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MEMORANDUM

Date:	January 2016
To:	Office
From:	Zenon Markewycz
Re:	EE Memo 3 – Loading on Promenade Sheet Piles Wills St. Promenade, Harbor Point, Baltimore, MD
File:	12582B - 130

MRCE has completed a review of the available information and evaluation of the existing permanent sheet pile wall at the foot of Wills Street. The purpose of this analysis is to assess ability of the existing sheet pile wall to support the proposed grade change.

Exhibits

1. DS-1a Existing AZ-13 Sheet pile Wall Section
2. DS-1b Proposed Modifications to AZ-13 Sheet pile Wall Section
3. DS-2a Existing BZ-26 Bulkhead Wall Section
4. DS-2b Proposed Modifications to BZ-26 Sheet pile Wall Section – Anchored Option
5. DS-2c Proposed Modifications to BZ-26 Sheet pile Wall Section – Rip Rap Option MRCE 12582, Wills Wharf Office / Hotel; Drawing DDP F1.40 – Foundation Plan, December 2015
6. MRCE 10609, Harbor Point – Area 2; Drawing B-1 – Boring Location Plan, June 2006
7. MRCE 10609, Thames Street Wharf Office Building & Garage
    a. Drawing F1.03 – Promenade and Sheeting Plan, October 2007
    b. Drawing F2.02 – Sections and Details, October 2007
    c. Drawing F2.03 – Sections and Details, October 2007
8. MRCE 6909, Baltimore Works Remediation
    a. Drawing 1300D - Sheeting and Shoring General Plan, December 1992
9. Drawing 1305D – Permanent Sheeting East of Wills Street, December 1992

References

1. MRCE 10609, Geotechnical Data Report Harbor Point Areas 2 and 3 Philpot and Block Sts., between Wills & Thames, Boring No. MR-718, June 2006

Existing Sheet Pile Wall

The existing sheet pile wall is located at the south end of the proposed Wills Street Extension and runs east along the shoreline to the Thames Street Wharf Promenade, serving to retain backfilled material. The sheet pile wall consists of two continuous segments represented by Design Section 1a (DS-1a) and Design Section 2a (DS-2a).

DS-1a represents the eastern segment starting just east of column line D.7 as shown on Drawing F1.03 and running approx. 114 ft., towards the west. Along this segment, the existing grade is assumed to be at

EL. +7.5, sloping upward to EL. +10.0 inboard at a 1:1 slope, with water level at EL. +2.0. South of the sheet pile wall, the top of rip rap is at EL +3.0 and water at EL. 0.0. The existing top of the AZ-13 sheet piles is at EL. +10.0 with a toe at EL. -40.0. This profile is shown on Section B on Drawing F2.02.

The western segment of the existing ERS is represented by DS-2a, and runs approximately 118 ft. from the west end of DS-1a, continuing to the west, ending at the proposed centerline of the Wills St. Extension as shown on drawing 1305D. Along this segment, existing grade surface is at EL. +7.5 with water at EL. +2.0 behind the ERS and at EL. 0.0 in front. The top of the BZ-26 steel sheet piles at EL. +7.5 and extend to El. -40.0. South of this segment, the top of rip-rap is at EL. -12.0. This profile is shown on drawing 1305D. Sheet pile has corrosion losses and holes which require repair. Structural analysis considered loses but hole damage has not been accounted for.

<u>Proposed Development</u>

The proposed new promenade is to be constructed south of the new Wills Wharf Office & Hotel structure, extending over the existing sheet pile wall. This will require the existing grade elevation north of the sheet pile wall to be raised to El. +13.0. The proposed profiles are represented in two segments, by Design Segment 1b (DS-1b), and 2b and 2c (DS-2b & DS-2c). A 600 psf vertical construction surcharge was used in the analysis.

<u>Assessment</u>

<u>Design Section 1 – AZ 13 Sheet pile Installed Circa 2008</u>

The proposed grade of EL. +13 results in a 10 ft., cantilever flexible wall. The maximum expected deflection, at the top of the wall is approximately 2.6in. The bending stress in the sheet pile is within code allowable stress. For this analysis, a total of 1/8 in. steel thickness loss due to corrosion was assumed in the calculation of AZ-13 sheet pile section properties. The embedment of the sheet pile was adequate to provide the required safety factor.

<u>Design Section 2 – BZ-26 Sheetpile Installed Circa 1990:</u>

The proposed raised grade north of the sheet pile wall of EL. +13.0 results in a retained height of 25ft. The resulting forces would overstress and de-stabilize the existing BZ-26 sheet pile.

<u>Conclusions</u>

Design Section 1

Analysis shows that raising the grade from El. +10.0 to El. +13.0 north of the sheet pile wall, will increase the sheet pile deflection to an estimated 2.5 inches. The stresses in the sheet pile would be within allowable and the sheet pile embedment provides an adequate factor of safety. To reduce deflection the sheetpile could be anchored using a shallow concrete deadmen or rip-rap placed south of the sheet pile wall. .

