0.273 inches

BIPLANAR (SECONDARY COLLECTION SYSTEM)

Purpose

Calculate the design transmissivity, k, of a 250-mil biplanar geocomposite under geomembrane/geocomposite/geomembrane boundary conditions for various loading conditions.

From the GSE technical department, the following Transmissivity (T) values are known: (Based on GSE Drainage Design Manual). Refer to graph in references.

@ 45% Gradient		(2H:1V)
Load (psf)	T (m^2/sec)	
1,000	4.10E-04	
2,500	3.85E-04	(interpolated value)
10,000	2.60E-04	

Reduction Factors

RF-Intrusion, RF_{IN}

RF-Chemical Clogging, RF_{CC}

RF-Biological Clogging, RF_{BC}

RF-Creep, RF_{CR}

FS - Factor of Safety

thickness, t = 250 mil
0.25 inches
0.635 cm

Equations

$$T_{allow} = \frac{T_{ultimate}}{RF_{IN} * RF_{CC} * RF_{BC} * RF_{CR} * FS}$$

$$t' = \frac{t}{RF_{CR}}$$

$$k = \frac{T_{allow}}{t'}$$

Leachate Collection System

Chemical Clogging RF_{CC} = 1.5 to 2.0
Biological Clogging RF_{BC} = 1.1 to 1.3

} Obtained from GRI Standard GC8 page GC8-9 provided in reference.

Leachate Detection System

Chemical Clogging RF_{CC} = 1.1 to 1.5
Biological Clogging RF_{BC} = 1.1 to 1.3

} Obtained from GRI Standard GC8 page GC8-9 provided in reference.

WASTE LOAD 2,500 PSF

Reduction Factors

RF_{IN} = 1.0
RF_{CC} = 1.1
RF_{BC} = 1.1
RF_{CR} = 1.1
FS = 2.0

thickness, t = 250 mil
0.25 inches
0.635 cm

2H:1V						
Load (psf)	T (m^2/sec)	T_{allow} (m^2/sec)	T_{allow} (cm^2/sec)	t' (cm)	k (cm/sec)	
2,500	3.85E-04	1.45E-04	1.4	0.577	2.5	case 3

t' = 0.227 inches

Rainfall Data
Citrus County Central Landfill

2003	
JAN	2.53
FEB	6.13
MAR	5.36
APR	1.62
MAY	3.39
JUN	24.55
JUL	8.85
AUG	6.23
SEP	1.64
OCT	1.44
NOV	1.28
DEC	0.99
YTD TOT	**64.01**

2004	
JAN	2.94
FEB	3.26
MAR	2.35
APR	0.68
MAY	1.38
JUN	8.20
JUL	13.13
AUG	8.40
SEP	20.26
OCT	1.27
NOV	0.70
DEC	3.15
YTD TOT	**65.72**

2005	
JAN	1.20
FEB	1.50
MAR	6.30
APR	7.40
MAY	8.35
JUN	7.85
JUL	13.50
AUG	5.50
SEP	2.27
OCT	3.32
NOV	4.58
DEC	3.85
YTD TOT	**65.62**

2006	
JAN	0.47
FEB	3.83
MAR	0.00
APR	0.20
MAY	1.43
JUN	6.13
JUL	8.11
AUG	6.06
SEP	5.00
OCT	1.12
NOV	1.61
DEC	4.34
YTD TOT	**38.30**

2007	
JAN	1.53
FEB	3.19
MAR	1.80
APR	2.62
MAY	1.68
JUN	5.08
JUL	10.17
AUG	7.95
SEP	5.19
OCT	8.73
NOV	1.25
DEC	2.71
YTD TOT	**51.90**

CITRUS COUNTY CENTRAL LANDFILL

2003 Month Day	January Rainfall	February Rainfall	March Rainfall	April Rainfall	May Rainfall	June Rainfall	July Rainfall	August Rainfall	September Rainfall	October Rainfall	November Rainfall	December Rainfall
1	2.43	0.00	0.09	0.00	0.00	0.02	0.00	0.00	0.15	0.00	0.00	0.00
2	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.12	0.00
3	0.00	0.00	1.39	0.00	0.00	2.02	0.00	1.17	0.01	0.00	0.00	0.00
4	0.00	0.36	0.18	0.00	0.00	3.81	0.94	0.00	0.00	0.00	0.00	0.03
5	0.00	0.00	0.01	0.00	0.00	0.04	0.00	0.08	0.09	0.00	0.48	0.00
6	0.02	0.18	0.00	0.00	0.00	0.00	0.56	0.00	0.03	0.00	0.00	0.00
7	0.00	0.00	1.63	0.00	0.00	0.00	0.00	0.55	0.00	0.03	0.00	0.00
8	0.00	0.00	0.58	0.09	0.00	0.79	0.14	0.43	0.00	0.00	0.00	0.00
9	0.01	1.01	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
10	0.00	0.35	0.00	0.05	0.00	0.11	1.81	0.00	0.00	0.01	0.00	0.11
11	0.01	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	1.34	0.67	0.47	0.00	0.00	0.00	0.00
13	0.04	0.00	0.00	0.00	0.00	0.00	0.05	0.03	0.05	0.28	0.00	0.79
14	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.10	0.00	0.02	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.26	2.48	0.00	0.00	0.00	0.00	0.00
16	0.00	1.38	0.28	0.02	0.00	0.31	0.02	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.92	0.79	0.00	0.00	0.00	0.00	0.00	0.01
18	0.00	0.00	0.00	0.00	0.00	5.40	0.00	0.04	0.00	0.00	0.20	0.00
19	0.00	0.00	0.00	0.00	0.55	1.58	0.00	1.51	0.00	0.00	0.35	0.00
20	0.00	0.00	0.09	0.00	0.00	2.37	0.00	0.80	0.00	0.00	0.00	0.00
21	0.00	0.00	0.01	0.00	0.02	1.70	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	1.72	0.00	0.00	1.90	0.01	0.00	0.75	0.00	0.00	0.00	0.00
23	0.00	0.00	0.29	0.00	0.00	0.00	0.60	0.00	0.03	0.00	0.00	0.03
24	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	1.39	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.30	0.20	0.12	0.00	0.00
27	0.00	0.42	0.71	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
28	0.00	0.71	0.00	0.00	0.00	3.64	0.00	0.00	0.12	0.98	0.13	0.00
29	0.00		0.00	0.03	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
30	0.00		0.10	0.00	0.00	0.36	0.02	0.00	0.00	0.00	0.00	0.00
31	0.00		0.00		0.00		0.01	0.00		0.00		0.00
Total	**2.53**	**6.13**	**5.36**	**1.62**	**3.39**	**24.55**	**8.85**	**6.23**	**1.64**	**1.44**	**1.28**	**0.99**

CITRUS COUNTY CENTRAL LANDFILL

2004 Month Day	January Rainfall	February Rainfall	March Rainfall	April Rainfall	May Rainfall	June Rainfall	July Rainfall	August Rainfall	September Rainfall	October Rainfall	November Rainfall	December Rainfall
1	0.00	0.01	0.00	0.00	0.00	0.00	0.00	1.80	0.10	0.10	0.00	0.00
2	0.00	0.00	0.00	0.00	0.55	0.20	0.00	0.00	0.20	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.77	0.00	0.00	0.40	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.02	0.00	0.00
5	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.10	6.00	0.00	0.10	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	5.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	1.30	0.05	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.06	0.00	0.00	0.20	0.40	0.00	0.36	0.00	0.00	0.00
10	0.09	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.15	0.00	0.20
11	0.00	0.00	0.00	0.65	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	1.30	0.00	0.00	0.00
13	0.00	0.00	0.00	0.03	0.00	1.10	0.20	1.40	0.00	0.00	0.00	0.00
14	0.00	0.89	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	2.23	0.00	0.00	1.00	0.00	0.00	0.20	0.00	0.00	0.00
16	0.01	0.01	0.06	0.00	0.00	0.20	0.90	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.96	0.00	0.00	0.00	0.00	0.00	4.40	1.00	0.00	0.00	0.00	0.00
19	0.43	0.00	0.00	0.00	0.00	0.00	1.20	0.00	0.00	0.55	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.40	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.20	0.00	0.00	0.00	0.00
23	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	1.80
24	0.00	1.87	0.00	0.00	0.00	0.00	1.40	0.00	0.00	0.00	0.00	0.00
25	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.53	0.00	0.00	0.00	0.00	1.10	0.10	0.00	5.50	0.00	0.00	0.70
27	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.60	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	3.20	0.00	0.00	0.00	0.00	0.45
29	0.00	0.00	0.00	0.00	0.00	1.50	0.00	0.30	0.10	0.00	0.00	0.00
30	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.91		0.00		0.00		0.10	0.00		0.00		0.00
Total	2.94	3.26	2.35	0.68	1.38	8.20	13.13	8.40	20.26	1.27	0.70	3.15

CITRUS COUNTY CENTRAL LANDFILL

2005 Month Day	January Rainfall	February Rainfall	March Rainfall	April Rainfall	May Rainfall	June Rainfall	July Rainfall	August Rainfall	September Rainfall	October Rainfall	November Rainfall	December Rainfall
1	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.40	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.55	0.11	0.00
3	0.00	0.20	0.30	1.50	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00
4	0.00	0.00	0.00	0.00	2.80	0.00	0.90	0.20	0.20	0.10	0.00	0.00
5	0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.20	0.00	0.00	0.24
6	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.65	0.20	0.79	0.00	0.00
7	0.00	0.00	0.00	3.60	0.00	0.00	0.00	0.35	0.00	0.00	0.00	1.40
8	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.30	0.00	0.04	0.00	0.11
9	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.30	0.00	0.18
10	0.00	0.00	0.00	0.00	0.00	0.30	3.00	0.10	0.00	0.00	0.00	0.09
11	0.00	0.00	0.00	0.00	0.00	0.70	0.20	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.30	0.40	0.00	0.00	0.00	0.00	0.04
13	0.90	0.00	0.00	0.00	0.00	0.90	2.10	0.00	0.00	0.00	0.00	0.00
14	0.30	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.10	0.00	0.00	0.00	1.10	0.20	0.00	0.00	0.00	0.30
16	0.00	0.00	0.60	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.20	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.49
18	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.20	0.00	0.00	0.00	0.05
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.10	0.20	0.00	0.23	0.20	0.37	0.00
21	0.00	0.00	0.30	0.00	0.00	0.90	0.00	0.00	0.00	0.17	0.33	0.00
22	0.00	0.00	1.25	0.00	0.50	0.30	0.00	0.20	0.44	0.03	0.00	0.00
23	0.00	0.00	0.10	1.40	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.00
24	0.00	0.80	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.01	0.00	0.84
25	0.00	0.20	0.00	0.00	0.00	0.70	0.00	0.40	0.00	0.00	0.00	0.10
26	0.00	0.30	0.00	0.90	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
27	0.00	0.00	3.30	0.00	0.00	1.50	0.00	0.00	0.30	0.00	0.00	0.01
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.40	0.10	0.00	3.38	0.00
29	0.00		0.00	0.00	0.00	0.65	0.00	0.00	0.10	0.00	0.39	0.00
30	0.00		0.00	0.00	1.15	0.40	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00		0.00		2.00		2.80	0.50		0.00		0.00
Total	**1.20**	**1.50**	**6.30**	**7.40**	**8.35**	**7.85**	**13.50**	**5.50**	**2.27**	**3.32**	**4.58**	**3.85**

CITRUS COUNTY CENTRAL LANDFILL

2006 Month Day	January Rainfall	February Rainfall	March Rainfall	April Rainfall	May Rainfall	June Rainfall	July Rainfall	August Rainfall	September Rainfall	October Rainfall	November Rainfall	December Rainfall
1	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.40	0.00	0.00	0.00
2	0.36	1.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.10	0.26	0.00	0.00	0.18	0.00	0.00
4	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00
5	0.00	1.73	0.00	0.00	0.00	0.00	0.00	1.62	0.00	0.00	0.00	0.00
6	0.00	0.11	0.00	0.00	0.00	0.00	1.17	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	3.24	0.50	0.50	0.00	1.06	0.00
8	0.00	0.04	0.00	0.20	0.60	0.00	0.00	0.39	0.30	0.00	0.00	0.01
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.26	0.00	0.00	0.71	0.15	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	3.50	0.00	0.00	0.20	0.04	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.50	0.09	1.11	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.50	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.50	0.00
17	0.08	0.00	0.00	0.00	0.00	0.00	1.10	0.23	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.01	0.16	0.59	0.50	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	2.60	0.00	0.00	0.00
20	0.00	0.01	0.00	0.00	0.00	0.46	0.06	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.01	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	1.23
23	0.01	0.00	0.00	0.00	0.00	0.00	0.32	0.25	0.00	0.00	0.00	0.74
24	0.00	0.00	0.00	0.00	0.00	0.01	0.94	0.01	0.00	0.00	0.00	0.00
25	0.00	0.35	0.00	0.00	0.00	0.02	0.00	0.40	0.00	0.00	0.00	1.78
26	0.00	0.01	0.00	0.00	0.00	1.00	0.00	0.01	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.90	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
29	0.00		0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00		0.00		0.00		0.00	0.60		0.00		0.58
Total	**0.47**	**3.83**	**0.00**	**0.20**	**1.43**	**6.13**	**8.11**	**6.06**	**5.00**	**1.12**	**1.61**	**4.34**

CITRUS COUNTY CENTRAL LANDFILL

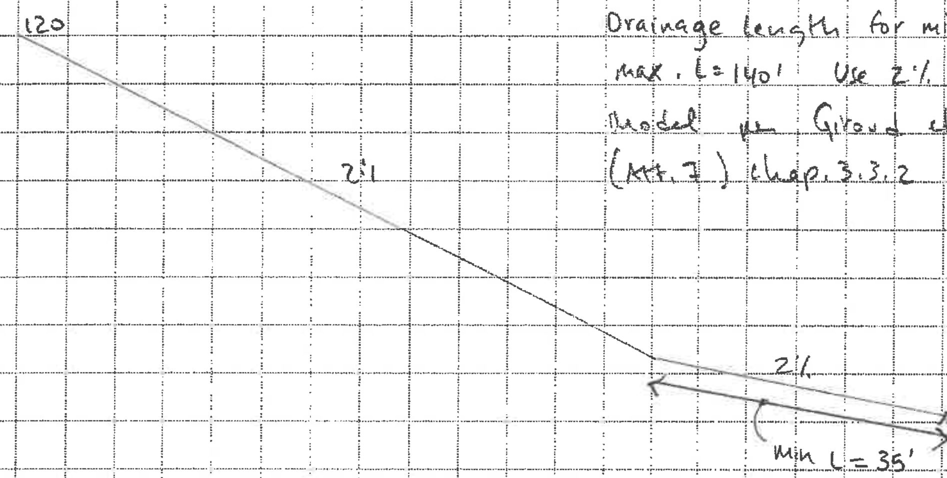
2007 Month Day	January Rainfall	February Rainfall	March Rainfall	April Rainfall	May Rainfall	June Rainfall	July Rainfall	August Rainfall	September Rainfall	October Rainfall	November Rainfall	December Rainfall
1	0.11	3.00	0.00	0.00	0.00	3.20	0.00	2.00	0.03	0.47	0.00	0.00
2	0.03	0.00	0.00	0.00	0.00	0.09	1.30	2.00	0.22	0.16	0.00	0.00
3	0.00	0.00	0.76	0.00	0.00	0.00	0.50	0.00	0.00	1.01	0.00	0.02
4	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	3.52	0.00	0.00
5	0.13	0.00	0.00	0.00	0.80	0.00	0.50	0.00	0.00	0.50	0.00	0.01
6	0.00	0.00	0.00	0.00	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.29	0.00	0.00
8	0.13	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
9	0.00	0.00	0.00	0.13	0.01	0.00	0.00	0.00	0.07	0.00	0.00	0.00
10	0.00	0.00	0.00	0.59	0.00	0.00	1.70	0.00	0.00	0.00	0.00	0.01
11	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.13	0.00	0.00	0.00	0.00
13	0.00	0.07	0.00	0.00	0.00	0.71	0.00	1.26	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.50	0.00	0.00	1.20	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.38	0.50	0.00	0.00	0.30	0.26	0.70	0.00	0.01	1.80
16	0.00	0.02	0.06	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00
17	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.04	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	1.00	0.23	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.76	0.12	0.00	1.60	0.00	0.00	0.40
21	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.30	0.50	0.00	0.00
22	0.40	0.00	0.00	0.00	0.00	0.01	2.75	0.00	0.24	0.00	0.45	0.01
23	0.00	0.00	0.00	0.00	0.01	0.00	0.18	0.00	0.73	0.89	0.00	0.00
24	0.43	0.00	0.00	0.00	0.00	0.00	0.06	0.19	0.00	0.08	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.00	0.20	0.00	0.00
27	0.30	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.01	0.00	0.01
29	0.00		0.00	0.00	0.00	0.00	0.06	0.00	0.10	0.00	0.79	0.00
30	0.00		0.00	0.00	0.00	0.18	0.26	0.48	0.02	0.01	0.00	0.07
31	0.00		0.00		0.00		0.21	0.35		0.00		0.38
Total	**1.53**	**3.19**	**1.80**	**2.62**	**1.68**	**5.08**	**10.17**	**7.95**	**5.19**	**8.73**	**1.25**	**2.71**

