MATLOCK BEND CLASS I LANDFILL – EXPANSION

PART 2B PERMIT APPLICATION

RESPONSE TO DECEMBER 17, 2013 TDEC COMMENTS

Prepared for:
Loudon County Solid Waste Disposal Commission
Loudon County, Tennessee

Prepared By:
Santek Waste Services, Inc.
650 25TH Street NW, Suite 100
Cleveland, TN 37311

Submitted To:
Tennessee Department of Environment and Conservation
Division of Solid Waste Management

MARCH 2014

HOUSE ENGINEERING

STABILITY

House Engineering LLC

PROJECT	MATLOCK BEND LANDFILL	PROJECT NO.	201401
Seismic Deformation and Liquefaction Screening		PAGE	1 OF 1
MADE BY JKH	DATE 2-17-14	CHECKED BY JKH	DATE 2-17-14

The following documents present the results of the global and veneer stability analyses along with the seismic deformation analysis and also the liquefaction screening evaluation performed for the proposed expansion to the Matlock Bend Landfill located in Loudon County, Tennessee. Deformation has been calculated using three different methods as follows:

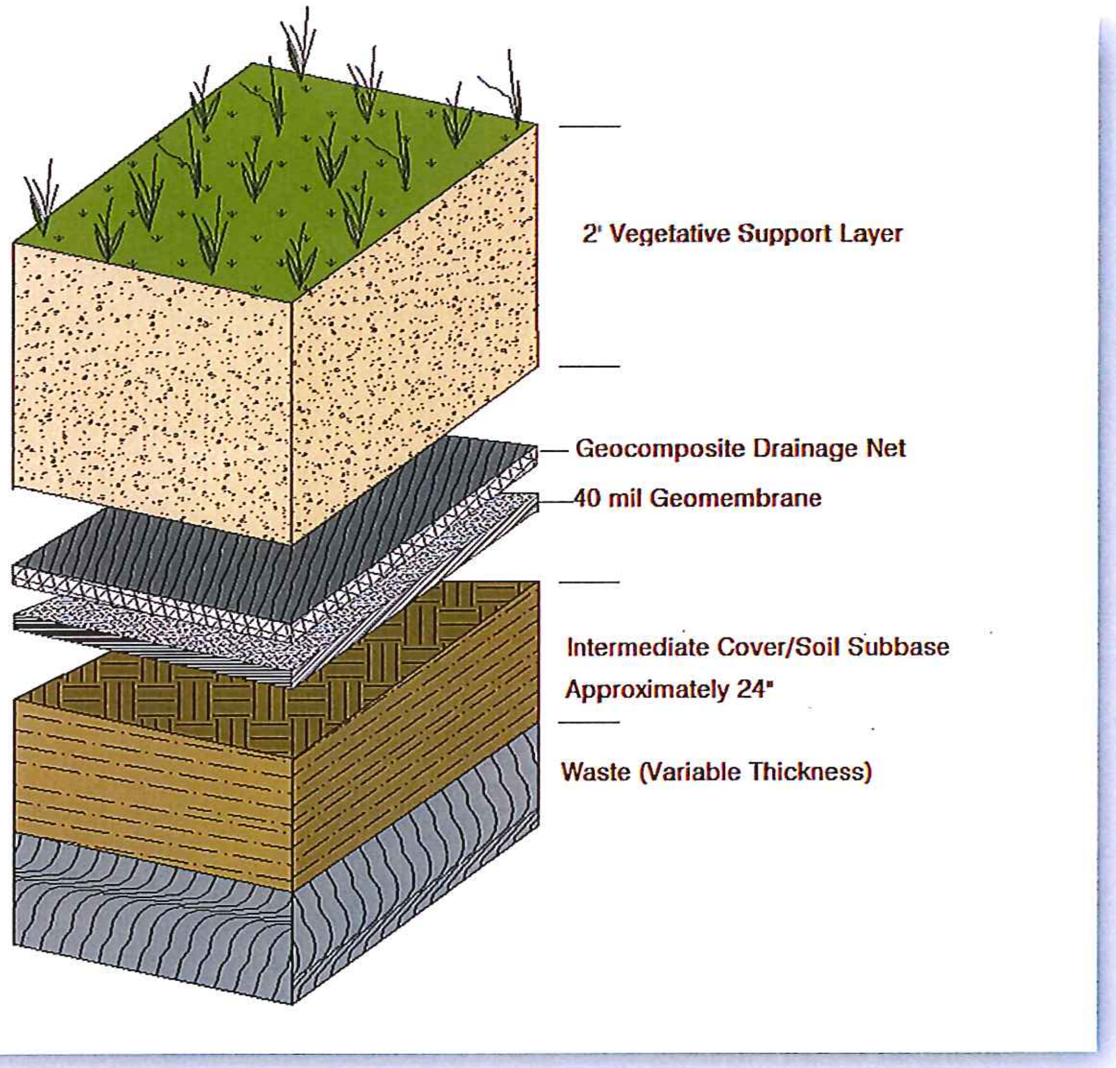
- Franklin/Hynes
- Simplified Procedure, Bray/Rathje/Augello
- Tennessee Division of Solid Waste Management's (TDSWM) Earthquake Evaluation Guidance Document.

The specific seismic event evaluated is described in the TDSWM regulations as the earthquake that has a two percent chance of probability of occurrence in fifty years or a 100 percent chance in approximately 2,500 years. The magnitude of the projected earthquake is estimated as a 7.0 on the Richter Scale.

HOUSE ENGINEERING LLC

VENEER STABILITY

SANTEK WasteServices



VENEER STABILITY NARRATIVE

2014 Matlock Bend Class I Landfill Expansion
Loudon, Tennessee

JO K. HOUSE
REGISTERED PROFESSIONAL ENGINEER
AGRICULTURE COMMERCE
No. 016277
STATE OF TENNESSEE

2/12/2014

Prepared By:

HOUSE ENGINEERING LLC

Matlock Bend Landfill Veneer Stability Analysis

TABLE OF CONTENTS

APPENDICES

TABLES

FIGURES

Matlock Bend Landfill Veneer Stability Analysis

GLOSSARY OF TERMS / NOTATIONS

c = soil cohesion (Pa)

cm/sec = centimeters per second

$D_{5\text{-}95}$ = significant duration of acceleration-time history (s)

FS = factor of safety (dimensionless)

FS_{static} = static factor of safety (dimensionless)

G = shear modulus (Pa)

G_{max} = maximum shear modulus (Pa)

g = acceleration due to gravity (m/s^2)

GRI = Geosynthetics Research Institute

H = height of landfill waste or cover thickness (m)

HE = House Engineering LLC

HEA = horizontal equivalent acceleration (m/s^2)

HCV = highest conceivable value

kN/m^3 = Kilonewtons per cubic meter

k = permeability (cm/sec)

k = seismic acceleration coefficient (dimensionless)

k_{max} = maximum seismic acceleration coefficient = *MHEA/g* (dimensionless

k_y = yield acceleration coefficient (dimensionless)

kPa = kilopascal

L = length of midsection of landfill (m)

LCV = lowest conceivable value

L_S = length of cover slope mass (m)

LLDPE = Low Density Polyethylene

MBL = Matlock Bend Landfill

MHA = maximum horizontal ground acceleration (m/s^2)

MHA_{Crest} = maximum horizontal ground acceleration at crest of landfill (m/s^2)

MHA_{Rock} = maximum horizontal ground acceleration of rock (m/s^2)

MHA_{Site} = maximum horizontal ground acceleration of site (m/s^2)

MHA_{Top} = maximum horizontal ground acceleration at top of landfill (m/s^2)

MHEA = maximum horizontal equivalent acceleration (m/s^2)

$MHEA_{Base}$ = maximum horizontal equivalent acceleration at base of landfill (m/s^2)

$MHEA_{Cover}$ = maximum horizontal equivalent acceleration of landfill cover sliding mass (m/s^2)

MLV = most likely value

GLOSSARY OF TERMS / NOTATIONS (continued)

mm = millimeter

m/s = meters per second

M_W = moment magnitude of earthquake event (dimensionless)

psf = pounds per square foot

PSR = parallel submergence ratio

NRF = nonlinear response factor (dimensionless)

RFCR = creep reduction factor

R = seismic displacement reduction factor = k_y / k_{max} at selected displacement (dimensionless)

R_B = seismic displacement reduction factor = k_y / k_{max} at selected base displacements (dimensionless)

R_C = seismic displacement reduction factor = k_y / k_{max} at selected cover displacements (dimensionless)

Santek = Santek Waste Services LLC

S_1 = back-slope run to height ratio (dimensionless)

S_2 =front-slope run to height ratio (dimensionless)

T_p = mean period of acceleration-time history (s)

$T_{m\text{-}EQ}$ = mean period of earthquake (s)

T_P = predominant period of ground motion (s)

$T_{p\text{-}EQ}$ = predominant period of earthquake (s)

T_s = fundamental period of column of waste fill (s)

$T_{s\text{-}FILL}$ = fundamental period of fill material (s)

$T_{s\text{-}WASTE}$ = fundamental period of waste

t = time (s)

U = seismically induced permanent displacement (mm)

USEPA = United States Environmental Protection Agency

V_s = average shear wave velocity (m/s)

β = slope angle of cover from horizontal (°)

ε = strain (dimensionless)

θ = transmissivity (cm/sec)

ϕ = internal friction angle (°)

γ = total unit weight (N/m^3)

1.0 INTRODUCTION

House Engineering LLC (HE) was contracted by Santek Waste Services, Inc. (Santek) to complete the responses to comments specific to the slope stability of the Matlock Bend Landfill located in Loudon County, Tennessee. Specifically, (HE) was subcontracted by Santek to perform the veneer slope stability evaluation for the proposed final cover system for the Matlock Bend Landfill in Loudon County, Tennessee. This report outlines the approach taken by HE during the performance of the veneer stability evaluation and presents the findings and recommendations that resulted from the evaluation.

Landfill cover systems have a high sensitivity to relatively small changes in various parameters. A number of analytical methods were used to calculate the veneer slope stability factor of safety of the proposed final cover system.

A number of landfill designers are of the opinion that of all the factors which contribute to the loss of veneer stability of a landfill final cover it is the depth of hydrostatic head above the liner that is most critical. Other parameters include the hydraulic conductivity of the overlying soil, transmissivity of the drainage layer, the slope angle, and spacing between outlet drains. (One significant final cover slide in Tennessee was attributable to an excessive length of drainage with an outlet). Interestingly, climatic conditions do not impact stability as much as it would seem primarily since a 30 minute rain event is generally enough to create a critical drainage condition within the cover system.

It is the intent of the design to ensure that the liquid thickness is less than the drainage layer thickness. Veneer failures often are attributable to conditions where water builds to a level that exceeds the thickness of the drainage layer such that it comes in contact with the overlying saturated soil cover resulting in a condition where the depth of saturation is suddenly from the top of the final cover to the top of the geocomposite drainage net. Therefore, when geocomposite drainage net is used as the drainage layer in a final cover system it is imperative that the hydraulic head be kept to less than 5mm. Limiting the hydraulic head to 5mm presents a situation where there is little room for error since a failure of the geocomposite can lead to a total slope failure.

2.0 DESIGN APPROACH

Santek provided House Engineering LLC (HE) with existing slope stability and investigation reports and historical data (performed by Geosyntec) generated from previous studies performed for the Matlock Bend Landfill. These reports/data included some geotechnical information such as boring logs, grain size data, and Atterberg Limits, but did not include interface testing of cover system components. It should be noted that this design approach establishes the parameters necessary to satisfy veneer stability of the final cover system. Again, the high level of sensitivity of final cover systems to relatively small changes of certain parameters emphasizes the importance of determining the limiting values of the parameters which are critical to providing a stable final cover system for the Matlock Bend Landfill.

Peak vs. Residual Interface Strength Approach

Numerous articles have been written specific to using the peak or residual interface strength for designing final cover systems. Based upon a review of the literature and personal discussions with geosynthetic industry researchers the final cover system for the Matlock Bend Landfill has been designed using peak strength. The following paragraphs provide excerpts taken from white papers and journal publications from which the Matlock Bend Landfill final cover design approach is based:

Tim Stark and H. Choi have stated:

"*The stability of the geosynthetic cover systems can be analyzed using the peak shear strength of the weakest interface, or, if necessary, the weakest composite interface, when the factor of safety greater is than 1.5. The use of peak strength is recommended for the cover system because of the lack of or limited amount of detrimental shear displacement along the weakest interface in a cover system compared with a liner side slope. However, if the average slope of the cover system is greater than the lowest peak interface friction, or large displacements such as construction – induced displacements or seismically induced displacements are expected, a residual shear strength with a factor of safety greater than unity should be used for the cover design.*" The preceding paragraph is taken verbatim from *'Geosynthetics International, 2004, 11. No. 6.*

Robert Koerner also has made the following comments in GRI Report #29 from 2003:

"Peak strength design, with adequate factor of safety for site specific conditions would have prevented every one of the previously mentioned failures! Even further, proper design such that peak strength will greatly lessen deformations and the subsequent serviceability concerns ..."

"When using residual strength in design there is no likelihood of failure and while extremely conservative it is unnecessarily so and in the author's opinion is not needed at all."

HE's design approach for the veneer slope stability evaluation was based on the performance of parametric analyses to determine the critical minimum physical properties of soils and geosynthetic materials that would yield a final cover system with the following:

- A factor of safety against sliding of 1.5 for veneer stability with peak strength parameters.
- A factor of safety against sliding ranging between 1.0 and 1.3 for veneer stability for seismic conditions.

(The United States Environmental Protection Agency (USEPA) accepts 1.0 as a suitable factor of safety).

The Cross Section identified on the permit drawings as Section C-C poses the greatest challenge from a slope stability perspective; hence, HE concentrated the veneer slope stability evaluation on this slope. It is noted that the stability of the final cover system is dependent upon the ability of final cover components to satisfy critical interface strength requirements. Therefore, ***the construction contractor will be responsible for verifying that the minimum strength criteria of the final cover components are satisfied using industry approved testing prior to construction of the final cover system.***

3.0 PROPOSED FINAL COVER CONFIGURATION

Veneer stability analyses have been performed on the cover system configuration illustrated in **Figure 1**. The final cover system design has been developed by Santek for the Matlock Bend Class I Landfill. The proposed layers of the cover system for the Matlock Bend Class I Landfill (from final landfill surface grade downward) are as follows:

- 24 inches of vegetative support
- Drainage layer (Double sided geocomposite)
- 40 mil textured LLDPE
- One foot (minimum) of compacted soil
- One foot of intermediate cover soil

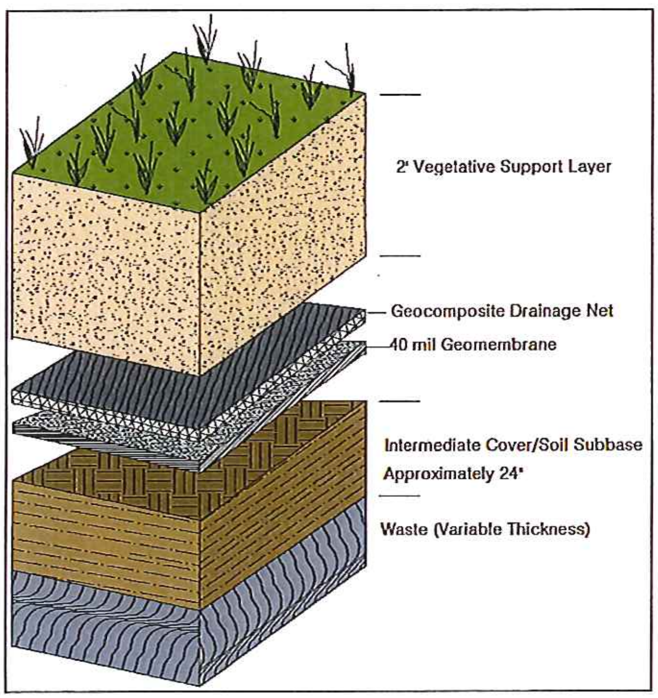


Figure 1 - Typical Final Cover Section

The final cover system also has the following properties:

- A final cover slope ratio with an approximated 3:1 slope (i.e., 3H : 1V).
- Benches for vertical relief and tack-on swales at a maximum of 128 foot intervals along the slope.
- A uniform final cover thickness (vegetative support soil layer) above the geosynthetics of 2.0 feet.

4.0 VENEER SLOPE STABILITY METHODOLOGY

Numerous analytical methods were used to calculate the veneer slope stability factor of safety of the proposed final cover system. In addition, a simple reliability analysis was performed as outlined by Duncan (2000), which utilizes a Taylor series method. The methods performed can be referenced to the following sources:

- Te-Yang Soong and Robert M. Koerner, "*The Design of Drainage Systems Over Geosynthetically Lined Slopes*", (GRI REPORT# 19), by June 17, 1997.
- Te-Yang Soong and Robert M. Koerner, "Analysis and Design of Veneer Cover Soils", Proceedings of 6th International Conference on Geosynthetics, 1995, Vol. 1, pp. 1-23, Atlanta, Georgia, USA.
- Ling and Leschinsky, (1997), "Seismic Stability and Permanent Displacement of Landfill Cover Systems", Feb. 1997, Vol. 123, No.2 Journal of Geotechnical and Geoenvironmental Engineering.
- Thiel, R.S. (1998), " Design Methodology for a Gas Pressure Relief Layer Below a Geomembrane Landfill Cover to Improve Slope Stability", Geosynthetic International, Vol. 5, No. 6 pp. 589-617.
- Thiel, R. S. (2008), "Slope Stability sensitivities of final covers", Geosynthetics, August September.
- Duncan, J. Michael, "Factors of Safety and Reliability in Geotechnical Engineering", 1999 Spencer J. Buchanan Lecture, Texas A&M University.
- Bray, Rathje, Augello and Merry, "Seismic Design for Lined Solid-Waste Landfills", 1998, Vol. %, Nos. 1-2.

4.1 Step One: Determine Impingement Rate,(q) and transmissivity of the geocomposite drainage layer.

Assume Unit Gradient Method for the design:

$$Q_i = k_{cover} = 1 \times 10^{-6}\ \text{cm/sec} = 1 \times 10^{-8}\ \text{m/s}$$

Solve for the required transmissivity with the following equation:

$$\theta_{req} = q_i * L / \sin\beta$$

For the proposed landfill side slope the required transmissivity of the geocomposite is,

$$\theta_{req} = k_{cover} * L / \sin\beta = \frac{1 \times 10^{-8}\ \text{m/s} * 30}{\text{Sin}18.4^{\circ}} = 9.5 \times 10^{-7}\text{cm/sec}$$

Determine the allowable Transmissivity $\theta_{req;}$

$$\theta_{allow} = \theta_{req} * F_{SD} * RF_{CC} * RF_{BC} * RF_{CR}$$

Where:

$FS_D = 3.0$ (accounts for uncertainty associated with inflow rate and the potential for particulate clogging)

$RF_{CC} = 1.0$ (See Table 1.0 - ranges from 1.0 to 1.2 based on alkalinity of protective soil; if soil is not alkaline in nature, then this can be ignored and set equal to 1.0)

$RF_{BC} = 2.0$ (See Table 1.0 - ranges from 1.2 to 3.5 based on anticipated biological growth environment; allow that potential root penetration could reduce transmissivity by half)

$RF_{CR} = 1.1$ = see Table 2.0 = Contact manufacturers of products being considered

Table 1 - Chemical clogging and biological clogging reduction factors

Application	Reduction Factor for Chemical Clogging (RF_{CC})	Reduction Factor for Biological Clogging (RF_{BC})
Cover Drainage Layer	1.0 to 1.2	1.2 to 3.5
Leachate Collection and Removal Layer	1.5 to 2.0	1.1 to 1.3
Leakage Detection Layer	1.1 to 1.5	1.1 to 1.3

Table 2 Creep reduction factors (RFCR) for geonets manufactured by GSE Lining Technology, Inc., (Narejo and Allen, 2004)

Pressure, kPa (psf)	Creep Reduction Factor (RF_{CR})
48 (1000)	1.1
240 (5000)	1.2
478 (10000)	1.3
718 (15000)	1.6

Therefore,

$$\theta_{allow} = \theta_{req} * F_{SD} * RF_{CC} * RF_{BC} * RF_{CR}$$

$$\theta_{allow} = 9.5 \times 10^{-7} \text{cm/sec} * 3 * 1 * 1.5 * 1.1$$

$$\theta_{allow} = 4.7 \times 10^{-6} \text{ cm/sec}$$

NOTE: Laboratory 100-hour transmissivity test value should be equal to or higher than the above allowable value. For relatively mild slopes, such as the top deck, where the slope is stable even under saturated conditions, the drainage requirements are much less demanding. In such cases, the primary function of a drainage layer might be to allow the cover soils to drain after precipitation events so they will not remain saturated for prolonged periods of time. Saturated soils, even on relatively flat slopes, are more susceptible to erosion and localized bearing capacity failures (e.g. under a wheel load or a deer hoof).

4.2 Step Two - Evaluate the Soil / Drainage Layer Interface Using the Parallel Submergence Ratio

Initially, GRI Report #19 was used to determine the impact of a specified rainfall event (input within the calculation in mm per hour) upon the drainage capability of the proposed geocomposite. Exceeding the drainage capacity of the geocomposite could potentially cause the final cover soil to become saturated and possibly unstable.

The required factor of safety for this analysis was set to 1.5. The following table summarizes the input parameters that were inserted into the Report #19 spreadsheet developed by Soong and Koerner to evaluate the veneer stability with respect to drainage capacity. The required angle of interface friction (δ) necessary between the cover soil and geocomposite material was determined using a trial and error approach. Numerous iterations revealed that a (δ) of 26 degrees between the soil and geocomposite drain material would produce a factor of safety of 1.5. A parametric evaluation was utilized to determine the parameters which are most critical to the stability of the slope. Table 3 summarizes the input values which were modified and how each modification impacted the factor of safety.

Table 3 - Parametric Veneer Stability Analysis of the Final Cover Soil over Geocomposite Drain Layer

	Conditions													
CONDITION EVALUATED	P (mm/hr.)	Hydraulic conductivity $k_{cover\ soil}$ cm/sec	$t_{cover\ soil}$ ft	$t_{cover\ soil}$ mm	RUNOFF COEFFICIENT RC	Slope Length L (ft)	Slope Length L (m)	Slope Angle β (deg)	Conductivity K_{GS} (cm/sec)	T_{GS} (mm)	SOIL FRICTION ANGLE Φ	INTERFACE FRICTION ANGLE, δ	FACTOR OF SAFETY	METHOD
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	18.4	0.27	7	28	26	1.531	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	18.4	0.27	7	28	31	1.884	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	18.4	0.27	7	28	19	1.084	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	21.8	0.27	7	28	26	1.271	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	15.8	0.27	7	28	26	1.806	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2.5	762	0.4	98	29.88	18.4	0.27	7	28	26	1.548	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	1.7	518.16	0.4	98	29.88	18.4	0.27	7	28	26	1.521	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	90	27.44	18.4	0.27	7	28	26	1.538	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	120	36.59	18.4	0.27	7	28	26	1.519	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	1.0E-05	2	609.6	0.4	98	29.88	18.4	0.27	7	28	26	1.527	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	5.0E-07	2	609.6	0.4	98	29.88	18.4	0.27	7	28	26	1.532	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	1.0E-06	2	609.6	0.4	98	29.88	18.4	0.27	7	33	26	1.533	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	1.0E-06	2	609.6	0.4	98	29.88	18.4	0.27	7	19	26	1.529	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	18.4	0.22	7	28	26	1.531	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	18.4	0.3	7	28	26	1.531	KOERNER

4.3 Step Three: Determine Minimum Interface Friction of all Geosynthetic Components (above the liner)

HE evaluated the geosynthetic-geosynthetic interfaces, such as geocomposite drainage net-geomembrane interface based on Stark and Poeppel (1994) whose study showed that the geosynthetic-geosynthetic interface was weaker under low normal stresses (up to approximately 150 to 300 kPa). Based upon the Stark and Poeppel study HE evaluated the geocomposite-geomembrane interface within the final cover system utilizing the veneer stability calculations presented by Ling and Leschinsky. HE utilized a trial and error approach using a spreadsheet developed with the equations presented in the *February 1997, Journal of Geotechnical and Geoenvironmental Engineering by Ling and Leschinsky*. (Note: At HE's request, the equations chosen by HE for use in this evaluation have been previously reviewed and checked by Dr. Robert Koerner, Director of the Geosynthetic Research Institute, (GRI) at Drexel University.) The results produced very similar results to other veneer equations. The designer selected these equations as they appear to provide a refinement of previously developed analytical methods (Koerner and Soong 1995). A parametric analysis was also conducted by varying the input parameters using the Ling/Leschinsky veneer stability method. Table 5 provides a summary table of the calculated results attained from the parametric analysis of the MBL final cover system.

The parameters used to input into the veneer slope stability equations developed by Ling and Leschinsky are provided in Table 4.

Table 4 - Parametric Veneer Stability Analysis of the Final Cover

	Parameters													
CONDITION EVALUATED	P (mm/hr.)	Hydraulic conductivity $k_{cover\ soil}$ cm/sec	Thickness of $t_{cover\ soil}$ ft	$t_{cover\ soil}$ mm	RUNOFF COEFFICIENT RC	Slope Length L (ft)	L (m)	Slope Angle β (deg)	Conductivity K_{GS} (cm/sec)	T_{GS} (mm)	SOIL FRICTION ANGLE Φ	INTERFACE FRICTION ANGLE, δ	FACTOR OF SAFETY	METHOD
Drainage Net to Geomembrane	81	1.00E-06	2	609.6	0.4	98	29.88	18.4	0.27	7	28	26	1.524	KOERNER
Drainage Net to Geomembrane	81	1.00E-06	2	609.6	0.4	98	29.88	18.4	0.27	7	28	31	1.864	KOERNER
	81	1.00E-06	2	609.6	0.4	98	29.88	18.4	0.27	7	28	19	1.092	KOERNER
Drainage Net to Geomembrane	81	1.00E-06	2	609.6	0.4	98	29.88	21.8	0.27	7	28	25	1.262	KOERNER
	81	1.00E-06	2	609.6	0.4	98	29.88	15.8	0.27	7	28	25	1.8	KOERNER
Drainage Net to Geomembrane	81	1.00E-06	2.7	822.96	0.4	98	29.88	18.4	0.27	7	28	25	1.544	KOERNER
	81	1.00E-06	1.7	518.16	0.4	98	29.88	18.4	0.27	7	28	25	1.515	KOERNER

Table 5 provides the minimum value for each of the input parameters to provide an acceptable factor of safety for veneer slope stability as determined with the Parallel Submergence Ratio and the Ling / Leschinsky method.

Table 5 - Minimum Required Parameters to Achieve Veneer Slope Stability per PSR and Ling/Leschinsky

INPUT PARAMETERS	Minimum Value Required
c = cohesion (PSF) =	0
Ca = adhesion (note: adhesion has been ignored) =	0
γ = wet unit weight of slope material(s) (KN/m^3) =	19
Φ = angle of internal friction of the soil (DEG) =	19°
δ = Interface Friction between soil and Geocomposite drain =	26°
H = thickness of soil cover (mm) =	518
t = thickness of drainage layer(mm) =	7
L = length of slope (m) =	36
k = soil permeability (cm/sec) =	1.00E-05
K_{gs} = geocomposite permeability (cm/sec) =	0.22
P = 100 yr 1 hr event precipitation in mm/hr =	81

In summary, the results of the parametric evaluations of the veneer stability analysis using both the Parallel Submergence Ratio (PSR) and the Ling / Leschinsky equations indicated that a 26° interface friction angle was required between each of the interfaces within the final cover system to achieve a factor of safety 1.5 against sliding failure of the cover slope.

4.4 Step Four: Calculate Infinite Slope Stability of the Final Cover System

An infinite slope stability evaluation of the final cover system was also performed using a slope angle of 18.4 degrees. The infinite slope stability analysis was performed with an equation presented by Koerner which is as follows:

$$\text{Factor of Safety} = \tan \delta / \tan \beta$$

Where: δ = interface friction angle and β = slope angle.

Given Input Parameters and Assumptions:

- Neglect Toe Restraint
- Neglect Excess Pore water, Gas
- σ_N applied from the soil cover at the interface $\cong$ 400 psf
- Minimum factor of safety = 1.5 for Stability

Solve for δ:

$$\text{Required Interface Friction} = \delta = 1.5 * (\tan 18.4°) = 26.5°$$

Therefore, the required Shear Strength of the interface $\tau_{INTERFACE}$ is = 254 psf * tan 26.5°

$$\tau_{INTERFACE} = 126.6 \text{ psf}$$

Geosynthetic Interfaces

The Nonwoven Geotextile to LLDPE Interface

Since the peak interface friction angle δ of most Composite Drains to Textured Geomembranes is greater than 26° the Factor of Safety is acceptable.

The Nonwoven to Soil Interface

Assume that the typical efficiency of the shear strength is 80%.

Therefore:

$$\text{Factor of Safety} = 1.5 = (\text{Shear Strength of Interface / Soil Shear Strength}) * 0.8$$

Therefore, since the required shear strength of the interface ($\tau_{INTERFACE}$) is 126.6 psf, then:

$$\text{Required Shear Strength of the Soil} = \tau_{SOIL} = (126.6/ .8) * 1.5 = 237.4 \text{ PSF}$$

4.5 Step Four: Perform Seismic Evaluation of the Final Cover System

The subtitle D regulations require landfill designs to be evaluated under seismic loading conditions resulting from the seismic event with a 2% probability of exceedence in 50 years. The United States Geological Survey (USGS) has developed an interactive hazard map to determine the peak horizontal ground acceleration which can be used to predict seismic induced ground deformations and movements. However, the use of one ground motion parameter as a design basis is considered somewhat simplistic since the frequency and duration of ground motion are equally important parameters. Bray, Rathje, Augello and Merry (1998) have developed a simplified seismic analysis procedure for geosynthetic-lined, solid waste landfills titled "Simplified Seismic Design Procedure for Geosynthetic Lined, Solid-Waste Landfills".

The procedure used to calculate the seismic coefficients, k, using the aforementioned procedure is detailed in the document titled "Seismic Coefficient Determination" located in **Appendix B**. The seismic coefficients determined from the "Simplified Procedure" for the final cover are as follows:

$$MHA_{TOP} = (0.21)(1.19)(0.95 \text{ to } 1.2) = 0.237g \text{ to } 0.299g$$

$$MHEA_{CREST} = (1.25)(0.237 \text{ to } 0.299) = 0.296g \text{ to } 0.373g$$

$$MHEA_{COVER\ SLOPE} = (0.65)(0.237 \text{ to } 0.299) = 0.154g \text{ to } 0.194g$$

Veneer Stability of Final Cover Slopes using Seismic Loading Coefficients

The highest seismic coefficient (MHEA) calculated using the "Simplified Procedure" within the final cover near the crest of the slope was determined to be 0.373g. This seismic coefficient was input into the Ling / Leschinsky equation along with the minimum critical parameters presented in **Table 5** of this document to estimate the factor of safety. The resulting factor of safety was determined to be less than one. Since the MHEA resulted in a FS of less than one HE used the Ling / Leschinsky equation to determine the yield acceleration K_y (acceleration which results in an FS = 1.0). The resulting K_y was calculated to be 0.145g.

Using the k_{max} and k_y HE estimated the seismically induced permanent displacements for localized sliding near the crest of the landfill for the design earthquake based on the Simplified Procedure using **Figure 3** and the following relationships:

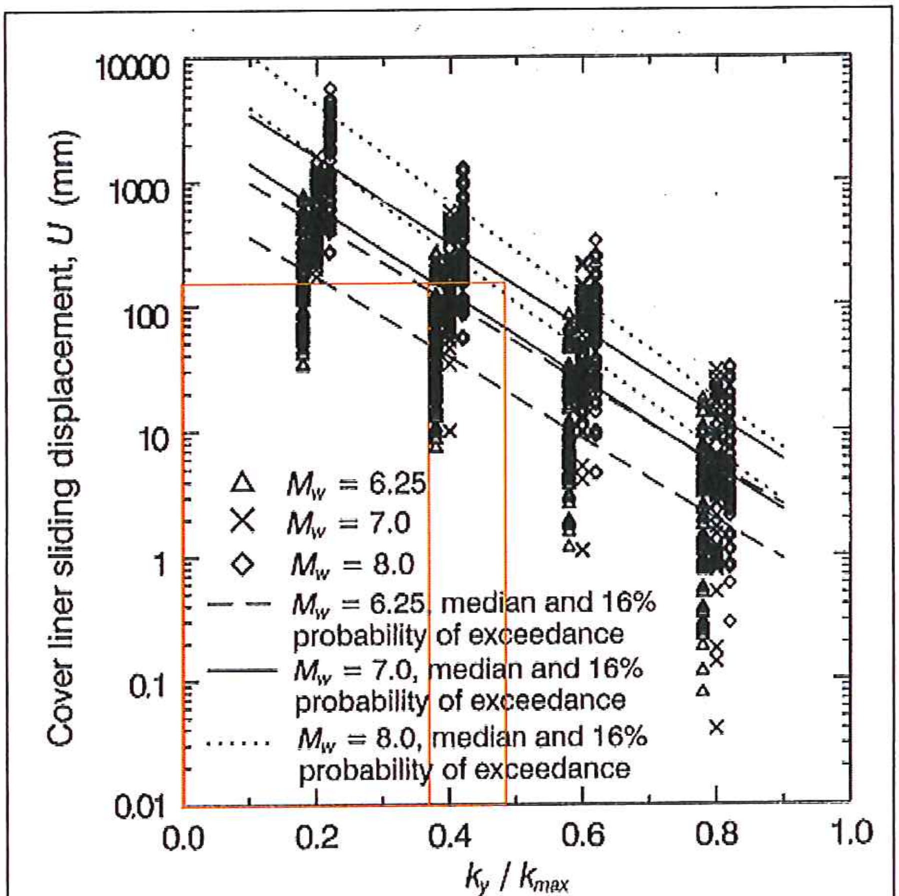
$k_{maxslopecrest}$ = MHEA/g = 0.296 to 0.373g, and k_y = 0.145g, so k_y / k_{max} = 0.49 to 0.387

To estimate the permanent displacements (U) use the values calculated for k_y / k_{max} to locate predicted displacements graphed in **Figure 3**.

Thus, from **Figure 3**, U = 150 mm = 5.9 inches near the crest and along the slope using both the 50 and 16% exceedence for M_w = 7.

It should also be noted that using the maximum k of 0.194g of the cover slope and increasing the minimum interface friction angle to 29° while holding all of the other critical parameters constant resulted in a factor of safety of the final cover slopes of 1.008 which is an acceptable factor of safety according to the USEPA guidance.

Figure 2 - Cover Liner Sliding Displacements (Bray, Rathje, Augello and Merry, 1998)



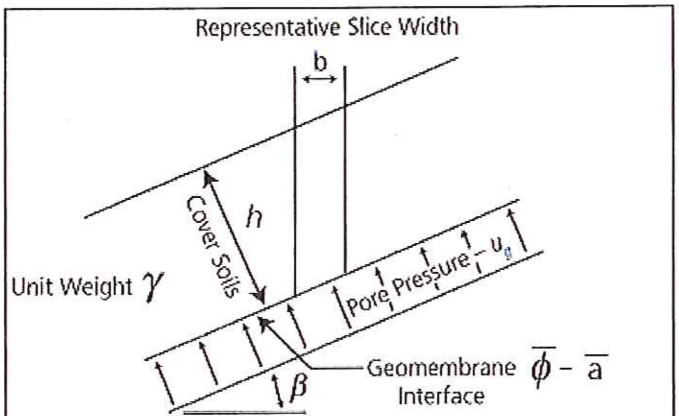
Note: The values of k_y / k_{max} (0.49 for 16% exceedence and 0.387 for 50% exceedence) were used to enter Figure 3 to determine the magnitude of displacements within the final cover.

4.6 Step Six: Check Equipment Loading During Construction

Final landfill cover design must be done with the ability to construct the design as a major consideration. Designs that require numerous geosynthetic components are susceptible to damage during construction. For example, a low ground pressure Caterpillar D4 bulldozer has a factor of safety of one when placing soil materials in one-foot lifts above geosynthetics based upon the spreadsheet developed by Te-Yang Soong. The spreadsheets used to calculate the equipment factor of safety are provided in **Appendix C**. Therefore, other iterations could be performed to determine the minimum cushion required between the equipment and the geosynthetics if the contractor proposes different equipment for placing soil materials on the side slopes. It should be further noted that soils should be pushed upslope if using a D4 rather than down slope. If soil is pushed downslope it requires a much thicker layer of soil to prevent damage to the geosynthetic layers within the final cover.

5.0 Determine Allowable Gas Pressure for Veneer Stability

Thiel (1998) developed a method for designing gas venting layers under landfill final covers which establishes the primary design criterion for geocomposite drainage nets to provide ample flow capacity. **Figure 4** provided below illustrates the infinite slope stability equation with gas forces. The formula can be rearranged so that the value of the maximum allowable gas pressure can be determined, which is the parameter that controls the design of the gas pressure relief system.



Infinite Slope Factor of Safety:

$$FS = \frac{\overline{a} + (h\gamma \cos\beta - u_g)\tan\overline{\phi}}{h\gamma \sin\beta}$$

Figure 3 - Infinite Slope Factor of Safety with Gas Pressure

Equation 5.1 Maximum Allowable Gas Pressure

$$u_{max} = \gamma_{cover} \bullet h_{cover} \bullet \cos\beta - \frac{(FS_s \bullet \gamma_{cover} \bullet h_{cover} \bullet \sin\beta)}{\tan\delta}$$

Where: μ_{max} = allowable gas pressure (kPa);

γ_{cover} = cover soil density (kN/m^3);

h_{cover} = soil cover thickness (m);

FS_s = factor of safety against sliding;

δ = interface friction angle (degrees) for geocomposite – geomembrane interface.

β = slope angle

It should be noted that the calculated maximum allowable gas pressure controls the design of the gas relief system.

Step 1 – Determine the maximum allowable gas pressure using Equation 5.1.

Given:	$\beta =$	18.4	degrees	0.321141	radians	
	$\delta =$	27	degrees	0.471239	radians	
	$\gamma_{cover} =$	19.9	kN/m^3			
	$h_{cover} =$	0.61	m			
	$FS =$	1.5				
Calculate:	$\cos\beta =$	0.948876				
	$\sin\beta =$	0.315649				
	$\tan\delta =$	0.509525				
	$\mu_{max} =$	0.238311	kPa =	4.98	psf	

Therefore, in order to maintain a FS of 1.5 the landfill gas collection system must maintain the maximum gas pressure under the liner system at less than 5 psf.

6.0 Reliability Analysis to Determine Probability of Failure

As a result of the sensitivity of landfill final covers to relatively small changes in loading, slope angle, pore pressures, and interface friction angles as well as observations of cover slope failures HE has performed an evaluation of the project reliability in addition to the factor of safety approach previously presented in this document. The reliability analysis presented in the following paragraphs is an approach outlined by Duncan (2000) and presented by Richard Thiel August September 2008 issue of GFR Magazine.

Step 1 – Determine the Most Likely Values (MLV)

Determine the Most Likely Values (MLV) of the parameters pertinent to the final cover in calculating the factor of safety. This analysis has utilized the Ling / Leschinsky veneer stability equations for determining the sensitivities of the critical parameters in calculating factors of safety.

Step 2 – Estimate the Standard Deviations of the Parameters

Estimate the Standard Deviations of the Parameters using the "Three Sigma Rule" due to a limited number of data points to base a standard deviation. Duncan states that the standard deviation can be determined using the "Three Sigma Rule" if the designer can estimate the highest conceivable value (HCV) and the lowest conceivable value (LCV) using the equation presented below:

$$\sigma = \frac{HCV - LCV}{6}$$

Table 6 summarizes the HCV and LCV of each of the critical slope stability parameters used to determine the standard deviation using the "Three Sigma Rule".

Table 6 - Standard Deviations of Critical Slope Parameters

CONDITION EVALUATED	$t_{cover\ soil}$ ft	$t_{cover\ soil}$ mm	Slope Angle β (deg)	Slope Angle β (Radians)	Slope Angle COS β	Liquid Depth h (mm)	Interface Friction Angle, δ	Interface Friction Angle, δ (Radians)	Interface Friction Angle, tan δ
MOST LIKELY VALUE (MLV)	2	609.6	18.4	0.3211	0.949	3	26	0.4538	0.4877
HIGHEST CONCEIVED VALUE (HCV)	2.5	762	21.8	0.3805	0.928	500	33	0.5760	0.6494
LOWEST CONCEIVED VALUE (LCV)	1.7	518.16	15.8	0.2758	0.962	0	21	0.3665	0.3839
Standard Deviation σ=	0.13	40.64			-0.0056	83.33			0.0443

Step 3 – Compute the Factor of Safety with Modified Parameters

Compute the factor of safety with each parameter increased by one standard deviation and then decreased by one standard deviation from its most likely values. Table 7 summarizes the results of the addition/subtraction of the standard deviation from each critical parameter and the resulting factor of safety for each.

Table 7 - Calculated Factors of Safety with Standard Deviations

Condition	Wet Unit Wt. (kN/m³)	Sat. Unit Wt. (kN/m³)	Interface Friction Angle phi	Slope Angle beta	Thickness t (mm)	Thickness t (ft)	Gas Pressure (kPa)	Factor of Safety	ΔF
MLV	19	19.9	26	18.4	610	2.0	0	1.524	
FS + σ for cos	19	19.9	26	19.4	610	2.0	0	1.437	0.193
FS - σ for cos	19	19.9	26	17.3	610	2.0	0	1.63	
FS + σ for tan	19	19.9	26.48	18.4	610	2.0	0	1.555	0.133
FS - σ for tan	19	19.9	24.41	18.4	610	2.0	0	1.422	
FS + σ for t	19	19.9	25	18.4	650.24	2.1	0	1.526	0.005
FS - σ for t	19	19.9	25	18.4	569.36	1.9	0	1.521	

Step 4 – Calculate the Standard Deviation of the Factors of Safety

The difference in the factors of safety using the plus-σ and the minus-σ values for a given parameter is termed ΔF. A separate ΔF is calculated for each of the parameters determined to be critical to the stability of the slope. The standard deviation of the factor of safety σ_F is calculated using the Taylor series technique presented below:

$$\sigma_F = \sqrt{\left(\frac{\Delta F_1}{2}\right)^2 + \left(\frac{\Delta F_2}{2}\right)^2 + \left(\frac{\Delta F_3}{2}\right)^2}$$

Standard Deviation σ_F= 0.117221

Step 5 – Calculate the Coefficient of Variation of the Factor of Safety

Calculate the Coefficient of Variation (V) using the Standard Deviation of the Factors of Safety and the Factor of Safety with the Most Likely Value (MLV).

$$\text{Coefficient of Variation } V = \frac{\sigma_F}{F_{MLV}} = 0.077$$

Step 6 – Calculate the Lognormal Reliability Index (β_{LN})

Calculate the Lognormal Reliability Index (β_{LN}) using the Coefficient of Variation (V) and the Factor of Safety with the Most Likely Value (MLV).

$$\text{Lognormal Reliability Index} = \beta_{ln} = \frac{\ln\left(\frac{F_{MLV}}{\sqrt{1+V^2}}\right)}{\sqrt{\ln(1+V^2)}}$$

$$\beta_{ln} = 5.6$$

Step 7 – Calculate the Reliability, (R) and Determine the Probability of Failure (P_f)

The NormDist Function in Microsoft Excel is used to calculate the Reliability, (R) using β_{LN} as the argument.

Based upon the Excel calculation Reliability R = 99.99%

Therefore, the Probability of Failure (P_f) = 1 – R = 0.01 expressed as a percent.

So the P_f represents about a 1 in 10,000 probability of failure.

7.0 SUMMARY

The veneer slope stability analyses performed in this study were focused on final cover slopes designed to be constructed at a three horizontal to one vertical slope ratio with a vertical relief ranging from 30 to 40 feet between benches/tack-on swales which provide drainage relief from above the geosynthetic components of the final cover.

The objective of this veneer stability analysis was to determine the required minimum parameters that will provide the proposed final cover system with adequate stability. The parametric studies did substantiate GRI report # 19 that cautioned designers about the impact of percolation rates on cover slope stability. Based upon numerous calculations it was determined that the maximum hydraulic conductivity for the 24 inch final cover layer should be 1 x 10 $^{-5}$ cm/sec. Again, all of the minimum required values for the parameters critical to the veneer stability of the Matlock Bend Landfill final cover system are summarized in **Table 8** along with the minimum required interface friction angles.

However, it is absolutely essential that laboratory interface friction testing be performed with the soil materials and geosynthetic materials to be used in the current final cover system prior to commencement of construction. Specifically, the following interfaces must be tested:

- Soil to Double Sided Geocomposite
- Double Sided Geocomposite to Textured FML
- Textured FML to Soil

The required interface friction angles appear to be attainable based on a review of the literature provided by various manufacturers.

Finally, with respect to seismic stability of final cover systems it has been the opinion of the Tennessee Division of Solid Waste Management (see TDSWM Earthquake Evaluation Guidance Policy, page 14) that the veneer type of slope failure will generally not result in a catastrophic type failure which would result in an adverse impact to human health and the environment.

Table 8 - Summary of Minimum Interface Friction Requirements

Interface	Method	Slope Angle β Degrees	Minimum Required δ Degrees
Soil to Geocomposite	Parallel Submergence[1]	18.4	26
Geocomposite to 40MIL LLDPE[4]	Finite Slope[2]	18.4	26
Any Interface under Seismic Loading	Finite Slope[2]	18.4	29[3]
Landfill Gas Pressure	Thiel/Richardson	18.4	27
Any Interface	Infinite Slope	18.4	26.5

Assumptions

c = cohesion (PSF) = 0

Ca = adhesion (note: adhesion has been ignored) = 0

γ = wet unit weight of slope material(s) (PCF) = 127

Φ = angle of internal friction of the soil (DEG) = 28

μ = pore water or gas pressure at the failure interface (psf) = 5

K_v and k_h = vertical and horizontal seismic coefficients (g's) = 0.

H = thickness of soil cover (FT) = 2.0

L = length of slope (FT) = 98

P = precipitation in mm/hr = 81

FACTOR OF SAFETY = 1.5

Other Required Parameters

K_{soil} = soil permeability (cm/sec) = 1.00E-05

$K_{geocomposite}$ = geocomposite permeability (cm/sec) = 0.27

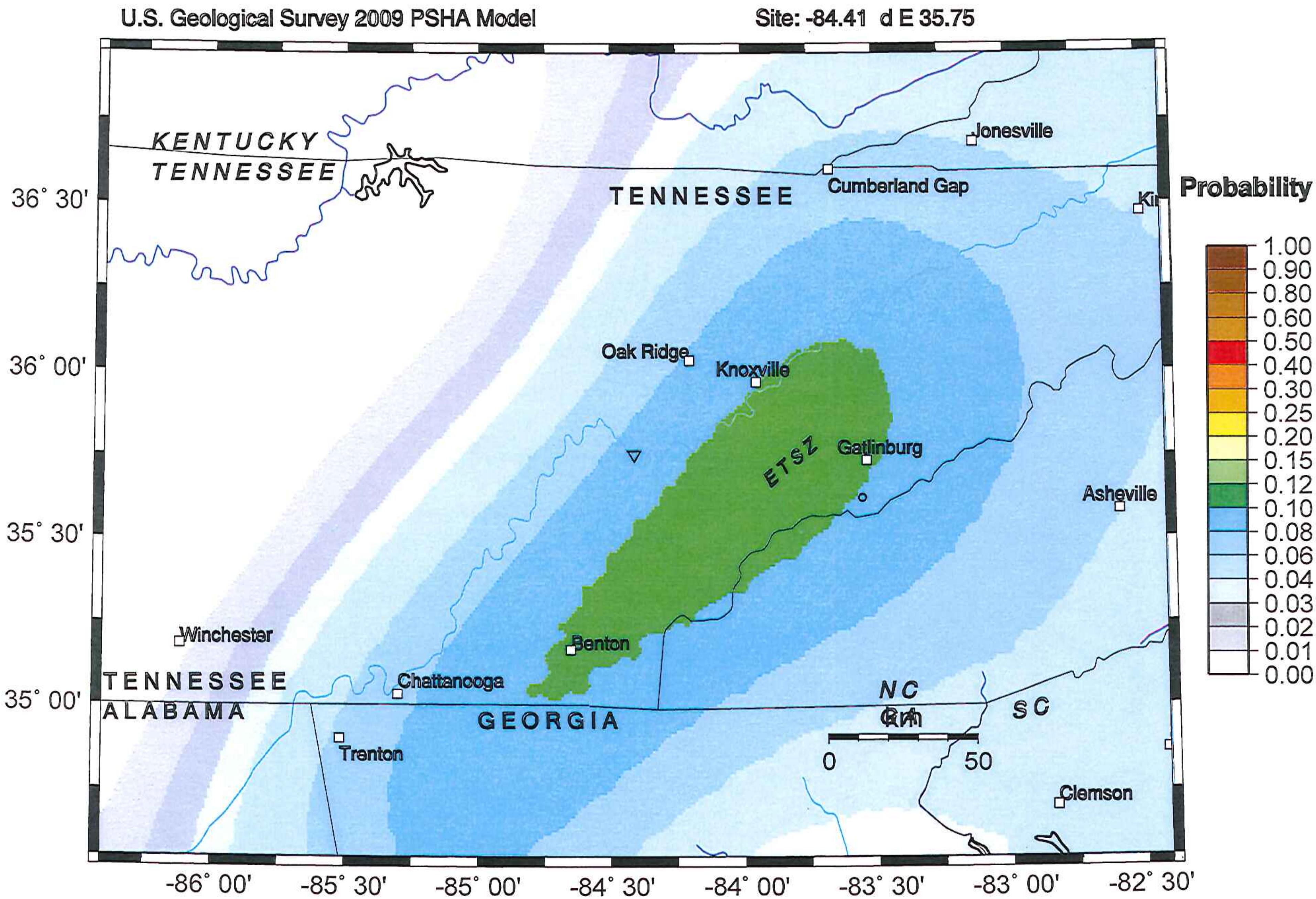
NOTES:

1. Koerner and Soong
2. Ling and Leshchinsky
3. Using k_{max} of the cover slope and a Factor of Safety of 1.0.
4. Weakest Interface.

APPENDIX A

MAPS/NOAA INFO

Probability of earthquake with M > 7.0 within 2500 years & 50 km



Earthqua Hazards Program | H About Us | Contact Us | Search

EARTHQUAKES | HAZARDS | DATA | LEARN | MONITORING | RESEARCH

US Seismic Hazard 2008

Layers | Tools

☑ Hazard maps

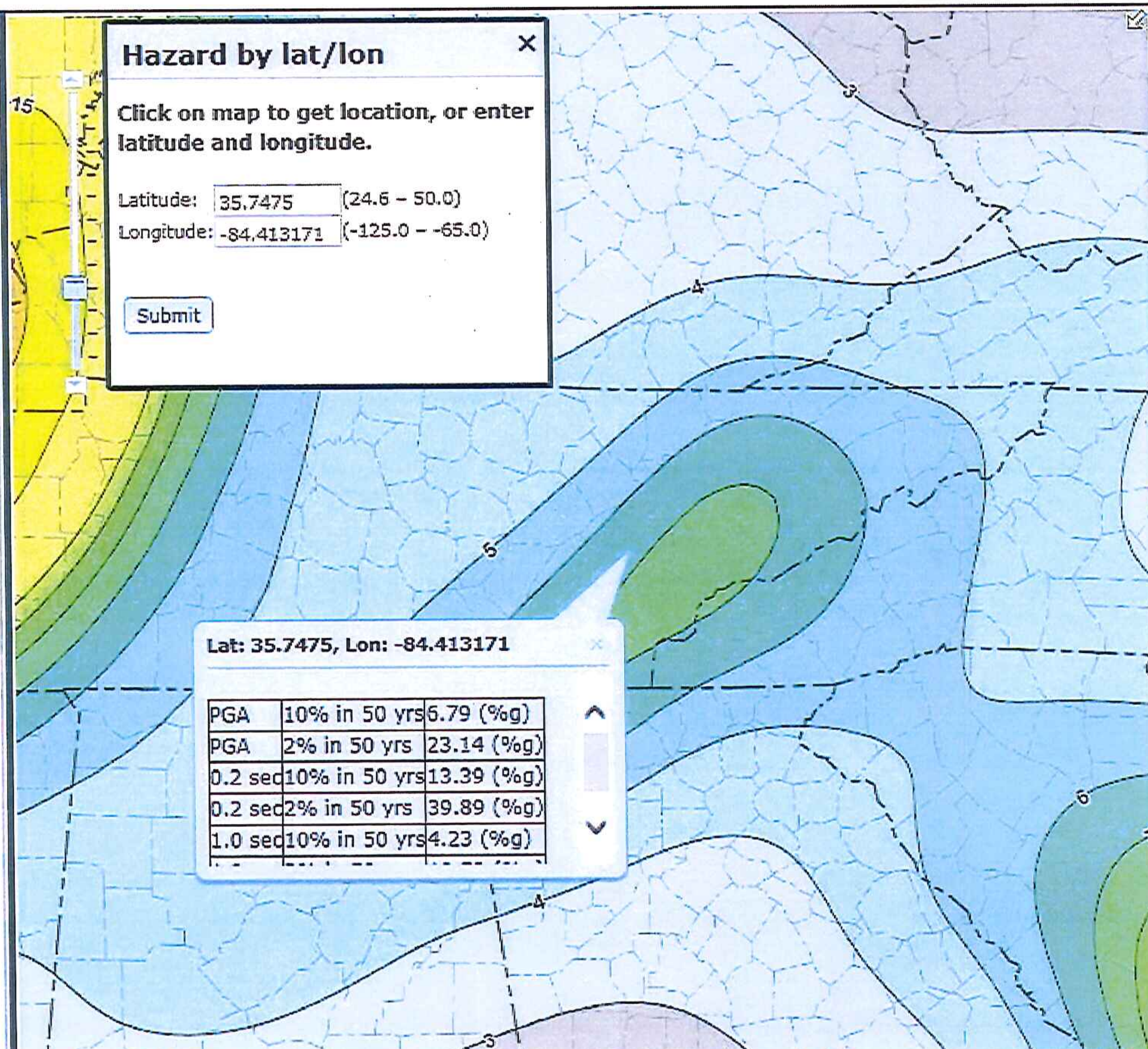
Transparency

- ◉ Peak ground acceleration (%g) with 10% probability of exceedance in 50 years
- ○ Peak ground acceleration (%g) with 2% probability of exceedance in 50 years
- ○ 0.2-second acceleration with 10% probability of exceedance in 50 years
- ○ 0.2-second acceleration with 2% probability of exceedance in 50 years
- ○ 1.0-second acceleration with 10% probability of exceedance in 50 years
- ○ 1.0-second acceleration with 2% probability of exceedance in 50 years

☑ Hazard map faults

☑ Basemap

Transparency



Hazard by lat/lon

Click on map to get location, or enter latitude and longitude.

Latitude: 35.7475 (24.6 – 50.0)

Longitude: -84.413171 (-125.0 – -65.0)

Submit

Lat: 35.7475, Lon: -84.413171

PGA	10% in 50 yrs	6.79 (%g)
PGA	2% in 50 yrs	23.14 (%g)
0.2 sec	10% in 50 yrs	13.39 (%g)
0.2 sec	2% in 50 yrs	39.89 (%g)
1.0 sec	10% in 50 yrs	4.23 (%g)

NOAA Atlas 14, Volume 2, Version 3 LOUDON
Station ID: 40-5451
Location name: Loudon, Tennessee, US*
Coordinates: 35.7333, -84.3333
Elevation:
Elevation (station metadata): 244 m*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in millimeters/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	102 (94–113)	120 (110–131)	140 (128–153)	161 (147–176)	186 (169–204)	208 (188–228)	231 (206–252)	253 (224–277)	283 (247–311)	311 (267–342)
10-min	82 (75–90)	96 (88–105)	112 (103–123)	129 (118–141)	148 (135–162)	166 (150–181)	183 (164–200)	201 (177–220)	224 (195–246)	245 (210–270)
15-min	68 (63–75)	80 (74–88)	95 (87–103)	109 (99–119)	125 (114–137)	140 (126–153)	154 (138–169)	169 (149–185)	188 (164–206)	205 (176–226)
30-min	47 (43–51)	55 (51–61)	67 (62–74)	79 (72–86)	93 (84–102)	106 (95–115)	118 (106–129)	131 (116–144)	150 (130–164)	166 (142–183)
60-min	29 (27–32)	35 (32–38)	43 (39–47)	51 (47–56)	62 (56–68)	72 (64–78)	81 (73–89)	92 (81–101)	107 (93–118)	121 (104–133)
2-hr	17 (16–19)	20 (19–22)	25 (23–27)	30 (27–33)	36 (33–39)	42 (38–46)	48 (43–52)	54 (48–59)	63 (55–69)	72 (61–79)
3-hr	12 (11–14)	15 (14–16)	18 (17–20)	21 (20–23)	26 (23–28)	30 (27–32)	34 (30–37)	38 (34–42)	45 (39–49)	50 (43–55)
6-hr	8 (7–8)	9 (8–10)	11 (10–12)	13 (12–14)	15 (14–17)	18 (16–19)	20 (18–22)	23 (20–24)	26 (23–28)	29 (25–32)
12-hr	5 (4–5)	6 (5–6)	7 (6–7)	8 (7–8)	9 (9–10)	11 (10–11)	12 (11–13)	13 (12–14)	15 (13–16)	17 (15–18)
24-hr	3 (3–3)	4 (3–4)	4 (4–5)	5 (5–5)	6 (5–6)	6 (6–7)	7 (7–7)	8 (7–8)	9 (8–9)	9 (9–10)
2-day	2 (2–2)	2 (2–2)	3 (2–3)	3 (3–3)	3 (3–4)	4 (4–4)	4 (4–5)	5 (4–5)	5 (5–6)	6 (5–6)
3-day	1 (1–1)	2 (1–2)	2 (2–2)	2 (2–2)	2 (2–3)	3 (3–3)	3 (3–3)	3 (3–3)	4 (3–4)	4 (4–4)
4-day	1 (1–1)	1 (1–1)	1 (1–2)	2 (2–2)	2 (2–2)	2 (2–2)	2 (2–3)	3 (2–3)	3 (3–3)	3 (3–3)
7-day	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–2)	2 (1–2)	2 (2–2)	2 (2–2)	2 (2–2)
10-day	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–2)	2 (1–2)
20-day	0 (0–0)	0 (0–0)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)
30-day	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)
45-day	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–1)	1 (0–1)	1 (1–1)	1 (1–1)
60-day	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–1)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

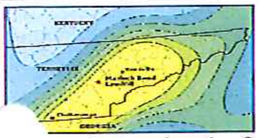
Back to Top

PF graphical

curve plots

APPENDIX B

PGA COEFFICIENTS



Determine the Seismic coefficients k_s for use in the analysis of the landfill waste mass and final cover

The subtitle D regulations require landfill designs to be evaluated under seismic loading conditions resulting from the seismic event with a 2% probability of exceedence in 50 years. The United States Geological Survey (USGS) has developed an interactive hazard map to determine the peak horizontal ground acceleration which can be used to predict seismic induced ground deformations and movements. However, the use of one ground motion parameter as a design basis is considered somewhat simplistic since the frequency and duration of ground motion are equally important parameters. Bray, Rathje, Augello and Merry (1998) have developed a simplified seismic analysis procedure for geosynthetic-lined, solid waste landfills titled "Simplified Seismic Design Procedure for Geosynthetic Lined, Solid-Waste Landfills. The following paragraphs follow the steps outlined in the Simplified Procedure to characterize predicted ground motions at the Matlock Bend Landfill.

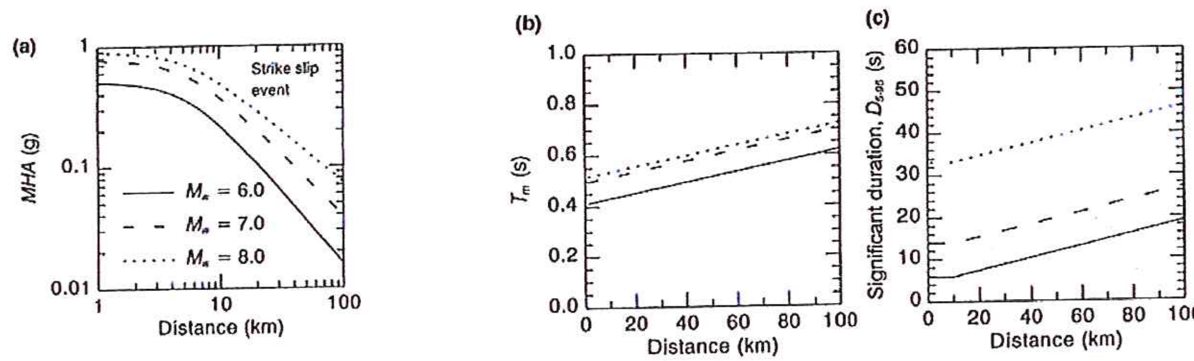
Given:

The proposed Matlock Bend Landfill a 60 m high landfill founded on stiff soils approximately 16 km from the East Tennessee Seismic Zone. The largest recorded earthquake to the Matlock Bend Landfill was a 5.6 magnitude earthquake located 41.29 km (25.66 miles) to the northeast.

Determine Earthquake Parameters:

1. Estimate the median Maximum Horizontal Ground Acceleration (*MHA*), Mean Period of Acceleration Time History (T_m), and Significant Duration of Acceleration-Time History ($D_{5\text{-}95}$) values of the rock ground motion:

M_w	6.0	7.0
Distance	16	100
MHA_{Rock}	0.1g	0.21g
T_m	0.45s	0.72s
$D_{5\text{-}95}$	7s	27



Check Design MHA Values:

HE performed a comparison of the probabilistic peak ground acceleration determined with Figures a-c by entering the latitude and longitude of the site was entered into the 2008 USGS Interactive Map (see Figure 1) to determine the peak ground acceleration (PGA) for the 2% and 5% probability of exceedence in 50 years which are presented below:

10% PGA in 50 yrs. 0.068g and the 2% PGA in 50 yrs. 0.23g

The PGA values from the USGS interactive map fall within close proximity to the range of values determined from Figures a-c therefore the seismic coefficients will be selected from the Figure a since it is sensitive to earthquake magnitudes.

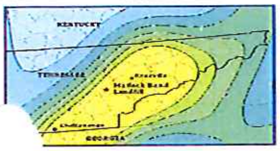
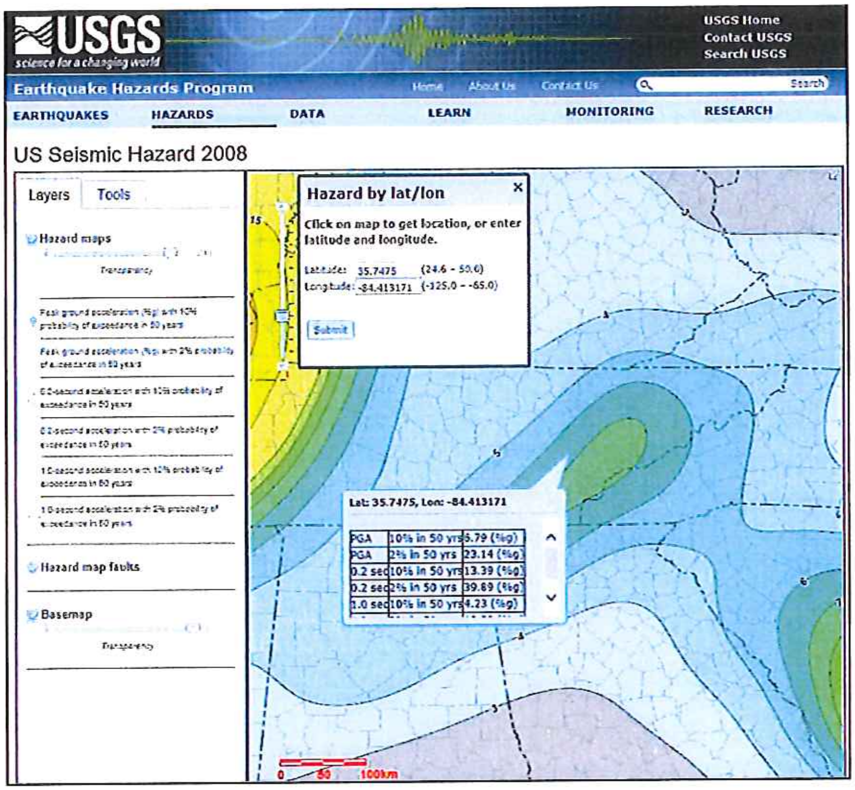


Figure 1 – USGS Hazard Map with Probability of Ground Accelerations



2. Calculate the seismic loading, $MHEA_{BASE.}$

Bray et al. (1995) found that the MHEA for important base sliding case depends primarily on the dynamic properties and height of the waste fill (i.e. its fundamental period, T_s, as described by $T_s = 4H/V_s$, where H= height of waste fill, and V_s = average initial shear wave velocity of the waste fill) and the MHA and T_p of the input earthquake rock motion. Based on an examination of Figure 3 the average velocity (V_S) profile of waste would approximate 180 m/s at the waste surface, approximately 250 m/s at a depth of 30 m, and approximately 325 m/s at a depth of 60 m. Therefore, a reasonable weighted average for V_S would approximate 250 m/s.

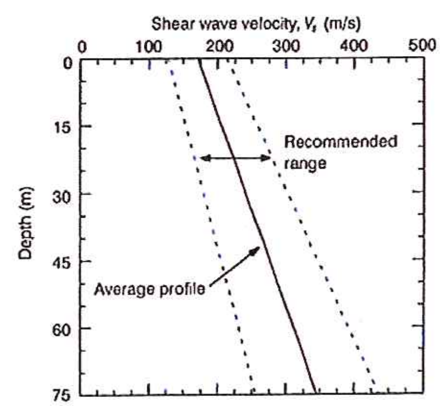


Figure 3. Shear wave velocity profiles for municipal solid-waste (after Kavazanjian et al. 1996).

Calculate the fundamental period T_s

$T_s = 4H/V_s$

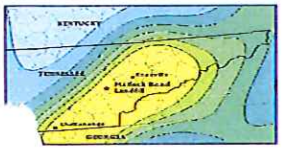
$T_s = 4 \times 60 / 250 = 0.96s$,

Where H = 60 meters and V_s = 250 m/s

Summary of Parameters

Fill Thickness (H)	Initial Shear Wave Velocity V_s = 250 m/s	Fundamental Period T_s
60 m (~200 ft.)	250 m/s (820 ft/sec)	0.96s

HOUSE ENGINEERING LLC



Base Sliding Analysis – Determine the seismic coefficients along the landfill base for the design earthquake.

Determine $MHEA_{BASE}$ of the waste fill for bottom liner sliding using Figure 6.

Calculate T_s/T_M which is the fundamental period of the waste divided by the mean period.

$T_s/T_M = 0.96/0.92 = 1.043$

Enter Figure 6 to determine *$MHEA_{BASE}$ / [(MHA_{ROCK})(NRF)]*

Based on Figure 6 the values of $MHEA_{BASE}$ / [(MHA_{ROCK})(NRF)] = 0.72 and 0.54 for the 16% and 50% exceedence

And also from Figure 6 NRF = 1.19 for MHA_{ROCK} = 0.21g

Therefore: *$MHEA_{BASE}$ = (0.21)(1.19)(0.72 to 0.54) = (0.18g to 0.13g)*

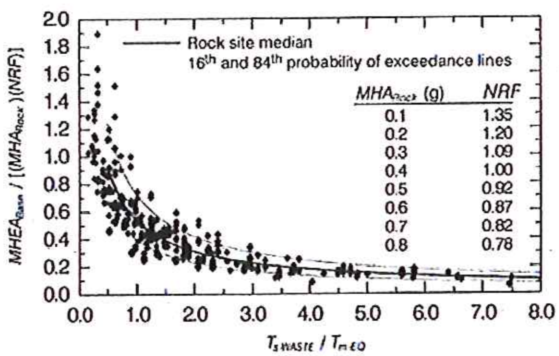


Figure 6. Normalized maximum horizontal equivalent acceleration for base sliding versus normalized fundamental period of waste fill (adapted from Bray and Rathje 1998).

Cover Sliding Analysis – Determine the seismic coefficients near the crest and slope for the design earthquake.

3. Calculate the seismic loading, $MHEA_{COVER:}$

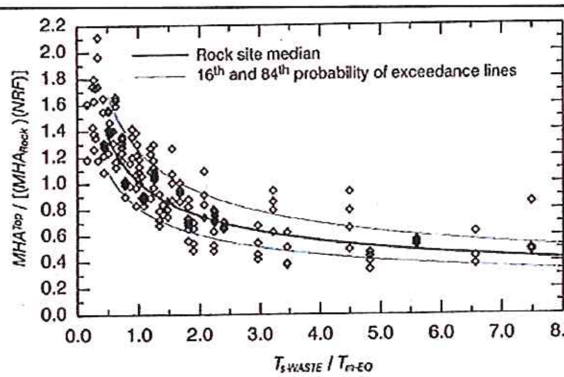


Figure 8. Normalized maximum horizontal acceleration at the top versus the normalized fundamental period of the waste fill (from Bray and Rathje 1998).

$MHA_{ROCK} = 0.21g$, $T_S/T_M = 1.043$

MHA_{TOP} / [(MHA_{ROCK})(NRF)] = 0.95g to 1.2g (50%/16% exceedence) (Figure 8)

Determine MHA_{TOP}

MHA_{TOP} / (0.21g)(1.19) = 0.95 to 1.2 (50% / 16%) from Figure 8

MHA_{TOP} = (0.21)(1.19)(0.95 to 1.2) = 0.237g to 0.299g

$MHEA_{COVER\ CREST}$ = (1.25)(0.237 to 0.299) = 0.296g to 0.373g

$MHEA_{COVER\ SLOPE}$ = (0.65)(0.237 to 0.299) = 0.154g to 0.194g

APPENDIX C

CALCULATIONS

SANTEK WasteServices

PARALLEL SUBMERGENCE CALCULATIONS

FINAL COVER SYSTEM SOIL OVER GEOCOMPOSITE DRAINAGE NET

PARAMETRIC ANALYSIS

	Conditions													
CONDITION EVALUATED	P (mm/hr.)	Hydraulic conductivity $k_{cover\ soil}$ cm/sec	$t_{cover\ soil}$ ft	$t_{cover\ soil}$ mm	RUNOFF COEFFICIENT RC	Slope Length L (ft)	Slope Length L (m)	Slope Angle β (deg)	Conductivity K_{GS} (cm/sec)	T_{GS} (mm)	SOIL FRICTION ANGLE Φ	INTERFACE FRICTION ANGLE, δ	FACTOR OF SAFETY	METHOD
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	18.4	0.27	7	28	26	1.531	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	18.4	0.27	7	28	31	1.884	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	18.4	0.27	7	28	19	1.084	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	21.8	0.27	7	28	26	1.271	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	15.8	0.27	7	28	26	1.806	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2.5	762	0.4	98	29.88	18.4	0.27	7	28	26	1.548	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	1.7	518.16	0.4	98	29.88	18.4	0.27	7	28	26	1.521	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	90	27.44	18.4	0.27	7	28	26	1.538	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	120	36.59	18.4	0.27	7	28	26	1.519	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	1.0E-05	2	609.6	0.4	98	29.88	18.4	0.27	7	28	26	1.527	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	5.0E-07	2	609.6	0.4	98	29.88	18.4	0.27	7	28	26	1.532	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	1.0E-06	2	609.6	0.4	98	29.88	18.4	0.27	7	33	26	1.533	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	1.0E-06	2	609.6	0.4	98	29.88	18.4	0.27	7	19	26	1.529	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	18.4	0.22	7	28	26	1.531	KOERNER
COVER SOIL TO GEOCOMPOSITE	81	0.000001	2	609.6	0.4	98	29.88	18.4	0.3	7	28	26	1.531	KOERNER

A review of the Factors of Safety calculated using the parallel submergence ratio clearly indicate that the most infuential parameters relative to the Factor of Safety are interface friction and the slope angle,

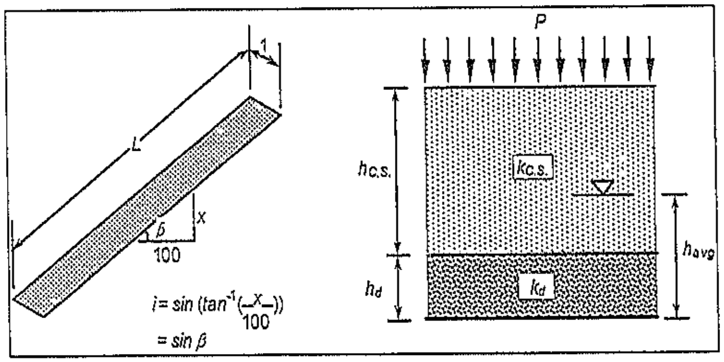
		LBS/CUFT	kN/m3	φ degrees	NORMAL STRESS PSF
CLAY SOIL γ_{dry}	γ_{dry}	106	16.6	18 - 26	212
CLAY SOIL $\gamma_{sat'd}$	$\gamma_{sat'd}$	127	19.9	18 - 26	254

	MAX Flow Rate gpm	T transmissivity m²/sec at 10,000psf - .0005 at 1000 - .001	req. min φ degrees	K cm/sec
TEX NET ULTRA	100.0			0.27
TenDrain 70CN-2	90.0			0.24

LOCAL PRECIPITATION SUMMARY (from NOAA Atlas 14)
Rainfall Intensity in units/hr.

DURATION	25 YR (IN)	25 YR (mm)	50 YR (IN)	50 YR (mm)	100 YR (IN)	100 YR (mm)
60-MIN	2.44	62.00	2.83	72.00	3.19	81.00
2 HR	1.43	36.00	1.65	42.00	1.89	48.00
24 HR	0.23	6.00	0.24	6.00	0.28	7.00

Calculation of DLC and PSR



L = 29.9 m
β = 18.4 °

$h_{c.s.}$ = 610 mm
h_d or t_{GS} = 7.0 mm

$k_{c.s.}$ = 1.0E-06 cm/s
k_d or k_{GS} = 3.0E-01 cm/s

P = 81.00 mm/hr
RC = 0.4

* Note: if only one soil layer above GM treat it as the drainage layer.

i = *0.3156*
$L(\cos\beta)$ = *28.35* m
x = *9.43* m
$h_{c.s.}$ = *0.6* m
h_d or t_{GS} = *0.01* m
$h_{c.s.} + h_d$ = *0.62* m

$k_{c.s.}$ = *1.0E-08* m/s
k_d or k_{GS} = *3.0E-03* m/s

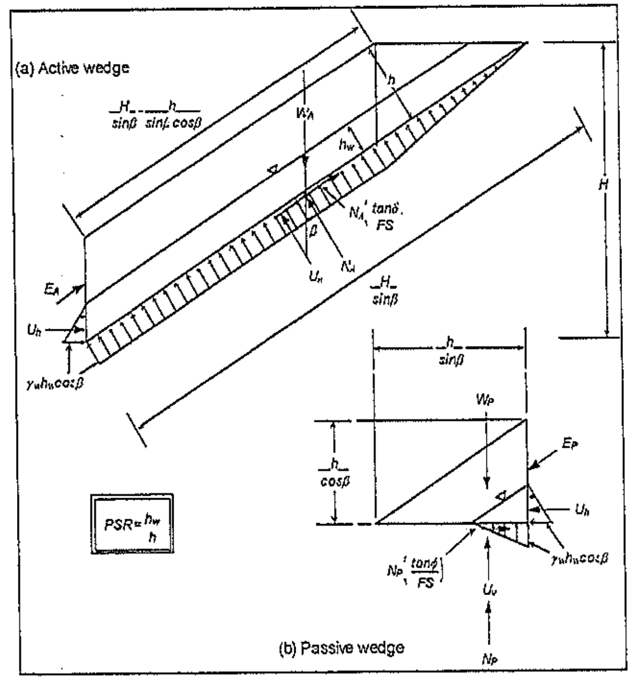
P (RC) = *32.4* mm/hr
Actual runoff = *80.96* mm/hr
PERC = *0.04* mm/hr
$FLUX_{actual}$ = *0.001* m^3/hr
$FLUX_{allow}$ = *0.024* m^3/hr *DLC = 23.3794*

q = *2.8E-07* m^3/sec

h_{avg} = *0.00* m

PSR = 0.000

DLC =	*23.379*
PSR	*0.000*
FS	*1.531*



thickness of cover soil = h = *0.62* m
length of slope measured along the geomembrane = L = *30* m
soil slope angle beneath the geomembrane = β = *18.4* ° = *0.32* (rad.)
vertical height of the slope measured from the toe = *H* = *9.4* m
parallel submergence ratio = *PSR* = *0.00*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

dry unit weight of the cover soil = γ_{dry} = 16.6 kN/m³
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = 19.9 kN/m³
unit weight of water = γ_w = 9.81 kN/m³
friction angle of the cover soil = ϕ = 28.0 ° = *0.49* (rad.)
interface friction angle between cover soil and geomembrane = δ = 26.0 ° = *0.45* (rad.)

Calculation of FS

Active Wedge:

W_A = *295.517* kN
U_n = *0.08328* kN
U_h = *4.4E-07* kN
N_A = *280.326* kN

Passive Wedge:

W_P = *10.5496* kN
U_V = *1.3E-06* kN

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

where a = *88.5*
b = *-150.5*
c = *22.9*

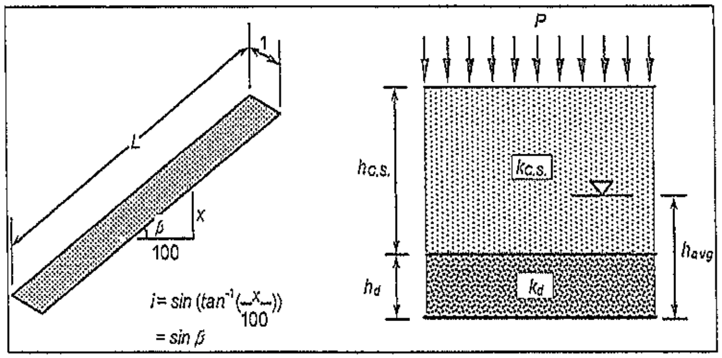
FS= 1.531

Note: numbers in boxes are input values
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

Calculation of DLC and PSR



L = 29.9 m
β = 18.4 °

$h_{c.s.}$ = 610 mm
h_d or t_{GS} = 7.0 mm

$k_{c.s.}$ = 1.0E-06 cm/s
k_d or k_{GS} = 2.7E-01 cm/s

P = 81.00 mm/hr
RC = 0.4

* Note: if only one soil layer above GM treat it as the drainage layer.

i = *0.3156*
$L(\cos\beta)$ = *28.35* m
x = *9.43* m
$h_{c.s.}$ = *0.6* m
h_d or t_{GS} = *0.01* m
$h_{c.s.} + h_d$ = *0.62* m

$k_{c.s.}$ = *1.0E-08* m/s
k_d or k_{GS} = *2.7E-03* m/s

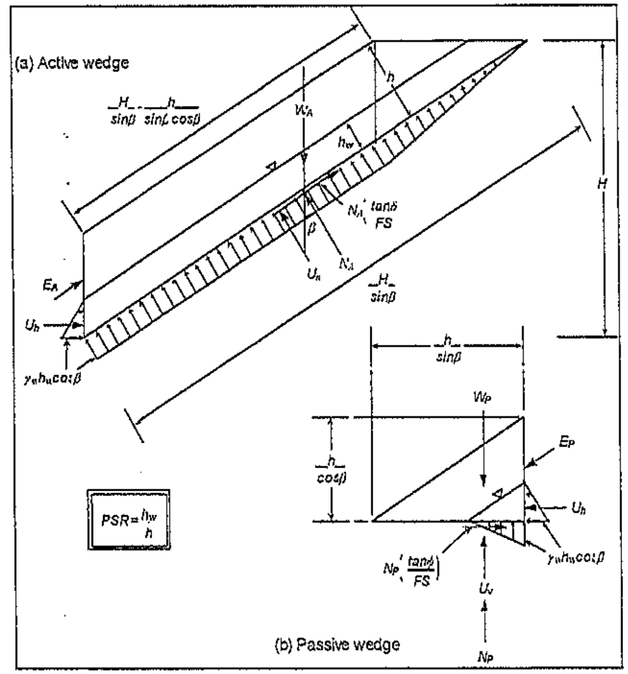
P (RC) = *32.4* mm/hr
Actual runoff = *80.96* mm/hr
PERC = *0.04* mm/hr
$FLUX_{actual}$ = *0.001* m^3/hr
$FLUX_{allow}$ = *0.021* m^3/hr *DLC* = *21.0415*

q = *2.8E-07* m^3/sec

h_{avg} = *0.00* m

PSR = *0.001*

DLC =	*21.041*
PSR	*0.001*
FS	*1.885*



thickness of cover soil = h = *0.62* m
length of slope measured along the geomembrane = L = *30* m
soil slope angle beneath the geomembrane = β = *18.4* ° = *0.32* (rad.)
vertical height of the slope measured from the toe = H = *9.4* m
parallel submergence ratio = *PSR* = *0.00*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

dry unit weight of the cover soil = γ_{dry} = 16.6 kN/m³
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = 19.9 kN/m³
unit weight of water = γ_w = 9.81 kN/m³
friction angle of the cover soil = ϕ = 28.0 ° = *0.49* (rad.)
interface friction angle between cover soil and geomembrane = δ = 31.0 ° = *0.54* (rad.)

