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MEMO

TO:	**Clint Richardson, Ph.D, PE, BCEE**
FROM:	**Robert H. (Holly) Holder, PE**
PROJECT NAME:	C.K. Disposal E & P Landfill and Processing Facility
PROJECT NO.:	01-0580-15
DATE:	April 1, 2016

In response to the letter dated March 25, 2016 regarding the initial assessment of the permit application, PSC is providing calculations sealed and signed by the engineer of record, Mr. Nicholas Ybarra, PE for the following items:

1. Volumetric calculations as per cover requirements
2. Soil erosion estimates for rain and wind erosion
3. Anchor trench capacity
4. Foundation settlement as it affects leachate collection
5. Waste settlement as it affects the top slope and surface drainage features
6. Leachate pipe performance as per deflection
7. Liner stability and tensile stress under filing as per a multi-layered liner
8. Waste stability via translational failure upon filling

As you and I discussed earlier this week by telephone the following items are not included at this time. We understand that these items, listed as A-E below, were not required for the most recent permit approval.
If it is determined by OCD that these calculations are preferred for permit approval, please notify me and we will comply as quickly as possible.

A Outside slope stability (static and pseudostatic)
B Final veneer stability for a multi-layered liner sequence
C Geotextile evaluation as per retention, permittivity, and porosity for leachate collection
D Minimum liner thickness based on projected overburden
E Geonet compression under overburden loading

If it is determined items A through E are required, we will so provide as soon as practical.

The following is a summary of the results from each calculation above:

1. Volumetric calculations as per cover requirements:

   For the final cover, protective cover, waste footprint perimeter berm, and daily/intermediate cover (20% of waste capacity) cover we will use 5,585,742 cubic yards of soil. Based on a cut and fill analysis performed on site we had an excess of 7,717,488.61 cubic yards of cut soil available. The site will have approximately 2,131,746.6 cubic yards of excess soil.

2. Soil erosion estimates for rain and wind erosion:

For erosion due to rain we used the RUSLE method. We estimate that we will lose 4.51 tons/acre/year due to rain. NRCS specifies a target rate of less than 5 tons/acre/year for non-farm application, therefor we are within the target range of NRCS.

(#2 continued) Wind erosion we used the National Agronomy Manual's Wind Erosion Equation. Using the attached E table we estimate that wind erosion will account for 1.2 tons/acre/year. NRCS specifies a target rate of less than 2.5 tons/acre/year for non-farm application, therefor we are within the target range of NRCS.

3. Anchor Trench Capacity:

   Using an equation from Geotechnical Aspects of Landfill Design and Construction we found the tension on the geomembrane to be 2,067lbs/in^2 this is less than the yield strength of GSE 60 mil liner. Therefor the anchor trench is adequately sized.

4. Foundation settlement as it affects leachate collection:
   Attached spreadsheets show that no slopes for the leachate collection were decreased below the required 2% slope.

5. Waste Settlement:

   Attachment spreadsheet shows the angular distortion. All angular distortions were minor and less than the design slopes for the drainage system. With the settlement the site will still have positive drainage.

6. Leachate Pipe performance:

   We evaluated both PVC pipe and HDPE pipe for performance in regard to deflection. We found a 8.1% deflection in the PVC pipe which is well below the 30% deflection that is the critical value from the Handbook of PVC Design. The HDPE pipe had a deflection of 7% which is below the standard of 8% from Performance Pipe Engineering Manual for HDPE pipe; therefor either pipe could be used on site.

   Wall buckling was evaluated for PVC and HDPE pipe as well. For the PVC pipe we calculated that the site would produce 82.6 psi which has a factor of safety of 13.6 compared to the critical value of PVC pipe. The HDPE pipe had an actual value of 182.4 psi on site. We calculated a factor of safety of 1.86 for the HDPE pipe which is adequate.

   The HDPE pipe was also evaluated for wall crushing. Our calculations show a 1.65 factor of safety between our actual value of 910 psi and the critical value of 1,500 psi.

7. Liner stability and tensile stress under filing as per a multi-layered liner:

   Using interface friction angles we calculated the liner stability of each layer of liner. We calculated the shearing force and the friction force for each liner interface. All friction forces were greater than the shearing force; therefore, the liner is stable.

   Equipment loading was also considered for the liner system. We used a D6N CAT dozer for the equipment loading calculation. The tensile stress in the geocomposite = 4,184 lbs/ft and the resistant force in the geocomposite = 12,036 lbs/ft. Therefore the tensile stress in the geocomposite = -7,852 lbs/ft, which indicates that the geocomposite is not in tension.

8. Liner stability via translational failure upon filling:

We found the total weight of the active and passive wedge at the site. With the calculated weights and the interface friction angles we found a factor of safety of 2.3. This indicates that the passive wedge will adequately support the active wedge on the sideslopes without slippage of geosynthetics.

End of Transmittal Memo

Permit Application

Lea County, New Mexico

C.K. Disposal E & P Landfill and Processing Facility

Permit No. TBD

Engineering Calculations

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04/01/16

April 2016

PSC Project # 01058015

PARKHILLSMITH&COOPER

Soil Volumetrics of Site

A cut and fill analysis was computed for our site. The analysis accounts for all excavation, drainage and grading for the site.

CUT	Fill	Net
8,215,177.16 CY	497,688.55 CY	7,717,488.61 CY

Waste Capacity for site = 20,897,298 CY

Protective Soil cover Volume (S_{pc})

Surface area of liner = 709060 SY
Protective Soil cover thickness = 2' = (2/3) yds
Volume of soil for protective soil cover = 472,707 CY = S_{pc}

Final Cover Soil Volume (S_{FC})

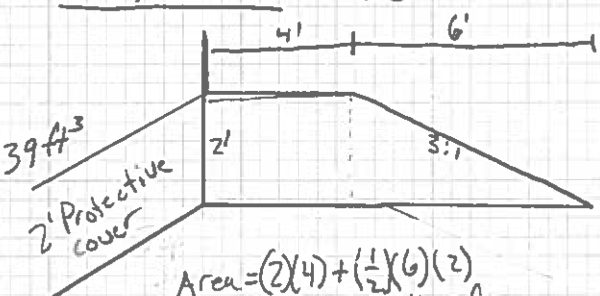
Surface area of Final Cover = 696,338 SY
Final cover thickness = 3' + 1' (Intermediate cover) = 4' = (4/3) yds
Volume of soil for Final cover = 928,451 CY = S_{FC}

Perimeter berm Soil Volume (S_P)

Perimeter around waste footprint = 9,881.36'

Volume of soil for waste perimeter berm = (9,881.36 ft)(14 sf) = 138,339 ft³

Volume of soil for waste perimeter berm = 5,124 CY = S_P



Area = (2)(4) + (1/2)(6)(2)
Area = 8 + 6 = 14 sf
Area = 14 sf

Volume of soil for Protective cover, Final Cover and Perimeter berm

$S_{pc} + S_{FC} + S_P$ = 472,707 CY + 928,451 CY + 5,124 CY = 1,406,282 CY = T_S

Continued on next page

Volume of soil for Protective cover, Final Cover and Perimeter Berm

$S_{pc}+S_{Fc}+S_p = 1{,}406{,}282CY$

Assume that 20% of the landfill capacity will be used for daily and intermediate cover

Waste capacity = 20,897,298CY

S_{di} = daily and intermediate Soilcover Volume = (20,897,298CY)(0.2)

daily and intermediate soil cover Volume = 4,179,460CY = S_{di}

$S_{pc}+S_{Fc}+S_p+S_{di} = S_T = 1{,}406{,}282CY + 4{,}179{,}460CY$

$S_T = 5{,}585{,}742CY$

Net Cut and fill = 7,717,488.61CY (surplus)

Excess Soil remaining after cover and perimeter berms are Constructed = S_E

$S_E = 7{,}717{,}488.61CY - 5{,}585{,}742CY$

$S_E = 2{,}131{,}746.61CY$ excess

$$\% \text{ of Soil remaining} = \frac{S_E}{\text{Net cut and fill}}(100) = \frac{2{,}131{,}746.61CY}{7{,}717{,}488.61CY}(100) = 27.6\%$$

- The site will have excess soil remaining after protective cover, Final cover, Daily cover, Intermediate cover and Waste perimeter berm have been constructed.