Design Section 2

Analysis shows that raising the grade surface elevation from El. +7.5 to El. +13.0 would have a significant adverse impact on the sheet pile wall. To accommodate the proposed grade, the sheet pile wall can anchored at the top of the sheet pile wall using a deadmen system or rip-rap placed south of the wall. Steel sheet repair is needed to prevent soil through holes.

Exhibits

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SHEET ____ OF ____
FILE 12582B
MADE BY 2M DATE 1/6/2016
CHECKED BY ____ DATE ____

PROJECT Wills Wharf OFFICE / HOTEL

SUBJECT WILLS STREET WHARF BULKHEAD - EXISTING

DS-1a

N.T.S

REF: BORING MR-718

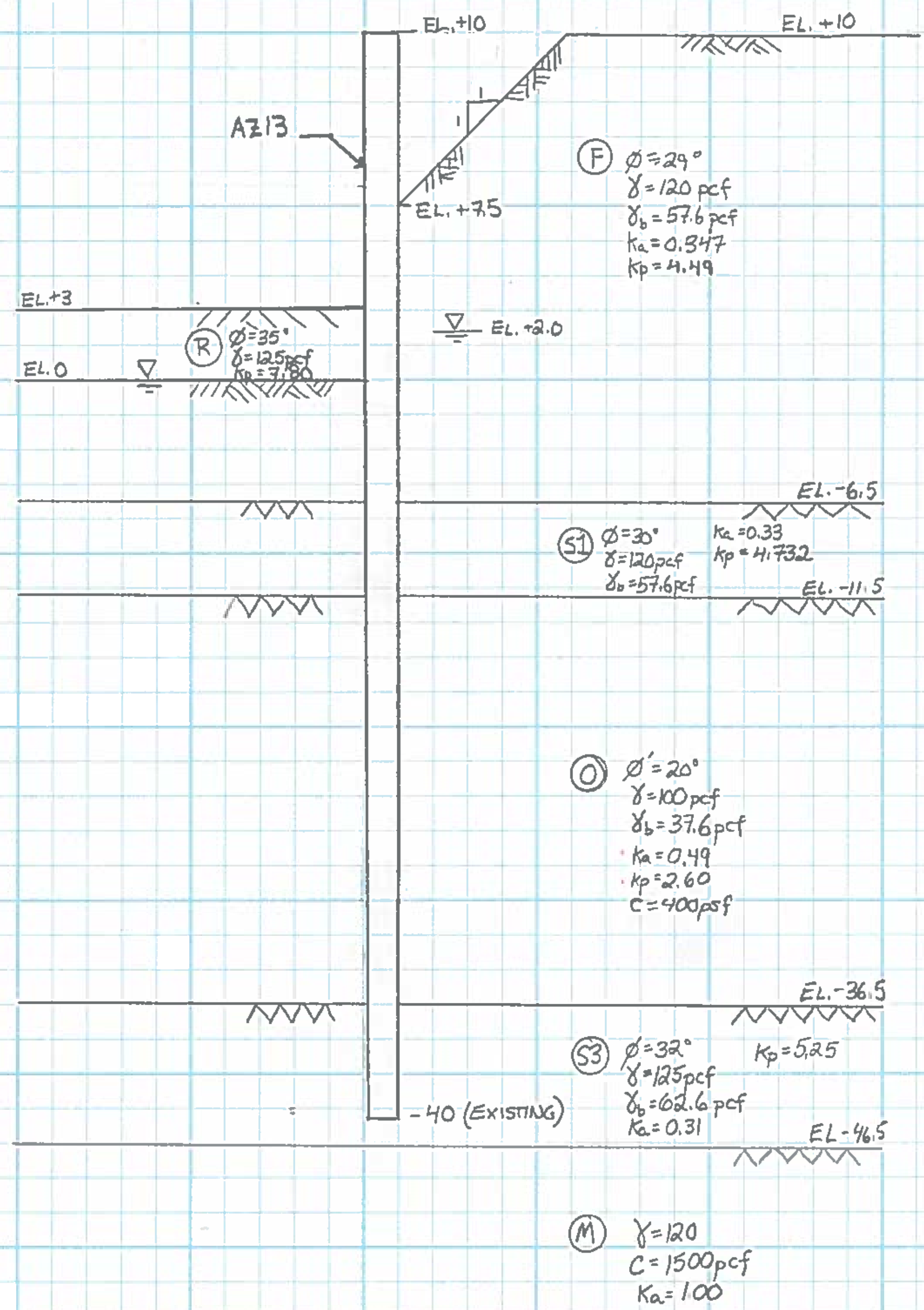
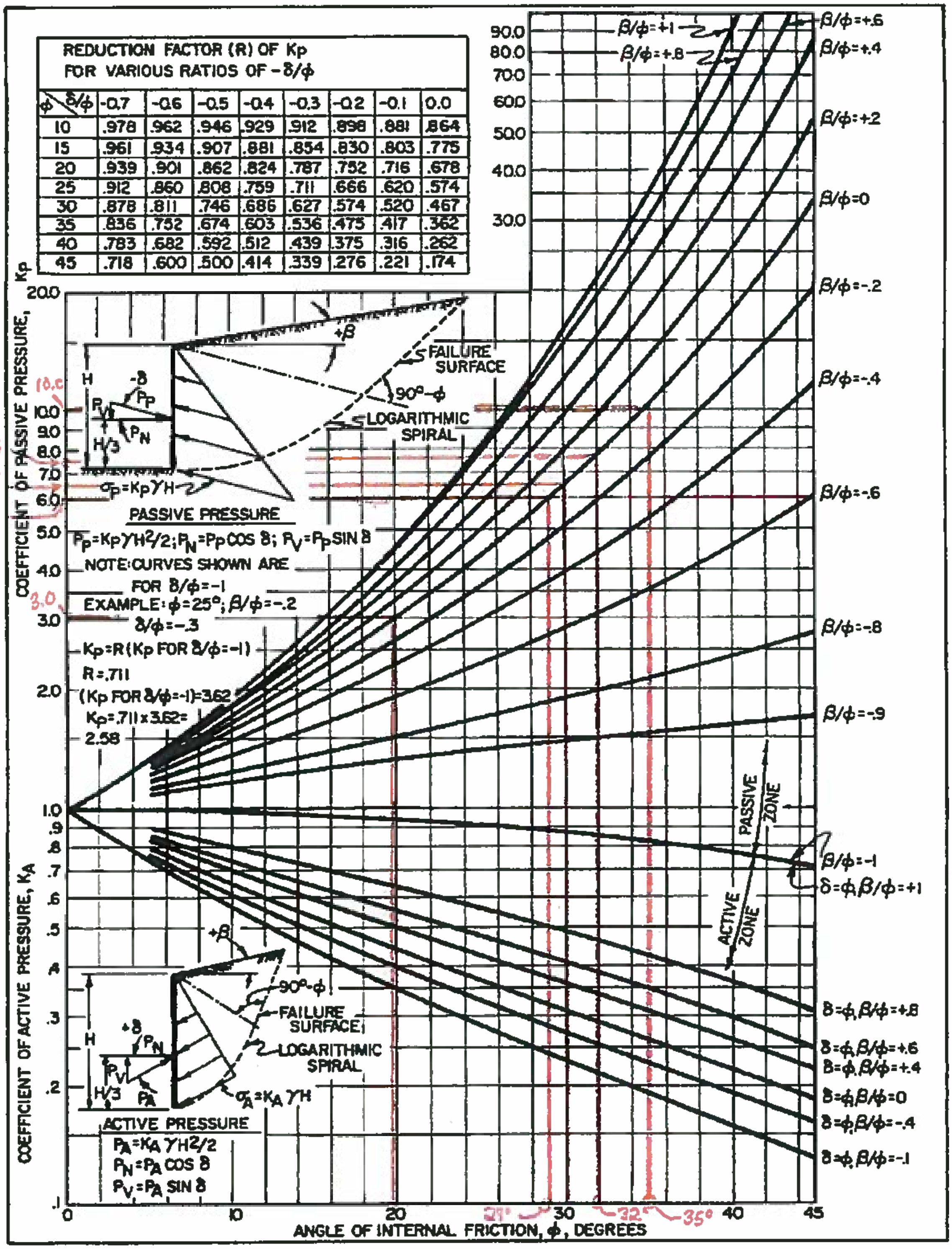


