98-09 9809- CDLF

Slope Stability And Settlement Evaluation

Wilson County - Westside C&D Landfill
Wilson, North Carolina

Prepared for:

Gary W. Ahlberg, P.E.
Wilmington, NC

Carver Johnson
Fac/Perm/Co ID # 98-09
Date 10/8/12
Doc ID#
DIN

August 2003

G.N. Richardson & Associates, Inc.
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

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GNRA Project No. AHLBERG-3

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WILSON COUNTY - WESTSIDE C&D LANDFILL
WILSON, NORTH CAROLINA

SLOPE STABILITY AND SETTLEMENT EVALUATION

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WILSON COUNTY - WESTSIDE C&D LANDFILL
WILSON, NORTH CAROLINA

SLOPE STABILITY AND SETTLEMENT EVALUATION

1.0 OVERVIEW

The slope stability of the overall waste mass is addressed in this report in addition to an estimate of foundation settlement. In that the project site lies outside a seismic impact zone ($a_{max} < 0.10$ g according to USGS[1,2]), seismic slope stability analyses were not required.

2.0 SLOPE STABILITY

Slope stability analyses performed meet 40 CFR 258 requirements as expressed in EPA guidance for MSW landfills, which require that the completed landfill have a minimum static factor of safety against slope failures of 1.5.

The slope stability analysis for the landfill was performed using the computer program STABL5M, a computer program developed by Purdue University. Circular failure surfaces were assumed for the evaluation of the worst case final geometry section shown in **Figure 1** and **Appendix A**. Complete output for this analysis is presented in **Appendix A**. The minimum factor of safety is 2.6 for static conditions, which is much greater than the minimum of 1.5.

A summary of material properties assumed in the slope stability analyses is presented in **Table 1**. Note that the shear strength assumed for the C&D waste in this evaluation was cohesion = 200 psf and phi = 30 degrees, which is conservative for this type of waste. Also, the shear strength assumed for the landfill subgrade was assumed to be low (c = 100 psf; phi = 20 degrees) based on the soft interbedded clays and sands found in Boring P-106.

3.0 FOUNDATION SETTLEMENT

The anticipated total settlement of the foundation of the proposed C&D landfill unit was estimated under the proposed loads. This value does not include subsidence of the waste itself, only settlement of the subgrade soils.

The settlement analysis evaluated both elastic and consolidation settlement using data from Boring P-106 in predicting the total settlement. This boring was determined to represent worst case site conditions (i.e. softest materials based on blow count information) under the proposed C&D landfill unit. The analysis indicates that the total foundation settlement will be typically about 0.5 feet with a maximum of about 1.2 feet under the maximum proposed fill height of 50 feet. Foundation settlement calculations are provided in **Appendix B**.