Soil Erosion Estimate for Rain and Wind Erosion

- Final cover crown max slope = 4%
- Side slope of Final Cover = 4H:1V = 25%
- Final cover was conservatively assumed to have 50% coverage of vegetation
- Target erosion rates is less than 5.0 tons/acre/year for rainfall and 2.5 tons/acre/year for wind erosion. These Values are from NRCS for non farm applications
- Design erosion rate shall not exceed the soil erosion layer of the Final Cover which is 12 inches thick

RUSLE was used for Soil Losses due to rainfall

$A = R \times K \times L \times S \times C$

A = Soil Loss per unit Area (tons/acre/year)

R = rainfall/runoff factor based on site specific climate = 45

K = Soil Erodability factor based on Soil type = 0.15
- Sand and Silty Sand is predominately onsite

L = Length Slope factor = $\left(\frac{L_h}{72.6}\right)^m$ L_h = horizontal slope length, m = slope length exponent

S = Slope factor = (16.8 sin(slope angle)) - 0.5

C = Cover factor = $C_{PLU} C_{CC} C_{SC} C_{SE} C_{SM}$

C_{PLU} = Prior Landuse (Design Hydrology and Sedimentology for Small Catchments) = 1.0 (rangeland) (DHASFSC)

C_{CC} = Canopy cover (Design Hydrology and Sedimentology for small catchments) = $1 - F_C * Exp(-0.1)H$

F_C = surface covered by canopy = 0.5

H = canopy height in feet = 1 ft

$C_{CC} = 1 - (0.5) * Exp(-0.1)(1) = \underline{0.55 = C_{CC}}$

$C_{SC} = \exp\left(-b R_C \left(\frac{6}{6+R_G}\right)^{0.08}\right)$

R_C = Fraction ground cover = 0.5 for 50% veg cover

R_G = Surface Roughness = $(25.4 R_R - 6)(1 - e^{-0.0015 R_S}) e^{-0.14 P_T}$

R_R = 0.8 = Random Roughness (DHASFSC)

R_S = 1200 from (DHASFSC)

P_T = 11.72 inches from Western Regional Climate Center (Hobbs, New Mexico)

b = 4.5 (constant)

$R_G = (25.4(0.8) - 6)(1 - e^{-0.0015(1200)}) e^{-0.14(11.72)}$

$R_G = (14.32)(0.8347)(0.1938)$

$R_G = 2.32$

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$C_{SC} = \exp\left(-bR_C\left(\frac{6}{6+R_6}\right)^{0.08}\right)$

$C_{SC} = \exp\left(-4.5(0.5)\left(\frac{6}{6+2.32}\right)^{0.08}\right) = \exp(-2.1919)$

$C_{SC} = 0.11$

C_{SR} = Surface Roughness = $e^{-0.026R_6}$

$C_{SR} = e^{-0.026(2.32)} = 0.94 = C_{SR}$

C_{SM} = Soil Moisture = 1.0 for rangeland

$C = C_{PLU} C_{CC} C_{SC} C_{SR} C_{SM}$

$C = (1)(0.55)(0.11)(0.94)(1)$

$C = 0.06$

RUSLE Soil Loss for Final Cover Crown (A_c)

$A_c = R \times K \times LS \times C$

$L = \left(\frac{L_h}{72.6}\right)^m = \left(\frac{1{,}266}{72.6}\right)^{0.36} = 2.80$

$A = (45)(0.15)(2.80)(0.17)(0.06)$

$L_h = 1{,}266$

$m = 0.36$ (OHASFSC)

$A_c = 0.19$ tons/acre/year

$S = (16.8\sin(2.29)) - 0.5$

$S = 0.17$

RUSLE Soil Loss for Sideslope of Final Cover (A_S)

$A_S = R \times K \times L \times S \times C$

$L = \left(\frac{L_h}{72.6}\right)^m = \left(\frac{400}{72.6}\right)^{0.64} = 2.98$

$L_h = 400$

$m = 0.64$

$S = (16.8\sin(14.04)) - 0.5$

$A_S = (45)(0.15)(2.98)(3.58)(0.06)$

$S = 3.58$

$A_S = 4.32$ tons/acre/year

$A_T = A_c + A_S = 0.19$ tons/acre/year $+ 4.32$ tons/acre/year

$A_T = 4.51$ tons/acre/year

With 50% vegetative cover, the soil loss is 4.51 tons/acre/year.

Target erosion Rate (NRCS) = 5 tons/acre/year > 4.51 tons/acre/year = site Value

Soil Losses Due to Wind

- Use the "National Agronomy Manual" 3rd Edition, Oct. 2002
- Soil type on site is predominately Loamy fine sands (web soil survey)

Wind Erosion Equation

E is a function of I, K, C, L, V

E = Potential average annual soil Loss (tons/acre/year)
I = Soil Erodibility Index (tons/acre/year)
K = Ridge Roughness factor (0.5 - 1.0)
C = Climatic Factor
L = Unsheltered Distance along prevailing wind direction across the area being evaluated
V = Equivalent Vegetative Cover

Soil Erodibility Index "I" (National Agronomy Manual Exhibit 502-2)

I = 134 tons/acre/year

Ridge Roughness factor "K"

No wind break ridges are proposed for the final cover
So a "K" Value of 1.0 was selected
K = 1.0

Climatic Factor "C" (Agronomy Tech Note 27, June 1992)

C = 150

Continued on next page

Unsheltered Distance along prevailing wind direction "L"

L = 2,321 ft

According to a wind rose from the Hobbs Lea County Airport, the predominate wind direction is from the south.

The longest unsheltered distance along the south wind is the western edge of the final cover. L is the length from the Southwest waste footprint to the northwest waste footprint.

Equivalent Vegetative Cover "V" (National Agronomy Manual)

Our Final cover quality control plan calls for seeding in accordance with USDA rules and the Federal seed act. With native and drought resistant grasses to be seeded, we should see about 1,500 pounds per acre of vegetative cover.

Using 1,500 lbs/Ac for veg. cover and pg. 502-92 of the "National Agronomy Manual" we get a V > 3,000.

Since E Tables only extend to 3,000 we will use:

→ V = 3,000

E Table to Solve (NRCS Wind Erosion Equation (WEQ) site

E Table from the website with the following parameters

I = 134 tons/acre/year
K = 1.0
C = 150
L = 2,321 ft
V = 3,000

we get that E = 1.2 tons/acre/year

Wind Erosion onsite = 1.2 tons/acre/year
NRCS Target Value = 2.5 tons/acre/year

Wind erosion onsite < NRCS Target value for Wind Erosion

Anchor Trench Capacity

The geocomposite/Double sided Textured HDPE Liner has the Minimum Interface friction angle and will be the limiting Interface.

$$T = \frac{(\gamma_s)(d_{cs})(L_{RO})(\tan\delta_c) + \left[(1-\sin\theta)(\gamma_s(d_{cs}+0.5d_{AT}))d_{AT} + \gamma_s(d_{cs}+d_{AT})L_{AT}\right](\tan\delta_c + \tan\delta_p)}{\cos\beta - \sin\beta\tan\delta_c}$$

$\gamma_s = 110$ pcf

d_{cs} = depth cover soil = 2'

L_{RO} = runout Length = 2'

δ_c = Friction angle of geocomposite/Double sided Textured HDPE = 20.1°

θ = Friction angle of compacted backfill = 35°

d_{AT} = depth anchor trench = 2'

L_{AT} = width anchor trench = 2'

δ_p = friction angle between geomembrane and compacted backfill = 32°

$\beta = 14.04$

$$T = \frac{(110\text{pcf})(2)(2)(\tan(20.1)) + \left[(1-\sin(35))(110\text{pcf})(3')(2') + 110(2'+2')(2')\right](\tan(20.1) + \tan(32°))}{\cos 14.04 - (\sin 14.04)\tan(20.1)}$$

$$T = \frac{161.02 + [(0.426)(660) + 880]\,0.9908}{.881} = 1{,}488.6 \text{ lbs/ft} = 124 \text{ lbs/in}$$

GSE use 126 lbs/in width as the yield Strength for 60 mil HDPE

$$\frac{126 \text{ lbs/in}}{0.06 \text{ in}} = 2{,}100 \text{ lbs/in}^2$$

$$\frac{124 \text{ lbs/in}}{0.06 \text{ in}} = 2{,}067 \text{ lbs/in}^2$$

So our value of 2,067 lbs/in² is less than GSE yield strength so the anchor trench is adequately sized.