SCS ENGINEERS

SHEET 1 OF 2

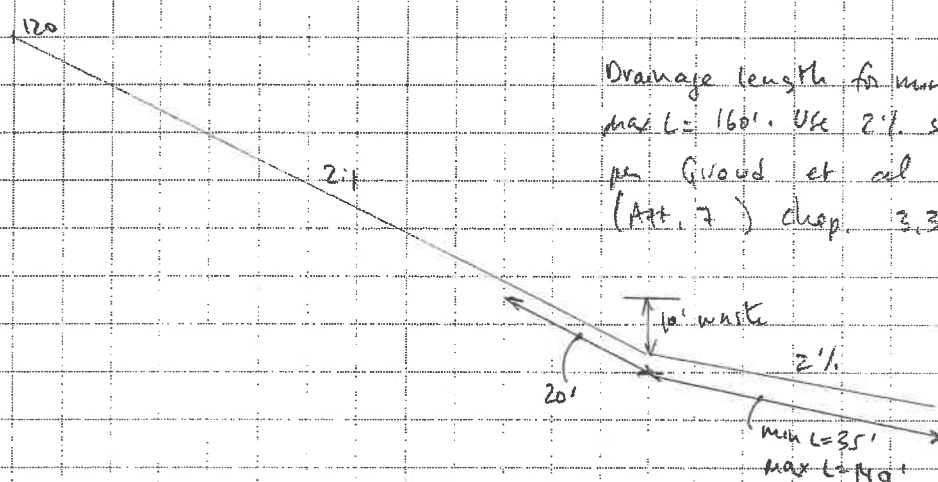
CLIENT Citrus County	PROJECT Citrus County Phase 3 Expansion	JOB NO. 09207049.02	
SUBJECT HELP model length Calculations		BY DHB	DATE 10/16/08
		CHECKED	DATE

Case 1 open cell (no waste)



Drainage length for minimum L=35' and max. L=140' Use 2% slope in HELP model per Giroud et al reference (Att. 7) chap. 3.3.2

Case 2 10' waste + 6" daily cover



Drainage length for min. L= 55' and max L= 160'. Use 2% slope in HELP Model per Giroud et al reference (Att. 7) chap. 3.3.2

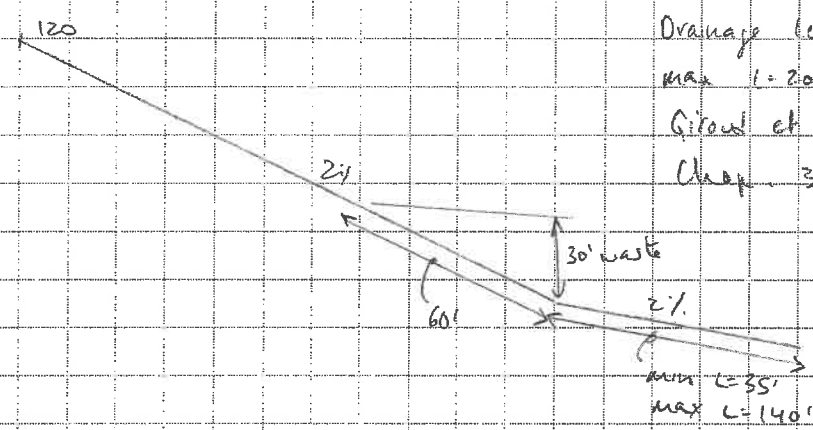
SCS ENGINEERS

SHEET 2 OF 2

CLIENT	PROJECT	JOB NO.
Citrus County	Citrus County Phase 3 Expansion	09207049.02

SUBJECT	BY	DATE
HELP Model length Calculations	DHB	10/16/08
	CHECKED	DATE

Case 3 30' waste + 6" daily cover

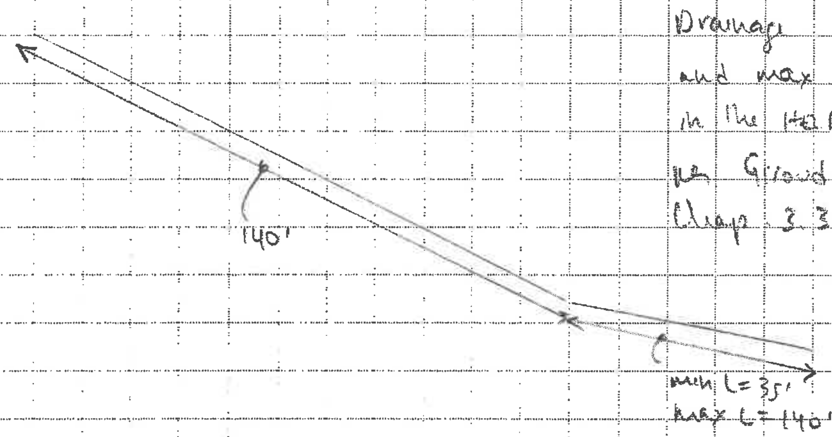


Drainage length for min. L=95' and max L=200'. Use 2% slope per Giroud et al reference (Att 7) Chap. 3.3.2

Case 4 & Case 5

Case 4 = 70' waste + 6" daily cover

Case 5 = 135' waste + 18" cover



Drainage length for min L=175' and max L=280'. Use 2% slope in the HELP model analysis per Giroud et al reference (Att. 7) Chap. 3.3.2

Drexel UNIVERSITY

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GRI GEI GII GSI GAI GCI

Original: April 17, 2001

GRI Standard – GC8

Standard Guide for

Determination of the Allowable Flow Rate of a Drainage Geocomposite

1. Scope

1.1 This guide presents a methodology for determining the allowable flow rate of a candidate drainage geocomposite. The resulting value can be used directly in a hydraulics-related design to arrive at a site-specific factor of safety.

1.2 The procedure is to first determine the candidate drainage composite's flow rate for 100-hours under site-specific conditions, and then modify this value by means of creep reduction and clogging reduction factors.

1.3 For aggressive liquids, a "go-no go" chemical resistance procedure is suggested. This is a product-specific verification test for both drainage core and geotextile covering.

1.4 The type of drainage geocomposites under consideration necessarily consists of a drainage core whose purpose it is to convey liquid within its manufactured plane. The drainage core can be a geonet, 3-D mesh, built-up columns, single or double cuspations, etc.

1.5 The drainage core usually consists of a geotextile on its upper and/or lower surface. In some cases, the drainage core is used by itself. The guide addresses all of these variations.

1.6 The guide is also applicable to thick nonwoven geotextiles when they are utilized for their drainage capability.

1.7 All types of polymers are under consideration in this guide.

1.8 The guide does not address the <u>required (or design)</u> flow rate to which a comparison is made for the final factor of safety value. This is clearly a site-specific issue.

2. Referenced Documents

2.1 ASTM Standards

D1987 – "Test Method for Biological Clogging of Geotextile or Soil/Geotextile Filters"
D2240 – "The Method for Rubber Property – Durometer Hardness"
D4716 – "Test Method for Constant Head Hydraulic Transmissivity (In Plane Flow) of Geotextiles and Geotextile Related Products"

D5322 – "Standard Practice for Immersion Procedures for Evaluating the Chemical Resistance of Geosynthetics to Liquids"
D6364 – "Test Method for Determining the Short-Term Compression Behavior of Geosynthetics"
D6388 – "Standard Practice for Tests to Evaluate the Chemical Resistance of Geonets to Liquids"
D6389 – "Standard Practice for Tests to Evaluate the Chemical Resistance of Geotextiles to Liquids"

2.2 GRI Standards
GS 4 Test Method for Time Dependent (Creep) Deformation Under Normal Pressure

2.3 Literature
Giroud, J.-P., Zhao, A. and Richardson, G. N. (2000), "Effect of Thickness Reduction on Geosynthetic Hydraulic Transmissivity," Geosynthetics International, Vol. 7, Nos. 4-6, pp. 433-452.
Koerner, R. M. (1998), Designing with Geosynthetics, Prentice Hall Publishing Co., Englewood Cliffs, NJ, 761 pgs.

3. Summary of Guide

3.1 This guide presents the necessary procedure to be used in obtaining an allowable flow rate of a candidate drainage geocomposite. The resulting value is then compared to a required (or design) flow rate for a product-specific and site-specific factor of safety. The guide does not address the required (or design) flow rate value, nor the subsequent factor of safety value.
3.2 The procedures recommended in this guide use either ASTM or GRI test methods.
3.3 The guide is applicable to all types of drainage geocomposites regardless of their core configuration or geotextile type. It can also be used to evaluate thick nonwoven geotextiles.

4. Significance and Use

4.1 The guide is meant to establish uniform test methods and procedures in order for a designer to determine the allowable flow rate of a candidate drainage geocomposite for site-specific conditions.
4.2 The guide requires communication between the designer, testing organization and manufacturer in setting site-specific control variables such as product orientation, stress level, stress duration, type of permeating liquid and materials below/above the geocomposite test specimen.
4.3 The guide is useful to testing laboratories in that a prescribed guide is at hand to provide appropriate data for both designer and manufacturer clients.

5. Structure of the Guide

5.1 Basic Formulation – This guide is focused on determination of a "q_{allow}" value using the following formula:

$$q_{allow} = q_{100}\left[\frac{1}{RF_{CR} \times RF_{CC} \times RF_{BC}}\right] \quad (1)$$

where

q_{allow} = allowable flow rate
q_{100} = initial flow rate determined under simulated conditions for 100-hour duration
RF_{CR} = reduction factor for creep to account for long-term behavior
RF_{CC} = reduction factor for chemical clogging
RF_{BC} = reduction factor for biological clogging

> Note 1: By simulating site-specific conditions (except for load duration beyond 100 hours and chemical/biological clogging), additional reduction factors such as intrusion need not be explicitly accounted for.
>
> Note 2: The value of q_{allow} is typically used to determine the product-specific and site-specific flow rate factor of safety as follows:
>
> $$FS = \frac{q_{allow}}{q_{reqd}} \quad (2)$$
>
> The value of "q_{reqd}" is a design issue and is not addressed in this guide. Likewise, the numeric value of the factor-of-safety is not addressed in this guide. Suffice it to say that, depending on the duration and criticality of the situation, FS-values should be conservative unless experience allows otherwise.

5.2 Upon selecting the candidate drainage geocomposite product, one must obtain the 100-hour duration flow rate according to the ASTM D4716 transmissivity test. This establishes the base value to which drainage core creep beyond 100-hours and clogging from chemicals and biological matter must be accounted for.

> Note 3: It is recognized that the default duration listed in ASTM D4716 is 15-minutes. This guide purposely requires that the test conditions be maintained for 100-hours.

5.3 Reduction Factor for Creep – This is a long-term (typically 10,000 hours) compressive load test focused on the stability and/or deformation of the drainage core without the covering geotextiles. Stress orientation can be perpendicular or at an angle to the test specimen depending upon site-specific conditions.

5.4 Chemical and/or Biological Clogging – The issue of long term reduction factors to account for clogging within the core space is a site-specific issue. The issue is essentially impractical to simulate in the laboratory, hence a table is provided for consideration by the designer.

5.5 Chemical Resistance/Durability – This procedure results in a "go-no go" decision as to potential chemical reactions between the permeating liquid and the polymers comprising the drainage core and geotextiles. The issue will be addressed in this guide but is not a reduction factor, per se.

6. Determination of the Base Line Flow Rate (q_{100})

6.1 Using the ASTM D4716 transmissivity test with the conditions stated below (unless otherwise agreed upon by the parties involved), determine the 100-hour flow rate of the drainage geocomposite under consideration.

6.1.1 The test specimen shall be the entire geocomposite. If geotextiles are bonded to the drainage core, they shall not be removed and the entire geocomposite shall be tested as a unit. A minimum of three replicate samples in the site-specific orientation shall be tested and the results averaged for the reported value.

6.1.2 Specimen size shall be 300 × 300 mm (12 × 12 in.) within the stressed area.

6.1.3 The specimen orientation is to be agreed upon by the designer, testing laboratory and manufacturer. In this regard, it should be recognized that the specimen orientation during testing has to match the proposed installation orientation. Thus the site-specific design governs both the testing orientation and subsequent field installation orientation.

6.1.4 Specimen substratum shall be one of the following four options. The decision of which is made by the project designer, testing organization and manufacturer. The options are (i) rigid platen, (ii) foam, (iii) sand or (iv) site-specific soil or other material.

6.1.4.1 If a rigid platen is used the choices are usually wood, plastic or metal. The testing laboratory must identify the specifics of the material used.

6.1.4.2 If closed cell foam is used, it shall be 12 mm (0.5 in.) thick and a maximum durometer of 2.0 as measured in ASTM D2240, Type D.

6.1.4.3 If sand is used it shall be Ottawa test sand at a relative density of 85%, water content of 10% and compacted thickness of 25 mm (1.0 in.).

6.1.4.4 If site-specific soil or other material is used it must be carefully considered and agreed upon between the parties involved. Size, gradation, moisture content, density, etc., are all important considerations.

6.1.5 Specimen superstratum shall also be one of the four same options as mentioned in § 6.1:3 above. It need not be the same as the substratum.

6.1.6 The applied stress level is at the discretion of the designer, testing organization and manufacturer. Unless stated otherwise, the orientation shall be normal to the test specimen.

6.1.7 The duration of the loading shall be for 100 hours. A single site-specific data point is obtained at that time, i.e., it is not necessary to perform intermediate flow rate testing, unless otherwise specified by the various parties involved.

6.1.8 The hydraulic gradient at which the above data point is taken (or a range of hydraulic gradients) is at the discretion of the designer, testing organization and manufacturer.

6.1.9 The permeating liquid is to be tap water, unless agreed upon otherwise by the designer, testing organization, and manufacturer.

6.1.10 Calculations

$$Q = kiA \qquad (3)$$

$$Q = ki(Wt)$$

$$Q/W = \theta i \qquad (4)$$

$$q = \theta i \qquad (5)$$

where

- Q = flow rate per unit time (m^3/sec)
- k = permeability (m/sec)
- i = hydraulic gradient (= H/L)
- H = head loss across specimen (m)
- L = length of specimen (m)
- A = cross sectional area of specimen (m^2)
- W = width of specimen (m)
- t = thickness of specimen (m)
- θ = transmissivity (m^3/sec-m or m^2/sec)
- q = flow rate per unit width (m^2/sec)

The results can be presented as flow rate per unit width (Q/W), or as transmissivity (θ), as agreed upon by the parties involved.

7. Reduction Factor for Creep

7.1 Using the GRI GS4 test method or ASTM D6364 (mod.) for time dependent (creep) deformation, the candidate drainage core is placed under compressive stress and its decrease in thickness (deformation) is monitored over time.