Calculation of FS

Active Wedge:

W_A = *295.52* kN
U_n = *0.09253* kN
U_h = *5.4E-07* kN
N_A = *280.319* kN

Passive Wedge:

W_P = *10.5496* kN
U_V = *1.6E-06* kN

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

where a = *88.5*
b = *-181.8*
c = *28.3*

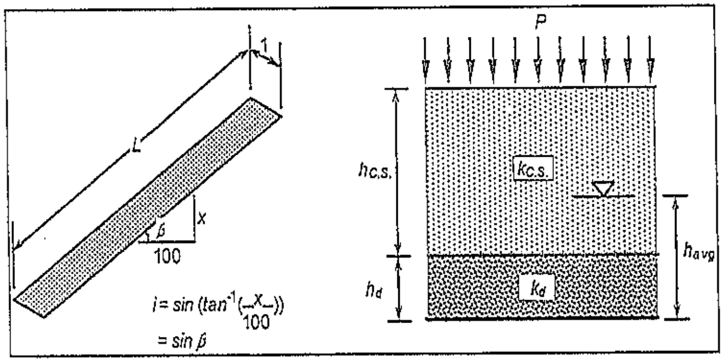
FS = *1.885*

Note: numbers in boxes are input values
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

Calculation of DLC and PSR



L = $\boxed{29.9}$ m
β = $\boxed{18.4}$ °

$h_{c.s.}$ = $\boxed{610}$ mm
h_d or t_{GS} = $\boxed{7.0}$ mm

$k_{c.s.}$ = $\boxed{1.0E-06}$ cm/s
k_d or k_{GS} = $\boxed{2.7E-01}$ cm/s

P = $\boxed{81.00}$ mm/hr
RC = $\boxed{0.4}$

* Note: If only one soil layer above GM treat it as the drainage layer.

i = *0.3156*
L (cos*β*) = *28.35* m
x = *9.43* m
$h_{c.s.}$ = *0.6* m
h_d or t_{GS} = *0.01* m
$h_{c.s.} + h_d$ = *0.62* m

$k_{c.s.}$ = *1.0E-08* m/s
k_d or k_{GS} = *2.7E-03* m/s

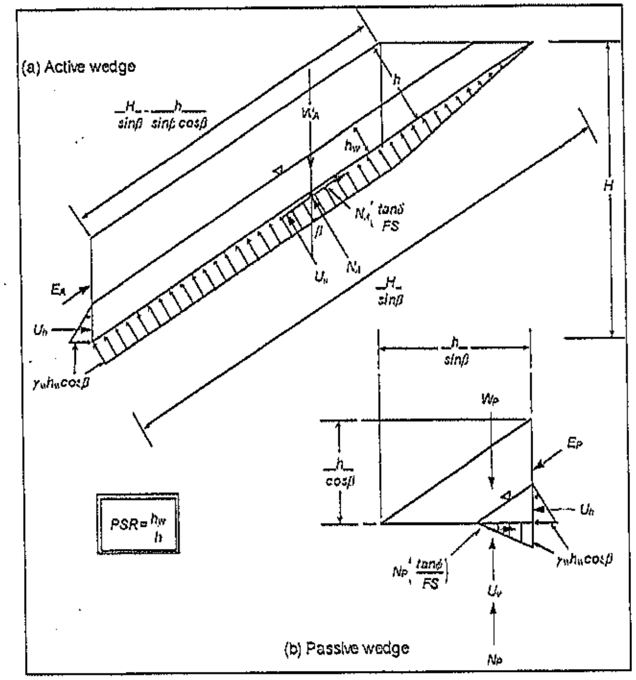
P (RC) = *32.4* mm/hr
Actual runoff = *80.96* mm/hr
PERC = *0.04* mm/hr
$FLUX_{actual}$ = *0.001* m³/hr
$FLUX_{allow}$ = *0.021* m³/hr *DLC = 21.0415*

q = *2.8E-07* m³/sec

h_{avg} = *0.00* m

PSR = 0.001

DLC =	***21.041***
PSR	***0.001***
FS	***1.084***



thickness of cover soil = h = *0.62* m
length of slope measured along the geomembrane = L = *30* m
soil slope angle beneath the geomembrane = β = *18.4* ° = *0.32* (rad.)
vertical height of the slope measured from the toe = *H* = *9.4* m
parallel submergence ratio = *PSR* = *0.00*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

dry unit weight of the cover soil = γ_{dry} = $\boxed{16.6}$ kN/m³
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = $\boxed{19.9}$ kN/m³
unit weight of water = γ_w = 9.81 kN/m³
friction angle of the cover soil = ϕ = $\boxed{28.0}$ ° = *0.49* (rad.)
interface friction angle between cover soil and geomembrane = δ = $\boxed{19.0}$ ° = *0.33* (rad.)

Calculation of FS

Active Wedge:
W_A = *295.52* kN
U_n = *0.09253* kN
U_h = *5.4E-07* kN
N_A = *280.319* kN

Passive Wedge:
W_P = *10.5496* kN
U_V = *1.6E-06* kN

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

where a = *88.5*
b = *-110.9*
c = *16.2*

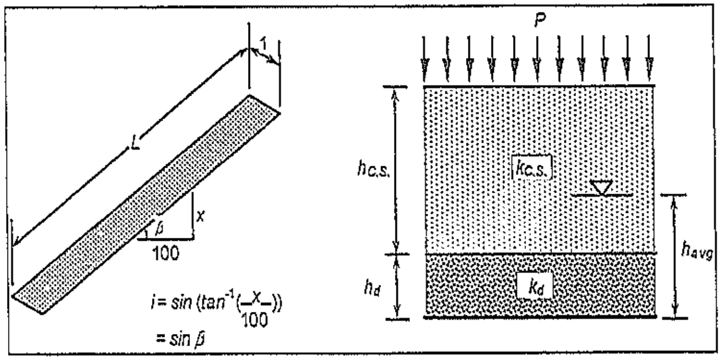
FS= 1.084

Note: $\boxed{\text{numbers in boxes are input values}}$
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

Calculation of DLC and PSR



L = 29.9 m
β = 21.8 °

$h_{c.s.}$ = 610 mm
h_d or t_{GS} = 7.0 mm

$k_{c.s.}$ = 1.0E-06 cm/s
k_d or k_{GS} = 2.7E-01 cm/s

P = 81.00 mm/hr
RC = 0.4

* Note: if only one soil layer above GN treat it as the drainage layer.

i = *0.3714*
$L(\cos\beta)$ = *27.74* m
x = *11.10* m
$h_{c.s.}$ = *0.6* m
h_d or t_{GS} = *0.01* m
$h_{c.s.} + h_d$ = *0.62* m

$k_{c.s.}$ = *1.0E-08* m/s
k_d or k_{GS} = *2.7E-03* m/s

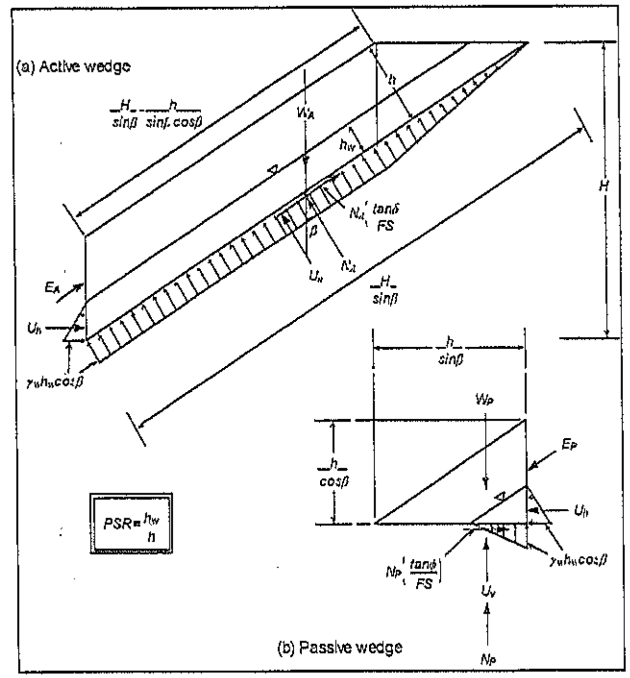
P (RC) = *32.4* mm/hr
Actual runoff = *80.96* mm/hr
PERC = *0.04* mm/hr
$FLUX_{actual}$ = *0.001* m^3/hr
$FLUX_{allow}$ = *0.025* m^3/hr ***DLC = 25.2994***

q = *2.8E-07* m^3/sec

h_{avg} = *0.00* m

PSR = 0.000

DLC =	***25.299***
PSR	***0.000***
FS	***1.272***



thickness of cover soil = h = *0.62* m
length of slope measured along the geomembrane = L = *30* m
soil slope angle beneath the geomembrane = β = *21.8* ° = *0.38* (rad.)
vertical height of the slope measured from the toe = H = *11.1* m
parallel submergence ratio = PSR = *0.00*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

dry unit weight of the cover soil = γ_{dry} = 16.6 kN/m³
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = 19.9 kN/m³
unit weight of water = γ_w = 9.81 kN/m³
friction angle of the cover soil = ϕ = 28.0 ° = *0.49* (rad.)
interface friction angle between cover soil and geomembrane = δ = 26.0 ° = *0.45* (rad.)

Calculation of FS

Active Wedge:

W_A = *296.901* kN
U_n = *0.0753* kN
U_h = *3.8E-07* kN
N_A = *275.593* kN

Passive Wedge:

W_P = *9.16366* kN
U_V = *9.4E-07* kN

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

where a = *102.4*
b = *-151.0*
c = *26.5*

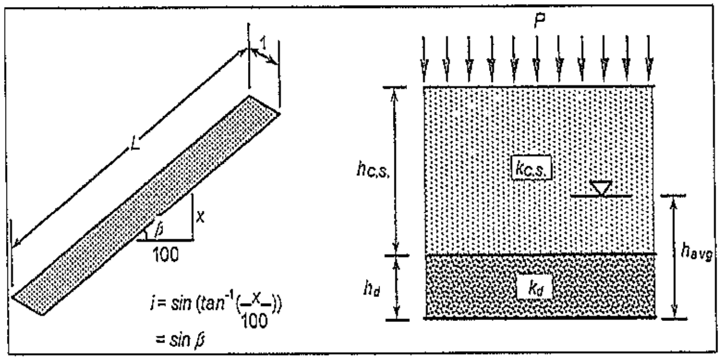
FS= 1.272

Note: numbers in boxes are input values
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

Calculation of DLC and PSR



L = 29.9 m
β = 15.8 °

$h_{c.s.}$ = 610 mm
h_d or t_{GS} = 7.0 mm

$k_{c.s.}$ = 1.0E-06 cm/s
k_d or k_{GS} = 2.7E-01 cm/s

P = 81.00 mm/hr
RC = 0.4

* Note: if only one soil layer above GM treat it as the drainage layer.

i = 0.2723
$L(\cos\beta)$ = *28.75* m
x = *8.14* m
$h_{c.s.}$ = *0.6* m
h_d or t_{GS} = *0.01* m
$h_{c.s.} + h_d$ = *0.62* m

$k_{c.s.}$ = *1.0E-08* m/s
k_d or k_{GS} = *2.7E-03* m/s

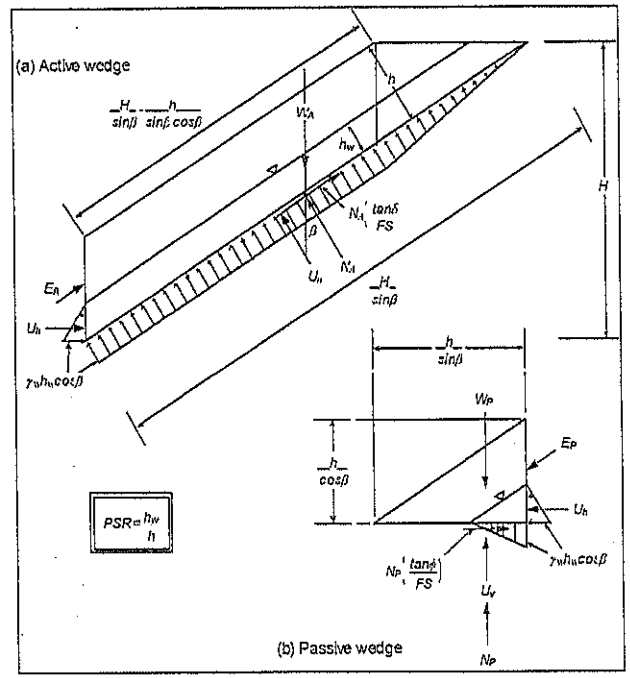
$P\ (RC)$ = *32.4* mm/hr
Actual runoff = *80.96* mm/hr
PERC = *0.04* mm/hr
$FLUX_{actual}$ = *0.001* m^3/hr
$FLUX_{allow}$ = *0.019* m^3/hr *DLC* = *17.8988*

q = *2.9E-07* m^3/sec

h_{avg} = *0.00* m

PSR = *0.001*

DLC =	*17.899*
PSR	*0.001*
FS	*1.806*



Calculation of FS

Active Wedge:

W_A = *294.015* kN
U_n = *0.1103* kN
U_h = *7.5E-07* kN
N_A = *282.796* kN

Passive Wedge:

W_P = *12.0603* kN
U_V = *2.7E-06* kN

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

where a = *77.0*
b = *-150.2*
c = *20.0*

FS = *1.806*

thickness of cover soil = h = *0.62* m
length of slope measured along the geomembrane = L = *30* m
soil slope angle beneath the geomembrane = β = *15.8* ° = *0.28* (rad.)
vertical height of the slope measured from the toe = H = *8.1* m
parallel submergence ratio = *PSR* = *0.00*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

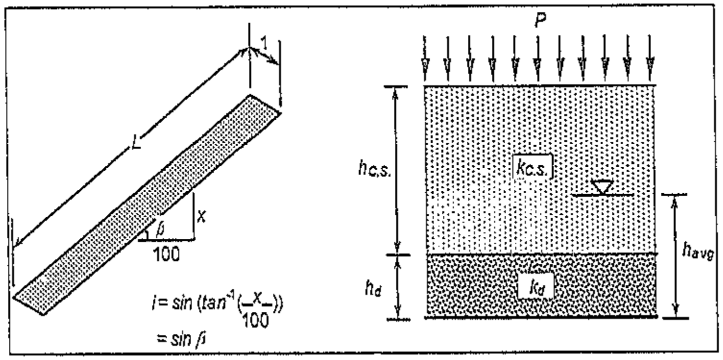
dry unit weight of the cover soil = γ_{dry} = 16.6 kN/m^3
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = 19.9 kN/m^3
unit weight of water = γ_w = 9.81 kN/m^3
friction angle of the cover soil = ϕ = 28.0 ° = *0.49* (rad.)
interface friction angle between cover soil and geomembrane = δ = 26.0 ° = *0.45* (rad.)

Note: numbers in boxes are input values
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

Calculation of DLC and PSR



L = $\boxed{29.9}$ m
β = $\boxed{18.4}$ °

$h_{c.s.}$ = $\boxed{762}$ mm
h_d or t_{GS} = $\boxed{7.0}$ mm

$k_{c.s.}$ = $\boxed{1.0E-06}$ cm/s
k_d or k_{GS} = $\boxed{2.7E-01}$ cm/s

P = $\boxed{81.00}$ mm/hr
RC = $\boxed{0.4}$

* Note: if only one soil layer above GN
treat it as the drainage layer.

i = *0.3156*
$L(\cos\beta)$ = *28.35* m
x = *9.43* m
$h_{c.s.}$ = *0.8* m
h_d or t_{GS} = *0.01* m
$h_{c.s.} + h_d$ = *0.77* m

$k_{c.s.}$ = *1.0E-08* m/s
k_d or k_{GS} = *2.7E-03* m/s

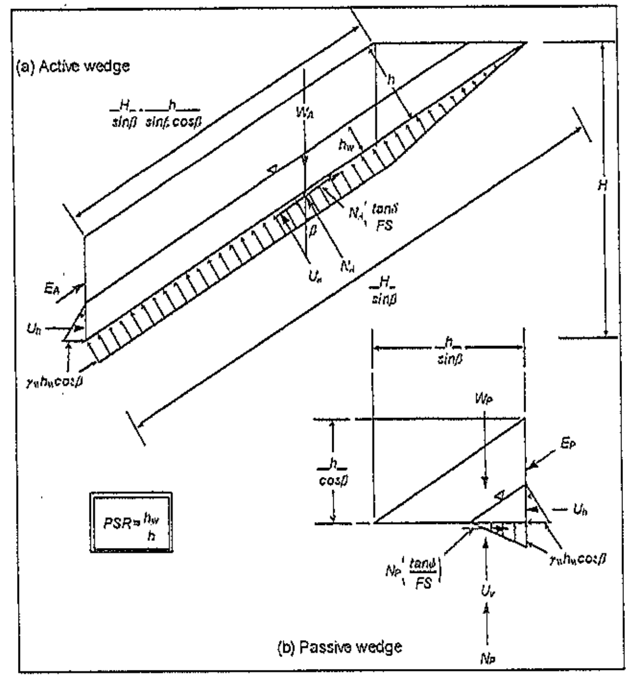
P (RC) = *32.4* mm/hr
Actual runoff = *80.96* mm/hr
PERC = *0.04* mm/hr
$FLUX_{actual}$ = *0.001* m^3/hr
$FLUX_{allow}$ = *0.021* m^3/hr *DLC = 21.0415*

q = *2.8E-07* m^3/sec

h_{avg} = *0.00* m

PSR = 0.000

DLC =	*21.041*
PSR	*0.000*
FS	*1.548*



thickness of cover soil = h = *0.77* m
length of slope measured along the geomembrane = L = *30* m
soil slope angle beneath the geomembrane = β = *18.4* ° = *0.32* (rad.)
vertical height of the slope measured from the toe = H = *9.4* m
parallel submergence ratio = *PSR* = *0.00*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

dry unit weight of the cover soil = γ_{dry} = $\boxed{16.6}$ kN/m^3
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = $\boxed{19.9}$ kN/m^3
unit weight of water = γ_w = 9.81 kN/m^3
friction angle of the cover soil = ϕ = $\boxed{28.0}$ ° = *0.49* (rad.)
interface friction angle between cover soil and geomembrane = δ = $\boxed{26.0}$ ° = *0.45* (rad.)

Calculation of FS

Active Wedge:
W_A = *365.075* kN
U_n = *0.09253* kN
U_h = *5.4E-07* kN
N_A = *346.319* kN

Passive Wedge:
W_P = *16.3877* kN
U_V = *1.6E-06* kN

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

where a = *109.3*
b = *-187.6*
c = *28.3*

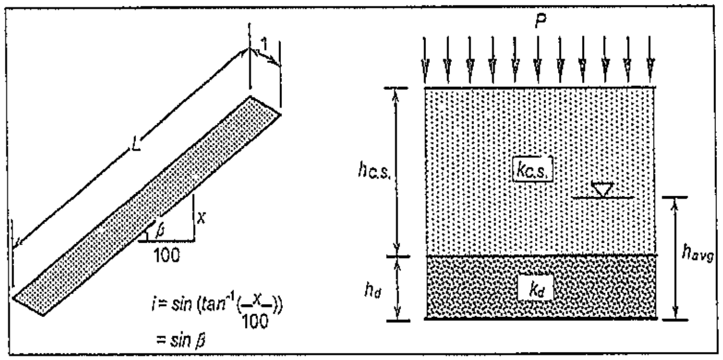
FS= 1.548

Note: $\boxed{\text{numbers in boxes are input values}}$
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

Calculation of DLC and PSR



$i = \sin(\tan^{-1}(\frac{x}{100}))$
$= \sin\beta$

L =	29.9	m
β =	18.4	°
$h_{c.s.}$ =	518	mm
h_d or t_{GS} =	7.0	mm
$k_{c.s.}$ =	1.0E-06	cm/s
k_d or k_{GS} =	2.7E-01	cm/s
P =	81.00	mm/hr
RC =	0.4	

* Note: if only one soil layer above GN treat it as the drainage layer.

i = *0.3156*
$L(\cos\beta)$ = *28.35* m
x = *9.43* m
$h_{c.s.}$ = *0.5* m
h_d or t_{GS} = *0.01* m
$h_{c.s.} + h_d$ = *0.53* m

$k_{c.s.}$ = *1.0E-08* m/s
k_d or k_{GS} = *2.7E-03* m/s

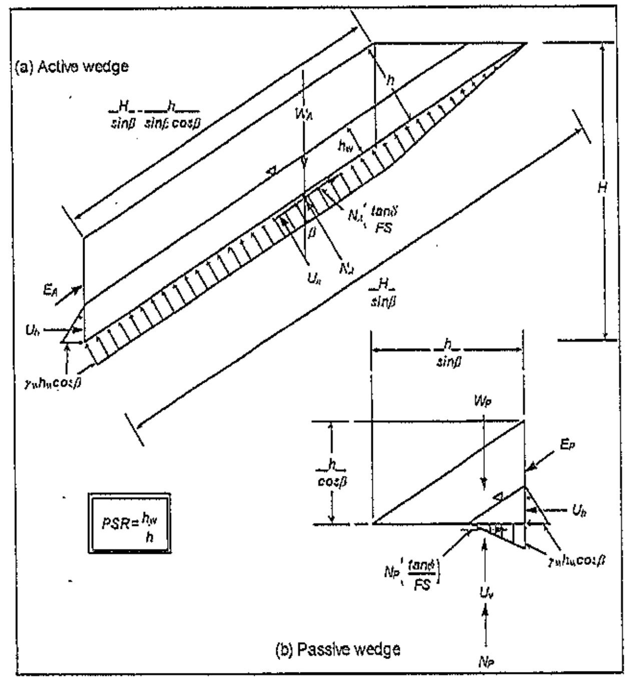
P (RC) = *32.4* mm/hr
Actual runoff = *80.96* mm/hr
PERC = *0.04* mm/hr
$FLUX_{actual}$ = *0.001* m^3/hr
$FLUX_{allow}$ = *0.021* m^3/hr *DLC* = ***21.0415***

q = *2.8E-07* m^3/sec

h_{avg} = *0.00* m

PSR = ***0.001***

DLC =	21.041
PSR	0.001
FS	1.521



thickness of cover soil = h = *0.53* m
length of slope measured along the geomembrane = L = *30* m
soil slope angle beneath the geomembrane = β = *18.4* ° = *0.32* (rad.)
vertical height of the slope measured from the toe = H = *9.4* m
parallel submergence ratio = *PSR* = *0.00*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

dry unit weight of the cover soil = γ_{dry} = 16.6 kN/m^3
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = 19.9 kN/m^3
unit weight of water = γ_w = 9.81 kN/m^3
friction angle of the cover soil = ϕ = 28.0 ° = *0.49* (rad.)
interface friction angle between cover soil and geomembrane = δ = 26.0 ° = *0.45* (rad.)

Calculation of FS

Active Wedge:

W_A = *252.799* kN
U_n = *0.09253* kN
U_h = *5.4E-07* kN
N_A = *239.782* kN

Passive Wedge:

W_P = *7.63806* kN
U_V = *1.6E-06* kN

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

where *a* = *75.7*
b = *-128.1*
c = *19.6*

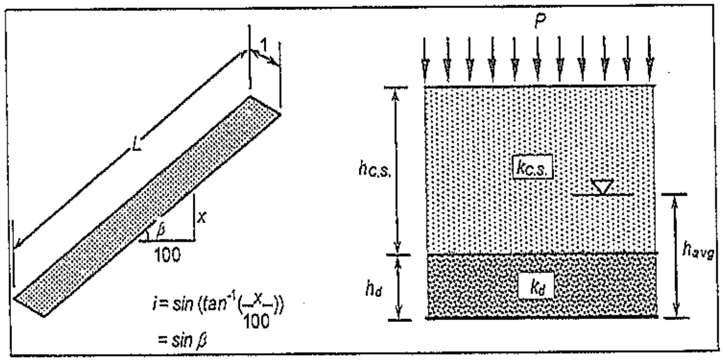
***FS* = 1.521**

Note: numbers in boxes are input values
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

Calculation of DLC and PSR



L = 27.4 m
β = 18.4 °

$h_{c.s.}$ = 610 mm
h_d or t_{GS} = 7.0 mm

$k_{c.s.}$ = 1.0E-06 cm/s
k_d or k_{GS} = 2.7E-01 cm/s

P = 81.00 mm/hr
RC = 0.4

* Note: if only one soil layer above GM treat it as the drainage layer.

i = *0.3156*
$L(\cos\beta)$ = *26.04* m
x = *8.66* m
$h_{c.s.}$ = *0.6* m
h_d or t_{GS} = *0.01* m
$h_{c.s.} + h_d$ = *0.62* m

$k_{c.s.}$ = *1.0E-08* m/s
k_d or k_{GS} = *2.7E-03* m/s

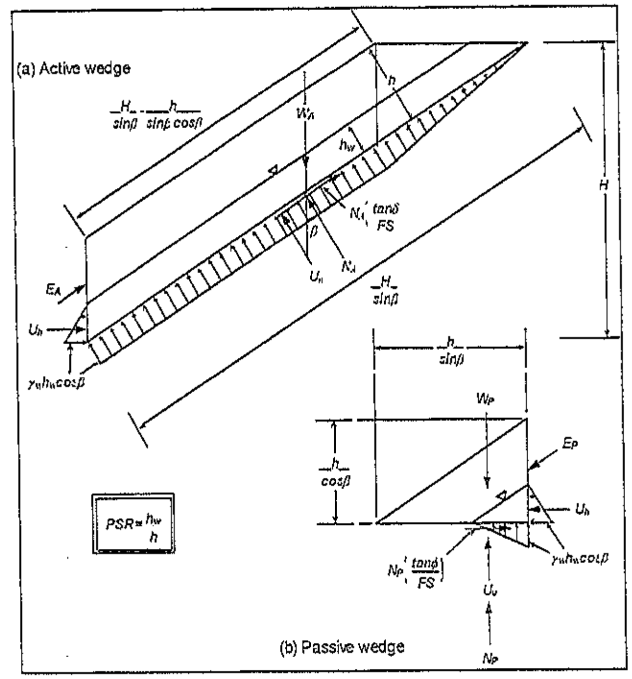
$P(RC)$ = *32.4* mm/hr
Actual runoff = *80.96* mm/hr
PERC = *0.04* mm/hr
$FLUX_{actual}$ = *0.001* m³/hr
$FLUX_{allow}$ = *0.021* m³/hr **DLC = 22.9125**

q = *2.6E-07* m³/sec

h_{avg} = *0.00* m

PSR = 0.000

DLC =	22.912
PSR	0.000
FS	1.537



thickness of cover soil = h = *0.62* m
length of slope measured along the geomembrane = L = *27* m
soil slope angle beneath the geomembrane = β = *18.4* ° = *0.32* (rad.)
vertical height of the slope measured from the toe = H = *8.7* m
parallel submergence ratio = PSR = *0.00*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

dry unit weight of the cover soil = γ_{dry} = 16.6 kN/m³
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = 19.9 kN/m³
unit weight of water = γ_w = 9.81 kN/m³
friction angle of the cover soil = ϕ = 28.0 ° = *0.49* (rad.)
interface friction angle between cover soil and geomembrane = δ = 26.0 ° = *0.45* (rad.)

Calculation of FS

Active Wedge:

W_A = *270.524 kN*
U_n = *0.07803 kN*
U_h = *4.6E-07 kN*
N_A = *256.616 kN*

Passive Wedge:

W_P = *10.5496 kN*
U_V = *1.4E-06 kN*

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

where a = *81.0*
b = *-138.2*
c = *21.0*

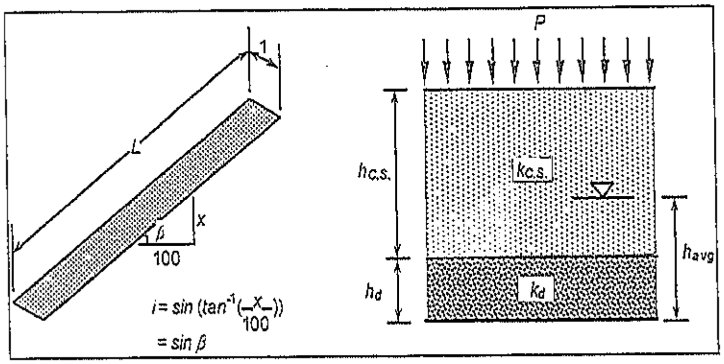
FS= *1.537*

Note: numbers in boxes are input values
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

Calculation of DLC and PSR



L = 36.6 m
β = 18.4 °

$h_{c.s.}$ = 610 mm
h_d or t_{GS} = 7.0 mm

$k_{c.s.}$ = 1.0E-06 cm/s
k_d or k_{GS} = 2.7E-01 cm/s

P = 81.00 mm/hr
RC = 0.4

* Note: if only one soil layer above GM treat it as the drainage layer.

i = *0.3156*
$L(\cos\beta)$ = *34.72* m
x = *11.55* m
$h_{c.s.}$ = *0.6* m
h_d or t_{GS} = *0.01* m
$h_{c.s.} + h_d$ = *0.62* m

$k_{c.s.}$ = *1.0E-08* m/s
k_d or k_{GS} = *2.7E-03* m/s

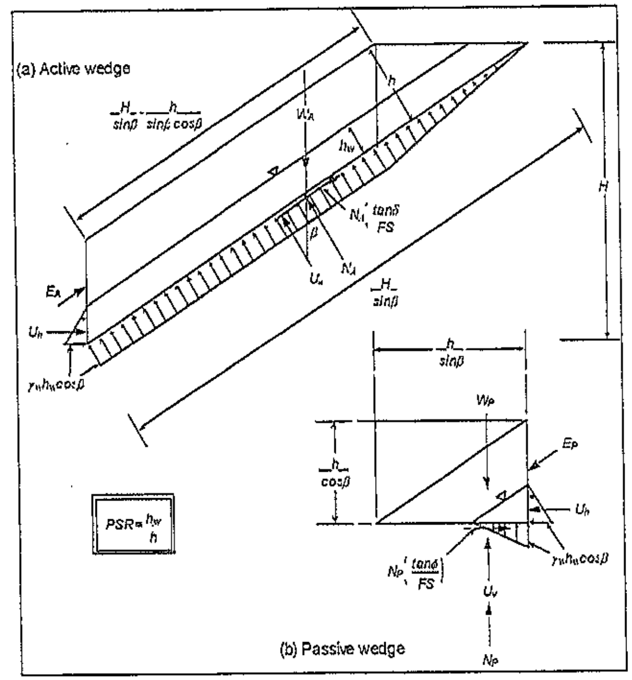
P (RC) = *32.4* mm/hr
Actual runoff = *80.96* mm/hr
PERC = *0.04* mm/hr
$FLUX_{actual}$ = *0.001* m^3/hr
$FLUX_{allow}$ = *0.021* m^3/hr **DLC = 17.1828**

q = *3.5E-07* m^3/sec

h_{avg} = *0.00* m

PSR = 0.001

DLC =	17.183
PSR	0.001
FS	1.519



thickness of cover soil = h = *0.62* m
length of slope measured along the geomembrane = L = *37* m
soil slope angle beneath the geomembrane = β = *18.4* ° = *0.32* (rad.)
vertical height of the slope measured from the toe = H = *11.5* m
parallel submergence ratio = PSR = *0.00*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

dry unit weight of the cover soil = γ_{dry} = 16.6 kN/m³
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = 19.9 kN/m³
unit weight of water = γ_w = 9.81 kN/m³
friction angle of the cover soil = ϕ = 28.0 ° = *0.49* (rad.)
interface friction angle between cover soil and geomembrane = δ = 26.0 ° = *0.45* (rad.)

Calculation of FS

Active Wedge:

W_A = *364.262* kN
U_n = *0.13875* kN
U_h = *8.1E-07* kN
N_A = *345.5* kN

Passive Wedge:

W_P = *10.5496* kN
U_V = *2.4E-06* kN

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

where a = *109.1*
b = *-184.3*
c = *28.3*

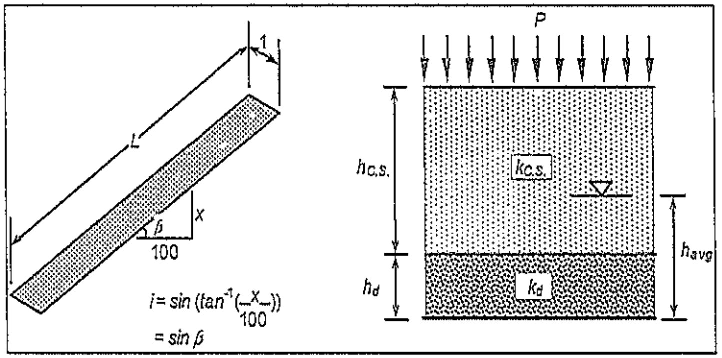
FS= 1.519

Note: numbers in boxes are input values
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

Calculation of DLC and PSR



L = 29.9 m
β = 18.4 °

$h_{c.s.}$ = 610 mm
h_d or t_{GS} = 7.0 mm

$k_{c.s.}$ = 1.0E-05 cm/s
k_d or k_{GS} = 2.7E-01 cm/s

P = 81.00 mm/hr
RC = 0.4

* Note: if only one soil layer above GM
treat it as the drainage layer.

i = *0.3156*
$L(\cos\beta)$ = *28.35* m
x = *9.43* m
$h_{c.s.}$ = *0.6* m
h_d or t_{GS} = *0.01* m
$h_{c.s.} + h_d$ = *0.62* m

$k_{c.s.}$ = *1.0E-07* m/s
k_d or k_{GS} = *2.7E-03* m/s

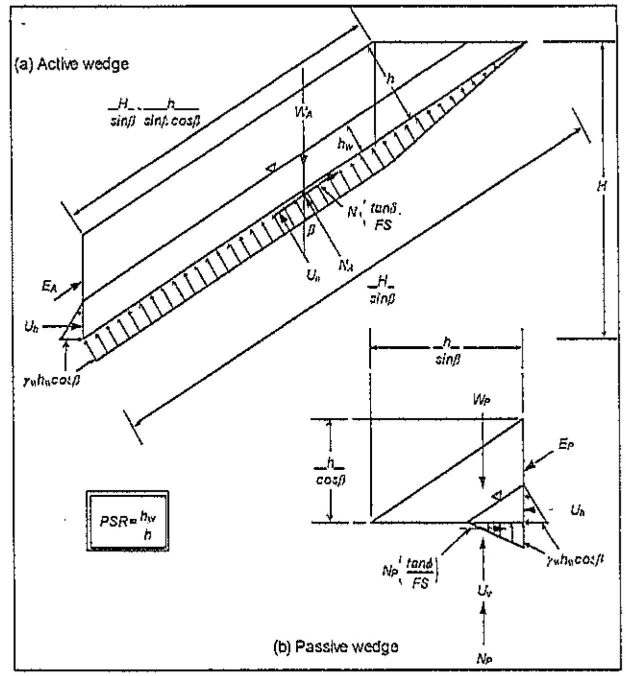
$P\,(RC)$ = *32.4* mm/hr
Actual runoff = *80.64* mm/hr
PERC = *0.36* mm/hr
$FLUX_{actual}$ = *0.010* m^3/hr
$FLUX_{allow}$ = *0.021* m^3/hr **DLC = 2.1041**

q = *2.8E-06* m^3/sec

h_{avg} = *0.00* m

PSR = 0.005

DLC =	2.104
PSR	0.005
FS	1.527



thickness of cover soil = h = *0.62* m
length of slope measured along the geomembrane = L = *30* m
soil slope angle beneath the geomembrane = β = *18.4* ° = *0.32* (rad.)
vertical height of the slope measured from the toe = H = *9.4* m
parallel submergence ratio = PSR = *0.01*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

dry unit weight of the cover soil = γ_{dry} = 16.6 kN/m^3
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = 19.9 kN/m^3
unit weight of water = γ_w = 9.81 kN/m^3
friction angle of the cover soil = ϕ = 28.0 ° = *0.49* (rad.)
interface friction angle between cover soil and geomembrane = δ = 26.0 ° = *0.45* (rad.)

Calculation of FS

Active Wedge:

W_A = *295.815* kN
U_n = *0.92513* kN
U_h = *5.4E-05* kN
N_A = *279.767* kN

Passive Wedge:

W_P = *10.5496* kN
U_V = *0.00016* kN

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

where a = *88.6*
b = *-150.3*
c = *22.9*

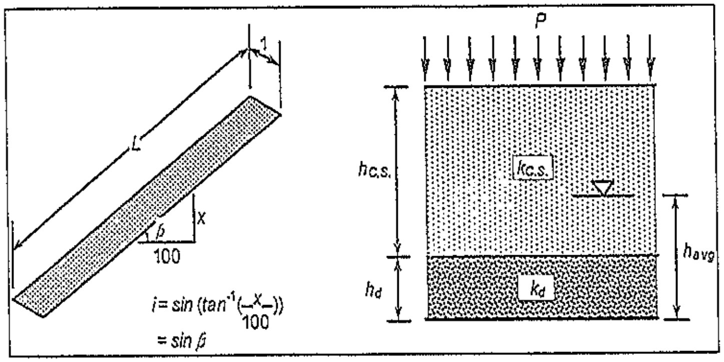
FS= 1.527

Note: numbers in boxes are input values
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

Calculation of DLC and PSR



L = 29.9 m
β = 18.4 °

$h_{c.s.}$ = 610 mm
h_d or t_{GS} = 7.0 mm

$k_{c.s.}$ = 5.0E-07 cm/s
k_d or k_{GS} = 2.7E-01 cm/s

P = 81.00 mm/hr
RC = 0.4

* Note: if only one soil layer above GM treat it as the drainage layer.

i = *0.3156*
L (cos*β*) = *28.35* m
x = *9.43* m
$h_{c.s.}$ = *0.6* m
h_d or t_{GS} = *0.01* m
$h_{c.s.} + h_d$ = *0.62* m

$k_{c.s.}$ = *5.0E-09* m/s
k_d or k_{GS} = *2.7E-03* m/s

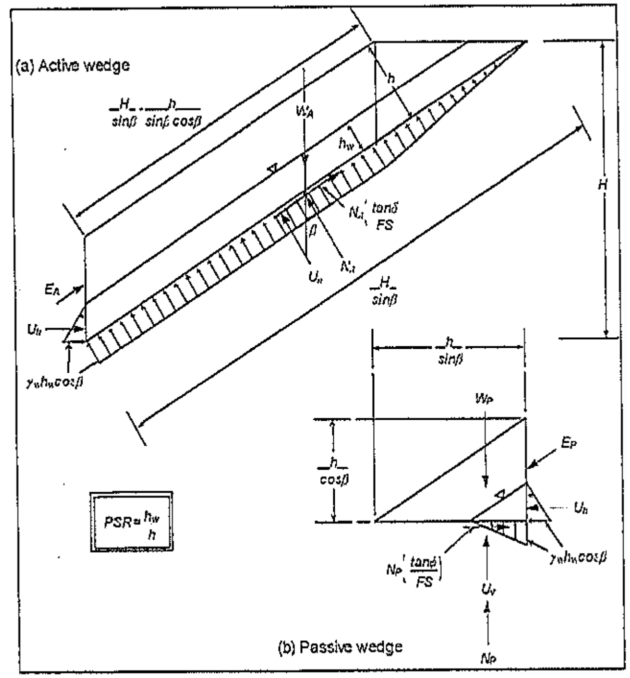
P (RC) = *32.4* mm/hr
Actual runoff = *80.98* mm/hr
PERC = *0.02* mm/hr
$FLUX_{actual}$ = *0.001* m³/hr
$FLUX_{allow}$ = *0.021* m³/hr *DLC* = *42.0829*

q = *1.4E-07* m³/sec

h_{avg} = *0.00* m

PSR = 0.000

DLC =	42.083
PSR	0.000
FS	1.532



thickness of cover soil = h = *0.62* m
length of slope measured along the geomembrane = L = *30* m
soil slope angle beneath the geomembrane = β = *18.4* ° = *0.32* (rad.)
vertical height of the slope measured from the toe = H = *9.4* m
parallel submergence ratio = *PSR* = *0.00*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

dry unit weight of the cover soil = γ_{dry} = 16.6 kN/m³
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = 19.9 kN/m³
unit weight of water = γ_w = 9.81 kN/m³
friction angle of the cover soil = ϕ = 28.0 ° = *0.49* (rad.)
interface friction angle between cover soil and geomembrane = δ = 26.0 ° = *0.45* (rad.)

Calculation of FS

Active Wedge:

W_A = *295.504* kN
U_n = *0.04626* kN
U_h = *1.4E-07* kN
N_A = *280.35* kN

Passive Wedge:

W_P = *10.5496* kN
U_V = *4.1E-07* kN

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

where a = *88.5*
b = *-150.5*
c = *22.9*

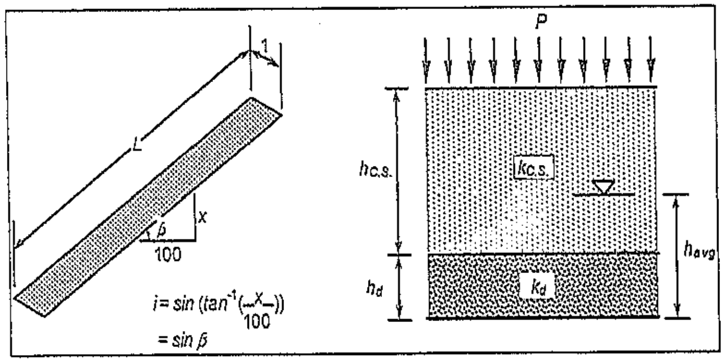
FS= 1.532

Note: numbers in boxes are input values
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

Calculation of DLC and PSR



$i = \sin(\tan^{-1}(\frac{x}{100}))$
$= \sin\beta$

$L =$	29.9	m
$\beta =$	18.4	°
$h_{c.s.} =$	610	mm
h_d or $t_{GS} =$	7.0	mm
$k_{c.s.} =$	1.0E-06	cm/s
k_d or $k_{GS} =$	2.7E-01	cm/s
$P =$	81.00	mm/hr
$RC =$	0.4	

* Note: if only one soil layer above GN treat it as the drainage layer.

$i =$	*0.3156*	
$L(\cos\beta) =$	*28.35*	m
$x =$	*9.43*	m
$h_{c.s.} =$	*0.6*	m
h_d or $t_{GS} =$	*0.01*	m
$h_{c.s.} + h_d =$	*0.62*	m
$k_{c.s.} =$	*1.0E-08*	m/s
k_d or $k_{GS} =$	*2.7E-03*	m/s
$P\ (RC) =$	*32.4*	mm/hr
Actual runoff $=$	*80.96*	mm/hr
$PERC =$	*0.04*	mm/hr
$FLUX_{actual} =$	*0.001*	m^3/hr
$FLUX_{allow} =$	*0.021*	m^3/hr

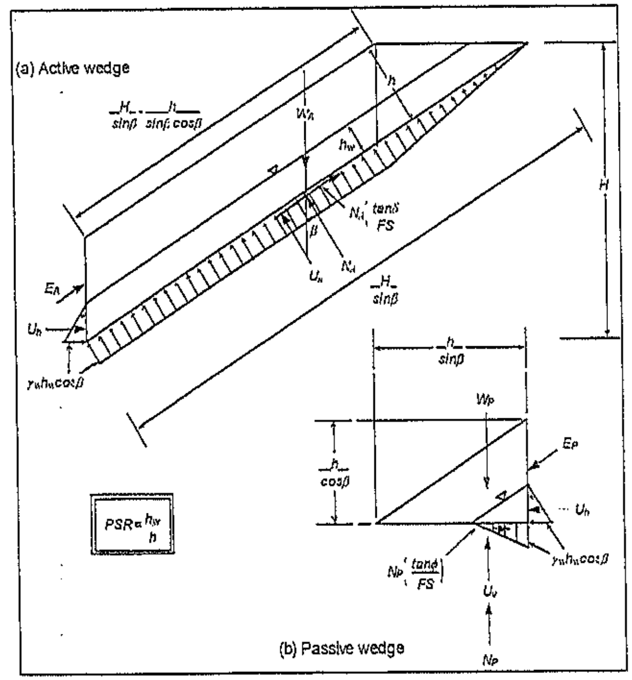
DLC =	21.041
PSR	0.001
FS	1.533

DLC = 21.0415

$q =$ *2.8E-07* m^3/sec

$h_{avg} =$ *0.00* m

PSR = 0.001



Calculation of FS

Active Wedge:

$W_A =$ *295.52 kN*
$U_n =$ *0.09253 kN*
$U_h =$ *5.4E-07 kN*
$N_A =$ *280.319 kN*

Passive Wedge:

$W_P =$ *10.5496 kN*
$U_V =$ *1.6E-06 kN*

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

where $a =$ *88.5*
$b =$ *-154.0*
$c =$ *28.0*

FS = 1.533

thickness of cover soil = h = *0.62* m
length of slope measured along the geomembrane = L = *30* m
soil slope angle beneath the geomembrane = β = *18.4* ° = *0.32* (rad.)
vertical height of the slope measured from the toe = H = *9.4* m
parallel submergence ratio = PSR = *0.00*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

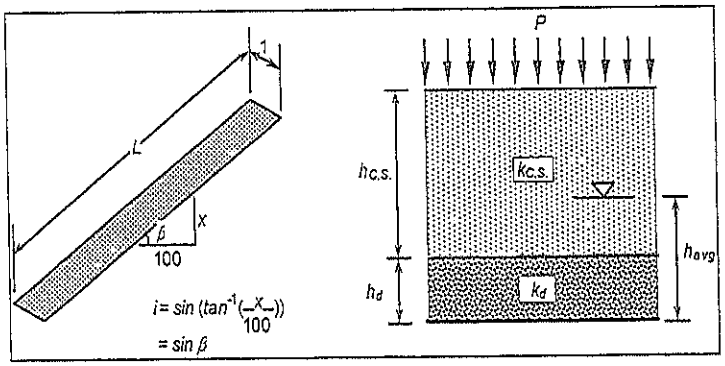
dry unit weight of the cover soil = γ_{dry} = 16.6 kN/m^3
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = 19.9 kN/m^3
unit weight of water = γ_w = 9.81 kN/m^3
friction angle of the cover soil = ϕ = 33.0 ° = *0.58* (rad.)
interface friction angle between cover soil and geomembrane = δ = 26.0 ° = *0.45* (rad.)

Note: numbers in boxes are input values
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

Calculation of DLC and PSR



L = 29.9 m
β = 18.4 °

$h_{c.s.}$ = 610 mm
h_d or t_{GS} = 7.0 mm

$k_{c.s.}$ = 1.0E-06 cm/s
k_d or k_{GS} = 2.7E-01 cm/s

P = 81.00 mm/hr
RC = 0.4

* Note: if only one soil layer above GN treat it as the drainage layer.

i = 0.3156
$L(\cos\beta)$ = *28.35* m
x = *9.43* m
$h_{c.s}$ = *0.6* m
h_d or t_{GS} = *0.01* m
$h_{c.s.} + h_d$ = *0.62* m

$k_{c.s.}$ = *1.0E-08* m/s
k_d or k_{GS} = *2.7E-03* m/s

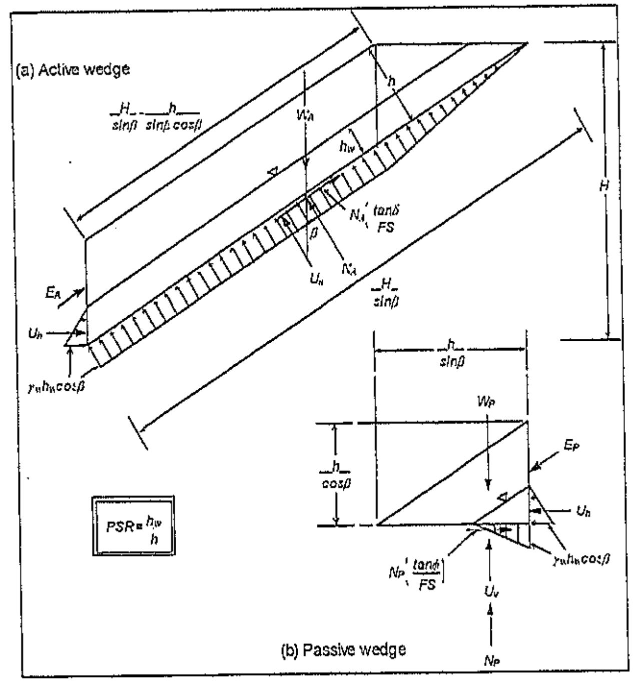
P (RC) = *32.4* mm/hr
Actual runoff = *80.96* mm/hr
PERC = *0.04* mm/hr
$FLUX_{actual}$ = *0.001* m^3/hr
$FLUX_{allow}$ = *0.021* m^3/hr **DLC = 21.0415**

q = *2.8E-07* m^3/sec

h_{avg} = *0.00* m

PSR = 0.001

DLC =	21.041
PSR	0.001
FS	1.529



thickness of cover soil = h = *0.62* m
length of slope measured along the geomembrane = L = *30* m
soil slope angle beneath the geomembrane = β = *18.4* ° = *0.32* (rad.)
vertical height of the slope measured from the toe = H = *9.4* m
parallel submergence ratio = *PSR* = *0.00*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

dry unit weight of the cover soil = γ_{dry} = 16.6 kN/m³
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = 19.9 kN/m³
unit weight of water = γ_w = 9.81 kN/m³
friction angle of the cover soil = ϕ = 19.0 ° = *0.33* (rad.)
interface friction angle between cover soil and geomembrane = δ = 26.0 ° = *0.45* (rad.)

Calculation of FS

Active Wedge:
W_A = *295.52* kN
U_n = *0.09253* kN
U_h = *5.4E-07* kN
N_A = *280.319* kN

Passive Wedge:
W_P = *10.5496* kN
U_V = *1.6E-06* kN

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

where a = *88.5*
b = *-145.0*
c = *14.9*

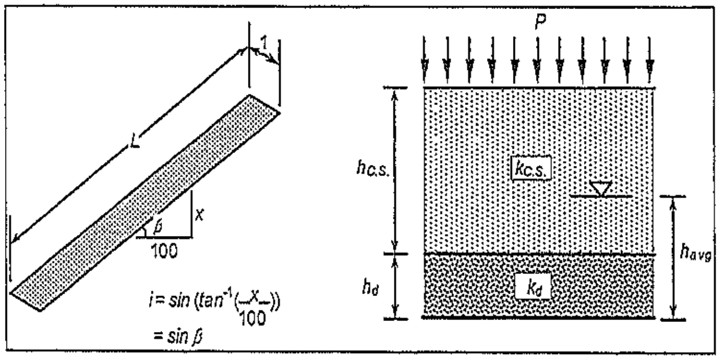
FS= 1.529

Note: numbers in boxes are input values
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

Calculation of DLC and PSR



L = 29.9 m
β = 18.4 °

$h_{c.s.}$ = 610 mm
h_d or t_{GS} = 7.0 mm

$k_{c.s.}$ = 1.0E-06 cm/s
k_d or k_{GS} = 2.2E-01 cm/s

P = 81.00 mm/hr
RC = 0.4

* Note: if only one soil layer above GM treat it as the drainage layer.

i = *0.3156*
$L(\cos\beta)$ = *28.35* m
x = *9.43* m
$h_{c.s.}$ = *0.6* m
h_d or t_{GS} = *0.01* m
$h_{c.s.} + h_d$ = *0.62* m

$k_{c.s.}$ = *1.0E-08* m/s
k_d or k_{GS} = *2.2E-03* m/s

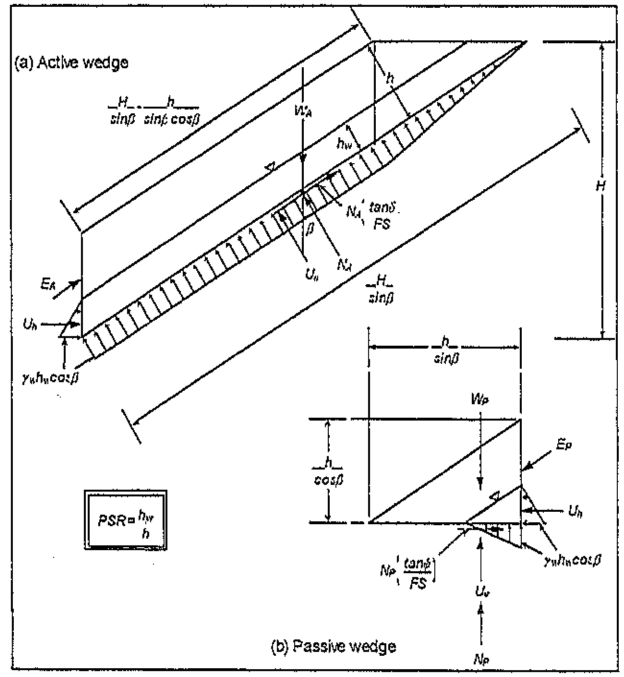
P (RC) = *32.4* mm/hr
Actual runoff = *80.96* mm/hr
PERC = *0.04* mm/hr
$FLUX_{actual}$ = *0.001* m^3/hr
$FLUX_{allow}$ = *0.017* m^3/hr *DLC = 17.1449*

q = *2.8E-07* m^3/sec

h_{avg} = *0.00* m

PSR = 0.001

DLC =	17.145
PSR	0.001
FS	1.531



thickness of cover soil = h = *0.62* m
length of slope measured along the geomembrane = L = *30* m
soil slope angle beneath the geomembrane = β = *18.4* ° = *0.32* (rad.)
vertical height of the slope measured from the toe = H = *9.4* m
parallel submergence ratio = PSR = *0.00*
depth of the water surface measured from the geomembrane = h_w = *0.00* m

dry unit weight of the cover soil = γ_{dry} = 16.6 kN/m^3
saturated unit weight of the cover soil = $\gamma_{sat'd}$ = 19.9 kN/m^3
unit weight of water = γ_w = 9.81 kN/m^3
friction angle of the cover soil = ϕ = 28.0 ° = *0.49* (rad.)
interface friction angle between cover soil and geomembrane = δ = 26.0 ° = *0.45* (rad.)

Calculation of FS

Active Wedge:
W_A = *295.528* kN
U_n = *0.11356* kN
U_h = *8.2E-07* kN
N_A = *280.306* kN

Passive Wedge:
W_P = *10.5496* kN
U_V = *2.5E-06* kN

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

where a = *88.5*
b = *-150.5*
c = *22.9*

FS = *1.531*

Note: numbers in boxes are input values
numbers in Italics are calculated values

Constructed by Te-Yang Soong

R.M.Koerner, and T-Y. Soong, 1998. Analysis and Design of Veneer Cover Soils. 6th International conference on Geosynthetics. Atlanta, Georgia, USA.

LING LESCHINSKY VENEER CALCULATIONS

Matlock Bend Landfill

VENEER STABILITY EVALUATION (Finite Slope Evaluation)

HOUSE ENGINEERING LLC

GEONET / GEOMEMBRANE INTERFACE

CALCULATE THE FACTOR OF SAFETY AGAINST SLIDING ALONG THE SLOPE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

c = cohesion (PSF) C_a = adhesion(note:adhesion has been ignored)
γ = unit weight of slope material(s) (PCF)
z = depth to the assumed failure interface or surface (FT)
β = slope angle (DEG)
Φ = angle of internal friction of the soil (DEG)
δ = friction angle of soil-geonet interface
k_v and k_h = vertical and horizontal seismic coefficients
H = thickness of soil cover
L = length of slope
W_A = weight of active wedge
W_B = weight of passive wedge
C_{ds} = ratio of the shear strength of soil-geosynthetic or geosynthetic-geosynthetic interface to that of the soil.
η = function of ϕ and β

EVALUATE GEONET-GEOMEMBRANE INTERFACE

$$C_{ds} = \frac{\tan\delta}{\tan\phi}$$

$$W_A = \gamma H L$$

C_{ds}	δ	ϕ	$\tan\phi$	k_v	$(1 - k_v)$	β	$\cos\beta$	k_h	$\sin\beta$	γ	H	L	W_A	c
0.917291587	26	28	0.531709	0	1	18.4	0.94888	0	0.31564904	127	1.7	98	21158.2	0

$$T_A = C_{ds} \tan\phi\ [(1 - k_v)\cos\beta - k_h \sin\beta\ ]\ W_A$$

T_A = **9791.967 lbf**

and

$$P = \frac{W_B[(1 - k_v)\tan\phi - k_h] + C}{\eta}$$

WHERE $W_B = \dfrac{\gamma H^2}{\sin 2\beta}$ AND $\eta = \cos(\phi+\beta)/\cos\phi$ $C = c\dfrac{H}{\sin\beta}$

2β	$\sin 2\beta$	W_B	$\phi+\beta$	$\cos\phi+\beta$	$\cos\phi$	η	C	Ca
36.8	0.5990236	612.7138	46.4	0.689619544	0.8829	0.78104	0.00	0

P= **325.79 lbf**

VENEER STABILITY EVALUATION
GEONET-GEOMEMBRANE INTERFACE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

$$Fs = \frac{10117.75}{6678.57} = 1.515$$

SOURCE:FEB. 1997 VOL. 123 NO.2 JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING , LING AND LESHCHINSKY

Matlock Bend Landfill

VENEER STABILITY EVALUATION (Finite Slope Evaluation)

HOUSE ENGINEERING LLC

GEONET / GEOMEMBRANE INTERFACE

CALCULATE THE FACTOR OF SAFETY AGAINST SLIDING ALONG THE SLOPE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

c = cohesion (PSF) C_a = adhesion(note:adhesion has been ignored)
γ = unit weight of slope material(s) (PCF)
z = depth to the assumed failure interface or surface (FT)
β = slope angle (DEG)
Φ = angle of internal friction of the soil (DEG)
δ = friction angle of soil-geonet interface
k_v and k_h = vertical and horizontal seismic coefficients
H = thickness of soil cover
L = length of slope
W_A = weight of active wedge
W_B = weight of passive wedge
C_{ds} = ratio of the shear strength of soil-geosynthetic or geosynthetic-geosynthetic interface to that of the soil.
η = function of ϕ and β

EVALUATE GEONET-GEOMEMBRANE INTERFACE

$$C_{ds} = \frac{\tan\delta}{\tan\phi}$$

$$W_A = \gamma H L$$

C_{ds}	δ	ϕ	$\tan\phi$	k_v	$(1 - k_v)$	β	$\cos\beta$	k_h	$\sin\beta$	γ	H	L	W_A	c
0.917291587	26	28	0.531709	0	1	18.4	0.94888	0	0.31564904	127	2.7	98	33604.2	0

$$T_A = C_{ds} \tan\phi\ [(1 - k_v)\cos\beta - k_h \sin\beta\ ]\ W_A$$

T_A = 15551.95 lbf

and

$$P = \frac{W_B[(1 - k_v)\tan\phi - k_h] + C}{\eta}$$

WHERE $W_B = \dfrac{\gamma H^2}{\sin 2\beta}$ AND $\eta = \cos(\phi + \beta)/\cos\phi$ $\quad C = c\dfrac{H}{\sin\beta}$

2β	$\sin 2\beta$	W_B	$\phi + \beta$	$\cos \phi + \beta$	$\cos\phi$	η	C	Ca
36.8	0.5990236	1545.565	46.4	0.689619544	0.8829	0.78104	0.00	0

P= 821.79 lbf

VENEER STABILITY EVALUATION
GEONET-GEOMEMBRANE INTERFACE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

$$Fs = \frac{16373.74}{10607.13} = 1.5437$$

SOURCE:FEB. 1997 VOL. 123 NO.2 JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING , LING AND LESHCHINSKY

Matlock Bend Landfill

VENEER STABILITY EVALUATION (Finite Slope Evaluation)

HOUSE ENGINEERING LLC

GEONET / GEOMEMBRANE INTERFACE

CALCULATE THE FACTOR OF SAFETY AGAINST SLIDING ALONG THE SLOPE

$$\boxed{F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}}$$

c = cohesion (PSF) C_a = adhesion(note:adhesion has been ignored)
γ = unit weight of slope material(s) (PCF)
z = depth to the assumed failure interface or surface (FT)
β = slope angle (DEG)
Φ = angle of internal friction of the soil (DEG)
δ = friction angle of soil-geonet interface
k_v and k_h = vertical and horizontal seismic coefficients
H = thickness of soil cover
L = length of slope
W_A = weight of active wedge
W_B = weight of passive wedge
C_{ds} = ratio of the shear strength of soil-geosynthetic or geosynthetic-geosynthetic interface to that of the soil.
η = function of ϕ and β

EVALUATE GEONET-GEOMEMBRANE INTERFACE

$$\boxed{C_{ds} = \frac{\tan\delta}{\tan\phi}}$$

$$\boxed{W_A = \gamma H L}$$

C_{ds}	δ	ϕ	$\tan\phi$	k_v	$(1 - k_v)$	β	$\cos\beta$	k_h	$\sin\beta$	γ	H	L	W_A	c
0.917291587	26	28	0.531709	0	1	15.8	0.96222	0	0.27228025	127	2	98	24892	0

$$\boxed{T_A = C_{ds} \tan\phi\ [(1 - k_v)\cos\beta - k_h \sin\beta\ ]\ W_A}$$

T_A = **11681.94 lbf**

and

$$\boxed{P = \frac{W_B[(1 - k_v)\tan\phi - k_h] + C}{\eta}}$$

WHERE $\boxed{W_B = \frac{\gamma H^2}{\sin 2\beta}}$ AND $\boxed{\eta = \cos(\phi + \beta)/\cos\phi}$ $\boxed{C = c\,\frac{H}{\sin\beta}}$

2β	$\sin 2\beta$	W_B	$\phi+\beta$	$\cos\phi+\beta$	$\cos\phi$	η	C	Ca
31.6	0.52398591	969.4917	43.8	0.721760228	0.8829	0.81744	0.00	0

P= **515.49 lbf**

VENEER STABILITY EVALUATION
GEONET-GEOMEMBRANE INTERFACE

$$\boxed{F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}}$$

$$Fs = \frac{12197.43}{6777.60} = 1.7997$$

SOURCE:FEB. 1997 VOL. 123 NO.2 JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING , LING AND LESHCHINSKY

Matlock Bend Landfill

HOUSE ENGINEERING LLC

VENEER STABILITY EVALUATION (Finite Slope Evaluation)

GEONET / GEOMEMBRANE INTERFACE

CALCULATE THE FACTOR OF SAFETY AGAINST SLIDING ALONG THE SLOPE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h\ \cos\beta + \sin\beta)}$$

c = cohesion (PSF) C_a = adhesion(note:adhesion has been ignored)
γ = unit weight of slope material(s) (PCF)
z = depth to the assumed failure interface or surface (FT)
β = slope angle (DEG)
Φ = angle of internal friction of the soil (DEG)
δ = friction angle of soil-geonet interface
k_v and k_h = vertical and horizontal seismic coefficients
H = thickness of soil cover
L = length of slope
W_A = weight of active wedge
W_B = weight of passive wedge
C_{ds} = ratio of the shear strength of soil-geosynthetic or geosynthetic-geosynthetic interface to that of the soil.
η = function of ϕ and β

EVALUATE GEONET-GEOMEMBRANE INTERFACE

$$C_{ds} = \frac{\tan\delta}{\tan\phi}$$

$$W_A = \gamma H L$$

C_{ds}	δ	ϕ	tan ϕ	k_v	(1 - k_v)	β	cos β	k_h	sin β	γ	H	L	W_A	c
0.647586055	19	28	0.531709	0	1	18.4	0.94888	0	0.31564904	127	2	98	24892	0

$$T_A = C_{ds} \tan\phi\ [(1 - k_v)\cos\beta - k_h \sin\beta\ ] W_A$$

T_A = 8132.819 lbf

and

$$P = \frac{W_B[(1 - k_v)\tan\phi - k_h] + C}{\eta}$$

WHERE

$$W_B = \frac{\gamma H^2}{\sin 2\beta}$$

AND

$$\eta = \cos(\phi + \beta)/\cos\phi$$

$$C = c\ \frac{H}{\sin\beta}$$

2β	sin 2β	W_B	ϕ+β	COS ϕ+β	COS ϕ	η	C	Ca
36.8	0.5990236	848.0467	46.4	0.689619544	0.8829	0.78104	0.00	0

P= 450.91 lbf

VENEER STABILITY EVALUATION
GEONET-GEOMEMBRANE INTERFACE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h\ \cos\beta + \sin\beta)}$$

$$Fs = \frac{8583.73}{7857.14} = 1.0925$$

SOURCE:FEB. 1997 VOL. 123 NO.2 JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING , LING AND LESHCHINSKY

Matlock Bend Landfill

HOUSE ENGINEERING LLC

VENEER STABILITY EVALUATION (Finite Slope Evaluation)

GEONET / GEOMEMBRANE INTERFACE

CALCULATE THE FACTOR OF SAFETY AGAINST SLIDING ALONG THE SLOPE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

c = cohesion (PSF) C_a = adhesion(note:adhesion has been ignored)
γ = unit weight of slope material(s) (PCF)
z = depth to the assumed failure interface or surface (FT)
β = slope angle (DEG)
Φ = angle of internal friction of the soil (DEG)
δ = friction angle of soil-geonet interface
k_v and k_h = vertical and horizontal seismic coefficients
H = thickness of soil cover
L = length of slope
W_A = weight of active wedge
W_B = weight of passive wedge
C_{ds} = ratio of the shear strength of soil-geosynthetic or geosynthetic-geosynthetic interface to that of the soil.
η = function of ϕ and β

EVALUATE GEONET-GEOMEMBRANE INTERFACE

$$C_{ds} = \frac{\tan\delta}{\tan\phi}$$

$$W_A = \gamma H L$$

C_{ds}	δ	ϕ	$\tan\phi$	k_v	$(1 - k_v)$	β	$\cos\beta$	k_h	$\sin\beta$	γ	H	L	W_A	c
0.917291587	26	28	0.531709	0	1	21.8	0.92849	0	0.37136784	127	2	98	24892	0

$$T_A = C_{ds} \tan\phi\ [(1 - k_v)\cos\beta - k_h \sin\beta\ ]\ W_A$$

T_A = **11272.41 lbf**

and

$$P = \frac{W_B[(1 - k_v)\tan\phi - k_h] + C}{\eta}$$

WHERE $W_B = \frac{\gamma H^2}{\sin 2\beta}$ AND $\eta = \cos(\phi + \beta)/\cos\phi$ $C = c\ \frac{H}{\sin\beta}$

2β	$\sin 2\beta$	W_B	$\phi + \beta$	COS $\phi + \beta$	COS ϕ	η	C	Ca
43.6	0.68961954	736.6381	49.8	0.645457688	0.8829	0.73103	0.00	0

P= **391.68 lbf**

VENEER STABILITY EVALUATION
GEONET-GEOMEMBRANE INTERFACE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

$$Fs = \frac{11664.09}{9244.09} = 1.2618$$

SOURCE:FEB. 1997 VOL. 123 NO.2 JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING , LING AND LESHCHINSKY

Matlock Bend Landfill

VENEER STABILITY EVALUATION (Finite Slope Evaluation)

HOUSE ENGINEERING LLC

GEONET / GEOMEMBRANE INTERFACE

CALCULATE THE FACTOR OF SAFETY AGAINST SLIDING ALONG THE SLOPE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

c = cohesion (PSF) C_a = adhesion(note:adhesion has been ignored)
γ = unit weight of slope material(s) (PCF)
z = depth to the assumed failure interface or surface (FT)
β = slope angle (DEG)
Φ = angle of internal friction of the soil (DEG)
δ = friction angle of soil-geonet interface
k_v and k_h = vertical and horizontal seismic coefficients
H = thickness of soil cover
L = length of slope
W_A = weight of active wedge
W_B = weight of passive wedge
C_{ds} = ratio of the shear strength of soil-geosynthetic or geosynthetic-geosynthetic interface to that of the soil.
η = function of ϕ and β

EVALUATE GEONET-GEOMEMBRANE INTERFACE

$$C_{ds} = \frac{\tan\delta}{\tan\phi}$$

$$W_A = \gamma H L$$

C_{ds}	δ	ϕ	$\tan\phi$	k_v	$(1 - k_v)$	β	$\cos\beta$	k_h	$\sin\beta$	γ	H	L	W_A	c
1.130054468	31	28	0.531709	0	1	18.4	0.94888	0	0.31564904	127	2	98	24892	0

$$T_A = C_{ds} \tan\phi\ [(1 - k_v)\cos\beta - k_h \sin\beta\ ]\ W_A$$

T_A = 14191.98 lbf

and

$$P = \frac{W_B[(1 - k_v)\tan\phi - k_h] + C}{\eta}$$

WHERE $W_B = \frac{\gamma H^2}{\sin 2\beta}$ AND $\eta = \cos(\phi + \beta)/\cos\phi$ $\quad C = c\,\frac{H}{\sin\beta}$

2β	$\sin 2\beta$	W_B	$\phi+\beta$	$\cos\phi+\beta$	$\cos\phi$	η	C	Ca
36.8	0.5990236	848.0467	46.4	0.689619544	0.8829	0.78104	0.00	0

P= 450.91 lbf

VENEER STABILITY EVALUATION
GEONET-GEOMEMBRANE INTERFACE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

$$Fs = \frac{14642.89}{7857.14} = 1.8636$$

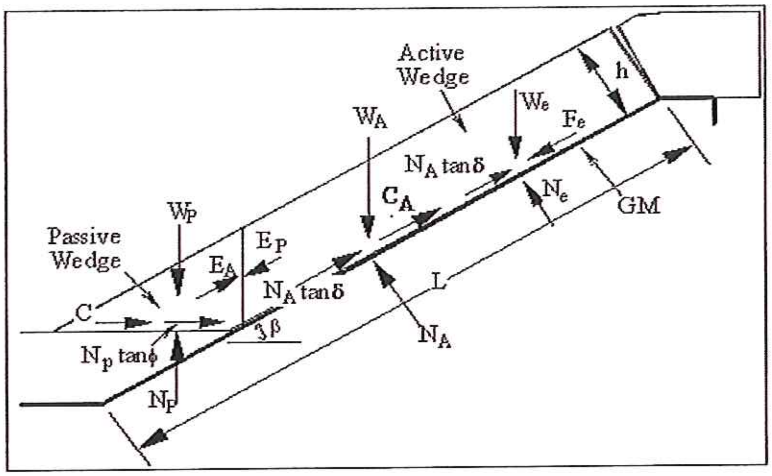
SOURCE:FEB. 1997 VOL. 123 NO.2 JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING , LING AND LESHCHINSKY

SANTEK WasteServices

EQUIPMENT LOADING AND VENEER STABILITY

Matlock Bend Landfill Veneer Stability Analysis

Placement of Protective CoverAnalysis with the Incorporation of Equipment Loads (Equipment is Moving Down-Slope)



Calculation of FS

Active Wedge:

Wa= 23198.1 lb

Na= 22012.1 lb

Passive Wedge:

Wp= 848.0 lb

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

a= 8849.9

b= -10270

c= 1366.2

FS= 1.01

thickness of cover soil = h =	2.00	ft		
soil slope angle beneath the geomembrane = β =	18.4	°	*= 0.32 (rad.)*	
finished cover soil slope angle = ω =	18.4	°	*= 0.32 (rad.)*	
length of slope measured along the geomembrane = L =	98.0	ft		
unit weight of the cover soil = γ =	127.0	lb/ft^3		
friction angle of the cover soil = ϕ =	26.0	°	*= 0.45 (rad.)*	
cohesion of the cover soil = c =	0.0	lb/ft^2		*C= 0 lb*
interface friction angle between RSL and geotextile = δ =	19.0	°	*= 0.33 (rad.)*	
adhesion between RSLand geotextile = ca =	0.0	lb/ft^2		*Ca= 0 lb*
weight of equipment = WE=	17163	lb		
thickness of cover soil = h =	2.00	ft		*b/h= 1.1*
equipment ground pressure (= wt. of equipment/(2 lw)) = q =	610	lb/ft^2		*We=q l I= 3963.8*
length of each equipment track = l =	6.7	ft		*Ne=Wecosβ = 3761.2*
width of each equipment track =w=	2.1	ft		*Fe=We x (a/g) x I = 753.1*
influence factor* at geomembrane interface = I =	0.97			
acceleration/deceleration of the bulldozer = a =	0.19	g		

*Influence Factor Default Values

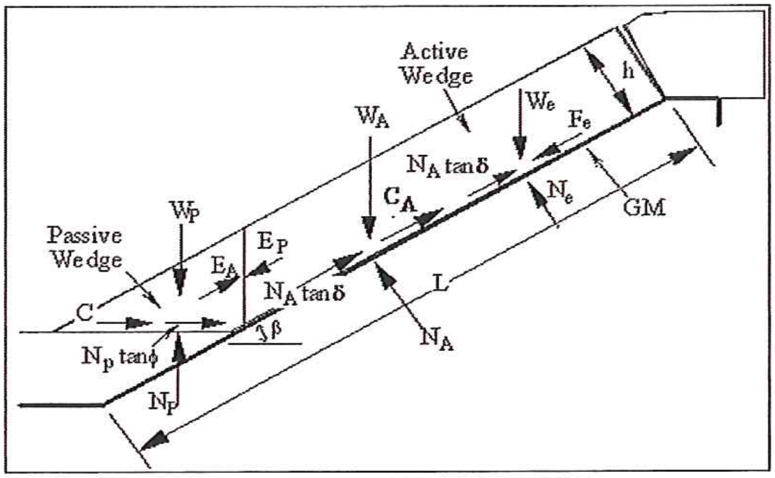
Cover Soil Thickness	Equipment Track Width		
	Very Wide	Wide	Standard
²300 mm	1.00	0.97	0.94
300-1000 mm	0.97	0.92	0.70
³ 1000 mm	0.95	0.75	0.30

Note: numbers in boxes are input values

numbers in Italics are calculated values

Matlock Ben Landfill Veneer Stability Analysis

Placement of Protective CoverAnalysis with the Incorporation of Equipment Loads
(Equipment is Moving Up-Slope)



Calculation of FS

Active Wedge:

Wa= 12022.5 lb

Na= 11407.9 lb

Passive Wedge:

Wp= 212.0 lb

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

a= 4788.1

b= -5916

c= 876.6

FS= 1.06

thickness of cover soil = h =	1.00	ft	
soil slope angle beneath the geomembrane = β =	18.4	°	*= 0.32 (rad.)*
finished cover soil slope angle = ω =	18.4	°	*= 0.32 (rad.)*
length of slope measured along the geomembrane = L =	98.0	ft	
unit weight of the cover soil = γ =	127.0	lb/ft^3	
friction angle of the cover soil = ϕ =	28.0	°	*= 0.49 (rad.)*
cohesion of the cover soil = c =	0.0	lb/ft^2	*C= 0 lb*
interface friction angle between RSL and geotextile = δ =	19.0	°	*= 0.33 (rad.)*
adhesion between RSLand geotextile = ca =	0.0	lb/ft^2	*Ca= 0 lb*
weight of equipment = WE=	17163	lb	
thickness of cover soil = h =	1.00	ft	*b/h= 2.1*
equipment ground pressure (= wt. of equipment/(2 lw)) = q =	610	lb/ft^2	*We=q l I= 3963.8*
length of each equipment track = l =	6.7	ft	*Ne=Wecos β = 3761.2*
width of each equipment track = w =	2.1	ft	*Fe=We x (a/g) x I = 0.0*
influence factor* at geomembrane interface = I =	0.97		
acceleration/deceleration of the bulldozer = a =	0.00	g	

*Influence Factor Default Values

Cover Soil Thickness	Equipment Track Width		
	Very Wide	Wide	Standard
²300 mm	1.00	0.97	0.94
300-1000 mm	0.97	0.92	0.70
³1000 mm	0.95	0.75	0.30

Note: numbers in boxes are input values

numbers in Italics are calculated values

SANTEK WasteServices

RELIABILITY ANALYSIS

Matlock Bend Landfill

VENEER STABILITY EVALUATION (Finite Slope Evaluation)

HOUSE ENGINEERING LLC

GEONET / GEOMEMBRANE INTERFACE

CALCULATE THE FACTOR OF SAFETY AGAINST SLIDING ALONG THE SLOPE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

c = cohesion (PSF) C_a = adhesion(note:adhesion has been ignored)
γ = unit weight of slope material(s) (PCF)
z = depth to the assumed failure interface or surface (FT)
β = slope angle (DEG)
Φ = angle of internal friction of the soil (DEG)
δ = friction angle of soil-geonet interface
k_v and k_h = vertical and horizontal seismic coefficients
H = thickness of soil cover
L = length of slope
W_A = weight of active wedge
W_B = weight of passive wedge
C_{ds} = ratio of the shear strength of soil-geosynthetic or geosynthetic-geosynthetic interface to that of the soil.
η = function of ϕ and β

EVALUATE GEONET-GEOMEMBRANE INTERFACE

$$C_{ds} = \frac{\tan\delta}{\tan\phi}$$

$$W_A = \gamma H L$$

C_{ds}	δ	ϕ	$\tan\phi$	k_v	$(1 - k_v)$	β	$\cos\beta$	k_h	$\sin\beta$	γ	H	L	W_A	c
0.936876076	26.48	28	0.531709	0	1	18.4	0.94888	0	0.31564904	127	2	98	24892	0

$$T_A = C_{ds} \tan\phi\ [(1 - k_v)\cos\beta - k_h \sin\beta\ ] W_A$$

$T_A =$ **11765.92 lbf**

and

$$P = \frac{W_B[(1 - k_v)\tan\phi - k_h] + C}{\eta}$$

WHERE

$$W_B = \frac{\gamma H^2}{\sin 2\beta}$$

AND

$$\eta = \cos(\phi + \beta)/\cos\phi$$

$$C = c\,\frac{H}{\sin\beta}$$

2β	$\sin 2\beta$	W_B	$\phi+\beta$	$\cos \phi+\beta$	$\cos\phi$	η	C	Ca
36.8	0.5990236	848.0467	46.4	0.689619544	0.8829	0.78104	0.00	0

P= **450.91 lbf**

VENEER STABILITY EVALUATION
GEONET-GEOMEMBRANE INTERFACE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

$$Fs = \frac{12216.83}{7857.14} = 1.5549$$

SOURCE:FEB. 1997 VOL. 123 NO.2 JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING , LING AND LESHCHINSKY

Matlock Bend Landfill

VENEER STABILITY EVALUATION (Finite Slope Evaluation)

HOUSE ENGINEERING LLC

GEONET / GEOMEMBRANE INTERFACE

CALCULATE THE FACTOR OF SAFETY AGAINST SLIDING ALONG THE SLOPE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

c = cohesion (PSF) C_a = adhesion(note:adhesion has been ignored)
γ = unit weight of slope material(s) (PCF)
z = depth to the assumed failure interface or surface (FT)
β = slope angle (DEG)
Φ = angle of internal friction of the soil (DEG)
δ = friction angle of soil-geonet interface
k_v and k_h = vertical and horizontal seismic coefficients
H = thickness of soil cover
L = length of slope
W_A = weight of active wedge
W_B = weight of passive wedge
C_{ds} = ratio of the shear strength of soil-geosynthetic or geosynthetic-geosynthetic interface to that of the soil.
η = function of ϕ and β

EVALUATE GEONET-GEOMEMBRANE INTERFACE

$$C_{ds} = \frac{\tan\delta}{\tan\phi}$$

$$W_A = \gamma H L$$

C_{ds}	δ	ϕ	$\tan\phi$	k_v	$(1 - k_v)$	β	$\cos\beta$	k_h	$\sin\beta$	γ	H	L	W_A	c
0.917291587	26	28	0.531709	0	1	17.3	0.95476	0	0.29737487	127	2	98	24892	0

$$T_A = C_{ds} \tan\phi\ [(1 - k_v)\cos\beta - k_h \sin\beta\ ] W_A$$

T_A = **11591.41 lbf**

and

$$P = \frac{W_B[(1 - k_v)\tan\phi - k_h] + C}{\eta}$$

WHERE

$$W_B = \frac{\gamma H^2}{\sin 2\beta}$$

AND

$$\eta = \cos(\phi + \beta)/ \cos\phi$$

$$C = c\ \frac{H}{\sin\beta}$$

2β	$\sin 2\beta$	W_B	$\phi + \beta$	$\cos\phi + \beta$	$\cos\phi$	η	C	Ca
34.6	0.56784375	894.6123	45.3	0.703394703	0.8829	0.79664	0.00	0

P= **475.67 lbf**

VENEER STABILITY EVALUATION
GEONET-GEOMEMBRANE INTERFACE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

$$Fs = \frac{12067.08}{7402.26} = 1.6302$$

SOURCE:FEB. 1997 VOL. 123 NO.2 JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING , LING AND LESHCHINSKY

Matlock Bend Landfill

VENEER STABILITY EVALUATION (Finite Slope Evaluation)

HOUSE ENGINEERING LLC

GEONET / GEOMEMBRANE INTERFACE

CALCULATE THE FACTOR OF SAFETY AGAINST SLIDING ALONG THE SLOPE

$$F_S = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A \ (k_h \cos\beta + \sin\beta)}$$

c = cohesion (PSF) C_a = adhesion(note:adhesion has been ignored)
γ = unit weight of slope material(s) (PCF)
z = depth to the assumed failure interface or surface (FT)
β = slope angle (DEG)
Φ = angle of internal friction of the soil (DEG)
δ = friction angle of soil-geonet interface
k_v and k_h = vertical and horizontal seismic coefficients
H = thickness of soil cover
L = length of slope
W_A = weight of active wedge
W_B = weight of passive wedge
C_{ds} = ratio of the shear strength of soil-geosynthetic or geosynthetic-geosynthetic interface to that of the soil.
η = function of ϕ and β

EVALUATE GEONET-GEOMEMBRANE INTERFACE

$$C_{ds} = \frac{\tan\delta}{\tan\phi}$$

$$W_A = \gamma H L$$

C_{ds}	δ	ϕ	$\tan\phi$	k_v	$(1 - k_v)$	β	$\cos\beta$	k_h	$\sin\beta$	γ	H	L	W_A	c
0.917291587	26	28	0.531709	0	1	19.4	0.94322	0	0.33216113	127	2	98	24892	0

$$T_A = C_{ds} \tan\phi \ [(1 - k_v)\cos\beta - k_h \sin\beta\ ] W_A$$

T_A = **11451.33 lbf**

and

$$P = \frac{W_B[(1 - k_v)\tan\phi - k_h] + C}{\eta}$$

WHERE

$$W_B = \frac{\gamma H^2}{\sin 2\beta}$$

AND

$$\eta = \cos(\phi + \beta) / \cos\phi$$

$$C = c\,\frac{H}{\sin\beta}$$

2β	$\sin 2\beta$	W_B	$\phi + \beta$	$\cos\phi + \beta$	$\cos\phi$	η	C	Ca
38.8	0.62660381	810.7196	47.4	0.67687597	0.8829	0.76661	0.00	0

P= 431.07 lbf

VENEER STABILITY EVALUATION
GEONET-GEOMEMBRANE INTERFACE

$$F_S = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A \ (k_h \cos\beta + \sin\beta)}$$

$$Fs = \frac{11882.39}{8268.15} = 1.4371$$

SOURCE:FEB. 1997 VOL. 123 NO.2 JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING, LING AND LESHCHINSKY

Matlock Bend Landfill

VENEER STABILITY EVALUATION (Finite Slope Evaluation)