Foundation Settlement

$$Z_e = \left(\frac{\Delta\sigma}{M_s}\right) H_o$$

Z_e = elastic settlement of soil layer (ft)
H_o = initial thickness of soil layer (ft)
$\Delta\sigma$ = increment of vertical effective stress (lbs/ft²)
M_s = constrained Modulus of soil (lb/ft²)
E_s = Elastic modulus of soil (lbs/ft²)
V_s = Poisson's ratio

$$M_s = \frac{E_s(1-V_s)}{(1+V_s)(1-2V_s)}$$

E_s & V_s values were found using "Geotechnical Aspects Of Landfill Design and construction"

unitweight of soil = 110pcf
Unitweight of waste = 74pcf

$\Delta\sigma$ = waste effective stress + protective soil cover effective stress + intermediate cover effective stress + Final cover effective stress

$$\Delta\sigma = (157'(74pcf)) + (2')(110pcf) + (1')(110pcf) + (3')(110pcf)$$

$$\Delta\sigma = 12{,}278 \text{ lbs/ft}^2$$

SM soil type was used for $E_{s(90\%)}$ & $V_{s(90\%)}$ calculations

$$E_{s(90\%)} = \frac{4700psi + 16{,}000psi}{2} = (10{,}350 psi)(144) = 1{,}490{,}400 \text{ lbs/ft}^2$$

$$V_{s(90\%)} = 0.29$$

$$M_s = \frac{1{,}490{,}400(1-0.29)}{(1+0.29)(1-2(0.29))} = \frac{1058184}{0.5418} = 1{,}953{,}090 \text{ lbs/ft}^2$$

$$Z_e = \left(\frac{12{,}278 \text{ lbs/ft}^2}{1{,}953{,}090 \text{ lbs/ft}^2}\right)(40) = 0.251ft = 3 \text{ inches} = Z_e$$

H_o = compressible soil depth = 40'

Attached spreadsheet has settlement calculations for the points shown in Figure 1.

The required 2% slope of the leachate collection system is not adversly effected by foundation settlement.

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Project C.K. Disposal E+P Landfill and Processing Facility
Job No. 01-0580-15
Subject Settlement
Drawn By
Date 3/31/2016 Sheet 2 of 3

Waste Settlements (Geotechnical Aspects of Landfill Design and Construction)

Primary Settlement $\Delta H_c = C_c \frac{H_o}{1+e_o} \log \frac{\sigma_i}{\sigma_o}$

ΔH_c = primary settlement

$\frac{C_c}{1+e_o} = 0.006$ (Geotechnical Engineering Principals and Practices) $D_r = 80\%$

H_o = Initial waste thickness

σ_o = applied pressure in waste layer, Assumed to be: 1,000 lb/ft²

σ_i = over burden pressure at midlayer of waste

$\Delta H_c = (0.006)(157') \log \frac{6{,}029 \text{ lbs/ft}^2}{1{,}000 \text{ lbs/ft}^2}$

$\sigma_i = 0.5[(157')(74\text{pcf}) + (4')(110\text{pcf})] = 6{,}029 \text{ lbs/ft}^2$

$\Delta H_c = 0.735'$

Secondary Settlement (Long term)

$\Delta H_s = C_\alpha \frac{H_o}{1+e_o} \log \frac{t_2}{t_1}$

$C_\alpha = 1/3\left[\frac{C_c}{1+e_o}\right] = 0.002$

H_o = waste thickness at start of secondary settlement $= H - H_c$

t_1 = starting time of secondary settlement = 1 year

t_2 = ending time of secondary settlement = 30 years

$H_o = 157 - 0.735' = 156.265'$

$\Delta H_s = (0.002)(156.265') \log\left(\frac{30}{1}\right) = 0.46'$

Total waste settlement = 0.735' + 0.46' = 1.2'

1.2' will not have nominal impact on drainage or integrity of final cover.

Waste settlement calcs are provided in attached spreadsheet.

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Project Ck. Disposal
Job No. 01-0580-15
Subject Settlement
Drawn By
Date 3/31/2016 Sheet 3 of 3

Soil Cover Settlement

Primary Soil Settlement

$$\Delta H_p = C_c\left(\frac{H_p}{1+e_o}\right)\log\left(\frac{P_o+\Delta P}{P_o}\right)$$

$$\frac{C_c}{1+e_o} = 0.006$$

$H_p = 6'$ (protective cover (2') + Intermediate cover (1') + Final cover (3'))

$$P_o = \left(\frac{H}{2}\right)(110\,pcf) = 330\ lbs/ft^2$$

$$\Delta P = (3')(110pcf) + (2')(114pcf) + (1')(110pcf) = 660\ lbs/ft^2$$

$$\Delta H_p = (0.006)(6')\log\left(\frac{(330\,lbs/ft^2 + (660\,lbs/ft^2))}{330\ lbs/ft^2}\right) = \underline{0.017' = \Delta H_p}$$

Secondary Soil Cover Settlement

$$\Delta H_s = C_\alpha \frac{H_s}{1+e_o}\log\left(\frac{t_2}{t_1}\right) \qquad H_s = 6' - 0.017 = 5.983'$$

$$\Delta H_s = (0.002)(5.983')\log\left(\frac{30}{1}\right) = \underline{0.018' = \Delta H_s}$$

Total soil cover settlement = 0.017' + 0.018' = $\underline{\underline{0.035'}}$

Final cover slope of the crown on the landfill is between 2.5% - 4%, the settlement does not adversly impact the Final cover

Spreadsheet calcs are attached

SETTLEMENT AND ANGULAR DISTORTION OF FOUNDATION SOILS BETWEEN POINTS; CROSS SECTION A-A								
Point Location	Total Settlement	Distance Between Points	Angular Distortion	Distortion Direction	Design Base Grade Elevation	Design Slope Between Points	Updated Base Grade Elevation	Update Slope Between Points
	(ft)	(ft)	(%)		(ft)	(%)	(ft)	(%)
A1	0.05				3371.16	25.00	3371.11	
		100	0.067	↑				2.43
A2	0.12				3351.85	2.50	3351.73	
		100	0.040	↑				2.46
A3	0.16				3350.94	2.50	3350.78	
		100	0.035	↑				2.46
A4	0.19				3353.01	2.50	3352.82	
		100	0.000	↓				2.50
A5	0.18				3354.84	2.50	3354.66	
		100	0.000	↑				2.50
A6	0.21				3352.76	2.50	3352.55	
		100	0.000	↑				2.50
A7	0.21				3350.67	2.50	3350.46	
		100	0.000	↑				2.50
A8	0.22				3352.05	2.50	3351.83	
		100	0.000	↑				2.50
A9	0.22				3354.13	2.50	3353.91	
		100	0.000	↑				2.50
A10	0.22				3353.68	2.50	3353.46	
		100	0.000	↑				2.50
A11	0.23				3351.62	2.50	3351.39	
		100	0.000	↑				2.50
A12	0.24				3351.12	2.50	3350.88	
		100	0.000	↑				2.50
A13	0.24				3353.13	2.50	3352.89	
		100	0.000	↓				2.50
A14	0.24				3354.46	2.50	3354.22	
		100	0.000	↑				2.50
A15	0.24				3352.32	2.50	3352.08	
		100	0.000	↓				2.50
A16	0.24				3350.18	2.50	3349.94	
		100	0.000	↓				2.50
A17	0.23				3351.95	2.50	3351.72	
		100	0.000	↓				2.50
A18	0.23				3353.98	2.50	3353.75	
		100	0.000	↓				2.50
A19	0.22				3353.03	2.50	3352.81	
		100	0.000	↓				2.50
A20	0.22				3350.91	2.50	3350.69	
		100	0.000	↓				2.50
A21	0.22				3350.81	2.50	3350.59	
		100	0.000	↓				2.50
A22	0.21				3352.77	2.50	3352.56	
		100	0.000	↓				2.50
A23	0.21				3353.65	2.50	3353.44	
		100	0.000	↓				2.50
A24	0.20				3351.62	2.50	3351.42	
		100	0.000	↓				2.50
A25	0.16				3349.62	2.50	3349.46	
		100	-0.001	↓				25.00
A26	0.10				3367.04	25.00	3366.94	
		100	-0.001	↓				25.00
A27	0.02				3392.04	25.00	3392.02	