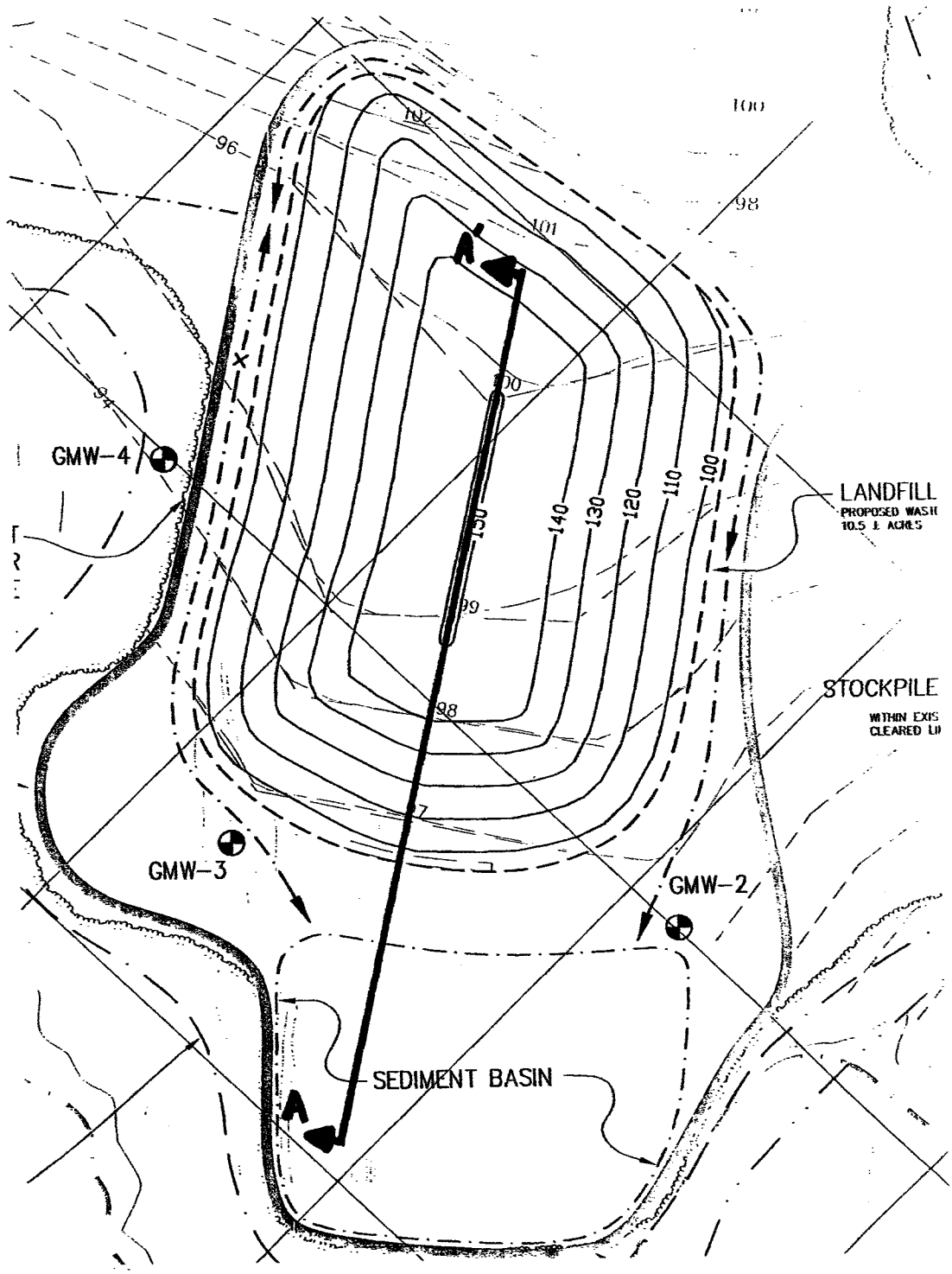
4.0 REFERENCES

1- Frankel, A.D., Peterson, M.D., et. al (2002), "Documentation for the 2002 Update of the National Seismic Hazard Maps," U.S. Geological Survey Open-File Report 02-420.

2- USGS (Oct. 2002), Map - Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years, U.S. Geological Survey.

TABLE 1: MATERIAL PROPERTIES USED IN SLOPE STABILITY ANALYSES

MATERIAL TYPE	UNIT WEIGHT (pcf)	COHESION, C (psf)	PHI, φ (degrees)
C&D Waste	50	200	30
Compacted Fill	110	500	25
Subgrade	100	100	20
Firm Layer (Depth of 26 Feet at P-106)	110	1,000	30



LOCATION OF SLOPE STABILITY

CROSS SECTION

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SCALE:	DRAWN BY:	CHECKED BY:	DATE:	PROJECT NO.	FIGURE NO.	FILE NAME
AS SHOWN	OTHERS	P.K.S.	AUG. 2003	AHLBERG-3	1	GNRA-A0005