HOUSE ENGINEERING LLC

GEONET / GEOMEMBRANE INTERFACE

CALCULATE THE FACTOR OF SAFETY AGAINST SLIDING ALONG THE SLOPE

$$F_S = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

c = cohesion (PSF) C_a = adhesion(note:adhesion has been ignored)
γ = unit weight of slope material(s) (PCF)
z = depth to the assumed failure interface or surface (FT)
β = slope angle (DEG)
Φ = angle of internal friction of the soil (DEG)
δ = friction angle of soil-geonet interface
k_v and k_h = vertical and horizontal seismic coefficients
H = thickness of soil cover
L = length of slope
W_A = weight of active wedge
W_B = weight of passive wedge
C_{ds} = ratio of the shear strength of soil-geosynthetic or geosynthetic-geosynthetic interface to that of the soil.
η = function of ϕ and β

EVALUATE GEONET-GEOMEMBRANE INTERFACE

$$C_{ds} = \frac{\tan\delta}{\tan\phi}$$

$$W_A = \gamma H L$$

C_{ds}	δ	ϕ	$\tan\phi$	k_v	$(1 - k_v)$	β	$\cos\beta$	k_h	$\sin\beta$	γ	H	L	W_A	c
0.917291587	26	28	0.531709	0	1	18.4	0.94888	0	0.31564904	127	1.9	98	23647.4	0

$$T_A = C_{ds} \tan\phi\ [(1 - k_v)\cos\beta - k_h \sin\beta\ ] W_A$$

T_A = **10943.96 lbf**

and

$$P = \frac{W_B[(1 - k_v)\tan\phi - k_h] + C}{\eta}$$

WHERE $W_B = \dfrac{\gamma H^2}{\sin 2\beta}$ AND $\eta = \cos(\phi + \beta) / \cos\phi$ $\quad C = c\dfrac{H}{\sin\beta}$

2β	$\sin 2\beta$	W_B	$\phi + \beta$	$\cos\phi + \beta$	$\cos\phi$	η	C	Ca
36.8	0.5990236	765.3622	46.4	0.689619544	0.8829	0.78104	0.00	0

P= **406.95 lbf**

VENEER STABILITY EVALUATION
GEONET-GEOMEMBRANE INTERFACE

$$F_S = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

Fs = $\dfrac{11350.91}{7464.28}$ = **1.5207**

SOURCE:FEB. 1997 VOL. 123 NO.2 JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING , LING AND LESHCHINSKY

Matlock Bend Landfill

VENEER STABILITY EVALUATION (Finite Slope Evaluation)

HOUSE ENGINEERING LLC

GEONET / GEOMEMBRANE INTERFACE

CALCULATE THE FACTOR OF SAFETY AGAINST SLIDING ALONG THE SLOPE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (\ k_h\ \cos\beta + \ \sin\beta\ )}$$

c = cohesion (PSF) C_a = adhesion(note:adhesion has been ignored)
γ = unit weight of slope material(s) (PCF)
z = depth to the assumed failure interface or surface (FT)
β = slope angle (DEG)
Φ = angle of internal friction of the soil (DEG)
δ = friction angle of soil-geonet interface
k_v and k_h = vertical and horizontal seismic coefficients
H = thickness of soil cover
L = length of slope
W_A = weight of active wedge
W_B = weight of passive wedge
C_{ds} = ratio of the shear strength of soil-geosynthetic or geosynthetic-geosynthetic interface to that of the soil.
η = function of ϕ and β

EVALUATE GEONET-GEOMEMBRANE INTERFACE

$$C_{ds} = \frac{\tan\delta}{\tan\phi}$$

$$W_A = \gamma H L$$

C_{ds}	δ	ϕ	$\tan\phi$	k_v	$(1 - k_v)$	β	$\cos\beta$	k_h	$\sin\beta$	γ	H	L	W_A	c
0.917291587	26	28	0.531709	0	1	18.4	0.94888	0	0.31564904	127	2.1	98	26136.6	0

$$T_A = C_{ds} \tan\phi\ [(1 - k_v)\cos\beta - \ k_h\ \sin\beta\ ]\ W_A$$

$T_A =$ **12095.96 lbf**

and

$$P = \frac{W_B[(1 - k_v)\tan\phi - \ k_h\ ] + C}{\eta}$$

WHERE $W_B = \dfrac{\gamma H^2}{\sin 2\beta}$ AND $\eta = \cos\ (\phi + \beta)/\ \cos\phi$ $C = c\ \dfrac{H}{\sin\beta}$

2β	$\sin 2\beta$	W_B	$\phi+\beta$	$COS\ \phi+\beta$	$COS\ \phi$	η	C	Ca
36.8	0.5990236	934.9715	46.4	0.689619544	0.8829	0.78104	0.00	0

P= **497.13 lbf**

VENEER STABILITY EVALUATION
GEONET-GEOMEMBRANE INTERFACE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (\ k_h\ \cos\beta + \ \sin\beta\ )}$$

$$Fs = \frac{12593.09}{8249.99} = 1.5264$$

SOURCE:FEB. 1997 VOL. 123 NO.2 JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING , LING AND LESHCHINSKY

Matlock Bend Landfill

VENEER STABILITY EVALUATION (Finite Slope Evaluation)

HOUSE ENGINEERING LLC

GEONET / GEOMEMBRANE INTERFACE

CALCULATE THE FACTOR OF SAFETY AGAINST SLIDING ALONG THE SLOPE

$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

c = cohesion (PSF) C_a = adhesion(note:adhesion has been ignored)
γ = unit weight of slope material(s) (PCF)
z = depth to the assumed failure interface or surface (FT)
β = slope angle (DEG)
Φ = angle of internal friction of the soil (DEG)
δ = friction angle of soil-geonet interface
k_v and k_h = vertical and horizontal seismic coefficients
H = thickness of soil cover
L = length of slope
W_A = weight of active wedge
W_B = weight of passive wedge
C_{ds} = ratio of the shear strength of soil-geosynthetic or geosynthetic-geosynthetic interface to that of the soil.
η = function of ϕ and β

EVALUATE GEONET-GEOMEMBRANE INTERFACE

$$C_{ds} = \frac{\tan\delta}{\tan\phi}$$

$$W_A = \gamma H L$$

C_{ds}	δ	ϕ	$\tan\phi$	k_v	$(1 - k_v)$	β	$\cos\beta$	k_h	$\sin\beta$	γ	H	L	W_A	c
0.853531186	24.41	28	0.531709	0	1	18.4	0.94888	0	0.31564904	127	2	98	24892	0

$$T_A = C_{ds} \tan\phi\ [(1 - k_v)\cos\beta - k_h \sin\beta\ ]\ W_A$$

T_A = **10719.22 lbf**

and

$$P = \frac{W_B[(1 - k_v)\tan\phi - k_h] + C}{\eta}$$

WHERE $W_B = \dfrac{\gamma H^2}{\sin 2\beta}$ AND $\eta = \cos(\phi + \beta)/\cos\phi$ $C = c\dfrac{H}{\sin\beta}$

2β	$\sin 2\beta$	W_B	$\phi+\beta$	$\cos\phi+\beta$	$\cos\phi$	η	C	Ca
36.8	0.5990236	848.0467	46.4	0.689619544	0.8829	0.78104	0.00	0

P= **450.91 lbf**

VENEER STABILITY EVALUATION
GEONET-GEOMEMBRANE INTERFACE

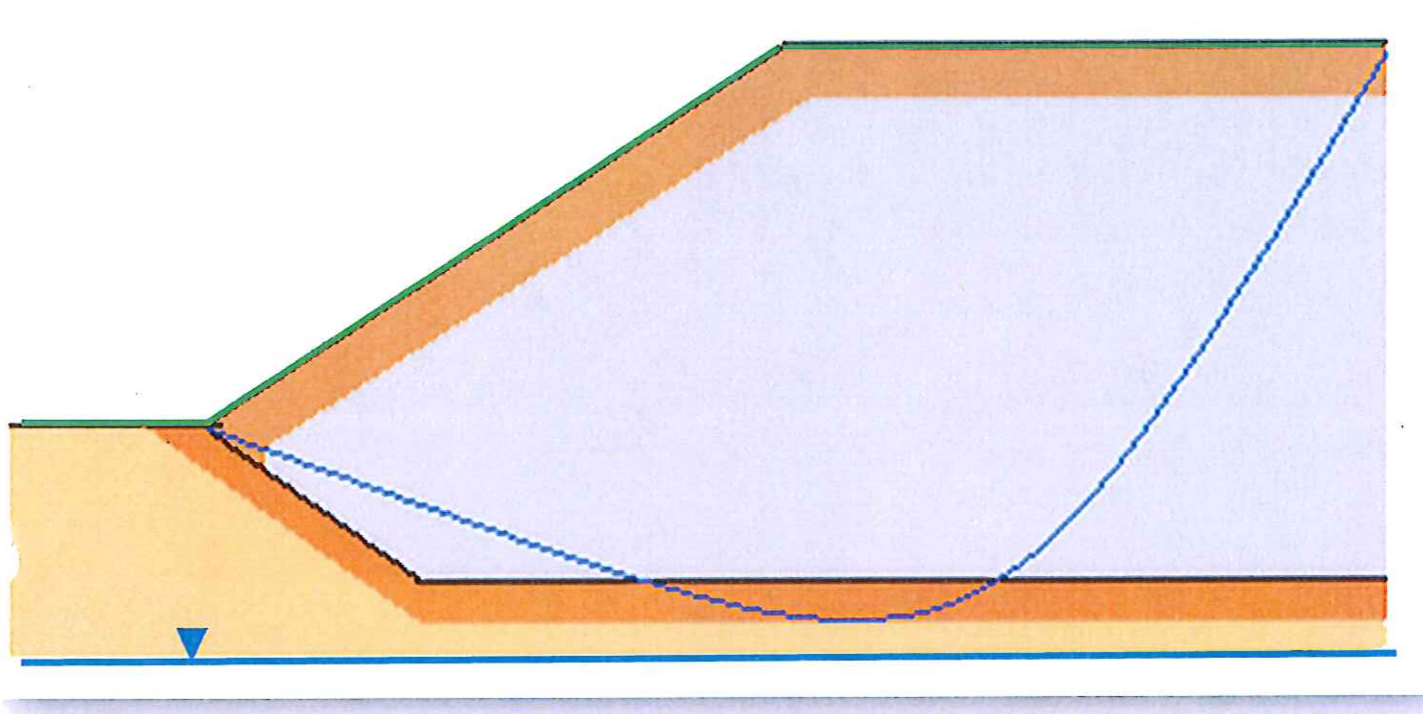
$$F_s = \frac{T_A + P + k_v W_A \sin\beta + C_a}{W_A\ (k_h \cos\beta + \sin\beta)}$$

$$Fs = \frac{11170.13}{7857.14} = 1.4217$$

SOURCE:FEB. 1997 VOL. 123 NO.2 JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING , LING AND LESHCHINSKY

GLOBAL STABILITY

SANTEK
WasteServices



GLOBAL STABILITY NARRATIVE

2014 Matlock Bend Class I Landfill Expansion
Loudon, Tennessee

JO K. HOUSE
REGISTERED PROFESSIONAL ENGINEER
AGRICULTURE
COMMERCE
No. 016277
STATE OF TENNESSEE

Prepared By:

HOUSE ENGINEERING LLC

SANTEK WasteServices

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

GLOSSARY OF TERMS / NOTATIONS

c = soil cohesion (Pa)

cm/sec = centimeters per second

$D_{5\text{-}95}$ = significant duration of acceleration-time history (s)

FS = factor of safety (dimensionless)

FS_{static} = static factor of safety (dimensionless)

G = shear modulus (Pa)

G_{max} = maximum shear modulus (Pa)

g = acceleration due to gravity (m/s^2)

GRI = Geosynthetics Research Institute

H = height of landfill waste or cover thickness (m)

HE = House Engineering LLC

HEA = horizontal equivalent acceleration (m/s^2)

HCV = highest conceivable value

kN/m^3 = Kilonewtons per cubic meter

k = permeability (cm/sec)

k = seismic acceleration coefficient (dimensionless)

k_{max} = maximum seismic acceleration coefficient = *MHEA/g* (dimensionless

k_y = yield acceleration coefficient (dimensionless)

kPa = kilopascal

L = length of midsection of landfill (m)

LCV = lowest conceivable value

L_S = length of cover slope mass (m)

LLDPE = Low Density Polyethylene

MBL = Matlock Bend Landfill

MHA = maximum horizontal ground acceleration (m/s^2)

MHA_{Crest} = maximum horizontal ground acceleration at crest of landfill (m/s^2)

MHA_{Rock} = maximum horizontal ground acceleration of rock (m/s^2)

MHA_{Site} = maximum horizontal ground acceleration of site (m/s^2)

MHA_{Top} = maximum horizontal ground acceleration at top of landfill (m/s^2)

MHEA = maximum horizontal equivalent acceleration (m/s^2)

$MHEA_{Base}$ = maximum horizontal equivalent acceleration at base of landfill (m/s^2)

$MHEA_{Cover}$ = maximum horizontal equivalent acceleration of landfill cover sliding mass (m/s^2)

MLV = most likely value

GLOSSARY OF TERMS / NOTATIONS (continued)

mm	= millimeter
m/s	= meters per second
M_W	= moment magnitude of earthquake event (dimensionless)
psf	= pounds per square foot
PSR	= parallel submergence ratio
NRF	= nonlinear response factor (dimensionless)
RFCR	= creep reduction factor
R	= seismic displacement reduction factor = $k_y / k_{max.}$ at selected displacement (dimensionless)
R_B	= seismic displacement reduction factor = k_y / k_{max} at selected base displacements (dimensionless)
R_C	= seismic displacement reduction factor = k_y / k_{max} at selected cover displacements (dimensionless)
Santek	= Santek Waste Services LLC
S_1	= back-slope run to height ratio (dimensionless)
S_2	=front-slope run to height ratio (dimensionless)
T_p	= mean period of acceleration-time history (s)
$T_{m\text{-}EQ}$	= mean period of earthquake (s)
T_P	= predominant period of ground motion (s)
$T_{p\text{-}EQ}$	= predominant period of earthquake (s)
T_s	= fundamental period of column of waste fill (s)
$T_{s\text{-}FILL}$	= fundamental period of fill material (s)
$T_{s\text{-}WASTE}$	= fundamental period of waste
t	= time (s)
U	= seismically induced permanent displacement (mm)
USEPA	= United States Environmental Protection Agency
V_s	= average shear wave velocity (m/s)
β	= slope angle of cover from horizontal (°)
ε	= strain (dimensionless)
θ	= transmissivity (cm/sec)
ϕ	= internal friction angle (°)
γ	= total unit weight (N/m^3)

SLOPE STABILITY ANALYSIS
MATLOCK BEND CLASS I LANDFILL
LOUDON, TENNESSEE

1.0 INTRODUCTION

The purpose of this analysis is to evaluate the slope stability of the proposed expansion of the Matlock Bend Class I Landfill (MBL) near Loudon, Tennessee. In addition, the impact of potential seismic forces on the stability of the proposed waste fill expansion has also been evaluated. A number of different slope analyses were utilized to evaluate the static slope stability and the stability of the waste fill under the projected seismic loadings for the event specified by the Environmental Protection Agency in the Subtitle D regulations. The specific event is noted as the earthquake event that has a two percent probability of occurrence in fifty years or a 100 percent probability of occurrence in approximately 2,500 years. **Figure 30** from the United States Geological Survey (USGS) Open-File No.2008-1128 and the interactive map provided on the USGS website were used to determine the maximum horizontal acceleration for the event specified as per the Subtitle D regulations.

The August 2008 hydrogeological report prepared by Civil & Environmental Consultants, Inc. (CEC) was the source of the subsurface and hydrogeological information used for this slope stability evaluation. The waste fill embankment sections were obtained from the design drawings prepared by Santek Environmental (SE). Currently accepted engineering methods were employed to evaluate the stability of the MBL slopes. In addition, the Tennessee Division of Solid Waste Management (TDSWM) guidance policy was used to assist with the determination of the impact of the specified seismic event on the proposed municipal solid waste facility.

The TDSWM guidance policy presents two major design concerns regarding the seismic impact on the stability and safety of municipal solid waste landfills in Tennessee. These concerns are as follows:

- Leachate collection systems and waste cells shall be designed to function without collection pipes for solid waste fill embankments that are predicted to undergo more than six inches of deformation.
- No landfill shall be acceptable if the predicted seismic induced deformations within the waste fill exceed one-half the thickness of the clay liner component of the liner system.

The cross section identified on the permit drawings as Section C poses the greatest challenge from a slope stability perspective; hence, House Engineering LLC (HE) concentrated the global slope stability evaluation on this section.

2.0 DEVELOPMENT OF MODEL FOR SLOPE STABILITY EVALUATION

Section C-C was developed to represent the worst case section through the proposed Matlock Bend Landfill. A number of borings and laboratory testing data were used to establish the subsurface conditions beneath the site. Borings B-60, PZ-51, B-58, B-59, SB-47, and PZ-48 were specifically used to help establish the subsurface conditions beneath the site due to their depth and location.

The following Drawings were used to prepare the seismic slope stability model:

CEC Drawing 3	Seasonal High Groundwater Contours and Summary Table
Santek Drawing 6	Top of Clay Liner and Geomembrane Plan
Santek Drawing	Final Cover Plan
Santek Drawing 12	Base Grade and Final Cover Details

2.1 FINAL CONDITION SLOPE CROSS-SECTION C DESCRIPTION

Cross-Section C is oriented from west to east through the Class I waste fill. The location of this cross-section was chosen to depict the deepest section of waste that also was representative of the subsurface conditions beneath the site. Another factor was due to the direction of the slope in the base of the landfill. The overall length of the cross-section evaluated exceeded 1,000 feet. The maximum depth from the base of the landfill to the crest of the top deck of the waste fill approximates 200 feet at an elevation of 1120 feet Average Mean Sea Level. This thickness of waste approximates the maximum thickness proposed at the facility.

2.2 CROSS-SECTION OF LANDFILL BASE

The bottom liner design of the landfill consists of the following components:

- 6 ounce Geotextile
- 12-inch thick #57 Stone Leachate Collection Layer;
- 6 ounce Geotextile
- 60-mil HDPE Textured Geomembrane;
- Geocomposite Clay Liner
- 24-inch thick layer of Recompacted Soil Liner (max. 1 x 10^{-5} cm/sec); and
- 5-foot thick Geologic Buffer layer (max. 1 x 10^{-6} cm/sec).

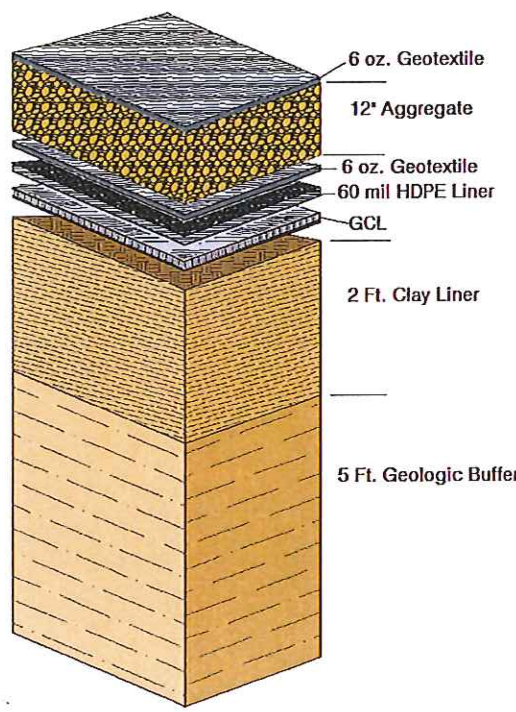


Figure 1 – Liner / Leachate Collection System Typical Section

Unit weights and shear strength parameters, consisting of internal and interface friction angles and cohesion or adhesion values, were assigned to the proposed soils and geosynthetics and, where possible, were based upon laboratory testing of site specific materials. Typical strength and unit weight parameters from the available literature were assigned to municipal solid waste (MSW) and compacted soil liner. The soil and waste materials and corresponding shear strength parameters used within the analysis are summarized and discussed in the following sections:

2.3 PHYSICAL PARAMETERS OF LANDFILL AND SUBGRADE MATERIALS

2.3a MSW Unit Weight

The unit weight for the Municipal Solid Waste (MSW) used in the stability analyses was taken from back-calculations performed by Geosyntec Consultants (Geosyntec) as a result of the slope failure in Module G of the Matlock Bend Landfill. Geosyntec determined the wet density of the waste in the MBL to approximate 90 pounds per cubic foot (PCF) from back-calculations performed from the 2010 slide whose failure plane was limited to the waste mass. A unit weight of 90 pcf is the upper limit of wet density as reported in the literature. It has been reported that MSW, which consists of 16% sludge, approximates a wet unit weight of 63 to 70 pcf. Based upon a review of the literature and experience at another site HE has used 75 pcf for static and dynamic modeling of the MBL waste fill.

2.3b MSW Shear Strength

The shear strength of the MSW was obtained from recent conversations with Dr. Robert Koerner and Greg Richardson. Koerner and Richardson both indicated that, generally, the strength of MSW could be modeled with an angle of internal friction (ϕ) of 33°.

In addition, a Mohr-Coulomb failure envelope was reviewed in an effort to model the shear strength of the MSW. Given the variability of MSW, at best an approximate shear strength envelope can be produced. The shear strength envelope input into the program was taken from a USEPA technical report entitled "*RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities,*" (Reference 10). Figure 2 below shows the waste shear strength envelope used within this analysis.

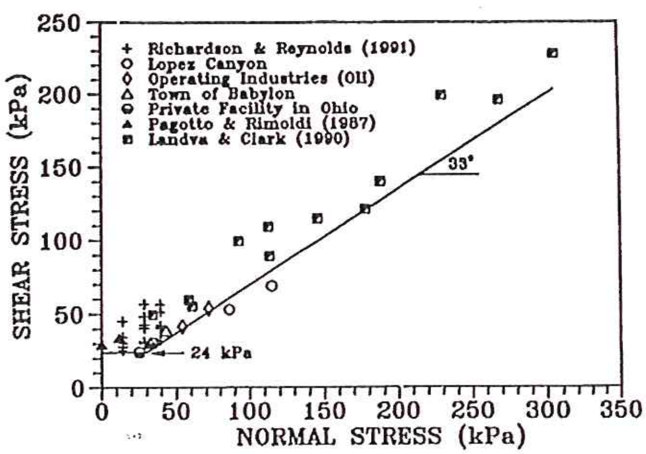


Figure 2 – Bi-Linear Shear Strength Envelope for Municipal Solid Waste Kavazanjian, et al.

The USEPA document references a study performed by Kavazanjian, et al. (Reference 6) that compared and graphed the results of seven studies performed on the strength of MSW. In six of the studies, the strength of the MSW was determined by back-analysis of waste slopes. One of the studies used the results of large-scale, in-situ direct shear tests. The waste strengths were plotted on a single figure that showed a bi-linear trend in the strength of the MSW. For low normal stresses, up to approximately 30 kPa (626 psf) the waste strength was primarily cohesive in nature with shear strength of approximately 24 kPa (500 psf). At normal stresses above 30 kPa, the waste strength was frictional in nature with the strength of the waste increasing with increasing normal stresses represented by a friction angle of approximately 33°.

Another source of shear strength of MSW by Mojan makes the following statement about the shear strength of MSW: "Most friction angles fall between 28° and 42° while cohesion fell within a range of 0 to 835 psf. The direct shear strength tests conducted in this study yielded a friction angle of 41° and cohesion of 501 psf."

Finally, Geosyntec back-calculated the shear strength of the waste which underwent a slide at the site in 2010 by varying the strength parameters input into the pseudo-static computer analysis to determine the values that would result in a factor of safety of one which is considered as imminent failure. The results of the analysis revealed that the angle of internal friction of the slide affected waste approximated 20°. Therefore, HE has decided to model the slope stability of the waste fill by using an angle of internal friction of the slide affected waste of 20° and future waste placed in the landfill with an angle of internal friction of 33°. The increased angle of friction for future waste placed in the landfill was recommended by Geosyntec due to the fact that Santek has adopted a sludge management plan which involves mixing of the waste with sludge as well as limiting the percentage of sludge disposed in the waste fill.

2.3c In-Place Soil Strength Parameters

The soil physical parameters used in the slope stability analyses were determined from correlations between tests performed during the Hydrogeological Investigation performed by CEC, back-calculations from the 2010 slide at the site, and typical strength parameters that have been encountered with similar soils. Effective strength parameters were used to estimate the factor of safety for slope stability of the proposed waste fill due to the low rate of waste disposal / loading of the underlying site soils. The effective friction angle used is 68% of the estimated actual strength of the site soils as determined from the hydrogeologic investigation. The strength of the site soils have been estimated to have an effective internal friction angle of 28°.

$$\gamma_{dry} = \text{Dry Unit weight} = 102 \text{ pcf},$$
$$\gamma_{wet} = \text{Wet Unit weight} = 126.5$$
$$\phi_{soil} = \text{Internal friction angle (effective)} = 19 \text{ degrees}$$
$$C_{eff} = \text{cohesion (effective)} = 0 \text{ psf}$$

2.4d Interface Strengths of Geosynthetics Liner Materials

HE has implemented the recommendations from Stark and Choi (2004) regarding the stability analysis of geosynthetic-lined landfill bottoms and interior sideslopes. Specifically, Stark and Choi recommend evaluating the failure envelope that corresponds to the lowest peak strength of one or more geosynthetic interfaces because geosynthetic interface strength is stress-dependent. Stark and Choi further state that if more than one interface is used to develop the failure envelope for the interface with the lowest peak strength, the envelope is referred to as a composite failure envelope.

(1) The procedure for constructing a peak composite failure envelope for multi-layer liner and cover systems uses the following three steps:

(a) Determine the interface(s) or material(s) in the composite liner system exhibiting the lowest peak strength for the full range of normal stresses encountered along the bottom liner system.

(b) Determine the peak composite failure envelope for the weakest interfaces(s) or material(s) in the composite liner system for the full range of effective normal stresses encountered along the liner system.

(c) Determine the residual composite failure envelope that corresponds to the peak composite failure envelope in Step (b).

(2) Utilizing the peak and residual composite failure envelopes obtained above, the two design scenarios for the bottom liner systems with a sideslope presented by Stark and Poeppel (1994) can be used:

(a) Assign residual shear strengths to the sideslopes and peak shear strengths to the base of the liner system and satisfy a factor of safety greater than 1.5, and

(b) Assign residual strengths to the sideslopes and base of the liner system and satisfy a factor of safety greater than 1.0 or 1.1 if direct shear data are used.

HE has applied residual and peak strengths as Stark and Choi have recommended in the procedure outlined above to analyze the stability of the geosynthetic-lined landfill bottom and interior sideslopes. HE has taken the results from recently performed peak and residual interface testing of actual geosynthetics used to construct a base liner system with an almost identical design to evaluate the block/wedge stability of the proposed MBL expansion. The actual laboratory test results determined from the aforementioned project which have been used in the geosynthetic interface stability analysis of the proposed MBL bottom liner design are provided in Table 1.

It is extremely important to note that for an interface involving a textured geomembrane and any other material, the key factor influencing the interface strength is the asperity height. Asperity should be measured per the GRI GM12 test method. An asperity height of 20 mils is the target value above which the shear strength properties of any geomembrane interface will not vary significantly. Figure 3 taken from the article "Interface Shear-Strength Properties of Textured Polyethylene Geomembranes", by Blond and Elie of Quebec, Canada illustrates the influence of asperity on shear strength.

Figure 3 - Comparison of Peak and Residual Shear Strengths of Tested Interfaces

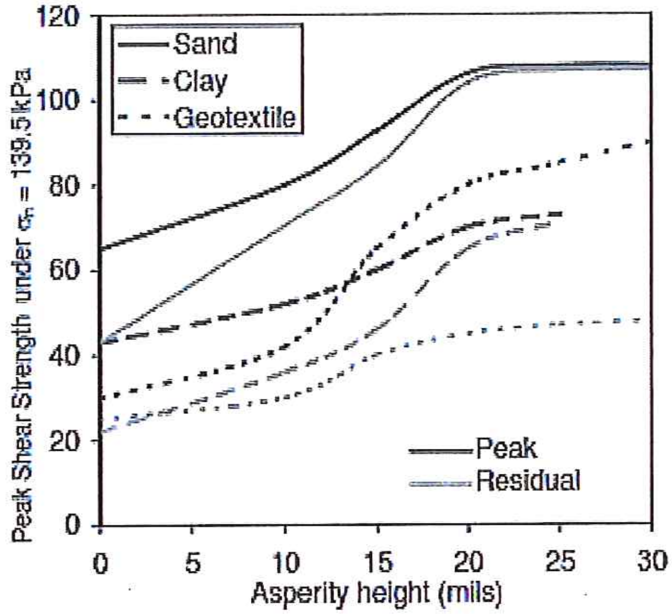


Table 1 – Summary of Material Properties

Material	Dry Unit Weight lbs./cu.ft.	Wet Unit Weight lbs./cu.ft.	Peak Angle of Internal Friction (∅) (degrees)	Residual Angle of Internal Friction (∅) (degrees)	Peak Cohesion / Adhesion (psf)	Residual Cohesion / Adhesion (psf)
In-Place Soil	121	127	23	19	0	0
Compacted Soil Berm	124	127	28	18	0	0
Future Waste	70	90	33	20	0	0
Slide Impacted Waste	79	90	NA[1]	20	0	0
Composite Geosynthetic Interface	62	62	13.3[2]	5.5[2]	1197[2]	700[2]

[1] Slide impacted waste is presently at residual strength.

[2] Values are taken from recent testing of similar interfaces proposed for the MBL liner system.

3.0 GLOBAL STABILITY ANALYSIS

Pseudo-Static Analysis

Pseudo-static slope stability methods were performed on the most critical section (section C) of the proposed landfill expansion. The landfill cross section was constructed by taking the design final cover, design liner grades, and groundwater table elevations and importing them into the STEDWin program which formats the information for input into STABL5M.

Slope Stability Methodology

The ordinary method of slices (OMS) also referred to as the Swedish Circle Method which was first used for slope stability analyses ignored both shear and normal interslice forces and considered only moment equilibrium. It was determined that the normal forces would not generally satisfy equilibrium in directions other than those normal and parallel to the base of each slice. Hence, such neglection of interslice forces could lead to unrealistic results.

The OMS has been modified to satisfy moment equilibrium and to include interslice normal and shear forces.

Generally, the modified Bishop procedure is recommended when the slip plane/surface can be approximated by a circular arc.

The method most convenient for irregular slip surfaces is Janbu's simplified procedure. The Janbu procedure includes interslice normal forces and satisfies horizontal force equilibrium. The Janbu method can lead to overly conservative designs.

The most accurate limit equilibrium method is referred to as Spencer's Method. The reason Spencer's Method is considered more accurate is based upon the fact that it considers moment equilibrium and includes both normal and shear interslice forces. Spencer's method of slices has been incorporated into STABL5M and the STEDWin program to enhance the accuracy of the stability methods.

Five different methods of evaluating the pseudo-static slope stability of the most critical MBL expansion cross section were performed which are as follows:

Janbu Circle
Modified Bishop Circle
Modified Janbu "Random Failure Plane Search Routine"
Block or Wedge Analysis
Spencer's Method

In summary, each of these methods was utilized to evaluate the global slope stability of the MBL proposed expansion. The Janbu Circle method identified a failure plane that penetrated the liner system and revealed the lowest factor of safety for slope stability of 1.54. Spencer's method was used to further evaluate the failure plane identified with the lowest FS. Spencer's method calculated the global factor of safety for slope stability of the weakest failure plane to approximate 1.71

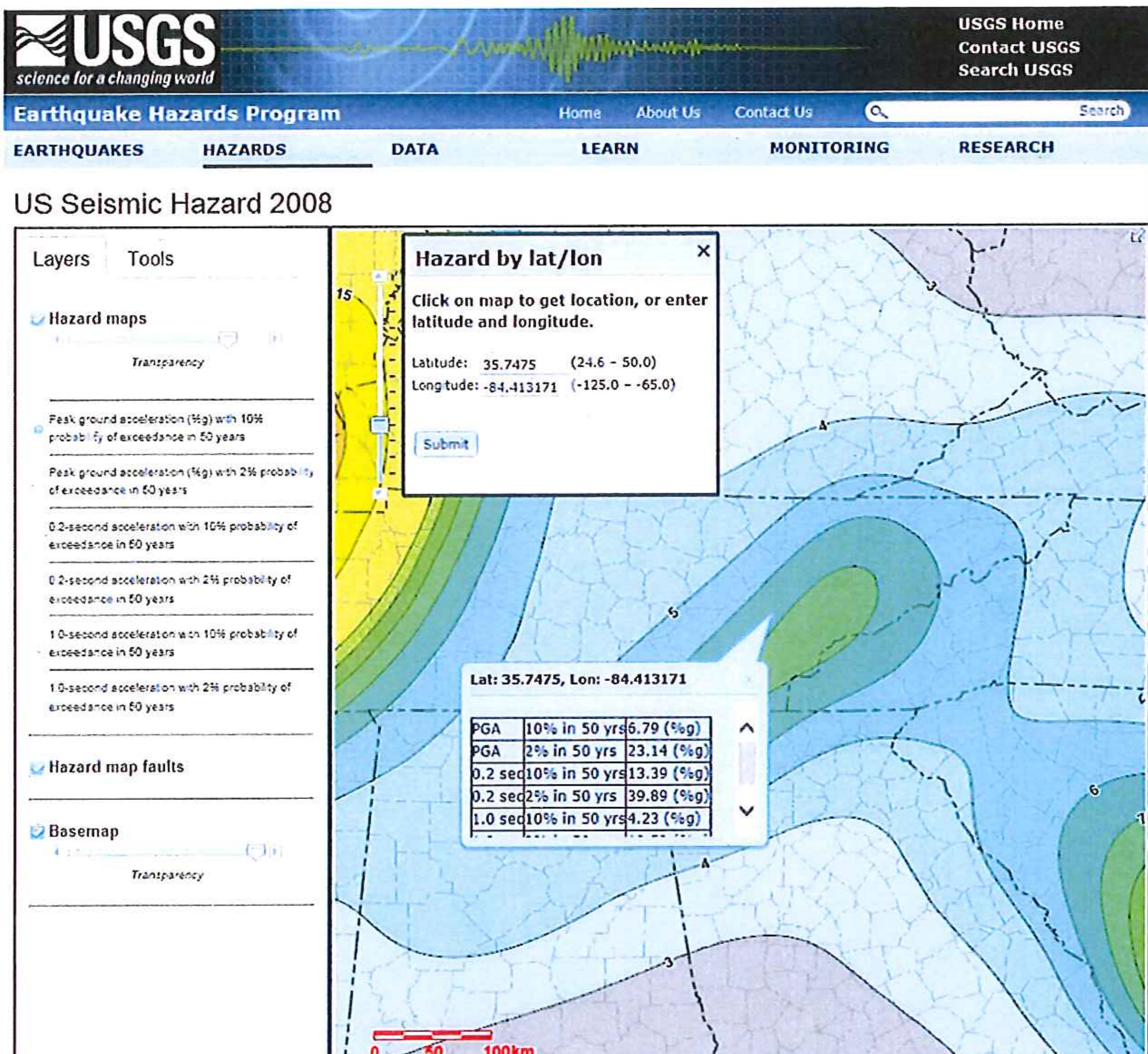
Table 2 has summarizes the results of the specific methods used to evaluate the slope stability of the landfill and the corresponding factors of safety for global and block/wedge failures . The estimated failure planes and output files are graphically depicted and provided in Appendix B.

A review of Table 2 reveals that all of the pseudo static methods used to evaluate the slope stability of the proposed MBL expansion produced factors of safety (FS) against slope failure which exceeded the industry accepted minimum threshold FS value of 1.5.

4.0 DETERMINATION OF SITE SPECIFIC SEISMIC COEFFICIENT

The subtitle D regulations require landfill designs to be evaluated under seismic loading conditions resulting from the seismic event with a 2% probability of exceedence in 50 years. The United States Geological Survey (USGS) has developed an interactive hazard map to determine the peak horizontal ground acceleration which can be used to predict seismic induced ground deformations and movements. **Figure 4** provides the results of the predicted peak ground accelerations resulting for different probabilities from the USGS interactive map.

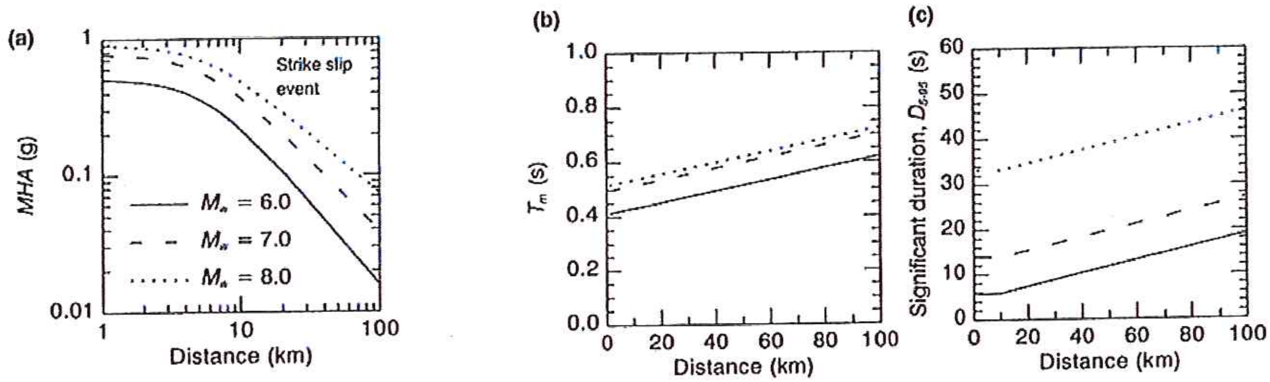
Figure 4 - USGS Seismic Map



However, the use of one ground motion parameter as a design basis is considered somewhat simplistic and overly conservative since the frequency and duration of ground motion are equally important parameters. Bray, Rathje, Augello and Merry (1998) have developed a simplified seismic analysis procedure for geosynthetic-lined, solid waste landfills titled "Simplified Seismic Design Procedure for Geosynthetic Lined, Solid-Waste Landfills".

The procedure used to calculate the seismic coefficients, k, using the aforementioned procedure is detailed in the following paragraphs.

The median Maximum Horizontal Ground Acceleration (*MHA),* Mean Period of Acceleration Time History *(T_m),* and Significant Duration of Acceleration-Time History($D_{5\text{-}95}$) values of the rock ground motion were determined from entering Figures a, b, and c which are provided below:



Summary of Dynamic Parameters from Figures a, b, and c

M_w	6.0	7.0
Distance	16	100
MHA_{Rock}	0.1g	0.21g
T_m	0.45s	0.72s
$D_{5\text{-}95}$	7s	27

The PGA values from the USGS interactive map fall within close proximity to the range of values determined from the "Simplified Procedure". Therefore, the seismic coefficients will be selected using the figures presented in the "Simplified Procedure" since they are sensitive to earthquake magnitudes, time, and duration of motion.

Based upon the calculations outlined in the "Simplified Procedure" the range of seismic coefficients for the liner base are as follows:

$$MHEA_{BASE} = (0.21)(1.19)(0.72 \text{ to } 0.54) = (0.18g \text{ to } 0.13g)$$

5.0 SEISMIC STABILITY ANALYSIS

5.1 Pseudo-Static Analysis with Seismic Loading

Stabl5M was used to perform a number of pseudo static slope stability methods with the site specific seismic coefficient on the most critical section (section C) of the proposed landfill.

A review of Table 2 reveals that several of the pseudo static methods produced an unacceptable factor of safety against slope failure. Therefore, several procedures were performed to estimate the magnitude of seismic induced ground deformations. HE has performed the Newmark Deformation Analysis Procedure "Newmark Procedure" outlined in the TDSWM Earthquake Evaluation Guidance Document (EEGD), the Franklin & Hynes deformation analysis, and the Simplified Method developed by Bray, Rathje, Augello and Merry (1998). The procedures used to estimate seismic induced permanent displacements are summarized in the following paragraphs.

5.2 Seismic Deformation Estimation Procedures

Newmark Procedure

The following steps were performed as per the TDSWM EEGD to estimate permanent displacements.

Step 1. The first step of the analysis was to prepare the model of Section C as previously discussed.

Step 2. Perform pseudo-static slope stability analyses of Section C using different methods to determine the lowest factor of safety.

Step 3. Calculate the seismic coefficients resulting from the seismic event defined statistically as the event with a two percent chance of probability of occurrence in 50 years.

Step 4. Perform the pseudo-static analysis on the landfill model with the peak horizontal coefficient of acceleration to determine the factor of safety. The pseudo static analysis resulted in a factor of safety of less than one. Therefore, the Newmark deformation analysis was required to determine the actual impact of the seismic event on the waste fill and liner/leachate collection system.

Step 5. The Newmark deformation analysis was performed as per the TDSWM Earthquake Evaluation Guidance Policy (EEGP). The Newmark deformation procedure was performed as per the following basic steps:

4a. Determine Yield Acceleration. Yield acceleration is determined from substituting different values for the horizontal acceleration into the pseudo static model until a factor of safety of one is obtained.

4b. Calculate the maximum crest acceleration induced in the embankment and the natural period of the embankment using the Makdisi and Seed approach.

4c. Upon determining the maximum value of the crest acceleration proceed with the Newmark procedure so as to calculate the total deformation predicted for the waste fill and liner/leachate collection system.

4c. Compare the permanent seismic deformation determined with the Newmark procedure to the allowable maximum permanent displacement, u_{max} of one half the soil liner thickness as recommended in the TDSWM EEGD.

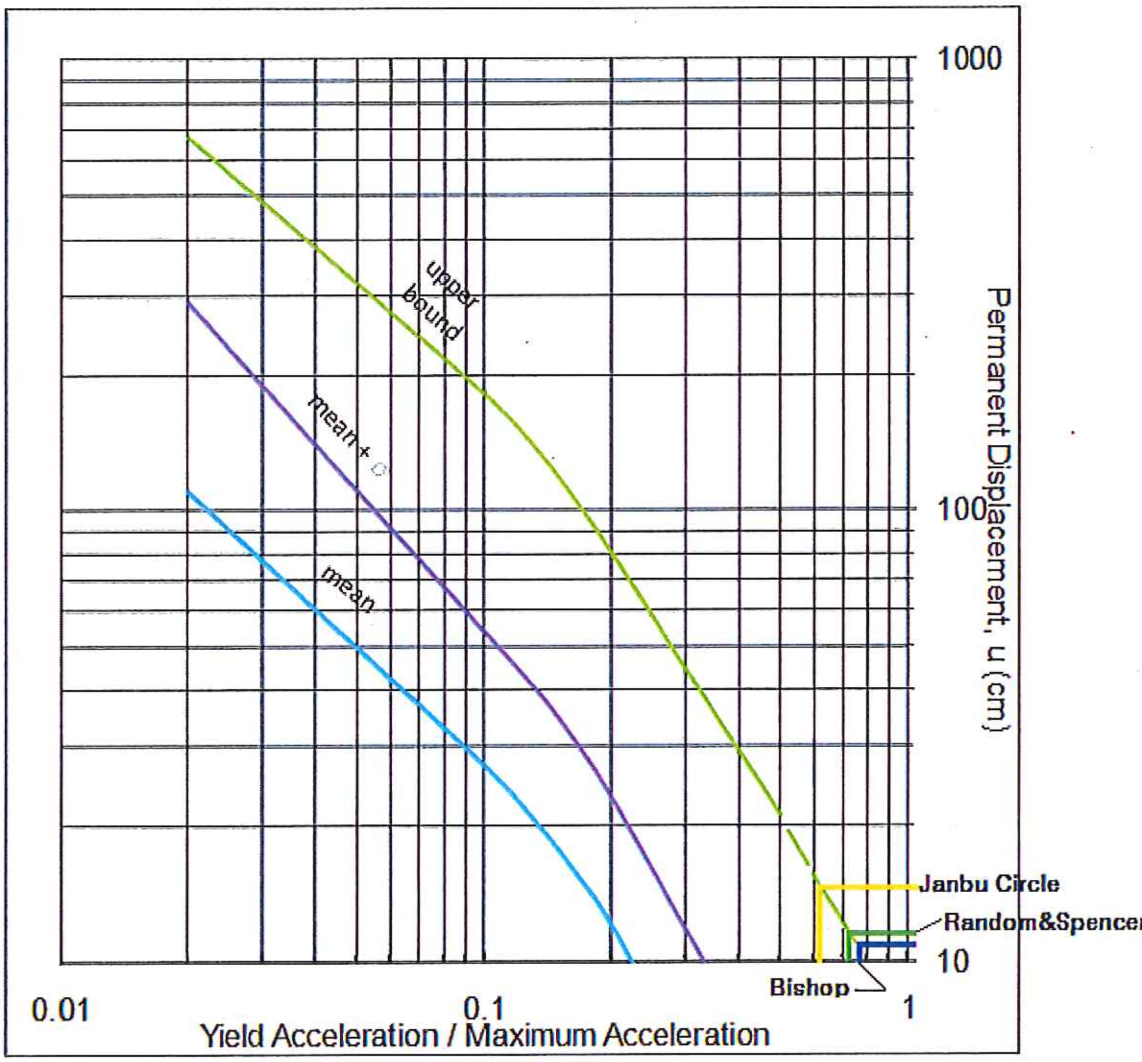
Step 4 of the Newmark Procedure requires that the seismic coefficient is entered into the pseudo-static model to determine if the FS is equal to or greater than 1.0. HE entered the seismic coefficient into the different pseudo-static slope stability methods provided in STABL5M to determine the factor of safety. With the exception of the block/wedge analysis and Spencer's Method, the slope stability methods performed with the seismic loading were less than one. In cases where the seismic loading results in a factor of safety of less than one the TDSWM EEGD requires the applicant to then determine the yield acceleration. The yield acceleration (k_y) is the seismic coefficient that when entered into a pseudo-static model results in a FS of 1.0. HE has calculated the yield accelerations and reported them in Table 2.

HE has taken the yield acceleration from each method and performed the Newmark Deformation Analysis procedure as per the TDSWM EEGD. The results of the Newmark Procedure indicated that the maximum deformation approximates 0.9 inches using the k_y and failure plane depth determined from the Bishop Circular Method. The pseudo static analysis with seismic loading and the Newmark Procedure worksheets are presented in Appendix B of this document.

Franklin & Hynes Method

An additional procedure for estimation of deformation was also executed. Franklin and Hynes (1984) have stated that slopes and embankments with a yield acceleration greater than or equal to half the peak ground acceleration would experience permanent seismic deformations of less than one foot in any earthquake. **Figure 5** is a graphical chart prepared by Franklin and Hynes for estimation of deformation due to seismic forces. The deformation determined from the Franklin and Hynes chart was estimated to approach 5.1 inches. All deformation estimates are presented in Table 2.

Figure 5 - Franklin & Hynes Displacement Chart



PERMANENT DISPLACEMENT CHART (FRANKLIN and HYNES, 1984)
Displacement from Janbu Circle Slope Stability Analysis = 16 cm = 6.3 inches
Displacement from Spencer's and Modified Janbu Random Method of Slope Stability = 12 cm = 4.7 inches
Displacement from Modified Bishop Circle Slope Stability Analysis = 11.0 cm = 4.3 inches

Simplified Procedure by Bray, Rathje, Augello and Merry (1998)

The Simplified Procedure has provided yet another method to estimate deformations induced by predicted seismic events. The Simplified Procedure is detailed in the following paragraphs based upon site specific conditions:

Step 1 - Use the median Maximum Horizontal Ground Acceleration *(MHA)*, Mean Period of Acceleration Time History *(T_m)*, and Significant Duration of Acceleration-Time History *($D_{5\text{-}95}$)* values of the rock ground motion determined in Section 5.0 of this document as provided below to determine the dynamic properties:

M_w	*6.0*	*7.0*
Distance	16	100
MHA_{Rock}	0.1g	0.21g
T_m	0.45s	0.72s
$D_{5\text{-}95}$	7s	27

Bray et al. (1995) found that the MHEA for important base sliding case depends primarily on the dynamic properties and height of the waste fill (i.e. its fundamental period, T_s, as described by $T_s = 4H/V_s$, where H= height of waste fill, and V_s = average initial shear wave velocity of the waste fill) and the MHA and T_p of the input earthquake rock motion. Based on an examination of Figure 6 the average velocity (V_S) profile of waste would approximate 180 m/s at the waste surface, approximately 250 m/s at a depth of 30 m, and approximately 325 m/s at a depth of 60 m. Therefore, a reasonable weighted average for V_S would approximate 250 m/s.

Calculate the fundamental period T_s
$T_s = 4H/V_s$
$T_s = 4 \times 60 / 250 = 0.96s$,
Where H = 60 meters and V_s = 250 m/s

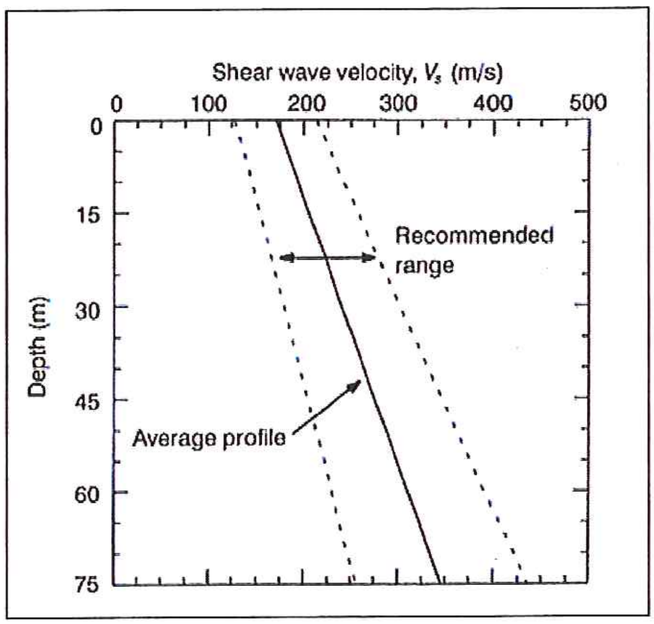


Figure 6 - Shear Wave Profiles for MSW (Kavazanjian et al. 1996)

Summary of Parameters

Fill Thickness (H)	Initial Shear Wave Velocity V_s = 250 m/s	Fundamental Period T_s
60 m (~200 ft.)	250 m/s (820 ft./sec)	0.96s

Step 2: Calculate $MHEA_{BASE}/[(MHA_{ROCK})(NRF)]$

Using the parameters determined in the previous paragraph enter **Figure 7** to determine normalized maximum horizontal equivalent acceleration "$MHEA_{BASE}/[(MHA_{ROCK})(NRF)]$".

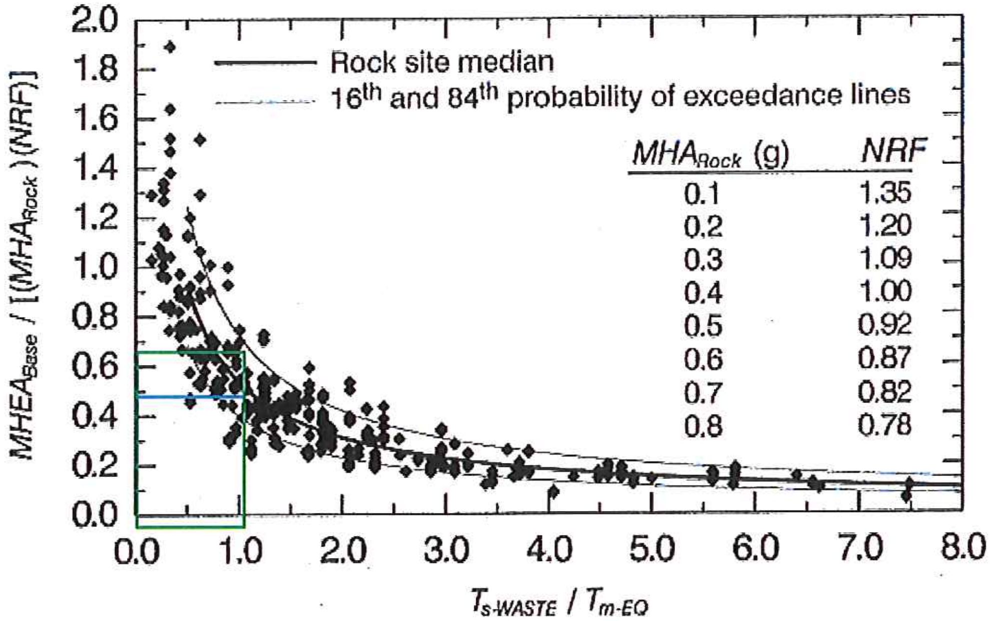


Figure 7 - Normalized Maximum Horizontal Equivalent Acceleration (from Bray and Rathje 1998)

Note: Figure 6 represents the normalized horizontal equivalent acceleration for base sliding versus normalized fundamental period of waste fill

Calculate $T_s / T_m = 0.96 / 0.92 = 1.04$

Enter **Figure** 7 with T_s / T_m at the 16% and 50% probability of exceedence to determine the value of $MHEA_{BASE}/[(MHA_{ROCK})(NRF)]$

Therefore from **Figure** 7 $MHEA_{BASE}/[(MHA_{ROCK})(NRF)] = 0.7$ at the 16^{th} and 0.51 at the 50^{th}

Determine NRF from the value previously determined for MHA_{ROCK} by entering **Figure** 7. Therefore from **Figure** 7 the value for NRF = 1.19

Therefore:

$MHEA_{BASE} = [(MHA_{ROCK})(NRF)] = (0.21g)(1.19)(0.51 \text{ to } 0.7) = 0.127g \text{ to } 0.175$

Step 3 = Estimate the Seismically Induced Permanent Displacements:

$k_{max} = MHEA/g = 0.13g$ to .18g, and; k_y from each of the methods can be used to calculate k_y / k_{max}:

$k_y = 0.14g$ for Bishop Circle Method, so $k_y / k_{max} = 0.78$

$k_y = 0.13g$ for Random Method, so $k_y / k_{max} = 0.72$

$k_y = 0.11g$ for Janbu Circle Method, so $k_y / k_{max} = 0.61$

$k_y = 0.13g$ for Spencer's Method, so $k_y / k_{max} = 0.72$

Using the values of k_{max} and k_y for each of the methods resulting in a FS of less than one with the seismic loading HE estimated the seismically induced permanent displacements (U) for localized sliding along the base of the landfill for the design earthquake based using Figure 8:

Using the values of k_y / k_{max} enter **Figure 8** to estimate the permanent displacements (U).

Thus, from **Figure 8**;

For Bishop Circle Method, enter $k_y / k_{max} = 0.78$ in **Figure 8** yields a $U / (k_{max})(D_{5\text{-}95}) = 3.50$ mm/s

So U = (3.5 mm/sec)(0.18)(27sec) = 17 mm = 0.67 inches for the 16% probability for a $M_w = 7$.

For the Random Method, enter $k_y / k_{max} = 0.72$ in **Figure 8** yields a $U / (k_{max})(D_{5\text{-}95}) = 5.0$ mm/s

So U = (5.0 mm/sec)(0.18)(27) = 24.3 mm = 0.95 inches for the 16% probability for a $M_w = 7$

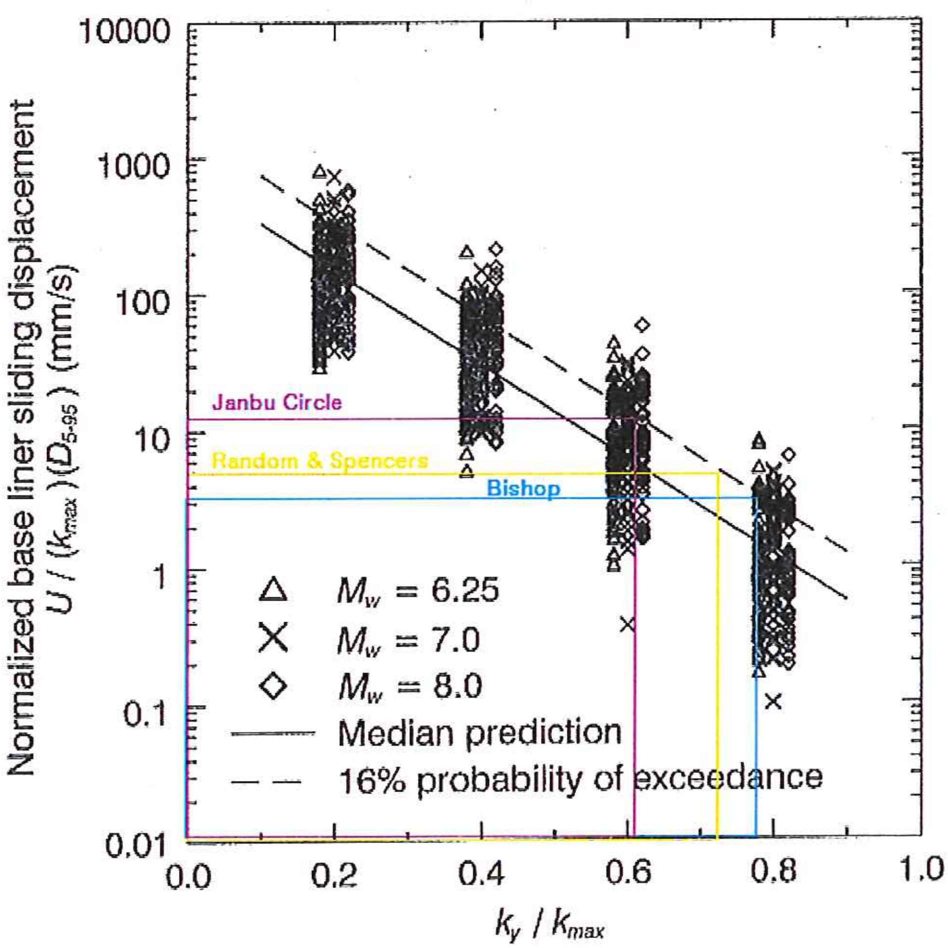
For the Janbu Circle Method, enter $k_y / k_{max} = 0.67$ in Figure 8 yields a $U / (k_{max})(D_{5\text{-}95}) = 8.5$ mm/s

So U = (13 mm/sec)(0.18)(27) = 63.2 mm = 2.5 inches for the 16% probability for a $M_w = 7$

For the Spencer Method, enter $k_y / k_{max} = 0.72$ in **Figure 8** yields a $U / (k_{max})(D_{5\text{-}95}) = 5.0$ mm/s

So U = (5.0 mm/sec)(0.18)(27) = 24.3 mm = 0.95 inches for the 16% probability for a $M_w = 7$

Figure 8- Normalized Base Liner Sliding Displacements



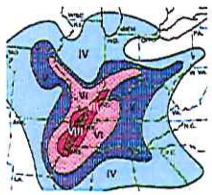


Table 2 - Summary of Global Slope Stability Analyses

SLOPE STABILITY ANALYSIS METHODOLOGY	Horizontal Acceleration at Landfill Base (from Bray) K_{MAX} % gravity	Pseudo Static Factor Of Safety	Seismic Loading Factor of Safety	Yield Acceleration K_{YIELD}[1] % gravity	Ratio of K_{YIELD}/K_{MAX}[2]	Displacement Based on Franklin & Hynes Chart (Inches)	Displacement Based on Makdisi & Seed Analysis (Inches)	Maximum Displacements Based on Simplified Procedure (Inches)
MODIFIED JANBU RANDOM	0.18	1.73	0.88	0.13	0.72	4.7	0.05	0.95
MODIFIED BISHOP CIRCLE	0.18	1.69	0.90	0.14	0.78	4.3	0.38	0.67
JANBU CIRCLE	0.18	1.54	0.81	0.11	0.61	6.3	4.89	2.5
SPENCER'S GLOBAL	0.18	1.71	0.86	0.13	0.72	4.7	0.52	0.95
BLOCK	0.18	2.06	1.15	NA	NA	NA	NA	NA
SPENCER'S BLOCK METHOD	0.18	2.55	1.27	NA	NA	NA	NA	NA

[1] K_{YIELD} - Yield acceleration determined from Stabl5M

[2] K_{MAX} – Maximum acceleration determined from the Bray "Simplified Procedure"

6.0 SUMMARY AND CONCLUSIONS

- Cross-Section C was used to depict the most critical waste slope relative to slope stability Factors of Safety (FS).
- The final cover slopes for the facility were generally found to approximate 3H:1V.
- HE used the results of recent laboratory shear strength testing of the geosynthetic interfaces of an almost identical bottom liner section to perform the stability analysis. However, it is imperative that interface friction testing be performed prior to construction of the bottom liner.
- Peak shear strength values were used for the wedge/block analysis between the interfaces along the shallow bottom liner grades and residual shear stress values were used on the interior side slopes.
- The existing waste which was impacted by the 2009 landslide was assigned residual strength parameters determined from the forensic investigation (back-calculations) performed by Geosyntec.
- The minimum target FS for static global slope stability of the proposed MBL expansion was 1.5.
- The minimum target FS for dynamic global slope stability of the proposed MBL expansion was 1.0.
- The factors of safety generated exceeded industry accepted values even though soil strength parameters used in the model were much lower than the estimated shear strength.
- STABL5M slope stability software developed by Purdue University and the interface program referred to as STEDWin developed by Harold Van Aller were used to calculate the FS using several methods.
- The Janbu Circle Method estimated the global slope stability factor of safety at 1.54 which was the lowest pseudo-static calculated FS determined from all the methods utilized to estimate global slope stability of the landfill.
- The only pseudo static slope stability methods employed to determine the factor of safety of the waste mass that indicated a stable slope under the site specific seismic peak ground acceleration (A factor of safety of 1.0 denotes imminent failure) was the wedge/block analysis using the Random Method and Spencer's Method. The random method for determining the critical failure surface under seismic loading conditions resulted in a safety of 1.15 while Spencer's Method calculated the seismic factor of safety at 1.27.
- Three separate seismic deformation analyses were conducted along Cross-Section C to estimate permanent deformation. The Newmark Method developed by Makdisi and Seed, the Simplified Method developed by Bray, Rathje, Augello and Merry (1998), and the method presented by Franklin and Hynes were both executed to estimate deformation resulting from the regulatory seismic event.

- The Makdisi and Seed Method was performed as per the TDSWM Earthquake Evaluation Guidance Policy and resulted in predicted deformation of approximately one inch.
- The Franklin and Hynes Method predicted approximately 6.3 inches of deformation using the Janbu Circle Method.
- The maximum estimated deformation attributed to the required design event based on execution of the TDSWM recommended procedure was 4.9 inches. Again, a permanent deformation of 6.3 inches was estimated using the curves illustrated in **Figure 5** developed by Franklin and Hynes. Finally, the "Simplified Method" was used to estimate deformation of the bottom liner. Execution of the "Simplified Method" resulted in a maximum deformation of 2.5 inches. Again, **Table 2** provides a summary of the calculated deformation. Also, **Appendix B**, "Displacement Calculations", provides the Newmark Method worksheets used for calculating deformation.

In conclusion, it appears that the FS determined from the global slope stability analysis of the most critical section through the proposed MBL expansion exceeds the minimum target FS of 1.5.

In addition, calculations performed to estimate the amount of deformation predicted from seismic loading were less than the TDSWM limiting criteria of one-half the thickness of the clay liner component (1 foot maximum deformation) of the liner system. Specifically, the maximum predicted deformation using several different methods approximated 6.3 inches using the Franklin & Hynes analysis which is well below the one foot maximum deformation threshold.

Based on the aforementioned analyses, it is the opinion of HE that the waste facility meets or exceeds the minimum requirements for adequate global slope stability of the proposed expansion to the Matlock Bend Landfill.

APPENDIX A

MAPS/DESIGN INFO

Written by:	Joseph Sura	Date:	5 April 2012	Reviewed by:	Ming Zhu/Robert Bachus	Date:	5 April 2012
Client:	LCSWDC	Project:	Matlock Bend Landfill Slope Stability	Project/ Proposal No.:	GG4773	Task No.:	02

Table 1. Summary of Material Properties Used in Analyses[1].

Material	Unit Weight (pcf)	Friction Angle (°)	Cohesion (psf)
Existing and New Waste	90	33	500
Slide-Affected Waste (conservative condition)	90	16	275
Fill Buttress	120	35	50
Liner Block Slip	90	20	0
Liner Block Slip	90	calculated[2]	0
Subgrade Soils[3]	120	35	50

Notes:

1. Properties based on Geosyntec's estimate of potential waste strength under sp. ific actual and assumed calculation conditions.
2. Values of interface shear strength are calculated to obtain a minimum calculated FS of 1.30 (Sequence 3) and FS of 1.50 (Sequence 4).
3. The slip surfaces (circular and liner block slip) occur in the liner or waste materials, therefore the subgrade soils are not expected to impact the calculated FS values.

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

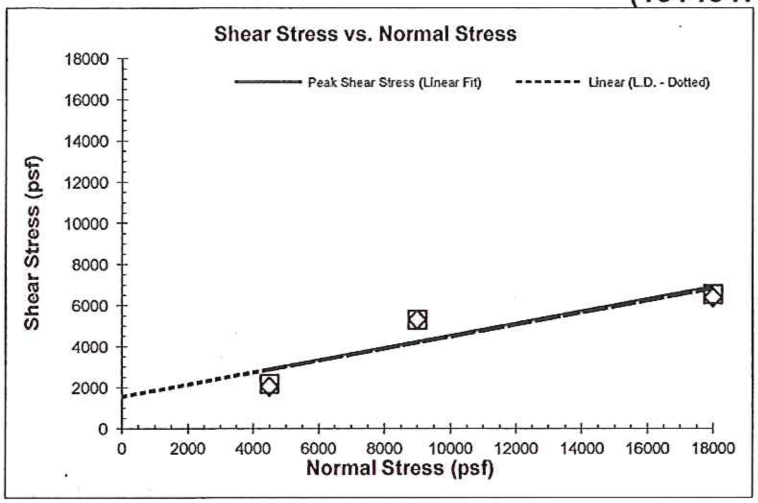
Interface Friction Test Report

Client: **House Engineering**
Project:
Test Date: 10/24/13-10/28/13

TRI Log#: E2373-94-07
Test Method: ASTM D5321

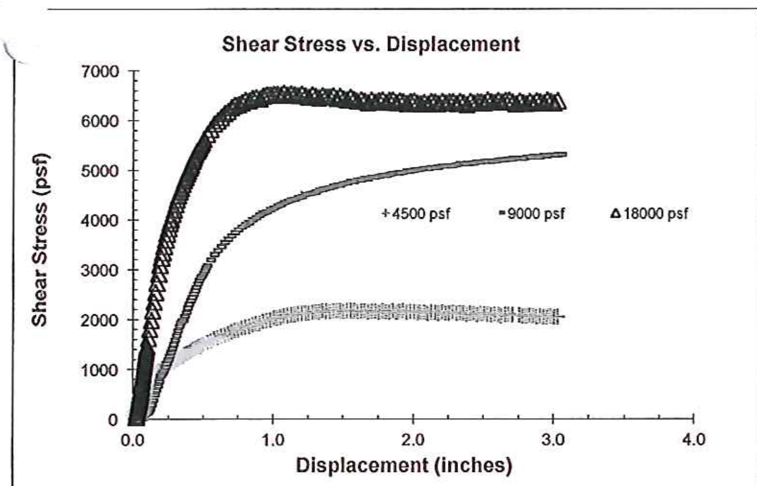
John M. Allen, P.E., 10/28/2013
Quality Review/Date

Tested Interface: Lean Brown Clay (LC-1) vs. GSE FS1-200E-08 Single-sided Geocomposite (131434748)



Test Results	Peak	Large Displacement (@ 3.0 in.)
Friction Angle (degrees):	16.5	16.3
Y-intercept or Adhesion (psf):	1571	1514

Shearing occurred at the interface.



Test Conditions

Upper Box &	Lean Brown Clay (LC-1) remolded to 103 pcf at 20.0% moisture content
Lower Box	GSE single-sided geocomposite (geonet side down)
Box Dimensions: 12"x12"x4"	
Interface Conditioning:	Interface loaded and held for a minimum of 24 hours prior to shear.
Test Condition: Wet	
Shearing Rate: 0.04 inches/minute	

Test Data

Specimen No.	1	2	3
Bearing Slide Resistance (lbs)	51	94	179
Normal Stress (psf)	4500	9000	18000
Corrected Peak Shear Stress (psf)	2187	5309	6540
Corrected Large Displacement Shear Stress (psf)	2049	5309	6379
Peak Secant Angle (degrees)	25.9	30.5	20.0
Large Displacement Secant Angle (degrees)	24.5	30.5	19.5

9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

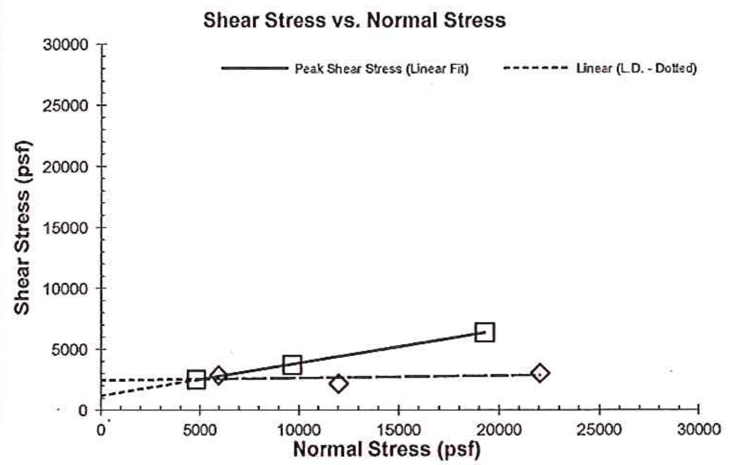
Interface Friction Test Report

Client: House Engineering
Project:
Test Date: 10/22/13-10/25/13

TRI Log#: E2373-94-07
Test Method: ASTM D6243

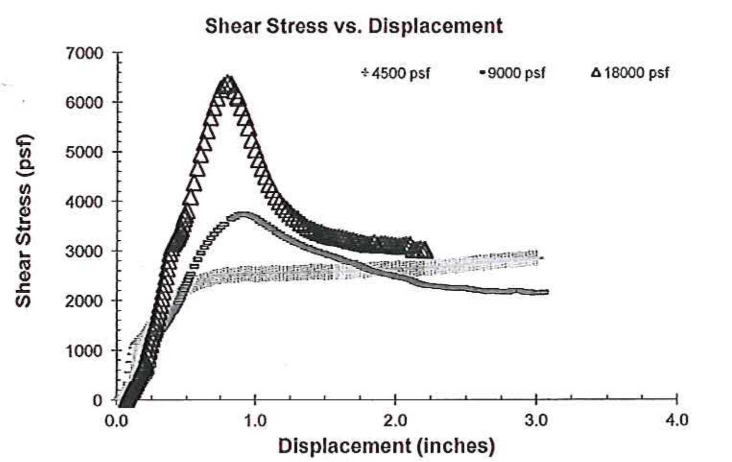
John M. Allen, P.E., 10/28/2013
Quality Review/Date

Tested Interface: BentoLiner NWL GCL vs. Lean Brown Clay (LC-1)



Test Results	Peak	Large Displacement (@ 3.0 in.)
Friction Angle (degrees):	15.0	1.0
Y-intercept or Adhesion (psf):	1174	2429

Note: Regression angles include an area correction. Shearing occurred at the interface.



Test Conditions

Upper Box &	BentoLiner NWL GCL (scrim side) hydrated under 150 psf for 24 hours prior to mounting in the shear box
Lower Box	Lean Brown Clay (LC-1) remolded to 103 pcf at 20.0%
Box Dimensions: 12"x12"x4"	
Interface Conditioning:	Interface loaded at 2.5 psi/hr to desired load and held for a minimum of 16 hours prior to shear.
Test Condition: Wet	
Shearing Rate: 0.04 inches/minute	

Test Data

Specimen No.	1	2	3
Bearing Slide Resistance (lbs)	51	94	179
Area Corrected Normal Stress (psf)	4811	9686	19286
Area Corrected Peak Shear Stress (psf)	2501	3721	6370
Area Corrected Large Displacement Normal Stress (psf)	6000	12034	22065
Area Corrected Large Displacement Shear Stress (psf)	2843	2157	3012
Peak Secant Angle (degrees)	27.5	21.0	18.3
Large Displacement Secant Angle (degrees)	25.4	10.2	7.8

TRI/ENVIRONMENTAL, INC.

A Texas Research International Company

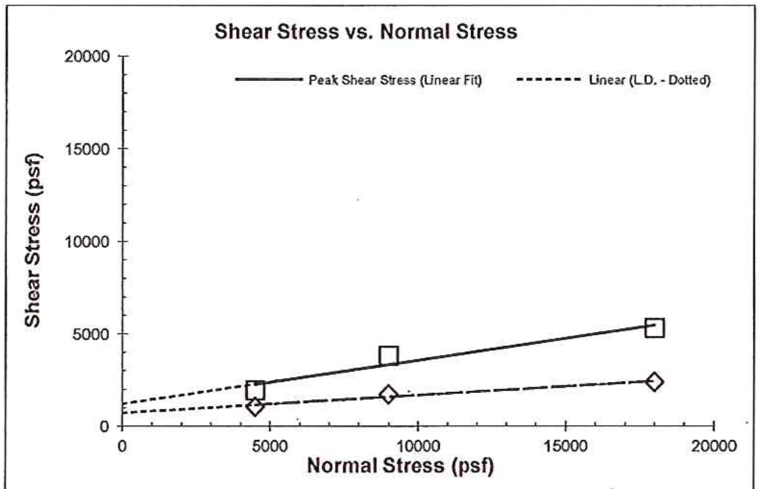
Interface Friction Test Report

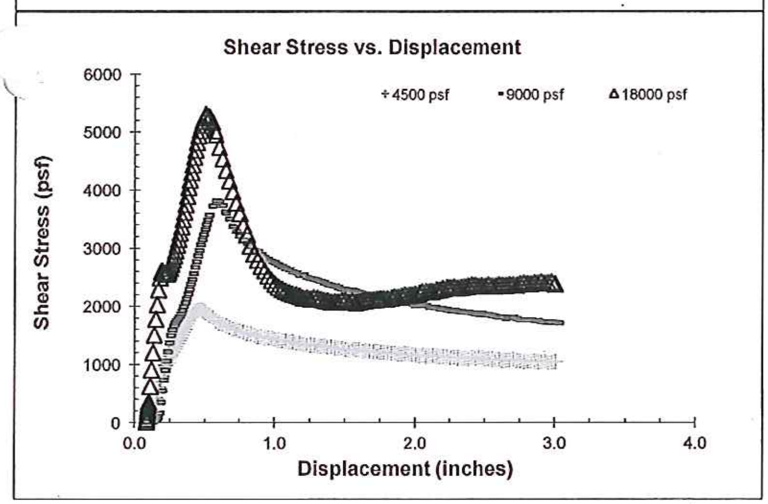
Client: **House Engineering**
Project:
Test Date: 10/15/13-10/18/13

TRI Log#: E2373-94-07
Test Method: ASTM D6243

John M. Allen, P.E., 10/18/2013
Quality Review/Date

Tested Interface: BentoLiner NWL GCL vs. GSE 60 mil HDPE Textured Geomembrane





Test Results		
	Peak	**Large Displacement (@ 3.0 in.)**
Friction Angle (degrees):	**13.3**	**5.5**
Y-intercept or Adhesion (psf):	**1197**	**703**

Shearing occurred at the interface under the 4500 and 9000 psf. The GCL sheared interally under the 18000 psf.

Test Conditions	
Upper Box &	BentoLiner NWL GCL hydrated under 150 psf for 24 hours prior to mounting in the shear box
Lower Box	GSE 60 mil HDPE textured geomembrane
Box Dimensions: 12"x12"x4"	
Interface Conditioning:	Interface loaded at 2.5 psi/hr to desired load and held for a minimum of 16 hours prior to shear.
Test Condition: Wet	
Shearing Rate: 0.04 inches/minute	

Test Data

Specimen No.	1	2	3
Bearing Slide Resistance (lbs)	51	94	179
Normal Stress (psf)	4500	9000	18000
Corrected Peak Shear Stress (psf)	1942	3810	5299
Corrected Large Displacement Shear Stress (psf)	1038	1712	2382
Peak Secant Angle (degrees)	23.3	22.9	16.4
Large Displacement Secant Angle (degrees)	13.0	10.8	7.5
Asperity (mils)	17.8	19.0	14.0

TABLE 2: SUMMARY OF LABORATORY TEST RESULTS FOR SANTEK ENVIRONMENTAL MATLOCK BEND LANDFILL EXPANSION

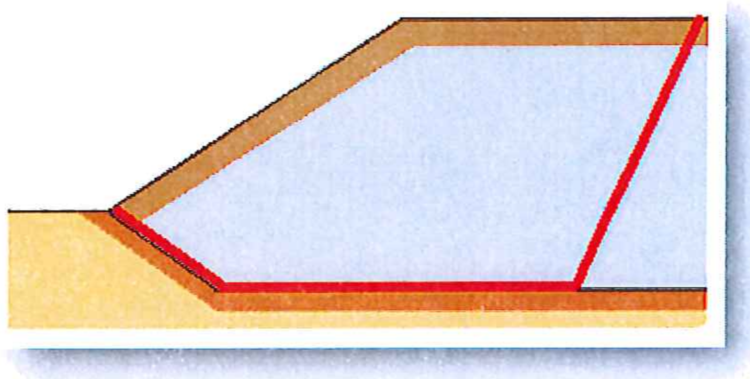
HYDROGEO INVESTIGATION	BORING NUMBER	boring elevation (ft msl)	SAMPLE DEPTH (FT)	SAMPLE TYPE	UNIFIED SOIL CLASS (USCS)	Pocket Penetrometer (tsf)	MAX DRY DENSITY (PCF)	OPTIMUM MOISTURE CONTENT ω %	IN-PLACE UNIT WEIGHT DRY (PCF)	IN-PLACE UNIT WEIGHT WET (PCF)	% FINER NO. 4 SIEVE	% FINER NO. 200 SIEVE	% FINER .002 MM	NATURAL MOISTURE CONTENT (%)	LIQUID LIMIT L.L.	PLASTIC LIMIT P.L.	PLASTICITY INDEX P.I.	REMOLDED HYDRAULIC CONDUCTIVITY ASTM D5084 (CM/SEC)	UNDISTURBED HYDRAULIC CONDUCTIVITY ASTM D5084 (CM/SEC)	COMMENTS
CEC STUDY 2008	B-58	876.6	3-5	ST	CL				102	102.6	80.2	57	33.4	24	43	22	21		3.5×10^{-7}	Test performed per ASTM D5084
	B-58	876.6	28-29.5	SS	CL	1.5					99.9	80.3	59.9	36	52	28	24			
	B-58	876.6	COMPOSITE	BAG	CL-CH		99.0	23.5							50	28	22	4.9×10^{-8}		remolded to 98% of standard proctor
	B-59	929.12	27-29	SS	CL	3.5					95.7	75.2	49.3	28	54	28	26			
	B-59	929.12	COMPOSITE	Bag	CL		107.5	16.8							41	21	20	2.5×10^{-6}		remolded to 95% of standard proctor
	B-61	960.99	32-34	ST	CL				88.9	85.3				30	57	31	26		1.4×10^{-7}	Test performed per ASTM D5084
	B-62	926.67	18-19.5	SS	CL	4.5					92.2	68.6	48.6	22	56	30	26			
	B-62	926.67	28-29.5	SS	CL						63.1	20.3	9.9	13	48	26	22			
	B-63	935.27	18-19.5	SS	CL	4					75.5	53.1	32.5	23	48	26	22			
	B-64	944.56	COMPOSITE	Bag	CL		106.2	17.8							42	22	20	2.3×10^{-6}		remolded to 95% of standard proctor
	B-64	944.56	34.5-36	ST	CL				100.7	101.2				26	55	29	26		3.4×10^{-8}	Test performed per ASTM D5084
	B-65	943.61	13-14.5	SS	OH	4.5								31	51	30	21			
	B-65	943.61	38-39.5	SS	CL	3.5								34	52	28	24			
	B-66	919.14	26-32	BAG	CL		109.0	17.4							40	21	19	8.6×10^{-8}		remolded to 98% of standard proctor
	B-67	912.31	17-19	ST	CH				87.2	85.5	97.3	69.3	56.5	32	63	33	30		1.3×10^{-5}	Test performed per ASTM D5084
	B-68	904.42	14-15.7	ST	OH				95.5	94.3				27	51	31	20		1.0×10^{-7}	Test performed per ASTM D5084
	B-68	904.42	29-30.5	SS	CL	1								30	42	20	22			
	B-68	924.98	COMPOSITE	BAG	CL-CH		101.1	21.8							50	26	24	6.2×10^{-8}		Test performed per ASTM D5084
Theta Engineering Inc. 1996 Study	SB-47	903.4	6-8	BAG	CL		114.8	14.1			82.5	40	NA	15.2	24.4	14.5	9.9	1.7×10^{-6}		remolded to 95% of standard proctor
	SB-47	903.4	10-12	ST	CL						90	65	NA	30.1	51.8	26.3	25.5		3.9×10^{-8}	Test performed per EPA Method 9100
	PZ-51	925.7	34-36	ST	CL						84	70			55.3	31.5	23.8		5.6×10^{-8}	Test performed per EPA Method 9100
	SB-52	928.8	20-22	BAG	CL		104.3	19.4			92.5	62	NA	28.4	43.4	23.3	20.1	2.3×10^{-7}		remolded to 95% of standard proctor @ opt. moisture
	SB-53	957.2	26-28	ST	ML						87	76	NA		40.4	26.8	13.6		1.3×10^{-6}	Test performed per EPA Method 9100
	SB-55	924.9	7-9	ST	CL														2.2×10^{-6}	Test performed per EPA Method 9100
CML Study (1993)	B-34	978.2	0.5-50	BAG	CL		98.7	22.5			90.4	65.2		32.1	45	24	21	2.05×10^{-7}		EPA 9100 remolded @ 95.4% std proctor density & 2% wet of opt. ω
	B-34	978.2	0.5-50	BAG	CL		98.7	22.5			90.4	65.2		32.1	45	24	21	4.99×10^{-8}		EPA 9100 remolded to 100% std proctor density @ opt.ω

NOTES: ST - SHELBY TUBE SS - SPLIT SPOON BAG- BULK SOIL SAMPLE N/A - NOT AVAILABLE SS - SPLIT SPOON SAMPLE NP - NOT PLASTIC

APPENDIX B

STABILITY CALCULATIONS

BLOCK / WEDGE SLOPE STABILITY ANALYSIS



** PCSTABL5M **
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 2/13/2014
Time of Run: 09:56AM
Run By: Jo K House
Input Data Filename: F:MATLOCK BEND LANDFILL blockwedge.dat
Output Filename: F:MATLOCK BEND LANDFILL blockwedge.OUT
Unit: ENGLISH
Plotted Output Filename: F:MATLOCK BEND LANDFILL blockwedge.PLT
PROBLEM DESCRIPTION MATLOCK BEND LANDFILL EXPANSION

Block Wedge

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)

1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

Searching Routine Will Be Limited To An Area Defined By 6 Boundaries
Of Which The First 6 Boundaries Will Deflect Surfaces Upward

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)
1	332.00	900.00	441.00	858.00
2	441.00	858.00	464.00	858.00
3	464.00	858.00	630.00	913.00
4	630.00	913.00	646.00	913.00
5	646.00	913.00	700.00	897.00
6	700.00	897.00	1094.00	914.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Sliding Block Surfaces, Has Been Specified.