TABLE 1

Ultimate Friction Factors and Adhesion for Dissimilar Materials

Interface Materials	Friction factor, tan [delta]	Friction angle [delta] degrees
Mass concrete on the following foundation materials:		
Clean sound rock	0.70	35
Clean gravel, gravel-sand mixtures, coarse sand	0.55 to 0.60	29 to 31
Clean fine to medium sand, silty medium to coarse sand, silty or clayey gravel	0.45 to 0.55	24 to 29
Clean fine sand, silty or clayey fine to medium sand	0.35 to 0.45	19 to 24
Fine sandy silt, nonplastic silt	0.30 to 0.35	17 to 19
Very stiff and hard residual or preconsolidated clay	0.40 to 0.50	22 to 26
Medium stiff and stiff clay and silty clay	0.30 to 0.35	17 to 19
(Masonry on foundation materials has same friction factors.)		
Steel sheet piles against the following soils:		
Clean gravel, gravel-sand mixtures, well-graded rock fill with spalls	0.40	22
Clean sand, silty sand-gravel mixture, single size hard rock fill	0.30	17
Silty sand, gravel or sand mixed with silt or clay	0.25	14
Fine sandy silt, nonplastic silt	0.20	11
Formed concrete or concrete sheet piling against the following soils:		
Clean gravel, gravel-sand mixture, well-graded rock fill with spalls	0.40 to 0.50	22 to 26
Clean sand, silty sand-gravel mixture, single size hard rock fill	0.30 to 0.40	17 to 22
Silty sand, gravel or sand mixed with silt or clay	0.30	17
Fine sandy silt, nonplastic silt	0.25	14
Various structural materials:		
Masonry on masonry, igneous and metamorphic rocks:		
Dressed soft rock on dressed soft rock	0.70	35
Dressed hard rock on dressed soft rock	0.65	33
Dressed hard rock on dressed hard rock	0.55	29
Masonry on wood (cross grain)	0.50	26
Steel on steel at sheet pile interlocks	0.30	17

Interface Materials (Cohesion)	Adhesion c+a, (psf)
Very soft cohesive soil (0 - 250 psf)	0 - 250
Soft cohesive soil (250 - 500 psf)	250 - 500
Medium stiff cohesive soil (500 - 1000 psf)	500 - 750
Stiff cohesive soil (1000 - 2000 psf)	750 - 950
Very stiff cohesive soil (2000 - 4000 psf)	950 - 1,300



REDUCTION FACTOR (R) OF Kp FOR VARIOUS RATIOS OF $-\delta/\phi$

ϕ \ δ/ϕ	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0.0
10	.978	.962	.946	.929	.912	.898	.881	.864
15	.961	.934	.907	.881	.854	.830	.803	.775
20	.939	.901	.862	.824	.787	.752	.716	.678
25	.912	.860	.808	.759	.711	.666	.620	.574
30	.878	.811	.746	.686	.627	.574	.520	.467
35	.836	.752	.674	.603	.536	.475	.417	.362
40	.783	.682	.592	.512	.439	.375	.316	.262
45	.718	.600	.500	.414	.339	.276	.221	.174

FIGURE 6

Active and Passive Coefficients with Wall Friction (Sloping Backfill)

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File: 12582B
Made By: ZM
Date: 1/6/2016
FOR: Will Street Wharf Bulkhead
Checked By:
Date:

SUBJECT: **SSP - Flexural Rigidity**

Section: AZ-13

Moment of Inertia of Section: $I_{pile} := 144.3\frac{in^4}{ft}$

Section Modulus of Section: $S_{pile} := 24.2\frac{in^3}{ft}$

Young's Modulus: $E := 29000ksi$

Thickness of Flange: $t_f := 0.375in$

Thickness of Web: $t_w := 0.375in$

Total Corrosion Thickness Loss: $t_{loss} := \frac{1}{8}in$

Corroded Section Modulus: $S_{red} := S_{pile}\cdot\left(\frac{\min(t_f, t_w) - t_{loss}}{\min(t_f, t_w)}\right) = 16.13\cdot\frac{in^3}{ft}$

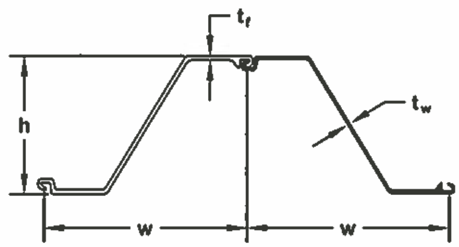
Corroded Moment of Inertia: $I_{red} := I_{pile}\cdot\left(\frac{\min(t_f, t_w) - t_{loss}}{\min(t_f, t_w)}\right) = 96.2\cdot\frac{in^4}{ft}$

Corroded Flexural Rigidity: $R_e := E\cdot I_{red}$ $R_e = 19373.61\frac{1}{ft}\cdot kip\cdot ft^2$

Initial Flexural Rigidity: $R_{ei} := E\cdot I_{pile}$ $R_{ei} = 29060.42\frac{1}{ft}\cdot kip\cdot ft^2$