> Note 4: This is not a flow rate test, although the test specimen can be immersed in a liquid to be agreed upon by the designer, testing organization, and manufacturer. However, it is usually a test conducted without liquid.

7.1.1 The test specimen shall be the drainage core only. If geotextiles are bonded to the drainage core they should be carefully removed. Alternatively, a sample of the drainage core can be obtained from the manufacturer before the geotextiles are attached. A minimum of three replicate tests shall be performed and the results averaged for the reported value.

7.1.2 Specimen size should be 150 × 150 mm (6.0 × 6.0 in.) and placed in a rigid box made from a steel base and sides. The steel load plate above the test specimen shall be used to transmit a constant stress over time. Deformation of the upper plate is measured by at least two dial gauges and the results averaged accordingly.

Note 5: For high stress conditions requiring a large size and number of weights with respect to laboratory testing and safety, the specimen size can be reduced to 100 × 100 mm (4.0 × 4.0 in.).

7.1.3 Specimen substratum and superstratum shall be rigid platens. Alternatively, a 1.5 mm (60 mil) thick HDPE geomembrane can be placed against the drainage core with the steel plates as back-ups.

7.1.4 The test specimen shall be dry unless water or a simulated or site-specific leachate is agreed upon by the parties involved.

7.1.5 The normal stress magnitude(s) shall be the same as applied in the transmissivity test described in Section 6.0. Alternatively, it can be as agreed upon by the designer, testing organization, and manufacturer.

7.1.6 The load inclination shall be normal to the test specimen. If there exists a tendency for the core structure to deform laterally, separate tests at the agreed upon load inclinations shall also be performed at the discretion of the parties involved.

7.1.7 The dwell time shall be 10,000 hours. If, however, this is a confirmation test (or if a substantial data base exists on similar products of the same type), the dwell time can be reduced to 1000 hours. This decision must be made with agreement between the designer, testing organization, and manufacturer.

Note 6: Alternative procedures to arrive at an acceptable value for the creep reduction factor based on shorter test times (e.g., the use of time-temperature superposition or stepped isothermal method) may be acceptable if agreed upon by the various parties involved.

7.1.8 The above process results in a set of creep curves similar to Figure 1(a). The curves are to be interpreted as shown in Figure 1(b). The reduction factor for creep of the core is interpreted according to the following formulas, after Giroud, Zhao and Richardson (2000).

$$RF_{CR} = \left[\frac{\left(t_{CO}/t_{original}\right) - \left(1 - n_{original}\right)}{\left(t_{CR}/t_{original}\right) - \left(1 - n_{original}\right)}\right]^3 \qquad (6)$$

where

RF_{CR}	=	reduction factor for creep
$t_{original}$	=	original thickness (m)
t_{CO}	=	thickness at 100-hours (m)
t_{CR}	=	thickness at >>100-hours, e.g., at 10,000 hours (m)
$n_{original}$	=	original porosity (see Equation 7)

$$n_{original} = 1 - \frac{\mu}{\rho t_{original}} \qquad (7)$$

where

μ	=	mass per unit area (kg/m^2)
ρ	=	density of the formulation (kg/m^3)

7.1.9 The above illustrated numeric procedure is not applicable to drainage geocomposites which include geotextiles. It is for the drainage core only.

Example: A HDPE geonet has the following properties: mass per unit area μ = 1216 g/m^2 (or 1.216 kg/m^2); density ρ = 950 kg/m^2 and original thickness of 8.55 mm.

Test specimens were evaluated according to ASTM D4716 for 100 hours and the average thickness decreased to 7.14 mm. A 10,000 hour creep test was then performed on a representative specimen according to GRI-GS4 and the resulting thickness further decreased to 6.30 mm. Thus Δy in Figure 1(b) is 7.14 – 6.30 = 0.84 mm. Determine the creep reduction factor "RF_{CR}".

Solution: The porosity n, is calculated according to Eq. (7) as follows

$$\begin{aligned} n_{original} &= 1 - \frac{\mu}{\rho t_{original}} \\ &= 1 - \frac{1.216}{(950)(0.00855)} \\ &= 1 - 0.150 \\ n_{original} &= 0.850 \end{aligned}$$

The reduction factor for creep is calculated according to Eq. (6) as follows:

$$RF_{CR} = \left[\frac{(t_{CO} / t_{original}) - (1 - n_{original})}{(t_{CR} / t_{original}) - (1 - n_{original})}\right]^3$$

$$= \left[\frac{(7.14 / 8.55) - (1 - 0.850)}{(6.30 / 8.55) - (1 - 0.850)}\right]^3$$

$$= \left[\frac{0.835 - 0.150}{0.737 - 0.150}\right]^3$$

$$= \left[\frac{0.685}{0.587}\right]^3$$

$$RF_{CR} = 1.59$$

Note 7: Other calculation methods to arrive at the above numeric value of creep reduction factor may be considered if agreed upon by the various parties involved.

8. Reduction Factors for Core Clogging

There are two general types of core clogging that might occur over a long time period. They are chemical clogging and biological clogging. Both are site-specific and both are essentially impractical to simulate in the laboratory.

8.1 Chemical clogging within the drainage core space can occur with precipitates deposited from high alkalinity soils, typically calcium and magnesium. Other precipitates can also be envisioned such as fines from turbid liquids although this is less likely since the turbid liquid must typically pass through a geotextile filter. It is obviously a site-specific situation.

8.2 Biological clogging within the drainage core space can occur by the growth of biological organisms or by roots growing through the overlying soil and extending downward, through the geotextile filter, and into the drainage core. It is a site-specific situation and depends on the local, or anticipated, vegetation, cover soil, hydrology, etc.

8.3 Default tables for the above two potential clogging mechanisms (chemical and biological) are very subjective and by necessity broad in their upper and lower limits. The following table is offered as a guide.

Range of Clogging Reduction Factors (modified from Koerner, 1998)

Application	Chemical Clogging (RF_{CC})	Biological Clogging (RF_{BC})
Sport fields	1.0 to 1.2	1.1 to 1.3
Capillary breaks	1.0 to 1.2	1.1 to 1.3
Roof and plaza decks	1.0 to 1.2	1.1 to 1.3
Retaining walls, seeping rock and soil slopes	1.1 to 1.5	1.0 to 1.2
Drainage blankets	1.0 to 1.2	1.0 to 1.2
Landfill caps	1.0 to 1.2	1.2 to 3.5
Landfill leak detection	1.1 to 1.5	1.1 to 1.3
Landfill leachate collection	1.5 to 2.0	1.1 to 1.3

9. Polymer Degradation

9.1 Degradation of the materials from which the drainage geocomposite are made, with respect to the site-specific liquid being transmitted, is a polymer issue. Most geocomposite drainage cores are made from polyethylene, polypropylene, polyamide or polystyrene. Most geotextile filter/separators covering the drainage cores are made from polypropylene, polyester or polyethylene.

Note 8: It is completely inappropriate to strip the factory bonded geotextile off of the drainage core and then test one or the other component. The properties of both the geotextile and drainage core will be altered in the lamination process from their original values.

9.2 If polymer degradation testing is recommended, the drainage core and the geotextile should be tested separately in their as-received condition before lamination and bonding.

9.3 The incubation of the drainage cores and/or geotextile coupons is to be done according to the ASTM D5322 immersion procedure.

9.4 The testing of the incubated drainage cores is to be done according to ASTM D6388 which stipulates various test methods for evaluation of incubated geonets.

Note 9: For drainage cores other than geonets, e.g., columnar, cuspated, meshes, etc., it may be necessary to conduct additional tests than appear in ASTM D6388. These tests, and their procedures, should be discussed and agreed upon by the project designer, testing organization, and manufacturer.

9.5 The testing of the incubated geotextiles is to be done according to ASTM D6389 which stipulates various test methods for evaluation of incubated geotextiles.

Note 10: The information obtained in testing the drainage core (Section 9.4) and the geotextile (Section 9.5) result in a "go-no go" situation and not in a reduction factor, per se. If an adverse chemical reaction is indicated, one must select a different type of geocomposite material (drainage core and/or geotextile).

10. Summary

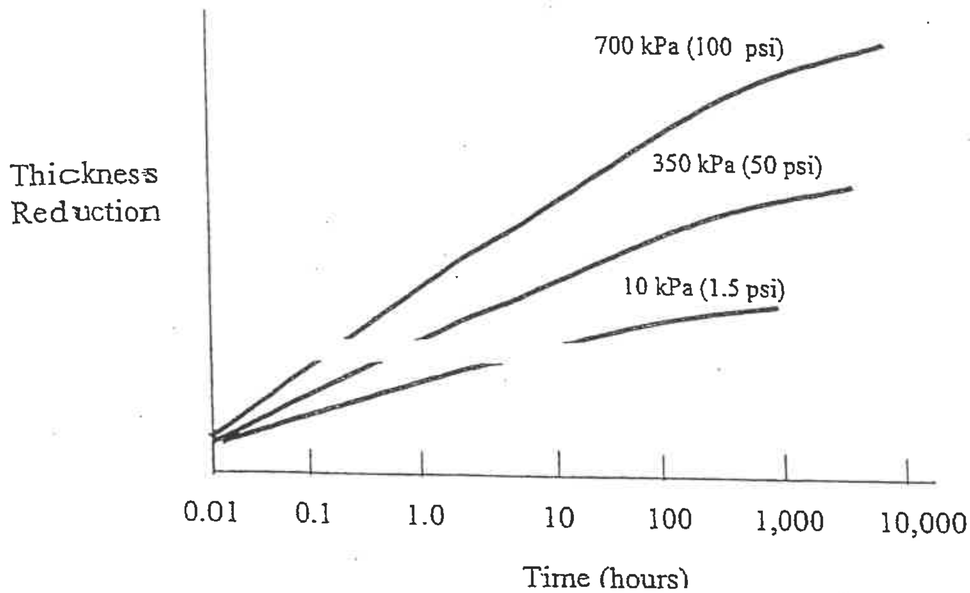
10.1 For a candidate drainage geocomposite, the 100-hour flow rate behavior under the site-specific set of variables, e.g., specimen orientation, stress level, hydraulic gradient, and permeating liquid is to be obtained per ASTM D4716 following procedures of Section 6.0.

10.2 A reduction factor for long term creep of the drainage core following Section 7.0 per GRI GS4 or ASTM D6364 (mod.) is then obtained. The result is usually a unique value for a given set of conditions.

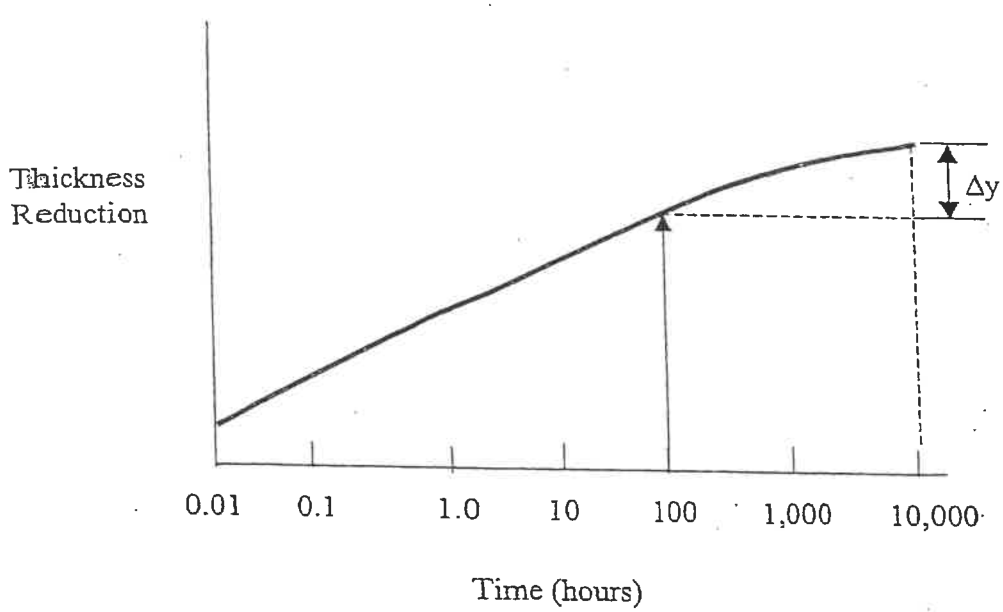
10.3 A reduction factor for chemical and/or biological clogging, as discussed in Section 8.0 can be included. It is very much a site-specific situation at the discretion of the parties involved.

10.4 Polymer degradation to aggressive liquids is covered in separate immersion and test protocols, e.g., ASTM D5322 (immersion), ASTM D6388 (geonets) and ASTM D6389 (geotextiles) as discussed in Section 9.0. The procedure does not result in a reduction factor, rather in a "go-no go" decision with the product under consideration.

10.5 Other possible flow rate reductions and/or concerns such as flow in overlap regions, effect of high or low temperatures, etc., are site-specific and cannot readily be generalized in a guide such as this.



(a) Hypothetical data from creep testing illustrating effect of normal load magnitude



(b) Interpretation of project specific normal load curve to obtain creep reduction factor

Figure 1 – Hypothetical example of creep test data and data interpretation to obtain creep reduction factor

Bramlett, Dominique

From: Aigen Zhao [AZhao@us.tenax.com]
Sent: Wednesday, October 22, 2008 10:49 AM
To: Banks, John
Cc: Bramlett, Dominique; JJ Leng
Subject: RE:
Attachments: TENDRAIN II_770_2.pdf; Tendrain 7 2000psf by Geotechnics.pdf

John and Dominique

Attached is the Tendrain 7 transmissivity data under 2000psf, at gradient = 0.5, trans =2 x10-3 m2/s (100 hour seating, in sand condition)

2:1 slope has a gradient = sin(26.6) = 0.45,

Your load is 2500psf, slightly higher than 2000psf, but gradient is lower than 0.5, so I recommend to use 2x10-3 m2/s as the transmissivity

Also I attached here the spec for the improved triplanar for your info, I will show you the sample tomorrow when we meet,

Best regards

Aigen

Aigen Zhao, PhD, PE
Vice President-Engineering
Tenax Corporation
4800 East Monument Street
Baltimore, Maryland 21205
U.S.A.
tel 410-522-7000, ext 2224
fax 410-522-7015
email azhao@tenax.com
website www.tenax.net

-----Original Message-----
From: Banks, John [mailto:JBanks@SCSEngineers.com]
Sent: Tuesday, October 21, 2008 5:54 PM
To: Aigen Zhao
Cc: Bramlett, Dominique
Subject: RE:

Hey Aigen, as discussed we are in need of transmissivity values for TD770 for a 2 to 1 slope (26.6 degrees). Hopefully this is something you already have available and you can have one of your team who forward this data to us. Thanks in advance for your help and I'll see you on Thursday.

John A. Banks, P.E.
Project Director
SCS Engineers
4041 Park Oaks Blvd, Suite 100
Tampa, FL 33610
813-621-0080 (Office)
813-623-6757 (Fax)
813-220-8556 (Cell)
jbanks@scsengineers.com

-----Original Message-----
From: Aigen Zhao [mailto:AZhao@us.tenax.com]
Sent: Tuesday, October 21, 2008 4:38 PM
To: Banks, John
Subject:

Hello John
I am in Tampa for the conf do you have time to get together for dinner tomorrow ?

Cell 4437222661

Best regards

Aigen

geotechnics
.... GEOTECHNICAL, GEOENVIRONMENTAL, AND GEOSYNTHETIC LABORATORIES

LABORATORY TEST REPORT

December 18, 2001

Ms. Ghada Ellithy
Tenax Corporation
4800 East Monument Street
Baltimore, MD 21205

Project No.: L01188-03

GAI-LAP
Initials: #: 14-41
Date: 12-17-01

RE: TRANSMISSIVITY TEST RESULTS
TENDRAIN 7 100-2 GEOCOMPOSITE

Transmitted herein are the results of the 100-hour transmissivity tests performed for the Tenax Corporation as directed on one pre-cut specimen of double-sided geocomposite submitted on December 12, 2001.