C:\CAD\GNRA\GNRA-A0002.dwg DATE: FEB 07, 2003 TIME: 10:46 AM

Appendix A

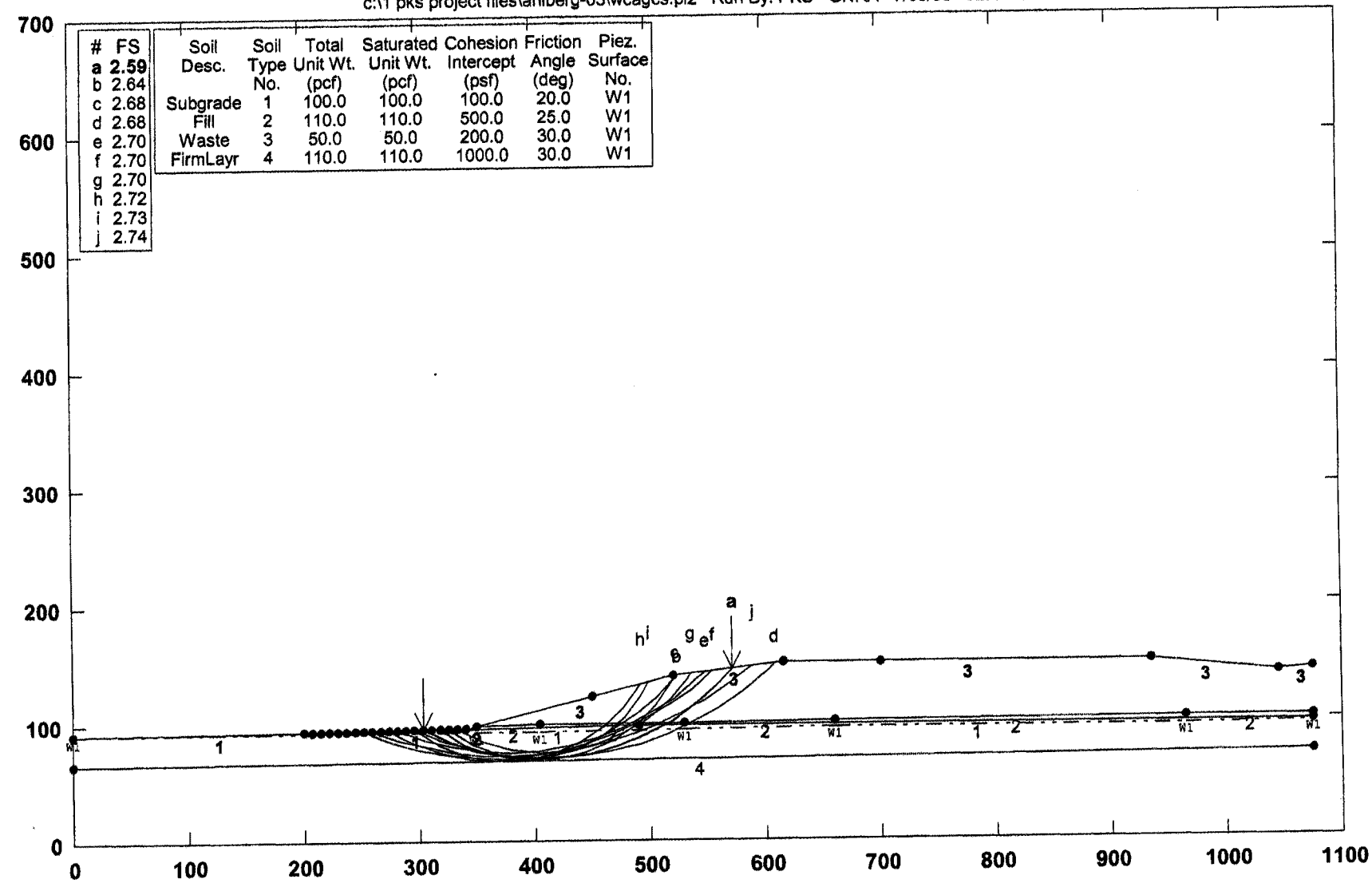
Slope Stability Analysis

Wilson Co. C&D LF - Sect. A-A Global - Circular - Static

c:\1 pks project files\ahlberg-03\wcagcs.pl2 Run By: PKS - GNRA 7/30/03 02:48PM

#	FS
a	2.59
b	2.64
c	2.68
d	2.68
e	2.70
f	2.70
g	2.70
h	2.72
i	2.73
j	2.74

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Subgrade	1	100.0	100.0	100.0	20.0	W1
Fill	2	110.0	110.0	500.0	25.0	W1
Waste	3	50.0	50.0	200.0	30.0	W1
FirmLayr	4	110.0	110.0	1000.0	30.0	W1



PCSTABL5M/si FSmin=2.59

Safety Factors Are Calculated By The Modified Bishop Method

STED

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

Run Date: 7/30/03
Time of Run: 02:48PM
Run By: PKS - GNRA
Input Data Filename: C:wcagcs.in
Output Filename: C:wcagcs.OUT
Unit: ENGLISH
Plotted Output Filename: C:wcagcs.PLT
PROBLEM DESCRIPTION Wilson Co. C&D LF - Sect. A-A
Global - Circular - Static