10 Trial Surfaces Have Been Generated.

7 Boxes Specified For Generation Of Central Block Base

Length Of Line Segments For Active And Passive Portions Of Sliding Block Is 50.0

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height (ft)
1	332.00	900.00	332.00	900.00	0.00
2	441.00	860.90	441.00	860.90	4.00
3	464.00	860.90	464.00	860.90	4.00
4	630.00	915.90	630.00	915.90	4.00
5	646.00	915.90	646.00	915.90	4.00
6	700.00	900.90	700.00	900.90	4.00
7	1000.00	916.00	1000.00	916.00	4.00

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	332.00	900.00
2	441.00	859.83
3	464.00	861.40
4	630.00	915.33
5	646.00	914.99
6	700.00	902.76
7	1000.00	917.11
8	1021.77	962.13
9	1035.26	1010.27
10	1067.58	1048.43
11	1075.36	1097.82
12	1086.66	1120.00

***** MINIMUM BLOCK FACTOR OF SAFETY 2.055 *****

Individual data on the 27 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	52.6	66195.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	56.4	219376.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	15.7	84444.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.5	8064.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	5.8	32459.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	33.0	184896.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	10.0	54430.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	18.6	98436.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	15.5	81991.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	88.9	473019.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	16.0	88686.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

```
12     13.1  78052.4     0.0     0.0     0.0     0.0     0.0     0.0     0.0
13      0.9   5829.8     0.0     0.0     0.0     0.0     0.0     0.0     0.0
14      5.7  35874.3     0.0     0.0     0.0     0.0     0.0     0.0     0.0
15      4.3  26989.5     0.0     0.0     0.0     0.0     0.0     0.0     0.0
16     30.0 207183.6     0.0     0.0     0.0     0.0     0.0     0.0     0.0
17     15.0 114519.5     0.0     0.0     0.0     0.0     0.0     0.0     0.0
18    117.0 ********     0.0     0.0     0.0     0.0     0.0     0.0     0.0
19     10.0 100815.3     0.0     0.0     0.0     0.0     0.0     0.0     0.0
20    158.0 ********     0.0     0.0     0.0     0.0     0.0     0.0     0.0
21     17.5 213369.1     0.0     0.0     0.0     0.0     0.0     0.0     0.0
22      4.2  45200.2     0.0     0.0     0.0     0.0     0.0     0.0     0.0
23     13.5 120193.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
24     12.7  89239.8     0.0     0.0     0.0     0.0     0.0     0.0     0.0
25     19.6 113919.2     0.0     0.0     0.0     0.0     0.0     0.0     0.0
26      7.8  25546.2     0.0     0.0     0.0     0.0     0.0     0.0     0.0
27     11.3   8775.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
        Failure Surface Specified By 12 Coordinate Points
          Point       X-Surf       Y-Surf
           No.         (ft)         (ft)
            1        332.00       900.00
            2        441.00       859.23
            3        464.00       862.28
            4        630.00       914.07
            5        646.00       914.96
            6        700.00       902.34
            7       1000.00       917.68
            8       1025.65       960.60
            9       1029.01      1010.49
           10       1064.20      1046.01
           11       1088.27      1089.83
           12       1091.28      1120.00
              ***     2.188    ***
        Failure Surface Specified By 12 Coordinate Points
          Point       X-Surf       Y-Surf
           No.         (ft)         (ft)
            1        332.00       900.00
            2        441.00       862.04
            3        464.00       860.16
            4        630.00       917.33
            5        646.00       914.42
            6        700.00       901.31
            7       1000.00       915.97
            8       1009.71       965.02
            9       1044.74      1000.70
           10       1059.52      1048.46
           11       1069.84      1097.39
           12       1087.62      1120.00
              ***     2.212    ***
        Failure Surface Specified By 12 Coordinate Points
          Point       X-Surf       Y-Surf
           No.         (ft)         (ft)
            1        332.00       900.00
            2        441.00       862.35
            3        464.00       862.88
            4        630.00       916.71
            5        646.00       914.71
            6        700.00       900.75
            7       1000.00       914.82
            8       1017.41       961.69
            9       1025.18      1011.08
           10       1044.37      1057.25
           11       1060.99      1104.41
           12       1075.32      1120.00
              ***     2.249    ***
        Failure Surface Specified By 12 Coordinate Points
          Point       X-Surf       Y-Surf
```

```
  No.        (ft)        (ft)
   1        332.00      900.00
   2        441.00      862.61
   3        464.00      859.52
   4        630.00      916.54
   5        646.00      917.05
   6        700.00      901.41
   7       1000.00      914.11
   8       1029.66      954.36
   9       1035.74     1003.99
  10       1042.64     1053.51
  11       1071.84     1094.10
  12       1077.84     1120.00
      ***     2.296    ***
Failure Surface Specified By 12 Coordinate Points
 Point      X-Surf      Y-Surf
  No.        (ft)        (ft)
   1        332.00      900.00
   2        441.00      859.09
   3        464.00      859.90
   4        630.00      915.26
   5        646.00      914.04
   6        700.00      902.11
   7       1000.00      917.46
   8       1003.76      967.32
   9       1032.75     1008.06
  10       1034.78     1058.01
  11       1066.17     1096.93
  12       1087.89     1120.00
      ***     2.444    ***
Failure Surface Specified By 12 Coordinate Points
 Point      X-Surf      Y-Surf
  No.        (ft)        (ft)
   1        332.00      900.00
   2        441.00      861.98
   3        464.00      862.85
   4        630.00      916.95
   5        646.00      916.66
   6        700.00      899.35
   7       1000.00      914.50
   8       1007.50      963.94
   9       1016.19     1013.18
  10       1037.43     1058.44
  11       1071.79     1094.76
  12       1078.57     1120.00
      ***     2.490    ***
Failure Surface Specified By 12 Coordinate Points
 Point      X-Surf      Y-Surf
  No.        (ft)        (ft)
   1        332.00      900.00
   2        441.00      862.07
   3        464.00      861.83
   4        630.00      917.44
   5        646.00      914.29
   6        700.00      902.75
   7       1000.00      917.29
   8       1035.24      952.77
   9       1040.82     1002.46
  10       1043.50     1052.38
  11       1057.66     1100.34
  12       1077.31     1120.00
      ***     2.605    ***
Failure Surface Specified By 12 Coordinate Points
 Point      X-Surf      Y-Surf
  No.        (ft)        (ft)
   1        332.00      900.00
```

2	441.00	861.72
3	464.00	860.00
4	630.00	917.40
5	646.00	917.28
6	700.00	900.02
7	1000.00	914.10
8	1001.28	964.08
9	1033.90	1001.97
10	1036.12	1051.92
11	1058.76	1096.50
12	1082.26	1120.00
***	2.993	***

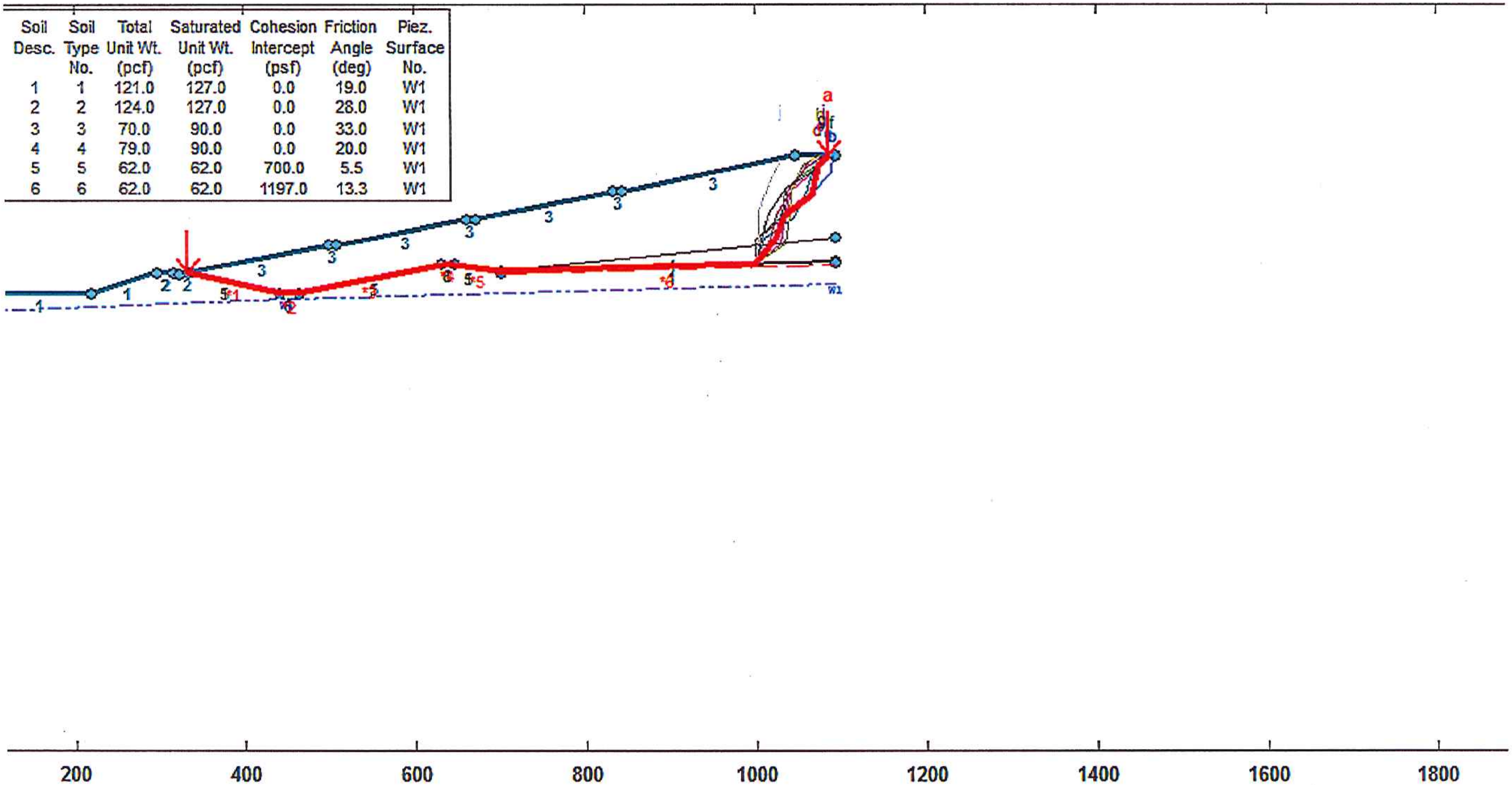
Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	332.00	900.00
2	441.00	862.52
3	464.00	861.02
4	630.00	917.56
5	646.00	917.03
6	700.00	901.29
7	1000.00	916.33
8	1001.62	966.30
9	1002.76	1016.29
10	1015.33	1064.68
11	1028.86	1112.82
12	1029.93	1113.95
***	3.888	***

MATLOCK BEND LANDFILL EXPANSION Block Wedge

ste\active projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\block-wedge analysis sect c\matlock bend landfill blockwedge.pl2 Run By: J

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
1	1	121.0	127.0	0.0	19.0	W1
2	2	124.0	127.0	0.0	28.0	W1
3	3	70.0	90.0	0.0	33.0	W1
4	4	79.0	90.0	0.0	20.0	W1
5	5	62.0	62.0	700.0	5.5	W1
6	6	62.0	62.0	1197.0	13.3	W1



PCSTABL5M/si FSmin=2.06

Safety Factors Are Calculated By The Modified Janbu Method

** PCSTABL5M **
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 2/13/2014
Time of Run: 01:29PM
Run By: Jo K House
Input Data Filename: F:MATLOCK BEND LANDFILL blockwedgewseismic.dat
Output Filename: F:MATLOCK BEND LANDFILL blockwedgewseismic.OUT
Unit: ENGLISH
Plotted Output Filename: F:MATLOCK BEND LANDFILL blockwedgewseismic.PLT
PROBLEM DESCRIPTION MATLOCK BEND LANDFILL EXPANSION
Block Wedge

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

Searching Routine Will Be Limited To An Area Defined By 6 Boundaries
Of Which The First 6 Boundaries Will Deflect Surfaces Upward

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)
1	332.00	900.00	441.00	858.00
2	441.00	858.00	464.00	858.00
3	464.00	858.00	630.00	913.00
4	630.00	913.00	646.00	913.00
5	646.00	913.00	700.00	897.00
6	700.00	897.00	1094.00	914.00

A Horizontal Earthquake Loading Coefficient
Of0.180 Has Been Assigned
A Vertical Earthquake Loading Coefficient
Of0.000 Has Been Assigned
Cavitation Pressure = 0.0 (psf)
A Critical Failure Surface Searching Method, Using A Random Technique For Generating Sliding Block Surfaces, Has Been Specified.
10 Trial Surfaces Have Been Generated.
7 Boxes Specified For Generation Of Central Block Base
Length Of Line Segments For Active And Passive Portions Of Sliding Block Is 50.0

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height (ft)
1	332.00	900.00	332.00	900.00	0.00
2	441.00	860.90	441.00	860.90	4.00
3	464.00	860.90	464.00	860.90	4.00
4	630.00	915.90	630.00	915.90	4.00
5	646.00	915.90	646.00	915.90	4.00
6	700.00	900.90	700.00	900.90	4.00
7	1000.00	916.00	1000.00	916.00	4.00

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.
* * Safety Factors Are Calculated By The Modified Janbu Method * *
Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	332.00	900.00
2	441.00	859.83
3	464.00	861.40
4	630.00	915.33
5	646.00	914.99
6	700.00	902.76
7	1000.00	917.11
8	1021.77	962.13
9	1035.26	1010.27
10	1067.58	1048.43
11	1075.36	1097.82
12	1086.66	1120.00

*** 1.149 ***

Individual data on the 27 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	52.6	66195.0	0.0	0.0	0.0	0.0	11915.1	0.0	0.0
2	56.4	219376.2	0.0	0.0	0.0	0.0	39487.7	0.0	0.0
3	15.7	84444.7	0.0	0.0	0.0	0.0	15200.0	0.0	0.0
4	1.5	8064.2	0.0	0.0	0.0	0.0	1451.6	0.0	0.0
5	5.8	32459.5	0.0	0.0	0.0	0.0	5842.7	0.0	0.0
6	33.0	184896.7	0.0	0.0	0.0	0.0	33281.4	0.0	0.0
7	10.0	54430.1	0.0	0.0	0.0	0.0	9797.4	0.0	0.0
8	18.6	98436.9	0.0	0.0	0.0	0.0	17718.6	0.0	0.0
9	15.5	81991.5	0.0	0.0	0.0	0.0	14758.5	0.0	0.0
10	88.9	473019.4	0.0	0.0	0.0	0.0	85143.5	0.0	0.0
11	16.0	88686.2	0.0	0.0	0.0	0.0	15963.5	0.0	0.0
12	13.1	78052.4	0.0	0.0	0.0	0.0	14049.4	0.0	0.0
13	0.9	5829.8	0.0	0.0	0.0	0.0	1049.4	0.0	0.0
14	5.7	35874.3	0.0	0.0	0.0	0.0	6457.4	0.0	0.0
15	4.3	26989.5	0.0	0.0	0.0	0.0	4858.1	0.0	0.0
16	30.0	207183.6	0.0	0.0	0.0	0.0	37293.1	0.0	0.0

17	15.0	114519.5	0.0	0.0	0.0	0.0	20613.5	0.0	0.0
18	117.0	********	0.0	0.0	0.0	0.0	*******	0.0	0.0
19	10.0	100815.3	0.0	0.0	0.0	0.0	18146.8	0.0	0.0
20	158.0	********	0.0	0.0	0.0	0.0	*******	0.0	0.0
21	17.5	213369.1	0.0	0.0	0.0	0.0	38406.4	0.0	0.0
22	4.2	45200.2	0.0	0.0	0.0	0.0	8136.0	0.0	0.0
23	13.5	120193.0	0.0	0.0	0.0	0.0	21634.7	0.0	0.0
24	12.7	89239.8	0.0	0.0	0.0	0.0	16063.2	0.0	0.0
25	19.6	113919.2	0.0	0.0	0.0	0.0	20505.5	0.0	0.0
26	7.8	25546.2	0.0	0.0	0.0	0.0	4598.3	0.0	0.0
27	11.3	8775.0	0.0	0.0	0.0	0.0	1579.5	0.0	0.0

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	332.00	900.00
2	441.00	859.23
3	464.00	862.28
4	630.00	914.07
5	646.00	914.96
6	700.00	902.34
7	1000.00	917.68
8	1025.65	960.60
9	1029.01	1010.49
10	1064.20	1046.01
11	1088.27	1089.83
12	1091.28	1120.00

*** 1.175 ***

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	332.00	900.00
2	441.00	862.04
3	464.00	860.16
4	630.00	917.33
5	646.00	914.42
6	700.00	901.31
7	1000.00	915.97
8	1009.71	965.02
9	1044.74	1000.70
10	1059.52	1048.46
11	1069.84	1097.39
12	1087.62	1120.00

*** 1.228 ***

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	332.00	900.00
2	441.00	859.09
3	464.00	859.90
4	630.00	915.26
5	646.00	914.04
6	700.00	902.11
7	1000.00	917.46
8	1003.76	967.32
9	1032.75	1008.06
10	1034.78	1058.01
11	1066.17	1096.93
12	1087.89	1120.00

*** 1.230 ***

Failure Surface Specified By 12 Coordinate Points

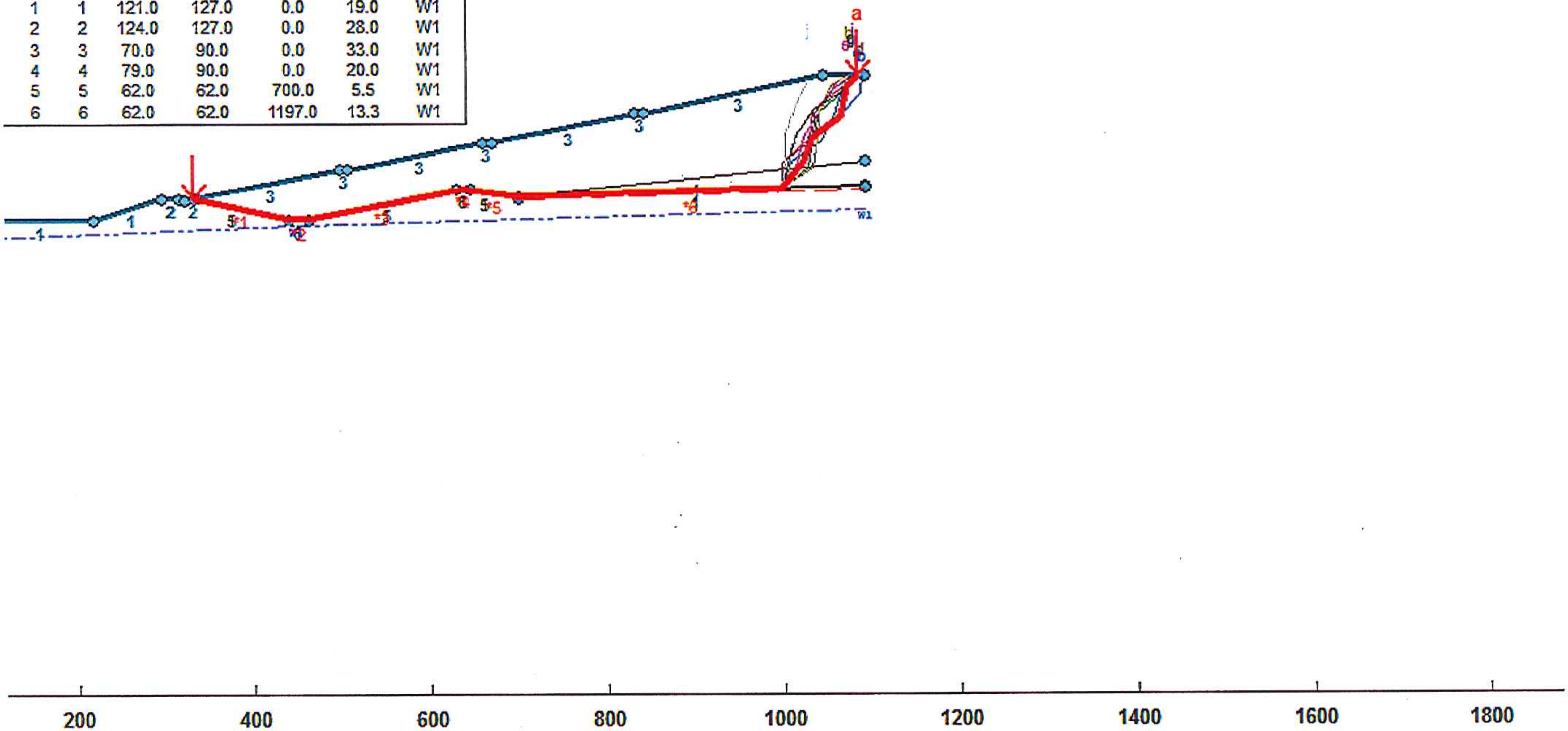
Point No.	X-Surf (ft)	Y-Surf (ft)
1	332.00	900.00
2	441.00	862.35
3	464.00	862.88
4	630.00	916.71
5	646.00	914.71
6	700.00	900.75
7	1000.00	914.82
8	1017.41	961.69

MATLOCK BEND LANDFILL EXPANSION Block Wedge

ictive projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\block-wedge analysis sect c\matlock bend landfill blockwedgewseismic.pl2 Run

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
1	1	121.0	127.0	0.0	19.0	W1
2	2	124.0	127.0	0.0	28.0	W1
3	3	70.0	90.0	0.0	33.0	W1
4	4	79.0	90.0	0.0	20.0	W1
5	5	62.0	62.0	700.0	5.5	W1
6	6	62.0	62.0	1197.0	13.3	W1

Load	Value
Horiz Eqk	0.180 g<



PCSTABL5M/si FSmin=1.15
Safety Factors Are Calculated By The Modified Janbu Method

** PCSTABL5M **
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 2/13/2014
Time of Run: 01:34PM
Run By: Jo K House
Input Data Filename: F:Spencer Block.dat
Output Filename: F:Spencer Block.OUT
Unit: ENGLISH
Plotted Output Filename: F:Spencer Block.PLT
PROBLEM DESCRIPTION MATLOCK BEND LANDFILL EXPANSION
Spencer Block

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

Searching Routine Will Be Limited To An Area Defined By 6 Boundaries
Of Which The First 6 Boundaries Will Deflect Surfaces Upward

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)
1	332.00	900.00	441.00	858.00
2	441.00	858.00	464.00	858.00
3	464.00	858.00	630.00	913.00
4	630.00	913.00	646.00	913.00
5	646.00	913.00	700.00	897.00
6	700.00	897.00	1094.00	914.00

Trial Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	332.00	900.00
2	441.00	859.83
3	464.00	861.40
4	630.00	915.33
5	646.00	914.99
6	700.00	902.76
7	1000.00	917.11
8	1021.77	962.13
9	1035.26	1010.27
10	1067.58	1048.43
11	1075.36	1097.82
12	1086.66	1120.00

Spencer`s Theta (deg)	FOS (Moment) (Equil.)	FOS (Force) (Equil.)
5.00	2.651	2.220
7.50	2.643	2.306
19.45	2.371	2.773
14.77	2.535	2.576
12.50	2.584	2.488
13.87	2.557	2.541
14.23	2.548	2.555
14.13	2.551	2.551

Factor Of Safety For The Preceding Specified Surface = 2.551
Spencer`s Theta = 14.13
Factor Of Safety Is Calculated By Spencer`s Method of Slices

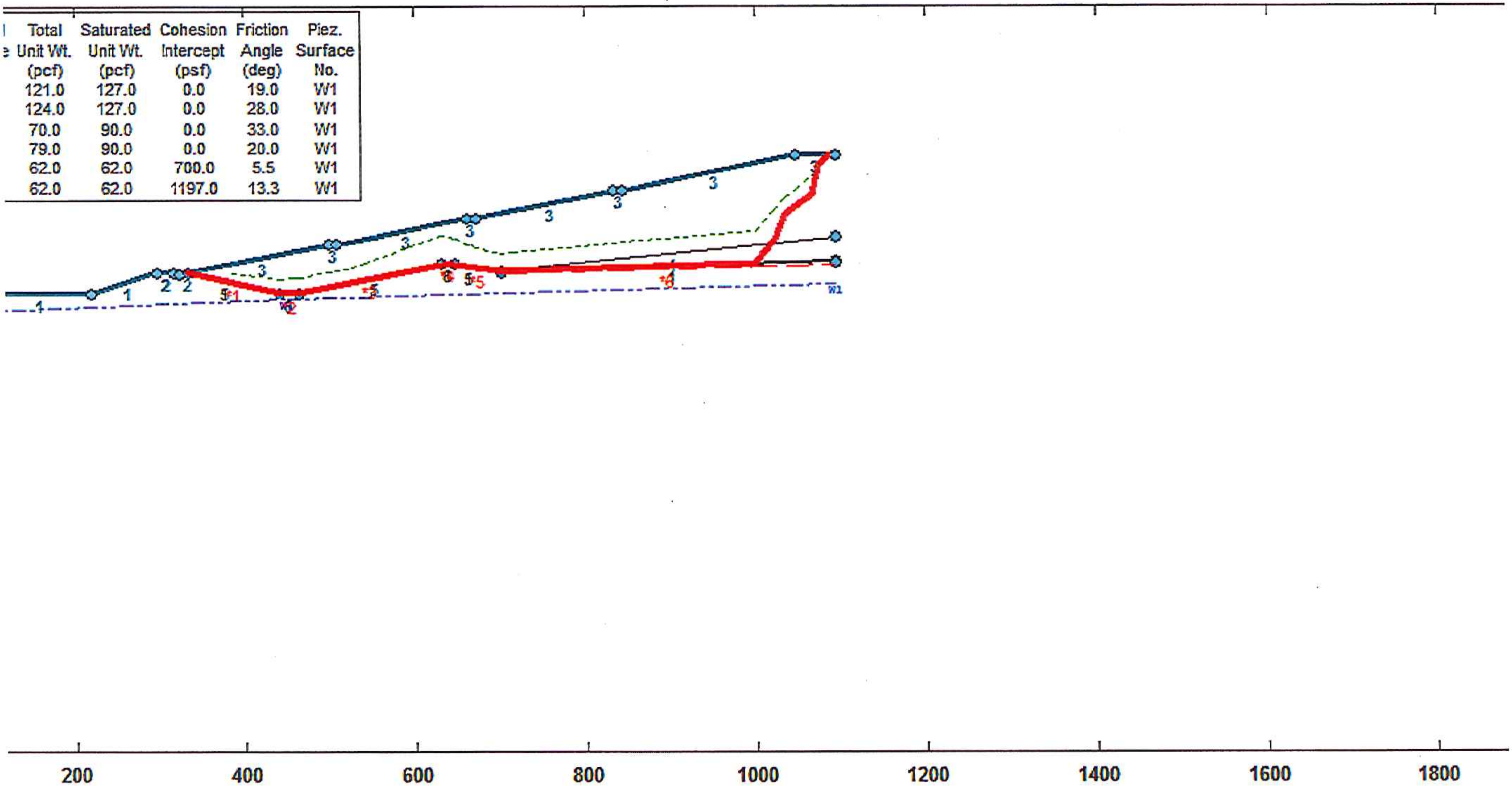
*** Line of Thrust ***

Slice No.	X Coord.	Y Coord.	L/H	Side Force (Lbs)
1	384.66	896.92	0.454	50543.
2	441.00	886.35	0.356	188831.
3	456.68	889.45	0.364	194676.
4	458.14	889.69	0.364	195591.
5	464.00	890.23	0.359	202046.
6	497.00	900.31	0.353	189868.
7	507.00	903.36	0.370	186283.
8	526.06	909.16	0.365	179636.
9	541.57	916.07	0.389	161679.
10	630.00	966.95	0.680	77319.
11	646.00	962.27	0.581	92235.
12	659.03	952.26	0.454	125277.
13	660.00	951.84	0.449	127357.
14	665.69	949.62	0.435	139689.
15	670.00	946.48	0.408	156126.
16	700.00	934.41	0.296	281271.
17	715.02	935.44	0.288	306709.
18	832.00	953.75	0.313	410869.
19	842.00	955.18	0.323	420902.
20	1000.00	976.16	0.316	604958.
21	1017.54	1008.55	0.353	366929.
22	1021.77	1015.33	0.357	328516.
23	1035.26	1041.47	0.296	184980.
24	1048.00	1053.59	0.299	130800.
25	1067.58	1078.55	0.421	57741.
26	1075.36	1108.37	0.476	9493.
27	1086.66	1554.65	0.000	-6.

MATLOCK BEND LANDFILL EXPANSION Spencer Block

vaste\active projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\block-wedge analysis sect c\spencer block\spencer block.plt Run By: Jo

Total	Saturated	Cohesion	Friction	Piez.
Unit Wt.	Unit Wt.	Intercept	Angle	Surface
(pcf)	(pcf)	(psf)	(deg)	No.
121.0	127.0	0.0	19.0	W1
124.0	127.0	0.0	28.0	W1
70.0	90.0	0.0	33.0	W1
79.0	90.0	0.0	20.0	W1
62.0	62.0	700.0	5.5	W1
62.0	62.0	1197.0	13.3	W1



PCSTABL5M/si FSmin=2.55
Factor Of Safety Is Calculated By Spencer`s Method of Slices

** PCSTABL5M **
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 2/13/2014
Time of Run: 01:36PM
Run By: Jo K House
Input Data Filename: F:Spencer Blockw seismic.dat
Output Filename: F:Spencer Blockw seismic.OUT
Unit: ENGLISH
Plotted Output Filename: F:Spencer Blockw seismic.PLT
PROBLEM DESCRIPTION MATLOCK BEND LANDFILL EXPANSION
Spencer Block

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

Searching Routine Will Be Limited To An Area Defined By 6 Boundaries
Of Which The First 6 Boundaries Will Deflect Surfaces Upward

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)
1	332.00	900.00	441.00	858.00
2	441.00	858.00	464.00	858.00
3	464.00	858.00	630.00	913.00
4	630.00	913.00	646.00	913.00
5	646.00	913.00	700.00	897.00
6	700.00	897.00	1094.00	914.00

A Horizontal Earthquake Loading Coefficient
Of0.180 Has Been Assigned
A Vertical Earthquake Loading Coefficient
Of0.000 Has Been Assigned
Cavitation Pressure = 0.0 (psf)
Trial Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	332.00	900.00
2	441.00	859.83
3	464.00	861.40
4	630.00	915.33
5	646.00	914.99
6	700.00	902.76
7	1000.00	917.11
8	1021.77	962.13
9	1035.26	1010.27
10	1067.58	1048.43
11	1075.36	1097.82
12	1086.66	1120.00

Spencer`s Theta (deg)	FOS (Moment) (Equil.)	FOS (Force) (Equil.)
5.00	1.293	1.194
7.50	1.287	1.217
15.75	1.239	1.297
10.80	1.274	1.248
11.24	1.272	1.252
13.08	1.261	1.270
12.34	1.266	1.263
12.54	1.265	1.265

Factor Of Safety For The Preceding Specified Surface = 1.265
Spencer`s Theta = 12.54
Factor Of Safety Is Calculated By Spencer`s Method of Slices

*** Line of Thrust ***

Slice No.	X Coord.	Y Coord.	L/H	Side Force (Lbs)
1	384.66	896.15	0.432	59808.
2	441.00	886.02	0.351	201929.
3	456.68	889.26	0.362	203763.
4	458.14	889.46	0.361	204677.
5	464.00	889.51	0.351	213916.
6	497.00	897.31	0.315	210311.
7	507.00	899.66	0.321	209249.
8	526.06	904.12	0.298	207281.
9	541.57	910.52	0.316	182524.
10	630.00	958.85	0.574	73679.
11	646.00	956.41	0.509	84882.
12	659.03	947.22	0.397	116685.
13	660.00	946.99	0.394	118160.
14	665.69	945.75	0.392	126880.
15	670.00	941.26	0.351	149401.
16	700.00	927.39	0.230	320867.
17	715.02	928.13	0.222	356705.
18	832.00	948.84	0.278	420889.
19	842.00	950.47	0.289	427072.
20	1000.00	974.14	0.305	540489.
21	1017.54	1007.60	0.347	313554.
22	1021.77	1014.64	0.352	278546.
23	1035.26	1039.93	0.281	156763.
24	1048.00	1052.21	0.284	107466.
25	1067.58	1078.89	0.426	42975.

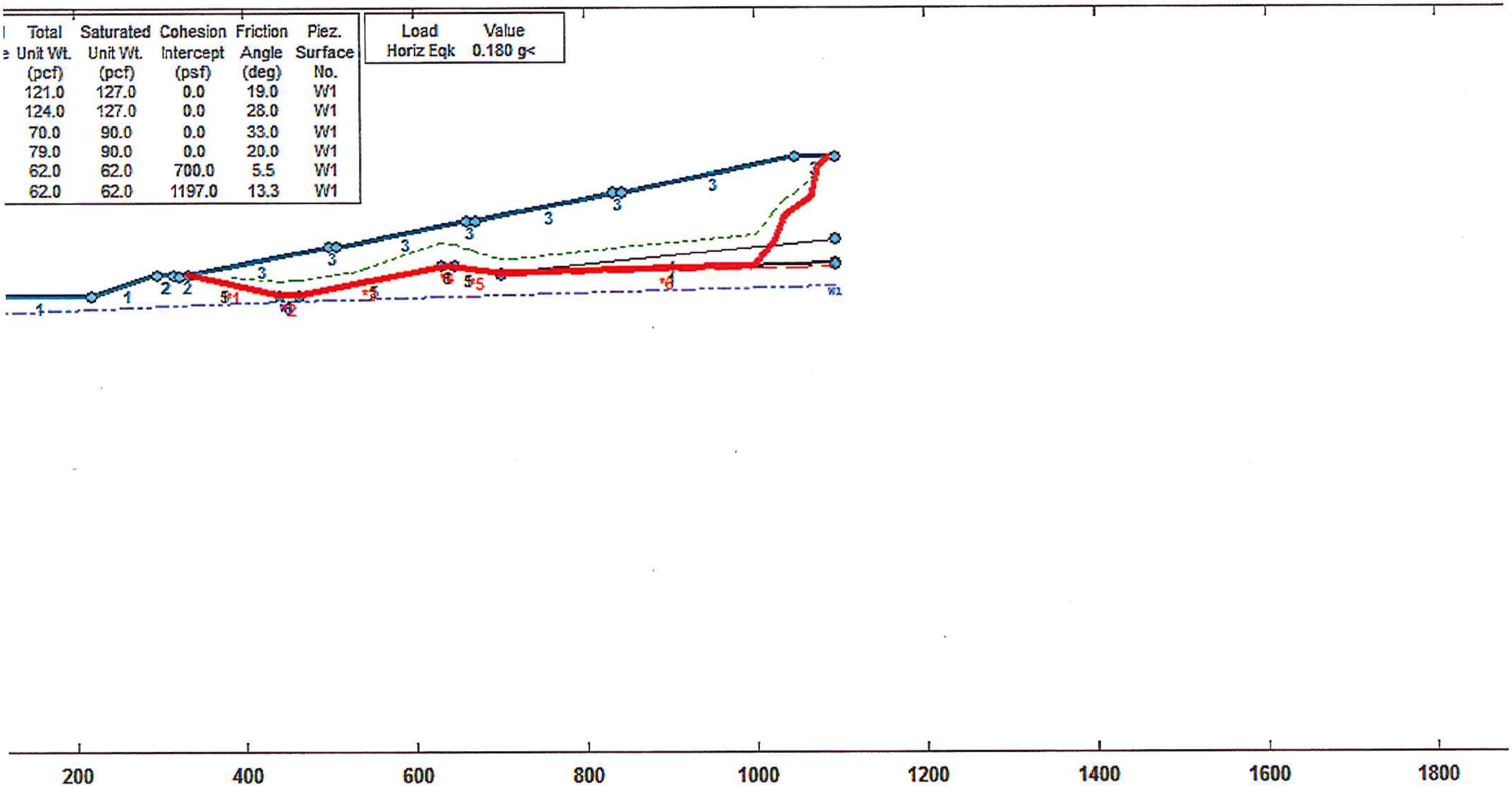
26	1075.36	1107.25	0.425	7675.
27	1086.66	1871.63	0.000	-14.

MATLOCK BEND LANDFILL EXPANSION Spencer Block

\active projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\block-wedge analysis sect c\spencer block\spencer blockw seismic.plt Run By

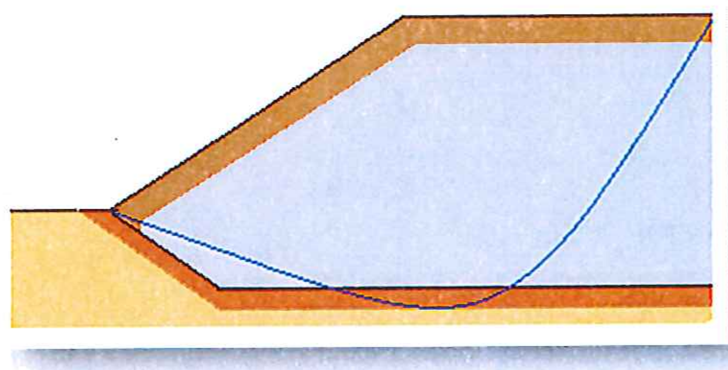
Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
121.0	127.0	0.0	19.0	W1
124.0	127.0	0.0	28.0	W1
70.0	90.0	0.0	33.0	W1
79.0	90.0	0.0	20.0	W1
62.0	62.0	700.0	5.5	W1
62.0	62.0	1197.0	13.3	W1

Load	Value
Horiz Eqk	0.180 g<



PCSTABL5M/si FSmin=1.27
Factor Of Safety Is Calculated By Spencer`s Method of Slices

MODIFIED BISHOP CIRCLE SLOPE ANALYSES



** PCSTABL5M **
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 2/13/2014
Time of Run: 08:32AM
Run By: Jo K House
Input Data Filename: F:MATLOCK BEND LANDFILLBISHOP.dat
Output Filename: F:MATLOCK BEND LANDFILLBISHOP.OUT
Unit: ENGLISH
Plotted Output Filename: F:MATLOCK BEND LANDFILLBISHOP.PLT
PROBLEM DESCRIPTION MATLOCK BEND LANDFILL EXPANSION
BISHOP CIRCLE

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

```
100 Trial Surfaces Have Been Generated.
 10 Surfaces Initiate From Each Of 10 Points Equally Spaced
Along The Ground Surface Between  X = 100.00 ft.
                            and   X = 600.00 ft.
Each Surface Terminates Between   X = 832.00 ft.
                            and   X =1094.00 ft.
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is  Y =700.00 ft.
50.00 ft. Line Segments Define Each Trial Failure Surface.
Following Are Displayed The Ten Most Critical Of The Trial
      Failure Surfaces Examined.  They Are Ordered - Most Critical
      First.
      * * Safety Factors Are Calculated By The Modified Bishop Method * *
      Failure Surface Specified By 24 Coordinate Points
```

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	146.91	843.69
3	194.74	829.13
4	243.34	817.36
5	292.53	808.43
6	342.16	802.35
7	392.06	799.17
8	442.06	798.88
9	491.99	801.48
10	541.69	806.97
11	590.99	815.33
12	639.71	826.53
13	687.71	840.53
14	734.82	857.29
15	780.88	876.75
16	825.73	898.84
17	869.23	923.50
18	911.23	950.63
19	951.59	980.15
20	990.17	1011.95
21	1026.84	1045.94
22	1061.49	1081.99
23	1093.99	1119.99
24	1093.99	1120.00

```
      Circle Center At X =  422.1 ; Y = 1661.7  and Radius,  863.1
            ***     1.694    ***
           Individual data on the    46  slices
```

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	46.9	49120.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	37.4	104257.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	10.4	38179.5	0.0	1302.3	0.0	0.0	0.0	0.0	0.0
4	25.3	107927.4	0.0	12547.3	0.0	0.0	0.0	0.0	0.0
5	23.3	134512.7	0.0	22811.2	0.0	0.0	0.0	0.0	0.0
6	49.2	442091.2	0.0	77732.1	0.0	0.0	0.0	0.0	0.0
7	2.5	27663.6	0.0	4847.1	0.0	0.0	0.0	0.0	0.0
8	20.0	232888.4	0.0	41942.2	0.0	0.0	0.0	0.0	0.0
9	9.0	105179.1	0.0	20421.1	0.0	0.0	0.0	0.0	0.0
10	8.0	94562.4	0.0	18958.2	0.0	0.0	0.0	0.0	0.0
11	10.2	121325.9	0.0	25175.6	0.0	0.0	0.0	0.0	0.0
12	49.9	616822.2	0.0	*******	0.0	0.0	0.0	0.0	0.0
13	48.9	627127.9	0.0	*******	0.0	0.0	0.0	0.0	0.0
14	1.1	13730.6	0.0	3335.0	0.0	0.0	0.0	0.0	0.0
15	7.9	103503.9	0.0	25076.3	0.0	0.0	0.0	0.0	0.0
16	14.0	184912.8	0.0	44265.7	0.0	0.0	0.0	0.0	0.0
17	28.0	385561.5	0.0	88187.1	0.0	0.0	0.0	0.0	0.0
18	5.0	71586.8	0.0	15762.4	0.0	0.0	0.0	0.0	0.0
19	10.0	143371.7	0.0	31156.8	0.0	0.0	0.0	0.0	0.0
20	34.7	512318.7	0.0	*******	0.0	0.0	0.0	0.0	0.0
21	49.3	772757.1	0.0	*******	0.0	0.0	0.0	0.0	0.0
22	39.0	637627.4	0.0	92748.9	0.0	0.0	0.0	0.0	0.0
23	9.7	160542.4	0.0	20273.3	0.0	0.0	0.0	0.0	0.0

24	6.3	103405.6	0.0	12627.8	0.0	0.0	0.0	0.0	0.0
25	14.0	226862.0	0.0	25838.7	0.0	0.0	0.0	0.0	0.0
26	10.0	157049.9	0.0	16521.6	0.0	0.0	0.0	0.0	0.0
27	17.7	268326.6	0.0	25308.9	0.0	0.0	0.0	0.0	0.0
28	12.3	180042.0	0.0	14538.9	0.0	0.0	0.0	0.0	0.0
29	34.8	493056.3	0.0	24258.9	0.0	0.0	0.0	0.0	0.0
30	13.4	183341.6	0.0	2314.4	0.0	0.0	0.0	0.0	0.0
31	32.6	425960.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	44.9	533600.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	6.3	69002.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	8.1	86253.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	1.9	18933.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	0.3	2844.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	27.0	266291.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	11.3	106671.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	30.7	276062.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	40.4	326456.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	38.6	264979.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42	36.7	199792.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	21.2	88133.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	13.5	42509.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	32.5	43245.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	143.63	836.58
3	188.90	815.34
4	235.56	797.37
5	283.38	782.78
6	332.12	771.64
7	381.53	763.99
8	431.37	759.89
9	481.36	759.35
10	531.27	762.38
11	580.84	768.96
12	629.81	779.05
13	677.93	792.61
14	724.97	809.56
15	770.68	829.83
16	814.83	853.30
17	857.19	879.85
18	897.56	909.36
19	935.71	941.68
20	971.47	976.63
21	1004.64	1014.04
22	1035.07	1053.72
23	1062.58	1095.46
24	1076.35	1120.00

Circle Center At X = 463.8 ; Y = 1459.4 and Radius, 700.3

*** 1.713 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	211.11	861.00
2	257.97	843.55
3	305.92	829.39
4	354.74	818.58
5	404.19	811.17
6	454.03	807.19
7	504.02	806.68
8	553.94	809.62
9	603.53	816.01
10	652.56	825.81
11	700.79	838.98
12	748.00	855.45
13	793.96	875.15
14	838.44	897.98
15	881.24	923.84

```
     16        922.14       952.59
     17        960.96       984.10
     18        997.51      1018.22
     19       1031.61      1054.79
     20       1063.10      1093.63
     21       1081.61      1120.00
Circle Center At X =   486.5 ; Y = 1529.0  and Radius,   722.5
          ***     1.738    ***
Failure Surface Specified By 21 Coordinate Points
    Point      X-Surf      Y-Surf
     No.        (ft)        (ft)
      1        211.11      861.00
      2        259.27      847.54
      3        308.16      837.09
      4        357.61      829.69
      5        407.42      825.37
      6        457.41      824.14
      7        507.37      826.00
      8        557.13      830.96
      9        606.48      838.99
     10        655.24      850.06
     11        703.22      864.13
     12        750.23      881.15
     13        796.10      901.04
     14        840.66      923.74
     15        883.72      949.15
     16        925.12      977.18
     17        964.71     1007.72
     18       1002.33     1040.66
     19       1037.84     1075.86
     20       1071.10     1113.19
     21       1076.45     1120.00
Circle Center At X =   452.3 ; Y = 1631.0  and Radius,   806.9
          ***     1.751    ***
Failure Surface Specified By 19 Coordinate Points
    Point      X-Surf      Y-Surf
     No.        (ft)        (ft)
      1        322.22      897.59
      2        367.34      876.03
      3        414.17      858.53
      4        462.36      845.20
      5        511.54      836.17
      6        561.32      831.49
      7        611.32      831.22
      8        661.15      835.33
      9        710.43      843.82
     10        758.76      856.60
     11        805.79      873.58
     12        851.14      894.64
     13        894.47      919.60
     14        935.43      948.27
     15        973.71      980.43
     16       1009.02     1015.84
     17       1041.07     1054.21
     18       1069.63     1095.25
     19       1083.80     1120.00
Circle Center At X =   589.5 ; Y = 1398.9  and Radius,   568.1
          ***     1.763    ***
Failure Surface Specified By 21 Coordinate Points
    Point      X-Surf      Y-Surf
     No.        (ft)        (ft)
      1        155.56      861.00
      2        199.29      836.76
      3        244.96      816.42
      4        292.23      800.12
      5        340.74      787.99
      6        390.11      780.12
      7        439.99      776.57
      8        489.98      777.37
      9        539.72      782.51
```

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	196.95	832.96
3	240.54	808.45
4	286.01	787.66
5	333.05	770.72
6	381.34	757.75
7	430.54	748.84
8	480.31	744.06
9	530.31	743.43
10	580.18	746.95
11	629.59	754.62
12	678.19	766.37
13	725.65	782.11
14	771.63	801.75
15	815.82	825.15
16	857.91	852.14
17	897.61	882.53
18	934.64	916.12
19	968.76	952.68
20	999.71	991.94
21	1027.29	1033.65
22	1051.31	1077.50
23	1070.18	1120.00

Circle Center At X = 512.9 ; Y = 1343.9 and Radius, 600.7
*** 1.790 ***

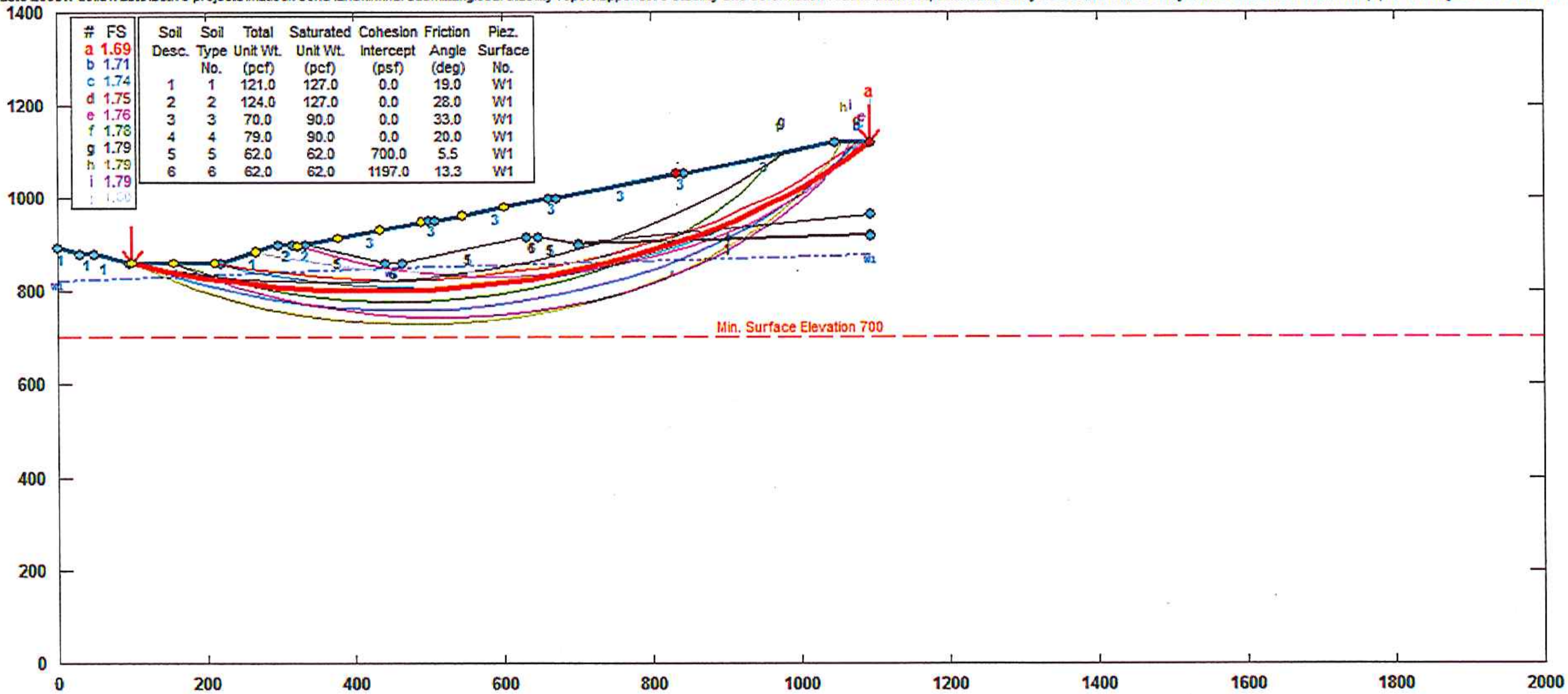
Failure Surface Specified By 20 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	266.67	885.27
2	314.17	869.67
3	362.63	857.36
4	411.82	848.39
5	461.51	842.80
6	511.46	840.62
7	561.45	841.86
8	611.23	846.51
9	660.58	854.56
10	709.26	865.95
11	757.05	880.65
12	803.73	898.57
13	849.07	919.65
14	892.87	943.77
15	934.91	970.83
16	975.01	1000.70
17	1012.97	1033.24
18	1048.62	1068.30
19	1081.79	1105.72
20	1092.81	1120.00

Circle Center At X = 518.3 ; Y = 1570.8 and Radius, 730.3
*** 1.801 ***

MATLOCK BEND LANDFILL EXPANSION BISHOP CIRCLE

f:\01 solid waste 2008\1 solidwaste\active projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\circular analysis section c\final analysis\matlock bend landfillbishop.pl2 Run By: Jo K House 2/13/2014 08:32AM



PCSTABL5M/si FSmin=1.69
Safety Factors Are Calculated By The Modified Bishop Method

**** PCSTABL5M ****
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 2/13/2014
Time of Run: 08:35AM
Run By: Jo K House
Input Data Filename: F:MATLOCK BEND LANDFILLBISHOPwSeismic.dat
Output Filename: F:MATLOCK BEND LANDFILLBISHOPwSeismic.OUT
Unit: ENGLISH
Plotted Output Filename: F:MATLOCK BEND LANDFILLBISHOPwSeismic.PLT
PROBLEM DESCRIPTION MATLOCK BEND LANDFILL EXPANSION
BISHOP CIRCLEw Seismic

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

A Horizontal Earthquake Loading Coefficient

Of0.180 Has Been Assigned
A Vertical Earthquake Loading Coefficient
Of0.000 Has Been Assigned
Cavitation Pressure = 0.0 (psf)
A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.
100 Trial Surfaces Have Been Generated.
10 Surfaces Initiate From Each Of 10 Points Equally Spaced
Along The Ground Surface Between X = 100.00 ft.
and X = 600.00 ft.
Each Surface Terminates Between X = 832.00 ft.
and X =1094.00 ft.
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =700.00 ft.
50.00 ft. Line Segments Define Each Trial Failure Surface.
Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.
* * Safety Factors Are Calculated By The Modified Bishop Method * *
Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	143.63	836.58
3	188.90	815.34
4	235.56	797.37
5	283.38	782.78
6	332.12	771.64
7	381.53	763.99
8	431.37	759.89
9	481.36	759.35
10	531.27	762.38
11	580.84	768.96
12	629.81	779.05
13	677.93	792.61
14	724.97	809.56
15	770.68	829.83
16	814.83	853.30
17	857.19	879.85
18	897.56	909.36
19	935.71	941.68
20	971.47	976.63
21	1004.64	1014.04
22	1035.07	1053.72
23	1062.58	1095.46
24	1076.35	1120.00

Circle Center At X = 463.8 ; Y = 1459.4 and Radius, 700.3
*** 0.904 ***
Individual data on the 46 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	43.6	64454.9	0.0	0.0	0.0	0.0	11601.9	0.0	0.0
2	13.1	43477.6	0.0	0.0	0.0	0.0	7826.0	0.0	0.0
3	32.2	150083.9	0.0	19099.6	0.0	0.0	27015.1	0.0	0.0
4	31.1	198906.9	0.0	50382.0	0.0	0.0	35803.2	0.0	0.0
5	15.6	124988.2	0.0	36135.8	0.0	0.0	22497.9	0.0	0.0
6	47.8	542676.1	0.0	*******	0.0	0.0	97681.7	0.0	0.0
7	11.6	166445.9	0.0	42913.6	0.0	0.0	29960.3	0.0	0.0
8	20.0	306700.4	0.0	79829.0	0.0	0.0	55206.1	0.0	0.0
9	9.0	140157.0	0.0	38384.7	0.0	0.0	25228.3	0.0	0.0
10	8.0	126572.2	0.0	35402.4	0.0	0.0	22783.0	0.0	0.0
11	0.1	1944.0	0.0	550.6	0.0	0.0	349.9	0.0	0.0
12	49.4	815152.4	0.0	*******	0.0	0.0	*******	0.0	0.0
13	49.8	870846.0	0.0	*******	0.0	0.0	*******	0.0	0.0
14	9.6	172276.6	0.0	53529.9	0.0	0.0	31009.8	0.0	0.0
15	9.0	162170.9	0.0	50412.6	0.0	0.0	29190.8	0.0	0.0
16	14.0	256098.2	0.0	79155.0	0.0	0.0	46097.7	0.0	0.0
17	17.4	326620.0	0.0	99091.9	0.0	0.0	58791.6	0.0	0.0

18	15.6	303503.6	0.0	89725.9	0.0	0.0	54630.6	0.0	0.0
19	10.0	196684.1	0.0	57244.2	0.0	0.0	35403.1	0.0	0.0
20	24.3	487205.9	0.0	*******	0.0	0.0	87697.1	0.0	0.0
21	49.6	********	0.0	*******	0.0	0.0	*******	0.0	0.0
22	49.0	********	0.0	*******	0.0	0.0	*******	0.0	0.0
23	0.2	4280.8	0.0	979.3	0.0	0.0	770.5	0.0	0.0
24	16.0	355089.3	0.0	79603.9	0.0	0.0	63916.1	0.0	0.0
25	14.0	306553.4	0.0	66413.1	0.0	0.0	55179.6	0.0	0.0
26	10.0	214125.0	0.0	45586.3	0.0	0.0	38542.5	0.0	0.0
27	7.9	166718.5	0.0	35073.5	0.0	0.0	30009.3	0.0	0.0
28	22.1	451819.1	0.0	93297.2	0.0	0.0	81327.4	0.0	0.0
29	25.0	496359.2	0.0	93253.6	0.0	0.0	89344.7	0.0	0.0
30	45.7	866155.8	0.0	*******	0.0	0.0	*******	0.0	0.0
31	44.1	766238.6	0.0	72757.3	0.0	0.0	*******	0.0	0.0
32	17.2	274526.5	0.0	9547.3	0.0	0.0	49414.8	0.0	0.0
33	4.4	67076.7	0.0	409.8	0.0	0.0	12073.8	0.0	0.0
34	5.6	84166.8	0.0	0.0	0.0	0.0	15150.0	0.0	0.0
35	15.2	218105.8	0.0	0.0	0.0	0.0	39259.0	0.0	0.0
36	40.4	514390.4	0.0	0.0	0.0	0.0	92590.3	0.0	0.0
37	0.7	8128.1	0.0	0.0	0.0	0.0	1463.1	0.0	0.0
38	1.4	15751.6	0.0	0.0	0.0	0.0	2835.3	0.0	0.0
39	33.4	356002.6	0.0	0.0	0.0	0.0	64080.5	0.0	0.0
40	2.6	25984.2	0.0	0.0	0.0	0.0	4677.2	0.0	0.0
41	35.8	323441.4	0.0	0.0	0.0	0.0	58219.5	0.0	0.0
42	33.2	242873.4	0.0	0.0	0.0	0.0	43717.2	0.0	0.0
43	30.4	163329.7	0.0	0.0	0.0	0.0	29399.3	0.0	0.0
44	12.9	49167.9	0.0	0.0	0.0	0.0	8850.2	0.0	0.0
45	14.6	36337.7	0.0	0.0	0.0	0.0	6540.8	0.0	0.0
46	13.8	11825.4	0.0	0.0	0.0	0.0	2128.6	0.0	0.0

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	146.91	843.69
3	194.74	829.13
4	243.34	817.36
5	292.53	808.43
6	342.16	802.35
7	392.06	799.17
8	442.06	798.88
9	491.99	801.48
10	541.69	806.97
11	590.99	815.33
12	639.71	826.53
13	687.71	840.53
14	734.82	857.29
15	780.88	876.75
16	825.73	898.84
17	869.23	923.50
18	911.23	950.63
19	951.59	980.15
20	990.17	1011.95
21	1026.84	1045.94
22	1061.49	1081.99
23	1093.99	1119.99
24	1093.99	1120.00

Circle Center At X = 422.1 ; Y = 1661.7 and Radius, 863.1

*** 0.909 ***

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	140.54	831.73
3	183.30	805.82
4	228.01	783.45
5	274.39	764.75
6	322.12	749.85
7	370.89	738.85
8	420.40	731.82
9	470.30	728.81

10	520.29	729.82
11	570.04	734.87
12	619.21	743.91
13	667.50	756.89
14	714.58	773.72
15	760.16	794.29
16	803.92	818.46
17	845.60	846.09
18	884.91	876.99
19	921.60	910.96
20	955.43	947.77
21	986.18	987.20
22	1013.66	1028.97
23	1037.67	1072.83
24	1058.07	1118.48
25	1058.61	1120.00

Circle Center At X = 482.7 ; Y = 1348.2 and Radius, 619.6
*** 0.936 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	211.11	861.00
2	257.97	843.55
3	305.92	829.39
4	354.74	818.58
5	404.19	811.17
6	454.03	807.19
7	504.02	806.68
8	553.94	809.62
9	603.53	816.01
10	652.56	825.81
11	700.79	838.98
12	748.00	855.45
13	793.96	875.15
14	838.44	897.98
15	881.24	923.84
16	922.14	952.59
17	960.96	984.10
18	997.51	1018.22
19	1031.61	1054.79
20	1063.10	1093.63
21	1081.61	1120.00

Circle Center At X = 486.5 ; Y = 1529.0 and Radius, 722.5
*** 0.945 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	199.29	836.76
3	244.96	816.42
4	292.23	800.12
5	340.74	787.99
6	390.11	780.12
7	439.99	776.57
8	489.98	777.37
9	539.72	782.51
10	588.82	791.96
11	636.91	805.63
12	683.63	823.44
13	728.63	845.24
14	771.56	870.86
15	812.11	900.12
16	849.96	932.80
17	884.82	968.63
18	916.44	1007.37
19	944.57	1048.70
20	969.01	1092.33
21	969.65	1093.76

Circle Center At X = 455.8 ; Y = 1351.1 and Radius, 574.8
*** 0.947 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	196.95	832.96
3	240.54	808.45
4	286.01	787.66
5	333.05	770.72
6	381.34	757.75
7	430.54	748.84
8	480.31	744.06
9	530.31	743.43
10	580.18	746.95
11	629.59	754.62
12	678.19	766.37
13	725.65	782.11
14	771.63	801.75
15	815.82	825.15
16	857.91	852.14
17	897.61	882.53
18	934.64	916.12
19	968.76	952.68
20	999.71	991.94
21	1027.29	1033.65
22	1051.31	1077.50
23	1070.18	1120.00

Circle Center At X = 512.9 ; Y = 1343.9 and Radius, 600.7
*** 0.949 ***

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	144.32	837.86
3	190.55	818.80
4	238.31	804.00
5	287.20	793.55
6	336.84	787.56
7	386.82	786.06
8	436.73	789.07
9	486.16	796.57
10	534.72	808.50
11	582.00	824.75
12	627.63	845.20
13	671.23	869.68
14	712.44	897.99
15	750.94	929.90
16	786.40	965.14
17	818.54	1003.44
18	847.10	1044.49
19	852.89	1054.65

Circle Center At X = 378.4 ; Y = 1340.2 and Radius, 554.2
*** 0.951 ***

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	138.83	829.49
3	180.13	801.31
4	223.62	776.64
5	269.00	755.65
6	315.96	738.49
7	364.18	725.28
8	413.33	716.10
9	463.07	711.02
10	513.06	710.07
11	562.96	713.26
12	612.43	720.57
13	661.11	731.95
14	708.69	747.31
15	754.84	766.57

16	799.23	789.57
17	841.57	816.17
18	881.56	846.18
19	918.94	879.39
20	953.43	915.59
21	984.81	954.51
22	1012.87	995.90
23	1037.40	1039.47
24	1058.24	1084.92
25	1070.94	1120.00

Circle Center At X = 499.5 ; Y = 1313.7 and Radius, 603.7
*** 0.957 ***

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	199.65	837.43
3	245.73	818.01
4	293.39	802.90
5	342.24	792.23
6	391.86	786.09
7	441.84	784.52
8	491.74	787.55
9	541.16	795.15
10	589.68	807.25
11	636.87	823.75
12	682.36	844.52
13	725.75	869.37
14	766.67	898.10
15	804.78	930.46
16	839.77	966.18
17	871.32	1004.97
18	899.19	1046.48
19	914.98	1075.45

Circle Center At X = 433.8 ; Y = 1328.7 and Radius, 544.2
*** 0.959 ***

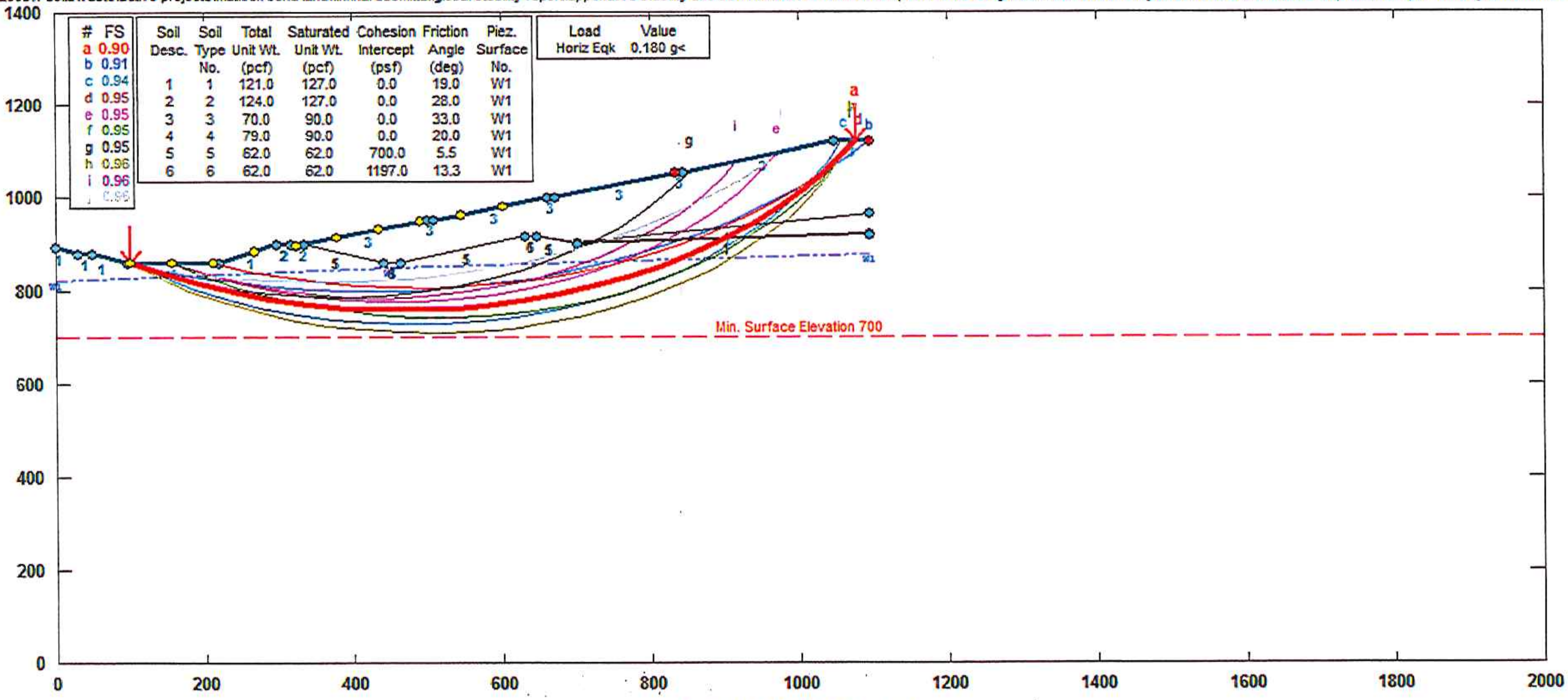
Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	147.79	846.30
3	196.39	834.55
4	245.62	825.81
5	295.29	820.10
6	345.22	817.45
7	395.22	817.87
8	445.10	821.35
9	494.67	827.88
10	543.75	837.44
11	592.15	850.00
12	639.69	865.49
13	686.18	883.87
14	731.47	905.07
15	775.37	929.01
16	817.71	955.59
17	858.35	984.72
18	897.13	1016.29
19	933.89	1050.18
20	968.51	1086.25
21	976.95	1096.20

Circle Center At X = 363.4 ; Y = 1632.2 and Radius, 815.0
*** 0.961 ***

MATLOCK BEND LANDFILL EXPANSION BISHOP CIRCLEw Seismic

)1 solid waste 2008\1 solidwaste\active projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\circular analysis section c\final analysis\matlock bend landfillbishopwseismic.pl2 Run By: Jo K House 2/13/2014 08:35/



PCSTABL5M/si FSmin=0.90
Safety Factors Are Calculated By The Modified Bishop Method

** PCSTABL5M **
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 2/13/2014
Time of Run: 08:39AM
Run By: Jo K House
Input Data Filename: F:MATLOCK BEND LANDFILLBISHOPwYIELD14g.dat
Output Filename: F:MATLOCK BEND LANDFILLBISHOPwYIELD14g.OUT
Unit: ENGLISH
Plotted Output Filename: F:MATLOCK BEND LANDFILLBISHOPwYIELD14g.PLT
PROBLEM DESCRIPTION MATLOCK BEND LANDFILL EXPANSION
BISHOP CIRCLEw Yield Acc

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

A Horizontal Earthquake Loading Coefficient
Of0.140 Has Been Assigned

A Vertical Earthquake Loading Coefficient
Of0.000 Has Been Assigned
Cavitation Pressure = 0.0 (psf)
A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.
100 Trial Surfaces Have Been Generated.
10 Surfaces Initiate From Each Of 10 Points Equally Spaced
Along The Ground Surface Between X = 100.00 ft.
and X = 600.00 ft.
Each Surface Terminates Between X = 832.00 ft.
and X =1094.00 ft.
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =700.00 ft.
50.00 ft. Line Segments Define Each Trial Failure Surface.
Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.
* * Safety Factors Are Calculated By The Modified Bishop Method * *
Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	143.63	836.58
3	188.90	815.34
4	235.56	797.37
5	283.38	782.78
6	332.12	771.64
7	381.53	763.99
8	431.37	759.89
9	481.36	759.35
10	531.27	762.38
11	580.84	768.96
12	629.81	779.05
13	677.93	792.61
14	724.97	809.56
15	770.68	829.83
16	814.83	853.30
17	857.19	879.85
18	897.56	909.36
19	935.71	941.68
20	971.47	976.63
21	1004.64	1014.04
22	1035.07	1053.72
23	1062.58	1095.46
24	1076.35	1120.00

Circle Center At X = 463.8 ; Y = 1459.4 and Radius, 700.3
*** 1.013 ***
Individual data on the 46 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	43.6	64454.9	0.0	0.0	0.0	0.0	9023.7	0.0	0.0
2	13.1	43477.6	0.0	0.0	0.0	0.0	6086.9	0.0	0.0
3	32.2	150083.9	0.0	19099.6	0.0	0.0	21011.7	0.0	0.0
4	31.1	198906.9	0.0	50382.0	0.0	0.0	27847.0	0.0	0.0
5	15.6	124988.2	0.0	36135.8	0.0	0.0	17498.3	0.0	0.0
6	47.8	542676.1	0.0	*******	0.0	0.0	75974.7	0.0	0.0
7	11.6	166445.9	0.0	42913.6	0.0	0.0	23302.4	0.0	0.0
8	20.0	306700.4	0.0	79829.0	0.0	0.0	42938.1	0.0	0.0
9	9.0	140157.0	0.0	38384.7	0.0	0.0	19622.0	0.0	0.0
10	8.0	126572.2	0.0	35402.4	0.0	0.0	17720.1	0.0	0.0
11	0.1	1944.0	0.0	550.6	0.0	0.0	272.2	0.0	0.0
12	49.4	815152.4	0.0	*******	0.0	0.0	*******	0.0	0.0
13	49.8	870846.0	0.0	*******	0.0	0.0	*******	0.0	0.0
14	9.6	172276.6	0.0	53529.9	0.0	0.0	24118.7	0.0	0.0
15	9.0	162170.9	0.0	50412.6	0.0	0.0	22703.9	0.0	0.0
16	14.0	256098.2	0.0	79155.0	0.0	0.0	35853.8	0.0	0.0
17	17.4	326620.0	0.0	99091.9	0.0	0.0	45726.8	0.0	0.0
18	15.6	303503.6	0.0	89725.9	0.0	0.0	42490.5	0.0	0.0

19	10.0	196684.1	0.0	57244.2	0.0	0.0	27535.8	0.0	0.0
20	24.3	487205.9	0.0	*******	0.0	0.0	68208.8	0.0	0.0
21	49.6	********	0.0	*******	0.0	0.0	*******	0.0	0.0
22	49.0	********	0.0	*******	0.0	0.0	*******	0.0	0.0
23	0.2	4280.8	0.0	979.3	0.0	0.0	599.3	0.0	0.0
24	16.0	355089.3	0.0	79603.9	0.0	0.0	49712.5	0.0	0.0
25	14.0	306553.4	0.0	66413.1	0.0	0.0	42917.5	0.0	0.0
26	10.0	214125.0	0.0	45586.3	0.0	0.0	29977.5	0.0	0.0
27	7.9	166718.5	0.0	35073.5	0.0	0.0	23340.6	0.0	0.0
28	22.1	451819.1	0.0	93297.2	0.0	0.0	63254.7	0.0	0.0
29	25.0	496359.2	0.0	93253.6	0.0	0.0	69490.3	0.0	0.0
30	45.7	866155.8	0.0	*******	0.0	0.0	*******	0.0	0.0
31	44.1	766238.6	0.0	72757.3	0.0	0.0	*******	0.0	0.0
32	17.2	274526.5	0.0	9547.3	0.0	0.0	38433.7	0.0	0.0
33	4.4	67076.7	0.0	409.8	0.0	0.0	9390.7	0.0	0.0
34	5.6	84166.8	0.0	0.0	0.0	0.0	11783.3	0.0	0.0
35	15.2	218105.8	0.0	0.0	0.0	0.0	30534.8	0.0	0.0
36	40.4	514390.4	0.0	0.0	0.0	0.0	72014.7	0.0	0.0
37	0.7	8128.1	0.0	0.0	0.0	0.0	1137.9	0.0	0.0
38	1.4	15751.6	0.0	0.0	0.0	0.0	2205.2	0.0	0.0
39	33.4	356002.6	0.0	0.0	0.0	0.0	49840.4	0.0	0.0
40	2.6	25984.2	0.0	0.0	0.0	0.0	3637.8	0.0	0.0
41	35.8	323441.4	0.0	0.0	0.0	0.0	45281.8	0.0	0.0
42	33.2	242873.4	0.0	0.0	0.0	0.0	34002.3	0.0	0.0
43	30.4	163329.7	0.0	0.0	0.0	0.0	22866.2	0.0	0.0
44	12.9	49167.9	0.0	0.0	0.0	0.0	6883.5	0.0	0.0
45	14.6	36337.7	0.0	0.0	0.0	0.0	5087.3	0.0	0.0
46	13.8	11825.4	0.0	0.0	0.0	0.0	1655.6	0.0	0.0

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	146.91	843.69
3	194.74	829.13
4	243.34	817.36
5	292.53	808.43
6	342.16	802.35
7	392.06	799.17
8	442.06	798.88
9	491.99	801.48
10	541.69	806.97
11	590.99	815.33
12	639.71	826.53
13	687.71	840.53
14	734.82	857.29
15	780.88	876.75
16	825.73	898.84
17	869.23	923.50
18	911.23	950.63
19	951.59	980.15
20	990.17	1011.95
21	1026.84	1045.94
22	1061.49	1081.99
23	1093.99	1119.99
24	1093.99	1120.00

Circle Center At X = 422.1 ; Y = 1661.7 and Radius, 863.1

*** 1.017 ***

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	140.54	831.73
3	183.30	805.82
4	228.01	783.45
5	274.39	764.75
6	322.12	749.85
7	370.89	738.85
8	420.40	731.82
9	470.30	728.81
10	520.29	729.82

```
    11        570.04       734.87
    12        619.21       743.91
    13        667.50       756.89
    14        714.58       773.72
    15        760.16       794.29
    16        803.92       818.46
    17        845.60       846.09
    18        884.91       876.99
    19        921.60       910.96
    20        955.43       947.77
    21        986.18       987.20
    22       1013.66      1028.97
    23       1037.67      1072.83
    24       1058.07      1118.48
    25       1058.61      1120.00
Circle Center At X =   482.7 ; Y = 1348.2  and Radius,   619.6
       ***      1.049    ***
Failure Surface Specified By 21 Coordinate Points
  Point        X-Surf       Y-Surf
   No.          (ft)         (ft)
    1         211.11       861.00
    2         257.97       843.55
    3         305.92       829.39
    4         354.74       818.58
    5         404.19       811.17
    6         454.03       807.19
    7         504.02       806.68
    8         553.94       809.62
    9         603.53       816.01
   10         652.56       825.81
   11         700.79       838.98
   12         748.00       855.45
   13         793.96       875.15
   14         838.44       897.98
   15         881.24       923.84
   16         922.14       952.59
   17         960.96       984.10
   18         997.51      1018.22
   19        1031.61      1054.79
   20        1063.10      1093.63
   21        1081.61      1120.00
Circle Center At X =   486.5 ; Y = 1529.0  and Radius,   722.5
       ***      1.056    ***
Failure Surface Specified By 21 Coordinate Points
  Point        X-Surf       Y-Surf
   No.          (ft)         (ft)
    1         155.56       861.00
    2         199.29       836.76
    3         244.96       816.42
    4         292.23       800.12
    5         340.74       787.99
    6         390.11       780.12
    7         439.99       776.57
    8         489.98       777.37
    9         539.72       782.51
   10         588.82       791.96
   11         636.91       805.63
   12         683.63       823.44
   13         728.63       845.24
   14         771.56       870.86
   15         812.11       900.12
   16         849.96       932.80
   17         884.82       968.63
   18         916.44      1007.37
   19         944.57      1048.70
   20         969.01      1092.33
   21         969.65      1093.76
Circle Center At X =   455.8 ; Y = 1351.1  and Radius,   574.8
       ***      1.061    ***
Failure Surface Specified By 23 Coordinate Points
```

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	196.95	832.96
3	240.54	808.45
4	286.01	787.66
5	333.05	770.72
6	381.34	757.75
7	430.54	748.84
8	480.31	744.06
9	530.31	743.43
10	580.18	746.95
11	629.59	754.62
12	678.19	766.37
13	725.65	782.11
14	771.63	801.75
15	815.82	825.15
16	857.91	852.14
17	897.61	882.53
18	934.64	916.12
19	968.76	952.68
20	999.71	991.94
21	1027.29	1033.65
22	1051.31	1077.50
23	1070.18	1120.00

Circle Center At X = 512.9 ; Y = 1343.9 and Radius, 600.7

*** 1.062 ***

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	144.32	837.86
3	190.55	818.80
4	238.31	804.00
5	287.20	793.55
6	336.84	787.56
7	386.82	786.06
8	436.73	789.07
9	486.16	796.57
10	534.72	808.50
11	582.00	824.75
12	627.63	845.20
13	671.23	869.68
14	712.44	897.99
15	750.94	929.90
16	786.40	965.14
17	818.54	1003.44
18	847.10	1044.49
19	852.89	1054.65

Circle Center At X = 378.4 ; Y = 1340.2 and Radius, 554.2

*** 1.067 ***

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	138.83	829.49
3	180.13	801.31
4	223.62	776.64
5	269.00	755.65
6	315.96	738.49
7	364.18	725.28
8	413.33	716.10
9	463.07	711.02
10	513.06	710.07
11	562.96	713.26
12	612.43	720.57
13	661.11	731.95
14	708.69	747.31
15	754.84	766.57
16	799.23	789.57

17	841.57	816.17
18	881.56	846.18
19	918.94	879.39
20	953.43	915.59
21	984.81	954.51
22	1012.87	995.90
23	1037.40	1039.47
24	1058.24	1084.92
25	1070.94	1120.00

Circle Center At X = 499.5 ; Y = 1313.7 and Radius, 603.7

*** 1.073 ***

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	199.65	837.43
3	245.73	818.01
4	293.39	802.90
5	342.24	792.23
6	391.86	786.09
7	441.84	784.52
8	491.74	787.55
9	541.16	795.15
10	589.68	807.25
11	636.87	823.75
12	682.36	844.52
13	725.75	869.37
14	766.67	898.10
15	804.78	930.46
16	839.77	966.18
17	871.32	1004.97
18	899.19	1046.48
19	914.98	1075.45

Circle Center At X = 433.8 ; Y = 1328.7 and Radius, 544.2

*** 1.074 ***

Failure Surface Specified By 21 Coordinate Points

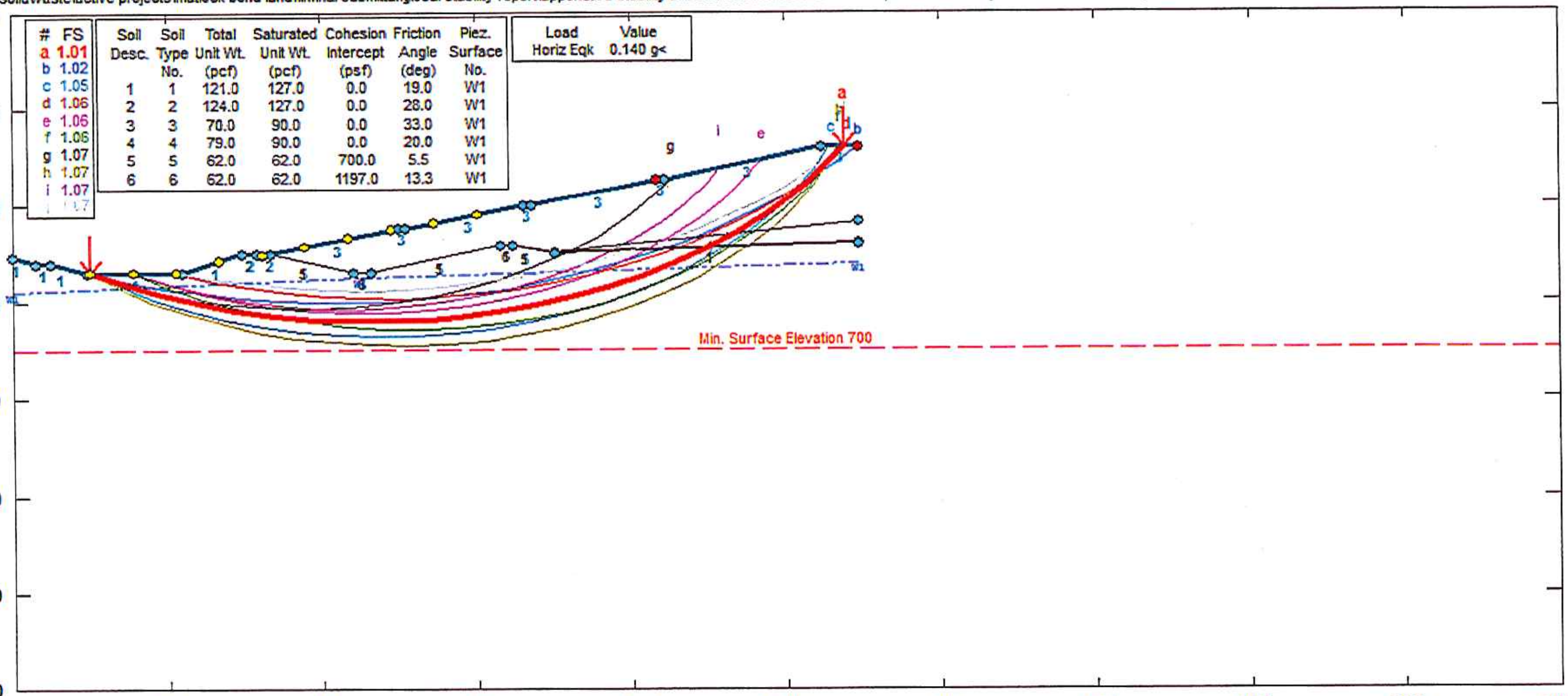
Point No.	X-Surf (ft)	Y-Surf (ft)
1	211.11	861.00
2	259.27	847.54
3	308.16	837.09
4	357.61	829.69
5	407.42	825.37
6	457.41	824.14
7	507.37	826.00
8	557.13	830.96
9	606.48	838.99
10	655.24	850.06
11	703.22	864.13
12	750.23	881.15
13	796.10	901.04
14	840.66	923.74
15	883.72	949.15
16	925.12	977.18
17	964.71	1007.72
18	1002.33	1040.66
19	1037.84	1075.86
20	1071.10	1113.19
21	1076.45	1120.00