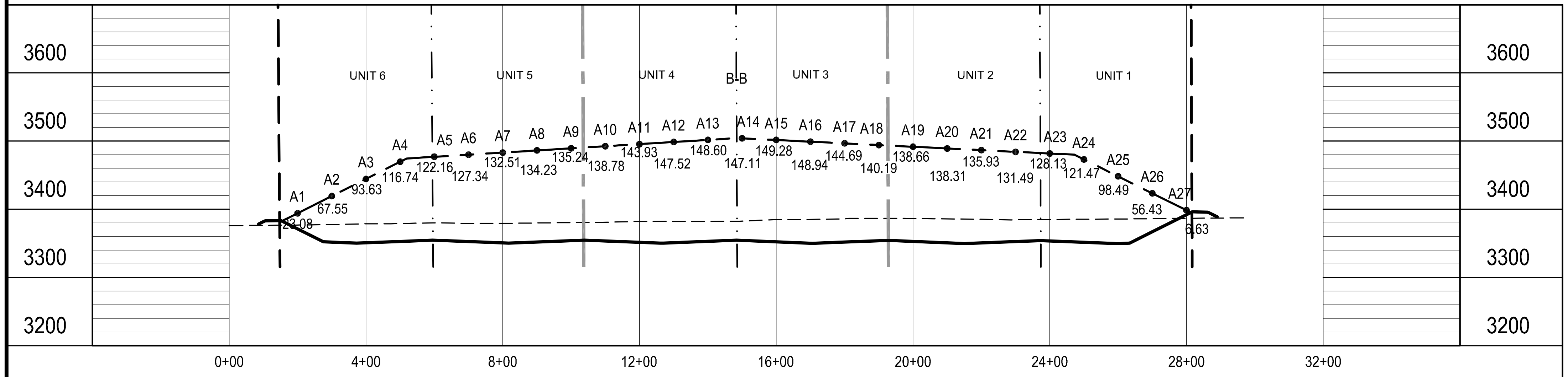
SETTLEMENT AND ANGULAR DISTORTION OF FOUNDATION SOILS BETWEEN POINTS; CROSS SECTION B-B								
Point Location	Total Settlement	Distance Between Points	Angular Distortion	Distortion Direction	Design Base Grade Elevation	Design Slope Between Points	Updated Base Grade Elevation	Update Slope Between Points
	(ft)	(ft)	(%)		(ft)	(%)	(ft)	(%)
B1	0.13				3371.57	25	3371.44	
		100	0.203	↑				24.80
B2	0.34				3346.59	25.00	3346.25	
		100	0.142	↑				2.36
B3	0.48				3336.63	2.50	3336.15	
		100	0.094	↑				2.41
B4	0.57				3338.64	2.50	3338.07	
		100	0.016	↑				2.48
B5	0.59				3340.66	2.50	3340.07	
		100	0.008	↑				2.49
B6	0.60				3342.67	2.50	3342.07	
		100	0.008	↑				2.49
B7	0.60				3344.69	2.50	3344.09	
		100	0.008	↑				2.49
B8	0.61				3346.70	2.50	3346.09	
		100	0.008	↑				2.49
B9	0.62				3348.69	2.50	3348.07	
		100	0.008	↑				2.49
B10	0.63				3350.68	2.50	3350.05	
		100	0.008	↑				2.49
B11	0.64				3352.66	2.50	3352.02	
		100	0.008	↑				2.49
B12	0.64				3354.65	2.50	3354.01	
		100	-0.002	↓				2.50
B13	0.64				3352.96	2.50	3352.32	
		100	-0.002	↓				2.50
B14	0.64				3350.95	2.50	3350.31	
		100	-0.002	↓				2.50
B15	0.64				3348.93	2.50	3348.29	
		100	-0.002	↓				2.50
B16	0.63				3346.92	2.50	3346.29	
		100	-0.002	↓				2.50
B17	0.63				3344.90	2.50	3344.27	
		100	-0.002	↓				2.50
B18	0.63				3342.89	2.50	3342.26	
		100	-0.004	↓				2.50
B19	0.62				3340.87	2.50	3340.25	
		100	-0.001	↓				2.50
B20	0.62				3338.86	2.50	3338.24	
		100	-0.088	↓				2.59
B21	0.54				3336.84	2.50	3336.30	
		100	-0.171	↓				25.17
B22	0.37				3354.40	25.00	3354.03	
		100	-0.201	↓				25.20
B23	0.16				3379.40	25.00	3379.24	

WASTE SETTLEMENT AND ANGULAR DISTORTION BETWEEN POINTS; CROSS SECTION A-A				
Point Location	Total Settlement	Distance Between Points	Angular Distortion	Distortion Direction
	(ft)	(ft)	(%)	
A1	0.08			
		100	0.31	↑
A2	0.39			
		100	0.22	↑
A3	0.61			
		100	0.21	↑
A4	0.82			
		100	-0.04	↓
A5	0.78			
		100	0.14	↑
A6	0.92			
		100	0.05	↑
A7	0.97			
		100	0.02	↑
A8	0.99			
		100	0.01	↑
A9	1.00			
		100	0.03	↑
A10	1.03			
		100	0.05	↑
A11	1.08			
		100	0.04	↑
A12	1.12			
		100	0.01	↑
A13	1.13			
		100	0.26	↑
A14	1.39			
		100	-0.25	↓
A15	1.14			
		100	-0.003	↓
A16	1.13			
		100	-0.04	↓
A17	1.09			
		100	-0.04	↓
A18	1.05			
		100	-0.02	↓
A19	1.03			
		100	0.00	↓
A20	1.03			
		100	-0.02	↓
A21	1.00			
		100	-0.04	↓
A22	0.96			
		100	-0.03	↓
A23	0.93			
		100	-0.06	↓
A24	0.86			
		100	-0.21	↓
A25	0.65			
		100	-0.35	↓
A26	0.30			
		100	-0.29	↓
A27	0.01			

WASTE SETTLEMENT AND ANGULAR DISTORTION BETWEEN POINTS; CROSS SECTION B-B				
Point Location	Total Settlement	Distance Between Points	Angular Distortion	Distortion Direction
	(ft)	(ft)	(%)	
B1	0.08			
		100	0.32	↑
B2	0.40			
		100	0.29	↑
B3	0.69			
		100	0.21	↑
B4	0.90			
		100	0.038	↑
B5	0.94			
		100	0.018	↑
B6	0.96			
		100	0.018	↑
B7	0.97			
		100	0.018	↑
B8	0.99			
		100	0.018	↑
B9	1.01			
		100	0.019	↑
B10	1.03			
		100	0.019	↑
B11	1.05			
		100	0.019	↑
B12	1.07			
		100	-0.006	↓
B13	1.06			
		100	-0.006	↓
B14	1.06			
		100	-0.006	↓
B15	1.05			
		100	-0.006	↓
B16	1.04			
		100	-0.006	↓
B17	1.04			
		100	-0.006	↓
B18	1.03			
		100	-0.010	↓
B19	1.02			
		100	-0.002	↓
B20	1.02			
		100	-0.20	↓
B21	0.82			
		100	-0.36	↓
B22	0.46			
		100	-0.35	↓
B23	0.11			