BOUNDARY COORDINATES
8 Top Boundaries
16 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	92.00	245.00	94.00	1
2	245.00	94.00	340.00	96.00	1
3	340.00	96.00	350.00	98.50	2
4	350.00	98.50	520.00	140.00	3
5	520.00	140.00	615.00	150.00	3
6	615.00	150.00	935.00	150.00	3
7	935.00	150.00	1045.00	140.00	3

No.	(ft)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
1	6.1	888.6	.0	.0	.0	.0	.0	.0	.0
2	16.6	11450.1	.0	4343.1	.0	.0	.0	.0	.0
3	14.1	18721.9	.0	9161.2	.0	.0	.0	.0	.0
4	9.7	18030.8	.0	8758.8	.0	.0	.0	.0	.0
5	.3	680.6	.0	309.0	.0	.0	.0	.0	.0
6	24.2	62022.8	.0	27705.1	.0	.0	.0	.0	.0
7	24.9	80383.8	.0	33924.3	.0	.0	.0	.0	.0
8	5.9	20804.5	.0	8439.3	.0	.0	.0	.0	.0
9	19.1	69547.3	.0	26976.5	.0	.0	.0	.0	.0
10	24.8	92018.6	.0	32451.9	.0	.0	.0	.0	.0
11	24.2	85495.0	.0	25099.0	.0	.0	.0	.0	.0
12	17.0	53454.3	.0	11154.6	.0	.0	.0	.0	.0
13	6.3	18063.8	.0	2298.8	.0	.0	.0	.0	.0
14	8.2	21256.4	.0	1212.5	.0	.0	.0	.0	.0
15	8.0	18303.8	.0	.0	.0	.0	.0	.0	.0
16	3.6	7358.9	.0	.0	.0	.0	.0	.0	.0
17	2.3	4544.3	.0	.0	.0	.0	.0	.0	.0
18	1.5	2873.8	.0	.0	.0	.0	.0	.0	.0
19	19.2	31044.3	.0	.0	.0	.0	.0	.0	.0
20	19.0	18695.2	.0	.0	.0	.0	.0	.0	.0
21	12.9	4054.8	.0	.0	.0	.0	.0	.0	.0

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	273.68	94.60
2	296.07	83.47
3	319.69	75.29
4	344.17	70.20
5	369.10	68.28
6	394.06	69.56
7	418.66	74.02
8	442.49	81.59
9	465.15	92.15
10	486.28	105.51
11	505.52	121.47
12	522.57	139.76
13	522.97	140.31

Circle Center At X = 371.6 ; Y = 263.4 and Radius, 195.1

*** 2.639 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	325.26	95.69
2	346.53	82.55
3	369.90	73.66
4	394.53	69.36
5	419.52	69.79
6	443.99	74.94
7	467.03	84.63
8	487.83	98.50
9	505.64	116.05
10	519.80	136.65
11	521.32	140.14

9	491.44	82.51
10	515.11	90.55
11	538.00	100.61
12	559.93	112.62
13	580.73	126.49
14	600.24	142.11
15	607.70	149.23

Circle Center At X = 410.9 ; Y = 358.6 and Radius, 287.6

*** 2.683 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	281.05	94.76
2	304.61	86.38
3	328.88	80.38
4	353.62	76.83
5	378.60	75.75
6	403.56	77.16
7	428.26	81.05
8	452.44	87.38
9	475.88	96.07
10	498.34	107.06
11	519.59	120.22
12	539.43	135.44
13	547.36	142.88

Circle Center At X = 376.9 ; Y = 326.9 and Radius, 251.1

*** 2.699 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	251.58	94.14
2	274.90	85.12
3	298.92	78.21
4	323.46	73.45
5	348.33	70.88
6	373.33	70.53
7	398.26	72.39
8	422.93	76.46
9	447.14	82.69
10	470.70	91.05
11	493.43	101.46
12	515.15	113.84
13	535.68	128.10
14	554.26	143.61