Circle Center At X = 452.3 ; Y = 1631.0 and Radius, 806.9

*** 1.074 ***

MATLOCK BEND LANDFILL EXPANSION BISHOP CIRCLEw Yield Acc

\1 solid waste 2008\1 solidwaste\active projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\circular analysis section c\final analysis\matlock bend landfillbishopwyield14g.pl2 Run By: Jo K House 2/13/2014 08:39,



PCSTABL5M/si FSmin=1.01
Safety Factors Are Calculated By The Modified Bishop Method

```
    2        450.00        850.00
    3       1094.00        878.00
A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.
100 Trial Surfaces Have Been Generated.
 10 Surfaces Initiate From Each Of 10 Points Equally Spaced
Along The Ground Surface Between  X = 100.00 ft.
                                and  X = 600.00 ft.
Each Surface Terminates Between   X = 832.00 ft.
                                and  X =1094.00 ft.
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is  Y =700.00 ft.
50.00 ft. Line Segments Define Each Trial Failure Surface.
Following Are Displayed The Ten Most Critical Of The Trial
      Failure Surfaces Examined.  They Are Ordered - Most Critical
      First.
      * * Safety Factors Are Calculated By The Modified Janbu Method * *
      Failure Surface Specified By 24 Coordinate Points
        Point      X-Surf        Y-Surf
         No.        (ft)          (ft)
          1        100.00        861.00
          2        143.63        836.58
          3        188.90        815.34
          4        235.56        797.37
          5        283.38        782.78
          6        332.12        771.64
          7        381.53        763.99
          8        431.37        759.89
          9        481.36        759.35
         10        531.27        762.38
         11        580.84        768.96
         12        629.81        779.05
         13        677.93        792.61
         14        724.97        809.56
         15        770.68        829.83
         16        814.83        853.30
         17        857.19        879.85
         18        897.56        909.36
         19        935.71        941.68
         20        971.47        976.63
         21       1004.64       1014.04
         22       1035.07       1053.72
         23       1062.58       1095.46
         24       1076.35       1120.00
                                    ***   1.536   ***
              Individual data on the    46  slices
```

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	43.6	64454.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	13.1	43477.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	32.2	150083.9	0.0	19099.6	0.0	0.0	0.0	0.0	0.0
4	31.1	198906.9	0.0	50382.0	0.0	0.0	0.0	0.0	0.0
5	15.6	124988.2	0.0	36135.8	0.0	0.0	0.0	0.0	0.0
6	47.8	542676.1	0.0	*******	0.0	0.0	0.0	0.0	0.0
7	11.6	166445.9	0.0	42913.6	0.0	0.0	0.0	0.0	0.0
8	20.0	306700.4	0.0	79829.0	0.0	0.0	0.0	0.0	0.0
9	9.0	140157.0	0.0	38384.7	0.0	0.0	0.0	0.0	0.0
10	8.0	126572.2	0.0	35402.4	0.0	0.0	0.0	0.0	0.0
11	0.1	1944.0	0.0	550.6	0.0	0.0	0.0	0.0	0.0
12	49.4	815152.4	0.0	*******	0.0	0.0	0.0	0.0	0.0
13	49.8	870846.0	0.0	*******	0.0	0.0	0.0	0.0	0.0
14	9.6	172276.6	0.0	53529.9	0.0	0.0	0.0	0.0	0.0
15	9.0	162170.9	0.0	50412.6	0.0	0.0	0.0	0.0	0.0
16	14.0	256098.2	0.0	79155.0	0.0	0.0	0.0	0.0	0.0

17	17.4	326620.0	0.0	99091.9	0.0	0.0	0.0	0.0	0.0
18	15.6	303503.6	0.0	89725.9	0.0	0.0	0.0	0.0	0.0
19	10.0	196684.1	0.0	57244.2	0.0	0.0	0.0	0.0	0.0
20	24.3	487205.9	0.0	*******	0.0	0.0	0.0	0.0	0.0
21	49.6	********	0.0	*******	0.0	0.0	0.0	0.0	0.0
22	49.0	********	0.0	*******	0.0	0.0	0.0	0.0	0.0
23	0.2	4280.8	0.0	979.3	0.0	0.0	0.0	0.0	0.0
24	16.0	355089.3	0.0	79603.9	0.0	0.0	0.0	0.0	0.0
25	14.0	306553.4	0.0	66413.1	0.0	0.0	0.0	0.0	0.0
26	10.0	214125.0	0.0	45586.3	0.0	0.0	0.0	0.0	0.0
27	7.9	166718.5	0.0	35073.5	0.0	0.0	0.0	0.0	0.0
28	22.1	451819.1	0.0	93297.2	0.0	0.0	0.0	0.0	0.0
29	25.0	496359.2	0.0	93253.6	0.0	0.0	0.0	0.0	0.0
30	45.7	866155.8	0.0	*******	0.0	0.0	0.0	0.0	0.0
31	44.1	766238.6	0.0	72757.3	0.0	0.0	0.0	0.0	0.0
32	17.2	274526.5	0.0	9547.3	0.0	0.0	0.0	0.0	0.0
33	4.4	67076.7	0.0	409.8	0.0	0.0	0.0	0.0	0.0
34	5.6	84166.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	15.2	218105.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	40.4	514390.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	0.7	8128.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	1.4	15751.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	33.4	356002.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	2.6	25984.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	35.8	323441.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42	33.2	242873.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	30.4	163329.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	12.9	49167.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	14.6	36337.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	13.8	11825.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	140.54	831.73
3	183.30	805.82
4	228.01	783.45
5	274.39	764.75
6	322.12	749.85
7	370.89	738.85
8	420.40	731.82
9	470.30	728.81
10	520.29	729.82
11	570.04	734.87
12	619.21	743.91
13	667.50	756.89
14	714.58	773.72
15	760.16	794.29
16	803.92	818.46
17	845.60	846.09
18	884.91	876.99
19	921.60	910.96
20	955.43	947.77
21	986.18	987.20
22	1013.66	1028.97
23	1037.67	1072.83
24	1058.07	1118.48
25	1058.61	1120.00

*** 1.544 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	196.95	832.96
3	240.54	808.45
4	286.01	787.66
5	333.05	770.72

6	381.34	757.75
7	430.54	748.84
8	480.31	744.06
9	530.31	743.43
10	580.18	746.95
11	629.59	754.62
12	678.19	766.37
13	725.65	782.11
14	771.63	801.75
15	815.82	825.15
16	857.91	852.14
17	897.61	882.53
18	934.64	916.12
19	968.76	952.68
20	999.71	991.94
21	1027.29	1033.65
22	1051.31	1077.50
23	1070.18	1120.00

*** 1.546 ***

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	138.83	829.49
3	180.13	801.31
4	223.62	776.64
5	269.00	755.65
6	315.96	738.49
7	364.18	725.28
8	413.33	716.10
9	463.07	711.02
10	513.06	710.07
11	562.96	713.26
12	612.43	720.57
13	661.11	731.95
14	708.69	747.31
15	754.84	766.57
16	799.23	789.57
17	841.57	816.17
18	881.56	846.18
19	918.94	879.39
20	953.43	915.59
21	984.81	954.51
22	1012.87	995.90
23	1037.40	1039.47
24	1058.24	1084.92
25	1070.94	1120.00

*** 1.553 ***

Failure Surface Specified By 21 Coordinate Points

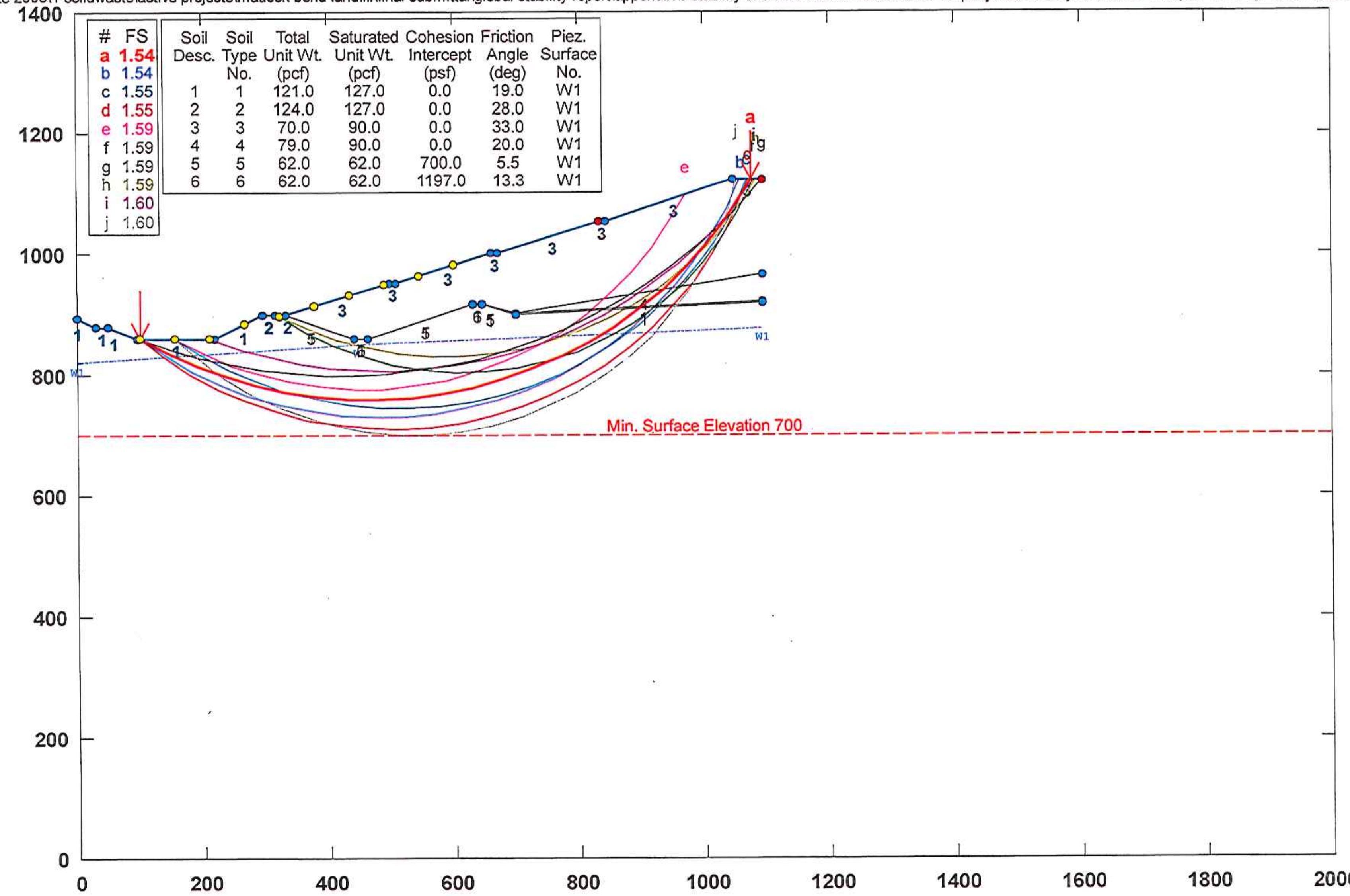
Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	199.29	836.76
3	244.96	816.42
4	292.23	800.12
5	340.74	787.99
6	390.11	780.12
7	439.99	776.57
8	489.98	777.37
9	539.72	782.51
10	588.82	791.96
11	636.91	805.63
12	683.63	823.44
13	728.63	845.24
14	771.56	870.86
15	812.11	900.12
16	849.96	932.80

```
 17        884.82      968.63
 18        916.44     1007.37
 19        944.57     1048.70
 20        969.01     1092.33
 21        969.65     1093.76
    ***     1.585    ***
Failure Surface Specified By 20 Coordinate Points
 Point      X-Surf      Y-Surf
  No.        (ft)        (ft)
  1        322.22      897.59
  2        364.23      870.47
  3        408.73      847.68
  4        455.29      829.45
  5        503.43      815.95
  6        552.68      807.33
  7        602.55      803.67
  8        652.53      805.00
  9        702.13      811.32
 10        750.85      822.56
 11        798.21      838.60
 12        843.72      859.30
 13        886.95      884.43
 14        927.44      913.76
 15        964.81      946.98
 16        998.68      983.76
 17       1028.70     1023.74
 18       1054.58     1066.52
 19       1076.07     1111.67
 20       1079.05     1120.00
    ***     1.585    ***
Failure Surface Specified By 24 Coordinate Points
 Point      X-Surf      Y-Surf
  No.        (ft)        (ft)
  1        100.00      861.00
  2        146.91      843.69
  3        194.74      829.13
  4        243.34      817.36
  5        292.53      808.43
  6        342.16      802.35
  7        392.06      799.17
  8        442.06      798.88
  9        491.99      801.48
 10        541.69      806.97
 11        590.99      815.33
 12        639.71      826.53
 13        687.71      840.53
 14        734.82      857.29
 15        780.88      876.75
 16        825.73      898.84
 17        869.23      923.50
 18        911.23      950.63
 19        951.59      980.15
 20        990.17     1011.95
 21       1026.84     1045.94
 22       1061.49     1081.99
 23       1093.99     1119.99
 24       1093.99     1120.00
    ***     1.586    ***
Failure Surface Specified By 19 Coordinate Points
 Point      X-Surf      Y-Surf
  No.        (ft)        (ft)
  1        322.22      897.59
  2        367.34      876.03
  3        414.17      858.53
  4        462.36      845.20
  5        511.54      836.17
  6        561.32      831.49
```

```
     7        611.32       831.22
     8        661.15       835.33
     9        710.43       843.82
    10        758.76       856.60
    11        805.79       873.58
    12        851.14       894.64
    13        894.47       919.60
    14        935.43       948.27
    15        973.71       980.43
    16       1009.02      1015.84
    17       1041.07      1054.21
    18       1069.63      1095.25
    19       1083.80      1120.00
        ***     1.589    ***
 Failure Surface Specified By 21 Coordinate Points
   Point       X-Surf       Y-Surf
    No.         (ft)         (ft)
     1        211.11       861.00
     2        257.97       843.55
     3        305.92       829.39
     4        354.74       818.58
     5        404.19       811.17
     6        454.03       807.19
     7        504.02       806.68
     8        553.94       809.62
     9        603.53       816.01
    10        652.56       825.81
    11        700.79       838.98
    12        748.00       855.45
    13        793.96       875.15
    14        838.44       897.98
    15        881.24       923.84
    16        922.14       952.59
    17        960.96       984.10
    18        997.51      1018.22
    19       1031.61      1054.79
    20       1063.10      1093.63
    21       1081.61      1120.00
        ***     1.599    ***
 Failure Surface Specified By 24 Coordinate Points
   Point       X-Surf       Y-Surf
    No.         (ft)         (ft)
     1        155.56       861.00
     2        191.98       826.75
     3        231.48       796.09
     4        273.70       769.31
     5        318.27       746.64
     6        364.77       728.28
     7        412.81       714.40
     8        461.94       705.13
     9        511.73       700.55
    10        561.73       700.70
    11        611.49       705.57
    12        660.57       715.13
    13        708.53       729.28
    14        754.93       747.91
    15        799.36       770.84
    16        841.42       797.87
    17        880.74       828.76
    18        916.97       863.22
    19        949.77       900.96
    20        978.85       941.63
    21       1003.96       984.87
    22       1024.87      1030.29
    23       1041.39      1077.48
    24       1051.89      1120.00
        ***     1.600    ***
```

MATLOCK BEND LANDFILL EXPANSION JANBU CIRCLE

f:\01 solid waste 2008\1 solidwaste\active projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\janbu circle\janbu circle final.pl2 Run By: Jo K House 2/12/2014 09



PCSTABL5M/si FSmin=1.54

Safety Factors Are Calculated By The Modified Janbu Method

**** PCSTABL5M ****
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 2/13/2014
Time of Run: 08:05AM
Run By: Jo K House
Input Data Filename: F:MATLOCK BEND LANDFILL basic modle w circlel.dat
Output Filename: F:MATLOCK BEND LANDFILL basic modle w circlel.OUT
Unit: ENGLISH
Plotted Output Filename: F:MATLOCK BEND LANDFILL basic modle w circlel.PLT
PROBLEM DESCRIPTION MATLOCK BEND LANDFILL EXPANSION
JANBU SEISMIC

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

A Horizontal Earthquake Loading Coefficient

Of0.180 Has Been Assigned
A Vertical Earthquake Loading Coefficient
Of0.000 Has Been Assigned
Cavitation Pressure = 0.0 (psf)
A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.
100 Trial Surfaces Have Been Generated.
10 Surfaces Initiate From Each Of 10 Points Equally Spaced
Along The Ground Surface Between X = 100.00 ft.
and X = 600.00 ft.
Each Surface Terminates Between X = 832.00 ft.
and X =1094.00 ft.
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =700.00 ft.
50.00 ft. Line Segments Define Each Trial Failure Surface.
Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.
* * Safety Factors Are Calculated By The Modified Janbu Method * *
Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	140.54	831.73
3	183.30	805.82
4	228.01	783.45
5	274.39	764.75
6	322.12	749.85
7	370.89	738.85
8	420.40	731.82
9	470.30	728.81
10	520.29	729.82
11	570.04	734.87
12	619.21	743.91
13	667.50	756.89
14	714.58	773.72
15	760.16	794.29
16	803.92	818.46
17	845.60	846.09
18	884.91	876.99
19	921.60	910.96
20	955.43	947.77
21	986.18	987.20
22	1013.66	1028.97
23	1037.67	1072.83
24	1058.07	1118.48
25	1058.61	1120.00

*** 0.806 ***

Individual data on the 47 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	40.5	71786.9	0.0	0.0	0.0	0.0	12921.6	0.0	0.0
2	3.5	12875.7	0.0	0.0	0.0	0.0	2317.6	0.0	0.0
3	39.3	208722.8	0.0	37721.9	0.0	0.0	37570.1	0.0	0.0
4	36.7	293894.2	0.0	94041.3	0.0	0.0	52901.0	0.0	0.0
5	8.0	77661.8	0.0	27611.9	0.0	0.0	13979.1	0.0	0.0
6	46.4	596053.8	0.0	*******	0.0	0.0	*******	0.0	0.0
7	20.6	341547.0	0.0	*******	0.0	0.0	61478.5	0.0	0.0
8	20.0	364216.0	0.0	*******	0.0	0.0	65558.9	0.0	0.0
9	7.1	132400.0	0.0	41904.4	0.0	0.0	23832.0	0.0	0.0
10	1.9	35002.1	0.0	11045.6	0.0	0.0	6300.4	0.0	0.0
11	8.0	151010.4	0.0	47660.6	0.0	0.0	27181.9	0.0	0.0
12	38.9	761997.9	0.0	*******	0.0	0.0	*******	0.0	0.0
13	49.5	********	0.0	*******	0.0	0.0	*******	0.0	0.0
14	20.6	442875.1	0.0	*******	0.0	0.0	79717.5	0.0	0.0
15	9.0	195812.0	0.0	67026.0	0.0	0.0	35246.2	0.0	0.0
16	14.0	309447.0	0.0	*******	0.0	0.0	55700.5	0.0	0.0
17	6.3	141599.5	0.0	47936.1	0.0	0.0	25487.9	0.0	0.0

18	26.7	616617.1	0.0	*******	0.0	0.0	*******	0.0	0.0
19	10.0	236247.1	0.0	76576.5	0.0	0.0	42524.5	0.0	0.0
20	13.3	317874.9	0.0	*******	0.0	0.0	57217.5	0.0	0.0
21	49.7	********	0.0	*******	0.0	0.0	*******	0.0	0.0
22	49.2	********	0.0	*******	0.0	0.0	*******	0.0	0.0
23	10.8	284345.2	0.0	78140.1	0.0	0.0	51182.1	0.0	0.0
24	16.0	420917.8	0.0	*******	0.0	0.0	75765.2	0.0	0.0
25	14.0	364499.2	0.0	95647.9	0.0	0.0	65609.9	0.0	0.0
26	7.5	192338.6	0.0	50074.8	0.0	0.0	34620.9	0.0	0.0
27	2.5	63338.8	0.0	16903.6	0.0	0.0	11401.0	0.0	0.0
28	30.0	740810.9	0.0	*******	0.0	0.0	*******	0.0	0.0
29	14.6	350763.0	0.0	86970.9	0.0	0.0	63137.3	0.0	0.0
30	45.6	********	0.0	*******	0.0	0.0	*******	0.0	0.0
31	43.8	942792.8	0.0	*******	0.0	0.0	*******	0.0	0.0
32	28.1	555119.9	0.0	80281.4	0.0	0.0	99921.6	0.0	0.0
33	10.0	185224.0	0.0	19771.2	0.0	0.0	33340.3	0.0	0.0
34	3.6	64672.3	0.0	5977.3	0.0	0.0	11641.0	0.0	0.0
35	28.4	479013.4	0.0	23789.3	0.0	0.0	86222.4	0.0	0.0
36	10.9	168152.2	0.0	0.0	0.0	0.0	30267.4	0.0	0.0
37	36.7	496106.3	0.0	0.0	0.0	0.0	89299.1	0.0	0.0
38	0.2	2194.5	0.0	0.0	0.0	0.0	395.0	0.0	0.0
39	1.1	12605.0	0.0	0.0	0.0	0.0	2268.9	0.0	0.0
40	27.6	303011.8	0.0	0.0	0.0	0.0	54542.1	0.0	0.0
41	5.0	50288.5	0.0	0.0	0.0	0.0	9051.9	0.0	0.0
42	30.8	272659.1	0.0	0.0	0.0	0.0	49078.6	0.0	0.0
43	27.5	184260.0	0.0	0.0	0.0	0.0	33166.8	0.0	0.0
44	24.0	103588.0	0.0	0.0	0.0	0.0	18645.8	0.0	0.0
45	10.3	24499.7	0.0	0.0	0.0	0.0	4409.9	0.0	0.0
46	10.1	9021.5	0.0	0.0	0.0	0.0	1623.9	0.0	0.0
47	0.5	28.7	0.0	0.0	0.0	0.0	5.2	0.0	0.0

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	143.63	836.58
3	188.90	815.34
4	235.56	797.37
5	283.38	782.78
6	332.12	771.64
7	381.53	763.99
8	431.37	759.89
9	481.36	759.35
10	531.27	762.38
11	580.84	768.96
12	629.81	779.05
13	677.93	792.61
14	724.97	809.56
15	770.68	829.83
16	814.83	853.30
17	857.19	879.85
18	897.56	909.36
19	935.71	941.68
20	971.47	976.63
21	1004.64	1014.04
22	1035.07	1053.72
23	1062.58	1095.46
24	1076.35	1120.00

*** 0.808 ***

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	138.83	829.49
3	180.13	801.31
4	223.62	776.64
5	269.00	755.65
6	315.96	738.49
7	364.18	725.28
8	413.33	716.10
9	463.07	711.02

10	513.06	710.07
11	562.96	713.26
12	612.43	720.57
13	661.11	731.95
14	708.69	747.31
15	754.84	766.57
16	799.23	789.57
17	841.57	816.17
18	881.56	846.18
19	918.94	879.39
20	953.43	915.59
21	984.81	954.51
22	1012.87	995.90
23	1037.40	1039.47
24	1058.24	1084.92
25	1070.94	1120.00

*** 0.809 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	196.95	832.96
3	240.54	808.45
4	286.01	787.66
5	333.05	770.72
6	381.34	757.75
7	430.54	748.84
8	480.31	744.06
9	530.31	743.43
10	580.18	746.95
11	629.59	754.62
12	678.19	766.37
13	725.65	782.11
14	771.63	801.75
15	815.82	825.15
16	857.91	852.14
17	897.61	882.53
18	934.64	916.12
19	968.76	952.68
20	999.71	991.94
21	1027.29	1033.65
22	1051.31	1077.50
23	1070.18	1120.00

*** 0.818 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	199.29	836.76
3	244.96	816.42
4	292.23	800.12
5	340.74	787.99
6	390.11	780.12
7	439.99	776.57
8	489.98	777.37
9	539.72	782.51
10	588.82	791.96
11	636.91	805.63
12	683.63	823.44
13	728.63	845.24
14	771.56	870.86
15	812.11	900.12
16	849.96	932.80
17	884.82	968.63
18	916.44	1007.37
19	944.57	1048.70
20	969.01	1092.33
21	969.65	1093.76

*** 0.839 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	191.98	826.75
3	231.48	796.09
4	273.70	769.31
5	318.27	746.64
6	364.77	728.28
7	412.81	714.40
8	461.94	705.13
9	511.73	700.55
10	561.73	700.70
11	611.49	705.57
12	660.57	715.13
13	708.53	729.28
14	754.93	747.91
15	799.36	770.84
16	841.42	797.87
17	880.74	828.76
18	916.97	863.22
19	949.77	900.96
20	978.85	941.63
21	1003.96	984.87
22	1024.87	1030.29
23	1041.39	1077.48
24	1051.89	1120.00

*** 0.840 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	146.91	843.69
3	194.74	829.13
4	243.34	817.36
5	292.53	808.43
6	342.16	802.35
7	392.06	799.17
8	442.06	798.88
9	491.99	801.48
10	541.69	806.97
11	590.99	815.33
12	639.71	826.53
13	687.71	840.53
14	734.82	857.29
15	780.88	876.75
16	825.73	898.84
17	869.23	923.50
18	911.23	950.63
19	951.59	980.15
20	990.17	1011.95
21	1026.84	1045.94
22	1061.49	1081.99
23	1093.99	1119.99
24	1093.99	1120.00

*** 0.848 ***

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	136.20	826.51
3	175.85	796.05
4	218.51	769.98
5	263.70	748.58
6	310.91	732.10
7	359.60	720.73
8	409.22	714.59
9	459.21	713.75
10	509.01	718.22
11	558.06	727.96
12	605.79	742.85

13	651.67	762.72
14	695.18	787.35
15	735.83	816.46
16	773.17	849.72
17	806.76	886.76
18	836.22	927.15
19	861.24	970.45
20	881.51	1016.15
21	896.82	1063.75
22	898.07	1069.78
***	0.849	***

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	135.37	825.66
3	174.24	794.21
4	216.18	766.99
5	260.73	744.29
6	307.41	726.36
7	355.70	713.40
8	405.08	705.55
9	455.01	702.90
10	504.94	705.47
11	554.34	713.24
12	602.65	726.12
13	649.35	743.97
14	693.94	766.60
15	735.92	793.76
16	774.84	825.15
17	810.27	860.43
18	841.83	899.21
19	869.17	941.07
20	891.99	985.56
21	910.04	1032.19
22	922.45	1077.95
***	0.850	***

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	199.65	837.43
3	245.73	818.01
4	293.39	802.90
5	342.24	792.23
6	391.86	786.09
7	441.84	784.52
8	491.74	787.55
9	541.16	795.15
10	589.68	807.25
11	636.87	823.75
12	682.36	844.52
13	725.75	869.37
14	766.67	898.10
15	804.78	930.46
16	839.77	966.18
17	871.32	1004.97
18	899.19	1046.48
19	914.98	1075.45
***	0.854	***

**** PCSTABL5M ****
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 2/13/2014
Time of Run: 08:13AM
Run By: Jo K House
Input Data Filename: F:MATLOCK BEND LANDFILL basic modle w circlel.dat
Output Filename: F:MATLOCK BEND LANDFILL basic modle w circlel.OUT
Unit: ENGLISH
Plotted Output Filename: F:MATLOCK BEND LANDFILL basic modle w circlel.PLT
PROBLEM DESCRIPTION MATLOCK BEND LANDFILL EXPANSION
JANBU SEISMIC YIELD ACCELERATION

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

A Horizontal Earthquake Loading Coefficient
Of0.110 Has Been Assigned

A Vertical Earthquake Loading Coefficient
Of0.000 Has Been Assigned
Cavitation Pressure = 0.0 (psf)
A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.
100 Trial Surfaces Have Been Generated.
10 Surfaces Initiate From Each Of 10 Points Equally Spaced
Along The Ground Surface Between X = 100.00 ft.
and X = 600.00 ft.
Each Surface Terminates Between X = 832.00 ft.
and X =1094.00 ft.
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =700.00 ft.
50.00 ft. Line Segments Define Each Trial Failure Surface.
Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.
* * Safety Factors Are Calculated By The Modified Janbu Method * *
Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	140.54	831.73
3	183.30	805.82
4	228.01	783.45
5	274.39	764.75
6	322.12	749.85
7	370.89	738.85
8	420.40	731.82
9	470.30	728.81
10	520.29	729.82
11	570.04	734.87
12	619.21	743.91
13	667.50	756.89
14	714.58	773.72
15	760.16	794.29
16	803.92	818.46
17	845.60	846.09
18	884.91	876.99
19	921.60	910.96
20	955.43	947.77
21	986.18	987.20
22	1013.66	1028.97
23	1037.67	1072.83
24	1058.07	1118.48
25	1058.61	1120.00

*** 0.995 ***

Individual data on the 47 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	40.5	71786.9	0.0	0.0	0.0	0.0	7896.6	0.0	0.0
2	3.5	12875.7	0.0	0.0	0.0	0.0	1416.3	0.0	0.0
3	39.3	208722.8	0.0	37721.9	0.0	0.0	22959.5	0.0	0.0
4	36.7	293894.2	0.0	94041.3	0.0	0.0	32328.4	0.0	0.0
5	8.0	77661.8	0.0	27611.9	0.0	0.0	8542.8	0.0	0.0
6	46.4	596053.8	0.0	*******	0.0	0.0	65565.9	0.0	0.0
7	20.6	341547.0	0.0	*******	0.0	0.0	37570.2	0.0	0.0
8	20.0	364216.0	0.0	*******	0.0	0.0	40063.8	0.0	0.0
9	7.1	132400.0	0.0	41904.4	0.0	0.0	14564.0	0.0	0.0
10	1.9	35002.1	0.0	11045.6	0.0	0.0	3850.2	0.0	0.0
11	8.0	151010.4	0.0	47660.6	0.0	0.0	16611.1	0.0	0.0
12	38.9	761997.9	0.0	*******	0.0	0.0	83819.8	0.0	0.0
13	49.5	********	0.0	*******	0.0	0.0	*******	0.0	0.0
14	20.6	442875.1	0.0	*******	0.0	0.0	48716.3	0.0	0.0
15	9.0	195812.0	0.0	67026.0	0.0	0.0	21539.3	0.0	0.0
16	14.0	309447.0	0.0	*******	0.0	0.0	34039.2	0.0	0.0
17	6.3	141599.5	0.0	47936.1	0.0	0.0	15575.9	0.0	0.0
18	26.7	616617.1	0.0	*******	0.0	0.0	67827.9	0.0	0.0

19	10.0	236247.1	0.0	76576.5	0.0	0.0	25987.2	0.0	0.0
20	13.3	317874.9	0.0	*******	0.0	0.0	34966.2	0.0	0.0
21	49.7	********	0.0	*******	0.0	0.0	*******	0.0	0.0
22	49.2	********	0.0	*******	0.0	0.0	*******	0.0	0.0
23	10.8	284345.2	0.0	78140.1	0.0	0.0	31278.0	0.0	0.0
24	16.0	420917.8	0.0	*******	0.0	0.0	46301.0	0.0	0.0
25	14.0	364499.2	0.0	95647.9	0.0	0.0	40094.9	0.0	0.0
26	7.5	192338.6	0.0	50074.8	0.0	0.0	21157.2	0.0	0.0
27	2.5	63338.8	0.0	16903.6	0.0	0.0	6967.3	0.0	0.0
28	30.0	740810.9	0.0	*******	0.0	0.0	81489.2	0.0	0.0
29	14.6	350763.0	0.0	86970.9	0.0	0.0	38583.9	0.0	0.0
30	45.6	********	0.0	*******	0.0	0.0	*******	0.0	0.0
31	43.8	942792.8	0.0	*******	0.0	0.0	*******	0.0	0.0
32	28.1	555119.9	0.0	80281.4	0.0	0.0	61063.2	0.0	0.0
33	10.0	185224.0	0.0	19771.2	0.0	0.0	20374.6	0.0	0.0
34	3.6	64672.3	0.0	5977.3	0.0	0.0	7114.0	0.0	0.0
35	28.4	479013.4	0.0	23789.3	0.0	0.0	52691.5	0.0	0.0
36	10.9	168152.2	0.0	0.0	0.0	0.0	18496.7	0.0	0.0
37	36.7	496106.3	0.0	0.0	0.0	0.0	54571.7	0.0	0.0
38	0.2	2194.5	0.0	0.0	0.0	0.0	241.4	0.0	0.0
39	1.1	12605.0	0.0	0.0	0.0	0.0	1386.6	0.0	0.0
40	27.6	303011.8	0.0	0.0	0.0	0.0	33331.3	0.0	0.0
41	5.0	50288.5	0.0	0.0	0.0	0.0	5531.7	0.0	0.0
42	30.8	272659.1	0.0	0.0	0.0	0.0	29992.5	0.0	0.0
43	27.5	184260.0	0.0	0.0	0.0	0.0	20268.6	0.0	0.0
44	24.0	103588.0	0.0	0.0	0.0	0.0	11394.7	0.0	0.0
45	10.3	24499.7	0.0	0.0	0.0	0.0	2695.0	0.0	0.0
46	10.1	9021.5	0.0	0.0	0.0	0.0	992.4	0.0	0.0
47	0.5	28.7	0.0	0.0	0.0	0.0	3.2	0.0	0.0

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	143.63	836.58
3	188.90	815.34
4	235.56	797.37
5	283.38	782.78
6	332.12	771.64
7	381.53	763.99
8	431.37	759.89
9	481.36	759.35
10	531.27	762.38
11	580.84	768.96
12	629.81	779.05
13	677.93	792.61
14	724.97	809.56
15	770.68	829.83
16	814.83	853.30
17	857.19	879.85
18	897.56	909.36
19	935.71	941.68
20	971.47	976.63
21	1004.64	1014.04
22	1035.07	1053.72
23	1062.58	1095.46
24	1076.35	1120.00

*** 0.997 ***

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	138.83	829.49
3	180.13	801.31
4	223.62	776.64
5	269.00	755.65
6	315.96	738.49
7	364.18	725.28
8	413.33	716.10
9	463.07	711.02
10	513.06	710.07

11	562.96	713.26
12	612.43	720.57
13	661.11	731.95
14	708.69	747.31
15	754.84	766.57
16	799.23	789.57
17	841.57	816.17
18	881.56	846.18
19	918.94	879.39
20	953.43	915.59
21	984.81	954.51
22	1012.87	995.90
23	1037.40	1039.47
24	1058.24	1084.92
25	1070.94	1120.00

*** 0.998 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	196.95	832.96
3	240.54	808.45
4	286.01	787.66
5	333.05	770.72
6	381.34	757.75
7	430.54	748.84
8	480.31	744.06
9	530.31	743.43
10	580.18	746.95
11	629.59	754.62
12	678.19	766.37
13	725.65	782.11
14	771.63	801.75
15	815.82	825.15
16	857.91	852.14
17	897.61	882.53
18	934.64	916.12
19	968.76	952.68
20	999.71	991.94
21	1027.29	1033.65
22	1051.31	1077.50
23	1070.18	1120.00

*** 1.006 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	191.98	826.75
3	231.48	796.09
4	273.70	769.31
5	318.27	746.64
6	364.77	728.28
7	412.81	714.40
8	461.94	705.13
9	511.73	700.55
10	561.73	700.70
11	611.49	705.57
12	660.57	715.13
13	708.53	729.28
14	754.93	747.91
15	799.36	770.84
16	841.42	797.87
17	880.74	828.76
18	916.97	863.22
19	949.77	900.96
20	978.85	941.63
21	1003.96	984.87
22	1024.87	1030.29
23	1041.39	1077.48
24	1051.89	1120.00

*** 1.032 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	199.29	836.76
3	244.96	816.42
4	292.23	800.12
5	340.74	787.99
6	390.11	780.12
7	439.99	776.57
8	489.98	777.37
9	539.72	782.51
10	588.82	791.96
11	636.91	805.63
12	683.63	823.44
13	728.63	845.24
14	771.56	870.86
15	812.11	900.12
16	849.96	932.80
17	884.82	968.63
18	916.44	1007.37
19	944.57	1048.70
20	969.01	1092.33
21	969.65	1093.76

*** 1.033 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	146.91	843.69
3	194.74	829.13
4	243.34	817.36
5	292.53	808.43
6	342.16	802.35
7	392.06	799.17
8	442.06	798.88
9	491.99	801.48
10	541.69	806.97
11	590.99	815.33
12	639.71	826.53
13	687.71	840.53
14	734.82	857.29
15	780.88	876.75
16	825.73	898.84
17	869.23	923.50
18	911.23	950.63
19	951.59	980.15
20	990.17	1011.95
21	1026.84	1045.94
22	1061.49	1081.99
23	1093.99	1119.99
24	1093.99	1120.00

*** 1.044 ***

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	136.20	826.51
3	175.85	796.05
4	218.51	769.98
5	263.70	748.58
6	310.91	732.10
7	359.60	720.73
8	409.22	714.59
9	459.21	713.75
10	509.01	718.22
11	558.06	727.96
12	605.79	742.85
13	651.67	762.72

14	695.18	787.35
15	735.83	816.46
16	773.17	849.72
17	806.76	886.76
18	836.22	927.15
19	861.24	970.45
20	881.51	1016.15
21	896.82	1063.75
22	898.07	1069.78
***	1.049	***

Failure Surface Specified By 22 Coordinate Points

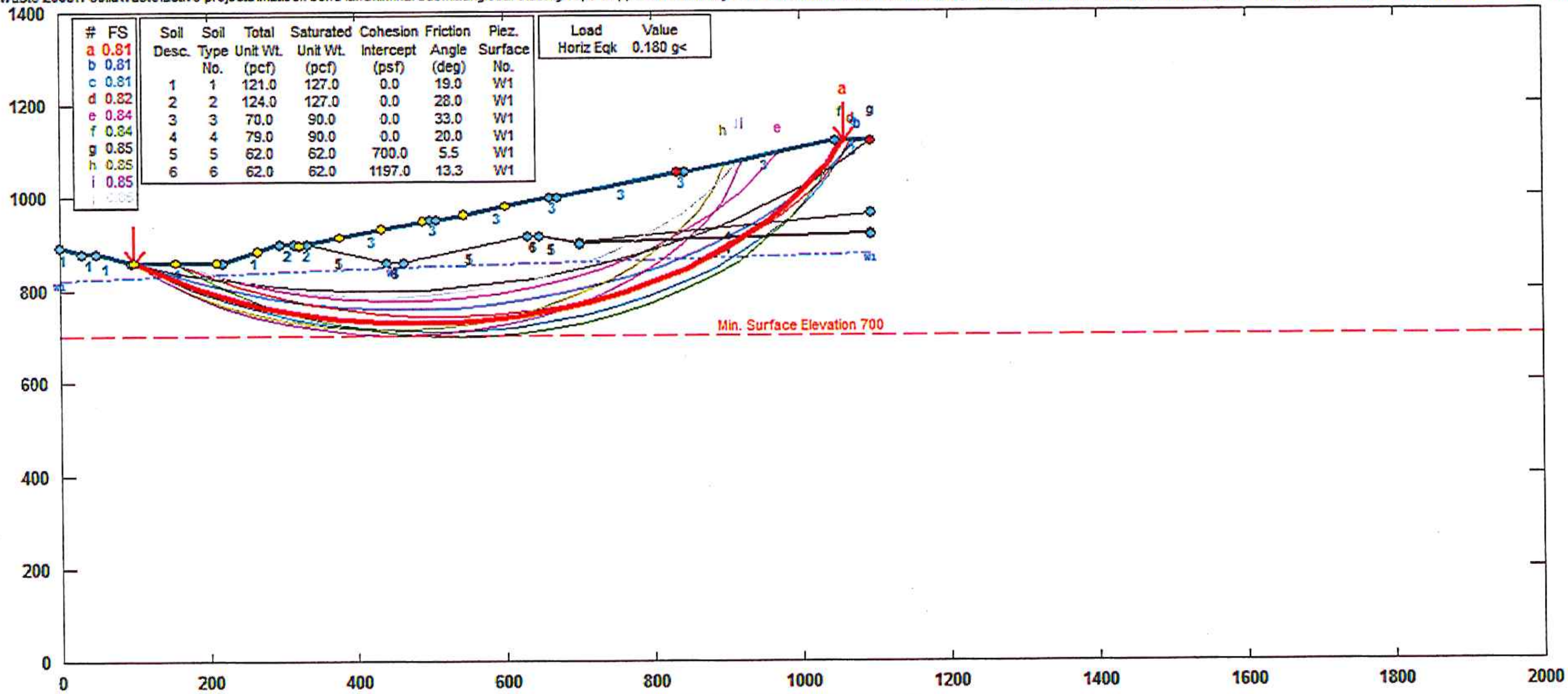
Point No.	X-Surf (ft)	Y-Surf (ft)
1	211.11	861.00
2	251.92	832.11
3	295.31	807.27
4	340.89	786.72
5	388.24	770.65
6	436.91	759.21
7	486.46	752.50
8	536.43	750.58
9	586.34	753.48
10	635.75	761.17
11	684.18	773.57
12	731.21	790.57
13	776.37	812.01
14	819.27	837.70
15	859.50	867.40
16	896.68	900.82
17	930.48	937.67
18	960.58	977.59
19	986.70	1020.23
20	1008.60	1065.18
21	1026.08	1112.02
22	1026.26	1112.72
***	1.049	***

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	135.37	825.66
3	174.24	794.21
4	216.18	766.99
5	260.73	744.29
6	307.41	726.36
7	355.70	713.40
8	405.08	705.55
9	455.01	702.90
10	504.94	705.47
11	554.34	713.24
12	602.65	726.12
13	649.35	743.97
14	693.94	766.60
15	735.92	793.76
16	774.84	825.15
17	810.27	860.43
18	841.83	899.21
19	869.17	941.07
20	891.99	985.56
21	910.04	1032.19
22	922.45	1077.95
***	1.050	***

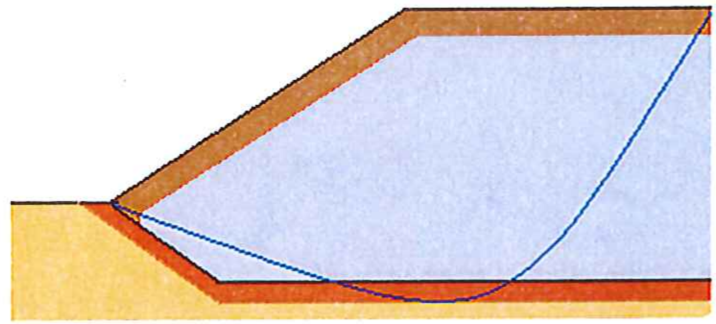
MATLOCK BEND LANDFILL EXPANSION JANBU SEISMIC

f:\01 solid waste 2008\1 solidwaste\active projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\janbu circle\input files\matlock bend landfill basic modle w circle.pl2 Run By: Jo K House 2/13/2014 08:05AM



PCSTABL5M/si FSmin=0.81
Safety Factors Are Calculated By The Modified Janbu Method

JANBU RANDOM SLOPE STABILITY ANALYSES



**** PCSTABL5M ****
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 2/13/2014
Time of Run: 08:22AM
Run By: Jo K House
Input Data Filename: F:MATLOCK BEND LANDFILLRANDOM.DAT
Output Filename: F:MATLOCK BEND LANDFILLRANDOM.OUT
Unit: **ENGLISH**
Plotted Output Filename: F:MATLOCK BEND LANDFILLRANDOM.PLT
PROBLEM DESCRIPTION MATLOCK BEND LANDFILL EXPANSION
Janbu Random

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

A Critical Failure Surface Searching Method, Using A Random

Technique For Generating Irregular Surfaces, Has Been Specified.
100 Trial Surfaces Have Been Generated.
10 Surfaces Initiate From Each Of 10 Points Equally Spaced
Along The Ground Surface Between X = 100.00 ft.
and X = 600.00 ft.
Each Surface Terminates Between X = 832.00 ft.
and X =1094.00 ft.
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =700.00 ft.
50.00 ft. Line Segments Define Each Trial Failure Surface.
Factor Of Safety Calculation Has Gone Through Ten Iterations
The Trial Failure Surface In Question Is Defined
By The Following 18 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	488.89	949.44
2	524.60	914.45
3	560.17	879.31
4	599.58	848.54
5	643.98	825.54
6	684.84	796.73
7	726.23	768.67
8	767.38	740.27
9	814.88	724.66
10	864.63	729.64
11	902.74	762.00
12	906.97	811.82
13	909.17	861.77
14	909.29	911.77
15	913.40	961.60
16	922.17	1010.83
17	934.96	1059.17
18	935.00	1082.15

Factor Of Safety For The Preceding Specified Surface = 10.525
Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.
* * Safety Factors Are Calculated By The Modified Janbu Method * *
Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	211.11	861.00
2	246.97	826.16
3	284.97	793.65
4	333.56	781.88
5	382.34	770.91
6	429.13	753.29
7	473.02	729.32
8	517.43	706.35
9	567.05	712.52
10	613.13	731.92
11	659.72	750.08
12	702.56	775.86
13	748.52	795.54
14	795.27	813.29
15	832.45	846.72
16	875.27	872.54
17	920.38	894.10
18	968.81	906.52
19	1006.18	939.74
20	1019.54	987.92
21	1022.47	1037.84
22	1035.06	1086.23
23	1047.35	1119.78

*** 1.730 ***

Individual data on the 44 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)

1	8.9	4643.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	17.0	44032.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	9.9	50112.5	0.0	4440.9	0.0	0.0	0.0	0.0	0.0
4	38.0	351103.9	0.0	86623.2	0.0	0.0	0.0	0.0	0.0
5	10.0	130244.0	0.0	30143.9	0.0	0.0	0.0	0.0	0.0
6	20.0	278858.2	0.0	66025.2	0.0	0.0	0.0	0.0	0.0
7	9.0	127852.1	0.0	32293.5	0.0	0.0	0.0	0.0	0.0
8	8.0	115751.5	0.0	30050.8	0.0	0.0	0.0	0.0	0.0
9	1.6	22746.5	0.0	6010.6	0.0	0.0	0.0	0.0	0.0
10	48.8	751834.5	0.0	*******	0.0	0.0	0.0	0.0	0.0
11	46.8	816635.5	0.0	*******	0.0	0.0	0.0	0.0	0.0
12	11.9	226915.8	0.0	83309.1	0.0	0.0	0.0	0.0	0.0
13	9.0	179761.6	0.0	67261.9	0.0	0.0	0.0	0.0	0.0
14	14.0	294407.2	0.0	*******	0.0	0.0	0.0	0.0	0.0
15	9.0	199810.8	0.0	76226.0	0.0	0.0	0.0	0.0	0.0
16	24.0	573381.8	0.0	*******	0.0	0.0	0.0	0.0	0.0
17	10.0	255445.7	0.0	96803.7	0.0	0.0	0.0	0.0	0.0
18	10.4	276101.4	0.0	*******	0.0	0.0	0.0	0.0	0.0
19	49.6	********	0.0	*******	0.0	0.0	0.0	0.0	0.0
20	46.1	********	0.0	*******	0.0	0.0	0.0	0.0	0.0
21	16.9	464390.8	0.0	*******	0.0	0.0	0.0	0.0	0.0
22	16.0	435851.2	0.0	*******	0.0	0.0	0.0	0.0	0.0
23	13.7	366900.3	0.0	*******	0.0	0.0	0.0	0.0	0.0
24	0.3	7437.2	0.0	2229.3	0.0	0.0	0.0	0.0	0.0
25	10.0	259474.6	0.0	77191.9	0.0	0.0	0.0	0.0	0.0
26	30.0	732634.9	0.0	*******	0.0	0.0	0.0	0.0	0.0
27	2.6	59881.1	0.0	15990.9	0.0	0.0	0.0	0.0	0.0
28	46.0	********	0.0	*******	0.0	0.0	0.0	0.0	0.0
29	46.7	********	0.0	*******	0.0	0.0	0.0	0.0	0.0
30	36.7	712611.4	0.0	*******	0.0	0.0	0.0	0.0	0.0
31	0.4	7990.0	0.0	758.2	0.0	0.0	0.0	0.0	0.0
32	9.6	165722.8	0.0	11986.3	0.0	0.0	0.0	0.0	0.0
33	26.0	425102.6	0.0	13803.2	0.0	0.0	0.0	0.0	0.0
34	7.2	112317.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	45.1	661536.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	48.4	671930.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	8.4	112639.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	1.3	17127.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	27.7	342384.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	3.4	38646.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	9.9	96554.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42	2.9	20136.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	12.6	45403.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	12.3	12662.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	190.94	825.67
3	226.78	790.81
4	273.92	774.13
5	323.09	765.07
6	368.49	744.13
7	418.20	738.70
8	466.67	726.44
9	515.38	715.16
10	564.78	722.93
11	614.18	730.63
12	662.41	743.80
13	706.50	767.38
14	755.02	779.45
15	803.21	792.79
16	850.34	809.50
17	880.14	849.65
18	918.70	881.48
19	951.35	919.34
20	955.41	969.18
21	966.31	1017.98
22	974.54	1067.30
23	975.64	1095.76

*** 1.759 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	198.64	835.63
3	244.89	816.64
4	294.88	817.72
5	344.22	809.60
6	391.04	792.04
7	439.67	803.67
8	487.40	818.54
9	535.82	831.00
10	585.40	837.48
11	635.02	843.64
12	681.08	863.09
13	711.43	902.83
14	745.11	939.78
15	784.43	970.67
16	808.51	1014.49
17	835.24	1051.68

*** 1.763 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	135.38	825.67
3	171.23	790.81
4	218.36	774.13
5	267.54	765.07
6	312.94	744.13
7	362.64	738.70
8	411.11	726.44
9	459.83	715.16
10	509.22	722.93
11	558.62	730.63
12	606.86	743.80
13	650.95	767.38
14	699.47	779.45
15	747.66	792.79
16	794.78	809.50
17	824.58	849.65
18	863.14	881.48
19	895.79	919.34
20	899.86	969.18
21	910.76	1017.98
22	918.98	1067.30
23	919.35	1076.91

*** 1.795 ***

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	322.22	897.59
2	357.77	862.43
3	393.25	827.20
4	428.99	792.23
5	469.92	763.52
6	519.46	770.29
7	566.31	787.76
8	608.34	814.84
9	653.97	835.29
10	693.05	866.48
11	738.43	887.47
12	776.61	919.75
13	819.76	945.01
14	851.26	983.84
15	892.54	1012.06
16	934.52	1039.21
17	979.40	1061.26
18	1013.81	1097.54

19	1051.82	1120.00

*** 1.817 ***

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	211.11	861.00
2	251.81	831.96
3	290.15	799.85
4	339.91	795.01
5	381.71	767.57
6	431.48	762.84
7	477.45	782.51
8	527.28	786.59
9	575.48	799.90
10	613.39	832.51
11	645.41	870.90
12	684.92	901.55
13	726.96	928.62
14	767.07	958.47
15	796.97	998.55
16	841.12	1022.02
17	888.46	1038.10
18	921.28	1075.82
19	921.37	1077.59

*** 1.818 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	211.11	861.00
2	251.40	831.39
3	301.34	828.88
4	350.69	820.88
5	399.78	811.34
6	447.25	795.64
7	490.99	771.42
8	536.16	749.99
9	586.04	753.58
10	636.01	751.86
11	684.64	740.24
12	734.37	745.39
13	774.71	774.94
14	815.21	804.25
15	843.45	845.51
16	879.14	880.53
17	908.04	921.33
18	921.36	969.53
19	944.35	1013.93
20	956.26	1062.49
21	957.37	1089.64

*** 1.821 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	192.21	826.99
3	227.68	791.75
4	268.81	763.33
5	309.57	734.36
6	359.51	732.04
7	409.42	735.13
8	458.11	723.75
9	506.43	710.90
10	556.17	715.96
11	604.48	703.07
12	654.11	709.14
13	694.61	738.45
14	710.25	785.94
15	746.47	820.41
16	789.16	846.44
17	818.25	887.10

18	861.03	912.99
19	909.67	924.59
20	939.86	964.44
21	954.78	1012.16
22	983.82	1052.86
23	1000.93	1099.84
24	1009.07	1106.96
***	1.838	***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	193.35	828.26
3	235.84	801.91
4	282.77	784.65
5	331.67	774.22
6	381.62	776.31
7	431.43	771.87
8	480.66	763.17
9	530.54	766.68
10	580.37	770.84
11	630.21	774.85
12	673.44	799.96
13	721.60	813.42
14	771.54	815.82
15	819.38	830.34
16	843.91	873.91
17	861.29	920.79
18	885.47	964.56
19	888.74	1014.45
20	891.01	1064.40
21	891.67	1067.64
***	1.842	***

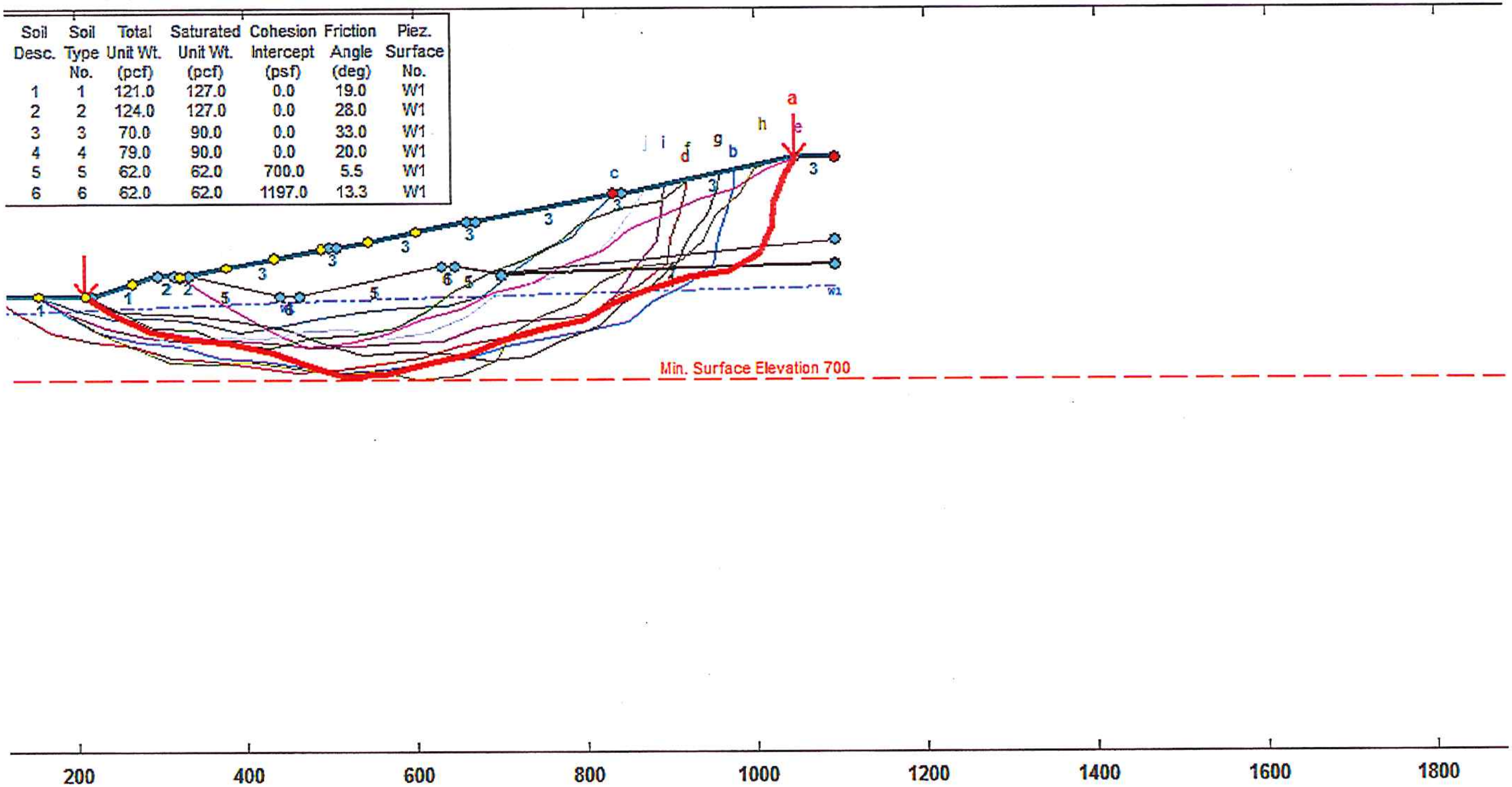
Failure Surface Specified By 18 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	211.11	861.00
2	246.50	825.67
3	281.91	790.38
4	326.32	767.39
5	374.02	782.38
6	423.82	778.01
7	471.46	793.20
8	521.39	795.83
9	568.07	777.90
10	616.29	791.11
11	658.60	817.74
12	690.26	856.45
13	732.57	883.08
14	777.92	904.14
15	813.74	939.03
16	837.56	982.99
17	856.55	1029.24
18	871.20	1060.78
***	1.843	***

MATLOCK BEND LANDFILL EXPANSION Janbu Random

\waste\active projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\random analysis section c\matlock bend landfillrandom.pl2 Run By: Jo K

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
1	1	121.0	127.0	0.0	19.0	W1
2	2	124.0	127.0	0.0	28.0	W1
3	3	70.0	90.0	0.0	33.0	W1
4	4	79.0	90.0	0.0	20.0	W1
5	5	62.0	62.0	700.0	5.5	W1
6	6	62.0	62.0	1197.0	13.3	W1



PCSTABL5M/si FSmin=1.73

Safety Factors Are Calculated By The Modified Janbu Method

** PCSTABL5M **
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 2/13/2014
Time of Run: 08:26AM
Run By: Jo K House
Input Data Filename: F:MATLOCK BEND LANDFILLRANDOMw equake.dat
Output Filename: F:MATLOCK BEND LANDFILLRANDOMw equake.OUT
Unit: ENGLISH
Plotted Output Filename: F:MATLOCK BEND LANDFILLRANDOMw equake.PLT
PROBLEM DESCRIPTION MATLOCK BEND LANDFILL EXPANSION
Janbu Random W SEISMIC

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

A Horizontal Earthquake Loading Coefficient

Of0.180 Has Been Assigned
A Vertical Earthquake Loading Coefficient
Of0.000 Has Been Assigned
Cavitation Pressure = 0.0 (psf)
A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Irregular Surfaces, Has Been Specified.
100 Trial Surfaces Have Been Generated.
10 Surfaces Initiate From Each Of 10 Points Equally Spaced
Along The Ground Surface Between X = 100.00 ft.
and X = 600.00 ft.
Each Surface Terminates Between X = 832.00 ft.
and X =1094.00 ft.
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =700.00 ft.
50.00 ft. Line Segments Define Each Trial Failure Surface.
Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.
* * Safety Factors Are Calculated By The Modified Janbu Method * *
Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	190.94	825.67
3	226.78	790.81
4	273.92	774.13
5	323.09	765.07
6	368.49	744.13
7	418.20	738.70
8	466.67	726.44
9	515.38	715.16
10	564.78	722.93
11	614.18	730.63
12	662.41	743.80
13	706.50	767.38
14	755.02	779.45
15	803.21	792.79
16	850.34	809.50
17	880.14	849.65
18	918.70	881.48
19	951.35	919.34
20	955.41	969.18
21	966.31	1017.98
22	974.54	1067.30
23	975.64	1095.76

*** 0.878 ***

Individual data on the 44 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	28.8	49944.4	0.0	0.0	0.0	0.0	8990.0	0.0	0.0
2	6.6	25820.5	0.0	2058.9	0.0	0.0	4647.7	0.0	0.0
3	29.1	177805.5	0.0	55930.9	0.0	0.0	32005.0	0.0	0.0
4	6.8	58006.2	0.0	24023.8	0.0	0.0	10441.1	0.0	0.0
5	47.1	553189.6	0.0	*******	0.0	0.0	99574.1	0.0	0.0
6	21.1	320450.5	0.0	89113.8	0.0	0.0	57681.1	0.0	0.0
7	20.0	330654.7	0.0	91071.9	0.0	0.0	59517.8	0.0	0.0
8	8.1	135110.8	0.0	38652.9	0.0	0.0	24319.9	0.0	0.0
9	0.9	15103.7	0.0	4776.1	0.0	0.0	2718.7	0.0	0.0
10	8.0	136497.9	0.0	43368.1	0.0	0.0	24569.6	0.0	0.0
11	36.5	671634.8	0.0	*******	0.0	0.0	*******	0.0	0.0
12	49.7	995152.1	0.0	*******	0.0	0.0	*******	0.0	0.0
13	22.8	476634.2	0.0	*******	0.0	0.0	85794.2	0.0	0.0
14	9.0	194110.8	0.0	68153.4	0.0	0.0	34939.9	0.0	0.0
15	14.0	310740.2	0.0	*******	0.0	0.0	55933.2	0.0	0.0
16	2.7	60495.6	0.0	21258.8	0.0	0.0	10889.2	0.0	0.0
17	30.3	722131.6	0.0	*******	0.0	0.0	*******	0.0	0.0
18	10.0	250458.9	0.0	85743.9	0.0	0.0	45082.6	0.0	0.0
19	8.4	214016.6	0.0	73220.7	0.0	0.0	38523.0	0.0	0.0

20	49.4	********	0.0	*******	0.0	0.0	*******	0.0	0.0
21	49.4	********	0.0	*******	0.0	0.0	*******	0.0	0.0
22	15.8	440783.2	0.0	*******	0.0	0.0	79341.0	0.0	0.0
23	16.0	444939.4	0.0	*******	0.0	0.0	80089.1	0.0	0.0
24	14.0	385403.5	0.0	*******	0.0	0.0	69372.6	0.0	0.0
25	2.4	65786.8	0.0	18037.0	0.0	0.0	11841.6	0.0	0.0
26	7.6	203834.9	0.0	60921.2	0.0	0.0	36690.3	0.0	0.0
27	30.0	768468.5	0.0	*******	0.0	0.0	*******	0.0	0.0
28	6.5	160229.6	0.0	43844.9	0.0	0.0	28841.3	0.0	0.0
29	48.5	********	0.0	*******	0.0	0.0	*******	0.0	0.0
30	48.2	********	0.0	*******	0.0	0.0	*******	0.0	0.0
31	28.8	678105.0	0.0	*******	0.0	0.0	*******	0.0	0.0
32	10.0	230463.6	0.0	41047.1	0.0	0.0	41483.4	0.0	0.0
33	8.3	189537.6	0.0	32651.8	0.0	0.0	34116.8	0.0	0.0
34	29.8	611359.4	0.0	*******	0.0	0.0	*******	0.0	0.0
35	24.4	424659.5	0.0	18763.0	0.0	0.0	76438.7	0.0	0.0
36	14.2	226670.6	0.0	0.0	0.0	0.0	40800.7	0.0	0.0
37	26.6	371226.2	0.0	0.0	0.0	0.0	66820.7	0.0	0.0
38	1.0	12280.2	0.0	0.0	0.0	0.0	2210.4	0.0	0.0
39	5.0	61229.3	0.0	0.0	0.0	0.0	11021.3	0.0	0.0
40	1.9	21193.4	0.0	0.0	0.0	0.0	3814.8	0.0	0.0
41	2.2	19992.6	0.0	0.0	0.0	0.0	3598.7	0.0	0.0
42	10.9	74168.2	0.0	0.0	0.0	0.0	13350.3	0.0	0.0
43	8.2	29578.4	0.0	0.0	0.0	0.0	5324.1	0.0	0.0
44	1.1	1085.5	0.0	0.0	0.0	0.0	195.4	0.0	0.0

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	135.38	825.67
3	171.23	790.81
4	218.36	774.13
5	267.54	765.07
6	312.94	744.13
7	362.64	738.70
8	411.11	726.44
9	459.83	715.16
10	509.22	722.93
11	558.62	730.63
12	606.86	743.80
13	650.95	767.38
14	699.47	779.45
15	747.66	792.79
16	794.78	809.50
17	824.58	849.65
18	863.14	881.48
19	895.79	919.34
20	899.86	969.18
21	910.76	1017.98
22	918.98	1067.30
23	919.35	1076.91

*** 0.886 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	211.11	861.00
2	246.97	826.16
3	284.97	793.65
4	333.56	781.88
5	382.34	770.91
6	429.13	753.29
7	473.02	729.32
8	517.43	706.35
9	567.05	712.52
10	613.13	731.92
11	659.72	750.08
12	702.56	775.86
13	748.52	795.54
14	795.27	813.29
15	832.45	846.72

16	875.27	872.54
17	920.38	894.10
18	968.81	906.52
19	1006.18	939.74
20	1019.54	987.92
21	1022.47	1037.84
22	1035.06	1086.23
23	1047.35	1119.78

*** 0.902 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	193.35	828.26
3	235.84	801.91
4	282.77	784.65
5	331.67	774.22
6	381.62	776.31
7	431.43	771.87
8	480.66	763.17
9	530.54	766.68
10	580.37	770.84
11	630.21	774.85
12	673.44	799.96
13	721.60	813.42
14	771.54	815.82
15	819.38	830.34
16	843.91	873.91
17	861.29	920.79
18	885.47	964.56
19	888.74	1014.45
20	891.01	1064.40
21	891.67	1067.64

*** 0.912 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	198.64	835.63
3	244.89	816.64
4	294.88	817.72
5	344.22	809.60
6	391.04	792.04
7	439.67	803.67
8	487.40	818.54
9	535.82	831.00
10	585.40	837.48
11	635.02	843.64
12	681.08	863.09
13	711.43	902.83
14	745.11	939.78
15	784.43	970.67
16	808.51	1014.49
17	835.24	1051.68

*** 0.930 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	211.11	861.00
2	251.40	831.39
3	301.34	828.88
4	350.69	820.88
5	399.78	811.34
6	447.25	795.64
7	490.99	771.42
8	536.16	749.99
9	586.04	753.58
10	636.01	751.86
11	684.64	740.24
12	734.37	745.39

13	774.71	774.94
14	815.21	804.25
15	843.45	845.51
16	879.14	880.53
17	908.04	921.33
18	921.36	969.53
19	944.35	1013.93
20	956.26	1062.49
21	957.37	1089.64

*** 0.944 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	192.21	826.99
3	227.68	791.75
4	268.81	763.33
5	309.57	734.36
6	359.51	732.04
7	409.42	735.13
8	458.11	723.75
9	506.43	710.90
10	556.17	715.96
11	604.48	703.07
12	654.11	709.14
13	694.61	738.45
14	710.25	785.94
15	746.47	820.41
16	789.16	846.44
17	818.25	887.10
18	861.03	912.99
19	909.67	924.59
20	939.86	964.44
21	954.78	1012.16
22	983.82	1052.86
23	1000.93	1099.84
24	1009.07	1106.96

*** 0.959 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	145.37	839.98
3	180.77	804.67
4	226.48	784.41
5	265.24	752.82
6	303.18	720.26
7	352.78	713.91
8	401.43	725.46
9	450.60	716.41
10	499.02	728.88
11	548.78	724.01
12	598.49	718.65
13	638.00	749.29
14	685.22	765.74
15	728.68	790.46
16	768.20	821.09
17	816.27	834.83
18	852.38	869.42
19	865.14	917.77
20	876.76	966.40
21	881.33	1016.19
22	909.34	1057.61
23	952.45	1082.93
24	962.90	1091.49

*** 0.962 ***

Failure Surface Specified By 26 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00

2	135.41	825.70
3	177.40	798.55
4	218.45	770.01
5	268.24	765.40
6	311.87	740.98
7	361.81	743.45
8	411.44	737.44
9	449.38	704.88
10	499.38	705.45
11	548.60	714.25
12	598.60	714.07
13	648.25	708.14
14	690.77	734.43
15	729.26	766.35
16	772.31	791.77
17	819.05	809.55
18	849.33	849.33
19	855.38	898.96
20	880.47	942.22
21	909.05	983.24
22	943.35	1019.63
23	989.96	1037.71
24	1039.56	1044.02
25	1070.85	1083.02
26	1080.20	1120.00
***	0.966	***

Failure Surface Specified By 21 Coordinate Points

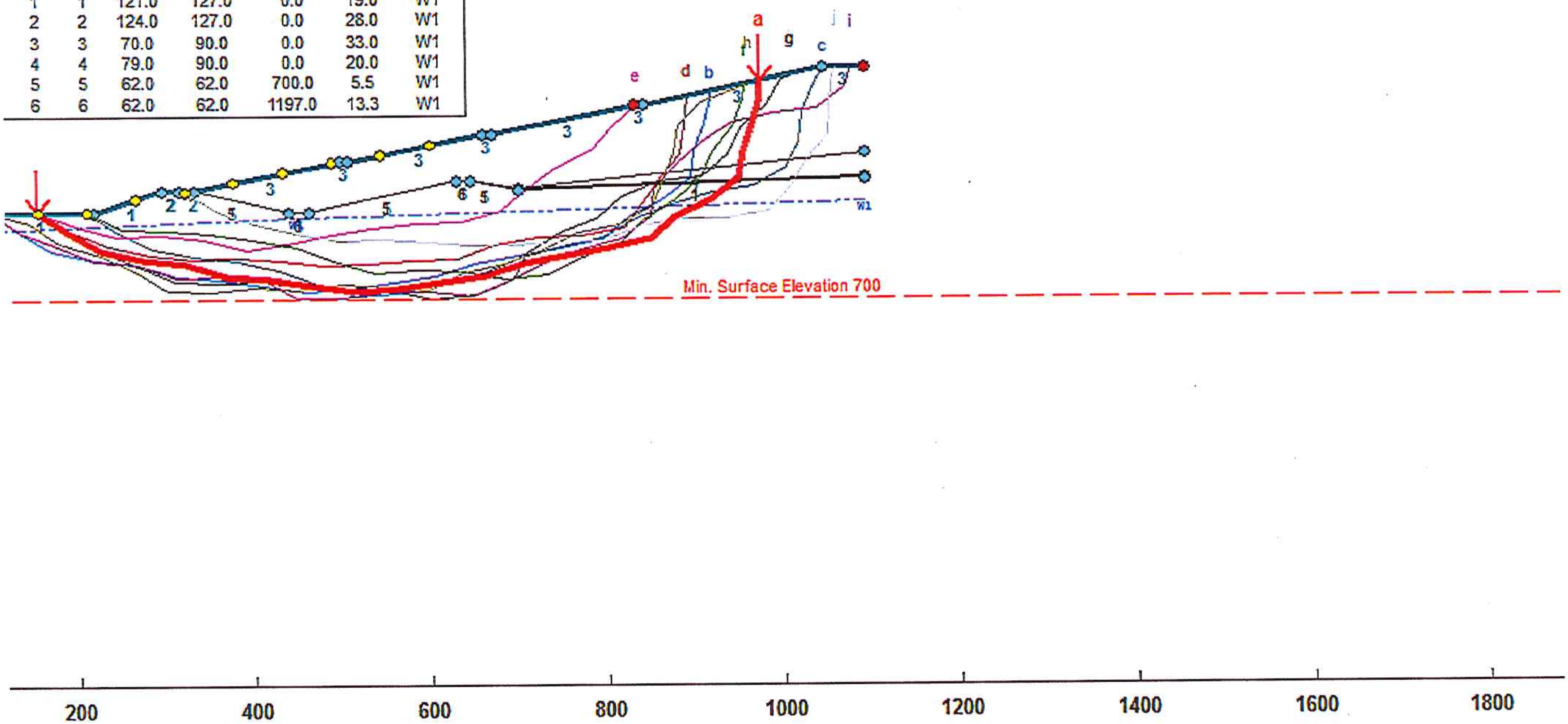
Point No.	X-Surf (ft)	Y-Surf (ft)
1	322.22	897.59
2	358.91	863.63
3	401.17	836.90
4	448.04	819.47
5	496.89	808.85
6	546.86	810.74
7	596.64	806.13
8	645.85	797.23
9	695.74	800.56
10	745.58	804.52
11	795.43	808.35
12	838.76	833.30
13	886.97	846.58
14	936.92	848.78
15	984.82	863.13
16	1009.51	906.61
17	1026.97	953.46
18	1051.22	997.19
19	1054.49	1047.08
20	1056.76	1097.03
21	1061.46	1120.00
***	0.973	***

MATLOCK BEND LANDFILL EXPANSION Janbu Random W SEISMIC

ve projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\random analysis section c\final random\matlock bend landfill\randomw equake.pl2 Ru

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
1	1	121.0	127.0	0.0	19.0	W1
2	2	124.0	127.0	0.0	28.0	W1
3	3	70.0	90.0	0.0	33.0	W1
4	4	79.0	90.0	0.0	20.0	W1
5	5	62.0	62.0	700.0	5.5	W1
6	6	62.0	62.0	1197.0	13.3	W1

Load	Value
Horiz Eqk	0.180 g<



PCSTABL5M/si FSmin=0.88

Safety Factors Are Calculated By The Modified Janbu Method

** PCSTABL5M **
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 2/13/2014
Time of Run: 08:29AM
Run By: Jo K House
Input Data Filename: F:MATLOCK BEND LANDFILLRANDOMw Yield Acc.dat
Output Filename: F:MATLOCK BEND LANDFILLRANDOMw Yield Acc.OUT
Unit: ENGLISH
Plotted Output Filename: F:MATLOCK BEND LANDFILLRANDOMw Yield Acc.PLT
PROBLEM DESCRIPTION MATLOCK BEND LANDFILL EXPANSION
Janbu Random W SEISMIC

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

A Horizontal Earthquake Loading Coefficient

Of0.130 Has Been Assigned
A Vertical Earthquake Loading Coefficient
Of0.000 Has Been Assigned
Cavitation Pressure = 0.0 (psf)
A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Irregular Surfaces, Has Been Specified.
100 Trial Surfaces Have Been Generated.
10 Surfaces Initiate From Each Of 10 Points Equally Spaced
Along The Ground Surface Between X = 100.00 ft.
and X = 600.00 ft.
Each Surface Terminates Between X = 832.00 ft.
and X =1094.00 ft.
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =700.00 ft.
50.00 ft. Line Segments Define Each Trial Failure Surface.
Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.
* * Safety Factors Are Calculated By The Modified Janbu Method * *
Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	190.94	825.67
3	226.78	790.81
4	273.92	774.13
5	323.09	765.07
6	368.49	744.13
7	418.20	738.70
8	466.67	726.44
9	515.38	715.16
10	564.78	722.93
11	614.18	730.63
12	662.41	743.80
13	706.50	767.38
14	755.02	779.45
15	803.21	792.79
16	850.34	809.50
17	880.14	849.65
18	918.70	881.48
19	951.35	919.34
20	955.41	969.18
21	966.31	1017.98
22	974.54	1067.30
23	975.64	1095.76

*** 1.022 ***

Individual data on the 44 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	28.8	49944.4	0.0	0.0	0.0	0.0	6492.8	0.0	0.0
2	6.6	25820.5	0.0	2058.9	0.0	0.0	3356.7	0.0	0.0
3	29.1	177805.5	0.0	55930.9	0.0	0.0	23114.7	0.0	0.0
4	6.8	58006.2	0.0	24023.8	0.0	0.0	7540.8	0.0	0.0
5	47.1	553189.6	0.0	*******	0.0	0.0	71914.6	0.0	0.0
6	21.1	320450.5	0.0	89113.8	0.0	0.0	41658.6	0.0	0.0
7	20.0	330654.7	0.0	91071.9	0.0	0.0	42985.1	0.0	0.0
8	8.1	135110.8	0.0	38652.9	0.0	0.0	17564.4	0.0	0.0
9	0.9	15103.7	0.0	4776.1	0.0	0.0	1963.5	0.0	0.0
10	8.0	136497.9	0.0	43368.1	0.0	0.0	17744.7	0.0	0.0
11	36.5	671634.8	0.0	*******	0.0	0.0	87312.5	0.0	0.0
12	49.7	995152.1	0.0	*******	0.0	0.0	*******	0.0	0.0
13	22.8	476634.2	0.0	*******	0.0	0.0	61962.4	0.0	0.0
14	9.0	194110.8	0.0	68153.4	0.0	0.0	25234.4	0.0	0.0
15	14.0	310740.2	0.0	*******	0.0	0.0	40396.2	0.0	0.0
16	2.7	60495.6	0.0	21258.8	0.0	0.0	7864.4	0.0	0.0
17	30.3	722131.6	0.0	*******	0.0	0.0	93877.1	0.0	0.0
18	10.0	250458.9	0.0	85743.9	0.0	0.0	32559.7	0.0	0.0
19	8.4	214016.6	0.0	73220.7	0.0	0.0	27822.2	0.0	0.0

20	49.4	********	0.0	*******	0.0	0.0	*******	0.0	0.0
21	49.4	********	0.0	*******	0.0	0.0	*******	0.0	0.0
22	15.8	440783.2	0.0	*******	0.0	0.0	57301.8	0.0	0.0
23	16.0	444939.4	0.0	*******	0.0	0.0	57842.1	0.0	0.0
24	14.0	385403.5	0.0	*******	0.0	0.0	50102.4	0.0	0.0
25	2.4	65786.8	0.0	18037.0	0.0	0.0	8552.3	0.0	0.0
26	7.6	203834.9	0.0	60921.2	0.0	0.0	26498.5	0.0	0.0
27	30.0	768468.5	0.0	*******	0.0	0.0	99900.9	0.0	0.0
28	6.5	160229.6	0.0	43844.9	0.0	0.0	20829.8	0.0	0.0
29	48.5	********	0.0	*******	0.0	0.0	*******	0.0	0.0
30	48.2	********	0.0	*******	0.0	0.0	*******	0.0	0.0
31	28.8	678105.0	0.0	*******	0.0	0.0	88153.6	0.0	0.0
32	10.0	230463.6	0.0	41047.1	0.0	0.0	29960.3	0.0	0.0
33	8.3	189537.6	0.0	32651.8	0.0	0.0	24639.9	0.0	0.0
34	29.8	611359.4	0.0	*******	0.0	0.0	79476.7	0.0	0.0
35	24.4	424659.5	0.0	18763.0	0.0	0.0	55205.7	0.0	0.0
36	14.2	226670.6	0.0	0.0	0.0	0.0	29467.2	0.0	0.0
37	26.6	371226.2	0.0	0.0	0.0	0.0	48259.4	0.0	0.0
38	1.0	12280.2	0.0	0.0	0.0	0.0	1596.4	0.0	0.0
39	5.0	61229.3	0.0	0.0	0.0	0.0	7959.8	0.0	0.0
40	1.9	21193.4	0.0	0.0	0.0	0.0	2755.1	0.0	0.0
41	2.2	19992.6	0.0	0.0	0.0	0.0	2599.0	0.0	0.0
42	10.9	74168.2	0.0	0.0	0.0	0.0	9641.9	0.0	0.0
43	8.2	29578.4	0.0	0.0	0.0	0.0	3845.2	0.0	0.0
44	1.1	1085.5	0.0	0.0	0.0	0.0	141.1	0.0	0.0

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	135.38	825.67
3	171.23	790.81
4	218.36	774.13
5	267.54	765.07
6	312.94	744.13
7	362.64	738.70
8	411.11	726.44
9	459.83	715.16
10	509.22	722.93
11	558.62	730.63
12	606.86	743.80
13	650.95	767.38
14	699.47	779.45
15	747.66	792.79
16	794.78	809.50
17	824.58	849.65
18	863.14	881.48
19	895.79	919.34
20	899.86	969.18
21	910.76	1017.98
22	918.98	1067.30
23	919.35	1076.91

*** 1.033 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	211.11	861.00
2	246.97	826.16
3	284.97	793.65
4	333.56	781.88
5	382.34	770.91
6	429.13	753.29
7	473.02	729.32
8	517.43	706.35
9	567.05	712.52
10	613.13	731.92
11	659.72	750.08
12	702.56	775.86
13	748.52	795.54
14	795.27	813.29
15	832.45	846.72

16	875.27	872.54
17	920.38	894.10
18	968.81	906.52
19	1006.18	939.74
20	1019.54	987.92
21	1022.47	1037.84
22	1035.06	1086.23
23	1047.35	1119.78
***	1.042	***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	193.35	828.26
3	235.84	801.91
4	282.77	784.65
5	331.67	774.22
6	381.62	776.31
7	431.43	771.87
8	480.66	763.17
9	530.54	766.68
10	580.37	770.84
11	630.21	774.85
12	673.44	799.96
13	721.60	813.42
14	771.54	815.82
15	819.38	830.34
16	843.91	873.91
17	861.29	920.79
18	885.47	964.56
19	888.74	1014.45
20	891.01	1064.40
21	891.67	1067.64
***	1.066	***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	198.64	835.63
3	244.89	816.64
4	294.88	817.72
5	344.22	809.60
6	391.04	792.04
7	439.67	803.67
8	487.40	818.54
9	535.82	831.00
10	585.40	837.48
11	635.02	843.64
12	681.08	863.09
13	711.43	902.83
14	745.11	939.78
15	784.43	970.67
16	808.51	1014.49
17	835.24	1051.68
***	1.075	***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	211.11	861.00
2	251.40	831.39
3	301.34	828.88
4	350.69	820.88
5	399.78	811.34
6	447.25	795.64
7	490.99	771.42
8	536.16	749.99
9	586.04	753.58
10	636.01	751.86
11	684.64	740.24
12	734.37	745.39