We are pleased to be of service and trust that our efforts have contributed to the success of your project. Should you have any questions or if we may be of any further assistance, please do not hesitate to call.

Respectfully submitted,

Richard S. Lacey, P.E.
Laboratory Director

attachments: 5 Data Pages

544 Braddock Avenue • East Pittsburgh, PA 15112 • Phone (412) 823-7600 • Fax (412) 823-8999

CAVEAT

The tests were performed in general accordance with the procedures referenced on the data tables as well as industry practice on test specimens believed to be representative of the samples submitted. The test results are indicative only of the specimens that were actually evaluated. There were no sample remnants.

Geotechnics has no direct knowledge of the origin of the samples submitted, implies no position with regard to the disposition of the test results, i.e. pass/fail, and makes no claims as to the suitability of the material for its intended end use.

The test data and all associated project information provided shall be held in confidence and disclosed to other parties not directly involved with the project only with the authorization of the Client and Geotechnics.

The test data transmitted herein is considered integral with this report and is not to be reproduced except in whole and only with the authorization of the Client and Geotechnics.

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TRANSMISSIVITY TEST RESULTS

ASTM D 4716

geotechnics

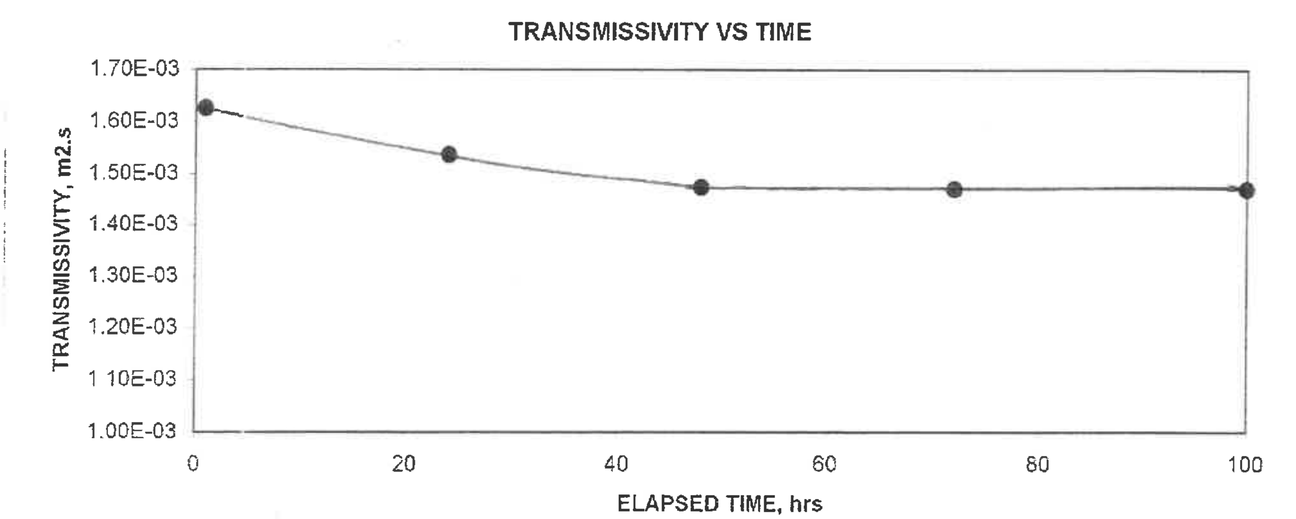
CLIENT: TENAX CORP.
PROJECT: QC
PROJECT NO.: L01188-03
MATERIAL: TENDRAIN 7 100-2

LAB I.D. NO.: L01188-03-01
LOT NO.: n.p.
ROLL NO.: n.p.
REPLICATE NO.: 1 of 1

TEST SECTION: SAND
GEOCOMPOSITE-MD
60-MIL SMOOTH HDPE

2,000 psf NORMAL COMPRESSIVE STRESS

ELAPSED TIME (hrs)	MANOMETERS RES. (cm)	MANOMETERS WEIR (cm)	HYDR. GRAD.	COLLECTION DATA VOLUME (ml)	COLLECTION DATA TIME (sec.)	WATER TEMP °C	AVERAGE FLOW RATE (l/s-m)	AVERAGE FLOW RATE (gpm/ft)	CALCULATED TRANSMISSIVITY (m2/sec)
1	40.60	10.12	1.000	17120 17120 17120	33.5 33.3 33.6	20.2	1.63E+00	7.857	1.63E-03
24	40.60	10.12	1.000	17120 17120 17120	35.2 35.5 35.5	20.2	1.54E+00	7.425	1.54E-03
48	40.60	10.12	1.000	17120 17120 17120	36.7 36.4 36.8	20.5	1.47E+00	7.123	1.47E-03
72	40.60	10.12	1.000	17120 17120 17120	37.4 37.2 37.1	19.9	1.47E+00	7.105	1.47E-03
100	40.60	10.12	1.000	17120 17120 17120	37.2 37.0 37.3	20.0	1.47E+00	7.107	1.47E-03



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TRANSMISSIVITY TEST RESULTS
ASTM D 4716

geotechnics

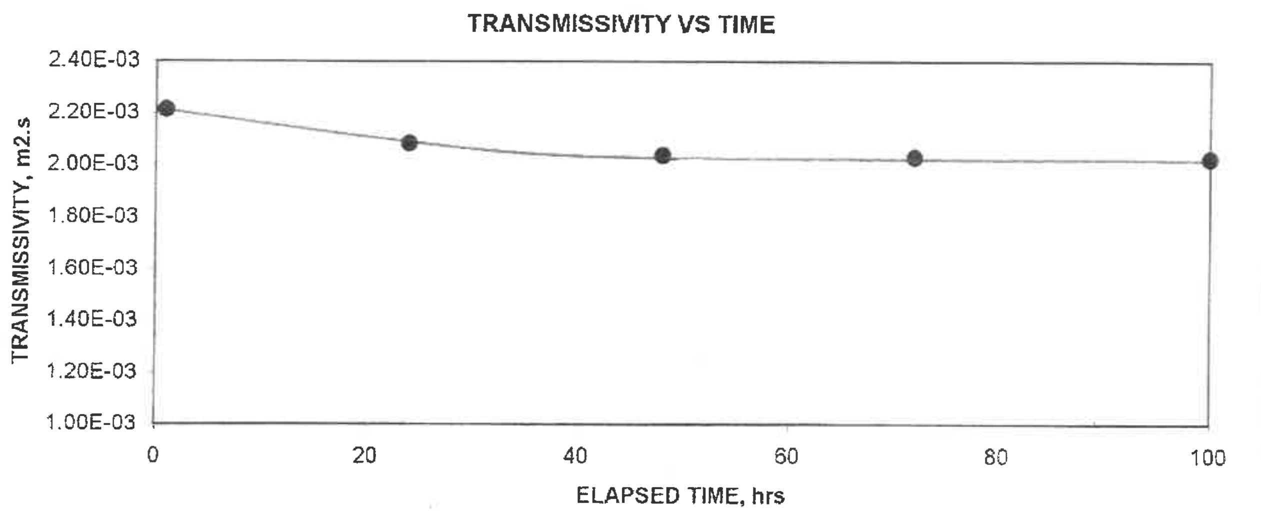
CLIENT: TENAX CORP.
PROJECT: QC
PROJECT NO.: L01188-03
MATERIAL: TENDRAIN 7 100-2

LAB I.D. NO.: L01188-03-01
LOT NO.: n.p.
ROLL NO.: n.p.
REPLICATE NO.: 1 of 1

TEST SECTION: SAND
GEOCOMPOSITE-MD
60-MIL SMOOTH HDPE

2,000 psf NORMAL COMPRESSIVE STRESS

ELAPSED TIME (hrs)	MANOMETERS RES. (cm)	MANOMETERS WEIR (cm)	HYDR. GRAD.	COLLECTION DATA VOLUME (ml)	COLLECTION DATA TIME (sec.)	WATER TEMP °C	AVERAGE FLOW RATE (l/s-m)	AVERAGE FLOW RATE (gpm/ft)	CALCULATED TRANSMISSIVITY (m2/sec)
1	25.17	9.93	0.500	11410 11410 11410	32.6 32.9 32.7	20.2	1.11E+00	5.352	2.22E-03
24	25.17	9.93	0.500	11410 11410 11410	34.7 34.9 34.8	20.2	1.04E+00	5.034	2.08E-03
48	25.17	9.93	0.500	11410 11410 11410	35.2 35.3 35.4	20.5	1.02E+00	4.927	2.04E-03
72	25.17	9.93	0.500	11410 11410 11410	35.9 36.0 35.9	19.9	1.02E+00	4.907	2.03E-03
100	25.17	9.93	0.500	11410 11410 11410	35.8 36.0 36.0	20.0	1.01E+00	4.899	2.03E-03



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TRANSMISSIVITY TEST RESULTS

ASTM D 4716

geotechnics

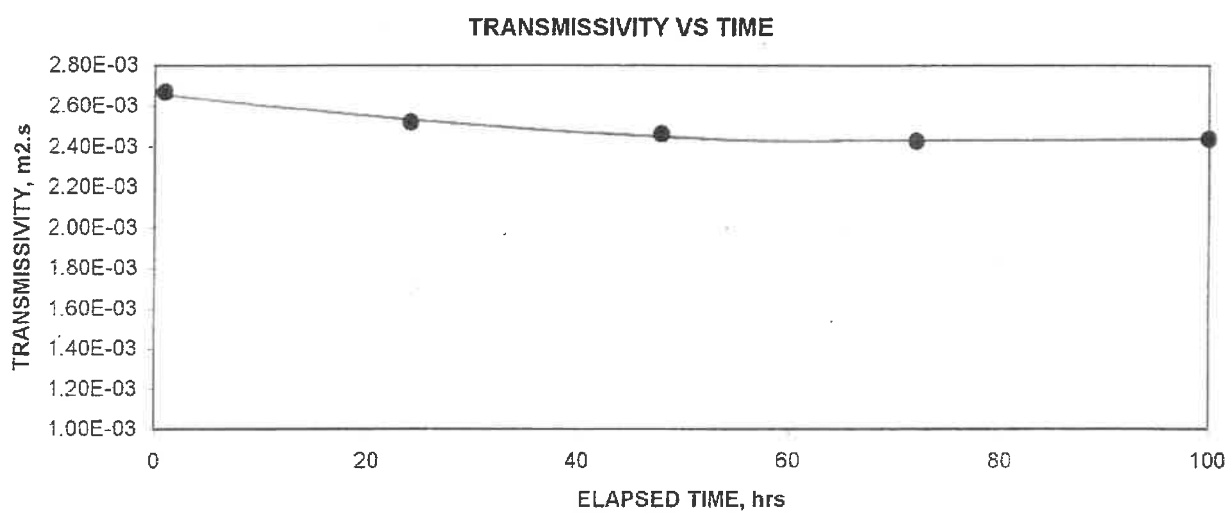
CLIENT: TENAX CORP.
PROJECT: QC
PROJECT NO.: L01188-03
MATERIAL: TENDRAIN 7 100-2

LAB I.D. NO.: L01188-03-01
LOT NO.: n.p.
ROLL NO.: n.p.
REPLICATE NO.: 1 of 1

TEST SECTION: SAND
GEOCOMPOSITE-MD
60-MIL SMOOTH HDPE

2,000 psf NORMAL COMPRESSIVE STRESS

ELAPSED TIME (hrs)	MANOMETERS RES. (cm)	MANOMETERS WEIR (cm)	HYDR. GRAD.	COLLECTION DATA VOLUME (ml)	COLLECTION DATA TIME (sec.)	WATER TEMP °C	AVERAGE FLOW RATE (l/s-m)	AVERAGE FLOW RATE (gpm/ft)	CALCULATED TRANSMISSIVITY (m2/sec)
1	19.90	9.84	0.330	8560 8560 8560	30.8 30.9 30.9	20.2	8.81E-01	4.258	2.67E-03
24	19.90	9.84	0.330	8560 8560 8560	32.6 32.7 32.7	20.2	8.33E-01	4.023	2.52E-03
48	19.90	9.84	0.330	8560 8560 8560	33.1 33.3 33.2	20.5	8.13E-01	3.930	2.46E-03
72	19.90	9.84	0.330	8560 8560 8560	34.0 34.3 34.2	19.9	8.02E-01	3.873	2.43E-03
100	19.90	9.84	0.330	8560 8560 8560	34.0 33.8 34.0	20.0	8.05E-01	3.892	2.44E-03



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TRANSMISSIVITY TEST RESULTS
ASTM D 4716

geotechnics

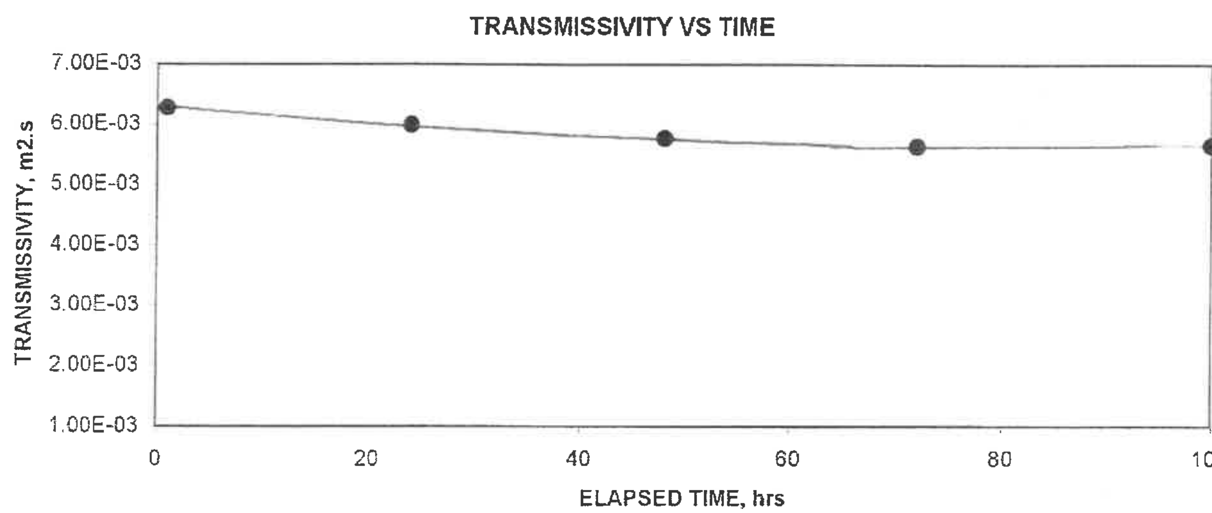
CLIENT: TENAX CORP.
PROJECT: QC
PROJECT NO.: L01188-03
MATERIAL: TENDRAIN 7 100-2

LAB I.D. NO.: L01188-03-01
LOT NO.: n.p.
ROLL NO.: n.p.
REPLICATE NO.: 1 of 1

TEST SECTION: SAND
GEOCOMPOSITE-MD
60-MIL SMOOTH HDPE

2,000 psf NORMAL COMPRESSIVE STRESS

ELAPSED TIME (hrs)	MANOMETERS RES. (cm)	MANOMETERS WEIR (cm)	HYDR. GRAD.	COLLECTION DATA VOLUME (ml)	COLLECTION DATA TIME (sec.)	WATER TEMP °C	AVERAGE FLOW RATE (l/s-m)	AVERAGE FLOW RATE (gpm/ft)	CALCULATED TRANSMISSIVITY (m2/sec)
1	11.15	9.63	0.050	985 985 985	10.0 10.0 10.0	20.2	3.13E-01	1.512	6.28E-03
24	11.15	9.63	0.050	945 945 945	10.0 10.0 10.0	20.2	3.00E-01	1.451	6.01E-03
48	11.15	9.63	0.050	915 915 915	10.0 10.0 10.0	20.5	2.89E-01	1.395	5.77E-03
72	11.15	9.63	0.050	880 885 880	10.0 10.0 10.0	19.9	2.82E-01	1.364	5.64E-03
100	11.15	9.63	0.050	880 890 890	10.0 10.0 10.0	20.0	2.83E-01	1.368	5.66E-03