Circle Center At X = 364.8 ; Y = 352.2 and Radius, 281.8

*** 2.701 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	332.63	95.84
2	355.21	85.10
3	379.23	78.18
4	404.06	75.27
5	429.03	76.44
6	453.48	81.65
7	476.75	90.79
8	498.23	103.59
9	517.33	119.71
10	533.55	138.74
11	535.28	141.61

Circle Center At X = 409.4 ; Y = 228.2 and Radius, 153.0

*** 2.701 ***

Failure Surface Specified By 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	295.79	95.07
2	317.09	81.98

3	340.44	73.05
4	365.04	68.59
5	390.04	68.74
6	414.58	73.51
7	437.82	82.73
8	458.96	96.08
9	477.27	113.10
10	492.10	133.19

Circle Center At X = 376.7 ; Y = 202.9 and Radius, 134.8

*** 2.715 ***

Failure Surface Specified By 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	317.90	95.53
2	339.02	82.17
3	362.46	73.46
4	387.18	69.77
5	412.14	71.27
6	436.25	77.89
7	458.47	89.35
8	477.84	105.14
9	493.54	124.60
10	498.74	134.81

Circle Center At X = 392.2 ; Y = 189.2 and Radius, 119.6

*** 2.734 ***

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	258.95	94.29
2	282.62	86.26
3	306.83	80.03
4	331.44	75.62
5	356.31	73.07
6	381.30	72.39
7	406.27	73.59
8	431.08	76.65
9	455.60	81.57
10	479.67	88.31
11	503.17	96.83
12	525.97	107.09
13	547.94	119.03
14	568.95	132.58
15	588.25	147.18