13	774.71	774.94
14	815.21	804.25
15	843.45	845.51
16	879.14	880.53
17	908.04	921.33
18	921.36	969.53
19	944.35	1013.93
20	956.26	1062.49
21	957.37	1089.64

*** 1.094 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	155.56	861.00
2	192.21	826.99
3	227.68	791.75
4	268.81	763.33
5	309.57	734.36
6	359.51	732.04
7	409.42	735.13
8	458.11	723.75
9	506.43	710.90
10	556.17	715.96
11	604.48	703.07
12	654.11	709.14
13	694.61	738.45
14	710.25	785.94
15	746.47	820.41
16	789.16	846.44
17	818.25	887.10
18	861.03	912.99
19	909.67	924.59
20	939.86	964.44
21	954.78	1012.16
22	983.82	1052.86
23	1000.93	1099.84
24	1009.07	1106.96

*** 1.107 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	145.37	839.98
3	180.77	804.67
4	226.48	784.41
5	265.24	752.82
6	303.18	720.26
7	352.78	713.91
8	401.43	725.46
9	450.60	716.41
10	499.02	728.88
11	548.78	724.01
12	598.49	718.65
13	638.00	749.29
14	685.22	765.74
15	728.68	790.46
16	768.20	821.09
17	816.27	834.83
18	852.38	869.42
19	865.14	917.77
20	876.76	966.40
21	881.33	1016.19
22	909.34	1057.61
23	952.45	1082.93
24	962.90	1091.49

*** 1.115 ***

Failure Surface Specified By 26 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00

2	135.41	825.70
3	177.40	798.55
4	218.45	770.01
5	268.24	765.40
6	311.87	740.98
7	361.81	743.45
8	411.44	737.44
9	449.38	704.88
10	499.38	705.45
11	548.60	714.25
12	598.60	714.07
13	648.25	708.14
14	690.77	734.43
15	729.26	766.35
16	772.31	791.77
17	819.05	809.55
18	849.33	849.33
19	855.38	898.96
20	880.47	942.22
21	909.05	983.24
22	943.35	1019.63
23	989.96	1037.71
24	1039.56	1044.02
25	1070.85	1083.02
26	1080.20	1120.00
***	1.122	***

Failure Surface Specified By 19 Coordinate Points

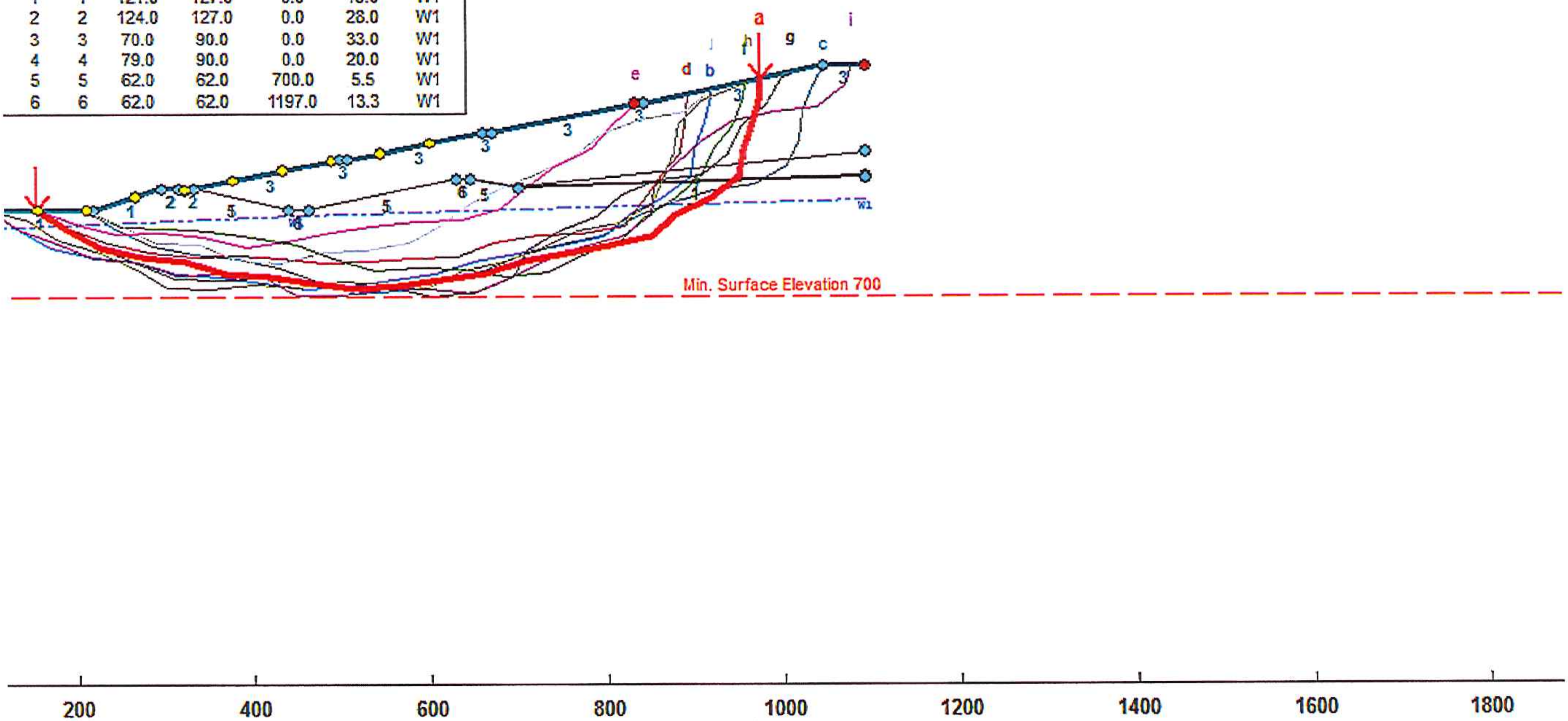
Point No.	X-Surf (ft)	Y-Surf (ft)
1	211.11	861.00
2	251.81	831.96
3	290.15	799.85
4	339.91	795.01
5	381.71	767.57
6	431.48	762.84
7	477.45	782.51
8	527.28	786.59
9	575.48	799.90
10	613.39	832.51
11	645.41	870.90
12	684.92	901.55
13	726.96	928.62
14	767.07	958.47
15	796.97	998.55
16	841.12	1022.02
17	888.46	1038.10
18	921.28	1075.82
19	921.37	1077.59
***	1.127	***

MATLOCK BEND LANDFILL EXPANSION Janbu Random W SEISMIC

e projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\random analysis section c\final random\matlock bend landfillrandomw yield acc.pl2 R

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
1	1	121.0	127.0	0.0	19.0	W1
2	2	124.0	127.0	0.0	28.0	W1
3	3	70.0	90.0	0.0	33.0	W1
4	4	79.0	90.0	0.0	20.0	W1
5	5	62.0	62.0	700.0	5.5	W1
6	6	62.0	62.0	1197.0	13.3	W1

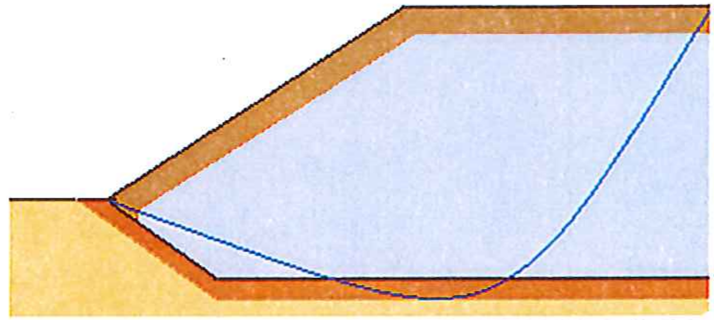
Load	Value
Horiz Eqk	0.130 g<



PCSTABL5M/si FSmin=1.02

Safety Factors Are Calculated By The Modified Janbu Method

SPENCER'S SLOPE STABILITY ANALYSES



```
                    ** PCSTABL5M **
                          by
                   Purdue University
              --Slope Stability Analysis--
          Simplified Janbu, Simplified Bishop
             or Spencer`s Method of Slices
Run Date:                  2/12/2014
Time of Run:               09:22PM
Run By:                    Jo K House
Input Data Filename:       F:SPENCER METHOD.in
Output Filename:           F:SPENCER METHOD.OUT
Unit:                      ENGLISH
Plotted Output Filename:   F:SPENCER METHOD.PLT
PROBLEM DESCRIPTION    MATLOCK BEND LANDFILL EXPANSION
```

SPENCER METHOD

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

Trial Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	143.63	836.58
3	188.90	815.34
4	235.56	797.37
5	283.38	782.78
6	332.12	771.64
7	381.53	763.99
8	431.37	759.89
9	481.36	759.35
10	531.27	762.38
11	580.84	768.96
12	629.81	779.05
13	677.93	792.61
14	724.97	809.56
15	770.68	829.83
16	814.83	853.30
17	857.19	879.85
18	897.56	909.36
19	935.71	941.68
20	971.47	976.63
21	1004.64	1014.04
22	1035.07	1053.72
23	1062.58	1095.46
24	1076.35	1120.00

Spencer`s Theta (deg)	FOS (Moment) (Equil.)	FOS (Force) (Equil.)
0.50	1.993	1.543
0.75	1.988	1.546
18.23	1.391	1.868
11.95	1.677	1.731
8.77	1.786	1.673
10.56	1.726	1.705
11.12	1.707	1.716
10.96	1.713	1.713

Factor Of Safety For The Preceding Specified Surface = 1.713

Spencer`s Theta = 10.96

Factor Of Safety Is Calculated By Spencer`s Method of Slices

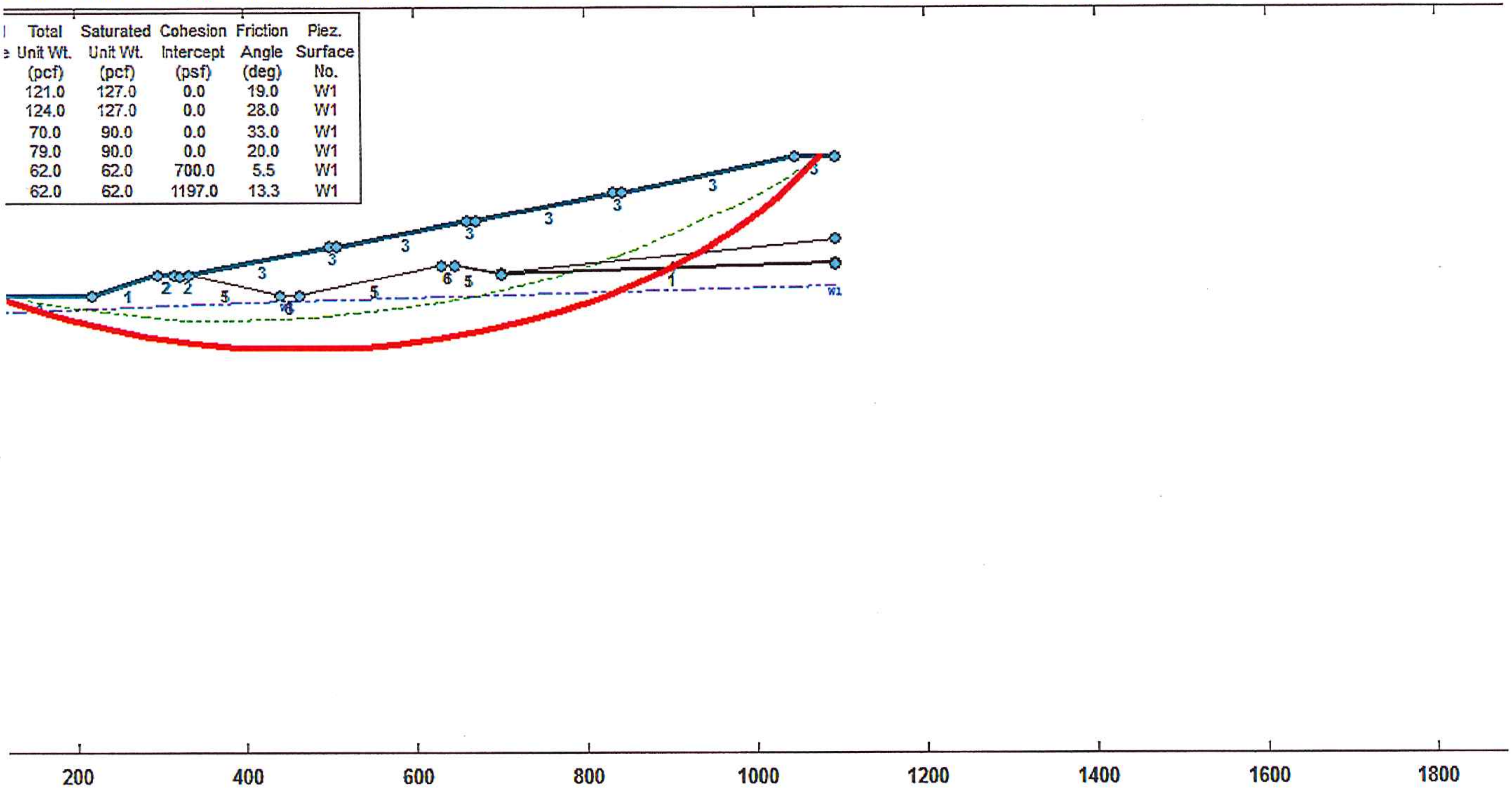
*** Line of Thrust ***

Slice No.	X Coord.	Y Coord.	L/H	Side Force (Lbs)
1	143.63	853.01	0.673	67485.
2	156.70	848.03	0.576	105740.
3	188.90	838.87	0.515	232265.
4	220.00	833.04	0.515	365371.
5	235.56	829.76	0.452	447829.
6	283.38	821.41	0.347	743204.
7	295.00	819.97	0.332	816496.
8	315.00	816.15	0.326	989294.
9	324.00	814.78	0.334	1067510.
10	332.00	813.67	0.327	1137854.
11	332.12	813.66	0.327	1138682.
12	381.53	813.41	0.326	1412545.
13	431.37	815.72	0.326	1624565.
14	441.00	816.64	0.326	1651952.
15	450.00	817.49	0.326	1677738.
16	464.00	818.80	0.325	1718556.
17	481.36	820.35	0.325	1771002.
18	497.00	822.50	0.324	1796367.
19	507.00	823.86	0.331	1812988.
20	531.27	827.11	0.329	1854848.
21	580.84	836.17	0.326	1869942.
22	629.81	847.76	0.324	1812971.
23	630.00	847.81	0.324	1812454.
24	646.00	852.56	0.324	1769427.
25	660.00	856.72	0.324	1732740.
26	670.00	859.68	0.331	1707274.
27	677.93	862.02	0.331	1687541.
28	700.00	869.88	0.332	1602681.
29	724.97	878.78	0.333	1511307.
30	770.68	898.15	0.337	1296494.
31	814.83	920.15	0.346	1061764.
32	832.00	930.07	0.351	961346.
33	836.37	932.59	0.356	937211.
34	842.00	935.84	0.363	906996.
35	857.19	944.65	0.368	828759.
36	897.56	972.24	0.392	606514.
37	898.27	972.68	0.392	603150.
38	899.65	973.10	0.389	599277.
39	933.08	999.01	0.419	424364.
40	935.71	1000.19	0.416	417293.
41	971.47	1024.44	0.406	284237.
42	1004.64	1050.01	0.393	164292.
43	1035.07	1076.45	0.367	68614.
44	1048.00	1089.87	0.354	35059.
45	1062.58	1105.42	0.406	9700.
46	1076.35	1756.13	0.000	-32.

MATLOCK BEND LANDFILL EXPANSION SPENCER METHOD

2008\1 solidwaste\active projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\spencer method\spencer method.plt Run By: Jo K House 2/'

Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
121.0	127.0	0.0	19.0	W1
124.0	127.0	0.0	28.0	W1
70.0	90.0	0.0	33.0	W1
79.0	90.0	0.0	20.0	W1
62.0	62.0	700.0	5.5	W1
62.0	62.0	1197.0	13.3	W1



PCSTABL5M/si FSmin=1.71
Factor Of Safety Is Calculated By Spencer`s Method of Slices

```
                    ** PCSTABL5M **
                          by
                   Purdue University
             --Slope Stability Analysis--
          Simplified Janbu, Simplified Bishop
             or Spencer`s Method of Slices
Run Date:                 2/12/2014
Time of Run:              10:12PM
Run By:                   Jo K House
Input Data Filename:      F:SPENCER METHOD SEISMIC.in
Output Filename:          F:SPENCER METHOD SEISMIC.OUT
Unit:                     ENGLISH
Plotted Output Filename:  F:SPENCER METHOD SEISMIC.PLT
PROBLEM DESCRIPTION   MATLOCK BEND LANDFILL EXPANSION
```

SPENCER METHOD SEISMIC

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

A Horizontal Earthquake Loading Coefficient Of 0.180 Has Been Assigned
A Vertical Earthquake Loading Coefficient
Of0.000 Has Been Assigned
Cavitation Pressure = 0.0 (psf)
Trial Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	143.63	836.58
3	188.90	815.34
4	235.56	797.37
5	283.38	782.78
6	332.12	771.64
7	381.53	763.99
8	431.37	759.89
9	481.36	759.35
10	531.27	762.38
11	580.84	768.96
12	629.81	779.05
13	677.93	792.61
14	724.97	809.56
15	770.68	829.83
16	814.83	853.30
17	857.19	879.85
18	897.56	909.36
19	935.71	941.68
20	971.47	976.63
21	1004.64	1014.04
22	1035.07	1053.72
23	1062.58	1095.46
24	1076.35	1120.00

Spencer`s Theta (deg)	FOS (Moment) (Equil.)	FOS (Force) (Equil.)
0.50	0.902	0.810
0.75	0.901	0.811
15.05	0.796	0.896
9.79	0.851	0.860
7.32	0.869	0.846
8.85	0.858	0.854
9.14	0.856	0.856

Factor Of Safety For The Preceding Specified Surface = 0.856
Spencer`s Theta = 9.14
Factor Of Safety Is Calculated By Spencer`s Method of Slices
*** Line of Thrust ***

Slice No.	X Coord.	Y Coord.	L/H	Side Force (Lbs)
1	143.63	852.30	0.644	86581.
2	156.70	847.37	0.554	134174.
3	188.90	838.19	0.501	285705.
4	220.00	832.53	0.506	433188.
5	235.56	829.28	0.445	523177.
6	283.38	820.84	0.342	836668.
7	295.00	819.38	0.327	912108.
8	315.00	813.97	0.309	1140061.
9	324.00	812.10	0.313	1242528.
10	332.00	810.63	0.304	1334402.

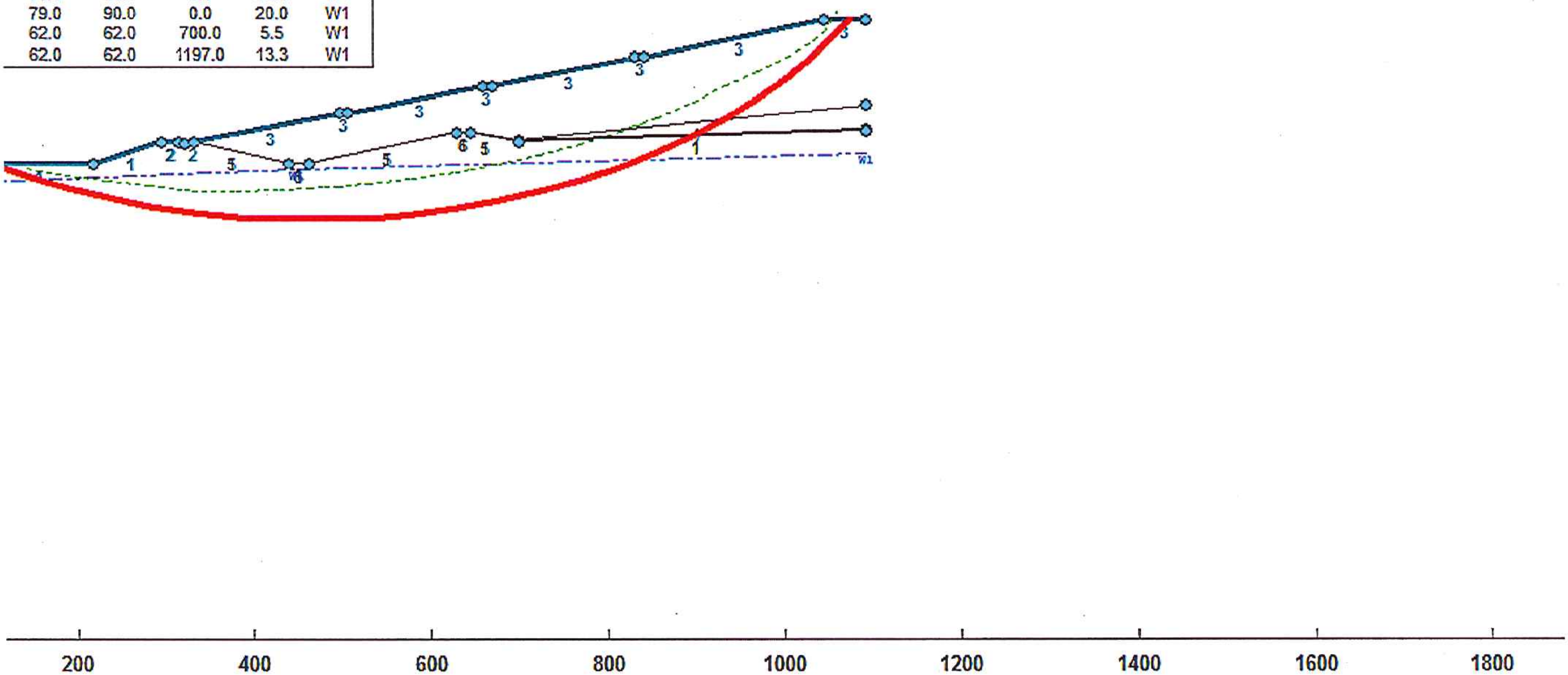
11	332.12	810.62	0.304	1335241.
12	381.53	810.87	0.309	1598196.
13	431.37	813.37	0.312	1784326.
14	441.00	814.30	0.312	1804748.
15	450.00	815.17	0.313	1823969.
16	464.00	816.49	0.313	1854522.
17	481.36	818.05	0.313	1894297.
18	497.00	820.19	0.312	1906334.
19	507.00	821.54	0.319	1914514.
20	531.27	824.76	0.317	1936164.
21	580.84	833.70	0.314	1906850.
22	629.81	845.13	0.312	1806076.
23	630.00	845.19	0.312	1805387.
24	646.00	849.89	0.311	1748284.
25	660.00	854.00	0.311	1699881.
26	670.00	856.94	0.318	1666383.
27	677.93	859.26	0.317	1640478.
28	700.00	867.06	0.318	1538933.
29	724.97	875.91	0.319	1430925.
30	770.68	895.23	0.323	1192641.
31	814.83	917.19	0.331	946767.
32	832.00	927.08	0.335	846077.
33	836.37	929.58	0.340	822208.
34	842.00	932.80	0.346	792417.
35	857.19	941.60	0.350	715277.
36	897.56	970.02	0.379	497940.
37	898.27	970.56	0.379	494184.
38	899.65	971.39	0.379	487885.
39	933.08	1001.01	0.433	319992.
40	935.71	1002.43	0.432	313576.
41	971.47	1026.29	0.422	215561.
42	1004.64	1052.31	0.418	125002.
43	1035.07	1081.29	0.445	52207.
44	1048.00	1099.26	0.555	26602.
45	1062.58	1138.03	1.735	7511.
46	1076.35	1895.19	0.000	290.

MATLOCK BEND LANDFILL EXPANSION SPENCER METHOD SEISMIC

\1 solidwaste\active projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\spencer method\spencer method seismic.plt Run By: Jo K House

Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
121.0	127.0	0.0	19.0	W1
124.0	127.0	0.0	28.0	W1
70.0	90.0	0.0	33.0	W1
79.0	90.0	0.0	20.0	W1
62.0	62.0	700.0	5.5	W1
62.0	62.0	1197.0	13.3	W1

Load	Value
Horiz Eqk	0.180 g<



PCSTABL5M/si FSmin=0.86
Factor Of Safety Is Calculated By Spencer`s Method of Slices

** PCSTABL5M **
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 2/12/2014
Time of Run: 10:17PM
Run By: Jo K House
Input Data Filename: F:SPENCER METHOD yield accelaeration.in
Output Filename: F:SPENCER METHOD yield accelaeration.OUT
Unit: ENGLISH
Plotted Output Filename: F:SPENCER METHOD yield accelaeration.PLT
PROBLEM DESCRIPTION MATLOCK BEND LANDFILL EXPANSION

SPENCER METHOD YIELD ACCELERATION

BOUNDARY COORDINATES
16 Top Boundaries
29 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	895.00	30.00	880.00	1
2	30.00	880.00	50.00	880.00	1
3	50.00	880.00	95.00	861.00	1
4	95.00	861.00	220.00	861.00	1
5	220.00	861.00	295.00	900.00	1
6	295.00	900.00	315.00	900.00	2
7	315.00	900.00	324.00	897.00	2
8	324.00	897.00	332.00	900.00	2
9	332.00	900.00	497.00	952.00	3
10	497.00	952.00	507.00	951.00	3
11	507.00	951.00	660.00	1001.00	3
12	660.00	1001.00	670.00	1000.00	3
13	670.00	1000.00	832.00	1052.00	3
14	832.00	1052.00	842.00	1051.00	3
15	842.00	1051.00	1048.00	1120.00	3
16	1048.00	1120.00	1094.00	1120.00	3
17	332.00	900.00	441.00	861.00	5
18	441.00	861.00	464.00	861.00	6
19	464.00	861.00	630.00	916.00	5
20	630.00	916.00	646.00	916.00	6
21	646.00	916.00	700.00	901.00	5
22	700.00	901.00	1094.00	966.00	4
23	700.00	901.00	1094.00	921.00	1
24	332.00	899.00	441.00	860.90	1
25	441.00	860.90	464.00	860.90	1
26	464.00	860.90	630.00	915.90	1
27	630.00	915.90	646.00	915.90	1
28	646.00	915.90	700.00	899.90	1
29	700.00	899.90	1094.00	919.90	1

ISOTROPIC SOIL PARAMETERS
6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	121.0	127.0	0.0	19.0	0.00	0.0	1
2	124.0	127.0	0.0	28.0	0.00	0.0	1
3	70.0	90.0	0.0	33.0	0.00	0.0	1
4	79.0	90.0	0.0	20.0	0.00	0.0	1
5	62.0	62.0	700.0	5.5	0.00	0.0	1
6	62.0	62.0	1197.0	13.3	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	820.00
2	450.00	850.00
3	1094.00	878.00

A Horizontal Earthquake Loading Coefficient
Of0.130 Has Been Assigned
A Vertical Earthquake Loading Coefficient
Of0.000 Has Been Assigned
Cavitation Pressure = 0.0 (psf)
Trial Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	861.00
2	143.63	836.58
3	188.90	815.34
4	235.56	797.37
5	283.38	782.78
6	332.12	771.64
7	381.53	763.99
8	431.37	759.89
9	481.36	759.35
10	531.27	762.38
11	580.84	768.96
12	629.81	779.05
13	677.93	792.61
14	724.97	809.56
15	770.68	829.83
16	814.83	853.30
17	857.19	879.85
18	897.56	909.36
19	935.71	941.68
20	971.47	976.63
21	1004.64	1014.04
22	1035.07	1053.72
23	1062.58	1095.46
24	1076.35	1120.00

Spencer`s Theta (deg)	FOS (Moment) (Equil.)	FOS (Force) (Equil.)
0.50	1.068	0.937
0.75	1.066	0.939
15.90	0.906	1.050
10.23	0.990	1.003
7.65	1.017	0.984
9.32	1.001	0.996
9.60	0.998	0.998

Factor Of Safety For The Preceding Specified Surface = 0.998

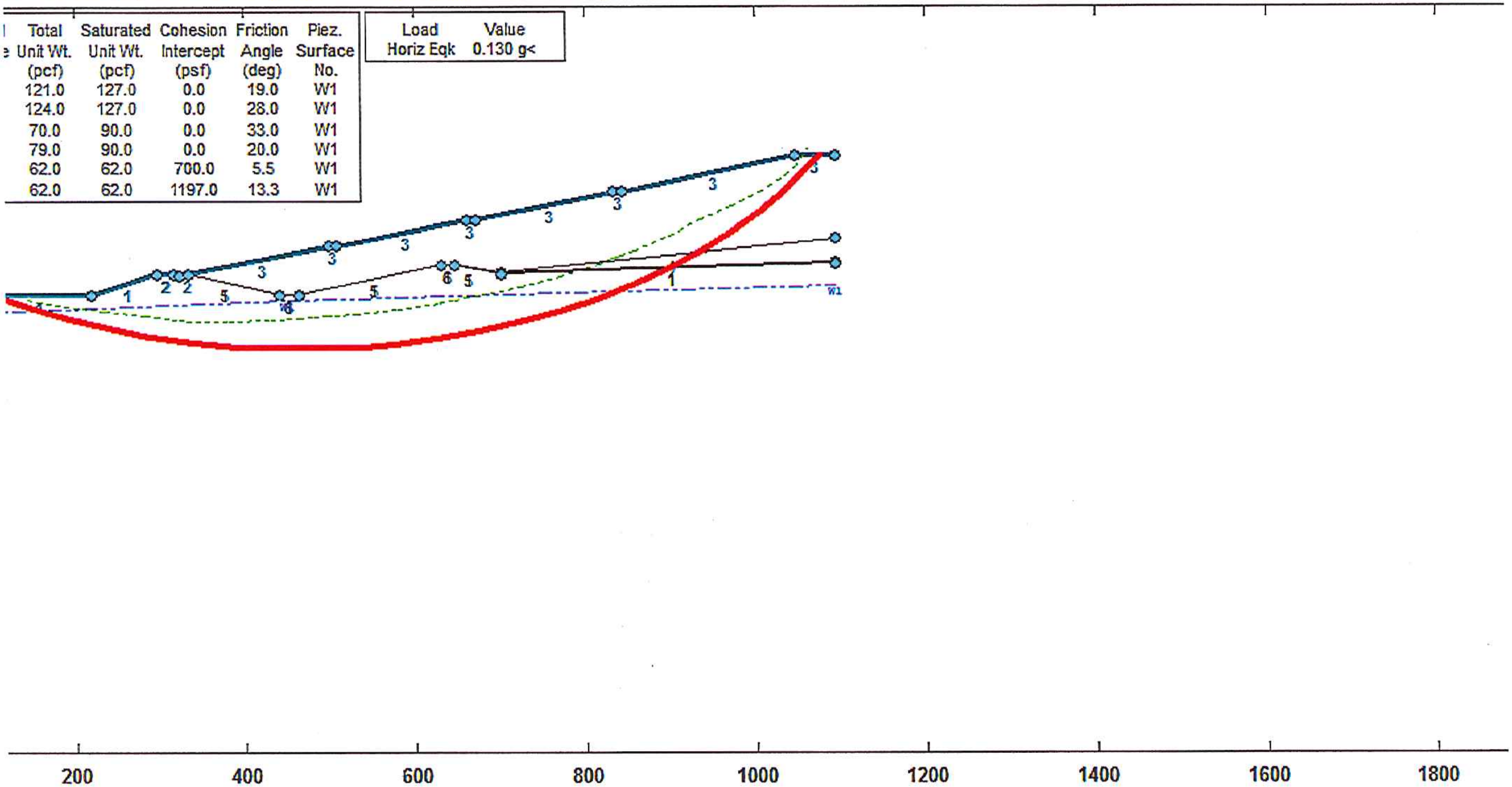
Spencer`s Theta = 9.60
Factor Of Safety Is Calculated By Spencer`s Method of Slices
*** Line of Thrust ***

Slice No.	X Coord.	Y Coord.	L/H	Side Force (Lbs)
1	143.63	852.48	0.651	79984.
2	156.70	847.53	0.559	124390.
3	188.90	838.35	0.504	267183.
4	220.00	832.63	0.508	409275.
5	235.56	829.37	0.446	496337.
6	283.38	820.93	0.343	802230.
7	295.00	819.47	0.328	876519.
8	315.00	814.49	0.313	1086134.
9	324.00	812.76	0.318	1180515.
10	332.00	811.38	0.309	1265202.

11	332.12	811.37	0.309	1266032.
12	381.53	811.49	0.313	1530283.
13	431.37	813.92	0.315	1722456.
14	441.00	814.85	0.315	1744687.
15	450.00	815.71	0.316	1765613.
16	464.00	817.02	0.316	1798830.
17	481.36	818.57	0.315	1841881.
18	497.00	820.71	0.315	1857530.
19	507.00	822.06	0.322	1867995.
20	531.27	825.28	0.320	1895105.
21	580.84	834.24	0.317	1878188.
22	629.81	845.69	0.314	1790002.
23	630.00	845.75	0.314	1789363.
24	646.00	850.46	0.314	1736423.
25	660.00	854.58	0.314	1691493.
26	670.00	857.52	0.320	1660378.
27	677.93	859.84	0.320	1636307.
28	700.00	867.65	0.321	1539859.
29	724.97	876.51	0.322	1436984.
30	770.68	895.83	0.326	1206405.
31	814.83	917.81	0.334	964982.
32	832.00	927.72	0.339	864978.
33	836.37	930.23	0.343	841188.
34	842.00	933.46	0.349	811471.
35	857.19	942.28	0.354	734524.
36	897.56	970.58	0.382	517213.
37	898.27	971.09	0.382	513551.
38	899.65	971.83	0.381	507768.
39	933.08	1000.64	0.431	339024.
40	935.71	1002.02	0.429	332442.
41	971.47	1026.08	0.420	227903.
42	1004.64	1052.18	0.417	132010.
43	1035.07	1081.15	0.443	55134.
44	1048.00	1098.98	0.550	28126.
45	1062.58	1137.17	1.700	7932.
46	1076.35	1959.45	0.000	275.

MATLOCK BEND LANDFILL EXPANSION SPENCER METHOD YIELD ACC

lidwaste\active projects\matlock bend landfill\final submittal\global stability report\appendix b stability and deformation results\stabl output\spencer method\spencer method yield accelaeration.plt Run By: Jo K H

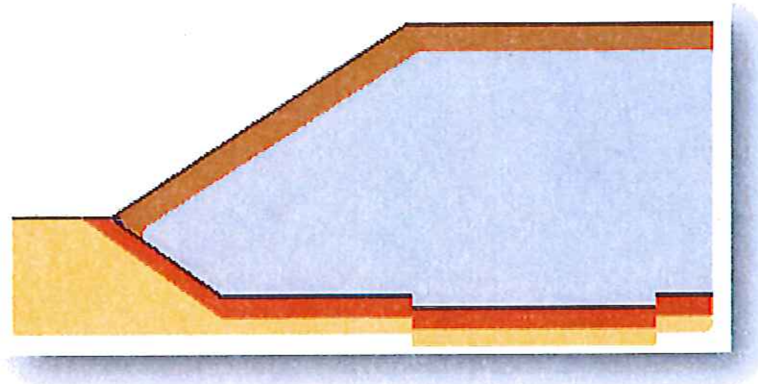


I	Total	Saturated	Cohesion	Friction	Piez.
e	Unit Wt.	Unit Wt.	Intercept	Angle	Surface
	(pcf)	(pcf)	(psf)	(deg)	No.
	121.0	127.0	0.0	19.0	W1
	124.0	127.0	0.0	28.0	W1
	70.0	90.0	0.0	33.0	W1
	79.0	90.0	0.0	20.0	W1
	62.0	62.0	700.0	5.5	W1
	62.0	62.0	1197.0	13.3	W1

Load	Value
Horiz Eqk	0.130 g<

PCSTABL5M/si FSmin=1.00
Factor Of Safety Is Calculated By Spencer`s Method of Slices

MAKDISI AND SEED
NEWMARK DEFORMATION ANALYSIS



SANTEK WasteServices

Evaluation of Earthquake Forces

DEFORMATION ANALYSIS

Step 1.

Develop a model of the landfill slope configurations to be used for psuedo-static analysis.

Step 2.

Determine the maximum undrained shear strengths of the soil and waste layers within the landfill model.

Step 3.

Determine the dynamic shear strength parameters and enter them into the Psuedostatic model for the dynamic analysis.

It should be noted that the static shear strength may be used in most cases for the dynamic shear strength.

However, for saturated soft clays multiply the maximum undrained shear strengths by 0.80 and

Step 4.

Perform pseudo-static analyses on the landfill model substituting different values for the horizontal

SANTEK WasteServices

Evaluation of Earthquake Forces on the Slope Stability of Solid Waste Landfills

Step 5. JANBU RANDOM

Determine the maximum crest acceleration (u_{max}) induced in the embankment and the natural period (T_O) of the embankment. This can be accomplished by several different methods which include the following:

I. a finite element analysis of the embankment section (Clough and Chopra, 1966; Idress and Seed, 1967)

II. by a shear slice analysis (Ambraseys, 1960; Seed and Martin, 1966).

III. a simplified approach developed by Makdisi and Seed that lends itself to hand calculations is presented in the following paragraphs.

Step 5a.

Determine the following embankment and subsurface soil properties;

Yield acceleration	k_y	0.13	g
Height of embankment	h	205	ft
Unit weight of waste fill materials	γ	90	pcf
Mass density, $\rho = \gamma / 32.2$ ft/sec			
Maximum shear wave velocity			

(obtain from crosshole velocity survey or from approximations using the following relationships):

Gmax = 65 N (taken from Eval. Of Liquifaction Potential by Seed, Idriss, Jour. Of Eng. Div. ASCE, pg 476)

$G_{max} = 120\ N^{0.8}$ See NavFaq 7.1-89 (Note: G_{max} is in TSF)	Gmax =	1422.72	TSF
$(G_{max} / \rho)^{1/2} = V_{max}$	V_{max}=	873.80	FPS
Maximum Horizontal Acceleration, a_{max} (obtained from Simplified Procedure)	a_{max} =	0.18	g

Step 5b. First Iteration for determining crest acceleration

Perform First Iteration

Step one: determine G/G_{max}, shear strain, and damping

I. Assume value of v_s	v_s	656	fps	FROM USGS MAP
II. Calculate $G/G_{max} = (V_S/V_{max})^2$	$(VS/Vmax)^2$ =	0.564		
III. From **Figure 1**: for calculated G/G_{max}, determine:	shear strain, γ	.024	%	
	damping, λ	16.7	%	

Step two: Calculate the natural frequencies (ω) and the associated natural periods (T)

$\omega_1 = 2.4\ (V_S / h)$	ω_1	7.68	rad/sec
$T_1 = 2\pi / \omega_1$	T_1	0.82	sec
$\omega_2 = 5.52\ (V_S / h)$	ω_2	17.66	rad/sec
$T_2 = 2\pi / \omega_2$	T_2	0.36	sec
$\omega_3 = 8.65\ (V_S / h)$	ω_3	27.68	rad/sec
$T_3 = 2\pi / \omega_3$	T_3	0.227	sec

Step three: Determine the spectral accelerations for the three frequencies in step one and the periods (T) determined in step two to enter **Figure 2**, to determine the spectral

From Figure 2[1]	**S_{a1} / max accel.**[1] =	0.8	S_{a1}	0.14
	S_{a2} / max accel.[1] =	1.6	S_{a2}	0.29
	S_{a3} / max accel.[1] =	1.4	S_{a3}	0.25

frequencies

$\phi_1 = 1.6$ $\phi_2 = 1.06$ $\phi_3 = 0.86$

$u_{1max} = \phi 1\ (S_{a1})$	u_{1max}	0.2304	g
$u_{2max} = \phi 2\ (S_{a2})$	u_{2max}	0.305	g
$u_{3max} = \phi 3\ (S_{a3})$	u_{3max}	0.217	g

Step five: use the following equation to determine the maximum crest acceleration (u_{max})

$[(u_{1max})^2 + (u_{2max})^2 + (u_{3max})^2]^{1/2} = u_{max}$	u_{max}	0.44	g

Step 5b. First Iteration for determining crest acceleration (continued)

Calculate the average equivalent shear strain (γ_{ave})eq from the following equation

$(\gamma_{ave})eq = 0.65 * 0.3 * h / V_s^2\ (S_{a1})$	(γ_{ave})eq	0.043	%

***Note:** If the shear strain calculated from the above equation does not match the value determined in Step One it is necessary to perform a second iteration.*

***Note:** The shear strain obtained from the above calculation is generally different from the shear strain determined from using assumed velocity values and entering Figure 1 as was done in step III of 5b. If there is a difference between the assumed shear strain values and the calculated values, it will be necessary to perform a new iteration using the value obtained from the above equation to determine a new set of modulus and damping parameters. Generally, it will take three iterations for the strain compatible properties to converge.*

Step 5c. Perform a second iteration so as to determine crest acceleration

From **Figure 1:** for shear strain calculated in step 5b, determine G/G_{max} and damping (λ)

for shear strain:	0.043	%
G/G_{max}	0.42	
λ	12	%
thus $G/G_{max} = (V_S/V_{max})^2$ and so V_S/V_{max} =	0.648	
$\therefore V_S$	566	fps

Therefore the frequencies are as follows:

$\omega_1 = 2.4\ (V_S / h)$	ω_1	6.63	rad/sec
$T_1 = 2\pi / \omega_1$	T_1	**0.95**	**sec**
$\omega_2 = 5.52\ (V_S / h)$	ω_2	15.25	rad/sec
$T_2 = 2\pi / \omega_2$	T_2	**0.41**	**sec**
$\omega_3 = 8.65\ (V_S / h)$	ω_3	23.89	rad/sec
$T_3 = 2\pi / \omega_3$	T_3	**0.263**	**sec**

Spectral accelerations (S_{an}) from Figure 2 are as follows:

1 From Figure 2	**S_{a1} / max accel.[1] =**	0.8	S_{a1}	0.144
	S_{a2} / max accel.[1] =	1.7	S_{a2}	0.306
	S_{a3} / max accel.[1] =	1.6	S_{a3}	0.288

Determine the Crest accelerations (u) for each of the natural frequencies (ω):

$\phi_1 = 1.6$ $\phi_2 = 1.06$ $\phi_3 = 0.86$

$u_{1max} = \phi 1\ (S_{a1})$	u_{1max}	0.230	g
$u_{2max} = \phi 2\ (S_{a2})$	u_{2max}	0.324	g
$u_{3max} = \phi 3\ (S_{a3})$	u_{3max}	0.248	g

Calculate the maximum crest acceleration (u_{max})

$[(u_{1max})^2 + (u_{2max})^2 + (u_{3max})^2]^{1/2} = u_{max}$ u_{max} 0.469 g

Calculate maximum shear strain (γ_{ave})eq

$(\gamma_{ave})eq = 0.65 * 0.3 * h / V_s^2\ (S_{a1})$ **(γ_{ave})eq** **0.058** **%**

Step 5d. Perform a third iteration so as to determine crest acceleration

From **Figure 1**: for shear strain calculated in step 5c, determine G/G_{max} and damping (λ)

for shear strain	**0.058**	**%**
G/G_{max}	0.44	
λ	12.8	%
thus $G/G_{max} = (V_S/V_{max})^2$ and so V_S/V_{max} =	0.663	
$\therefore V_S$	579.61	fps

Therefore the frequencies are as follows:

$\omega_1 = 2.4\ (V_S / h)$	ω_1	6.79	rad/sec
$T_1 = 2\pi / \omega_1$	T_1	**0.93**	**sec**
$\omega_2 = 5.52\ (V_S / h)$	ω_2	15.61	rad/sec
$T_2 = 2\pi / \omega_2$	T_2	**0.40**	**sec**
$\omega_3 = 8.65\ (V_S / h)$	ω_3	24.46	rad/sec
$T_3 = 2\pi / \omega_3$	T_3	**0.257**	**sec**

Spectral accelerations (S_{an}) from **Figure 2** are as follows:

1 From Figure 2	**S_{a1} / max accel.[1] =**	0.75	S_{a1}	0.135
	S_{a2} / max accel.[1] =	1.5	S_{a2}	0.270
	S_{a3} / max accel.[1] =	1.6	S_{a3}	0.288

Determine the Crest accelerations (u) for each of the natural frequencies (ω):

$\phi_1 = 1.6$ $\phi_2 = 1.06$ $\phi_3 = 0.86$

$u_{1max} = \phi 1\ (S_{a1})$	u_{1max}	0.216	g
$u_{2max} = \phi 2\ (S_{a2})$	u_{2max}	0.286	g
$u_{3max} = \phi 3\ (S_{a3})$	u_{3max}	0.248	g

Calculate the maximum crest acceleration (u_{max})

$[(u_{1max})^2 + (u_{2max})^2 + (u_{3max})^2]^{1/2} = u_{max}$ u_{max} 0.436 g

Calculate maximum shear strain (γ_{ave})eq

$(\gamma_{ave})eq = 0.65 * 0.3 * h / V_s^2\ (S_{a1})$ **(γ_{ave})eq** **0.052** **%**

T_O	**0.93**	**sec**
G/G_{max}	0.44	
u_{max}	**0.436**	**g**
λ	12.8	%
V_S	579.6	fps
(γ_{ave})eq	**0.052**	**%**

Step 6.

crest acceleration (u_{max}) determined in Step 5 and entering into **Figure 3**

Calculate y/h

height of embankment	h	205	ft
depth of failure plane	y	237	ft
	y/h	1.16	
k_{max} / u_{max} from **Figure 3**		0.35	
	k_{max}	**0.153**	**g**

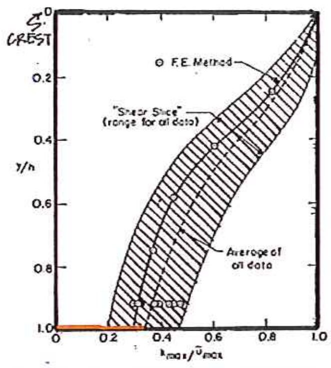


FIGURE 3: VARIATION OF " MAXIMUM ACCELERATION RATIO " WITH DEPTH OF SLIDING MASS

Step 7.

values of k_{max} and T_O

Calculate k_y/k_{max}

k_y	0.13	
k_{max}	0.153	g
k_y/k_{max}	0.852	
From **Figure 4**, $U/k_{max}(T_O)$	0.001	
TOTAL DEFORMATION - U	**0.005**	**ft**
TOTAL DEFORMATION - U	**0.05**	**inches**

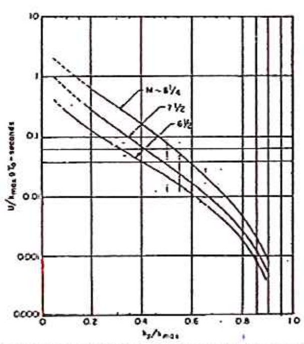


FIGURE 4: VARIATION OF AVERAGE NORMALIZED DISPLACEMENT WITH YIELD ACCELERATION

SANTEK WasteServices

Evaluation of Earthquake Forces on the Slope Stability of Solid Waste Landfills

Step 5. MODIFIED BISHOP

Determine the maximum crest acceleration (u_{max}) induced in the embankment and the natural period (T_O) of the embankment. This can be accomplished by several different methods which include the following:

I. a finite element analysis of the embankment section (Clough and Chopra, 1966; Idress and Seed, 1967)

II. by a shear slice analysis (Ambraseys, 1960; Seed and Martin, 1966).

III. a simplified approach developed by Makdisi and Seed that lends itself to hand calculations is presented in the following paragraphs.

Step 5a.

Determine the following embankment and subsurface soil properties;

Yield acceleration	k_y	0.14	g
Height of embankment	h	205	ft
Unit weight of waste fill materials	γ	90	pcf
Mass density, $\rho = \gamma / 32.2$ ft/sec			
Maximum shear wave velocity			

(obtain from crosshole velocity survey or from approximations using the following relationships):

Gmax = 65 N (taken from Eval. Of Liquifaction Potential by Seed, Idriss, Jour. Of Eng. Div. ASCE, pg 476)

$G_{max} = 120\ N^{0.8}$ See NavFaq 7.1-89 (Note: G_{max} is in TSF)	Gmax =	1422.72	TSF
$(G_{max} / \rho)^{1/2} = V_{max}$	V_{max}=	873.80	FPS
Maximum Horizontal Acceleration, a_{max} (obtained from Simplified Procedure)	a_{max} =	0.18	g

Step 5b. First Iteration for determining crest acceleration

Perform First Iteration

Step one: determine G/G_{max}, shear strain, and damping

I. Assume value of v_s	V_s	656	fps	FROM USGS MAP
II. Calculate $G/G_{max} = (V_S/V_{max})^2$	$(VS/Vmax)^2$ =	0.564		
III. From **Figure 1**: for calculated G/G_{max}, determine:	shear strain, γ	.024	%	
	damping, λ	16.7	%	

Step two: Calculate the natural frequencies (ω) and the associated natural periods (T)

$\omega_1 = 2.4\ (V_S / h)$	ω_1	7.68	rad/sec
$T_1 = 2\pi / \omega_1$	T_1	0.82	sec
$\omega_2 = 5.52\ (V_S / h)$	ω_2	17.66	rad/sec
$T_2 = 2\pi / \omega_2$	T_2	0.36	sec
$\omega_3 = 8.65\ (V_S / h)$	ω_3	27.68	rad/sec
$T_3 = 2\pi / \omega_3$	T_3	0.227	sec

Step three: Determine the spectral accelerations for the three frequencies in step one and the periods (T) determined in step two to enter **Figure 2**, to determine the spectral frequencies

[1] From Figure 2	**S_{a1} / max accel.[1] =**	0.8	S_{a1}	0.14
	S_{a2} / max accel.[1] =	1.6	S_{a2}	0.29
	S_{a3} / max accel.[1] =	1.4	S_{a3}	0.25

$\phi_1 = 1.6$ $\phi_2 = 1.06$ $\phi_3 = 0.86$

$u_{1max} = \phi 1\ (S_{a1})$	u_{1max}	0.2304	g
$u_{2max} = \phi 2\ (S_{a2})$	u_{2max}	0.305	g
$u_{3max} = \phi 3\ (S_{a3})$	u_{3max}	0.217	g

Step five: use the following equation to determine the maximum crest acceleration (u_{max})

$[(u_{1max})^2 + (u_{2max})^2 + (u_{3max})^2]^{1/2} = u_{max}$ u_{max} 0.44 g

Step 5b. First Iteration for determining crest acceleration (continued)

Calculate the average equivalent shear strain (γ_{ave})eq from the following equation

$(\gamma_{ave})eq = 0.65 * 0.3 * h / V_s^2\ (S_{a1})$ **(γ_{ave})eq 0.043 %**

Note: If the shear strain calculated from the above equation does not match the value determined in Step One it is necessary to perform a second iteration.

Note: The shear strain obtained from the above calculation is generally different from the shear strain determined from using assumed velocity values and entering Figure 1 as was done in step III of 5b. If there is a difference between the assumed shear strain values and the calculated values, it will be necessary to perform a new iteration using the value obtained from the above equation to determine a new set of modulus and damping parameters. Generally, it will take three iterations for the strain compatible properties to converge.

Step 5c. Perform a second iteration so as to determine crest acceleration

From **Figure 1:** for shear strain calculated in step 5b, determine G/G_{max} and damping (λ)

for shear strain:	0.043	%
G/G_{max}	0.42	
λ	12	%
thus $G/G_{max} = (V_S/V_{max})^2$ and so V_S/V_{max} =	0.648	
$\therefore V_S$	566	fps

Therefore the frequencies are as follows:

$\omega_1 = 2.4\ (V_S / h)$	ω_1	6.63	rad/sec
$T_1 = 2\pi / \omega_1$	T_1	**0.95**	**sec**
$\omega_2 = 5.52\ (V_S / h)$	ω_2	15.25	rad/sec
$T_2 = 2\pi / \omega_2$	T_2	**0.41**	**sec**
$\omega_3 = 8.65\ (V_S / h)$	ω_3	23.89	rad/sec
$T_3 = 2\pi / \omega_3$	T_3	**0.263**	**sec**

Spectral accelerations (S_{an}) from Figure 2 are as follows:

[1] **From Figure 2**	S_{a1} / max accel.[1] =	0.8	S_{a1}	0.144
	S_{a2} / max accel.[1] =	1.7	S_{a2}	0.306
	S_{a3} / max accel.[1] =	1.6	S_{a3}	0.288

Determine the Crest accelerations (u) for each of the natural frequencies (ω):

$\phi_1 = 1.6$ $\phi_2 = 1.06$ $\phi_3 = 0.86$

$u_{1max} = \phi 1\ (S_{a1})$	u_{1max}	0.230	g
$u_{2max} = \phi 2\ (S_{a2})$	u_{2max}	0.324	g
$u_{3max} = \phi 3\ (S_{a3})$	u_{3max}	0.248	g

Calculate the maximum crest acceleration (u_{max})

$[(u_{1max})^2 + (u_{2max})^2 + (u_{3max})^2]^{1/2} = u_{max}$ — u_{max} 0.469 g

Calculate maximum shear strain (γ_{ave})eq

$(\gamma_{ave})eq = 0.65 * 0.3 * h / V_s^2\ (S_{a1})$ — **(γ_{ave})eq 0.058 %**

Step 5d. Perform a third iteration so as to determine crest acceleration

From **Figure 1:** for shear strain calculated in step 5c, determine G/G_{max} and damping (λ)

for shear strain	**0.058**	%
G/G_{max}	0.44	
λ	12.8	%
thus $G/G_{max} = (V_S/V_{max})^2$ and so V_S/V_{max} =	0.663	
$\therefore V_S$	579.61	fps

Therefore the frequencies are as follows:

$\omega_1 = 2.4\ (V_S / h)$	ω_1	6.79	rad/sec
$T_1 = 2\pi / \omega_1$	T_1	**0.93**	**sec**
$\omega_2 = 5.52\ (V_S / h)$	ω_2	15.61	rad/sec
$T_2 = 2\pi / \omega_2$	T_2	**0.40**	**sec**
$\omega_3 = 8.65\ (V_S / h)$	ω_3	24.46	rad/sec
$T_3 = 2\pi / \omega_3$	T_3	**0.257**	**sec**

Spectral accelerations (S_{an}) from **Figure 2** are as follows:

[1] **From Figure 2**	S_{a1} / max accel.[1] =	0.75	S_{a1}	0.135
	S_{a2} / max accel.[1] =	1.5	S_{a2}	0.270
	S_{a3} / max accel.[1] =	1.6	S_{a3}	0.288

Determine the Crest accelerations (u) for each of the natural frequencies (ω):

$\phi_1 = 1.6$ $\phi_2 = 1.06$ $\phi_3 = 0.86$

$u_{1max} = \phi 1\ (S_{a1})$	u_{1max}	0.216	g
$u_{2max} = \phi 2\ (S_{a2})$	u_{2max}	0.286	g
$u_{3max} = \phi 3\ (S_{a3})$	u_{3max}	0.248	g

Calculate the maximum crest acceleration (u_{max})

$[(u_{1max})^2 + (u_{2max})^2 + (u_{3max})^2]^{1/2} = u_{max}$ — u_{max} 0.436 g

Calculate maximum shear strain (γ_{ave})eq

$(\gamma_{ave})eq = 0.65 * 0.3 * h / V_s^2\ (S_{a1})$ — **(γ_{ave})eq 0.052 %**

T_O	**0.93**	**sec**
G/G_{max}	0.44	
u_{max}	**0.436**	**g**
λ	12.8	%
V_S	579.6	fps
(γ_{ave})eq	**0.052**	**%**

SANTEK WasteServices

Step 6.

crest acceleration (u_{max}) determined in Step 5 and entering into **Figure 3**

Calculate y/h

height of embankment	h	205	ft
depth of failure plane	y	189	ft
	y/h	0.92	
k_{max} / u_{max}, from **Figure 3**		0.35	
	k_{max}	**0.153**	**g**

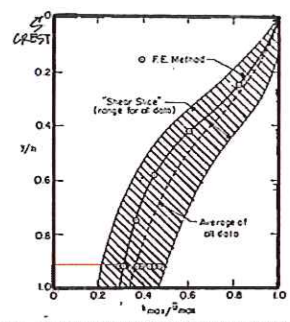


FIGURE 3: VARIATION OF " MAXIMUM ACCELERATION RATIO " WITH DEPTH OF SLIDING MASS

Step 7.

values of k_{max} and T_O

Calculate k_y/k_{max}

k_y	0.14	
k_{max}	0.153	g
k_y/k_{max}	0.918	
From **Figure 4**, $U/k_{max}(T_O)$	0.007	
'OTAL DEFORMATION - U	**0.032**	**ft**
'OTAL DEFORMATION - U	**0.38**	**inches**

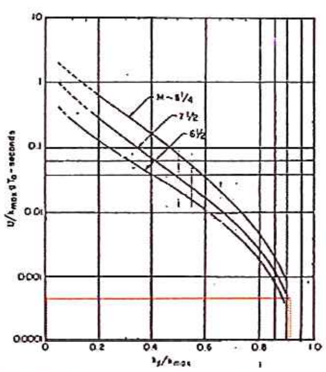


FIGURE 4: VARIATION OF AVERAGE NORMALIZED DISPLACEMENT WITH YIELD ACCELERATION

HOUSE ENGINEERING LLC

SANTEK WasteServices

Evaluation of Earthquake Forces on the Slope Stability of Solid Waste Landfills

Step 5. JANBU CIRCLE

Determine the maximum crest acceleration (u_{max}) induced in the embankment and the natural period (T_O) of the embankment. This can be accomplished by several different methods which include the following:

I. a finite element analysis of the embankment section (Clough and Chopra, 1966; Idress and Seed, 1967)

II. by a shear slice analysis (Ambraseys, 1960; Seed and Martin, 1966).

III. a simplified approach developed by Makdisi and Seed that lends itself to hand calculations is presented in the following paragraphs.

Step 5a.

Determine the following embankment and subsurface soil properties;

Yield acceleration	k_y	0.11	g
Height of embankment	h	205	ft
Unit weight of waste fill materials	γ	90	pcf

Mass density, $\rho = \gamma / 32.2$ ft/sec

Maximum shear wave velocity

(obtain from crosshole velocity survey or from approximations using the following relationships):

Gmax = 65 N (taken from Eval. Of Liquifaction Potential by Seed, Idriss, Jour. Of Eng. Div. ASCE, pg 476)

$G_{max} = 120\ N^{0.8}$ See NavFaq 7.1-89 (Note: G_{max} is in TSF)	Gmax =	1422.72	TSF
$(G_{max} / \rho)^{1/2} = V_{max}$	V_{max}=	873.80	FPS
Maximum Horizontal Acceleration, a_{max} (obtained from Simplified Procedure)	a_{max} =	0.18	g

Step 5b. First Iteration for determining crest acceleration

Perform First Iteration

Step one: determine G/G_{max}, shear strain, and damping

I. Assume value of v_s	v_s	656	fps	FROM USGS MAP
~~II. Calculate $G/G_{max} = (V_S/V_{max})^2$~~	$(VS/Vmax)^2$ =	0.564		
III. From **Figure 1**: for calculated G/G_{max}, determine:	shear strain, γ	.024	%	
	damping, λ	16.7	%	

Step two: Calculate the natural frequencies (ω) and the associated natural periods (T)

$\omega_1 = 2.4\ (V_S / h)$	ω_1	7.68	rad/sec
$T_1 = 2\pi / \omega_1$	T_1	0.82	sec
$\omega_2 = 5.52\ (V_S / h)$	ω_2	17.66	rad/sec
$T_2 = 2\pi / \omega_2$	T_2	0.36	sec
$\omega_3 = 8.65\ (V_S / h)$	ω_3	27.68	rad/sec
$T_3 = 2\pi / \omega_3$	T_3	0.227	sec

Step three: Determine the spectral accelerations for the three frequencies in step one and the periods (T) determined in step two to enter **Figure 2**, to determine the spectral

[1] From Figure 2	**S_{a1} / max accel.[1] =**	0.8	S_{a1}	0.14
	S_{a2} / max accel.[1] =	1.6	S_{a2}	0.29
	S_{a3} / max accel.[1] =	1.4	S_{a3}	0.25

frequencies

$\phi_1 = 1.6$ $\phi_2 = 1.06$ $\phi_3 = 0.86$

$u_{1max} = \phi 1\ (S_{a1})$	u_{1max}	0.2304	g
$u_{2max} = \phi 2\ (S_{a2})$	u_{2max}	0.305	g
$u_{3max} = \phi 3\ (S_{a3})$	u_{3max}	0.217	g

Step five: use the following equation to determine the maximum crest acceleration (u_{max})

$[(u_{1max})^2 + (u_{2max})^2 + (u_{3max})^2]^{1/2} = u_{max}$ u_{max} 0.44 g

Step 5b. First Iteration for determining crest acceleration (continued)

Calculate the average equivalent shear strain $(\gamma_{ave})eq$ from the following equation

$(\gamma_{ave})eq = 0.65 * 0.3 * h / V_s^2\ (S_{a1})$ $(\gamma_{ave})eq$ **0.043 %**

Note: If the shear strain calculated from the above equation does not match the value determined in Step One it is necessary to perform a second iteration.

Note: The shear strain obtained from the above calculation is generally different from the shear strain determined from using assumed velocity values and entering Figure 1 as was done in step III of 5b. If there is a difference between the assumed shear strain values and the calculated values, it will be necessary to perform a new iteration using the value obtained from the above equation to determine a new set of modulus and damping parameters. Generally, it will take three iterations for the strain compatible properties to converge.

HOUSE ENGINEERING LLC

Step 5c. Perform a second iteration so as to determine crest acceleration

From **Figure 1:** for shear strain calculated in step 5b, determine G/G_{max} and damping (λ)

	for shear strain:	0.043	%
	G/G_{max}	0.42	
	λ	12	%
	thus $G/G_{max} = (V_S/V_{max})^2$ and so V_S/V_{max} =	0.648	
	$\therefore V_S$	566	fps

Therefore the frequencies are as follows:

$\omega_1 = 2.4\ (V_S / h)$	ω_1	6.63	rad/sec
$T_1 = 2\pi / \omega_1$	T_1	**0.95**	**sec**
$\omega_2 = 5.52\ (V_S / h)$	ω_2	15.25	rad/sec
$T_2 = 2\pi / \omega_2$	T_2	**0.41**	**sec**
$\omega_3 = 8.65\ (V_S / h)$	ω_3	23.89	rad/sec
$T_3 = 2\pi / \omega_3$	T_3	**0.263**	**sec**

Spectral accelerations (S_{an}) from Figure 2 are as follows:

[1] **From Figure 2**	**S_{a1} / max accel.[1] =**	0.8	S_{a1}	0.144
	S_{a2} / max accel.[1] =	1.6	S_{a2}	0.288
	S_{a3} / max accel.[1] =	1.4	S_{a3}	0.252

Determine the Crest accelerations (u) for each of the natural frequencies (ω):

$\phi_1 = 1.6$ $\phi_2 = 1.06$ $\phi_3 = 0.86$

$u_{1max} = \phi1\ (S_{a1})$	u_{1max}	0.230	g
$u_{2max} = \phi2\ (S_{a2})$	u_{2max}	0.305	g
$u_{3max} = \phi3\ (S_{a3})$	u_{3max}	0.217	g

Calculate the maximum crest acceleration (u_{max})

$[(u_{1max})^2 + (u_{2max})^2 + (u_{3max})^2]^{1/2} = u_{max}$ u_{max} 0.440 g

Calculate maximum shear strain $(\gamma_{ave})eq$

$(\gamma_{ave})eq = 0.65 * 0.3 * h / V_s^2\ (S_{a1})$ **$(\gamma_{ave})eq$ 0.058 %**

Step 5d. Perform a third iteration so as to determine crest acceleration

From **Figure 1**: for shear strain calculated in step 5c, determine G/G_{max} and damping (λ)

	for shear strain	**0.058**	**%**
	G/G_{max}	0.48	
	λ	14	%
	thus $G/G_{max} = (V_S/V_{max})^2$ and so V_S/V_{max} =	0.693	
	$\therefore V_S$	605.39	fps

Therefore the frequencies are as follows:

$\omega_1 = 2.4\ (V_S / h)$	ω_1	7.09	rad/sec
$T_1 = 2\pi / \omega_1$	T_1	**0.89**	**sec**
$\omega_2 = 5.52\ (V_S / h)$	ω_2	16.30	rad/sec
$T_2 = 2\pi / \omega_2$	T_2	**0.39**	**sec**
$\omega_3 = 8.65\ (V_S / h)$	ω_3	25.54	rad/sec
$T_3 = 2\pi / \omega_3$	T_3	**0.246**	**sec**

Spectral accelerations (S_{an}) from **Figure 2** are as follows:

[1] **From Figure 2**	**S_{a1} / max accel.[1] =**	0.8	S_{a1}	0.144
	S_{a2} / max accel.[1] =	1.7	S_{a2}	0.306
	S_{a3} / max accel.[1] =	1.4	S_{a3}	0.252

Determine the Crest accelerations (u) for each of the natural frequencies (ω):

$\phi_1 = 1.6$ $\phi_2 = 1.06$ $\phi_3 = 0.86$

$u_{1max} = \phi1\ (S_{a1})$	u_{1max}	0.230	g
$u_{2max} = \phi2\ (S_{a2})$	u_{2max}	0.324	g
$u_{3max} = \phi3\ (S_{a3})$	u_{3max}	0.217	g

Calculate the maximum crest acceleration (u_{max})

$[(u_{1max})^2 + (u_{2max})^2 + (u_{3max})^2]^{1/2} = u_{max}$ u_{max} 0.453 g

Calculate maximum shear strain $(\gamma_{ave})eq$

$(\gamma_{ave})eq = 0.65 * 0.3 * h / V_s^2\ (S_{a1})$ **$(\gamma_{ave})eq$ 0.051 %**

T_O	**0.89**	**sec**
G/G_{max}	0.48	
u_{max}	**0.453**	**g**
λ	14.0	%
V_S	605.4	fps
$(\gamma_{ave})eq$	**0.051**	**%**

SANTEK WasteServices

Step 6.

crest acceleration (u_{max}) determined in Step 5 and entering into **Figure 3**

Calculate y/h

height of embankment	h	205	ft
depth of failure plane	y	189	ft
	y/h	0.92	
k_{max} / u_{max}, from **Figure 3**		0.35	
	k_{max}	**0.159**	**g**

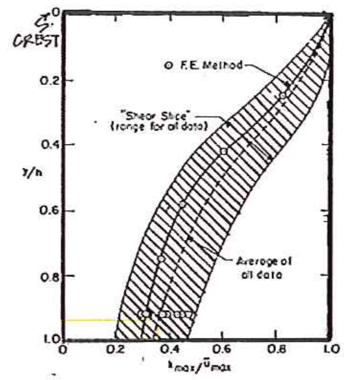


FIGURE 3: VARIATION OF " MAXIMUM ACCELERATION RATIO " WITH DEPTH OF SLIDING MASS

Step 7.

values of k_{max} and T_O

Calculate k_y/k_{max}

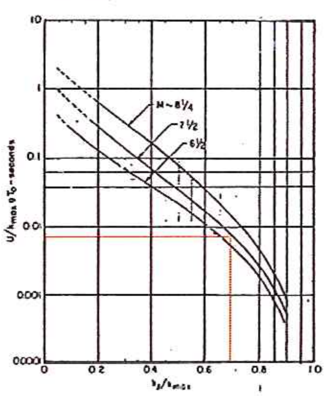


FIGURE 4: VARIATION OF AVERAGE NORMALIZED DISPLACEMENT WITH YIELD ACCELERATION

k_y	0.11	
k_{max}	0.159	g
k_y/k_{max}	0.694	
From **Figure 4**, $U/k_{max}(T_O)$	0.09	
TOTAL DEFORMATION - U	**0.407**	**ft**
TOTAL DEFORMATION - U	**4.89**	**inches**

HOUSE ENGINEERING LLC

SANTEK WasteServices

Evaluation of Earthquake Forces on the Slope Stability of Solid Waste Landfills

Step 5. SPENCERS METHOD

Determine the maximum crest acceleration (u_{max}) induced in the embankment and the natural period (T_O) of the embankment. This can be accomplished by several different methods which include the following:

I. a finite element analysis of the embankment section (Clough and Chopra, 1966; Idress and Seed, 1967)

II. by a shear slice analysis (Ambraseys, 1960; Seed and Martin, 1966).

III. a simplified approach developed by Makdisi and Seed that lends itself to hand calculations is presented in the following paragraphs.

Step 5a.

Determine the following embankment and subsurface soil properties;

Yield acceleration	k_y	0.13	g
Height of embankment	h	205	ft
Unit weight of waste fill materials	γ	90	pcf

Mass density, $\rho = \gamma / 32.2$ ft/sec

Maximum shear wave velocity

(obtain from crosshole velocity survey or from approximations using the following relationships):

Gmax = 65 N (taken from Eval. Of Liquifaction Potential by Seed, Idriss, Jour. Of Eng. Div. ASCE, pg 476)

$G_{max} = 120\ N^{0.8}$ See NavFaq 7.1-89 (Note: G_{max} is in TSF) Gmax = 1422.72 TSF

$(G_{max} / \rho)^{1/2} = V_{max}$ V_{max}= 873.80 FPS

Maximum Horizontal Acceleration, a_{max} (obtained from Simplified Procedure) a_{max} = 0.18 g

Step 5b. First Iteration for determining crest acceleration

Perform First Iteration

Step one: determine G/G_{max}, shear strain, and damping

I. Assume value of v_s	v_s	656	fps	FROM USGS MAP
II. Calculate $G/G_{max} = (V_S/V_{max})^2$	$(VS/Vmax)^2$ =	0.564		
III. From **Figure 1**: for calculated G/G_{max}, determine:	shear strain, γ	.024	%	
	damping, λ	16.7	%	

Step two: Calculate the natural frequencies (ω) and the associated natural periods (T)

$\omega_1 = 2.4\ (V_S / h)$	ω_1	7.68	rad/sec
$T_1 = 2\pi / \omega_1$	T_1	0.82	sec
$\omega_2 = 5.52\ (V_S / h)$	ω_2	17.66	rad/sec
$T_2 = 2\pi / \omega_2$	T_2	0.36	sec
$\omega_3 = 8.65\ (V_S / h)$	ω_3	27.68	rad/sec
$T_3 = 2\pi / \omega_3$	T_3	0.227	sec

Step three: Determine the spectral accelerations for the three frequencies

in step one and the periods (T) determined in step two to enter **Figure 2**, to determine the spectral

From Figure 2[1]	**S_{a1} / max accel.[1] =**	0.8	S_{a1}	0.14
	S_{a2} / max accel.[1] =	1.6	S_{a2}	0.29
	S_{a3} / max accel.[1] =	1.4	S_{a3}	0.25

frequencies

$\phi_1 = 1.6$ $\phi_2 = 1.06$ $\phi_3 = 0.86$

$u_{1max} = \phi 1\ (S_{a1})$	u_{1max}	0.2304	g
$u_{2max} = \phi 2\ (S_{a2})$	u_{2max}	0.305	g
$u_{3max} = \phi 3\ (S_{a3})$	u_{3max}	0.217	g

Step five: use the following equation to determine the maximum crest acceleration (u_{max})

$[(u_{1max})^2 + (u_{2max})^2 + (u_{3max})^2]^{1/2} = u_{max}$ u_{max} 0.44 g

Step 5b. First Iteration for determining crest acceleration (continued)

Calculate the average equivalent shear strain $(\gamma_{ave})eq$ from the following equation

$(\gamma_{ave})eq = 0.65 * 0.3 * h / V_s^2\ (S_{a1})$ (γ_{ave})eq 0.043 %

Note: If the shear strain calculated from the above equation does not match the value determined in Step One it is necessary to perform a second iteration.

Note: The shear strain obtained from the above calculation is generally different from the shear strain determined from using assumed velocity values and entering Figure 1 as was done in step III of 5b. If there is a difference between the assumed shear strain values and the calculated values, it will be necessary to perform a new iteration using the value obtained from the above equation to determine a new set of modulus and damping parameters. Generally, it will take three iterations for the strain compatible properties to converge.

HOUSE ENGINEERING LLC

Step 5c. Perform a second iteration so as to determine crest acceleration

From **Figure 1:** for shear strain calculated in step 5b, determine G/G_{max} and damping (λ)

	for shear strain:	0.043	%
	G/G_{max}	0.42	
	λ	12	%
thus $G/G_{max} = (V_S/V_{max})^2$ and so V_S/V_{max} =		0.648	
	$\therefore V_S$	566	fps

Therefore the frequencies are as follows:

$\omega_1 = 2.4\ (V_S / h)$	ω_1	6.63	rad/sec
$T_1 = 2\pi / \omega_1$	T_1	**0.95**	**sec**
$\omega_2 = 5.52\ (V_S / h)$	ω_2	15.25	rad/sec
$T_2 = 2\pi / \omega_2$	T_2	**0.41**	**sec**
$\omega_3 = 8.65\ (V_S / h)$	ω_3	23.89	rad/sec
$T_3 = 2\pi / \omega_3$	T_3	**0.263**	**sec**

Spectral accelerations (S_{an}) from Figure 2 are as follows:

[1] **From Figure 2**	S_{a1} / max accel.[1] =	0.8	S_{a1}	0.144
	S_{a2} / max accel.[1] =	1.9	S_{a2}	0.342
	S_{a3} / max accel.[1] =	1.7	S_{a3}	0.306

Determine the Crest accelerations (u) for each of the natural frequencies (ω):

$\phi_1 = 1.6$ $\phi_2 = 1.06$ $\phi_3 = 0.86$

$u_{1max} = \phi 1\ (S_{a1})$	u_{1max}	0.230	g
$u_{2max} = \phi 2\ (S_{a2})$	u_{2max}	0.363	g
$u_{3max} = \phi 3\ (S_{a3})$	u_{3max}	0.263	g

Calculate the maximum crest acceleration (u_{max})

$[(u_{1max})^2 + (u_{2max})^2 + (u_{3max})^2]^{1/2} = u_{max}$ — u_{max} 0.504 g

Calculate maximum shear strain $(\gamma_{ave})eq$

$(\gamma_{ave})eq = 0.65 * 0.3 * h / V_s^2\ (S_{a1})$ — $(\gamma_{ave})eq$ **0.058 %**

Step 5d. Perform a third iteration so as to determine crest acceleration

From **Figure 1:** for shear strain calculated in step 5c, determine G/G_{max} and damping (λ)

	for shear strain	**0.058**	**%**
	G/G_{max}	0.46	
	λ	13.5	%
thus $G/G_{max} = (V_S/V_{max})^2$ and so V_S/V_{max} =		0.678	
	$\therefore V_S$	592.64	fps

Therefore the frequencies are as follows:

$\omega_1 = 2.4\ (V_S / h)$	ω_1	6.94	rad/sec
$T_1 = 2\pi / \omega_1$	T_1	**0.91**	**sec**
$\omega_2 = 5.52\ (V_S / h)$	ω_2	15.96	rad/sec
$T_2 = 2\pi / \omega_2$	T_2	**0.39**	**sec**
$\omega_3 = 8.65\ (V_S / h)$	ω_3	25.01	rad/sec
$T_3 = 2\pi / \omega_3$	T_3	**0.251**	**sec**

Spectral accelerations (S_{an}) from **Figure 2** are as follows:

[1] **From Figure 2**	S_{a1} / max accel.[1] =	0.8	S_{a1}	0.144
	S_{a2} / max accel.[1] =	1.9	S_{a2}	0.342
	S_{a3} / max accel.[1] =	1.7	S_{a3}	0.306

Determine the Crest accelerations (u) for each of the natural frequencies (ω):

$\phi_1 = 1.6$ $\phi_2 = 1.06$ $\phi_3 = 0.86$

$u_{1max} = \phi 1\ (S_{a1})$	u_{1max}	0.230	g
$u_{2max} = \phi 2\ (S_{a2})$	u_{2max}	0.363	g
$u_{3max} = \phi 3\ (S_{a3})$	u_{3max}	0.263	g

Calculate the maximum crest acceleration (u_{max})

$[(u_{1max})^2 + (u_{2max})^2 + (u_{3max})^2]^{1/2} = u_{max}$ — u_{max} 0.504 g

Calculate maximum shear strain $(\gamma_{ave})eq$

$(\gamma_{ave})eq = 0.65 * 0.3 * h / V_s^2\ (S_{a1})$ — $(\gamma_{ave})eq$ **0.053 %**

T_O	**0.91**	**sec**
G/G_{max}	0.46	
u_{max}	**0.504**	**g**
λ	13.5	%
V_S	592.6	fps
$(\gamma_{ave})eq$	**0.053**	**%**

SANTEK WasteServices

Step 6.

crest acceleration (u_{max}) determined in Step 5 and entering into **Figure 3**

Calculate y/h

height of embankment	h	205	ft
depth of failure plane	y	170	ft
	y/h	0.83	
k_{max} / u_{max}, from **Figure 3**		0.35	
	k_{max}	**0.176**	**g**

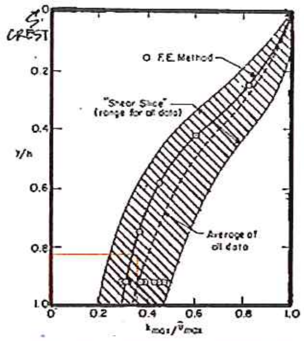


FIGURE 3: VARIATION OF " MAXIMUM ACCELERATION RATIO " WITH DEPTH OF SLIDING MASS

Step 7.

values of k_{max} and T_O

Calculate k_y/k_{max}

k_y	0.13	
k_{max}	0.176	g
k_y/k_{max}	0.737	
From **Figure 4**, $U/k_{max}(T_O)$	0.0085	
TOTAL DEFORMATION - U	**0.044**	**ft**
TOTAL DEFORMATION - U	**0.52**	**inches**

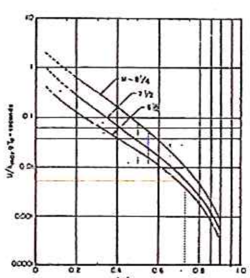


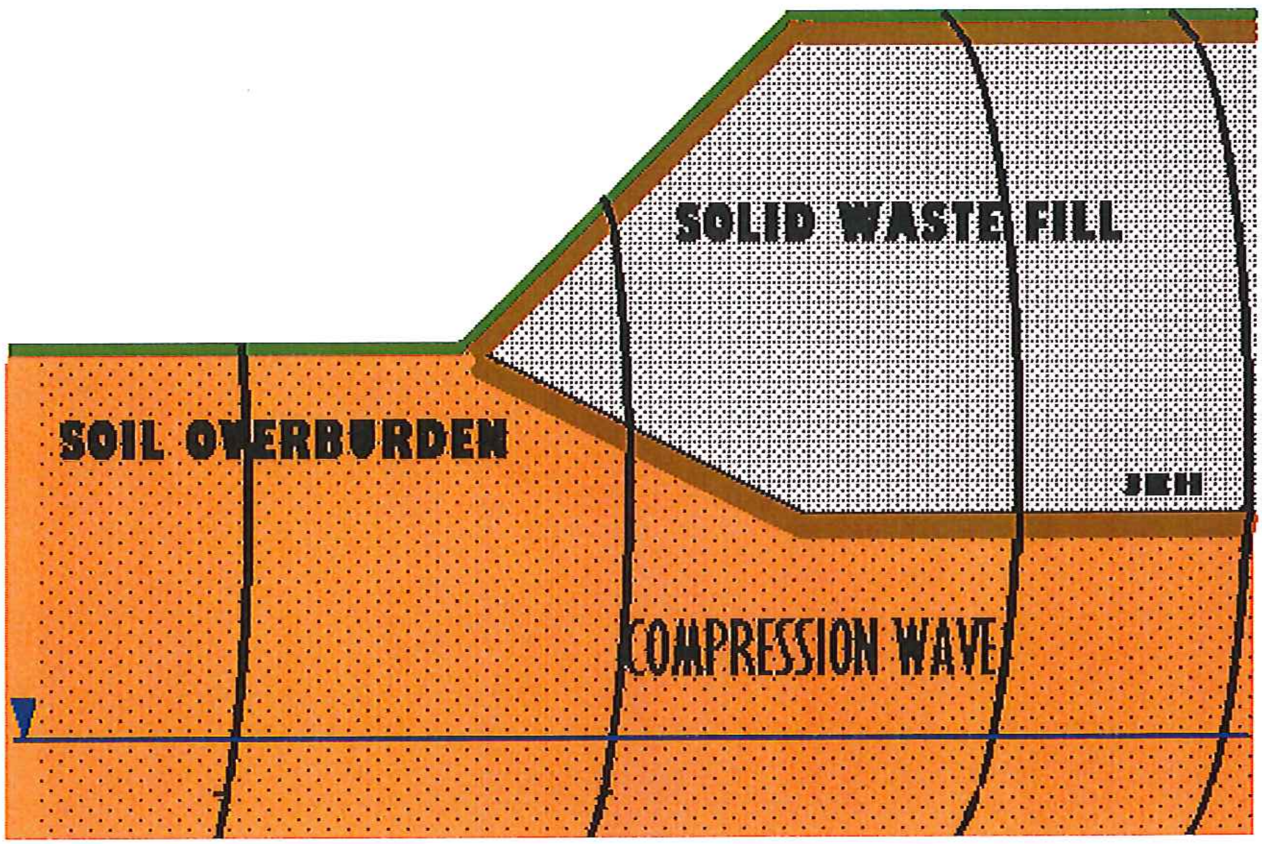
FIGURE 4: VARIATION OF AVERAGE NORMALIZED DISPLACEMENT WITH YIELD ACCELERATION

HOUSE ENGINEERING LLC

LIQUEFACTION SCREENING

Santek Environmental Inc. – Matlock Bend Landfill Proposed 2014 Expansion

LIQUEFACTION SCREENING



Original Submittal by: Civil & Environmental Consultants, Inc.

August 2009

Reviewed by House Engineering LLC 2014

MATLOCK BEND CLASS I LANDFILL
CEC Project Number 090-604

Civil & Environmental Consultants, Inc.

INTRODUCTION

This document has been prepared to screen the potential of the soils which underlay the proposed expansion of the Santek Environmental, Inc. Matlock Bend Class I Landfill (MBLF) to undergo liquefaction under earthquake induced motions. Liquefaction is a phenomenon most often observed in shallow, loose, saturated deposits of cohesionless soils (sands or silts, sometimes gravels) subjected to strong ground motions in large magnitude earthquakes. The severe shaking induced by the earthquake increases pore pressures and reduces effective stress between solid particles generated by the presence of liquid.