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TRANSMISSIVITY TEST RESULTS
ASTM D 4716

geotechnics

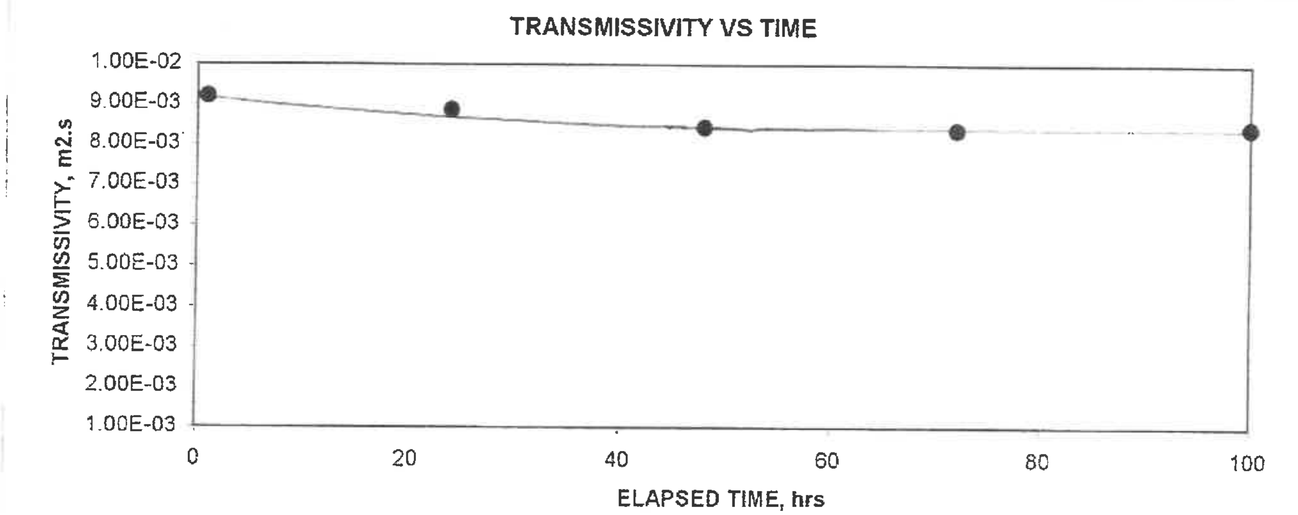
CLIENT: TENAX CORP.
PROJECT: QC
PROJECT NO.: L01188-03
MATERIAL: TENDRAIN 7 100-2

LAB I.D. NO.: L01188-03-01
LOT NO.: n.p.
ROLL NO.: n.p.
REPLICATE NO.: 1 of 1

TEST SECTION: SAND
GEOCOMPOSITE-MD
60-MIL SMOOTH HDPE

2,000 psf NORMAL COMPRESSIVE STRESS

ELAPSED TIME (hrs)	MANOMETERS RES. (cm)	MANOMETERS WEIR (cm)	HYDR. GRAD.	COLLECTION DATA VOLUME (ml)	COLLECTION DATA TIME (sec.)	WATER TEMP °C	AVERAGE FLOW RATE (l/s-m)	AVERAGE FLOW RATE (gpm/ft)	CALCULATED TRANSMISSIVITY (m2/sec)
1	10.19	9.58	0.020	585 580 580	10.0 10.0 10.0	20.2	1.85E-01	0.893	9.21E-03
24	10.19	9.58	0.020	560 560 560	10.0 10.0 10.0	20.2	1.78E-01	0.860	8.87E-03
48	10.19	9.58	0.020	535 540 535	10.0 10.0 10.0	20.5	1.69E-01	0.818	8.44E-03
72	10.19	9.58	0.020	525 525 525	10.0 10.0 10.0	19.9	1.68E-01	0.812	8.37E-03
100	10.19	9.58	0.020	530 530 530	10.0 10.0 10.0	20.0	1.69E-01	0.818	8.43E-03



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L01188-03

12/17/01

product specifications

TENDRAIN II 770-2 Double-Sided Geocomposite

The drainage geocomposite is comprised of a tri-planar geonet structure with thermally bonded nonwoven geotextiles on both sides. The product is capable of providing high transmissivity in a soil environment under both low and high loads and will have properties conforming to the values and test methods listed below.

PROPERTY	TEST METHODS	UNITS	VALUE	QUALIFIER	TEST FREQUENCY
Resin					
• Density	ASTM D 1505	g/cm^3	0.94	MAV	lot
• Melt Flow Index	ASTM D 1238	g/10min	1.0	MAX	lot
Geonet Core[1]					
• Thickness	ASTM D 5199	mil (mm)	300 (7.6)	MAV	50,000 sf
• Carbon Black	ASTM D 4218	%	2-3	range	50,000 sf
• Tensile Strength – Machine Direction	ASTM D 4595	lb/ft (kN/m)	600 (8.7)	MAV	50,000 sf
• Creep Reduction Factor[2]	GRI-GC8		1.2		
Geotextile[1]					
• U.V. Resistance (500 hrs)	ASTM D 4355	%	70		Per formula
• Grab Tensile	ASTM D 4632	lbs (N)	160 (712)	MARV	100,000 sf
• Grab Elongation	ASTM D 4632	%	50	MARV	100,000 sf
• Tear Strength	ASTM D 4533	lbs (N)	60 (267)	MARV	100,000 sf
• Puncture Resistance	ASTM D 4833	lbs (N)	85 (378)	MARV	100,000 sf
• AOS	ASTM D 4751	US Sieve (mm)	70 (0.212)	MaxARV	500,000 sf
• Permittivity	ASTM D 4491	Sec^{-1}	1.1	MARV	500,000 sf
Geocomposite					
• Roll Sizes	12.5 ft x 200 ft (3.8 m x 61 m)				
• Peel Adhesion – Machine Direction	ASTM D7005	lb/in (g/in)	1.0 (454)	MAV	100,000 sf
• Transmissivity[3] - Machine Direction Gradient / Load	ASTM D 4716 GRI - GC8	m^2/sec	15,000 psf (720 kPa)		
0.1			$2.2*10^{-3}$	MAV	200,000 sf
0.02			$4.5*10^{-3}$	MAV	200,000 sf

Qualifiers: MARV=Minimum Average Roll Value (MARV), MAV=Minimum Average Value, MAX=Maximum Value, MaxARV=Maximum average roll value.

NOTES: 1. Geotextile and geonet properties listed are prior to lamination. 2. Creep reduction factor is determined under 15,000 psf load and 40° C temperature, extrapolated to 30 years of design life. 3.Geocomposite transmissivity measured by manufacturer per ASTM D4716 with testing boundary conditions as follows: steel plate / Ottawa sand / geocomposite / 60 mil HDPE geomembrane / steel plate (The Tendrain II geonet has a circular aperture side and a ribbed side. The side with circular apertures should be placed against the soil while the ribbed side should be placed against the geomembrane), corresponding load conditions and a seating period of 100 hours.

SCS TELEPHONE CONVERSATION RECORD

Job No: 09199033.09 **Date:** 12/3/03 **SCS Personnel: Lindsey Kennelly**

Person (called, calling): JP Kline **Time:** 2 pm

Representing: Tenax

Subject: Creep Factors for Triplanar Geocomposite **Tel. #:** (412)371-2973

Items Discussed:

Tenax

Any load less than 25,000 psf will have a creep reduction factor of 1.20

APPENDIX A
100-HOUR TRANSMISSIVITY DATA FOR SELECTED PRODUCTS

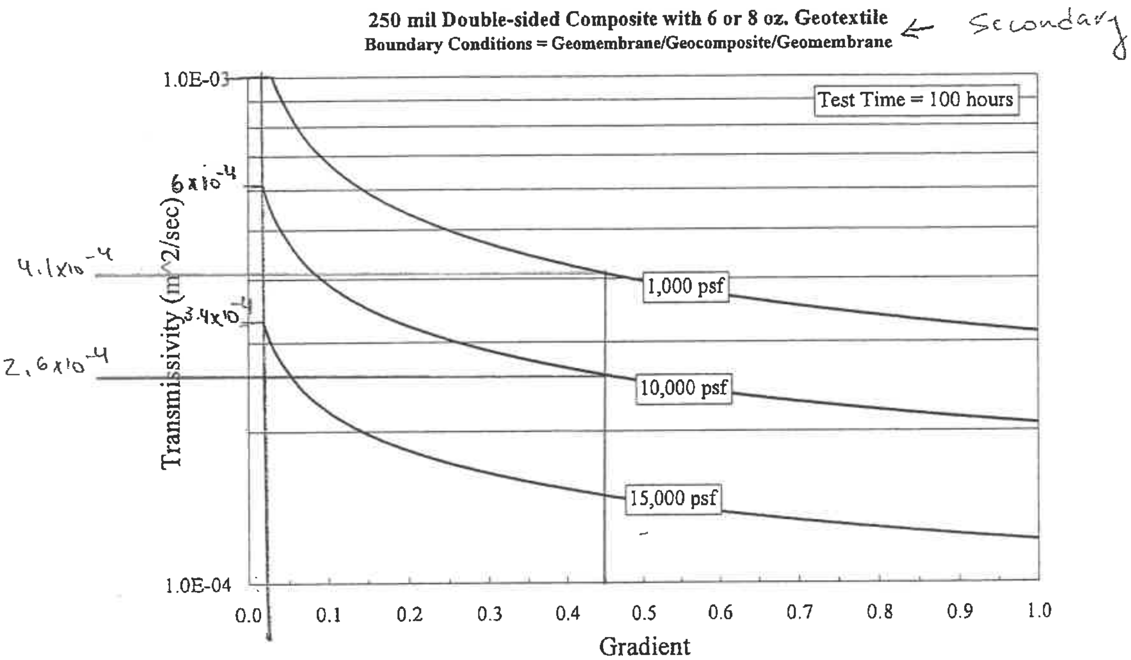


Figure A-5 100-hour transmissivity of a 250 mil biplanar geocomposite between two geomembranes.

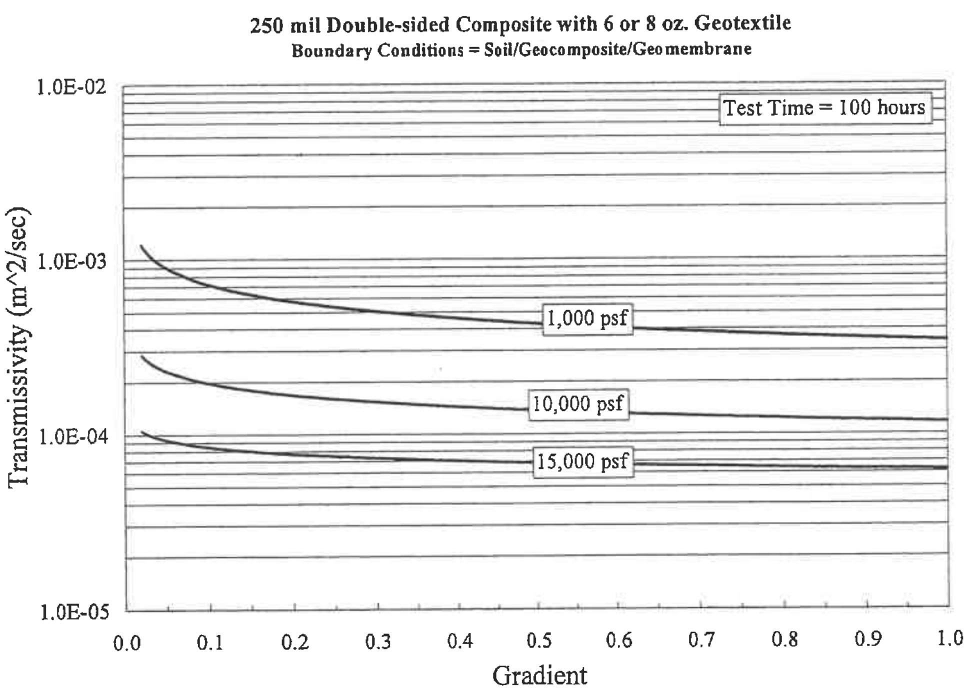


Figure A-6 100-hour transmissivity of a 250 mil biplanar geonet under soil/geocomposite/geomembrane boundary conditions.

Reference: The Hydrologic evaluation of landfill performance (HELP) model User's Guide for Version 3.

TABLE 4. DEFAULT SOIL, WASTE, AND GEOSYNTHETIC CHARACTERISTICS

Classification (SOIL TEXTURE)			Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	USDA	USCS	vol/vol	vol/vol	vol/vol	cm/sec
1	CoS	SP	0.417	0.045	0.018	$1.0x10^{-2}$
2	S	SW	0.437	0.062	0.024	$5.8x10^{-3}$
3	FS	SW	0.457	0.083	0.033	$3.1x10^{-3}$
4	LS	SM	0.437	0.105	0.047	$1.7x10^{-3}$
5	LFS	SM	0.457	0.131	0.058	$1.0x10^{-3}$
6	SL	SM	0.453	0.190	0.085	$7.2x10^{-4}$
7	FSL	SM	0.473	0.222	0.104	$5.2x10^{-4}$
8	L	ML	0.463	0.232	0.116	$3.7x10^{-4}$
9	SiL	ML	0.501	0.284	0.135	$1.9x10^{-4}$
10	SCL	SC	0.398	0.244	0.136	$1.2x10^{-4}$
11	CL	CL	0.464	0.310	0.187	$6.4x10^{-5}$
12	SiCL	CL	0.471	0.342	0.210	$4.2x10^{-5}$
6" CLAY → 13	SC	SC	0.430	0.321	0.221	~~$3.3x10^{-5}$~~ 1x10⁻⁵ cm/s
14	SiC	CH	0.479	0.371	0.251	$2.5x10^{-5}$
15	C	CH	0.475	0.378	0.265	$1.7x10^{-5}$
16	Barrier Soil		0.427	0.418	0.367	$1.0x10^{-7}$
17	Bentonite Mat (0.6 cm)		0.750	0.747	0.400	$3.0x10^{-9}$
18	Municipal Waste (900 lb/yd³ or 312 kg/m³)		0.671	0.292	0.077	$1.0x10^{-3}$
19	Municipal Waste (channeling and dead zones)		0.168	0.073	0.019	$1.0x10^{-3}$
20	Drainage Net (0.5 cm)		0.850	0.010	0.005	$1.0x10^{+1}$
21	Gravel		0.397	0.032	0.013	$3.0x10^{-1}$
22	L*	ML	0.419	0.307	0.180	$1.9x10^{-5}$
23	SiL*	ML	0.461	0.360	0.203	$9.0x10^{-6}$
24	SCL*	SC	0.365	0.305	0.202	$2.7x10^{-6}$
25	CL*	CL	0.437	0.373	0.266	$3.6x10^{-6}$
26	SiCL*	CL	0.445	0.393	0.277	$1.9x10^{-6}$
27	SC*	SC	0.400	0.366	0.288	$7.8x10^{-7}$
28	SiC*	CH	0.452	0.411	0.311	$1.2x10^{-6}$
29	C*	CH	0.451	0.419	0.332	$6.8x10^{-7}$
30	Coal-Burning Electric Plant Fly Ash*		0.541	0.187	0.047	$5.0x10^{-5}$
31	Coal-Burning Electric Plant Bottom Ash*		0.578	0.076	0.025	$4.1x10^{-3}$
32	Municipal Incinerator Fly Ash*		0.450	0.116	0.049	$1.0x10^{-2}$
33	Fine Copper Slag*		0.375	0.055	0.020	$4.1x10^{-2}$
34	Drainage Net (0.6 cm)		0.850	0.010	0.005	$3.3x10^{+1}$

COMPACTED

* Moderately Compacted

(Continued)

TABLE 4 (continued). DEFAULT SOIL, WASTE, AND GEOSYNTHETIC CHARACTERISTICS

Classification		Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	Geomembrane Material	vol/vol	vol/vol	vol/vol	cm/sec
35	High Density Polyethylene (HDPE)				2.0×10^{-13}
36	Low Density Polyethylene (LDPE)				4.0×10^{-13}
37	Polyvinyl Chloride (PVC)				2.0×10^{-11}
38	Butyl Rubber				1.0×10^{-12}
39	Chlorinated Polyethylene (CPE)				4.0×10^{-12}
40	Hypalon or Chlorosulfonated Polyethylene (CSPE)				3.0×10^{-12}
41	Ethylene-Propylene Diene Monomer (EPDM)				2.0×10^{-12}
42	Neoprene				3.0×10^{-12}

(concluded)

user-defined soil option accepts non-default soil characteristics for layers assigned soil type numbers greater than 42. This is especially convenient for specifying characteristics of waste layers. User-specified soil characteristics can be assigned any soil type number greater than 42.