Circle Center At X = 377.8 ; Y = 405.8 and Radius, 333.4

*** 2.735 ***

Appendix B

Foundation Settlement Evaluation

PROJECT Wilson Co, C&D LF

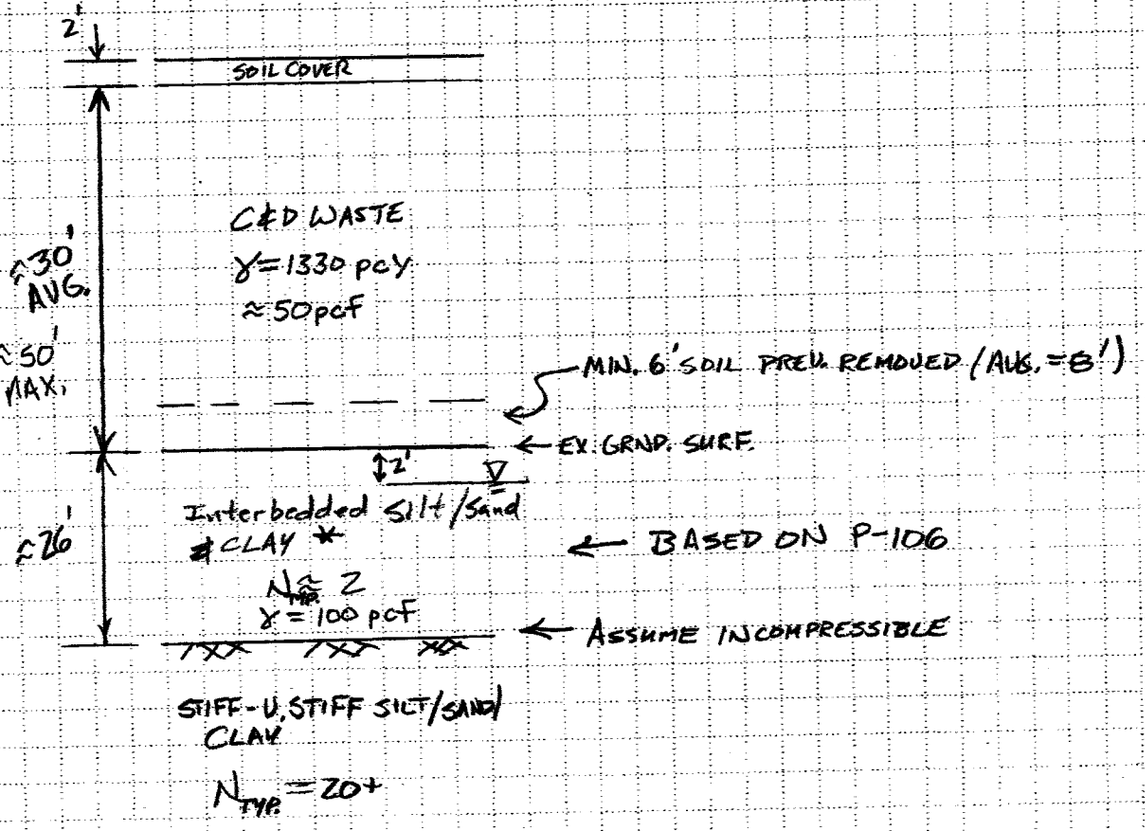
SUBJECT Settlement Analysis

SHEET 1 OF 4
JOB NO. AHLBERG-3
DATE 7/30/03
COMPUTED BY PKS
CHECKED BY

- **Objective:** To analyze the settlement potential of the proposed C&DLF unit. Compute both elastic & consolidation settlements.

- **Assumptions:**

  - Simplified Site Stratigraphy/Loadings:



* Assume 1/2 is Sand - Elastic Settlement
1/2 is Clay - Consol. Settlement
E_s = 150 ksf - V. Soft Clay or V. Loose Sands[1]

[1] Bowles, J.E. (1988), Foundation Analysis & Design, McGraw-Hill, New York, p. 99.

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Appendix B

Foundation Settlement Evaluation

PROJECT Wilson Co. C&D LF

SUBJECT Settlement Analysis

SHEET 1 OF 4
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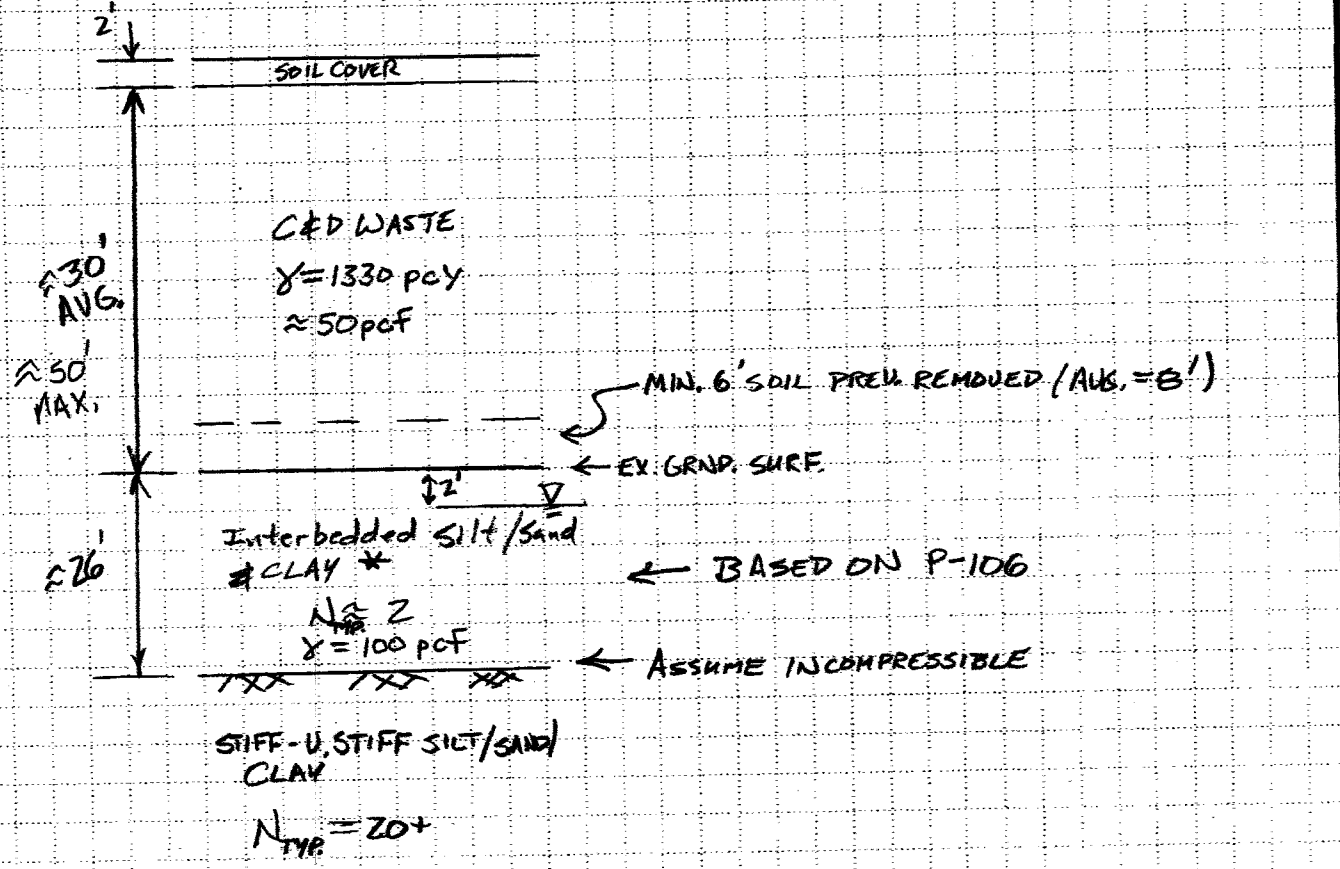