AZ

AZ Hot Rolled Steel Sheet Piling



SECTION	Width (w) in	Height (h) in	THICKNESS Flange (t_f) in	Web (t_w) in	Cross Sectional Area in²/ft	WEIGHT Pile lb/ft	Wall lb/ft²	SECTION MODULUS Elastic in³/ft	Plastic in³/ft	Moment of Inertia in⁴/ft	COATING AREA Both Sides ft²/ft of single	Wall Surface ft²/ft²
AZ 12	26.38	11.89	0.335	0.335	5.94	44.42	20.22	22.3	26.2	132.8	5.45	1.23
AZ 13	26.38	11.93	0.375	0.375	6.47	48.38	22.02	24.2	28.4	144.3	5.45	1.23
AZ 14	26.38	11.97	0.413	0.413	7.03	52.62	23.94	26.0	30.7	156.0	5.45	1.23
AZ 12-770	30.31	13.52	0.335	0.335	5.67	48.78	19.31	23.2	27.5	156.9	6.10	1.20
AZ 13-770	30.31	13.54	0.354	0.354	5.94	51.14	20.24	24.2	28.8	163.7	6.10	1.20
AZ 14-770	30.31	13.56	0.375	0.375	6.21	53.42	21.14	25.2	30.0	170.6	6.10	1.20
AZ 17	24.80	14.92	0.335	0.335	6.53	45.96	22.24	31.0	36.2	231.3	5.64	1.35
AZ 18	24.80	14.96	0.375	0.375	7.11	49.99	24.19	33.5	39.1	250.4	5.64	1.35
AZ 19	24.80	15.00	0.413	0.413	7.74	54.43	26.34	36.1	42.3	270.8	5.64	1.35
AZ 17-700	27.56	16.52	0.335	0.335	6.28	49.12	21.38	32.2	37.7	265.3	6.10	1.33
AZ 18-700	27.56	16.54	0.354	0.354	6.58	51.41	22.39	33.5	39.4	276.8	6.10	1.33
AZ 19-700	27.56	16.56	0.375	0.375	6.88	53.76	23.41	34.8	41.0	288.4	6.10	1.33
AZ 25	24.80	16.77	0.472	0.441	8.74	61.49	29.74	45.7	53.4	382.6	5.91	1.41
AZ 26	24.80	16.81	0.512	0.480	9.35	65.72	31.79	48.4	56.9	406.5	5.91	1.41
AZ 28	24.80	16.85	0.551	0.520	9.97	70.15	33.94	51.2	60.5	431.6	5.91	1.41
AZ 24-700	27.56	18.07	0.441	0.441	8.23	64.30	28.00	45.2	53.5	408.8	6.33	1.38
AZ 26-700	27.56	18.11	0.480	0.480	8.84	69.12	30.10	48.4	57.1	437.3	6.33	1.38
AZ 28-700	27.56	18.15	0.520	0.520	9.46	73.93	32.19	51.3	60.9	465.9	6.33	1.38
AZ 37-700	27.56	19.65	0.669	0.480	10.68	83.46	36.33	68.9	79.2	676.6	6.76	1.46
AZ 39-700	27.56	19.69	0.709	0.520	11.34	88.63	38.59	72.5	83.7	714.0	6.76	1.46
AZ 41-700	27.56	19.72	0.748	0.559	12.00	93.74	40.84	76.2	88.3	751.4	6.76	1.46
AZ 46	22.83	18.94	0.709	0.551	13.76	89.10	46.82	85.5	98.5	808.8	6.23	1.63
AZ 48	22.83	18.98	0.748	0.591	14.48	93.81	49.28	89.3	103.3	847.1	6.23	1.63
AZ 50	22.83	19.02	0.787	0.630	15.22	98.58	51.80	93.3	108.2	886.5	6.23	1.63

MUESER RUTLEDGE CONSULTING ENGINEERS

Sheet No. ______ Of ______

FOR : **Wills Wharf Office / Hotel**

FILE 12582B
MADE BY ZM DATE 01/06/16
CHECKED BY ______ DATE ______

SUBJECT: **STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-1a)**

Lateral Earth Pressures:

DRIVING FORCES

Layer	Elev. (ft.)	H (ft.)	γ (pcf)	σ_v (psf)	φ (°)	k_a	c (psf)	R_a	Active Pressures (psf)	Surcharge* (psf)	Sidewalk Surcharge	Net Water Pressures (psf)
	10	0	0	0	0	1.000	0	1.0	0	0	0	0
	10	0	0	0	0	1.000	0	1.0	0	0	0	0
	7.5	2.5	120	300	29	0.347	0	1.0	104	0	0	0
	3	4.5	120	840	29	0.347	0	1.0	291	0	0	0
	3	0	120	840	29	0.347	0	1.0	291	0	0	0
	2	1	120	960	29	0.347	0	1.0	333	0	0	0
	2	0	57.6	960	29	0.347	0	1.0	333	0	0	0
F	0	2	57.6	1075	29	0.347	0	1.0	373	0	0	125
	0	0	57.6	1075	29	0.347	0	1.0	373	0	0	125
	-2.5	2.5	57.6	1219	29	0.347	0	1.0	423	0	0	125
	-2.5	0	57.6	1219	29	0.347	0	1.0	423	0	0	125
	-5	2.5	57.6	1363	29	0.347	0	1.0	473	0	0	125
	-5	0	57.6	1363	29	0.347	0	1.0	473	0	0	125
	-6.5	1.5	57.6	1450	29	0.347	0	1.0	503	0	0	125
	-6.5	0	57.6	1450	30	0.333	0	1.0	483	0	0	125
S1	-10	3.5	57.6	1651	30	0.333	0	1.0	550	0	0	125
	-10	0	57.6	1651	30	0.333	0	1.0	550	0	0	125
	-11.5	1.5	57.6	1738	30	0.333	0	1.0	579	0	0	125
	-11.5	0	37.6	1738	0	1.000	400	1.0	938	0	0	125
O	-12.5	1	37.6	1775	0	1.000	400	1.0	975	0	0	125
	-12.5	0	37.6	1775	0	1.000	400	1.0	975	0	0	125
	-36.5	24	37.6	2678	0	1.000	400	1.0	1878	0	0	125
	-36.5	0	62.6	2678	32	0.307	0	1.0	823	0	0	125
S3	-40	3.5	62.6	2897	32	0.307	0	1.0	890	0	0	125
	-46.5	6.5	62.6	3304	32	0.307	0	1.0	1015	0	0	125
	-46.5	0	57.6	3304	0	1.000	1500	1.0	304	0	0	125
M	-50	3.5	57.6	3505	0	1.000	1500	1.0	505	0	0	125
	-50	0	57.6	3505	0	1.000	1500	1.0	505	0	0	125