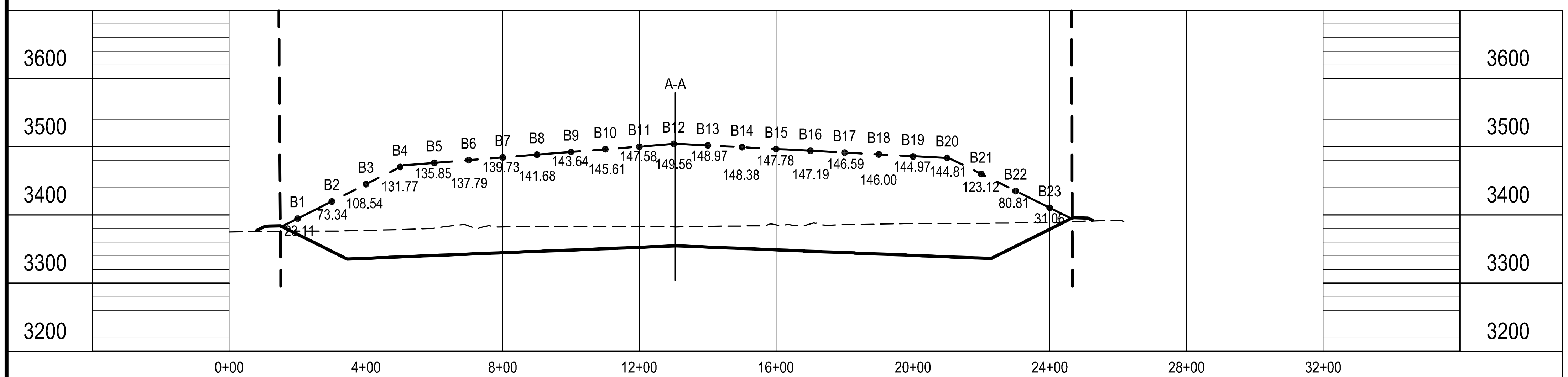
SOIL COVER SETTLEMENT AND ANGULAR DISTORTION BETWEEN POINTS; CROSS SECTION A-A				
Point Location	Total Settlement	Distance Between Points	Angular Distortion	Distortion Direction
	(ft)	(ft)	(%)	
A1	0.13			
		100	0.26	↑
A2	0.39			
		100	0.15	↑
A3	0.54			
		100	0.13	↑
A4	0.68			
		100	-0.03	↓
A5	0.65			
		100	0.27	↑
A6	0.92			
		100	-0.15	↓
A7	0.77			
		100	0.01	↑
A8	0.78			
		100	0.01	↑
A9	0.79			
		100	0.02	↑
A10	0.81			
		100	0.03	↑
A11	0.84			
		100	0.02	↑
A12	0.86			
		100	0.01	↑
A13	0.86			
		100	0.15	↑
A14	1.01			
		100	-0.14	↓
A15	0.87			
		100	-0.144	↓
A16	0.87			
		100	0.00	↓
A17	0.84			
		100	-0.02	↓
A18	0.82			
		100	-0.03	↓
A19	0.81			
		100	-0.01	↓
A20	0.80			
		100	0.00	↓
A21	0.79			
		100	-0.01	↓
A22	0.76			
		100	-0.03	↓
A23	0.75			
		100	-0.02	↓
A24	0.71			
		100	-0.17	↓
A25	0.57			
		100	-0.24	↓
A26	0.33			
		100	-0.29	↓
A27	0.04			

SOIL COVER SETTLEMENT AND ANGULAR DISTORTION BETWEEN POINTS; CROSS SECTION B-B				
Point Location	Total Settlement	Distance Between Points	Angular Distortion	Distortion Direction
	(ft)	(ft)	(%)	
B1	0.13			
		100	0.29	↑
B2	0.43			
		100	0.20	↑
B3	0.63			
		100	0.14	↑
B4	0.77			
		100	0.024	↑
B5	0.79			
		100	0.011	↑
B6	0.80			
		100	0.011	↑
B7	0.81			
		100	0.011	↑
B8	0.82			
		100	0.011	↑
B9	0.84			
		100	0.011	↑
B10	0.85			
		100	0.011	↑
B11	0.86			
		100	0.012	↑
B12	0.87			
		100	-0.003	↓
B13	0.87			
		100	-0.003	↓
B14	0.86			
		100	-0.003	↓
B15	0.86			
		100	-0.003	↓
B16	0.86			
		100	-0.003	↓
B17	0.85			
		100	-0.003	↓
B18	0.85			
		100	-0.006	↓
B19	0.84			
		100	-0.001	↓
B20	0.84			
		100	-0.13	↓
B21	0.72			
		100	-0.25	↓
B22	0.47			
		100	-0.29	↓
B23	0.18			



SECTION A-A

SCALE: 1" = 400'



SECTION B-B

SCALE: 1" = 400'

SCALES:

HORIZONTAL

0 400' 800'

VERTICAL

0 200' 400'

LEGEND

— — — —	LIMIT OF WASTE
- - - - - - -	EXISTING GRADE
———	BASE GRADE
—— - - ——	TOP OF WASTE
B4 •	SETTLEMENT POINT LOCATION
146.00	DEPTH OF WASTE

PARKHILL SMITH & COOPER

PSC

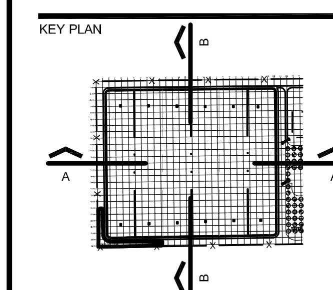
C. K. DISPOSAL E & P LANDFILL & PROCESSING FACILITY

NMED PERMIT NO. ___

NEW LANDFILL SITE & PROCESSING FACILITY

LEA COUNTY, NEW MEXICO

KEY PLAN



NO	DATE	DESCRIPTION
1	09/23/15	ISSUE FOR REVIEW

ISSUING OFFICE: EL PASO PROJECT NO: 0580.15

SETTLEMENT POINTS

FIGURE 1

PARKHILL SMITH & COOPER

PSC

Project C.K. Disposal E&P Landfill and Processing Facility
Job No. 01-0580-15
Subject Pipe ~~loading~~ Performance Calcs
Drawn By
Date March 28, 2016 Sheet 1 of 7

Pipe strength Calculations for 6"-schedule 80 pvc perforated Pipe

PVC Pipe Dimensions (Handbook of PVC Pipe Design)

Pipe nominal diameter - 6"
Pipe outside diameter (OD) - 6.625"
Pipe wall thickness (t) - 0.432"
Pipe inner diameter (ID) - 5.76"
Perforation hole (/FT) - 12 perforation holes
Perforated hole diameter (IN) - 0.5 in

Loads acting on PVC Leachate Collection Pipe

Layer 1 - 3-ft thick Final cover
Layer 2 - 1-ft thick intermediate cover
Layer 3 - fifteen 10-ft thick layers of waste for 150-ft total waste
Layer 4 - 2-ft thick layer of protective soil
Layer 5 - 1-ft thick leachate collection layer

Layer Unit weights and actual loads

Layer 1	3 ft thick	Unit weight = 110 pcf	Actual Load = 330 psf
Layer 2	1 ft thick	Unit weight = 110 pcf	Actual load = 110 psf
Layer 3	150 ft thick	Unit weight = 74 pcf	Actual load = 11,100 psf
Layer 4	2 ft thick	Unit weight = 110 pcf	Actual load = 220 psf
Layer 5	1 ft thick	Unit weight = 130 pcf	Actual load = 130 psf

Total Actual Load = 11,890 psf
= 82.6 psi

Continued on next page

Load of pipe with perforations

- Static Vertical load per Unit length of pipe (W_c)

$$W_c = \frac{(P_T)(D_o)}{(1-((n)(d)/12))}$$

(Geotechnical Aspects of Landfill Design and Construction)

P_T = design load (psi) = 82.6

D_o = Outside diameter (in) = 6.625

n = number of perforations per foot of pipe = 12

d = diameter of perforated hole (in) = 0.5

$$W_c = \frac{(82.6)(6.625)}{\left(1 - \frac{(12)(0.5)}{12}\right)} = \frac{547.225}{0.5} = 1094.45 \text{ lbs/in} = 13{,}133.4 \text{ lbs/ft}$$

Deflection

(Geotechnical Aspects of Landfill Design and Construction)

$$\Delta X = \left(\frac{(D_L)(K)(W_c)(r^3)}{(E)(I)+0.061(E')(r^3)}\right)$$

D_L = Conservative value of 1.5 for lag or time dependent behavior

K = bedding constant for support from the bottom of the trench (K = 0.083 for a bedding angle of 180°)

r = mean radius of pipe = $\frac{(6.625-0.432)}{2}$ = 3.1 in

E = Modulus of elasticity = 400,000 psi (Handbook of PVC pipe Design)

E' = Modulus of passive soil resistance in crushed rock = 3000 psi

I = moment of inertia = $I = \frac{t^3}{12} = \frac{0.432^3}{12} = 0.0067 \text{ in}^4/\text{in}$

$$\Delta X = \left(\frac{(1.5)(0.083)(1094.45)(29.79)}{(400000)(0.0067)+0.061(3000)(29.79)}\right)$$

$$= \frac{4059.2 \text{ lbs/in}^2}{~~2680+5451.6~~ \; 8131.57} = \underline{0.5 \text{ in}}$$