When a default soil type is used to describe the top soil layer, the program adjusts the saturated hydraulic conductivities of the soils in the top half of the evaporative zone for the effects of root channels. The saturated hydraulic conductivity value is multiplied by an empirical factor that is computed as a function of the user-specified maximum leaf area index. Example values of this factor are 1.0 for a maximum LAI of 0 (bare ground), 1.8 for a maximum LAI of 1 (poor stand of grass), 3.0 for a maximum LAI of 2 (fair stand of grass), 4.2 for a maximum LAI of 3.3 (good stand of grass) and 5.0 for a maximum LAI of 5 (excellent stand of grass).

The manual option requires values for porosity, field capacity, wilting point, and saturated hydraulic conductivity. These and related soil properties are defined below.

Soil Water Storage (Volumetric Content): the ratio of the volume of water in a soil to the total volume occupied by the soil, water and voids.

Total Porosity: the soil water storage/volumetric content at saturation (fraction of total volume).

ATTACHMENT B

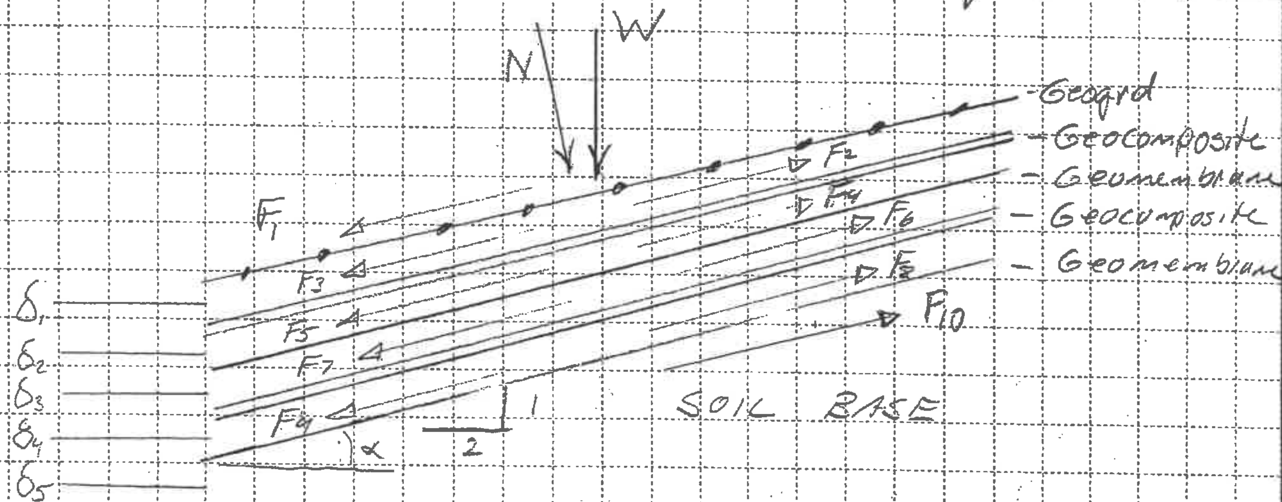
LINER STRESS ANALYSIS

SCS ENGINEERS

SHEET 1 OF 6

CLIENT	PROJECT	JOB NO.
Citrus Co.	Phase 2 Expansion	09199056.02

SUBJECT	BY	DATE
Liner Stress Analysis	JAB	12-6-02
	CHECKED	DATE 12/16/02



Given: Slope angle $\alpha = 26.6°$

δ_1 = Friction Angle Between the Geogrid and the Geocomposite ≈ 12°

$\delta_2 = \delta_3 = \delta_4$ = Friction Angle Between Geocomposite and Textured HDPE Liner ≈ 15-18°

δ_5 = Friction Angle Between Textured HDPE the underlying sandy soil ≈ 17-20°

F_1 on Geogrid = W Sin 26.6°

F_2, F_4, F_6, F_8 and F_{10} = N Tan δ
= Resistance Force due to Friction

Because $\delta_2 = \delta_3 = \delta_4$ $F_4 = F_6 = F_8$

$\delta_5 = 17° - 20°$

$N = \cos\alpha\, W$

Objective: Calculate Forces on the layers

SCS ENGINEERS

CLIENT Citrus Co.	PROJECT Phase 2 Expansion		JOB NO. 09199056.02
SUBJECT Liner Stress Analysis		BY JAB	DATE 11-27-02
		CHECKED [illegible]	DATE 12/16/02

Calculations using Residual Friction Angles
Calculate Various Weight components acting on liner system using one lift of waste (SEE example problem Koerner Second Ed page 469)

A) Calculated Loads

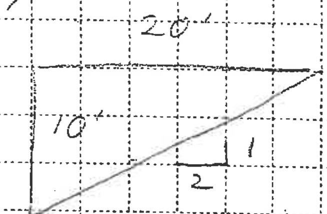
GIVEN: Density of waste = 1200 lb/cy
= 45 lb/ft³

Friction Angle of Waste = 32°
(Based on SCS studies)

Waste lift Thickness = 10 ft

Side slope = 2:1

Area of waste =



(1) Weight of waste = $\frac{1}{2}(10')(20')\left(45\ \frac{lb}{ft^3}\right)$

$W_w = 4500\ \frac{lb}{ft}$

(2) Calculate Shear resistance of waste

$T_w = \sigma_H \tan\phi\,(D)$ where $D = 10'$

$= K_0\,\sigma_v \tan\phi\,(D)$ $\quad \sigma_v = .5\,\sigma_H$

$= (1 - \sin 32°)(.5)\ 634\ \frac{lb}{ft^2} \tan 32°\ (10\ ft)$

$= 931\ \frac{lb}{ft}$

See bottom of next page.

SCS ENGINEERS

SHEET 3 OF 6

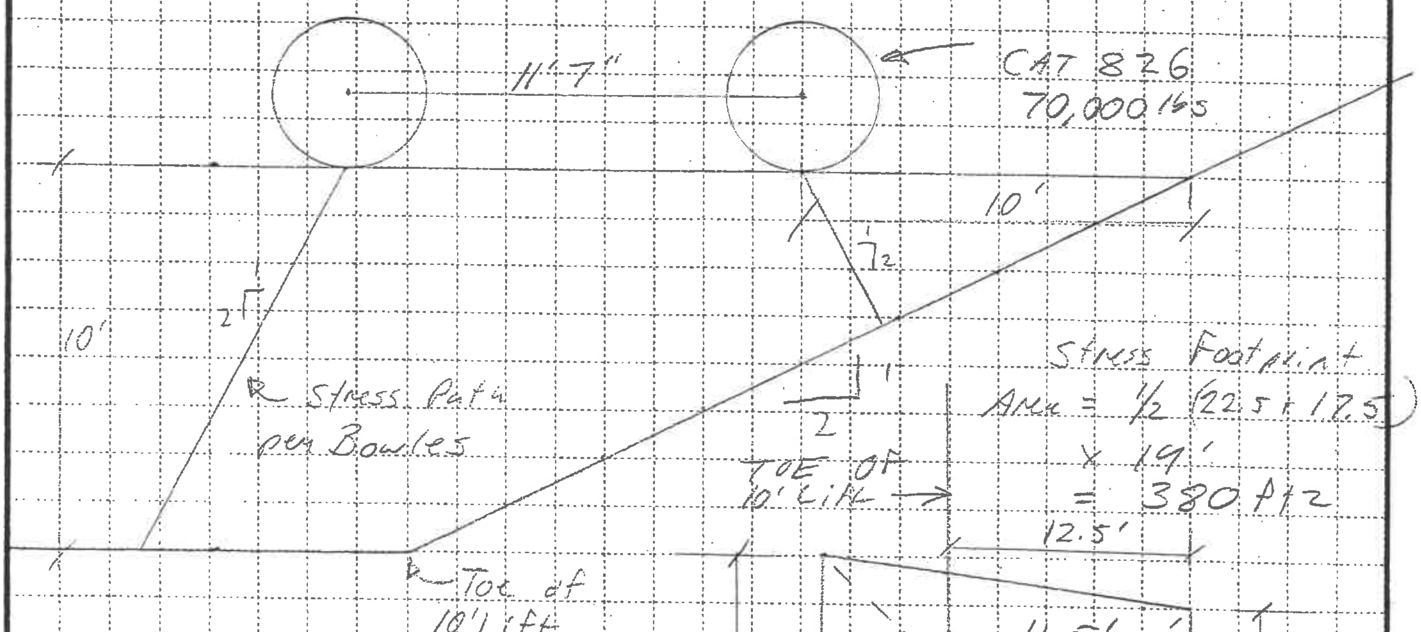
CLIENT Citrus Co.	PROJECT Phase 2 Expansion	JOB NO. 0919905602
SUBJECT Liner Stress Analysis	BY JAB	DATE 11-27-02
	CHECKED [signature]	DATE 12/16/02

(3) W_w net = $W_w - T_w$ = 4500 - 931

= 3569 lb/ft

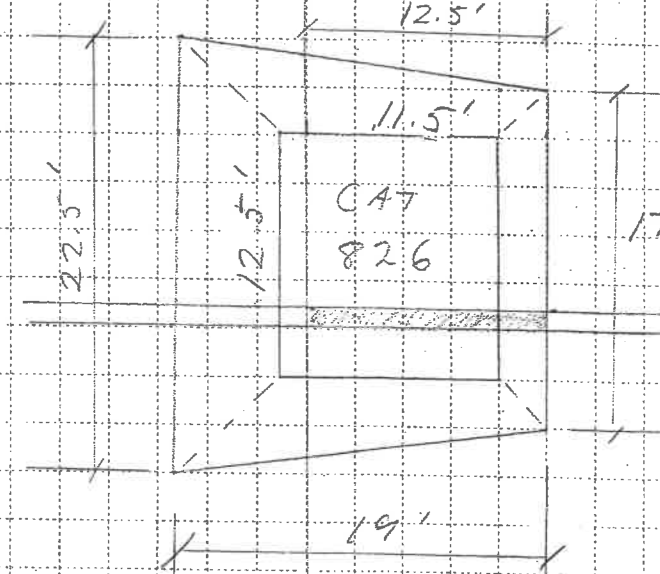
(4) Calculate weight of compactor

Assume compactor maintains 10 ft from liner slope



Stress Footprint

Area = ½ (22.5 + 17.5) × 19' = 380 ft²



Load = 70,000 lb / 380 ft² = 184 lb/sft

Calculate force on sideslope per foot width

Area = 12.5 sq ft/ft

Load = 12.5 sq ft/ft × 184 lb/sq ft

= 2,303 lb/ft

σ_H = (10 × 45) + 184 lb/ft²

= 634 lb/ft²

SCS ENGINEERS

CLIENT Citrus Co.	PROJECT Phase 2 Expansion		JOB NO. 01199056.02
SUBJECT Liner Stress Analysis		BY JAB	DATE 11-27-02
		CHECKED [initials]	DATE 12/16/02

(3) Calculate weight of sand layer

$(2 ft \times 22 ft \times 110 lb/ft^3) + (2 ft \times 10 ft \times 110 lb/ft^3)$

$= 7040 lb/ft$

(4) Calculate weight of Geosynthetics

Liner @ $0.94 g/cm^3 \times 0.0361 = 0.0339 lb/in^3$

$V_L = 180 ft \times 0.005 ft = 0.9 ft^2/ft$

$W_L = 0.9 \frac{ft^3}{ft} \times \frac{0.0339 lb}{in^3} \frac{12 in}{ft} \frac{144 in^2}{ft^2}$

$0.9 \frac{ft^3}{ft} = 58.6 \frac{lb}{ft^3}$

$W_L = 52.7 lb/ft$

Geonet @ $0.51 lb/ft^2$ Assume 25% Moisture

$W_G = 0.51 \times 1.25 = 64 lb/ft^2$

Total for 2 Liners + 2 geonets

$(58.6 \times 2) + (64 \times 2) = 245 lb/ft$

(5) Total W is sum of above weights

3569 + 2,303 + 7040 + 245

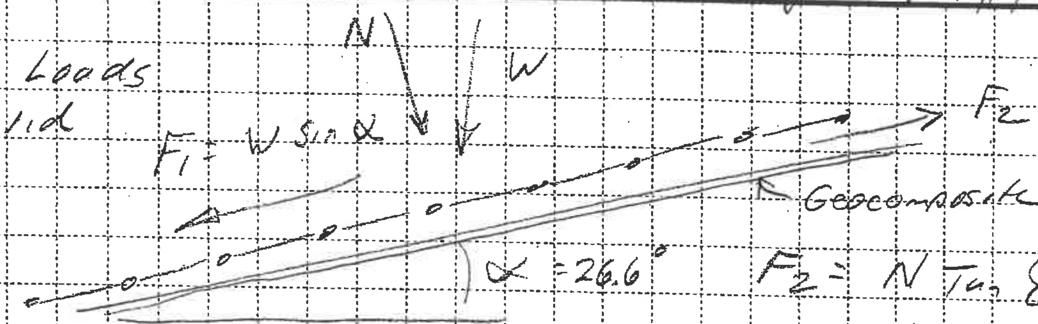
= 13,157 lb/ft

SCS ENGINEERS

SHEET 5 OF 6

CLIENT Citrus Co.	PROJECT Phase 2 Expansion	JOB NO. 69199056.02
SUBJECT Liner Stress Analysis	BY JAB	DATE 12-6-02
(2) Calculate Forces	CHECKED [initials]	DATE 12/16/02

(1) Calculate Loads on Geogrid



$F_2 = N \tan \delta_1$

$W = 13,157$ lb/ft

$N = W \cos\alpha$

$= 11,764$ lb/ft

$\delta_1 = 12°$

$F_2 = 2501$ lb/ft

$F_1 = 13,157$ lb/ft $\sin 26.6° = 5891$ lb/ft

Stress on Geogrid

$\sigma = F_1 - F_2 = 5891 - 2501 = 3,390$ lb/ft

Use Tensar UX 1700HS

Tensile Strength @ 5% Strain = 5,140 lb/ft

$FS = \frac{5140}{3390} = 1.52$ OK

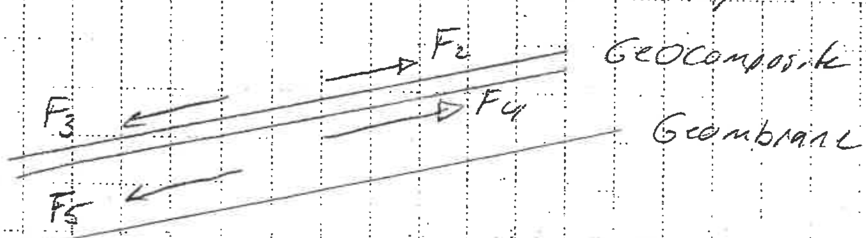
(2) Calculate Loads on Underlying Materials