Geologically, the MBLF is situated in the valley and ridge physiographic province of Tennessee. More specifically, the landfill is located at 21712 Highway 72 N near Loudon, Tennessee.

The following paragraphs outline a liquefaction screening procedure for the soils that underlay the MBLF Class I Landfill. The "screening procedure" was performed as per the procedure detailed in the "RCRA SUBTITLE D (258) SEISMIC DESIGN GUIDANCE FOR MUNICIPAL SOLID WASTE LANDFILL FACILITIES" prepared by Richardson, Kavazanjian and Matasovic for the U. S. Environmental Protection Agency (USEPA).

INITIAL SCREENING

The first step in any liquefaction evaluation is to assess whether the potential for soil liquefaction exists at the site. A variety of screening techniques exists to distinguish sites that are clearly safe with respect to liquefaction from those sites that require more detailed study (e.g., Dobry et al., 1980). Five major screening criteria which are commonly used to make this assessment are addressed in the following pages:

1. *Geologic age and origin.* Liquefaction potential decreases with increasing age of a soil deposit. Pre-Holocene age soil deposits generally do not liquefy, though liquefaction has occasionally been observed in Pleistocene-age deposits. Table 5.1 presents the liquefaction susceptibility of soil deposits as a function of age and origin (Youd and Perkins, 1978).

Table 5.1 Estimated Susceptibility of Sedimentary Deposits to Liquefaction During Strong Seismic Shaking (Youd and Perkins, 1978).

Type of deposit (1)	General distribution of cohesionless sediments in deposits (2)	Likelihood that Cohesionless Sediments, When Saturated, Would Be Susceptible to Liquefaction (by Age of Deposit)			
		<500 yr (3)	Holocene (4)	Pleistocene (5)	Pre-pleistocene (6)
(a) Continental Deposits					
River channel	Locally variable	Very high	High	Low	Very low
Flood plain	Locally variable	High	Moderate	Low	Very low
Alluvial fan and plain	Widespread	Moderate	Low	Low	Very low
Marine terraces and plains	Widespread	—	Low	Very low	Very low
Delta and fan-delta	Widespread	High	Moderate	Low	Very low
Lacustrine and playa	Variable	High	Moderate	Low	Very low
Colluvium	Variable	High	Moderate	Low	Very low
Talus	Widespread	Low	Low	Very low	Very low
Dunes	Widespread	High	Moderate	Low	Very low
Loess	Variable	High	High	High	Unknown
Glacial till	Variable	Low	Low	Very low	Very low
Tuff	Rare	Low	Low	Very low	Very low
Tephra	Widespread	High	High	?	?
Residual soils	Rare	Low	Low	Very low	Very low
Sebka	Locally variable	High	Moderate	Low	Very low
(b) Coastal Zone					
Delta	Widespread	Very high	High	Low	Very low
Esturine	Locally variable	High	Moderate	Low	Very low
Beach					
High wave energy	Widespread	Moderate	Low	Very low	Very low
Low wave energy	Widespread	High	Moderate	Low	Very low
Lagoonal	Locally variable	High	Moderate	Low	Very low
Fore shore	Locally variable	High	Moderate	Low	Very low
(c) Artificial					
Uncompacted fill	Variable	Very high	—	—	—
Compacted fill	Variable	Low	—	—	—

A review of published information and data generated from the Hydrogeologic investigations reveals that the soil overburden materials which blanket the site are residual clay soils developed during the Ordovician Age of the Paleozoic Era which is a Pre-Pleistocene period approximating 425 to 500 million years ago. An inspection of Table 5.1 reveals that the residual site soils from the Pre-Pleistocene Epoch have a very low likelihood for liquefaction. Therefore, based on the geologic age and origin criteria of the site soils, there is a very low potential for liquefaction.

2. *Fines content, liquid limit and in-place soil moisture content.* The fines content, liquid limit and in-place moisture content of soils provide a viable means to screen the soils at a site for liquefaction potential. Soils with clay contents (particle size <0.005 mm) are considered non-liquefiable. Based upon the "Chinese Criteria" (Seed and Idriss, 1982) clayey soils having all of the following characteristics may be susceptible to strength loss and liquefaction.

    a. Percent finer than 0.005 mm less than 15 percent
    b. Liquid limit less than 35 percent, and
    c. an in-situ water content greater than 0.9 times the liquid limit

The parameters listed above which are specific to the Matlock Bend Landfill are provided in Table 2 Summary of Lab Test Data for reference and review. The following paragraphs address each of the clay soil screening parameters listed above.

2a. Percentage of Clay Fraction in the Site Soils

Perhaps the most critical screening criteria for liquefaction potential is the percent clay content (percent finer than 0.005 mm). As previously stated, soils with percentages of clay greater than 15 percent are not considered liquefiable. A review of the Hydrometer test results on the samples taken within the limits of the waste footprint revealed percent clay contents that exceeded 15 percent. Only one sample taken outside of the proposed waste footprint revealed a percent clay content less than 15 percent. Based upon the percent clay criteria, the site soils are not susceptible to liquefaction.

Table 2: Summary of Lab Test Data

HYDROGEO INVESTIGATION	BORING NUMBER	boring elevation (ft msl)	SAMPLE DEPTH (FT)	SAMPLE TYPE	UNIFIED SOIL CLASS (USCS)	Pocket Penetrometer (tsf)	MAX DRY DENSITY (PCF)	OPTIMUM MOISTURE CONTENT ω %	IN-PLACE UNIT WEIGHT DRY (PCF)	IN-PLACE UNIT WEIGHT WET (PCF)	% FINER NO. 4 SIEVE	% FINER NO. 200 SIEVE	% CLAY SOIL (PARTICLES FINER 0.005 MM)	NATURAL MOISTURE CONTENT (%)	LIQUID LIMIT L.L.	PLASTIC LIMIT P.L.	PLASTICITY INDEX P.I.	0.9 X LIQUID LIMIT	DEGREE OF SATURATION (%)
CEC STUDY 2008	B-58	876.6	3-5	ST	CL				102	102.6	80.2	57	33.4	24	43	22	21	21.6	93.7
	B-58	876.6	28-29.5	SS	CL	1.5					99.9	80.3	59.9	36	52	28	24	32.40	
	B-58	876.6	COMPOSITE	BAG	CL-CH		99.0	23.5							50	28	22	0.00	
	B-59	929.12	27-29	SS	CL	3.5					95.7	75.2	49.3	28	54	28	26	25.20	
	B-59	929.12	COMPOSITE	Bag	CL		107.5	16.8							41	21	20	0.00	
	B-61	960.99	32-34	ST	CL				88.9	85.3				30	57	31	26	27.00	89.10
	B-62	926.67	18-19.5	SS	CL	4.5					92.2	68.6	48.6	22	56	30	26	19.80	
	B-62	926.67	28-29.5	SS	CL						63.1	20.3	9.9	13	48	26	22	11.70	
	B-63	935.27	18-19.5	SS	CL	4					75.5	53.1	32.5	23	48	26	22	20.70	
	B-64	944.56	COMPOSITE	Bag	CL		106.2	17.8							42	22	20	0.00	
	B-64	944.56	34.5-36	ST	CL				100.7	101.2				26	55	29	26	23.40	104.70
	B-65	943.61	13-14.5	SS	OH	4.5								31	51	30	21	27.90	
	B-65	943.61	38-39.5	SS	CL	3.5								34	52	28	24	30.60	
	B-66	919.14	26-32	BAG	CL		109.0	17.4							40	21	19	0.00	
	B-67	912.31	17-19	ST	CH				87.2	85.5	97.3	69.3	56.5	32	63	33	30	28.80	92.10
	B-68	904.42	14-15.7	ST	OH				95.5	94.3				27	51	31	20	24.30	96.40
	B-68	904.42	29-30.5	SS	CL	1								30	42	20	22	27.00	
	B-68	924.98	COMPOSITE	BAG	CL-CH		101.1	21.8							50	26	24	0.00	
Theta Engin[illegible] St[illegible] [illegible]996	SB-47	903.4	6-8	BAG	CL		114.8	14.1			82.5	40	NA	15.2	24.4	14.5	9.9	13.68	
	SB-47	903.4	10-12	ST	CL						90	65	NA	30.1	51.8	26.3	25.5	27.09	
	PZ-51	925.7	34-36	ST	CL						84	70			55.3	31.5	23.8	0.00	
	SB-52	928.8	20-22	BAG	CL		104.3	19.4			92.5	62	NA	28.4	43.4	23.3	20.1	25.56	
	SB-53	957.2	26-28	ST	ML						87	76	NA		40.4	26.8	13.6	0.00	
	SB-55	924.9	7-9	ST	CL														
CML Study (1993)	B-34	978.2	0.5-50	BAG	CL		98.7	22.5			90.4	65.2		32.1	45	24	21	28.89	
	B-34	978.2	0.5-50	BAG	CL		98.7	22.5			90.4	65.2		32.1	45	24	21	28.89	

NOTES: ST - SHELBY TUBE SS - SPLIT SPOON BAG- BULK SOIL SAMPLE N/A - NOT AVAILABLE SS - SPLIT SPOON SAMPLE NP - NOT PLASTIC

2b. Liquid Limit of Site Soils Examination

Soils with liquid limits less than 35 are considered to be potentially susceptible to liquefaction. A review of the liquid limits of the site soils revealed that only one of the on-site soil samples tested had a liquid limit less than 35. Most of the soil samples exhibited liquid limits that far exceeded 35. Therefore, based upon the liquid limit criteria, the site soils would not be susceptible to liquefaction.

2c. In-Situ Water Content Greater than 0.9 times the Liquid Limit

None of the samples obtained at the site had natural moisture contents that exceeded 90% of the liquid limit which is indicative of soils with a potential for liquefaction. However, it should be noted that surface effects from liquefaction are not likely to occur more than 50 ft (15 m) below the ground surface. Therefore, the in-situ water content of the site soils does not present a condition that is susceptible to liquefaction.

3. *Degree of Saturation.* Although partially saturated soils have been reported to liquefy, at least 80 to 85 percent saturation is generally deemed to be a necessary condition for soil liquefaction. An inspection of Table 2 reveals that each of the samples taken during the most recent Hydrogeologic Investigation exceeded 85 percent saturation. Therefore, based upon this criterion alone, the soils would be susceptible to liquefaction.

4. *Depth below ground surface.* Again, to reiterate, surface effects from liquefaction have not been reported below 50 feet (15 meters). Based on a review of the Hydrogeologic Investigations performed at the site it appears that there are no liquefiable sand layers within 50 feet of the base of the proposed landfill expansion. Therefore, the "depth below the surface criteria" suggests there is little risk of liquefaction.

5. *Soil Penetration Resistance.* According to the data presented in Seed and Idriss (1985), liquefaction has not been observed in soil deposits having normalized Standard Penetration Test (SPT) blowcount, $(N_1)_{60}$ larger than 22. Marcuson, et al. (1990) suggest a normalized SPT value of 30 as the threshold value above which liquefaction will not occur. However, Chinese experience, as quoted in Seed et al. (1983), suggests that in extreme conditions liquefaction is possible in soils having normalized SPT blow counts as high as 40. Shibata and Teparska (1998), based on a large number of observations, conclude that no liquefaction is possible if normalized Cone Penetration Test (CPT) cone resistance, q_c, is larger than 157 tsf. This CPT resistance corresponds to normalized blow counts between 30 and 60, depending on the grain size of the soil. Examining the borehole logs developed from the Hydrogeologic Investigations at the MBLF revealed a number of SPT blow counts that were below 22. Therefore, based solely upon the soil penetration criteria there is a potential for liquefaction.

SUMMARY

The purpose of this document is to evaluate whether the potential for liquefaction exists at the MBLF site. Generally, liquefaction is limited to cohesionless soils. However, since reports of liquefaction of fine grained (cohesive) soils have been reported, this site was screened for liquefaction potential.

The liquefaction screening procedure detailed in the previously referenced EPA SEISMIC DESIGN GUIDANCE FOR MUNICIPAL SOLID WASTE LANDFILL FACILITIES manual indicates that if three or more of the five liquefaction screening criteria indicate that liquefaction is not likely, the potential for liquefaction is considered small. A review of each of the criteria reveals that the potential for liquefaction is low since three of the criteria indicated a "not likely" conclusion. This conclusion is realistic since the overall characteristics of the site soils are fine grained cohesive materials. However, the Seed and Idriss liquefaction screening criteria for fine grained soils also indicated that the site soils were not likely to undergo liquefaction. As previously described, the Seed and Idriss established criteria referred to as the "Chinese Criteria indicated that fine grained soils susceptible to liquefaction must satisfy each of the following criteria;

(1) Less than 15% clay content,

(2) Liquid limit less than 35 percent, and

(3) An in-situ water content greater than 0.9 times the liquid limit.

Therefore, since none of the site soils satisfied any of the three "Chinese Criteria" it has been determined that a further evaluation of liquefaction at the MBLF is not necessary. This conclusion is in keeping with the Tennessee Division of Solid Waste Management's (TDSWM) "Earthquake Evaluation Guidance Policy" prepared by House in 1993.

CEC

ATTACHMENTS A – D

ATTACHMENT A

SOIL LOSS CALCULATIONS

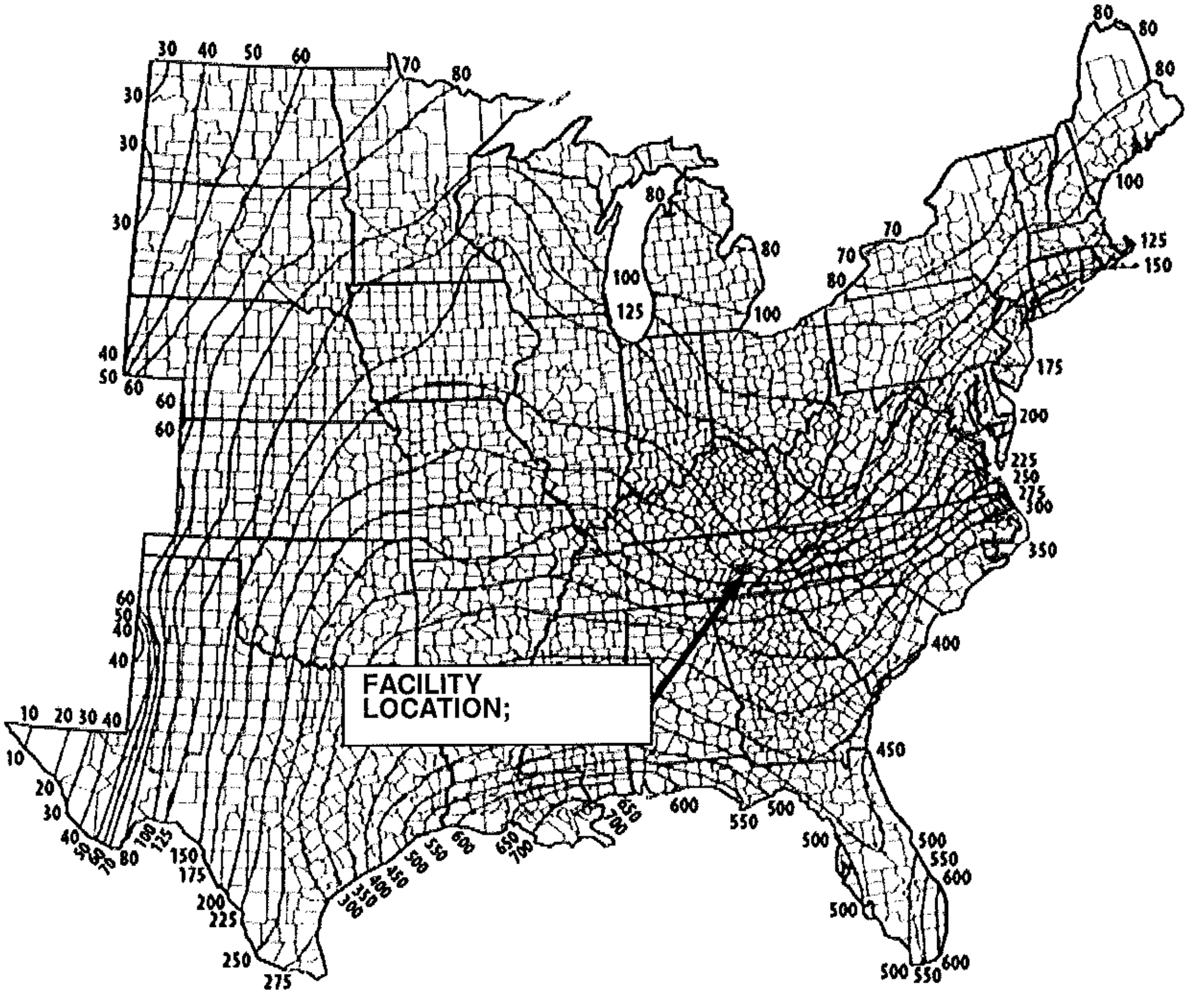
Universal Soil Loss Calculations

Project:	**Matlock Bend Proposed Expansion**	**Proj. #**	140-334
Application:	**Soil Loss**		
Date:	**February 6, 2013**		
Calculations by:	**Jeff Williams**		

EQUATION - X = R * K * LS * C * P

R = RAINFALL EROSION INDEX (Figure 20)	200
K = SOIL ERODIBILITY INDEX (Table 5,)	0.295
LS = SLOPE GRADIENT AND LENGTH FACTOR (Table 6)	5.58
C = CROP MANAGEMENT FACTOR (Table 7)	0.004
P = EROSION CONTROL FACTOR (Table 8)	1.000
X = SOIL LOSS IN TONS / ACRE / YEAR	**1.32**

R FACTOR



R= 200.00

K Factor, Whole Soil—Loudon County, Tennessee

Map Scale: 1:6,640 if printed on A size (8.5" x 11") sheet.

N

0 50 100 200 300 Meters

0 250 500 1,000 1,500 Feet

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Soil Ratings
- .02
- .05
- .10
- .15
- .17
- .20
- .24
- .28
- .32
- .37
- .43
- .49
- .55
- .64
- Not rated or not available

Political Features
- Cities

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:6,640 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:15,840.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 16N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Loudon County, Tennessee
Survey Area Data: Version 6, Sep 20, 2007

Date(s) aerial images were photographed: 12/8/2006

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

K Factor, Whole Soil

K Factor, Whole Soil— Summary by Map Unit — Loudon County, Tennessee				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
CaD	CLARKSVILLE CHERTY SILT LOAM, MODERATELY STEEP PHASE	.32	3.7	3.0%
CaE	CLARKSVILLE CHERTY SILT LOAM, STEEP PHASE	.32	0.9	0.7%
Em	EMORY SILT LOAM	.37	3.2	2.6%
FcC	FULLERTON CHERTY SILT LOAM, SLOPING PHASE	.28	10.0	8.1%
FcD	FULLERTON CHERTY SILT LOAM, MODERATELY STEEP PHASE	.28	14.3	11.6%
FcE	FULLERTON CHERTY SILT LOAM, STEEP PHASE	.28	38.5	31.2%
FsC	FULLERTON SILT LOAM, SLOPING PHASE (DEWEY)	.32	8.6	7.0%
FsE	FULLERTON SILT LOAM, STEEP PHASE (DEWEY)	.32	31.8	25.7%
Gc	GREENDALE CHERTY SILT LOAM	.28	5.5	4.4%
MrC2	MINVALE CHERTY SILT LOAM, ERODED SLOPING PHASE	.28	1.5	1.2%
MsC2	MINVALE SILT LOAM, ERODED SLOPING PHASE	.32	1.9	1.6%
NoC	NOLICHUCKY GRAVELLY FINE SANDY LOAM, SLOPING PHASE	.20	3.7	3.0%
Totals for Area of Interest			**123.4**	**100.0%**

Description

Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and saturated hydraulic conductivity (Ksat). Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

"Erosion factor Kw (whole soil)" indicates the erodibility of the whole soil. The estimates are modified by the presence of rock fragments.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Layer Options: All Layers

K FACTOR

	K	AREA (ac)	K*AREA
	0.32	3.7	1.184
	0.32	0.9	0.288
	0.37	3.2	1.184
	0.28	10	2.8
	0.28	14.3	4.004
	0.28	38.5	10.78
	0.32	8.6	2.752
	0.32	31.8	10.176
	0.28	5.5	1.54
	0.28	1.5	0.42
	0.32	1.9	0.608
	0.2	3.7	0.74
WEIGHTED K FACTOR	0.295	123.6	36.476

LS FACTOR

from Design Drawings: Avg. Slope = 30% Horizontal Slope Lenth (between benches) = 90 ft

Table 4-3

Values for topographic factor, LS, for high ration of rill to interill erosion[1]

	Horizontal slope length (ft)																
Slope %	**<3**	**6**	**9**	**12**	**15**	**25**	**50**	**75**	**100**	**150**	**200**	**250**	**300**	**400**	**600**	**800**	**1000**
0.20	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
0.50	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.13
1.00	0.09	0.09	0.09	0.09	0.09	0.10	0.13	0.14	0.15	0.17	0.18	0.19	0.20	0.22	0.24	0.26	0.27
2.00	0.13	0.13	0.13	0.13	0.13	0.16	0.21	0.25	0.28	0.33	0.37	0.40	0.43	0.48	0.56	0.63	0.69
3.00	0.17	0.17	0.17	0.17	0.17	0.21	0.30	0.36	0.41	0.50	0.57	0.64	0.69	0.80	0.96	1.10	1.23
4.00	0.20	0.20	0.20	0.20	0.20	0.26	0.38	0.47	0.55	0.68	0.79	0.89	0.98	1.14	1.42	1.65	1.86
5.00	0.23	0.23	0.23	0.23	0.23	0.31	0.46	0.58	0.68	0.86	1.02	1.16	1.28	1.51	1.91	2.25	2.55
6.00	0.26	0.26	0.26	0.26	0.26	0.36	0.54	0.69	0.82	1.05	1.25	1.43	1.60	1.90	2.43	2.89	3.30
8.00	0.32	0.32	0.32	0.32	0.32	0.45	0.70	0.91	1.10	1.43	1.72	1.99	2.24	2.70	3.52	4.24	4.91
10.00	0.35	0.37	0.38	0.39	0.40	0.57	0.91	1.20	1.46	1.92	2.34	2.72	3.09	3.75	4.95	6.03	7.02
12.00	0.36	0.41	0.45	0.47	0.49	0.71	1.15	1.54	1.88	2.51	3.07	3.60	4.09	5.01	6.67	8.17	9.57
14.00	0.38	0.45	0.51	0.55	0.58	0.85	1.40	1.87	2.31	3.09	3.81	4.48	5.11	6.30	8.45	10.40	12.23
16.00	0.39	0.49	0.56	0.62	0.67	0.98	1.64	2.21	2.73	3.68	4.56	5.37	6.15	7.60	10.26	12.69	14.96
20.00	0.41	0.56	0.67	0.76	0.84	1.24	2.10	2.86	3.57	4.85	6.04	7.16	8.23	10.24	13.94	17.35	20.57
25.00	0.45	0.64	0.80	0.93	1.04	1.56	2.67	3.67	4.59	6.30	7.88	9.38	10.81	13.53	18.57	23.24	27.66
30.00	0.48	0.72	0.91	1.08	1.24	1.86	3.22	4.44	5.58	7.70	9.67	11.55	13.35	16.77	23.14	29.07	34.71
40.00	0.53	0.85	1.13	1.37	1.59	2.41	4.24	5.89	7.44	10.35	13.07	15.67	18.17	22.95	31.89	40.29	48.29
50.00	0.58	0.97	1.31	1.62	1.91	2.91	5.16	7.20	9.13	12.75	16.16	19.42	22.57	28.60	39.95	50.63	60.84
60.00	0.63	1.07	1.47	1.84	2.19	3.36	5.97	8.37	10.63	14.89	18.92	22.78	26.51	33.67	47.18	59.93	72.15

[1] Such as for freshly prepared construction and other highly disturbed soil conditons with little or no cover (not applicable to thawing soil)

LS = 5.58

C FACTOR

Cover management, "C" factors

Type of Mulch	Mulch Rate (tons/acre)	Land Slope (%)	Max Length (ft)	C Factor
None	0.00	all	-	1.00
Poor grass	-	-	-	0.01
Good grass	-	-	-	0.004
GECB		* consult manufacturer		
Straw/hay	1.00	39818.00	200.00	0.20
Straw/hay	1.00	39974.00	100.00	0.20
Straw/hay	1.50	39818.00	300.00	0.12
Straw/hay	1.50	39974.00	150.00	0.12
Straw/hay	1.50	39818.00	400.00	0.06
Straw/hay	2.00	39974.00	200.00	0.06
Straw/hay	2.00	40132.00	150.00	0.07
Straw/hay	2.00	16-20	100.00	0.11
Straw/hay	2.00	21-25	75.00	0.14
Straw/hay	2.00	26-33	50.00	0.17
Straw/hay	2.00	34-50	35.00	0.20
Crushed stone	135.00	<16	200.00	0.05
Crushed stone	135.00	16-20	150.00	0.05
Crushed stone	135.00	21-33	100.00	0.05
Crushed stone	135.00	34-50	75.00	0.05
Crushed stone	240.00	<21	300.00	0.02
Crushed stone	240.00	21-33	200.00	0.02
Crushed stone	240.00	34-50	150.00	0.02
Wood chips	7.00	<16	75.00	0.08
Wood chips	7.00	16-20	50.00	0.08
Wood chips	12.00	<16	150.00	0.05
Wood chips	12.00	16-20	100.00	0.05
Wood chips	12.00	21-33	75.00	0.05
Wood chips	25.00	<16	200.00	0.02
Wood chips	25.00	16-20	150.00	0.02
Wood chips	25.00	21-33	100.00	0.02
Wood chips	25.00	34-50	75.00	0.02

P FACTOR

are listed in Table 8. These values are based on rather limited field data, but P has a narrower range of possible values than the other five factors.

TABLE 8. VALUES OF FACTOR P[11]

Practice	Land slope (percent)				
	1.1-2	2.1-7	7.1-12	12.1-18	18.1-24
	(Factor P)				
Contouring (P_c)	0.60	0.50	0.60	0.80	0.90
Contour strip cropping (P_{sc})					
R-R-M-M[1]	0.30	0.25	0.30	0.40	0.45
R-W-M-M	0.30	0.25	0.30	0.40	0.45
R-R-W-M	0.45	0.38	0.45	0.60	0.68
R-W	0.52	0.44	0.52	0.70	0.90
R-O	0.60	0.50	0.60	0.80	0.90
Contour listing or ridge planting (P_{cl})	0.30	0.25	0.30	0.40	0.45
Contour terracing (P_t)[2]	[3] $0.6/\sqrt{n}$	$0.5/\sqrt{n}$	$0.6/\sqrt{n}$	$0.8/\sqrt{n}$	$0.9/\sqrt{n}$
No support practice	1.0	1.0	1.0	1.0	$\boxed{1.0}$

P = 1.000

[1] R = rowcrop, W = fall-seeded grain, O = spring-seeded grain, M = meadow. The crops are grown in rotation and so arranged on the field that rowcrop strips are always separated by a meadow or winter-grain strip.

[2] These P_t values estimate the amount of soil eroded to the terrace channels and are used for conservation planning. For predictic of off-field sediment, the P_t values are multiplied by 0.2.

[3] n = number of approximately equal-length intervals into which the field slope is divided by the terraces. Tillage operations must be parallel to the terraces.

ATTACHMENT B

REVISED HYDROLOGIC AND HYDRAULIC CALCULATIONS

CHANNEL SUMMARY
SANTEK MATLOCK BEND LANDFILL
PROPOSED CLASS I LANDFILL EXPANSION

DITCH SECTION	APPROX. SLOPE (%)	BOTTOM WIDTH (FT)	TOTAL DEPTH (FT)	SIDE SLOPE (Z:1, L,R)	Q_{25} (cfs)	MANNING'S [1] 'n'	25-YR DEPTH (ft)	MAX. SHEAR (psf)	REQUIRED LINING	ALTERNATE LINING[2]
1	2.5	2	2	3, 3	1.9	0.026	0.24	0.37	GRASS	
2	21.2	0	2	2, 2	0.2	0.127	0.27	3.57	RIPRAP, D_{50}=1.5'	SC250
3	20.0	2	2	3, 3	5.7	0.072	0.43	5.37	RIPRAP, D_{50}=1.0'	SC250
4	Intentionally Omitted									
5	3.0	2	2	3, 3	8.3	0.026	0.50	0.94	GRASS	
6	18.0	0	2	3.2, 3.2	17.7	0.078	1.05	11.79	RIPRAP, D_{50}=2.0'	P550
7	6.0	2	2	3, 3	31.8	0.048	1.08	4.04	RIPRAP, D_{50}=0.75'	SC250
8	19.6	0	2	2.5, 7	1.4	0.066	0.19	2.32	RIPRAP, D_{50}=0.5'	SC250
9	7.0	2	2	3, 3	6.5	0.026	0.36	1.57	GRASS	
10	19.0	0	2	4.5, 2	3.0	0.048	0.45	5.34	RIPRAP, D_{50}=1.0'	SC250
11	8.3	2	2	3, 3	7.6	0.026	0.37	1.90	GRASS	
12	17.6	0	2	2, 7.5	1.6	0.077	0.37	4.06	RIPRAP, D_{50}=0.75'	SC250
13	13.0	2	2	3, 3	2.4	0.026	0.10	0.81	GRASS	
14	2.5	2	2	3, 3	3.8	0.026	0.21	0.33	GRASS	
15	28.0	4	2	3, 3	14.0	0.068	0.46	8.04	RIPRAP, D_{50}=1.5'	P550
16	3.0	2	2	3, 3	7.8	0.026	0.49	0.92	GRASS	
UPPER ACCESS ROAD DITCH	10.0	0	2	3, 3	13.4	0.055	0.95	5.93	RIPRAP, D_{50}=1.0'	SC250
MAX SLOPE BENCH	2.0	2	2	2.0, 3.0	17.0	0.026	0.79	0.99	GRASS	

1 - Manning's n has been calculated for specific 25-yr, 24-hr storm depths.
2 - SC250 and P550 refer to North American Green SC250 and P550 composite turf reinforcement mat.

CULVERT SUMMARY

SANTEK MATLOCK BEND LANDFILL
PROPOSED CLASS I LANDFILL EXPANSION

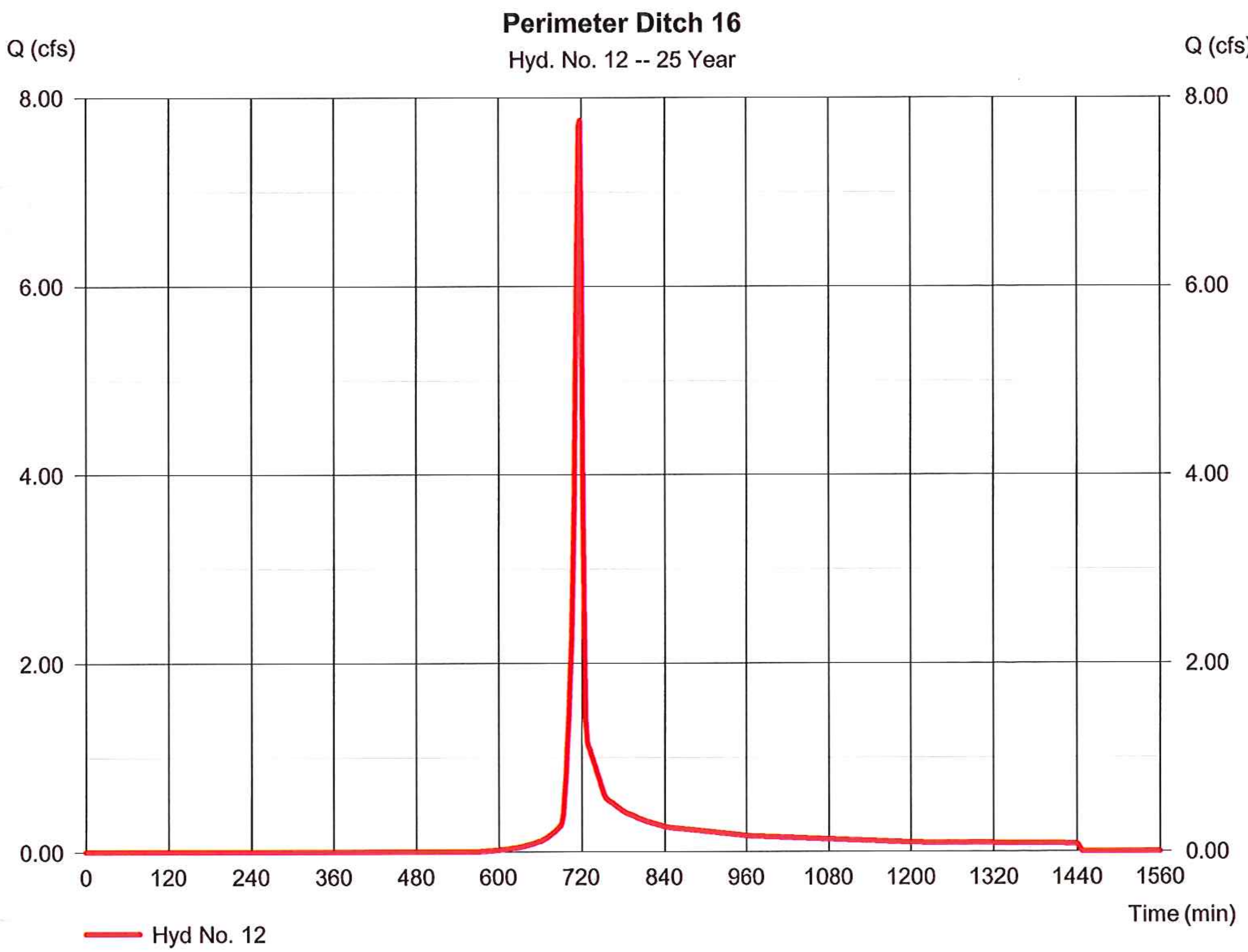
Culvert	Size (in)	Material	Q_{25} (cfs)	Invert Elevation Up (MSL)	Invert Elevation Down (MSL)	Length (ft)	Slope (%)	Outlet Apron Length (ft)	TDOT Rip-rap Class
C-1	30	CMP	36.00	929.10	927.30	33	5.45	16	A-1
C-2	30	CMP	36.00	907.34	907.27	15	0.47	16	A-1
C-3	36	CMP	48.00	978.33	978.09	62	0.39	EXISTING	
C-4	36	CMP	65.50	978.09	976.36	204	0.85	EXISTING	
C-5	36	CMP	69.00	976.36	974.87	232	0.64	EXISTING	
C-6	18	CMP	7.80	1005.50	1004.00	80	1.88	EXISTING	
MAX. DOWN CHUTE	24	CPP	65.00	VARIES	VARIES	VARIES	33.30	N/A	N/A
CULVERT ABOVE HW-2	2 @ 24	CPP	112.00	891.30	989.90	32	4.70	55	A-1
MAX. SLOPE BENCH INLET	18	CPP	13.66	VARIES	VARIES	VARIES	N/A	N/A	N/A
DS-4 INLET	60" DIAM.	CONC.	47.60	888.30	N/A	N/A	N/A	N/A	N/A

Hydrograph Report

Hyd. No. 12

Perimeter Ditch 16

Hydrograph type	= SCS Runoff	Peak discharge	= 7.755 cfs
Storm frequency	= 25 yrs	Time to peak	= 718 min
Time interval	= 2 min	Hyd. volume	= 15,574 cuft
Drainage area	= 1.920 ac	Curve number	= 70
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 5.00 min
Total precip.	= 5.46 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



Channel Report

Hydraflow Express by Intelisolve

Friday, Feb 7 2014

itch 16

Trapezoidal

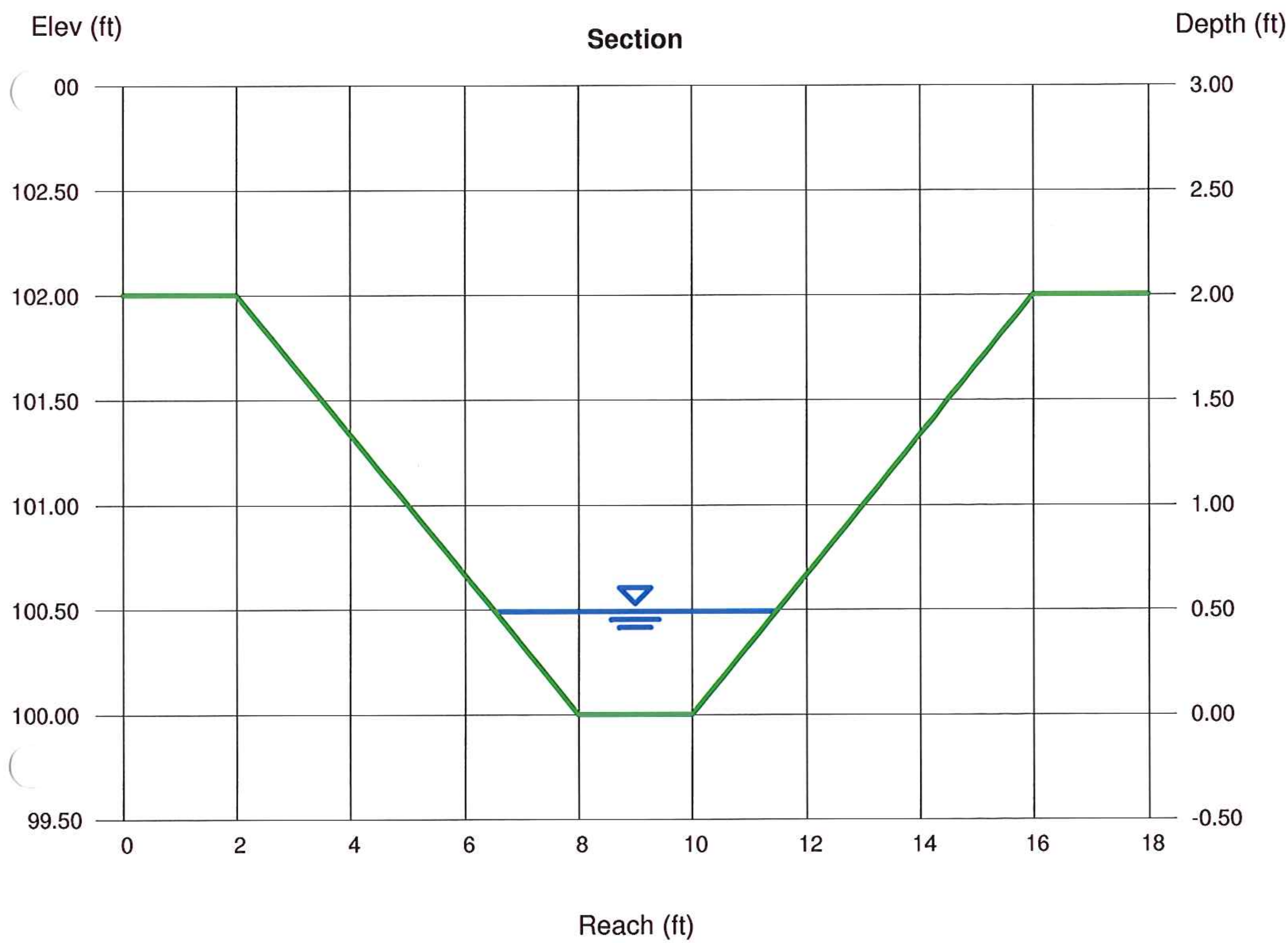
Botom Width (ft)	= 2.00
Side Slopes (z:1)	= 3.00, 3.00
Total Depth (ft)	= 2.00
Invert Elev (ft)	= 100.00
Slope (%)	= 3.00
N-Value	= 0.026

Calculations

Compute by:	Known Q
Known Q (cfs)	= 8.00

Highlighted

Depth (ft)	= 0.49
Q (cfs)	= 8.000
Area (sqft)	= 1.70
Velocity (ft/s)	= 4.71
Wetted Perim (ft)	= 5.10
Crit Depth, Yc (ft)	= 0.60
Top Width (ft)	= 4.94
EGL (ft)	= 0.83



Culvert Report

ulvert C-6

Invert Elev Dn (ft)	= 1004.00
Pipe Length (ft)	= 80.00
Slope (%)	= 1.88
Invert Elev Up (ft)	= 1005.50
Rise (in)	= 18.0
Shape	= Circular
Span (in)	= 18.0
No. Barrels	= 1
n-Value	= 0.024
Culvert Type	= Circular Corrugate Metal Pipe
Culvert Entrance	= Headwall
Coeff. K,M,c,Y,k	= 0.0078, 2, 0.0379, 0.69, 0.5

Embankment

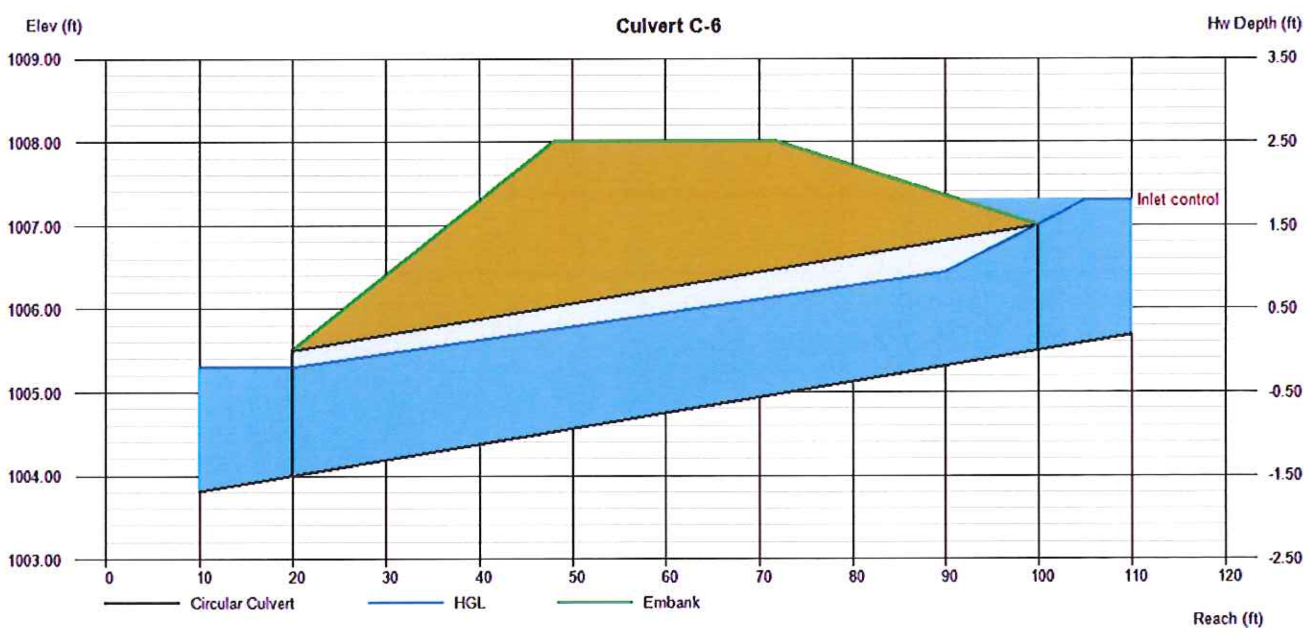
Top Elevation (ft)	= 1008.00
Top Width (ft)	= 24.00
Crest Width (ft)	= 20.00

Calculations

Qmin (cfs)	= 8.00
Qmax (cfs)	= 8.00
Tailwater Elev (ft)	= (dc+D)/2

Highlighted

Qtotal (cfs)	= 8.00
Qpipe (cfs)	= 8.00
Qovertop (cfs)	= 0.00
Veloc Dn (ft/s)	= 4.92
Veloc Up (ft/s)	= 5.79
HGL Dn (ft)	= 1005.30
HGL Up (ft)	= 1006.60
Hw Elev (ft)	= 1007.30
Hw/D (ft)	= 1.20
Flow Regime	= Inlet Control



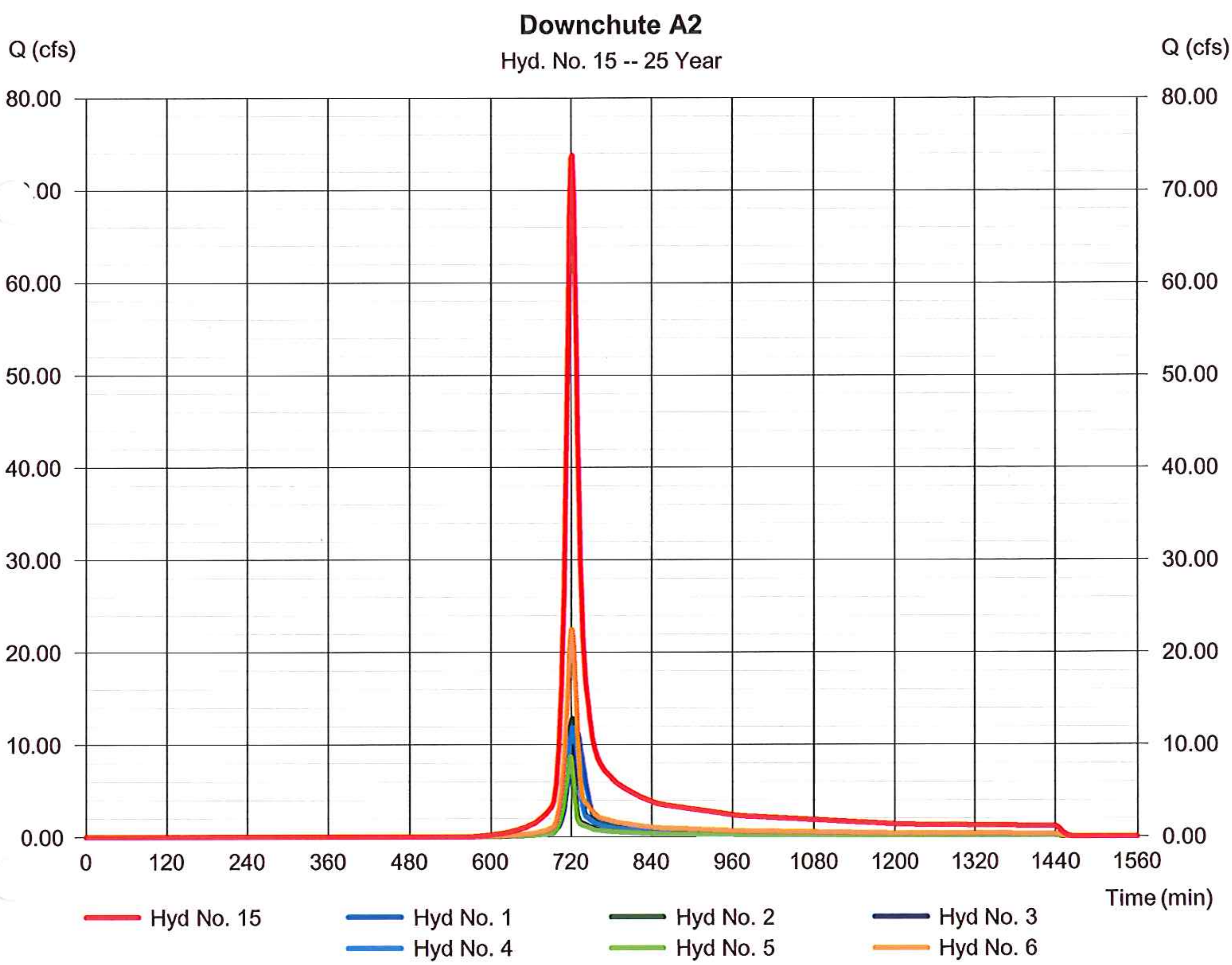
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Friday, 02 / 7 / 2014

Hyd. No. 15

Downchute A2

Hydrograph type	= Combine	Peak discharge	= 73.76 cfs
Storm frequency	= 25 yrs	Time to peak	= 722 min
Time interval	= 2 min	Hyd. volume	= 212,428 cuft
Inflow hyds.	= 1, 2, 3, 4, 5, 6	Contrib. drain. area	= 24.470 ac

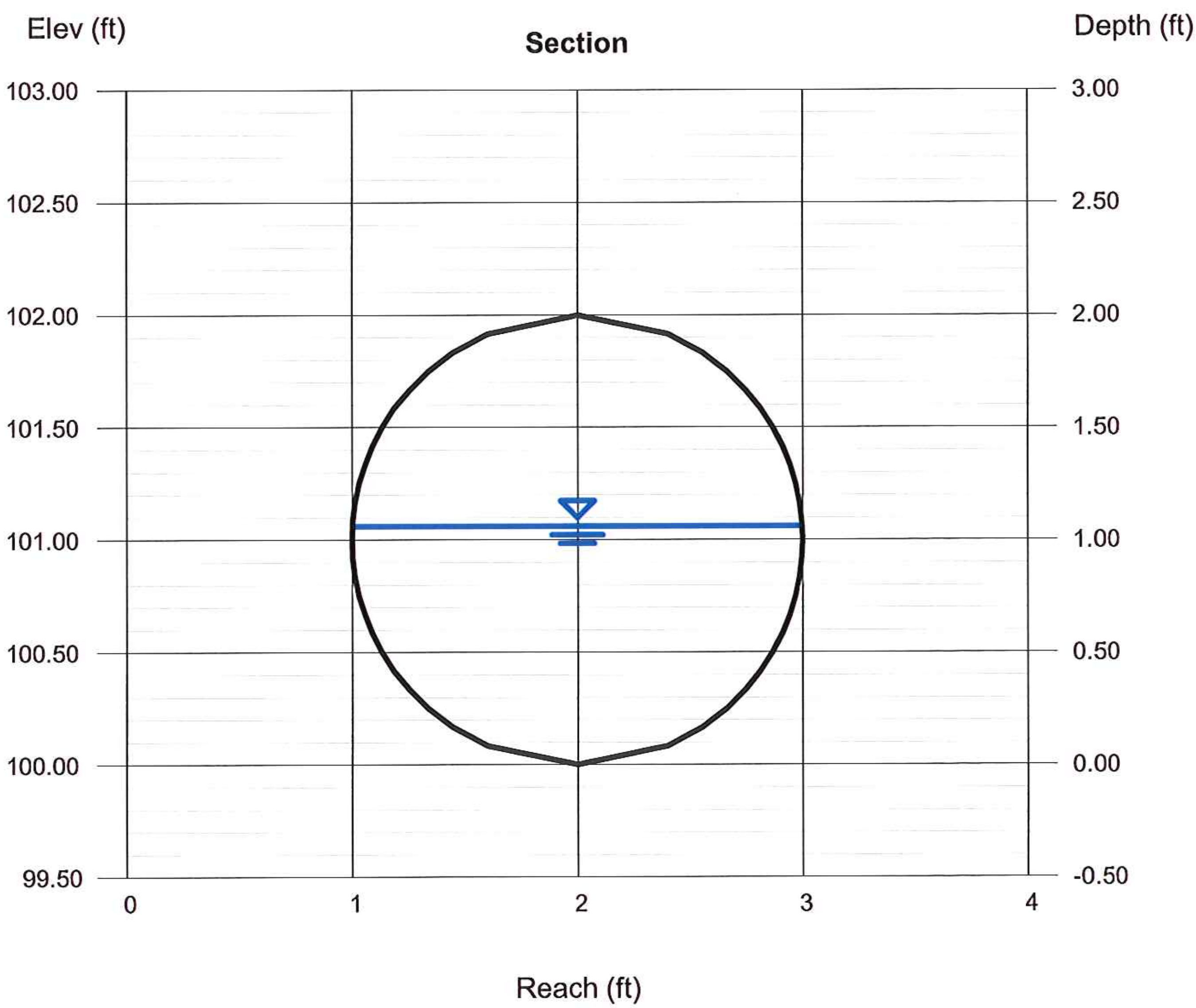


Channel Report

.AXIMUM DOWNCHUTE

Circular	
Diameter (ft)	= 2.00
Invert Elev (ft)	= 100.00
Slope (%)	= 30.00
N-Value	= 0.012
Calculations	
Compute by:	Known Q
Known Q (cfs)	= 73.80

Highlighted	
Depth (ft)	= 1.06
Q (cfs)	= 73.80
Area (sqft)	= 1.70
Velocity (ft/s)	= 43.44
Wetted Perim (ft)	= 3.27
Crit Depth, Yc (ft)	= 2.00
Top Width (ft)	= 2.00
EGL (ft)	= 30.39

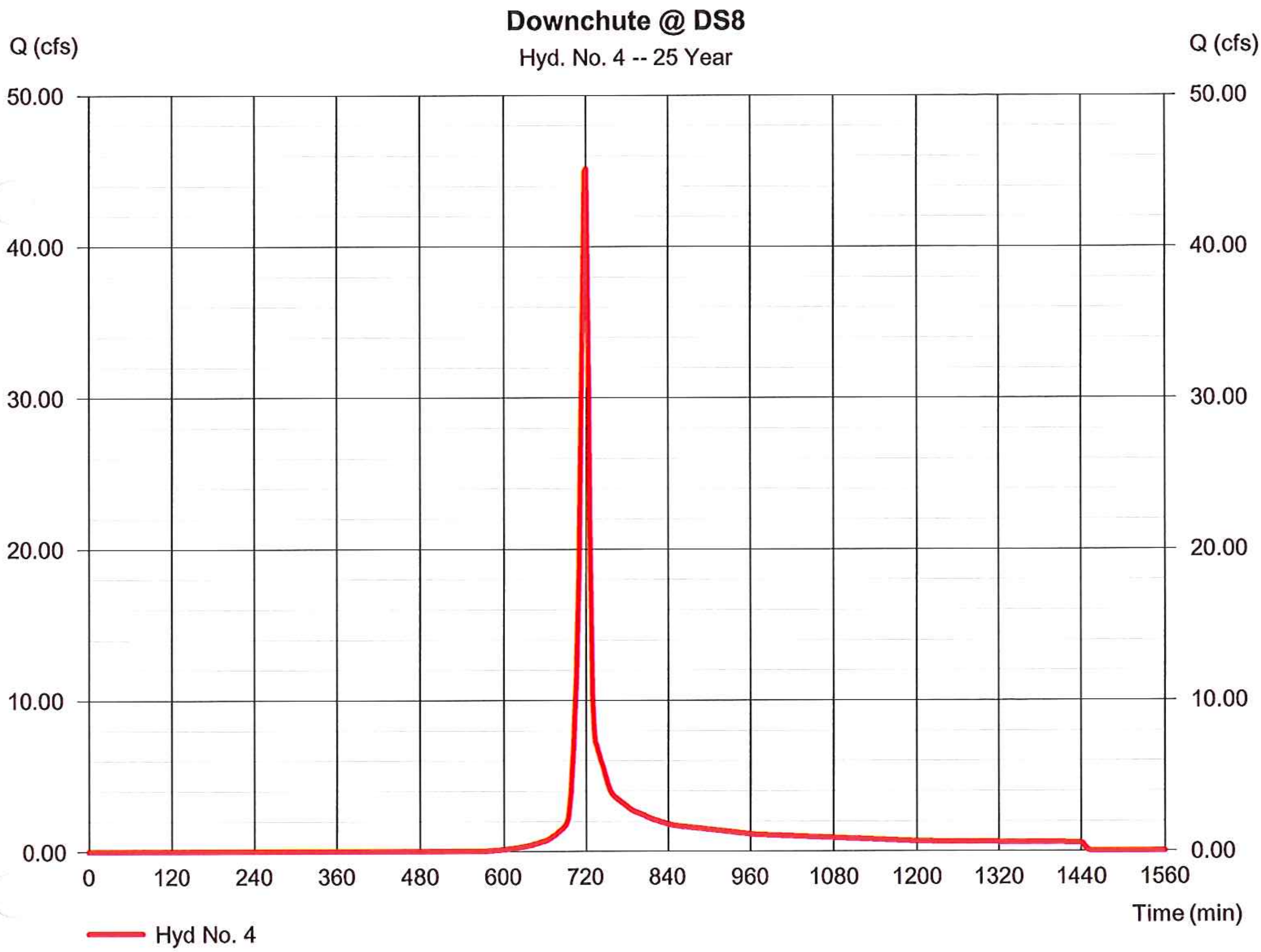


Hydrograph Report

Hyd. No. 4

Downchute @ DS8

Hydrograph type	= SCS Runoff	Peak discharge	= 45.13 cfs
Storm frequency	= 25 yrs	Time to peak	= 720 min
Time interval	= 2 min	Hyd. volume	= 103,308 cuft
Drainage area	= 11.940 ac	Curve number	= 70
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.70 min
Total precip.	= 5.46 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



Channel Report

Hydraflow Express by Intelisolve — Thursday, Feb 6 2014

,AXIMUM SLOPE BENCH

Trapezoidal

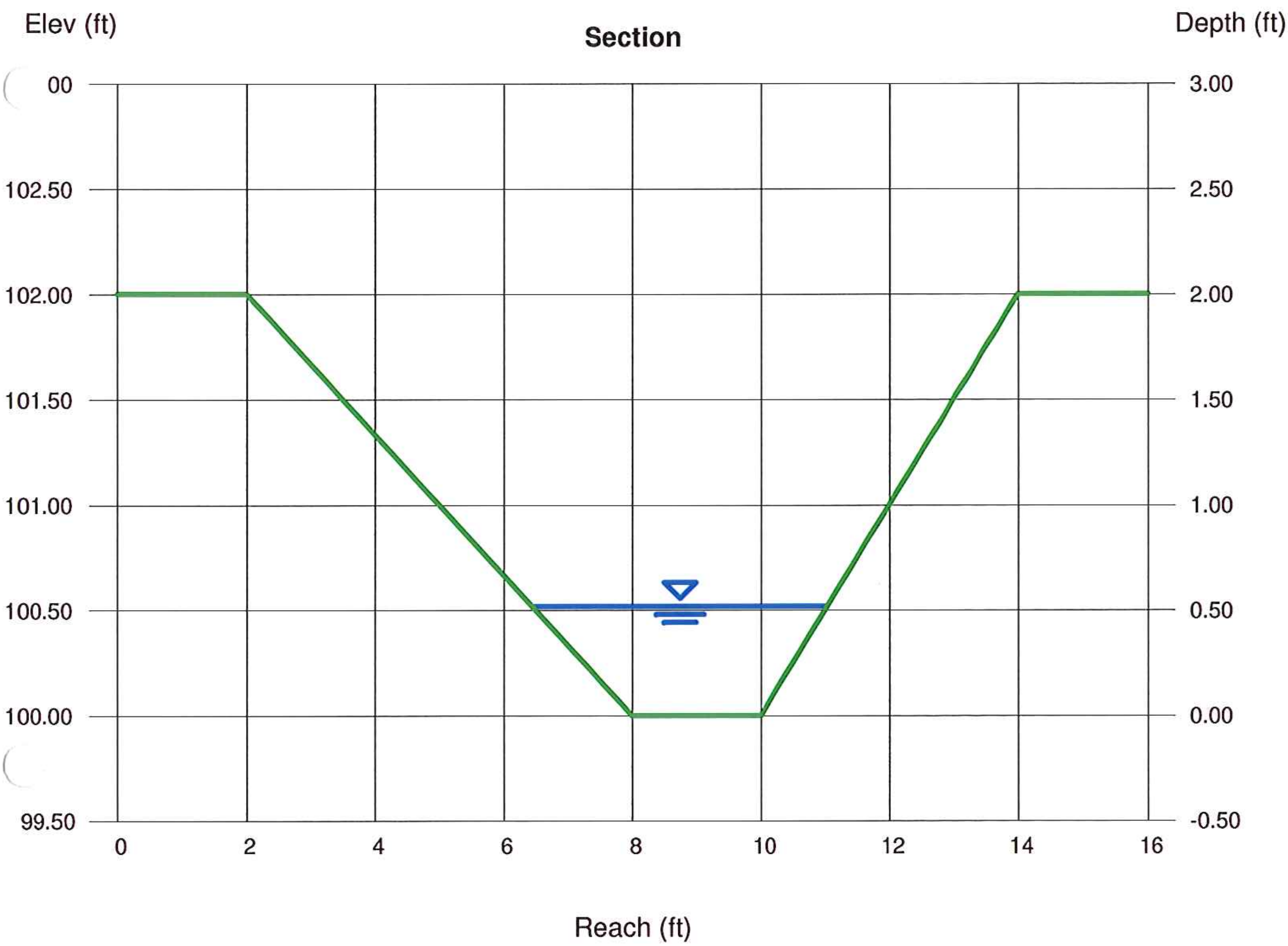
Botom Width (ft)	= 2.00
Side Slopes (z:1)	= 3.00, 2.00
Total Depth (ft)	= 2.00
Invert Elev (ft)	= 100.00
Slope (%)	= 2.00
N-Value	= 0.026

Calculations

Compute by:	Known Q
Known Q (cfs)	= 6.90

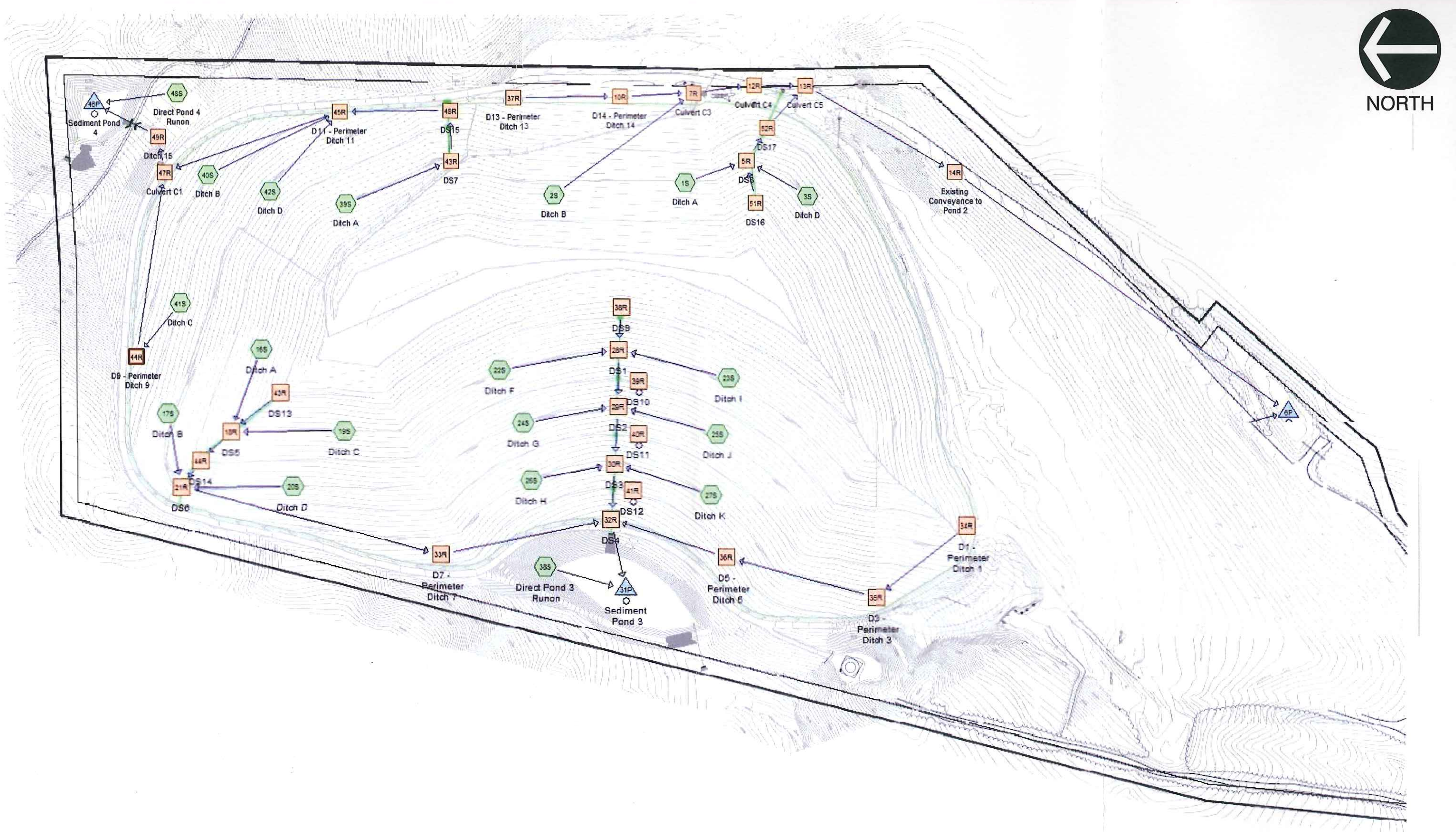
Highlighted

Depth (ft)	= 0.52
Q (cfs)	= 6.900
Area (sqft)	= 1.72
Velocity (ft/s)	= 4.02
Wetted Perim (ft)	= 4.81
Crit Depth, Yc (ft)	= 0.57
Top Width (ft)	= 4.60
EGL (ft)	= 0.77



ATTACHMENT C

STORMWATER NETWORK DIAGRAM



CEC

Civil & Environmental Consultants, Inc.

405 Duke Drive, Suite 270 - Franklin, TN 37067
615-333-7797 · 800-763-2326
www.cecinc.com

SANTEK WASTE SERVICES, INC.
MATLOCK BEND LANDFILL
LOUDON COUNTY, TENNESSEE

STORMWATER NETWORK FLOW DIAGRAM

DRAWN BY:	JLW	CHECKED BY:	BJW	APPROVED BY:	DRAFT
DATE:	FEBRUARY 2014	DWG SCALE:	N.T.S.	PROJECT NO:	140-334

DRAWING NO.: 1

ATTACHMENT D

TEMPORARY SEDIMENT POND 1 CALCULATIONS

JEFFREY L. WILLIAMS
REGISTERED ENGINEER
XVI
AGRICULTURE
COMMERCE
No. 112520
STATE OF TENNESSEE

3/7/2014

TEMPORARY SEDIMENT POND 1 SUMMARY
SANTEK MATLOCK BEND LANDFILL
PROPOSED CLASS I LANDFILL EXPANSION

BOTTOM OF POND ELEVATION (FT MSL)	TOP OF BERM ELEVATION (FT MSL)	BERM WIDTH (FT)	EMER. SPILLWAY ELEVATION (FT MSL)	EMER. SPILLWAY WIDTH (FT)	PRINCIPAL SPILLWAY ELEVATION (FT MSL)	RISER PIPE	DISCHARGE BARREL	DISCHARGE BARREL SLOPE	DEWATERING DEVICE	ELEVATION OF SKIMMER INVERT (FT MSL)	25-YR REQUIRED VOLUME (AC-FT)	VOLUME AT PRIMARY SW ELEV. (AC-FT)
892.0	910.0	10	908.0	15	907.25	36" CMP	24" CMP	0.50%	8" SKIMMER	900	2.60	3.1

Hydrograph Return Period Recap

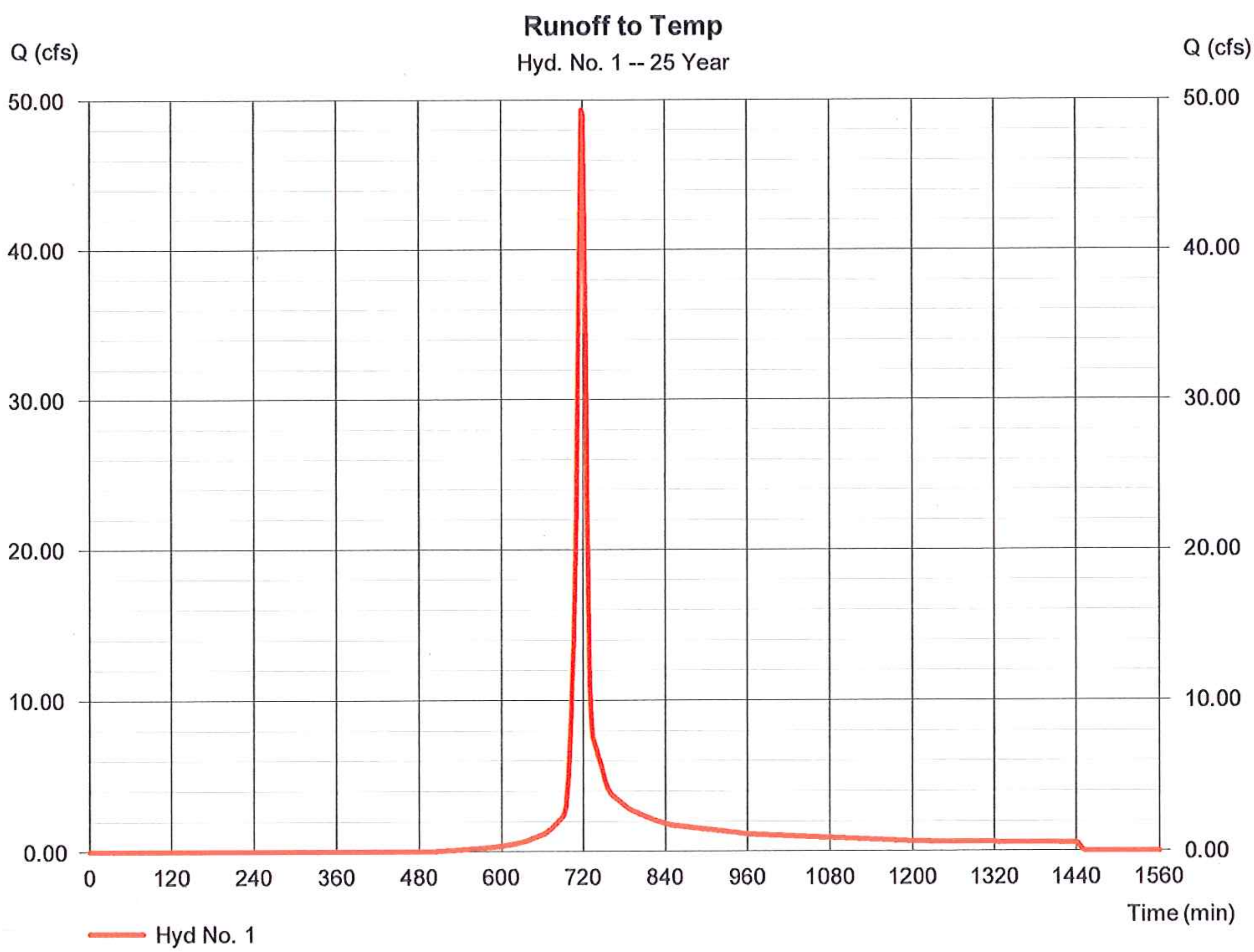
Hyd.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)								Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	-------	20.91	-------	30.26	38.08	49.35	58.54	68.02	Runoff to Temp
3	Reservoir	1	-------	1.130	-------	1.130	1.130	1.130	1.130	1.130	Temp Pond Routing

Hydrograph Report

Hyd. No. 1

Runoff to Temp

Hydrograph type	= SCS Runoff	Peak discharge	= 49.35 cfs
Storm frequency	= 25 yrs	Time to peak	= 718 min
Time interval	= 2 min	Hyd. volume	= 112,892 cuft
Drainage area	= 11.000 ac	Curve number	= 75
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.80 min
Total precip.	= 5.46 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3

Hyd. No. 1

Runoff to Temp

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.240		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.36		0.00		0.00		
Land slope (%)	= 14.00		0.00		0.00		
Travel Time (min)	**= 6.39**	**+**	**0.00**	**+**	**0.00**	**=**	**6.39**
Shallow Concentrated Flow							
Flow length (ft)	= 205.00		0.00		0.00		
Watercourse slope (%)	= 19.50		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=7.12		0.00		0.00		
Travel Time (min)	**= 0.48**	**+**	**0.00**	**+**	**0.00**	**=**	**0.48**
Channel Flow							
X sectional flow area (sqft)	= 8.00		0.00		0.00		
Wetted perimeter (ft)	= 10.00		0.00		0.00		
Channel slope (%)	= 2.00		0.00		0.00		
Manning's n-value	= 0.025		0.015		0.015		
Velocity (ft/s)	=7.26						
			0.00				
					0.00		
Flow length (ft)	({0})390.0		0.0		0.0		
Travel Time (min)	**= 0.90**	**+**	**0.00**	**+**	**0.00**	**=**	**0.90**
Total Travel Time, Tc							**7.80 min**

Hydrograph Report

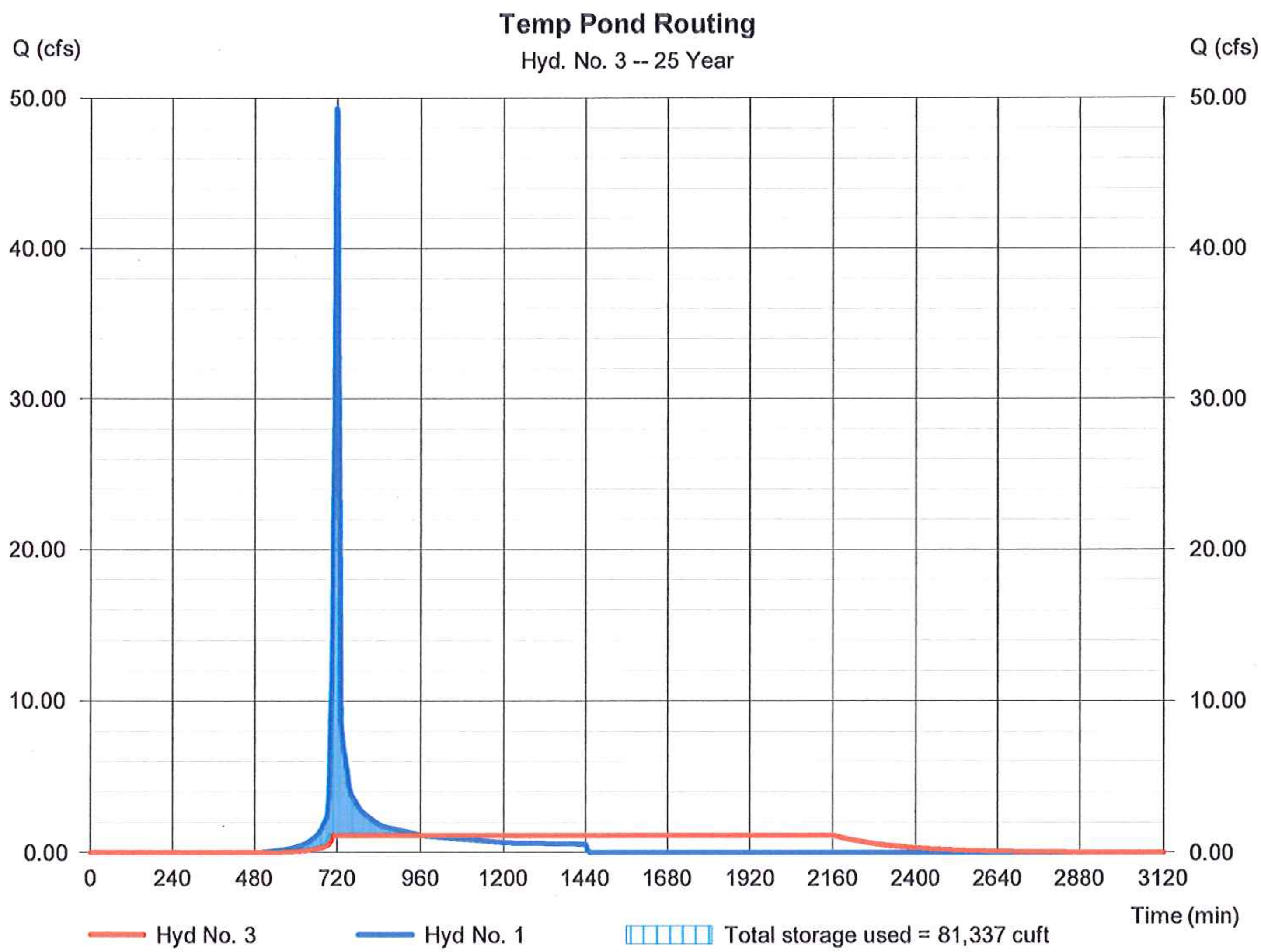
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 — Sunday, 03 / 9 / 2014

Hyd. No. 3

Temp Pond Routing

Hydrograph type	= Reservoir	Peak discharge	= 1.130 cfs
Storm frequency	= 25 yrs	Time to peak	= 710 min
Time interval	= 2 min	Hyd. volume	= 112,881 cuft
Inflow hyd. No.	= 1 - Runoff to Temp	Max. Elevation	= 904.70 ft
Reservoir name	= Temp Sed Pond	Max. Storage	= 81,337 cuft

Storage Indication method used. Wet pond routing start elevation = 898.00 ft.



Pond Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2014 by Autodesk, Inc. v10.3 Sunday, 03 / 9 / 2014

Pond No. 1 - Temp Sed Pond

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 892.00 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	892.00	43	0	0
0.10	892.10	45	4	4
2.00	894.00	625	530	535
4.00	896.00	1,970	2,469	3,004
6.00	898.00	4,567	6,357	9,361
8.00	900.00	7,924	12,337	21,698
10.00	902.00	11,615	19,420	41,118
12.00	904.00	15,948	27,446	68,564
14.00	906.00	20,886	36,720	105,283
16.00	908.00	26,574	47,341	152,625
18.00	910.00	32,533	59,001	211,625

Culvert / Orifice Structures

	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 24.00	0.00	0.00	Inactive
Span (in)	= 24.00	0.00	0.00	0.00
No. Barrels	= 1	0	0	1
Invert El. (ft)	= 892.00	0.00	0.00	0.00
Length (ft)	= 64.00	0.00	0.00	0.00
Slope (%)	= 0.50	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	No

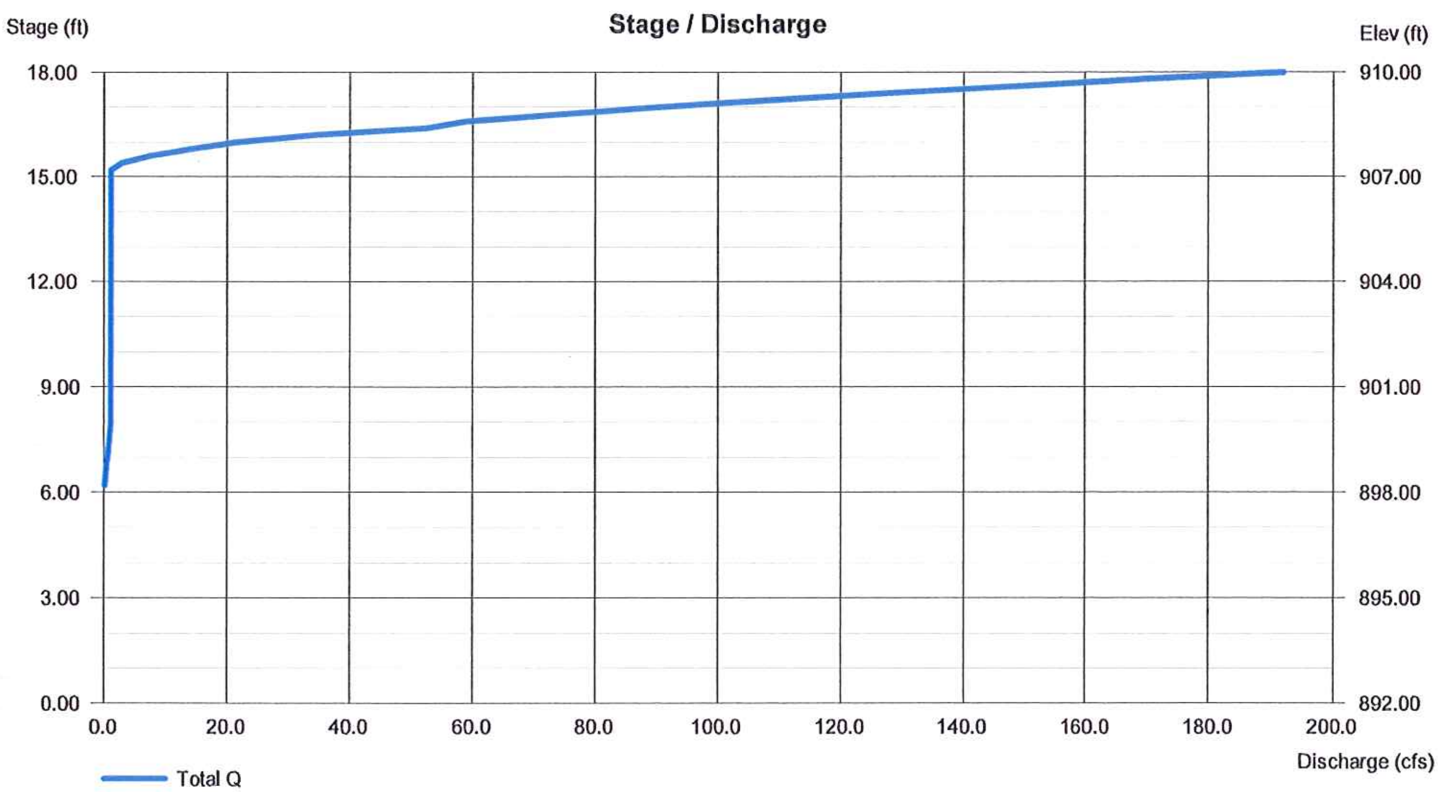
Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 9.42	15.00	0.00	0.00
Crest El. (ft)	= 907.25	908.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= 1	Ciplti	---	---
Multi-Stage	= Yes	No	No	No

Exfil.(in/hr) = 0.000 (by Wet area)

TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).