Ring Deflection (RD) (Geotechnical Aspects of Landfill Design and Construction)

$$\%RD = [\Delta X/(D_i+t)] \times 100$$

D_i = Internal pipe diameter

t = wall thickness

$$\%RD = [0.5/(5.76+0.432)] \times 100$$

$$\%RD = \underline{8.1\%}$$

Wall Buckling (Geotechnical Aspect of Landfill Design and Construction)

Critical buckling Pressure (P_{cr}) $= (2)\left\{\left[(E')/(1-v^2)\right]\left[\frac{(E)(I)}{r^3}\right]\right\}^{1/2}$

E' = Modulus of Soil reaction = 3,000 psi

E = Modulus of Elasticity of pipe = 400,000 psi

V = Poisson's Ratio = 0.38 for PVC pipe (Handbook of PVC Pipe Design)

I = Moment of Inertia = 0.0067 in⁴/in

t = pipe wall thickness = 0.432 in

r = mean radius of pipe = 3.1 in

$$P_{cr} = 2\left\{\left(\frac{3000}{(1-0.38^2)}\right)\left(\frac{(400000)(0.0067)}{29.79}\right)\right\}^{0.5}$$

$$P_{cr} = 2\left\{\left(\frac{3000}{0.8556}\right)(89.96)\right\}^{0.5}$$

$$P_{cr} = 2\{561.64\} = 1{,}123.3\text{ psi}$$

Factor of safety (FS)

$$FS = P_{cr} / \text{Actual Total load}$$

$$FS = \frac{1{,}123.3\text{ psi}}{82.6\text{ psi}} = \underline{\underline{13.6}}$$

Equipment Loading

- Type of equipment = CAT 627 Scraper
  - Tractor weight = 48,061 lbs
  - Scraper weight = 33,399 lbs
  - Soil load (20cy) = 48,000 lbs
  - total weight = 129,460 lbs
  - Max weight per tire = 32,365 lbs assuming equal distribution
  - tire width = 18 inches = 1.5 ft
  - Tire contact length = 4" = 0.33 ft
  - Tire contact area = (18")(4") = 72 in² = 0.5 ft²

$$W_{SD} = (C_s)(p)(F)(B_c)$$

- W_{SD} = Load on pipe (lbs/ft)
- p = Intensity of distributed load (lbs/ft²)
- F = Impact factor
- B_c = Outside diameter of pipe
- C_s = Load Coefficient

C_s ∴ D/2H & M/2H

$$\frac{D}{2H} = \frac{1.5\text{ ft}}{(2(3\text{ ft}))} = 0.25$$

$$\frac{M}{2H} = \frac{0.33\text{ ft}}{(2(3))} = 0.055$$

According to Table 4C.3 in the "Solid Waste Landfill Design Manual" published by "Washington State Department of Ecology"

$$C_s \approx 0.053$$

According to Table 4C.4 in the aforementioned reference, the impact factor for a 2 ft protective cover is the following

$$F = 1.2$$

$$W_{SD} = (0.053)\left(\frac{32,365\text{ lbs}}{(1.5\text{ ft})(.33\text{ ft})}\right)(1.2)(0.55\text{ ft})$$

$$W_{SD} = \underline{2,287\text{ lbs/ft}} = \underline{190\text{ lbs/in}}$$

Static vertical load is greater than load due to equipment therefor those calculations govern.

Pipe strength calculations for 6" SDR 11.0 HDPE Pipe

HDPE Pipe Dimensions (Design and Engineering guide for Polyethylene Piping)

- Pipe nominal diameter - 6"
- Pipe outside diameter - 6.625"
- Pipe wall thickness - 0.602"
- Pipe Inner diameter - 5.35"

Loads acting on HDPE Pipe

			unit weight	actual load
Layer 1	4-ft thick	final cover	110 pcf	330 psf
Layer 2	1-ft thick intermediate cover		110 pcf	110 psf
Layer 3	fifteen 10 ft thick waste		74 pcf	11,100 psf
Layer 4	2-ft thick	protective soil	110 pcf	220 psf
Layer 5	1-ft thick	leachate collection	130 pcf	130 psf
			Total =	11,890 psf
				= 82.6 psi

Load on Pipe with perforations (Geotechnical Aspects of Landfill design and Construction)

Static Vertical Load $= W_c = \dfrac{(P_T)(D_o)}{\left(1-\frac{(n)(d)}{12}\right)} = \dfrac{(82.6\text{ psi})(6.625'')}{\left(1-\frac{(12)(0.5\text{ in})}{12}\right)} = \dfrac{547.225}{0.5} = 1094.45\text{ lb/in} = 13,133.4\text{ lbs/Ft}$

$$\Delta X = \left(\frac{(D_L)(K)(W_c)(r^3)}{(E)(I)+0.061(E')(r^3)}\right)$$

$r = \dfrac{6.625-0.602}{2} = 3.0\text{ in}$

$E = 35,000\text{ psi}$

$I = t^3/12 = \dfrac{0.602^3}{12} = 0.0182$

$E' =$ Soil modulus $= 3,000\text{ psi}$

$D_L =$ same as PVC calc

$K =$ same as PVC calc

$$\Delta X = \left(\frac{(1.5)(0.083)(1094.45)(3^3)}{(35000)(0.0182)+0.061(3000)(3^3)}\right) = \frac{3678.993675}{637+4941}$$

$= 0.66\text{ in}$

Continued on Next page

Wall Strain

$$\varepsilon = f_D\left(\frac{\Delta X}{D_m}\right)\left(\frac{2C}{D_m}\right)$$

f_D = deformation shape factor = 6 (Polyethylene Piping Systems Manual)

D_m = Mean diameter

Δx = 0.66 in

C = Distance from outer fiber to wall centriod

$C = 0.5(1.06t)$

$= (0.5)(1.06)(0.602) = 0.319\,in$

$$\varepsilon = (6)\left(\frac{0.66\,in}{6}\right)\left(\frac{2(0.319)}{6}\right) = 0.07 = 7\%$$

(.11) (0.10633)

7% < 8% (From performance pipe engineering manual)

So it is acceptable

Wall Buckling (Polyethylene Piping Systems manual)

$$P_c = \frac{2.32(E)}{SDR^3} = \frac{2.32(35,000)}{11^3} = 61\,psi$$

Critical Collaspe (Polyethylene Piping Systems manual)

$$P_{cb} = 0.8\sqrt{(E')(P_c)} = 0.8\sqrt{(3000)(61)} = 339.41\,psi$$

Factor of Safety

$$FS = \frac{P_{cb}}{P_D} = \frac{339.41\,psi}{182.4\,psi} = \underline{1.86}$$

$$P_D = \frac{W_c}{\text{diameter of pipe}} = \frac{1094.45\,lb/in}{6\,in} = 182.4\,psi$$

P_D = total external pressure on top of pipe

Continued on next page

Wall Crushing (Polyethylene Piping Systems Manual)

$$S_A = \frac{(SDR-1)}{2} P_0 = \left(\frac{11-1}{2}\right)(182.4) = 910\,psi$$

S_A = Actual compressive stress (psi)
P_0 = Total external pressure on top of pipe (psi)

Factor of safety

According to "Polyethylene Piping Systems manual" the compressive yield strength of HDPE Pipe = 1,500 psi

$$FS = \frac{1{,}500\,psi}{910\,psi} = \underline{\underline{1.65}}$$

Equipment Loading

The equipment loading on HDPE Pipe is based on same assumptions used in PVC pipe calculation; therefor, static vertical load still govern HDPE pipe calculations

Perforated PVC Pipe load Summary

Design Criteria	Critical value	Actual Value	factor of Safety	OK?
Ring Deflection	30%*	8.1%	3.7	✓
Wall Buckling	1,123.3 psi	82.6 psi	13.6	✓

* From Handbook of PVC Design

SDR 11.0 HDPE Pipe Summary

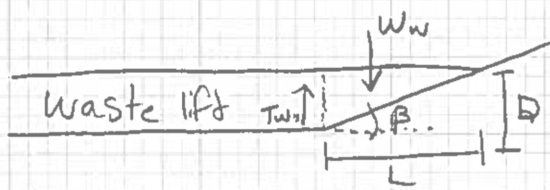
Design Criteria	Critical Value	Actual Value	Factor of Safety	OK?
Ring Deflection	8%	7%	1.14	✓
Wall Buckling	339.41 psi	182.4 psi	1.86	✓
Wall Crushing	1,500 psi	910 psi	1.65	✓