RESISTING FORCES

Layer	Elev. (ft.)	H (ft.)	γ (pcf)	σ_v (psf)	k_p	R_p	c (psf)	φ (°)	Passive Pressures (psf)	Total Pressures (psf)	Elev. (ft.)
										0	10
										0	10
										104	7.5
										291	3
	3	0	125	0	7.80	1.000	0	35	0	291	3
R	2	1	125	125	7.80	1.000	0	35	-975	-642	2
	2	0	125	125	7.80	1.000	0	35	-975	-642	2
	0	2	125	375	7.80	1.000	0	35	-2925	-2427	0
	0	0	57.6	375	4.49	1.000	0	29	-1684	-1186	0
	-2.5	2.5	57.6	519	4.49	1.000	0	29	-2330	-1782	-2.5
F	-2.5	0	57.6	519	4.49	1.000	0	29	-2330	-1782	-2.5
	-5	2.5	57.6	663	4.49	1.000	0	29	-2977	-2379	-5
	-5	0	57.6	663	4.49	1.000	0	29	-2977	-2379	-5
	-6.5	1.5	57.6	749	4.49	1.000	0	29	-3365	-2737	-6.5
	-6.5	0	57.6	749	4.72	1.000	0	30	-3536	-2928	-6.5
S1	-10	3.5	57.6	951	4.72	1.000	0	30	-4488	-3813	-10
	-10	0	57.6	951	4.72	1.000	0	30	-4488	-3813	-10
	-11.5	1.5	57.6	1037	4.72	1.000	0	30	-4895	-4191	-11.5
	-11.5	0	37.6	1037	2.64	1.000	400	0	-4039	-2976	-11.5
O	-12.5	1	37.6	1075	2.64	1.000	400	0	-4138	-3038	-12.5
	-12.5	0	37.6	1075	2.64	1.000	400	0	-4138	-3038	-12.5
	-36.5	24	37.6	1977	2.64	1.000	400	0	-6520	-4518	-36.5
	-36.5	0	62.6	1977	5.25	1.000	0	32	-10381	-9434	-36.5
S3	-40	3.5	62.6	2197	5.25	1.000	0	32	-11532	-10517	-40
	-46.5	6.5	62.6	2603	5.25	1.000	0	32	-13668	-12528	-46.5
	-46.5	0	57.6	2603	1.00	1.000	1.5	0	-2606	-2178	-46.5
M	-50	3.5	57.6	2805	1.00	1.000	1.5	0	-2808	-2178	-50
	-50	0	57.6	2805	1.00	1.000	1.5	0	-2808	-2178	-50