δ_2 = Geocomposite to textured HDPE

= 15 - 18° use 16.5°

$F_2 = F_3$ $\quad F_4 = N \tan 16.5 = 3,484$ lb/ft

$F_4 > F_3$ No tension F_2 gets transmitted to the next layer $= F_5$



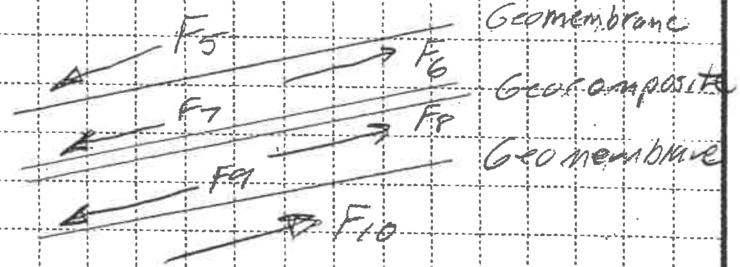
SCS ENGINEERS

SHEET 6 OF 6

CLIENT	PROJECT	JOB NO.
Citrus Co	Phase 2 Expansion	0919905602

SUBJECT	BY	DATE
Liner Stress Analysis	JAB	12-6-02
	CHECKED	DATE
	[illegible]	12/16/02

Because the friction resistance is Greater than the downward Force There is no stress on the material and the downward load is transferred to the next layer



$F_5 = F_7 = F_9$

Thus $F_9 = F_2 = 2501$ lb/ft

$F_{10} = N \tan \delta_5 = 11{,}764 \frac{lb}{ft} \tan 17^\circ$

Use $\delta_5 = 17^\circ$ as worste case

$F_{10} = 3597$ lb/ft

$F_{10} > F_9$ $\frac{3597}{2501} = 1.44$ FS

No stress on bottom Liner OK

ATTACHMENT C

ANCHOR TRENCH CALCULATIONS

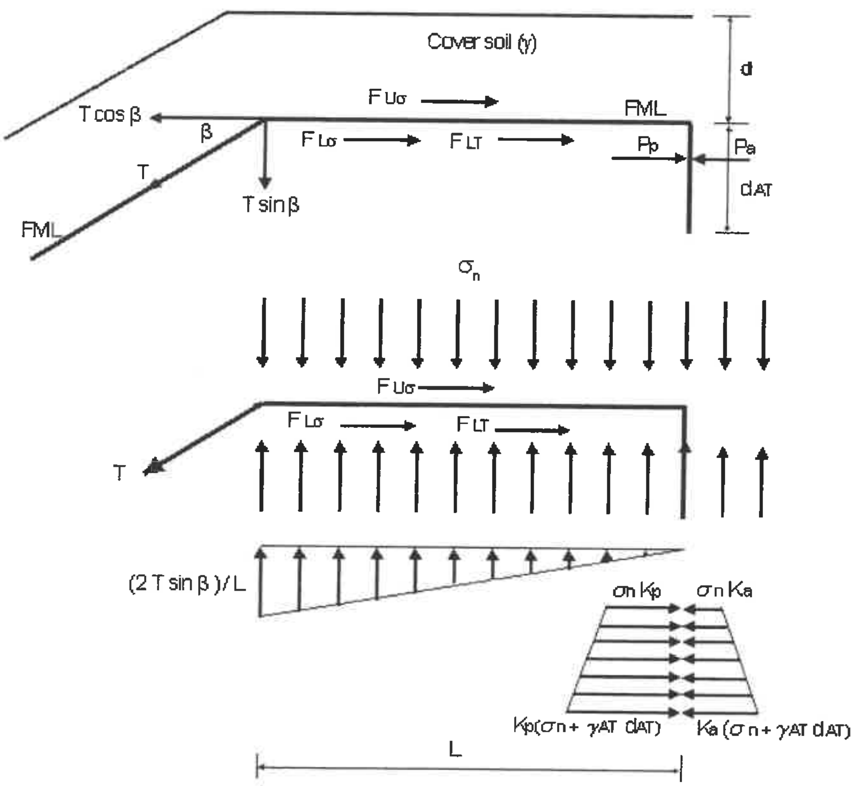
SCS ENGINEERS

SHEET ______ of ______

CLIENT	PROJECT	JOB NO.
Citrus County Central Landfill	Phase 3 Expansion Area	09207049.02
SUBJECT: Anchor Trench Calculations	BY: DHB	DATE: 10/17/2008
	CHECKED	DATE

OBJECTIVE:

- Calculate horizontal anchor runout length L.



Ref. Keorner's Designing with Gesoynthetics, 5th Ed.

Cross Section of Geomembrane Runout Section with Anchor Trench and Related Stresses and Forces Involved

CALCULATIONS:

$$\Sigma F_x = 0$$

$$T_{ult} \cos \beta = F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P \qquad (1)$$

WHERE:

T_{ult} = ultimate force in geomembrane at break (interpreted as ultimate per discussion with Dr. Koerner 7/29/2008)

t = geomembrane thickness;

β = sideslope angle;

SCS ENGINEERS SHEET ______ of ______			
CLIENT Citrus County Central Landfill	PROJECT Phase 3 Expansion Area		JOB NO. 09207049.02
SUBJECT Anchor Trench Calculations		BY DHB	DATE 10/17/2008
		CHECKED	DATE

$F_{U\sigma}$ = shear force above geomembrane due to cover soil (note that for thin cover soils tensile cracking will occur and this value will be negligible);
$F_{L\sigma}$ = shear force below geomembrane due to cover soil;
F_{LT} = shear force below geomembrane due to vertical component of T;
d_{cs} = the depth of cover soil;
δ = angle of shearing resistance between geomembrane and adjacent material (i.e., soil or geotextile);
P_A = active earth pressure against the backfill side of the anchor trench; and
P_P = passive earth pressure against the in-situ side of the anchor trench.

$P_A = 1/2\ (\gamma_{AT} d_{AT}) K_A d_{AT} + (\sigma_n) K_A d_{AT}$
$P_A = (0.5\gamma_{AT} d_{AT} + \sigma_n) K_A d_{AT}$
$P_P = (0.5\gamma_{AT} d_{AT} + \sigma_n) K_P d_{AT}$

WHERE:

γ_{AT} = unit weight of soil in anchor trench;
d_{AT} = depth of the anchor trench;
σ_n = applied normal stress from cover soil;
K_A = coefficient of active earth pressure = $\tan^2(45 - \phi/2)$;
K_P = coefficient of passive earth pressure = $\tan^2(45 + \phi/2)$, and
ϕ = angle of shearing resistance of respective soil.

GIVEN:

T_{ult} @break =	126.0	lb/in	(60 mil HDT060G010 Attachment 2)
=	1512.0	lb/ft	
t =	60.00	mil	
σ_{ult} =	2100.0	lb/in^2	
γ_{cs} =	105.0	lbs/ft^3	cover soil
d_{cs} =	2.00	ft	
σ_n =	210.0	lbs/ft^2	
γ_{AT} =	115.0	lbs/ft^3	
δ_L =	18.0	degrees	
β =	26.6	degrees	
ϕ =	25.0	degrees	

$\beta = \tan^{-1}(m/z)$
m = 1
z = 2

DETERMINE:

$F_{U\sigma} = \sigma_n \tan \delta_u (L_{RO})$
$F_{U\sigma}$ = 0.0 lb/ft (assume negligible, $\delta_U = 0$)

$F_{L\sigma} = \sigma_n \tan \delta_L (L_{RO})$
$F_{L\sigma}$ = 68.2 L_{RO} lb/ft

SCS ENGINEERS			
		SHEET ____ of ____	
CLIENT Citrus County Central Landfill	PROJECT Phase 3 Expansion Area		JOB NO. 09207049.02
SUBJECT Anchor Trench Calculations		BY DHB	DATE 10/17/2008
		CHECKED	DATE

$F_{LT} = T_{ult} \sin\beta \tan\delta_L$

$F_{LT} =$ 219.7 lb/ft

$K_A =$ 0.41

$K_P =$ 2.46

$P_A = (0.5\gamma_{AT}d_{AT} + \sigma_n)K_A d_{AT}$

$P_A =$ 23.34 d^2_{AT} + 85.23 d_{AT}

$P_P = (0.5\gamma_{AT}d_{AT} + \sigma_n)K_P d_{AT}$

$P_P =$ 141.7 d^2_{AT} + 517.4 d_{AT}

From Equation (1):

$$T_{ult}\cos\beta - F_{LT} = F_{U\sigma} + F_{L\sigma} - P_A + P_P \qquad (2)$$

1132.7 = 68.2 L_{RO} + 432.2 d_{AT} + 118.3 d^2_{AT}

Find L_{RO} at a given d_{AT}

d_{AT} =	0.50 ft	1.00 ft	1.50 ft	2.00 ft
L_{RO} =	13.00 ft	8.53 ft	3.20 ft	-3.01 ft

Recommend using: d_{AT} = 2.00 ft

L_{RO} = 3.00 ft

From Equation (1):

Anchorage Ratio, AR = R.H.S / L.H.S

AR = Horizontal forces T @ anchor trench & runout / horizontal force T @ geomembrane

= 1762.1 / 1352.4

= 1.30

CONCLUSION:

- Recommend a horizontal anchor of 3 feet runout length, assuming tensile (ult) at break of 126 lbs/in, and cover soil thickness = 24 inches; other components such as composite drainage net assume not in tensile or the load is transferred to the weakest interface.
- Assume shear strength efficiency is 100% between the interfaces; in reality it is not due to presence of wrinkles with liner
- Anchor trench dominates
- Horizontal anchor dimensions depends on the cover soil thickness, interface friction angle of soil/geomembrane interface, internal friction angle of soil backfill and soil unit weight assumed in the calculations.

Notes:

Anchorage Ratio	>	1	Anchor trench dominates
Anchorage Ratio	=	1	Balanced Design
Anchorage Ratio	<	1	Geomembrane pull-out mode

REFERENCES

Attachment-1

Designing with Geosynthetics

Fifth Edition

Robert M. Koerner

Director, Geosynthetic Institute
Emeritus Professor of Drexel University

PEARSON
Prentice Hall

Upper Saddle River, New Jersey 07458

$$c = (N_A \tan \delta + C_a) \sin \beta \sin\left(\frac{\omega + \beta}{2}\right) \tan \phi$$

$$= (370 \tan 22 + 0) \sin 18.4 \sin\left(\frac{15 + 18.4}{2}\right) \tan 30$$

$$= 8.07 \text{ kN/m}$$

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{62.8 + \sqrt{(-62.8)^2 - 4(37.2)(8.07)}}{2(37.2)}$$

$$FS = 1.55 \text{ (vs. 1.25 for the constant thickness cross section)}$$

Example 5.12 has also been extended to a set of design curves, as seen in Figure 5.26b. The anticipated trends are again noted, as is the agreement with the worked out example. Clearly, this type of stabilizing solution can be used if space at the toe of the slope is available. Often it is not or it occupies valuable air space and then geosynthetic reinforcement as discussed in Chapter 3 is the alternative solution.

[illegible]

As shown in Figure 5.18 and the profile sections of geomembrane-lined reservoirs, the liner coming up from the bottom of the excavation, covers the side slopes, and then runs over the top a short distance. It often terminates vertically down into an anchor trench. This anchor trench is typically dug by a small backhoe or trenching machine; the liner is draped over the edge, and then the trench is backfilled with the same soil that was there originally. The backfilled soil should be compacted in layers as the backfilling proceeds. Although concrete has been used as an anchorage block, it is rarely justified, at least on the basis of calculations, as will be seen in this section.

Regarding design, two separate cases will be analyzed: one with geomembrane runout only and no anchor trench at all (as is often used with canal liners), and the other as described above, with both runout and anchor trench considerations (as with reservoirs and landfills). Figure 5.27 defines the first situation, together with the forces and stresses involved. Note that the cover soil applies normal stress due to its weight but does not contribute frictional resistance above the geomembrane. This is due to the fact that the soil moves along with the geomembrane as it deforms and undoubtedly cracks, thereby losing its integrity.

From Figure 5.27, the following horizontal force summation results, which leads to the appropriate design equation:

$$\Sigma F_x = 0$$

$$T_{\text{allow}} \cos \beta = F_{U\sigma} + F_{L\sigma} + F_{LT}$$

$$= \sigma_n \tan \delta_U (L_{RO}) + \sigma_n \tan \delta_L (L_{RO}) + 0.5\left(\frac{2T_{\text{allow}} \sin \beta}{L_{RO}}\right)(L_{RO}) \tan \delta_L$$

$$L_{RO} = \frac{T_{\text{allow}}(\cos \beta - \sin \beta \tan \delta_L)}{\sigma_n(\tan \delta_U + \tan \delta_L)} \qquad (5.25)$$

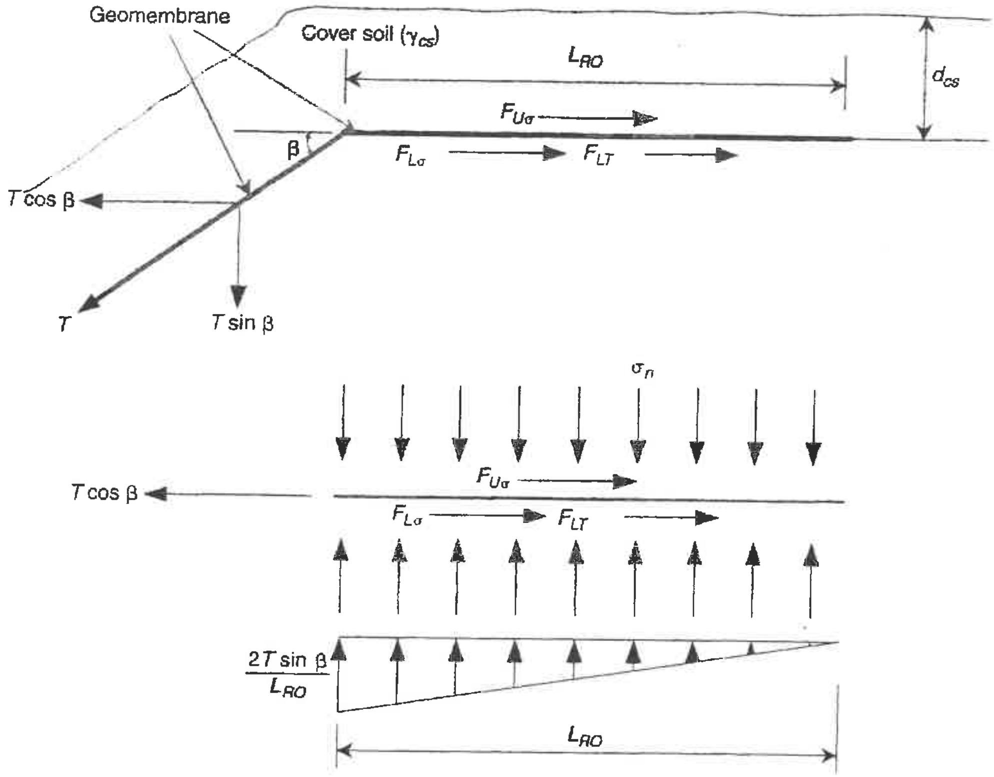


Figure 5.27 Cross section of geomembrane runout section and related stresses and forces involved.

where

T_{allow} = allowable force in geomembrane = $\sigma_{allow}\, t$, where
σ_{allow} = allowable stress in geomembrane, and
t = thickness of geomembrane;
β = side slope angle;
$F_{U\sigma}$ = shear force above geomembrane due to cover soil (note that for thin cover soils tensile cracking will occur and this value will be negligible);
$F_{L\sigma}$ = shear force below geomembrane due to cover soil;
F_{LT} = shear force below geomembrane due to vertical component of T_{allow};
σ_n = applied normal stress from cover soil;
δ = angle of shearing resistance between geomembrane and adjacent material (i.e., soil or geotextile); and
L_{RO} = length of geomembrane runout.

Example 5.13 illustrates the use of the concept and equations just developed.