Liner Stability and Tensile Stress

Liner design

24" protective Cover
200 mil Geocomposite
60 mil Geomembrane HDPE (Double sided Textured for sideslopes/smooth for floor)
200 mil Geonet (floor) / 200 mil HDPE Geocomposite (sideslope)
60 mil HDPE Geomembrane (Double sided Textured for sideslope/smooth for floor)
Geosynthetic Clay liner (GCL)
6" compacted Subgrade

Tensile Stress in Liner system



β = slope angle (4H:1V) = 14.04°
γ_w = 74 pcf
Φ = Internal angle of friction for waste = 33°
D = waste lift thickness = 10'
L = Length of Lift = 40'
$K_o = 1 - \sin\Phi = 0.455$

$$W_w = \frac{DL\gamma_w}{2} = \frac{(10')(40')(74pcf)}{2} = 14{,}800\,plf = W_w$$

$$T_w = K_o\left(\frac{D^2\gamma_w}{2}\right)\tan\Phi = (0.455)\left(\frac{(10^2)(74)}{2}\right)\tan(33) = 1093.3\,plf = T_w$$

$$W = W_w - T_w = \text{net force of waste} = (14{,}800\,plf) - (1093.3\,plf)$$

$$W = 13{,}707\,plf$$

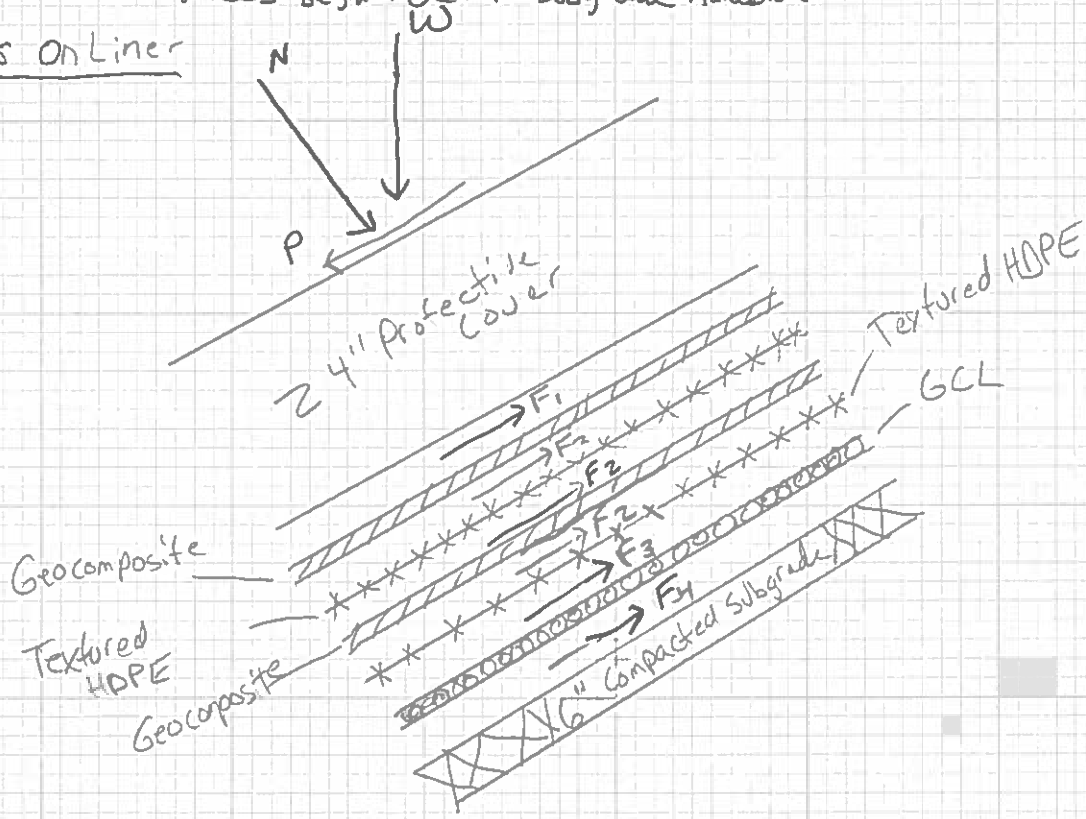
Continued on next Page

Sideslope Geosynthetic Interface friction angles and adhesion

Interface	Reference	Failure Envelope Φ	Adhesion ② "C"
Protective Soil to Geocomposite	"1"	32	0
Geocomposite to Textured HDPE	"1"	20.1	0
Textured HDPE to GCL	"1"	27.3	0
GCL to Subgrade	"1"	28.2	87

① Interface friction values are values that were tested on "Sm" (silty sand) which is pridominately on the C.K. Disposal E&P Landfill and processing Facility site.
② To be conservative cohesion is assumed to be zero for all interfaces besides GCL to Subgrade Adhesion

Forces on Liner



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Forces within Liner System

$N = W\cos\beta$ = Normal Force on Liner $= (13{,}707\,plf)\cos(14.04) = 13{,}298\,plf$

$P = W\sin\beta$ = Shearing Force on Liner $= (13{,}707\,plf)\sin(14.04) = 3{,}325\,plf$

$N = 13{,}298\,plf$ $P = 3{,}325\,plf$

Resistance in Protective Cover and Textured HDPE

$$F_1 = N\tan(\Phi) + \frac{C_1(L)}{\cos\beta} = (13{,}298\,plf)\tan(32) + \frac{0(40)}{\cos 14.04} = 8{,}310\,plf = F_1$$

$F_1 > P$ ∴ the protective cover is stable

Resistance in Geocomposite and Textured HDPE

$$F_2 = (13{,}298\,plf)\tan(20.1) + \frac{(0)(40)}{\cos 14.04} = 4866\,plf = F_2$$

$F_2 > P$ ∴ Geocomposite is stable

Resistance in Textured HDPE and GCL

$$F_3 = (13{,}298\,plf)\tan(27.3) + \frac{(0)(40)}{\cos 14.04} = 6{,}864\,plf = F_3$$

$F_3 > P$ ∴ Textured HDPE is Stable

Resistance in GCL to Subgrade

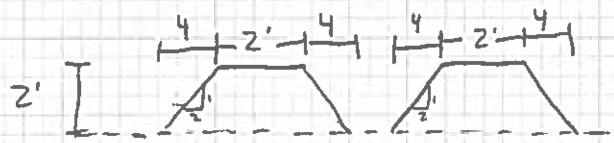
$$F_4 = (13{,}298\,plf)\tan(28.2) + \frac{(87)(40)}{\cos 14.04} = 10{,}717 = F_4$$

$F_4 > P$ ∴ GCL is stable

Since all F (Resistance) Forces are greater than the shearing force, there is no tensile stress in the Liner System

Tensile stress due to equipment loading

- Only protective cover is in place (2') = h_{soil}
- Max unsupported length of protective cover = 70' @ 4H:1V
- Unit weight of soil = 110 lbs/ft^3 = γ_s
- Internal Friction angle of soil = 33° = θ
- Critical Interface friction angle is between Geocomposite and Textured HDPE Liner = 20.1° = Φ
- Use CAT D6N Dozer (Tier 4 Final/Stage IV)
  - Operating weight = 36,943 lbs
  - 24" Track width
  - Width acting on Geocomposite = 20.0 ft
    - Assume 2H:1V Distribution



Tensile forces acting on Geocomposite

$F_{soil} = (h_{soil})(\text{unsupported Slope length})(\gamma_s)(\sin\beta)$ $\beta = 14.04$

$= (2')(70')(110pcf)(\sin 14.04) = F_{soil} = 3{,}736 \text{ lbs/ft}$

$F_{dozer} = \left(\frac{(\text{dozer weight})}{(\text{width acting on Geocomposite})}\right)\sin(\beta)$

$= \left(\frac{(36943 \text{ lbs})}{20.0'}\right)\sin(14.04) = F_{dozer} = 448 \text{ lbs/ft}$