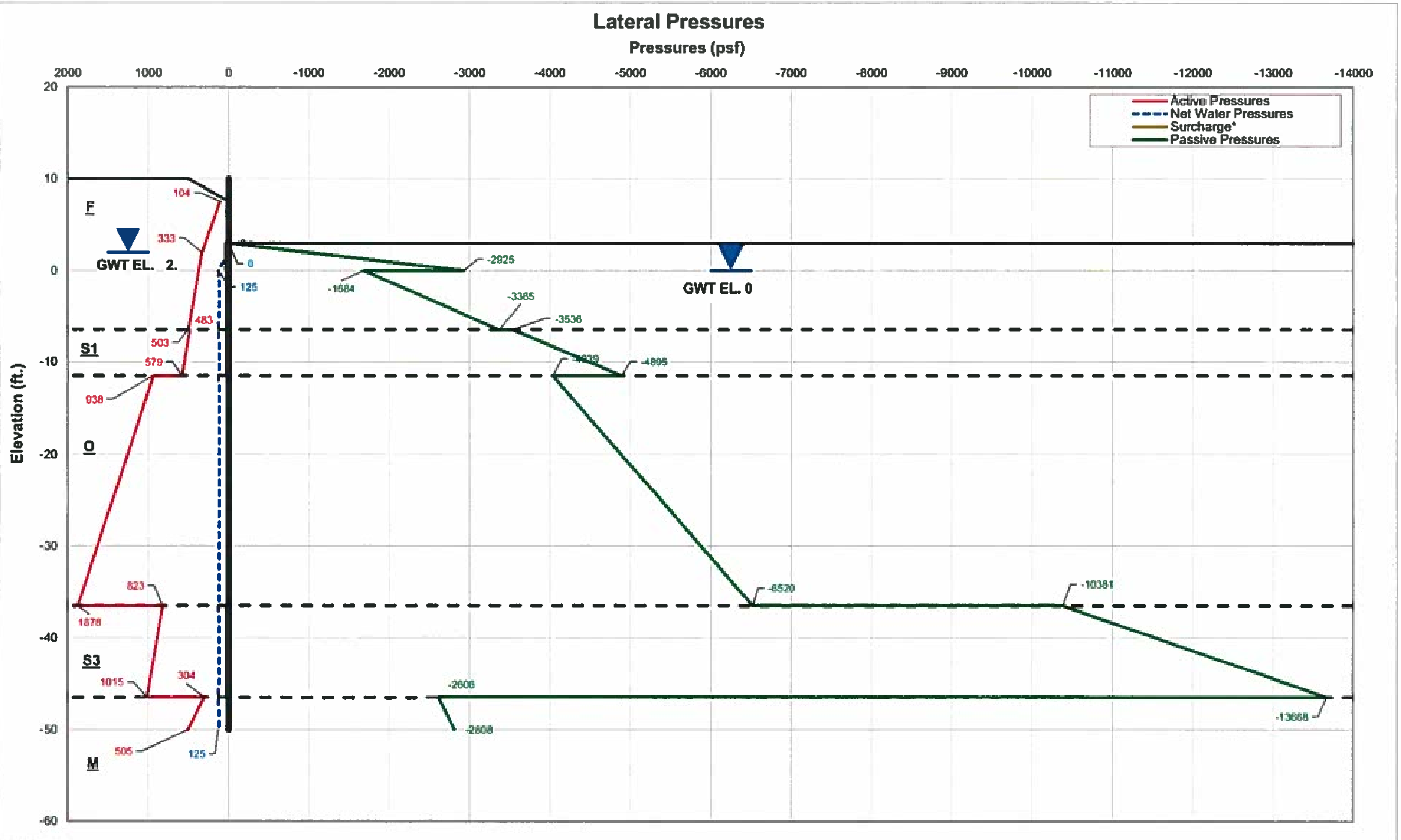
At rest Pressures: $\sigma_a = \gamma \cdot H \cdot k_a - 2C \cdot \sqrt{k_a}$ $k_a = \tan^2\left(45 - \frac{\phi}{2}\right)$

Passive Pressures: $\sigma_p = \gamma \cdot H \cdot k_p + 2C \cdot \sqrt{k_p}$

Reduction Factors applied below subgrade:
Ra = bf/s = 1.000
Rp = 3*Ra = 1.000
Undrained Clay Strength Ratio:
c/p Ra 0.2