Weir Report

Temp. Sed. Pond 1 Emer. SW - 100-yr Storm

Rectangular Weir

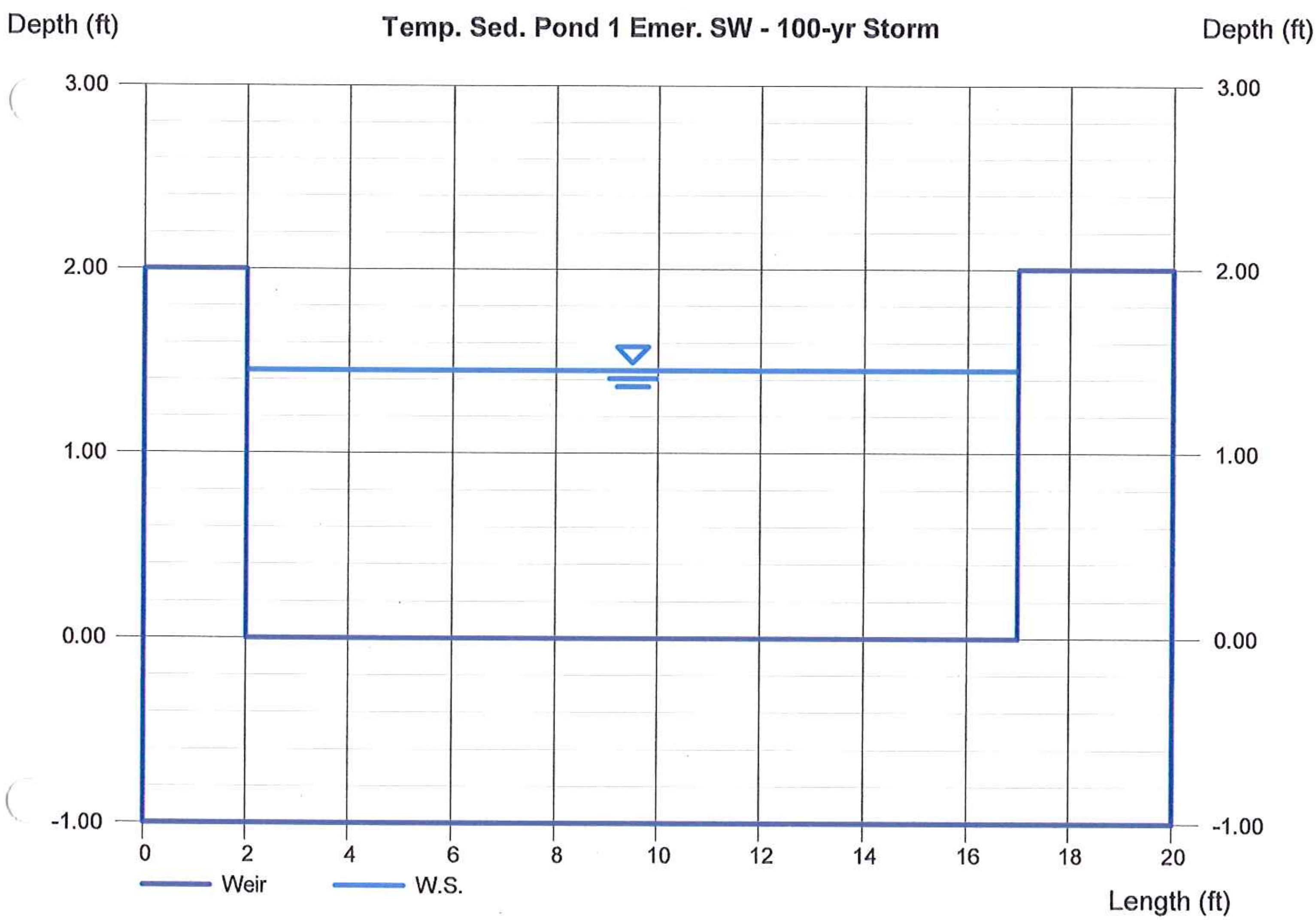
Crest	= Broad
Bottom Length (ft)	= 15.00
Total Depth (ft)	= 2.00

Calculations

Weir Coeff. Cw	= 2.60
Compute by:	Known Q
Known Q (cfs)	= 68.00

Highlighted

Depth (ft)	= 1.45
Q (cfs)	= 68.00
Area (sqft)	= 21.73
Velocity (ft/s)	= 3.13
Top Width (ft)	= 15.00



OPERATIONS PLAN

MATLOCK BEND CLASS I LANDFILL EXPANSION

FACILITY OPERATIONS PLAN

Prepared For:
Loudon County Solid Waste Disposal Commission
100 River Road
Loudon, Tennessee 37774

Prepared By:

Santek Waste Services Inc.
650 25th Street, NW, Suite 100
Cleveland, Tennessee 37311

Submitted To:

Tennessee Department of Environment and Conservation
Division of Solid Waste Management

August 2009
Revised April 2010
Revised September 2010
Revised May 2013
Revised February 2014

TABLE OF CONTENTS

APPENDICES

1.0 INTRODUCTION

1.1 Authorization

Santek Environmental, Inc. (Santek) has been authorized by Loudon County Solid Waste Disposal Commission to provide turnkey design and operational control of the Matlock Bend Subtitle D Landfill. Under that authorization, Santek is providing engineering services for the design of the Matlock Bend Class I Landfill (MBL) Expansion. A registered professional engineer will also be utilized for inspection of construction as required. This shall be in accordance to Rule 0400-11-01-.04(1)(c) of Chapter 0400-11-01 *Solid Waste Processing and Disposal*.

1.2 Purpose and Scope

Preparation of this Facility/Operations Plan (Plan) is in accordance with the Tennessee Department of Environment and Conservation (TDEC), Division of Solid Waste Management's rules. The requirements of Rule 0400-11-01-.04(9)(c) will be specifically addressed.

1.3 Facility Description

The MBL is a Class I municipal solid waste landfill Site which serves the sanitary and industrial waste disposal needs of Loudon County and surrounding areas outside of the county. The MBL is located on approximately 152.33 acres of land, about 5 miles west of the City of Loudon near State Route 72 and approximately 1.25 miles west of U.S. Interstate Route 75, at latitude 35°44'86" North and longitude 84° 24' 45" West. The above latitude and longitude were obtained from the Philadelphia, Tennessee 7.5 quadrangle map which is based on National Geodetic Vertical Datum of 1929 (NGVD29). Permanent benchmarks of known elevation have been constructed on-site as shown on Sheet 2 of the permit drawing package.

A Location Plan and Master Plan are provided on Sheets 1 and 2, respectively, of the permit drawing package. The facility is located on property with a Part II.A. Hydrogeological Report accepted as complete by the TDEC Division of Solid Waste Management on January 29, 2009. A copy of the TDEC acceptance letter is included in Appendix A. Adequate water supply and electrical service is located within 500 feet of the MBL and will be extended to incorporate the new Site as construction and operation requires.

At the time landfill development is completed, approximately 67 acres will have been used for solid waste disposal in this permit area. Existing permitted Modules A through J comprises approximately 40.7 acres and proposed Modules J through P comprises approximately 26.5 acres. Existing permitted, but unconstructed modules E, H, I and J will be altered and renamed in this expansion permit. The facility has a total volume estimated to be 10,582,709 cubic yards (cy) of airspace available for waste and cover soil. The remaining life (as of Sept. 19, 2012) of the facility is projected to be approximately 26.9 years based on an estimated average disposal rate of 925 tons per day. The life estimate is based on average in-place waste and cover soil density of 1,450 lb/cy and 273 operational days per year. The information above satisfies, in part, Rule 0400-11-01-.04(9)(c) 2, 9, and 10. For additional information on solid waste type and source, refer to Section 2.6 of this Plan.

1.4 Designation of Responsibility

Matlock Bend is ultimately responsible for the operation and maintenance of the MBL. All inquiries and correspondence concerning the landfill's permits and operations should be submitted to his/her attention at the following address:

Chairman Steve Field
Loudon County Solid Waste Disposal Commission
100 River Road
Loudon, Tennessee 37774
Telephone No. (865) 576-1057

Daily operation and maintenance of the landfill will be conducted by Santek. Landfill operations shall be supervised by a qualified individual who shall be thoroughly familiar with proper landfill operating procedures and who is trained and certified in accordance with Rule 0400-11-01-.12. The above information satisfies Rule 0400-11-01-.04(9)(c)1.

2.0 OPERATIONS PLAN – GENERAL CONSIDERATION

2.1 Introduction

This Plan is to set forth operating and maintenance procedures necessary to meet all environmental regulations and effectively dispose of solid waste. Establishment and enforcement of the proposed procedures for operation and plans for future development will be the ultimate responsibility of landfill management.

The objectives of the Operations Plan are to:

- Present operation details that are compatible with the site characteristics and are useful to, and understandable by, operating personnel;
- Protect the environment; and
- Provide an efficient and economical operation.

2.2 Compliance to Buffer Zone Standards

The landfill is located, designed, constructed, operated, and maintained in accordance to Rule 0400-11-01-.04(3)(a). The waste limit fill area is surrounded by a 100-ft buffer zone from the facility property line and greater than 500 feet from the nearest resident. The nearest existing downgradient drinking water well is greater than 500 feet from the waste limit. No springs, streams, lakes, or other bodies of water are located within 200 feet of the waste limit.

Table 1 provides a description of the surrounding features and their approximate distance to the waste limit.

Table 1

Structure / Feature	Requirement	Location and estimated distance relative to waste limit
Nearest Property Line	100 feet	A minimum 100 foot buffer will be in place between the property line and the placement of waste.
Nearest Residence	500 feet	Approximately 2,100 feet south of the proposed waste limit boundary.
Nearest Well	500 feet	43 private water wells are located within a 1 mile radius of the landfill site, as provided on page 9 of the approved hydrogeologic study.
Nearest Stream	200 feet	Unnamed Tributary 2,100 feet to the south.

2.3 Facility Access Controls

Entrance to the MBL property is provided with a locking gate to allow public access to the Site during working hours only. This gate is kept locked when the landfill is closed. Signs erected at the entrance gate will describe the following information:

1. Name of the facility
2. Emergency telephone numbers

3. Fees charged
4. Restricted materials
5. Normal operating hours
6. Penalty for unlawful dumping
7. Tarp policy

Furthermore, signs will be posted as needed to notify haulers of speed restrictions and to direct them to the proper disposal areas. Such signs shall be legible and placed conspicuously to encourage safe operation within the landfill.

A formal record of each authorized vehicle that enters the Site will be kept by the scale house attendant. The log may be in paper or electronic format. Preliminary load inspection takes place as the trucks are being weighed in at the MBL facility. The scale house operator will visually inspect open incoming trucks and randomly question the drivers about the materials being transported, including the place of origin. If the scale house operator determines that unacceptable material is being conveyed, the driver will be directed to consult a hazardous materials waste contractor for guidance on proper off-site disposal. Trucks carrying acceptable waste will be directed by the scale house operator to the proper location for on-site disposal. Signs along the road will be placed as required to guide the transporters to the appropriate disposal area.

Random physical inspections of 5% of all incoming vehicles will be conducted by MBL personnel. Records of these inspections will be kept including the time, date, type of waste, vehicle identification, driver signature, and name of waste transporter. If unacceptable materials are discovered during unloading of the trucks, the wastes will be reloaded and the driver will be directed to consult a hazardous material contractor for guidance on proper off-site disposal. Suspicious loads will also be inspected. For more information on the random inspection procedures, refer to Section 2.23, Random Inspection Program, of this Plan.

Review of the solid waste manifest and scale house records aid the landfill staff in tracing the origin of unacceptable loads which are placed and not discovered prior to the hauler leaving the Site. However, if the source is not discovered, then it will be the responsibility of the MBL operator to dispose of the material.

The landfill's operations hours for receiving waste are Monday through Friday (7:30 am – 4:00 pm), Saturday (7:30 am – 12:00 pm) and closed on Sunday. However, operations at the facility may take place 24 hours per day, 7 days a week.

2.4 Tire Disposal

Waste tires will be segregated from the waste stream and temporarily stored for up to one-year on-site in a designated tire storage area. The tires will be loaded into trailers within the tire storage area awaiting disposal in an approved manner. A buffer zone at least 50-feet wide will separate the storage trailers from each other and the active disposal area.

The tire storage area will be surrounded by an 18-inch high earthen berm to manage stormwater run-on and run-off and to provide containment of control water used in the event of a fire. The tire storage area will not be located within a 100 year floodplain, wetlands, or an area anticipated to be used for waste disposal within one year. To aid in insect and vector control, spraying and/or other approved methods may be employed on an as needed basis.

The potential for fires shall be kept to a minimum by restricting and monitoring access to the tire storage area. Flammable liquids and combustible materials will not be stored near the tire storage area. The area inside the berm and the remaining 50-foot buffer zone will be kept free of brush and high grass. The MBL facility will have sufficient fire extinguishers and a water tanker (used for dust control) for accidental small fires. A letter assuring response from the Loudon County Fire Department has been filed with the Division of Solid Waste Management (included in Appendix A) and the telephone number of the responding Fire Department will be posted at the MBL facility.

Trained personnel will be present during operating hours and are equipped with communication devices. One of the MBL employee duties is to direct and assist customers on where to unload waste tires. The access road to the tire storage area will be a compacted earthen road with gravel or other acceptable material. The immediate area for loading and unloading waste tires will be covered with gravel, or other acceptable material.

In compliance with Rule 0400-11-01-.04(2)(k)3(i)(II)VI, tires or shredded tires may not be stored for more than one (1) year, and the MBL will maintain records sufficient to establish the date each tire pile within a storage area was begun. These records will be maintained at the facility.

Disposal of waste tires will be in accordance with one or both of the following methods:

1. Tires will be disposed of off-site in an approved manner, or

2. Periodically, a mobile tire shredder can visit the Site and shred the tires. The shredded tires can be disposed of at the working face or sent off-site in an approved manner.

2.5 Method and Sequence of Operation

MBL anticipates the construction of Module I as the initial phase of construction of this expansion. Subsequent phases of construction may require placement of waste over existing waste. In such a case, intermediate soil cover will be stripped or windows excavated in the soil cover prior to waste placement to promote downward movement of leachate.

- The top twelve inches of soil material in the landfill expansion area is to be considered topsoil and should be stripped and stockpiled separately. It is preferable for stockpiles to be located in areas that will not disrupt construction or traffic flow around the perimeter of the new cell or existing landfill operations.

- After stripping of topsoil, the remaining excavation is to be completed to the grades and elevations shown on the permit drawing package. The materials removed by excavation are to be tested per the quality assurance standards outline in the Construction Specifications and Quality Assurance Plan (CSQA Plan) included in Appendix B. Any material having soil properties to obtain a remolded permeability of 1×10^{-5} cm/sec or less is to be stockpiled separately for use in the construction of barrier soil layers. Other material will be used as fill materials in the construction of roads and berms. Any excess excavation materials will be stockpiled for future use as operational cover materials.

- Prior to placement of the barrier soil layer, the subgrade will be proof rolled with a loaded, tandem-axle, dump truck or approved, pneumatic-tired construction equipment. Areas that pump, rut or behave in an unstable manner will be undercut to stiff soil.

- After inspection of the disposal area is complete, placement and compaction of the barrier soil layer with a maximum permeability of 1×10^{-7} cm/sec will begin. Barrier soil 1×10^{-5} cm/sec may be installed if 1×10^{-7} cm/sec is not available. The material will be placed in loose lifts not to exceed nine inches and each lift will be compacted to an approximate six inch lift and inspected in accordance with the CSQA Plan.

- After construction of the barrier soil layer, a geosynthetic clay liner (GCL) will be installed on the barrier soil if 1×10^{-5} cm/sec barrier soil was installed. A geomembrane installer shall place a textured 60 mil HDPE geomembrane liner over the 1×10^{-7} barrier soil or the GCL as shown in the permit drawing package. Santek's Project Manager and the construction quality assurance (CQA) Officer/Engineer or Field Technician will oversee the installation of the geomembrane liner and verify that the installer's quality control procedures meet those included in the project specifications.

- After the geomembrane liner is installed, approved and accepted, construction of the leachate drainage system will begin. A geotextile will be placed directly over the geomembrane to provide a cushion for the leachate drainage media. The leachate drainage media will be 12 inches of #57 washed limestone placed over the geotextile cushion. A layer of geotextile fabric will be placed on top of the drainage media. The drainage media will be spread over the geotextile cushion by a tracked dozer. A low-ground pressure

dozer will be used to spread a minimum one-foot bed of drainage media beneath it at all times. A standard-track dozer will supply the small low-ground pressure dozer by pushing a minimum three-foot bed of rock beneath it at all times. No equipment will be in direct contact with the geotextiles.

- Five leachate collection sumps will be constructed in the expansion area. The first leachate collection sump will be located within Module O and is designed to collect leachate from Modules A, O and F. The second leachate collection sump will be located within Module I and is designed to collect leachate from Modules B, C, D, G and P. The third leachate collection sump will be located in Module K and will collect leachate from Module K. The fourth leachate collection sump will be located in Module L and will collect leachate from Modules L, M and N. The fifth leachate collection sump will be located in Module J and will collect leachate from Modules H, I and J. Leachate from the existing Modules A through I of the existing landfill will be routed and collected in the three new leachate collection sumps as specified. The sumps have been designed to have up to 4-feet of hydraulic head. The remainder of the leachate collection system is designed for 1-foot of head.

- Leachate collection pipes will be installed during placement of the 12-inch drainage layer. The leachate collection pipes will be placed directly on the geotextile cushion and backfilled with #57 washed non-carbonate stone or equivalent to the specified depth of 12 inches. In addition, #57 washed non-carbonate stone will be placed at the toe of slopes in the landfill modules.

- For construction of the side slope composite liner profile, a geotextile (see Detail C on Sheet 12B of the permit drawing package) will be placed over the textured geomembrane to serve as a protective cushion and provide more interface shear strength. Washed #57 limestone will be placed directly on the geotextile to supplement protection of the textured geomembrane liner and provide a path for leachate drainage.

- After placement of the leachate drainage media is complete, a layer of geotextile will be placed over the leachate drainage media prior to placement of waste.

- The initial lift of waste will be visually screened to eliminate large sharp objects that have the potential to damage the liner system, be at least six feet in depth and will cover the entire lined portion of the disposal area so as to provide protection for the geomembrane liner.

In order to increase the overall efficiency and safety of waste placement operations, stormwater segregation berms may be installed. These physical divisions within a module reduce the volume of stormwater runoff that comes in contact with the waste and, consequently, reduce the volume of leachate to be processed. The actual time and location of construction of these berms is a function of the rate of waste placement and the volume of stormwater to be managed. Consequently, actual locations of these berms are not presented in the permit drawing package prior to construction. Stormwater control details are presented on Sheets 14A through 14D of the permit drawing package.

Fill progression is shown on Sheets 8A through 8G of the permit drawing package. The following narrative provides a general description of the fill procedures:

- Following construction of the first stormwater diversion berm (rain flap), waste placement will begin in the active module. Initial lifts of select waste (minimum four feet thick) will be placed in the lower portion of the active area. Select waste excludes bulky wastes, rods, poles, fence posts, and other waste with higher potential for damaging the liner. Waste filling will typically progress from the low point of the module and isolation berms upward to the first stormwater diversion berm.

- A sufficient number of pumps of adequate capacity will be maintained and employed on the stormwater diversion berm and the isolation berm bordering the active portion of the module. These pumps will be utilized to remove stormwater that collects along the upstream toe of the berms to prevent contact with in-place Class I waste. This will allow runoff to be discharged to the stormwater detention basins or other acceptable structures.

- When the active area reaches the toe of the stormwater diversion berm, the stormwater diversion berm will be removed and the removed rock material will be stockpiled for later use or spread into the leachate collection layer. If needed, the next stormwater diversion berm will be in place above the active area. A lift of waste will then be placed to the next stormwater diversion berm or isolation berm.

- Once the waste placement progresses to the level where exterior final or temporary slopes are constructed above the perimeter isolation berm or intercell berm, intermediate cover soil will be placed on the slope. Precipitation and other surface water will be directed to flow over the perimeter berm to a perimeter ditch or temporary stormwater pond before being diverted to one of the three stormwater management ponds. Only surface water that has avoided contact with the waste will be treated in this manner. Surface water that contacts the waste will be directed into the cell where it will be collected and handled as leachate.

- When the bottom area from the toe berm (low end) to the isolation berm (high end) within the active module is covered with a lift of select waste, the fill sequence will then progress from the high end of the module back toward the low end.

2.6 Solid Waste Type, Quantity, and Source

The MBL accepts Class I wastes for disposal. Class I wastes include: domestic wastes, commercial wastes, institutional wastes, industrial wastes, municipal wastes, demolition/construction debris, sewage solids, farming wastes, shredded or chipped waste tires, and dead animals. Special waste shall be disposed of in the Class I landfill area only if special provisions are made for such disposal and only if it is approved by the TDEC, Division of Solid Waste Management.

Based on the quantity of solid waste currently accepted, it is estimated that approximately 600 to 800 tons per day of Class I waste will be disposed at MBL. The facility will typically operate, a minimum of 273 days a year.

2.7 Landfill Acreage

A 150-acre Site, including the required buffer zones, has been designated for the MBL facility. The conceptual design of the expansion has designated a total of approximately 67 acres of this Site for the purpose of Class I waste disposal. The existing permitted modules comprise approximately 40.7 acres and the proposed expansion comprises approximately 26.5 acres.

Presently permitted Modules A through H operational areas have been utilized in the development of this Plan. The operational boundary and phasing plan for the expansion is shown on Sheets 8A through 8G of the permit drawing package in accordance to Rule 0400-11-01-.04(9)(b)1(viii). Modules are anticipated to be constructed in accordance with the phasing plan; however, the phasing plan will be assessed throughout the operational life of the facility. The module layout and sequence of module construction shown on Sheets 8A through 8G is proposed at the time of this submittal. Modifications to the module layout and sequencing may be required to better facilitate operational and construction needs in the future.

The module limits provide approximate boundaries of the anticipated progression of the landfilling operations. It is possible that changes in the waste stream, schedule or other factors could necessitate variations in the location of these module limits. Consequently, the module locations and limits should be considered approximate. The perimeter waste boundary will not be extended beyond the limits shown on the permit drawing package.

Also, the module may be constructed in whole or in part as required by operational and construction needs. For example, a module may be constructed in two sections, with each half given a designation, i.e. Module L could be divided into Module L-A and Module L-B.

In order to maintain drainage to the leachate collection sumps and control stormwater both above the active fill area and in the area adjacent to isolation berms, the bottom elevation within a module may be raised (but not lowered below the contours shown on the drawings) in localized areas to accommodate needed drainage improvements. Such changes would not affect the final contours nor lead to an increase in the total capacity of the facility.

2.8 Waste Handling and Covering Program

The waste hauling vehicles will deposit their loads at the open working face, as directed by MBL facility personnel. The facility personnel will be present to ensure safety and inspect the waste for acceptability. The solid waste will then be spread in lifts approximately three feet thick or less. Dimensions of the open working face will be minimized, yet will be a sufficient size for proper waste disposal and equipment maneuvering. The slope of the waste placement will be maintained at or less than three horizontal to one vertical (3:1), as shown on the permit drawing package. Lifts of waste will be sloped as required to promote drainage off of the lift. Benches or add on berms will be constructed to provide stormwater drainage and reduce erosion of cover soil.

At the end of each day, one or both of the following methods will be used as daily cover:

1. Six inches of soil cover material placed on the compacted wastes of the working face and/or
2. Synthetic daily cover material. (i.e. tarps)

In the event that only synthetic daily cover is used, at least once a week a minimum of six inches weekly soil cover material will be placed on the waste.

Intermediate cover soil consists of an additional 6 inches of compacted soil on top of the 6 inches of daily/weekly cover soil or other material approved by the TDEC. Intermediate cover soil will be utilized on all surfaces that will be exposed for a period of thirty days in accordance with Rule 0400-11-01-.04(6)(a)4. The intermediate cover soil will be maintained on all surfaces until either additional wastes are placed over the surfaces or final closure cover is applied. Stockpiled soil obtained from excavating the current module or future modules may be used for barrier soil layer construction, daily, weekly and intermediate cover.

2.9 Sanitary Landfill Equipment

The following is a list of the major equipment available that may be used on the Site:

Quantity	Description
1	816F CAT landfill compactor
1	D65 Komatsu bulldozer
1	D4 CAT bulldozer
1	D6R CAT bulldozer
1	62 CAT scraper
2	963 CAT loader
1	580 Dresser road grader
1	24,000 gallon Volvo water truck
1	International service truck
1	Manager Pickup
1	Landfill Pickup
1	John Deere tractor

Back-up equipment is available and included in the list above. In the event that additional back-up equipment is required, it may be rented, leased, or obtained from other landfill operations managed by Santek. The equipment list provided above is proposed at the time of this submittal, and may be modified during operations with alternate equipment of various makes and models. Maintenance shall be provided by in-house personnel or at a commercial location in the MBL area. Tools and supplies necessary for the proper operation and maintenance of the equipment shall be provided as needed.

2.10 Litter Control

The MBL landfill shall be kept free of litter and unloading shall be performed so as to minimize scattering of solid waste. Portable fencing may be located near the working face in order to capture windblown debris. One or more employees on staff shall have part in the responsibility of picking up any material that is windblown, including material caught in the permanent fencing around the perimeter of the property.

2.11 Stormwater Management

Surface water run-on and run-off may be diverted around the operating area by the means of interceptor ditches, sediment traps or diversions berms as needed. Permanent storm water run-on and run-off structures (i.e., culverts, ditches, etc.) have been designed to manage peak discharge resulting from a 25-year, 24-hour design storm event. Isolation berms may be constructed between modules as required to contain leachate and to prevent stormwater from entering the active area.

Temporary stormwater basins may be constructed outside of the isolation berm to collect stormwater from adjacent cut slopes. Swales and diversion ditches may be used to divert storm water run-on water and surface water on the slopes. Pumps may be used to remove the water from the temporary basins as needed. Culverts, drainage pipes and/or other controls may be employed as needed. Ponding water will not be allowed on the working face during or after the completion of operations in any area. Finished plateau areas will be graded to provide adequate drainage of the finished area to minimize erosion, decreases runoff velocities and increases filtration of water into the soil and supports vegetation. The final cover grades have been established to maintain positive drainage of surface water even as consolidation of the underlying waste occurs.

Storm water management basins will be utilized on the Site to control storm water run-off and migration of sediments. The storm water management basins have been designed to pass the run-off from a 25-year, 24-hour storm event through a primary spillway and pass the run-off from a 100-year, 24-hour storm event through a primary and an emergency spillway. The basins will be inspected for structural and operational integrity after significant rainfall events.

The storm water management basins are designed to accumulate naturally occurring sedimentation. A reference post, or equivalent, will be used to gauge sediment depth. Storm water management basins will be managed to assure the design capacity is maintained by excavating excessive soil sediment that may collect in the pond(s) upon reaching the 35% capacity mark noted on the reference post, or sooner.

As shown on Sheet 10B of the permit drawing package, Detention Basins 3 will be altered and 4 will be constructed to manage storm water at the Site through the completion of the post closure period. During the active operation of MBL, Basins 2, 3 and 4, as well as temporary structures, may be used to control stormwater. In general Basins 3 and 4 will be modified (Basin 3) or constructed (Basin 4) as the modules approach final grade elevations. Basin 2 is constructed and will not require any additional modifications. Basin 3 is anticipated to be altered as Module O fills above grade and approaches final grade. Similarly, Basin 4 is anticipated to be constructed as Modules L, M and N fill above grade.

Silt fences, hay bales and/or other erosion control methods may be constructed at the toe of slopes greater than 100 feet in length. At periodic intervals, not to exceed 200 feet, erosion control methods may be provided in collection ditches until vegetation has been established. Actual spacing of the erosion control device will be adjusted for steepness of the ditch slope. Erosion control devices will be maintained to limit transportation of sediments. Trapped sediments will be removed as needed. Rock check dams may also be used to improve the movement of suspended solids by controlling water velocity in the ditches.

Surface water run-off from soil stock pile area(s) will be controlled through the use of berms, ditches, and/or other erosion control methods to limit siltation of on-site ditches and stormwater management basins. Vegetation will be established as soon as practical on areas not part of daily operation. The vegetation shall be properly maintained (i.e. mowed, fertilized) to assure growth. The erosion control procedures used will be in general, conformance to the guidelines provided in the TDEC Erosion & Sediment Control Handbook, provided in part, in Appendix C.

2.12 Leachate Management

The MBL landfill's leachate containment system will include a composite liner system consisting of two feet of low permeability select fill barrier soil of $1x10^{-7}$ obtained from on-site sources (Alternate permeability of $1x10^{-5}$cm/sec, a geosynthetic clay liner (GCL)) and a textured 60 mil high density polyethylene (HDPE) geomembrane liner. The containment system will be underlain by not less than five feet of geologic buffer material (a maximum permeability of 1×10^{-6} cm/sec) from the bottom of the composite liner system to the seasonal high-water table. For information and data on the determination of the seasonal high-water table, refer to the Part II A Permit Application Hydrogeologic Report, dated August 2008, prepared by Civil & Environmental Consultants, Inc. and accepted by the TDEC on January 29, 2009.

Leachate from this development will be pumped by side slope riser sump pumps, located in the leachate collection sumps, to the leachate storage tank. A 100,000 gallon leachate storage tank is proposed at the time of this submittal. The tank may be expanded or additional tanks may be added in order to facilitate operations. The leachate collection sumps will be a minimum three feet deep and will include six-inch diameter, SDR 17 perforated HPDE pipes as indicated on Sheet 13C of the permit drawing package. The leachate collection pipes will have cleanouts in the event the collection pipes become clogged or inspection is required. The cleanout lines, which are attached to the end of each leachate collection pipe, parallel the pipes which house the pump(s) to the surface. Clean water can be flushed into the pipes using a jetting or other system appropriate for the purpose. Inspections and/or cleaning will be done annually until a steady state is reached within the area influencing the leachate collection pipes. Once steady state appears to be achieved (i.e. siltation becomes minimal) cleaning will be done as needed, such as when leachate flow decreases unexpectedly or leachate levels are inconsistent with the predicted flow volumes. The drainage layer consists of a minimum of one foot of washed limestone with a geotextile on top and bottom. The geotextile will also aid in protection of the composite liner system. Module bottoms are sloped toward the collection pipes to promote leachate movement. Final proposed base contours are as illustrated on Sheet 6 of the permit drawing package. The leachate will be disposed via existing Loudon Utilities sewer system.

Currently, Loudon County Solid Waste Disposal Commission has authorization from the Loudon Utilities Publically Owned Treatment Works (POTW) to discharge wastewater (leachate) from the Matlock Bend Landfill to the Loudon Utilities POTW. A copy of this authorization is included in Appendix A. A 100,000 gallon above ground leachate storage tank was certified on February 2012. Based on a four-year historical monthly average for the Matlock Bend Landfill, this storage tank will provide up to ten (10) days of storage capacity in the event of repairs, maintenance, or other disruption of the force main or other appurtances to the Loudon Utilities POTW. The design of the leachate storage tank has the capability of loading tanker trucks. In the unlikely event of such disruption, leachate will be temporarily rerouted to the leachate storage tank and an immediate plan to pump and haul leachate to a POTW will be implemented. When Loudon Utilities POTW becomes operational, the onsite leachate collection system will return to direct discharge.

Leachate will be sampled and analyzed annually for the constituents listed in Tables 1 and 2 below. Leachate analytical data results with pertinent supporting data will be reported to the TDEC with the following semi-annual ground water analysis report.

TABLE 1: INORGANIC CONSTITUENTS

Antimony	Lead
Arsenic	Mercury
Barium	Nickel
Beryllium	Selenium
Cadmium	Silver
Chromium	Thallium
Cobalt	Vanadium
Copper	Zinc
Fluoride	

TABLE 2: ORGANIC CONSTITUENTS

Acetone	trans-1,3-Dichloropropene
Acrylonitrile	Ethylbenzene
Benzene	2-Hexanone; Methyl butyl ketone
Bromochloromethane	Methyl bromide; Bromomethane
Bromodichloromethane	Methyl chloride; Chloromethane
Bromoform; Tribromomethane	Methylene bromide; Dibromomethane
Carbon disulfide	Methylene chloride; Dichloromethane
Carbon tetrachloride	Methyl ethyl ketone; MEK; 2-Butanone
Chlorobenzene	Methyl iodide; Iodomethane
Chloroethane; Ethyl chloride	4-Methyl-2-pentanone; Methyl isobutyl ketone
Chloroform; Trichloromethane	Styrene
Dibromochloromethane; Chlorodibromomethane	1,1,1,2-Tetrachloroethane
1,2-Dibromo-3-chloropropane; DBCP	1,1,2,2-Tetrachloroethane
1,2-Dibromoethane; Ethylene dibromide; EDB	Tetrachloroethylene; Tetrachloroethene; Perchloroethylene
o-Dichlorobenzene; 1,2-Dichlorobenzene	Toluene
p-Dichlorobenzene; 1,4-Dichlorobenzene	1,1,1-Trichloroethane; Methyl chloroform
trans-1,4-Dichloro-2-butene	1,1,2-Trichloroethane
1,1-Dichloroethane; Ethylidene chloride	Trichloroethylene; Trichloroethene
1,2-Dichloroethane; Ethylene dichloride	Trichlorofluoromethane; CFC-11
1,1-Dichloroethylene; 1,1,-Dichloroethene; Vinylidene chloride	1,2,3-Trichloropropane
cis-1,2-Dichloroethylene; cis-1,2-Dichloroethene	Vinyl acetate
trans-1,2-Dichloroethylene; trans-1,2-Dichloroethene	Vinyl chloride
1,2-Dichloropropane; Propylene dichloride	Xylenes

cis-1,3-Dichloropropene	

The Hydrologic Evaluation of Landfill Performance (HELP) model was used in the design of the leachate collection system. Additional information and HELP model calculations are provided in the Matlock Bend Class I Landfill Permit Application.

2.13 Dust Control Method

Dust control measures shall be taken at the MBL to prevent dust from creating a nuisance or safety hazard to adjacent land owners or to people engaged in supervising, operating, and using the Site. The on-site borrow area haul roads are expected to be the primary source of dust. Construction equipment traveling on the haul roads can disturb soil particulate matter, causing them to become airborne, particularly during periods of dry weather. A water truck may be utilized to suppress dust and to mitigate fugitive dust particles from migrating across the landfill property boundary by lightly spraying access roads and haul roads. Existing trees within the buffer zone provide wind breaks and help reduce off-site dust migration. Prompt seeding operations to establish vegetative cover on non-active areas will further minimize the potential for dust problems.

2.14 Fire Protection

Fire protection at the working face will be prevented by maintaining stockpiled earth for any fires that may occur. Any fires that occur may be smothered by placing soil on the burning area and working it back and forth with a bulldozer or other appropriate equipment. In no case shall operating personnel cross the burning refuse. A water truck is also available as fire protection back-up, if necessary. Supplemental fire protection may also be provided by the Loudon County Fire Department. The Tennessee Emergency Management Agency will be notified within 24 hours in the event of a fire or explosion on-site which could threaten the environment or human health outside the facility. The Loudon County Fire Department will respond to onsite emergencies if needed as stated in the letter provided in Appendix A.

In order to avoid injury and damages caused by landfill equipment fires, each piece of heavy landfill equipment shall have a mounted fire extinguisher. Proper cleaning and maintenance of the equipment will also reduce the possibility of equipment fires.

Solid waste that is burning or smoldering will not be deposited into the active portion of the landfill. The solid waste will be directed to a designated area, safely away from the active portion, and extinguished prior to being deposited into the landfill. Open burning of solid waste will not be allowed.

2.15 Personnel Facilities and Services

Three buildings are utilized at this time for the landfill site: a combination scale house/manager's office, maintenance building, and a storage/break room.

The scale house/office is a permanent structure approximately 12 feet by 46 feet. It is located adjacent the entrance road for the purpose of maintaining traffic control, charging for disposal, and landfill security. Sanitary facilities, electricity, and telephone services are provided in this building.

The maintenance building is located south of the active landfill. It is a permanent structure consisting of reinforced concrete for the floor slab and sheet metal for the walls and the roof structure. Plumbing, lighting, heat, and electrical connections are provided in this building. A storage/break room is located adjacent to the maintenance building. The scale house/manager's office is equipped with two way radios to monitor landfill personnel. The scale house operator will also be able to contact the local hospital and fire department by telephone in case of an emergency.

2.16 Landfill Gas Control Devices

The migration of landfill gases generated by the decomposition of solid wastes at the MBL may be controlled through a passive venting system.

The gas venting system indicated in this plan is for a passive gas system which meets the current regulatory requirements for this facility. The closure gas venting system will consist of a series of interconnected gas collection trenches. These trenches will be spaced at a maximum distance of 100-ft. and will be 18-in. wide and 18-in. deep. A geotextile will encapsulate the washed crushed stone placed in the trenches. A 3-in diameter perforated HDPE pipe will be placed in the trenches to convey the gas to the passive gas vents. An active gas system may be designed and installed at this facility in the future. Whether voluntary or required by regulations, a minor modification will be prepared prior to installation of an alternate active gas system.

To determine if landfill gas begins to migrate off-site, methane gas will be monitored at the following locations:

- Underneath or in the low are of each on-site building;
- At the compliance monitoring boundary shown in the permit;
- At any potential gas problem areas, as indicated by dead vegetation or other indicators; and
- At any other points required by the MBL permit.

Monitoring procedures will be in accordance with Section 1.2.8.2, "Landfill Gas Sampling Protocol," of the Closure/Post-Closure Plan. If necessary, gas migration control will be performed in accordance with Rule 0400-11-01-.04(5)(a).

2.16.1 Landfill Gas Monitoring Plan

Landfill gas will be monitored in the following locations:

- Inside/along the compliance monitoring boundary as shown on Sheet 4 of the permit drawing package.
- Monitoring inside all permanent structures at a rate of one test every 2,000 ft^2 or one test in every structure. Tests should be performed along exterior walls at columns and/or construction joints. In addition, cracks or expansion joints of building slabs on grade are possible monitoring locations.

If concentrations of explosive gases at the compliance monitoring boundary exceed the lower explosive limit (LEL), the following precautions shall be met:

- Immediate implementation of all necessary steps to ensure protection to human health.
- Within 48 hours, notification of the TDEC Division of Solid Waste Management.
- Within 14 days, chronicle in the facility's operating records detectable gas levels and steps taken to protect human health.
- Within 60 days of detection, implement remediation plan for release of methane gas. The TDEC Division of Solid Waste Management will be notified of remedial plan and implementation schedule.

If explosive gas concentrations in facility structures exceed 25% of LEL, the following precautions will be taken:

- evacuate facility structures,
- ventilate facility structures,
- notify the Loudon County Fire Department, and
- post notification on all facility entrances stating occupying building is prohibited.

2.16.2 Landfill Gas Sampling Protocol

Monitoring Equipment

Methane gas monitoring is to be performed with a meter scaled at 0-100% of LEL and Percent of Total Gases. The LEL is the lowest concentration of a gas (as a part of total gases) that will result in an explosion if an ignition source is present (at 25°C and atmospheric pressure).

Monitoring Frequency

Monitoring is to take place at least quarterly. Monitoring must also take place immediately if regular inspection reveals signs of landfill gas (LFG) migration.

Signs of LFG Migration

During quarterly gas monitoring events, landfill personnel will note possible signs of LFG migration which may include:

- Stress in vegetation in or around site (stress could include stunted growth, wilting, color changes, etc.), and
- Inability to grow vegetation (bare spots) in or around Site.

Upon noting possible gas migration indicators noted above, the cause of the stress shall be verified. If the cause of the stress is determined to be gas migration, the area of stressed vegetation shall be monitored for the presences of landfill gas through bar hole methods as describe below under Monitoring Methodology. If the cause of the stress is determined not to be from gas migration, gas monitoring will continue along the compliance monitoring boundary.

Monitoring Methodology

- Always extinguish all smoking materials before testing for LFG.
- Monitor ambient air for landfill gas a minimum of every 100 feet inside/along the compliance monitoring boundary.
- Methodology at location of LFG migration signs which are not in a final cover area:
  a. Punch a bar hole approximately 18 – 24 inches deep.
  b. Take readings in the bottom of hole.
  c. Record readings and location.

- Methodology at location of LFG migration signs which are in a final cover area:
  a. Inspect the area for cracks or signs of damage to the final cover.
  b. Take readings in the area of vegetative stress.
  c. Record readings and location.

2.17 Groundwater Monitoring Plan

The proposed groundwater monitoring plan consists of four monitoring wells. Well MW-4R is the up gradient (background) well and wells MW-03, MW-06 and MW-07 are the down gradient (compliance) wells. The groundwater monitoring network will be upgraded in accordance with Sheets 8A and 8B of the permit drawing package. The proposed locations of these monitoring wells are shown on Sheet 4 of the permit drawing package.

Construction of the ground water monitoring wells will begin following drilling. Individual well construction will include a 15-foot section of screened 2-inch diameter, flush-joint, threaded, polyvinyl chloride (PVC), or equivalent, and an appropriate length riser pipe. The screen will be premanufactured with 0.010-inch openings along the length. The lower end will be capped and located one foot above the bottom of the borehole.

Following installation of the screen and riser sections, clean industrial sand or equivalent will be placed in the boring to a depth approximately two feet above the top of the screen. This is to be followed by the placement of a 2-foot bentonite seal. A cement-bentonite grout will then be used to backfill the boreholes to ground level. A 4-inch square, steel cover with a lockable top will then embedded in the grout over the PVC riser pipe.

The groundwater sampling will be conducted on a semi-annual basis and will include analysis of the constituents listed in Tables 3 and 4 below. Groundwater monitoring data will be evaluated using statistical methods in accordance with Rule 0400-11-01-.04(7)(a)4(v). Revisions to the constituents listed in Tables 3 and 4 may be requested by the MBL based upon statistics.

TABLE 3: INORGANIC CONSTITUENTS

Antimony	Lead
Arsenic	Mercury
Barium	Nickel
Beryllium	Selenium
Cadmium	Silver

Chromium	Thallium
Cobalt	Vanadium
Copper	Zinc
Fluoride	

TABLE 4: ORGANIC CONSTITUENTS

Acetone	trans-1,3-Dichloropropene
Acrylonitrile	Ethylbenzene
Benzene	2-Hexanone; Methyl butyl ketone
Bromochloromethane	Methyl bromide; Bromomethane
Bromodichloromethane	Methyl chloride; Chloromethane
Bromoform; Tribromomethane	Methylene bromide; Dibromomethane
Carbon disulfide	Methylene chloride; Dichloromethane
Carbon tetrachloride	Methyl ethyl ketone; MEK; 2-Butanone
Chlorobenzene	Methyl iodide; Iodomethane
Chloroethane; Ethyl chloride	4-Methyl-2-pentanone; Methyl isobutyl ketone
Chloroform; Trichloromethane	Styrene
Dibromochloromethane; Chlorodibromomethane	1,1,1,2-Tetrachloroethane
1,2-Dibromo-3-chloropropane; DBCP	1,1,2,2-Tetrachloroethane
1,2-Dibromoethane; Ethylene dibromide; EDB	Tetrachloroethylene; Tetrachloroethene; Perchloroethylene
o-Dichlorobenzene; 1,2-Dichlorobenzene	Toluene
p-Dichlorobenzene; 1,4-Dichlorobenzene	1,1,1-Trichloroethane; Methyl chloroform
trans-1,4-Dichloro-2-butene	1,1,2-Trichloroethane
1,1-Dichloroethane; Ethylidene chloride	Trichloroethylene; Trichloroethene
1,2-Dichloroethane; Ethylene dichloride	Trichlorofluoromethane; CFC-11
1,1-Dichloroethylene; 1,1,-Dichloroethene; Vinylidene chloride	1,2,3-Trichloropropane
cis-1,2-Dichloroethylene; cis-1,2-Dichloroethene	Vinyl acetate
trans-1,2-Dichloroethylene; trans-1,2-Dichloroethene	Vinyl chloride
1,2-Dichloropropane; Propylene dichloride	Xylenes
cis-1,3-Dichloropropene	

Samples referred to above will be obtained in accordance with the groundwater monitoring program. Bailers or pumps will be utilized for monitoring well purging and sampling. The groundwater surface elevation will be determined and recorded at each monitoring well before each sample extraction, prior to any pumping or bailing of the well.

Groundwater sample analysis results and the associated groundwater surface elevations will be submitted to the TDEC, in the manner specified in the permit, within sixty days after completing the analysis. Additionally, records of all groundwater monitoring activities will be kept throughout the active life and post closure period of the MBL facility, as specified in Rule 0400-11-01-.02(4)(a)9(ii).

These monitoring records will include the following information:

- The date, exact place, and time of sampling;
- The individual(s) who performed the sampling;
- The date(s) analyses were performed;
- The techniques (including equipment utilized) used for the analyses; and
- The results of each analysis

2.18 Flood Frequency and Protection

The Matlock Bend Landfill is not located within a 100 year floodplain.

2.19 Facility Impacts on Endangered and Threatened Species

The facility design and Operations Plan have been prepared to have no impact on endangered or threatened species of plants, fish, wildlife, and their habitat.

2.20 Unstable Areas

No unstable areas exist on the landfill expansion Site per the 2008 Hydrogeologic Report. No geologic faults known to have exhibited movement since Holocene time have been identified within 200 ft of the proposed landfill extension. The nearest fault to the Matlock Bend facility is the Beaver Valley Fault, which is located approximately 3,000 ft northwest of the facility boundary. The Beaver Valley Fault is not known to have experienced any motion since the late Paleozoic Era, per the 1996 hydrogeologic investigation by Theta Engineering, Inc., which is included in the approved 2008 hydrogeologic investigation by Civil & Environmental Consultants.

2.21 Facility Impacts on Regulated Wetlands

No regulated wetland exists on the landfill expansion Site.

2.22 Sealing of Bore Holes

Prior to excavation, all bore holes drilled or dug during subsurface investigation, piezometers, and abandoned wells which are either in or within 100 feet of the areas to be filled will be backfilled with a bentonite slurry or other approved method by the Commissioner to an elevation at least ten feet greater than the elevation of the lowest point of the landfill base, or to the ground surface if the Site will be excavated less than ten feet.

2.23 Random Inspection Program

A random inspection program will be used to screen for regulated hazardous waste, infectious waste, PCBs (concentration $\geq$ 50 ppm), whole tires, lead-acid batteries, liquid wastes and unauthorized special waste. At a minimum, 5% of the daily incoming loads will be inspected by MBL personnel for prohibited wastes. The procedures and guidelines for this inspection program are as follows:

A. Complete Solid Waste Manifest on Every Facility User.

Know your customers. Do not accept wastes from unknown, unlicensed or otherwise questionable haulers. Manifests will contain, at a minimum, the following:

- inspection date
- vehicle identification
- driver signature
- identification of any unauthorized waste
- disposition of any unauthorized waste
- facility inspector signature

B. Require Customer to Sign Affidavit on Weight Ticket.

By signing the affidavit, haulers certify they are "not transporting any hazardous, infectious or regulated waste." This further enhances facility screening efforts and emphasizes to haulers the importance of closely monitoring customers' waste as well as increases awareness of shared liability.

C. Random Daily Inspections

A random selection procedure ensures <u>anyone</u> can be checked <u>anytime.</u>

- Complete the Random Inspection Manifest and return a copy to Santek's corporate office on a weekly basis. Landfill personnel shall retain a copy of the inspection manifest at the landfill in a bound notebook.
- Inspections should occur approximately once per day at different times during the day, but not less than 5% of daily incoming loads.

D. Upon Discovering Prohibited Waste

Use protective equipment (gloves, goggles, respirators) before proceeding if waste is potentially hazardous. The following steps should be taken:

- Segregate waste,
- Question hauler,
- Review Solid Waste Manifest for discrepancies,
- Identify and contact generator,
- Document findings in print and with camera,
- Contact proper authorities, including the TDEC field office,
- Contact laboratory support if necessary,
- Notify response agency, if required, and
- Prepare for alternative disposal methods, if required

E. Operator Training - Screening of Wastes

As part of routine safety meetings, the landfill operators are educated to recognize unacceptable wastes and special wastes, and to be aware of the approval conditions of special wastes. Training consists of:

- Reviewing TDEC's regulations and definitions of specific waste streams including solid wastes, bulky wastes, hazardous wastes, industrial wastes, liquid wastes, medical wastes, special wastes, and construction and demolition waste.
- Reviewing the approval process for special wastes which includes receiving the appropriate paper work issued by the Division Field Office to the waste generator indicating the waste has been granted approval for disposal at the landfill.
- Reviewing operating procedures and restrictions for the disposal of special wastes which require transportation to the landfill separately and securely contained.
- Receiving advance notice from the waste generator and establishing a routine delivery schedule, if necessary, in order to prepare for the receiving of special wastes.
- Confining unloading and disposal operations to a specific area, if necessary, to assure proper disposal with minimum complications.

- Covering the waste with approved cover material at the end of the working day.
- Maintaining proper records on the receipt and management of certain special wastes, and incorporating the records into the daily random inspection program.

F. Communications

Radio contact between the scale house attendant and equipment operator should be accessible at all times.

The following wastes will not be accepted for landfill disposal at the Matlock Bend Landfill:

- Biomedical wastes
- Powders & dusts - unless accompanied by State approval
- Lead acid or other batteries
- Used oil & other liquids (except waste oil placed in holding tank designated for waste oil)
- Unapproved sludges
- Unapproved ash
- Fluorescent bulbs - if more than 50 per load

Other Questionable Materials:

- Barrels and drums - unless rinsed and ends are cut out
- Refrigerators and air conditioners - unless generator can document that the Freon has been removed
- Asbestos - unless accompanied by 24-hour notification to the MBL (accepted under blanket special waste approval).

Personnel working at the scale house and the active face will be trained to identify suspicious wastes based on inherent characteristics. Landfill personnel will be familiar with the specific and detailed procedures of the screening program in the event that suspicious, hazardous, infectious, or unauthorized special waste is found. The solid waste manifest and the random inspection manifest forms are included in Appendix D.

CLOSURE/POST CLOSURE PLAN

MATLOCK BEND CLASS I LANDFILL EXPANSION

CLOSURE/POST-CLOSURE PLAN

Prepared For:

Loudon County Solid Waste Disposal Commission
100 River Road
Loudon, TN 37774

Prepared By:

Santek Waste Services, Inc.
650 25th Street, NW
Suite 100
Cleveland, TN 37311

Submitted To:

Tennessee Department of Environment and Conservation
Division of Solid Waste Management

August 2009
Revised May 2013
Revised February 2014

TABLE OF CONTENTS

1.0 CLOSURE/POST CLOSURE CARE PLAN

1.1 General Information

1.1.1 Introduction

The following Closure/Post Closure Plan has been prepared for the Matlock Bend Class I Landfill (MBL) in accordance with the closure and post-closure care requirements of the Tennessee Department of Environment and Conservation (TDEC), Division of Solid Waste Management's rules. The requirements included in Chapter 0400-11-01, *Solid Waste Processing and Disposal,* specifically Rule 0400-11-01-.04(8).

The MBL is a Class I municipal solid waste landfill Site which serves the sanitary and industrial waste disposal needs of Loudon County and surrounding areas outside of the county. The MBL is located on approximately 152.33 acres of land, about 5 miles west of the City of Loudon on Highway 72 and approximately 1.25 miles west of U.S. Interstate Route 75, at latitude 35° 44' 48" North and longitude 84° 24' 43" West. The above latitude and longitude were obtained from the Philadelphia, Tennessee 7.5 quadrangle map which is based on National Geodetic Vertical Datum of 1929 (NGVD29). Permanent benchmarks of known elevation have been constructed on-site as shown on Sheet 2 of the permit drawing package.

At the time landfill development is completed, approximately 67 acres will have been used for solid waste disposal in this permit area. Existing permitted Modules A through J comprises approximately 40.7 acres and proposed Modules J through P comprises approximately 26.5 acres. Existing permitted, but unconstructed modules E and J will be altered and renamed in this expansion permit. The facility has a total volume estimated to be 10,582,709 cubic yards (cy) of airspace available for waste and cover soil. The remaining life (as of Sept. 19, 2012) of the facility is approximately 24.0 years based on an estimated average disposal rate of 925 ton per day. The life estimate is based on average in-place waste and cover soil density of 1,450 lb/cy and 273 operational days per year. Based on current projections, including airspace provided by the currently permitted Class I landfill and future modules, the final waste placement for the Matlock Bend Landfill is year 2036.

The Matlock Bend Landfill post-closure care-period contact shall be:

Chairman Steve Field
Loudon County Solid Waste Disposal Commission
100 River Road
Loudon, TN 37774
Telephone No. (865) 576-1057

1.2 Closure Operating Plan

1.2.1 General Overview

The Closure Plan is developed in a manner to minimize maintenance needs during the post-closure care period. Features include:

- promotion of effective drainage designed to minimize infiltration and erosion,
- vegetation of the top surface and side slopes to minimize erosion, and
- use of flexible components to allow for settlement of all closure components located over the waste.

The Closure Plan and post-closure care activities also are developed to minimize threats to human health and the environment resulting from waste decomposition by-products, such as leachate and landfill gases. Features to control these releases include:

- final cap design (storm water and surface water management system),
- leachate collection system, and
- installation of a landfill gas management system.

Monitoring and maintenance of the MBL Site will be provided for a 30-year period after closure is completed. This is in accordance with Rule 0400-11-01-.04(8)(d).

1.2.2 Closure Schedule

At least 60 days prior to beginning any final closure activities, Santek Environmental Inc. (Santek) will notify the TDEC Director of the Solid Waste Division of its intent to perform landfill closure. Interim closure activities, including grading and establishing vegetative cover will be accomplished as waste placement of each module achieves final grade. It is noted that a minor portion of each module shall be allowed to be incomplete in order to provide an access road the width of three times the maximum construction equipment width. This access road is necessary to allow for ingress and egress at uncompleted modules that are located beyond completed modules. As portions of the fill areas achieve final grade, intermediate cover will be placed. Vegetation will be planted and maintained. It is the intent of this Plan to place the final closure cap after all available airspace has been utilized or exhausted. These time allowances and provisions are in accordance with Rule 0400-11-01-.04(8)(c) 1 through 3, respectively. If contingencies force exceptions to the schedule times set forth above, Santek will request a waiver.

In accordance with Rule 0400-11-01-.04(8)(c)2, construction of final closure is not required until the landfill reaches final grade, which is approximately 1,125 ft. msl. Final closure placement at the end of a landfill's operational life has its advantages, as referenced below:

1) The Matlock Bend Landfill has several opportunities for future expansion. If partial closure construction were to occur and the landfill expanded prior to the end of its operational life, then the final cap would need to be removed prior to additional waste placement, thereby squandering the resources required to construct the closure cap.

2) The construction of partial closure can be more susceptible to veneer slope failures. This can be attributable to storm water run-on in the higher portions of the partial closure. The run-on can slowly erode the anchor trench, sending water beneath the geosynthetics, thereby creating a veneer slope failure. If final closure were to occur once the apex of the landfill were constructed, then the possibility of storm water run-on flowing beneath the geosynthetics is greatly reduced.

3) Settlement in the waste mass is another reason to construct final closure at the end of the landfill's useful life. Settlement is generally uneven and can be up to 20% of the overall landfill height. Allowing the majority of the settlement to occur prior to closure will allow for additional waste placement over the settled waste as well as allowing for uneven areas to be filled to minimize stress on geosynthetic components in the final closure cap.

Although placing final closure over the 67-acre landfill at one time is advantageous for the reasons mentioned above, partial closure may be requested through the minor modification process in the future. The Loudon County Solid Waste Disposal Commission or Santek, may request a minor modification to allow for partial closure in areas deemed necessary. The following reasons are a few examples that could lead to a minor modification request:

1) A remedial effort in the event of an environmental release where partial

closure would resolve the issue.

2) The installation of an active gas collection and control system to capture more landfill gas and reduce air infiltration into the waste mass.

3) Partial closure could be deemed beneficial in reducing storm water infiltration thereby reducing leachate volumes and disposal costs.

Santek will notify TDEC in writing within 60 days when all closure activities are complete. This notification will include a certification that the area has been closed in accordance with this Closure/Post-Closure Plan. This is in accordance with Rule 0400-11-01-.04(8)(c)9.

Within 90 days of completing final closure of the entire landfill, and prior to the sale or lease of the property, Loudon County Solid Waste Disposal Commission or Santek will ensure that a notation is recorded on the property deed, or on some other instrument which is normally examined during a title search, that will perpetually notify any person conducting a title search that the land has been used as a waste disposal facility. This is in accordance with Rule 0400-11-01-.04(8)(f).

1.2.3 Final Cap Design

The MBL will be closed with a final cap designed to achieve the following:

- reduce and minimize infiltration of precipitation through the top surface of the landfill so that infiltration volume will be equal to or less than the percolation volume through the bottom liner system;
- minimize maintenance;
- promote efficient drainage while preventing excessive erosion of the final cover; and,
- allow for settling and subsidence while maintaining the integrity of the cap system.

The final cap will incorporate the following closure system profile:

- 24 inches of vegetative cover;
- a drainage layer consisting of a polyethylene geonet sandwiched between two layers of non-woven geotextile fabric;
- A 40 mil very low-density polyethylene (VLDPE) textured geomembrane ;
- 12 inches of 90% standard proctor compacted soil;
- passive gas collection system consisting vents and collection trenches; and

- 6 to 12 inches of intermediate cover soil.

The geosynthetic components of the final closure cap will utilize the same construction quality assurance plan as the composite bottom liner. The liner construction specification and quality assurance (CSQA) plan is presented in Appendix B of the Facility Operations Plan (located in Section 6) of this Part 2B Permit Application Package.

The closure system's hydraulic performance was modeled using the Hydrologic Evaluation of Landfill Performance (HELP) computer model. The HELP model is primarily utilized to evaluate closure system profiles for comparative performance; i.e., approximate infiltration rates for different cap configurations. The HELP model is generally not used for a quantitative analysis of actual closure system infiltration rates, due to the many variables associated with actual precipitation infiltration. The complete HELP model results and analysis for the landfill closure system percolation simulation is located in the Section 4 of the Part 2B Permit Application Package.

1.2.3.1 Acquisition of Final Cover System Soil

The current plan for cover soil acquisition is to use soil obtained from existing soil stockpiles, excavation from the construction of the landfill base grades and on-site borrow areas. Stabilization of the borrow area will be conducted as follows:

- maximum finished slope ≤ 33%;
- sediment and erosion control devices will be placed as required to prevent excessive soil loss on the current site and sediment build up on adjacent tracts of land; and
- finished slopes are to be seeded and fertilized as required to provide healthy vegetative cover.

A soil balance chart is provided in the Part 2B Permit Application, Class I Landfill Expansion Package that shows the estimated cut and fill volumes over the life of the facility. Assuming a volume equivalent to 15% of the total available air space is required as daily cover soil, approximately 2,031,014 cubic yards of soil fill will be needed for construction, operation and closure of the facility. Because the fill volume exceeds the volume of soil to be excavated, on-site borrow areas as well as an additional sources will be required to acquire the adequate soil volume. About 1,508,296 cubic yards of soil will be needed from this additional source.

<u>Alternative Off-site Borrow Material</u>

In the event off-site borrow material must be used, a procedure will be used to evaluate the best off-site option.

1.2.4 Permanent Vegetative Cover

Upon completion of the placement of the vegetative cover soil, at a minimum, the following seasonal seed mixtures will be utilized for the appropriate season of planting:

SEASON	SEED	APPLICATION RATE
Spring (Mar. 15 – May 15)	Kentucky 31 Fescue Clover	100 lb/ac 5 lb/ac
Summer (May 15 – Aug. 15)	Kentucky 31 Fescue Clover	100 lb/ac 5 lb/ac
Fall (Aug. 15 – Oct. 15)	Kentucky 31 Fescue White Clover	60 lb/ac 15 lb/ac
Winter (Oct. 15 – Mar. 15)	Annual Ryegrass White Clover	80 lb/ac 10 lb/ac

Fertilizer: Readily available commercial fertilizers will be used. Application rates will be approximate due to varying quality of cover soil material. Approximate minimum application rates will be as follows:

15-15-15 200lb/ac, or
6-12-12 300lb/ac

As required:

Limestone 1 tons/ac, or
Hydrated lime .5 ton/ac

Mulch: Apply hay that has been thoroughly fluffed, or chopped and blown, at the rate of 3 tons per acre, or fiber as used in hydro-seeder.

The planting specifications will be modified throughout the post-closure care period as required to maintain an efficient vegetative cover. Provisions also have been made (in post-closure cost estimates) to accommodate further soil testing (as it relates to fertilizing requirements) and professional turf management assistance.

1.2.5 Surface and Stormwater Management System

1.2.5.1 Run-On Control System

Drainage of stormwater onto the MBL will be managed by a series of permanent and temporary diversion ditches and drainage swales designed to divert surface water from the active module areas.

1.2.5.2 Erosion and Sediment Control System

To minimize infiltration through the cover material, and to provide adequate drainage, the final cover system will be constructed with a finished grade of 5% for the plateau area. The slopes shall be constructed on a maximum 3 (horizontal) to 1 (vertical) slope. The 3:1 slope will facilitate adequate maintenance of the side slope vegetative cover and will simplify remediation of any rills and gullies, if required.

MBL's on site erosion and sediment control program will follow and establish Best Management Practices, silt fences/hay bales shall be constructed at the toe of all distressed slopes greater than 100 feet in length. These gradient treatments are used to decrease runoff velocities, trap sediments locally and increase filtration of water into the soil thus limiting erosion and supporting vegetation growth. Graded surfaces will be roughened prior to seeding to decrease runoff velocity, thereby reducing erosion and aid in establishment of vegetation. At periodic intervals not to exceed 200 feet silt fences/hay bales or rip-rap dams shall be provided in all collection ditches until vegetation has been established. Actual spacing of silt fences/hay bales will be adjusted for the steepness of the ditch slop. Silt fences/hay bales will be maintained in order to assure minimization of silt transportation and cleaned when sediment exceeds one–half the height of the fence. Once vegetation is established, the use of silt fences/hay bales will not be required. Surface water run-off from stockpile areas will be routed through silt fences/hay bales to aid in prevention of on-site ditches and storm water management basins.

Vegetation will be established as soon as practical on all areas that will not be part of daily operation prior to closure. The vegetation shall be properly maintained (i.e. mowed, fertilized, re-seed) to assure its growth. The facility operating plan addresses erosion and sediment control practices during the active period of the landfill.

1.2.5.3 Run-Off Control System

Silt fences/hay bales shall be constructed at the toe of all slopes greater than 100 feet in length. At periodic intervals not to exceed 200 feet, silt fences/hay bales shall be provided in collection ditches until vegetation has been established. Actual spacing of silt fences/hay bales will be adjusted for the steepness of the ditch slope. Silt fences/hay bales will be maintained in order to ensure minimization of silt transportation and cleaned when sediment exceeds one-half the height of the fence. Once vegetation is established, the use of silt fences/hay bales will not be required. Sediment fences/hay bales along with rock check dams are utilized in ditches to capture sediment before it reaches the ponds, and to reduce storm flow velocities. Surface water run-off from stockpile areas will be routed through silt fences/hay bales to aid in prevention of siltation of on-site ditches and stormwater management basins. Vegetation will be established as soon as possible on all areas that will not be part of daily operation. The vegetation shall be properly maintained (i.e., mowed, fertilized) to assure its growth.

To provide for controlled drainage of storm water from the final cover system to the storm water management basins, precipitation falling on the landfill will be directed to engineered diversion ditches by final cover contours. Sheet 10A of the permit drawing package illustrates the final grading contours, which have been designed to reduce hydraulic length and the surface area contributing to sheet flow. The grading and ditch design will properly manage storm water and will significantly reduce erosion.

Diversion ditches have been designed to safely flow the runoff from the 25-year, 24-hour design storm event. The ditches will be lined with graded crushed stone or vegetated as required. Rock check dams will be located at strategic positions along each reach to reduce flow rates.

Surface water run-on and run-off will be diverted around the operating area by the means of interceptor ditches or diversion berms as necessary. Permanent run-on and run-off structures (i.e., culverts, ditches, stormwater management basins) will be designed and constructed to manage peak discharge from a 100-year 24-hour storm event.

Three storm water management basins will be used to control surface water run-off and sediment leaving the site. A detailed description of the stormwater basin design information, flow calculation and spillway design is provided in the Section 5, Storm Water Calculation, of this Part 2B Permit Application Expansion Package.

1.2.6 Groundwater Monitoring Plan

1.2.6.1 Compliance Monitoring Boundary

The compliance monitoring boundary shall be an imaginary line encompassing the limits of waste for all of the Class I waste disposal areas on the landfill property. For this site the compliance monitoring boundary is shown on Sheet 4 of the permit drawing package.

1.2.6.2 Groundwater Monitoring Well and Analysis

The proposed groundwater monitoring plan consists of four monitoring wells. Well MW-4R is the up gradient (background) well and wells MW-03, MW-06 and MW-07 are the downgradient (compliance) wells. The proposed locations of these monitoring wells are shown on Sheet 4 of the permit expansion drawing package.

The groundwater monitoring plan for the remaining closure/post closure period calls for semi-annual sampling and analysis of the parameters summarized in Tables 1 and 2 below.

TABLE 1: INORGANIC CONSTITUENTS

Antimony	Lead
Arsenic	Mercury
Barium	Nickel
Beryllium	Selenium
Cadmium	Silver
Chromium	Thallium
Cobalt	Vanadium
Copper	Zinc
Fluoride	

TABLE 2: ORGANIC CONSTITUENTS

Acetone	trans-1,3-Dichloropropene
Acrylonitrile	Ethylbenzene
Benzene	2-Hexanone; Methyl butyl ketone
Bromochloromethane	Methyl bromide; Bromomethane
Bromodichloromethane	Methyl chloride; Chloromethane
Bromoform; Tribromomethane	Methylene bromide; Dibromomethane
Carbon disulfide	Methylene chloride; Dichloromethane
Carbon tetrachloride	Methyl ethyl ketone; MEK; 2-Butanone
Chlorobenzene	Methyl iodide; Iodomethane
Chloroethane; Ethyl chloride	4-Methyl-2-pentanone; Methyl isobutyl ketone
Chloroform; Trichloromethane	Styrene
Dibromochloromethane; Chlorodibromomethane	1,1,1,2-Tetrachloroethane
1,2-Dibromo-3-chloropropane; DBCP	1,1,2,2-Tetrachloroethane
1,2-Dibromoethane; Ethylene dibromide; EDB	Tetrachloroethylene; Tetrachloroethene; Perchloroethylene
o-Dichlorobenzene; 1,2-Dichlorobenzene	Toluene
p-Dichlorobenzene; 1,4-Dichlorobenzene	1,1,1-Trichloroethane; Methylchloroform
trans-1,4-Dichloro-2-butene	1,1,2-Trichloroethane
1,1-Dichloroethane; Ethylidene chloride	Trichloroethylene; Trichloroethene
1,2-Dichloroethane; Ethylene dichloride	Trichlorofluoromethane; CFC-11
1,1-Dichloroethylene; 1,1,-Dichloroethene; Vinylidene chloride	1,2,3-Trichloropropane
cis-1,2-Dichloroethylene; cis-1,2-Dichloroethene	Vinyl acetate
trans-1,2-Dichloroethylene; trans-1,2-Dichloroethene	Vinyl chloride
1,2-Dichloropropane; Propylene dichloride	Xylenes
cis-1,3-Dichloropropene	

Monitoring data will be reported in writing to the TDEC within 60 days after completion of the analysis. Additionally, records of all groundwater monitoring activities will be maintained throughout the active life of the facility and the post-closure care period.

1.2.6.3 Groundwater Sampling Protocol

Prior to any pumping or bailing of wells, the groundwater surface elevation will be determined and recorded at each monitoring well before each sample extraction. Prior to sample collection, three well volumes will be purged from each well. Wells which have a slow recovery rate will be allowed a maximum recovery period of 72 hours. Wells which cannot recover sufficiently for sampling in the allowed period will be considered dry for that sampling event.

Sampling will be accomplished with disposable bailers or pumps. Groundwater samples will be placed in properly prepared and preserved bottles equipped with Teflon lined caps then packed in ice for transportation to the laboratory. A Chain-of-Custody form will accompany all samples from the time they are collected until they are relinquished to the laboratory.

In addition to the laboratory analysis to be performed on all water samples, field analysis will include water level, pH, specific conductance, and temperature. A groundwater sampling form will be utilized to record pertinent information derived in the field for each sampling event. The monitoring records will include the following information:

- date, exact place, and time of sampling;
- individual(s) performing sampling;
- date(s) analyses were performed;
- techniques (including equipment utilized) used for the analysis; and,
- analytical results.

1.2.7 Leachate Collection, Removal and Treatment System

The leachate management system will continue to operate as described in the facility/operational plan.

Closure activities which will limit the amount of leachate to be handled include:

- Well graded top and sideslopes to quickly convey rainfall off the landfill thus minimizing ponding and infiltration.
- A surface water management system consisting of swales and corrugated plastic pipe to remove stormwater from the landfill surface while minimizing erosion.
- A VLDPE or approved alternate top cap liner to reduce percolation into the landfill thus limiting leachate generation.
- A well-vegetated final cover to limit percolation, improve evapotranspiration and prevent erosion of the cover soil.

The HELP computer model was used to simulate the amount of leachate collected by the system.

Leachate from the disposal areas will be pumped from Module sump pumps via forcemain to the 100,000 gallon storage tank. A leachate pump will then be used to move the leachate from the leachate storage tank into an on-site force main to the Loudon Utilities Public Sanitary Sewer System.

The Hydrologic Evaluation of Landfill Performance (HELP) model was used in the design of the leachate collection system. Results of the HELP model and a brief narrative are presented in Section 4, Leachate Collection System, of this Part 2B Permit Expansion Application Package.

1.2.8 Landfill Gas Management System

The migration of landfill gases generated by the decomposition of solid wastes at the MBL will be controlled through a passive venting system.

To determine if landfill gas begins to migrate off-site, methane gas will be monitored at the compliance monitoring boundary. Monitoring will also be conducted in facility structures. Monitoring procedures are in accordance with Section 1.2.8.2, "Landfill Gas Sampling Protocol," of this document. Methane gas concentration monitoring will be a part of the post-closure care period activities. If necessary, landfill gas migration control will be performed in accordance with Rule 0400-11-01-.04(5)(a).

The gas venting system indicated in this plan is for a passive gas system which meets the current regulatory requirements for this facility. The closure gas venting system will consist of a series of interconnected gas collection trenches. These trenches will be spaced at a maximum distance of 100-ft. and will be 18-in. wide and 18-in. deep. A geotextile will encapsulate the washed crushed stone placed in the trenches. A 3-in diameter perforated HDPE pipe will be placed in the trenches to convey the gas to the passive gas vents. An active gas system may be designed and installed at this facility in the future. Whether voluntary or required by regulations, a minor modification will be prepared prior to installation of an alternate active gas system.

1.2.8.1 Landfill Gas Monitoring Plan

Landfill gas will be monitored in the following locations:

- Along the compliance monitoring boundary as shown on Sheet 4 of the permit drawing package.

- Monitoring inside all permanent structures at a rate of one test every 2,000 ft^2 or one test in every structure. Tests should be performed along exterior walls at columns and/or construction joints. In addition, cracks or expansion joints of building slabs on grade are possible monitoring locations.

If concentrations of explosive gases at the compliance monitoring boundary exceed the lower explosive limit (LEL), the following precautions shall be met:

- Immediate implementation of all necessary steps to ensure protection to human health.
- Within 48 hours, notification of the Tennessee Division of Solid Waste Management.
- Within 14 days, chronicle in the facility's operating records detectable gas levels and steps taken to protect human health.
- Within 90 days of detection, propose remediation plan for release of methane gas. The TDEC Division of Solid Waste Management will be notified of remedial plan and implementation schedule.

If explosive gas concentrations in facility structures exceed 25% of LEL, the following precautions will be taken:

- evacuate facility structures,
- ventilate facility structures,
- notify the Matlock Bend Fire Department, and
- post notification on all facility entrances stating occupying building is prohibited.

1.2.8.2 Landfill Gas Sampling Protocol

A. Monitoring Equipment

Methane gas monitoring is to be performed with a meter scaled at 0-100% of LEL and Percent of Total Gases. The LEL is the lowest concentration of a gas (as a part of total gases) that will result in an explosion if an ignition source is present (at 25°C and atmospheric pressure).

B. Monitoring Frequency

Monitoring is to take place at least quarterly. Monitoring must also take place immediately if regular inspection reveals signs of landfill gas (LFG) migration.

C. Signs of LFG Migration

During quarterly gas monitoring events, landfill personnel will note possible signs of LFG migration which may include:

- Stress in vegetation in or around site (stress could include stunted growth, wilting, color changes, etc.), and
- Inability to grow vegetation (bare spots) in or around Site.

Upon noting possible gas migration indicators noted above, the cause of the stress shall be verified. If the cause of the stress is determined to be gas migration, the area of stressed vegetation shall be monitored for the presences of landfill gas through bar hole methods as describe below under Monitoring Methodology. If the cause of the stress is determined not to be from gas migration, gas monitoring will continue along the compliance monitoring boundary.

D. Monitoring Methodology

1. Always extinguish all smoking materials before testing for LFG.
2. Monitor ambient air for landfill gas a minimum of every 100 feet inside/along the compliance monitoring boundary.
3. Methodology at location of LFG migration signs which are not in a final cover area:
   a. Punch a bar hole approximately 18 – 24 inches deep.
   b. Take readings in the bottom of hole.
   c. Record readings and location.
4. Methodology at location of LFG migration signs which are in a final cover area:
   a. Inspect the area for cracks or signs of damage to the final cover.
   b. Take readings in the area of vegetative stress.
   c. Record readings and location.

1.3 Post Closure Plan

1.3.1 General

The Post-Closure Plan and care activities for the MBL will include routine site inspections, monitoring, maintenance, and repair. The objective of these activities is to continue to minimize:

- maintenance requirements and
- threats to human health and the environment from waste constituents or by-products.

The post-closure activities will continue for a period of 30 years after closure is complete. This is in accordance with Rule 0400-11-01-.04(8)(d).

1.3.2 Maintenance of Final Cap System

The final cap system will be inspected to ensure that the integrity of the closure cap is maintained. Any effects of erosion will be remediated as soon as possible. Any damaged materials will be repaired with the same type of material originally installed and constructed in accordance with the original plans.

The operator will ensure that a healthy vegetative cover is maintained over the cap system and the remainder of the Site. This will include re-seeding, mulching, fertilizing, and mowing, as well as final cover and side-slope repair, on an as-needed basis.

1.3.3 Maintenance of Surface and Stormwater Management System

All drainage structures will be inspected and maintained to prevent settlement, erosion, and clogging, and to ensure proper drainage of the landfill as designed. Culvert inlets and outlets will be visually inspected and cleaned as necessary to ensure proper operation of the landfill drainage system design.

Stormwater management basins will be dredged, as necessary during the post-closure care period to remove silt accumulation, as required to maintain the designed stormwater storage volume.

1.3.4 Maintenance of Groundwater Management System

1.3.4.1 Groundwater Monitoring Well

The groundwater monitoring wells are described in Section 1.2.6.2. These wells are intended to be used for the entire post-closure period.

1.3.4.2 Groundwater Analysis

Beginning at the post-closure care period, all wells shall be monitored in accordance with Tennessee Rule Chapter 0400-11-01-.04(7)(a) 4 through 6. Throughout the post-closure care period, each well will be sampled on a semi-annual basis for the following parameters:

TABLE 3: INORGANIC CONSTITUENTS

Antimony	Lead
Arsenic	Mercury
Barium	Nickel
Beryllium	Selenium
Cadmium	Silver
Chromium	Thallium
Cobalt	Vanadium
Copper	Zinc
Fluoride	

TABLE 4: ORGANIC CONSTITUENTS

Acetone	trans-1,3-Dichloropropene
Acrylonitrile	Ethylbenzene
Benzene	2-Hexanone; Methyl butyl ketone
Bromochloromethane	Methyl bromide; Bromomethane
Bromodichloromethane	Methyl chloride; Chloromethane
Bromoform; Tribromomethane	Methylene bromide; Dibromomethane
Carbon disulfide	Methylene chloride; Dichloromethane
Carbon tetrachloride	Methyl ethyl ketone; MEK; 2-Butanone
Chlorobenzene	Methyl iodide; Iodomethane
Chloroethane; Ethyl chloride	4-Methyl-2-pentanone; Methyl isobutyl ketone
Chloroform; Trichloromethane	Styrene
Dibromochloromethane; Chlorodibromomethane	1,1,1,2-Tetrachloroethane
1,2-Dibromo-3-chloropropane; DBCP	1,1,2,2-Tetrachloroethane
1,2-Dibromoethane; Ethylene dibromide; EDB	Tetrachloroethylene; Tetrachloroethene; Perchloroethylene
o-Dichlorobenzene; 1,2-Dichlorobenzene	Toluene
p-Dichlorobenzene; 1,4-Dichlorobenzene	1,1,1-Trichloroethane; Methylchloroform
trans-1,4-Dichloro-2-butene	1,1,2-Trichloroethane
1,1-Dichloroethane; Ethylidene chloride	Trichloroethylene; Trichloroethene
1,2-Dichloroethane; Ethylene dichloride	Trichlorofluoromethane; CFC-11
1,1-Dichloroethylene; 1,1,-Dichloroethene; Vinylidene chloride	1,2,3-Trichloropropane
cis-1,2-Dichloroethylene; cis-1,2-Dichloroethene	Vinyl acetate
trans-1,2-Dichloroethylene; trans-1,2-Dichloroethene	Vinyl chloride
1,2-Dichloropropane; Propylene dichloride	Xylenes
cis-1,3-Dichloropropene	

1.3.5 Monitoring and Maintenance of the Leachate Management System

The leachate collection and removal system will be maintained throughout the post-closure care period. Inspection of all appurtenances (e.g., valves, pumps, etc.) of the system, including the leachate transfer facility, will be conducted with any necessary remedial actions performed as soon as possible. Leachate will continue to be collected in the leachate storage tank and pumped via the forcemain into the public sewer system of the Loudon Utilities Wastewater Treatment Plant (or other permitted disposal site), as required, during the post-closure care period.

Samples of the leachate will be collected and analyzed as required by the Loudon Utilities Wastewater Treatment Plant.

1.3.6 Monitoring and Maintenance of the Landfill Gas Management System

The primary function of the landfill gas management system is to control odor, explosive gas emissions, and their migration off-site. Methane gas surveys will be conducted during the first year of post-closure and quarterly thereafter. The survey shall be composed of ambient air samples collected once every 100 ft along the compliance monitoring boundary, and once in every room of every structure on the landfill property. Samples shall be analyzed by the use of a combustible gas indicator, which has direct methane gas measurement capability. The results of the quarterly survey will be maintained as part of the permanent records.

The landfill gas vents will be visually inspected periodically to ensure proper operation. Any damage to the vents will be repaired as soon as practical.

1.3.7 Schedule for Inspections during Post-Closure

A schedule for performing inspections will be as follows:

Item	Frequency
Final Cap System	Quarterly
Surface and Stormwater Management System	Quarterly
Groundwater Management System	Semi-Annually
Leachate Management System	Monthly
Landfill Gas Management System	Quarterly

Any systems that are found to be functioning improperly or are damaged will be repaired as soon as practical in accordance with this plan.

1.3.8 Post-Closure Land Use

There is no proposed land use for the closed landfill at the time of this submittal.

2.0 CLOSURE AND POST-CLOSURE CARE COST ESTIMATES

2.1 Introduction

The cost estimates in this document are budgetary estimates. Costs are based on a variety of information including quotes from manufacturers, generic unit costs, vendor information, and prior experience. Cost estimates are developed for total closure of the MBL – Modules A through N totaling approximately 67 acres will be used for disposal. Actual closure and post-closure costs depend on true labor and material costs, actual site conditions, competitive market conditions, final project scope, implementation schedule, and any other variable factors.

Regarding financial assurance, the planned cost to completely close the Matlock Bend Class I Landfill is defined. Cost information represented in the following tables, "Table 5 - Closure Cost" and "Table 6 - Post-Closure Cost," are in a format which models Cost Estimate Work Sheets A and B, as recommended by the TDEC, Division of Solid Waste Management.

REDLINE PAGES 3 & 4

closure cap after all available airspace has been utilized or exhausted. These time allowances and provisions are in accordance with Rule 0400-1-7-.04(8)(c) 1 through 3, respectively. If contingencies force exceptions to the schedule times set forth above, Santek will request a waiver.

In accordance with Rule 0400-1-7-.04(8)(c)2, construction of final closure is not required until the landfill reaches final grade, which is approximately 1,125 ft. msl. Final closure placement at the end of a landfill's operational life has its advantages, as referenced below:

1) The Matlock Bend Landfill has several opportunities for future expansion. If partial closure construction were to occur and the landfill expanded prior to the end of its operational life, then the final cap would need to be removed prior to additional waste placement, thereby squandering the resources required to construct the closure cap.

2) The construction of partial closure can be more susceptible to veneer slope failures. This can be attributable to storm water run-on in the higher portions of the partial closure. The run-on can slowly erode the anchor trench, sending water beneath the geosynthetics, thereby creating a veneer slope failure. If final closure were to occur once the apex of the landfill were constructed, then the possibility of storm water run-on flowing beneath the geosynthetics is greatly reduced.

3) Settlement in the waste mass is another reason to construct final closure at the end of the landfill's useful life. Settlement is generally uneven and can be up to 20% of the overall landfill height. Allowing the majority of the settlement to occur prior to closure will allow for additional waste placement over the settled waste as well as allowing for uneven areas to be filled to minimize stress on geosynthetic components in the final closure cap.

Although placing final closure over the 67-acre landfill at one time is advantageous for the reasons mentioned above, partial closure may be requested through the minor modification process in the future. The Loudon County Solid Waste Disposal Commission or Santek, may request a minor modification to allow for partial closure in areas deemed necessary. The following reasons are a few examples that could lead to a minor modification request:

1) A remedial effort in the event of an environmental release where partial

closure would resolve the issue.

2) The installation of an active gas collection and control system to capture more landfill gas and reduce air infiltration into the waste mass.

3) Partial closure could be deemed beneficial in reducing storm water infiltration thereby reducing leachate volumes and disposal costs.

Santek will notify TDEC in writing within 60 days when all closure activities are complete. This notification will include a certification that the area has been closed in accordance with this Closure/Post-Closure Plan. This is in accordance with Rule 0400-1-7-.04(8)(c)9.

Within 90 days of completing final closure of the entire landfill, and prior to the sale or lease of the property, Loudon County Solid Waste Disposal Commission or Santek will ensure that a notation is recorded on the property deed, or on some other instrument which is normally examined during a title search, that will perpetually notify any person conducting a title search that the land has been used as a waste disposal facility. This is in accordance with Rule 0400-1-7-.04(8)(f).

1.2.3 Final Cap Design

The MBL will be closed with a final cap designed to achieve the following:

- reduce and minimize infiltration of precipitation through the top surface of the landfill so that infiltration volume will be equal to or less than the percolation volume through the bottom liner system;
- minimize maintenance;
- promote efficient drainage while preventing excessive erosion of the final cover; and,
- allow for settling and subsidence while maintaining the integrity of the cap system.

The final cap will incorporate the following closure system profile:

- 24 inches of vegetative cover;
- a drainage layer consisting of a polyethylene geonet sandwiched between two layers of non-woven geotextile fabric;
- A 40 mil very low-density polyethylene (VLDPE) textured geomembrane ;
- 12 inches of 90% standard proctor compacted soil;