Ex

Consider a 1.0 mm ... LLDPE geomembrane with a mobilized allowable stress of 7000 kPa which is on a 3(H) to 1(V) side slope. Determine the required runout length to resist this stress without use of a vertical anchor trench. In this analysis use 300 mm of cover soil weighing 16.5 kN/m³ and a friction angle of 30° with the geomembrane.

From the design equations just presented,

$$T_{allow} = \sigma_{allow}\, t$$
$$= (7000)(0.001)$$
$$T_{allow} = 7.0 \text{ kN/m}$$

and

$$L_{RO} = \frac{T_{allow}(\cos\beta - \sin\beta\tan\delta_L)}{\sigma_n(\tan\delta_U + \tan\delta_L)}$$
$$= \frac{(7.0)[\cos 18.4 - (\sin 18.4)(\tan 30)]}{(16.5)(0.30)[\tan 0 + \tan 30]}$$
$$= \frac{5.37}{2.86}$$
$$L_{RO} = 1.9 \text{ m}$$

Note that this value is strongly dependent on the value of mobilized allowable stress used in the analysis. To mobilize the failure strength of the geomembrane would require a longer runout length or embedment in an anchor trench. This, however, might not be desirable. Pullout without geomembrane failure might be a preferable phenomenon. It is a site-specific situation left up to the designer.

The situation with an anchor trench at the end of the runout section is illustrated in Figure 5.28. The configuration requires some important assumptions regarding the state of stress within the anchor trench and its resistance mechanism. In order to provide lateral resistance, the vertical portion within the anchor trench has lateral forces acting upon it. More specifically, an active earth pressure (P_A) is tending to destabilize the situation, whereas a passive earth pressure (P_P) is tending to resist pullout. As will be shown, this passive earth pressure is very effective in providing a resisting force (see Holtz and Kovacs [48]). Using the free-body diagram of Figure 5.28,

$$\Sigma F_x = 0$$
$$T_{allow}\cos\beta = F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P \qquad (5.26)$$

where

T_{allow} = allowable force in geomembrane = $\sigma_{allow}\, t$, where
σ_{allow} = allowable stress in geomembrane, and
t = thickness of geomembrane;
β = side slope angle;
$F_{U\sigma}$ = shear force above geomembrane due to cover soil (note that for thin cover soils, tensile cracking will occur, and this value will be negligible);

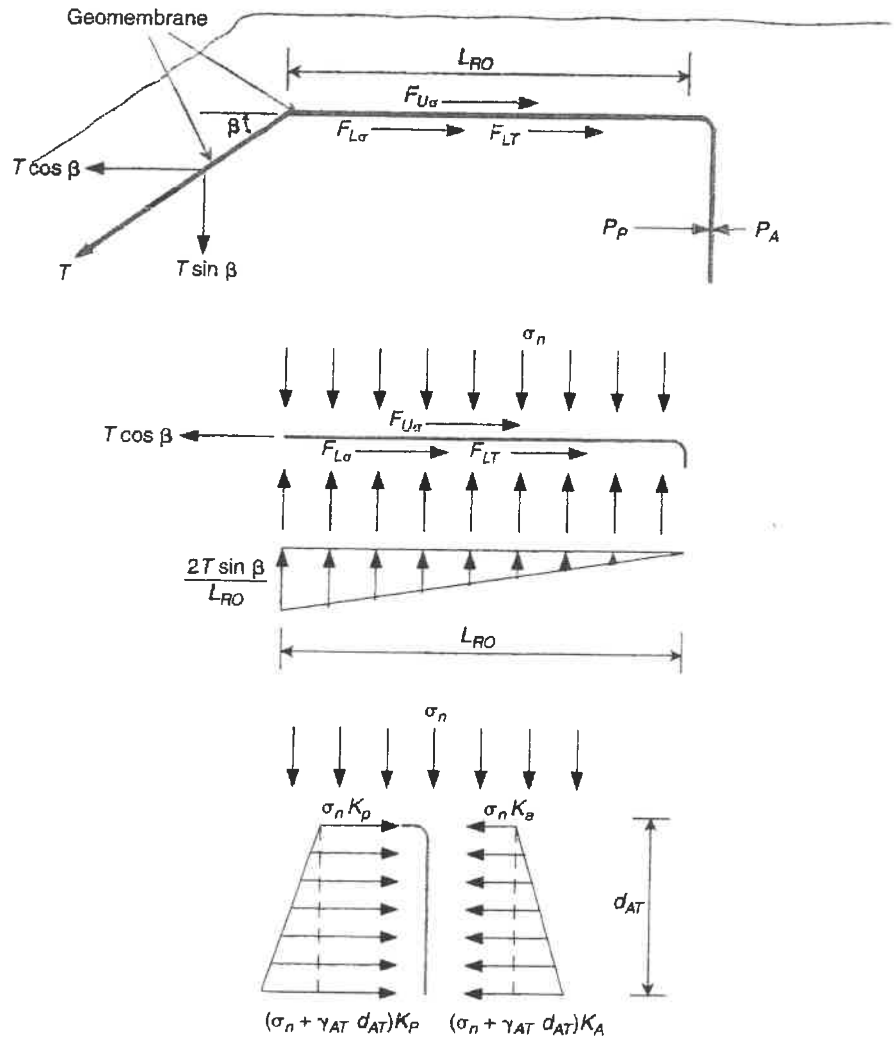


Figure 5.28 Cross section of geomembrane runout section with anchor trench and related stresses and forces involved.

$F_{L\sigma}$ = shear force below geomembrane due to cover soil
F_{LT} = shear force below geomembrane due to vertical component of T_{allow};
P_A = active earth pressure against the backfill side of the anchor trench; and
P_P = passive earth pressure against the in-situ side of the anchor trench.

The values of $F_{U\sigma}$, $F_{L\sigma}$, and F_{LT} have been defined previously. The values of P_A and P_P require the use of lateral earth pressure theory.

$$P_A = \frac{1}{2}(\gamma_{AT} d_{AT})K_A d_{AT} + (\sigma_n)K_A d_{AT}$$

$$P_A = (0.5\gamma_{AT} d_{AT} + \sigma_n)K_A d_{AT} \quad (5.27)$$

$$P_P = (0.5\gamma_{AT} d_{AT} + \sigma_n)K_P d_{AT} \quad (5.28)$$

where

γ_{AT} = [illegible] weig[illegible] of soil in anchor trench,
d_{AT} = [illegible] of the anchor trench,
σ_n = a[illegible] stress from cover soil,
K_A = [illegible]cient of active earth pressure = $\tan^2(45 - \phi/2)$,
K_P = coefficient of passive earth pressure = $\tan^2(45 + \phi/2)$, and
ϕ = angle of shearing resistance of respective soil.

This situation results in one equation with two unknowns; t[illegible]s a choice of e[illegible]her L_{RO} or d_{AT} is necessary to calculate the other. As with the previous situation, the factor of safety is placed on the geomembrane force T, which is used as an a[illegible]owable value, T_{allow}. Example 5.14 illustrates the procedure.

E[illegible] 5.14

Consider a 1.5 mm thick HD[illegible] geomembrane extending out of a facility as shown in Figure 5.28. What [illegible]epth anchor trench is needed if the runout distance is limited to 1.0 m? In the solution, use a geomembrane allowable stress of 16,000 kPa on a 3(H) to 1(V) side slope. Cover soil at 16.5 kN/m³ and 300 mm thick is placed over the geomembrane runout and anchor trench (this is also the unit weight of the anchor trench soil). The friction angle of the geomembrane to the soil is 30° (although assume 0° for the top of the geomembrane under a soil-cracking assumption) and the soil itself is 35°. Also, develop a design chart for this e[illegible]mple assuming that the runout length is not limited to 1.0 m.

[illegible]on: [illegible]sing the previously developed design equations based on Figure 5.28.

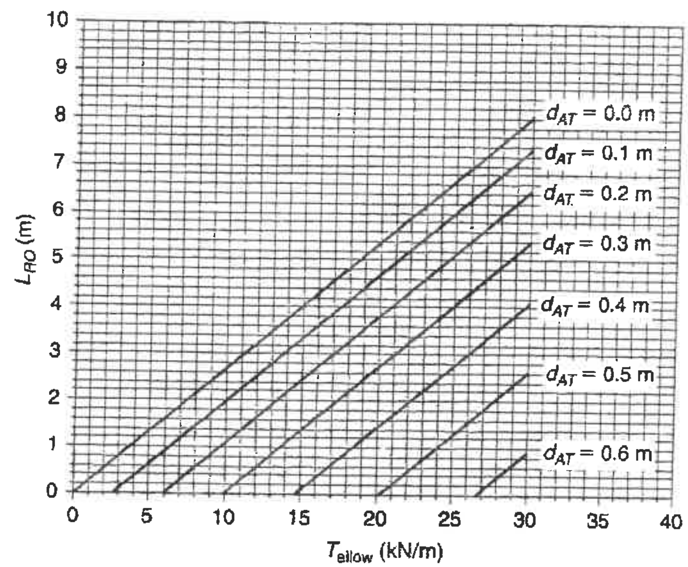
$$T_{allow} = \sigma_{allow} t = 16000(0.0015) = 24.0 \text{ kN/m}$$

and

$$F_{U\sigma} = \sigma_n \tan \delta_U (L_{RO}) = (0.3)(16.5) \tan 0 (L_{RO}) = 0$$

$$F_{L\sigma} = \sigma_n \tan \delta_L (L_{RO}) = (0.3)(16.5) \tan 30 (L_{RO}) = 2.86 L_{RO}$$

$$F_{LT} = T_{allow} \sin \beta \tan \delta_L = (24.0) \sin 18.4 \tan 30 = 4.37 \text{ kN/m}$$



$$
\begin{aligned}
P_A &= (0.5\gamma_{AT}d_{AT} + \sigma_n)K_A d_{AT} \\
&= [(0.5)(16.5)d_{AT} + (0.3)(16.5)]\tan^2(45 - 35/2)d_{AT} \\
&= [8.25d_{AT} + 4.95](0.271)d_{AT} \\
&= 2.24d_{AT}^2 + 1.34d_{AT}
\end{aligned}
$$

$$
\begin{aligned}
P_P &= (0.5\gamma_{AT}d_{AT} + \sigma_n)K_P d_{AT} \\
&= [(0.5)(16.5)d_{AT} + (0.3)(16.5)]\tan^2(45 + 35/2)d_{AT} \\
&= [8.25d_{AT} + 4.95](3.69)d_{AT} \\
&= 30.4d_{AT}^2 + 18.3d_{AT}
\end{aligned}
$$

This is substituted into the general force equation (5.26) to arrive at the solution in terms of the two variables L_{RO} and d_{AT}:

$$
\begin{aligned}
T_{allow}\cos\beta &= F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P \\
(24.0)\cos 18.4 &= 0 + 2.86\,L_{RO} + 4.37 - 2.24d_{AT}^2 \\
&\quad - 1.34d_{AT} + 30.4d_{AT}^2 + 18.3d_{AT} \\
18.4 &= 2.86L_{RO} + 17.0d_{AT} + 28.2d_{AT}^2
\end{aligned}
$$

Since L_{RO} = 1.0 m, the equation can be solved for the unknown d_{AT}.

$$d_{AT} = 0.50 \text{ m}$$

Using this formulation, we can develop a *design chart* for a wide range of geomembranes and thicknesses as characterized by different values of T_{allow}. For the specific conditions of Example 5.14, we obtain

$$
\begin{aligned}
\beta &= 18.4°, \text{ which is } 3(H) \text{ to } 1(V) \\
\sigma_n &= d_{cs}\gamma_{cs} \\
&= (0.30)(16.5) \\
&= 4.95 \text{ kN/m}^2
\end{aligned}
$$

$$\delta_L = 0°$$
$$\delta_L = 30°$$
$$\phi = 35°$$
$$\gamma_{AT} = 16.5\ kN/m^3$$
$$\delta_{AT} = 30°$$

The response in terms of the two unknowns L_{RO} and d_{AT} is given in the previous diagram. Based on this figure and with the 1.5 mm thick HDPE at 24.0 kN/m (from Table 5.5b, HDPE = 15,900 × 0.0015 = 24 kN/m allowable) gives an anchor trench depth of 0.50 m for an assumed runout length of 1.0 m. Other values can be readily selected.

It should be noted that many manufacturers specify 500 mm deep anchor trenches and 1000 mm long runout sections. As seen above, this is very simplistic, for each geomembrane type and thickness suggests its own analysis. By using a model as presented here, any set of conditions can be used to arrive at a solution. Even situations in which geotextiles and/or geonets are used in conjunction with the geomembrane (under, over, or both) and brought into the anchor trench can be analyzed in a similar manner.

[illegible]

Projects involving liquid containment using geomembranes are often extremely large. With large size come some inherent advantages over smaller projects. Foremost of these advantages is that most parties involved take the project seriously and approve of and enter into a planned and sequential design procedure. This section was laid out with this in mind, so that the design process proceeded step by step. Each element of design that is made leads to a new issue, which is followed by a new design element. Eventually, the quantitative process is concluded, and we must attend to extremely important details, often qualitative by nature, such as seam type, seam layout, piping layout, and appurtenance details. They are, however, common to all geomembrane projects and therefore will be handled in Sections 5.11 and 5.12.

Although such large projects obviously warrant a careful design procedure, it does not follow that smaller projects do not deserve the same attention. Indeed, failures of small liner systems can be significant. Many warrant a design effort comparable to that of large projects, as illustrated in this section.

With this section behind us, we can now focus on other applications involving geomembranes. Where a similar analysis is called for, reference will be made back to this section. Thus [illegible] and/or unique features of geomembrane projects will form the basis of the sections to follow.

5.4 CO[illegible]

Geomembrane covers are often used above the surface of storage reservoirs for liquids and quasi-solids such as industrial and agricultural sludges. They are of fixed, floating, or suspended types.

Attachment - 2

GSE®

Product Data Sheet

GSE STANDARD PRODUCTS

GSE White Textured Geomembranes

GSE White Textured is the textured version of GSE White. It is a high quality, high density polyethylene (HDPE) geomembrane with one or two coextruded, textured surfaces. It has a UV-stabilized, white upper surface that is approximately 3 mils (0.125 mm) thick. This layer is part of the total thickness, the remainder of which is a carbon black stabilized primary layer. The light reflective surface improves detection of post-installation damage and reduces heat buildup on the liner by reflecting solar energy. Reducing liner temperature leads to fewer wrinkles and less subgrade desiccation. This textured product provides enhanced interface friction with adjoining materials. *These product specifications meet or exceed GRI GM13.*

Product Specifications

GSE Advantage Products
GSE GundSeal • GSE Conductive • GSE White • GSE Permaliet • GSE BioDrain System

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM VALUE			
Product Code			HDT 040G010	HDT 060G010	HDT 080G010	HDT 100G010
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(4), 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(2)(4), %	ASTM D 1603*/4218	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(3), hr	ASTM D 5397, Appendix	200,000 lb	300	300	300	300
REFERENCE PROPERTY	**TEST METHOD**	**FREQUENCY**	**NOMINAL VALUE**			
Oxidative Induction Time(4), min	ASTM D 3895, 200° C; O_2, 1 atm	200,000 lb	>100	>100	>100	>100
Roll Length(5) (approximate), ft (m)			700 (213)	520 (158)	400 (122)	330 (101)
Roll Width(5), ft (m)			22.5 (6.9)	22.5 (6.9)	22.5 (6.9)	22.5 (6.9)
Roll Area, ft² (m²)			15,750 (1,463)	11,700 (1,087)	9,000 (836)	7,425 (690)

126 lb/in / 0.060 in = 2100 lb/in²

NOTES:

- +Note 1: Dispersion only applies to near spherical agglomerates. 9 or 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 White 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)GSE White Textured may have an overall ash content greater than 3.0% due to the white layer.
- (3)NCTL 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.
- (4)The values apply to the black layer only.
- (5)Roll lengths and widths have a tolerance of ± 1%.
- *Modified.

DS015 Whtext R01/07/08

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