Tensile forces on Geocomposite = 3,736 lbs/ft + 448 lbs/ft = 4,184 lbs/ft

Resistant forces on Geocomposite

$F_{Geo} = (\text{weight of soil} + \text{weight of Dozer})\cos\beta\sin\Phi$

$F_{Geo} = \left((2')(70')(110pcf) + \frac{36{,}943 \text{ lbs}}{20'}\right)\cos(14.04)\sin(20.1) = 11{,}293 \text{ lbs/ft} = F_{Geo}$

$F_{buttress} = \left[\frac{\cos(\theta)}{\cos(\theta+\beta)}\right]\left[\frac{\gamma_s (h_{soil})^2}{\sin(2(\beta))}\right]\tan(\theta) = \left[\frac{\cos(33)}{\cos(33+14.04)}\right]\left[\frac{(110)(4)}{\sin(2)(14.04)}\right]\tan(33)$

$F_{buttress} = [1.23][934.77][0.6494] = 743 \text{ lbs/ft} = F_{buttress}$

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Resistance Force in Geocomposite

Resistance Force in Geocomposite = $F_{Geo} + F_{buttress}$

Resistance Force = 11,293 lbs/ft + 743 lbs/ft = **12,036 lbs/ft**

Tensile Stress in Geocomposite

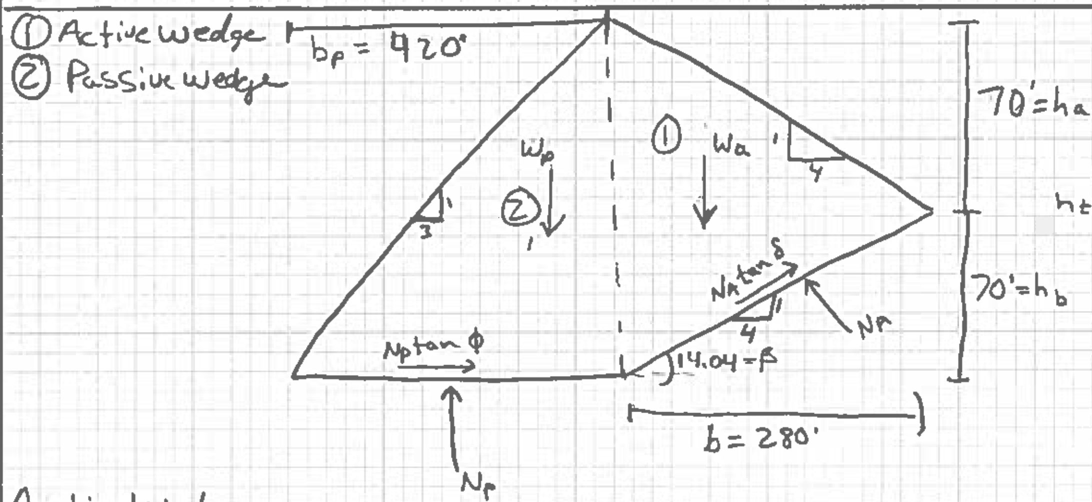
T_{Geo} = Tensile stress in Geocomposite = $(F_{soil} + F_{dozer})$ − Resistance Forces

$T_{Geo} = (3{,}736\ lbs/ft + 448\ lbs/ft) - 12{,}036\ lbs/ft$

$T_{Geo} = -7{,}852\ lbs/ft$

Negative Tensile Stress indicates that Geocomposite is not in tension.

Translational Failure Analysis



Active Wedge

$$W_a = \frac{1}{2}\left((b)(h_a)(\gamma) + (b)(h_b)(\gamma)\right)$$

W_a = Weight of Active Wedge (waste over side slope)
b = horizontal length of active wedge = 280'
h_a = height of final cover = 70'
h_b = Depth of cell = 70'
γ = unit weight of waste = 74 pcf

$$W_a = \frac{1}{2}\left((280')(70')(74\text{pcf}) + (280')(70')(74\text{pcf})\right)$$

$$W_a = 1{,}450{,}400 \text{ lbs/ft}$$

Passive Wedge

$$W_p = \frac{1}{2}(b_p)(h_t)(\gamma)$$

W_p = weight of passive wedge
b_p = Horizontal length of passive wedge = 420'
h_t = Height of wedge = 140'
γ = 74 pcf

$$W_p = \frac{1}{2}(420')(140')(74\text{pcf}) = 2{,}175{,}600 \text{ lbs/ft}$$

$$W_T = W_a + W_p = 1{,}450{,}400 \text{ lbs/ft} + 2{,}175{,}600 \text{ lbs/ft}$$

$$W_T = 3{,}626{,}000 \text{ lbs/ft}$$

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Factor of Safety (Geotechnical Aspects of Landfill Design and construction)

$$aFS^3 + bFS^2 + cFS + d = 0$$

$$a = W_A \sin\beta \cos\theta + W_P \cos\beta \sin\theta$$

$$b = (W_A \tan\delta_P + W_P \tan\delta_A + W_T \tan\phi)\sin\beta\sin\theta - (W_A \tan\delta_A + W_P \tan\delta_P)\cos\beta\cos\theta$$

$$c = -[W_T \tan\phi(\sin\beta\cos\theta\tan\delta_P + \cos\beta\sin\theta\tan\delta_A) + (W_A\cos\beta\sin\theta + W_P\sin\beta\cos\theta)(\tan\delta_A)(\tan\delta_P)]$$

$$d = W_T \cos\beta\cos\theta\tan\delta_A\tan\delta_P\tan\phi$$

θ = Landfill floor (2%) = 1.15°
δ_P = Minimum Friction angle of floor Liner system = 10°
δ_A = Minimum Friction angle of sideslope liner system = 20.1°
ϕ = Friction angle of waste = 33°

Floor Liner Geosynthetic Interface Friction

	Reference	Φ	Adhesion ②
Protective soil to Geocomposite	①	32°	0
Geotextile of Geocomposite to Smooth HDPE liner	③	8°-12° Average = 10°	0
Smooth HDPE to Geonet	③	5°-19° Average = 12°	0
Smooth HDPE to Nonwoven Geotextile of GCL	③	8°-12° Average = 10°	0
GCL to subgrade	①	28.2°	87

① Value from tests ran with SM soil, which is pridominately onsite
② Cohesion is assumed to be
③ Excerpt from Waste Containment Systems, Waste Stabilization, and Landfills: Design and Evaluation

$$a = (1{,}450{,}400)(\sin(14.04))\cos(1.15) + (2{,}175{,}600)(\cos 14.04)(\sin(1.15))$$

$$a = 394{,}155 \text{ lbs/ft}$$

$$b = ((1{,}450{,}400)\tan(10) + (2{,}175{,}600\tan(20.1)) + 3{,}626{,}000\tan(33))\sin(14.04)\sin(1.15) \rightarrow$$

$$\rightarrow - (1{,}450{,}400\tan(20.1)) + (2{,}175{,}600\tan(10))\cos(14.04)\cos(1.15)$$

$$b = 3406653(0.004869) - 886893$$

$$b = 16{,}587 - 886893$$

$$b = -870{,}306 \text{ lbs/ft}$$

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$C = -[3,626,000 \tan(33)(\sin(14.04)\cos(1.15)\tan(10) + \cos(14.04)\sin(1.15)\tan(20.1)) +$
$(1,450,400\cos(14.04)\sin(1.15) + 2,175,600\sin(14.04)\cos(1.15))\tan(20.1)\tan(10)]$

$C = -[117,486.4 + 35,872.4]$

$C = -153,359 \text{ lbs/ft}$

$d = (3,626,000)\cos(14.04)\cos(1.15)\tan(20.1)\tan(10)\tan(33)$

$d = 147,375 \text{ lbs/ft}$

So,

$394,155FS^3 - 870,306FS^2 - 153,359FS + 147,375 = 0$

Now we solve for "FS" by trial and error using an excel spreadsheet. Example calculations are shown below.

Assume FS = 1

$394,155(1^3) - 870,306(1^2) - 153,359(1) + 147,375 = -482,135$

Assume FS = 2.31

$394,155(2.31^3) - 870306(2.31^2) - 153,359(2.31) + 147,375 = 7,585$

Assume FS = 2.30

$394,155(2.30^3) - 870306(2.30^2) - 153,359(2.3) + 147,375 = -13,586$

Therefor the factor of safety is between 2.30 and 2.31

FS = 2.3 which indicates the waste is stable