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PROJECT _____ SHEET 2 OF 4

SUBJECT _____ JOB NO. _____

DATE _____

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- Calculate Stress Increase @ Mid Pt. of 50Ft Layer:

$\Delta\sigma_v$ @ Ground Surf. = 3' FILL (ASSUMED) + 30' C&D + 2' SOIL COVER

$= 5'(110\ pcf) + 30(50\ pcf) = 2{,}050\ psf$

$$\Delta\sigma_{MIDPT} = \frac{\Delta\sigma_v \times B \times L}{(B+z)(L+z)} \qquad z = 13'$$

(B & L: WIDTH & LENGTH OF LF)

$$= \frac{2050 \times 600 \times 900}{(600+13)(900+13)} = 1{,}978\ psf = \Delta\sigma_{v=13'}$$

W/ 50' C&D, $\Delta\sigma_v = 3{,}050\ psf$; $\Delta\sigma_{MIDPT} = 2{,}943\ psf$

- Calculate Elastic Settlement:

$$\Delta H_E = \frac{PL}{AE}$$

$\frac{P}{A} = \Delta\sigma_{v=13'} = 1{,}978\ psf$

L = Layer Thickness (Assume $\frac{1}{2} \times 26' = 13'$)

$E = 150\ ksf = 150{,}000\ psf$

$$\Delta H_E = \frac{1{,}978(13')}{150{,}000} = 0.17' \cong 2''$$

W/ 50' C&D, $\Delta H_E = 0.26' \cong 3''$

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PROJECT _____ SHEET 3 OF 4

SUBJECT _____ JOB NO. _____

DATE _____

COMPUTED BY _____

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- Calculate Consolidation Settlement:

$$\Delta H_c = RR\, H_o \log \frac{P_p}{P_o} + CR\, H_o \log \frac{P_o + \Delta P}{P_p}$$

$P_p = 2200$ psf

$P_o = 13' \times 100\ pcf - 11' \times 62.4' \cong 614$ psf

$\Delta P = \Delta T_{V=13'} = 1{,}978$ psf

$H_o = 1/2 \times 26' = 13'$

$RR = .008$ } - CONSOL. TEST DATA - ATTACHED

$CR = .33$ }

$$\Delta H_c = .008(13) \log \frac{2200}{614} + 0.33(13) \log \frac{614 + 1978}{2200}$$

$= .06' + 0.31' = 0.37'$

w/ 50' C&D, $\Delta H_c = .06 + .90 = 0.96'$

- Total Settlement:

$\Delta H_{TOTAL} = \Delta H_e + \Delta H_c = .17' + 0.37' = 0.54' = 6.5''$

w/ 50' C&D, $\Delta H_{TOTAL} = 0.26' + 0.96' = 1.22'$

∴ MAX Settlement = 1.2'; TYP. Settlement = 0.5'

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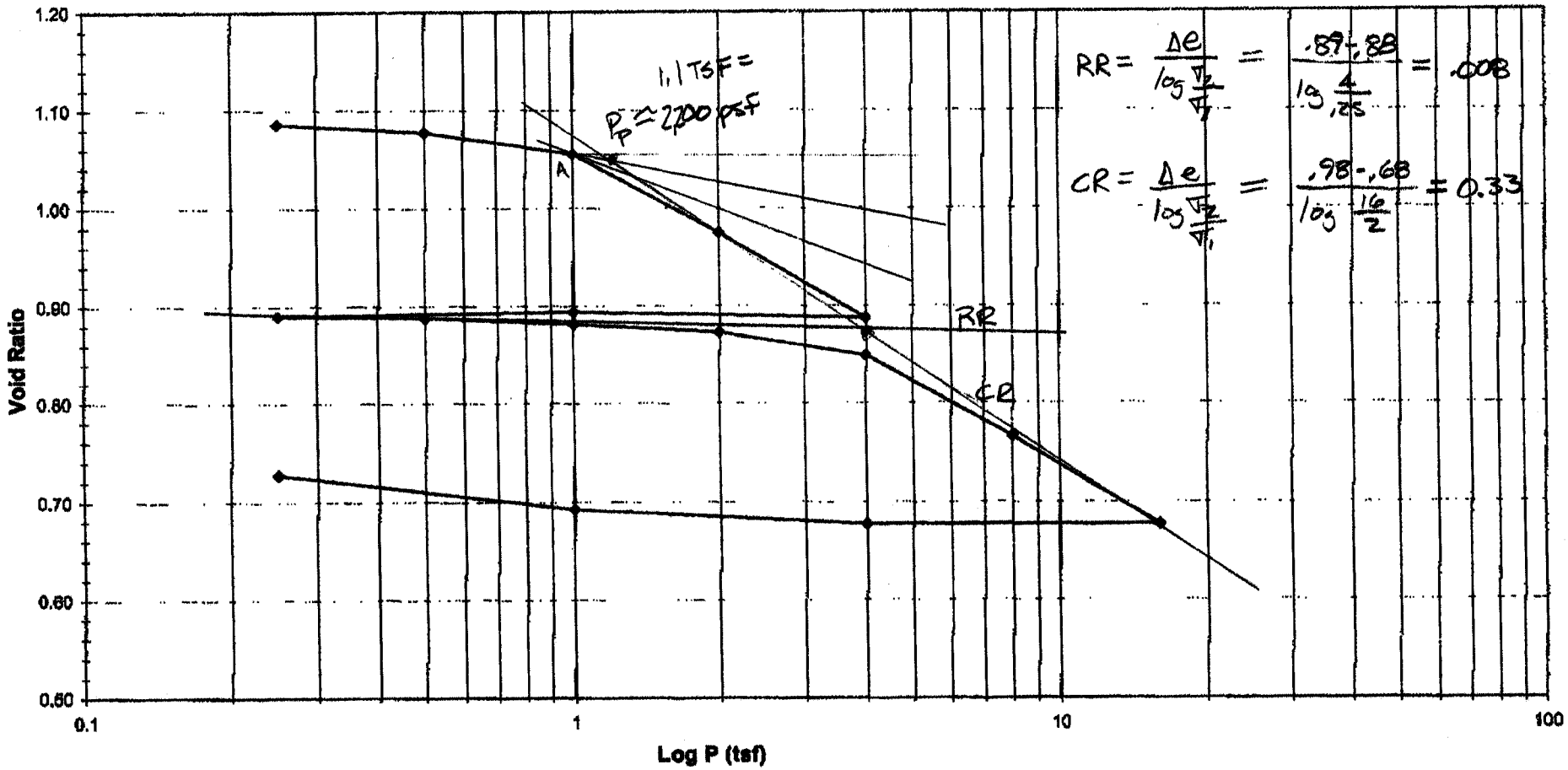
ONE DIMENSIONAL CONSOLIDATION

ASTM D 2435/96 (SOP-S24)

Client	DABB ASSOCIATES	Boring No.	P-106
Client Reference	WESTSIDE CDLF	Depth (ft)	12.0-14.0
Project No.	R02085-01	Sample No.	11-5-02
Lab ID	R02085-01.01	Visual Description	GRAY CLAY & SAND

Sample Conditions: UNDISTURBED, INUNDATED AND DOUBLE DRAINED



4/4

Tested By DAJ *Date* 12/16/02 *Approved By* *Date*

DCN: CT-S24F Date: 11/8/00 Revision: 4

C:\2002 Projects\R02085 Dabb\[R02085-01.01 CONSOL...xls]Sheet1

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