Wall Type: Continous

SUBJECT: **STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-1a)**



MUESER RUTLEDGE CONSULTING ENGINEERS

Sheet No. ________ Of ________

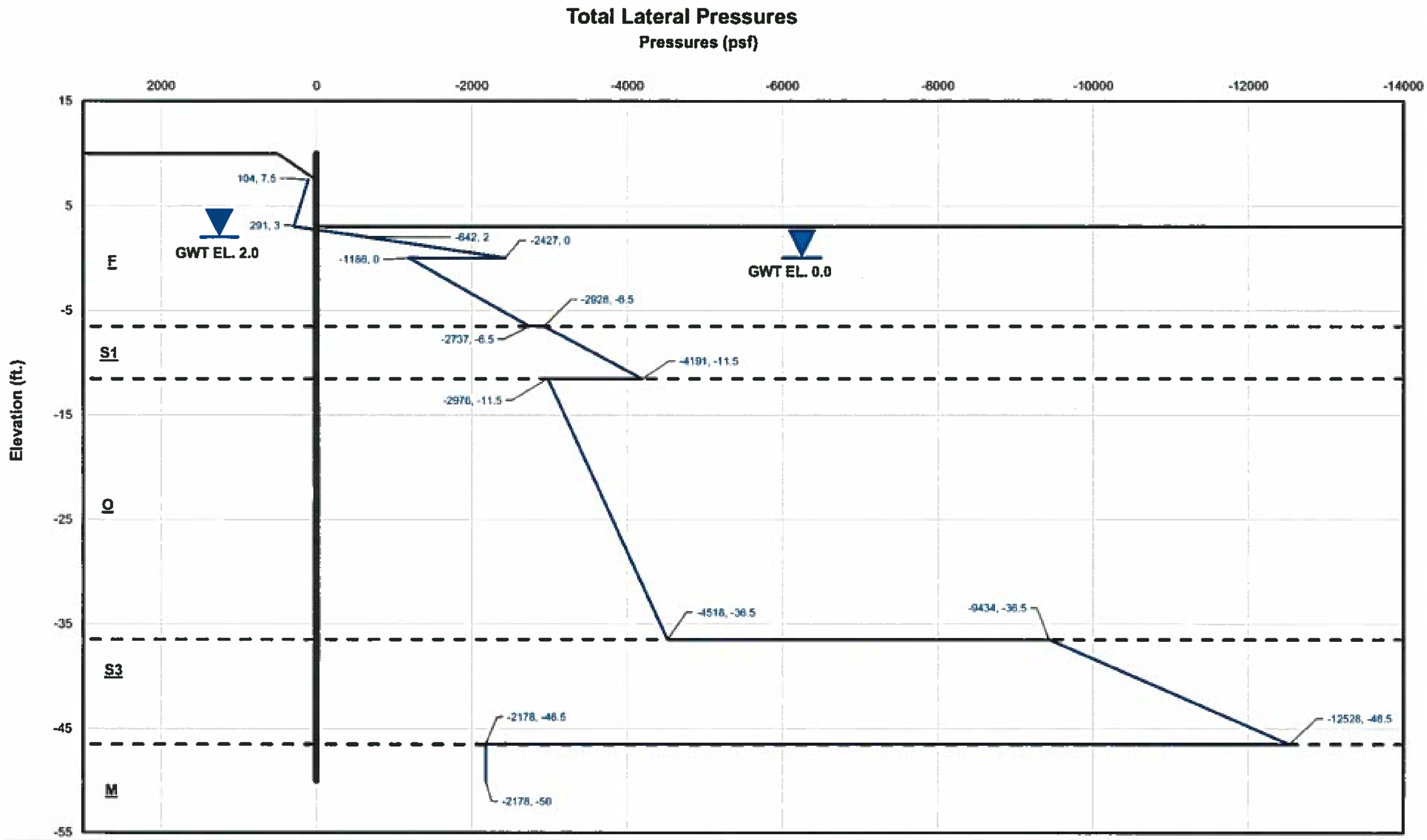
FOR : **Wills Wharf Office / Hotel**

FILE 12582B

MADE BY ZM DATE 01/06/16

CHECKED BY ________ DATE ________

SUBJECT: **STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-1a)**



F:\125\12582\12582B\Task 130 - Retaining Wall Design\SSP Bulkhead Analysis\Staging Analysis AREA 2 - Cantilevered

MUESER RUTLEDGE CONSULTING ENGINEERS

Cantilever v3.0 BETA for Windows, 32-bit

Subject: DS-1a

INPUT

P	Q	Interval Lengths
0.000	0.000	2.500
0.104	0.291	4.500
0.291	-0.642	1.000
-0.642	-2.427	2.000

Passive pressure at subgrade : 1.186
Passive pressure slope : .239
Flexural rigidity : 19374

OUTPUT

At end of int. 1, Shear= 0.00, Moment= 0.00
At end of int. 2, Shear= 0.89, Moment= 1.68
At end of int. 3, Shear= 0.71, Moment= 2.56
At end of int. 4, Shear= -2.36, Moment= 1.52

D= 0.56 embedment below subgrade with F.S.= 1 $D(FOS=1.2) = 1.44(3\ ft + 0.56 ft) = 5.13\ ft$ [EL. -2.13]

Total Length of sheetpile is 10.56

Depth of max. moment= 8.74

Max. moment= 2.85 $M_{ALL} = 0.6(50ksi)(16.13\ in^3/ft)(1'/12'') = 40.33\ k\text{-}ft$

Depth of max. shear= 10.56 $M_{MAX} < M_{ALL}$ ∴ OK
Max. shear= 3.05

X	V	M	Defl.
0.00	0.00	0.00	0.00
0.53	0.00	0.00	0.00
1.06	0.00	0.00	0.00
1.58	0.00	0.00	0.00
2.11	0.00	0.00	0.00
2.64	0.01	0.00	0.00
3.17	0.08	0.03	0.00
3.69	0.15	0.09	0.00
4.22	0.24	0.19	0.00
4.75	0.34	0.34	0.00
5.28	0.45	0.55	0.00
5.81	0.57	0.82	0.00
6.33	0.70	1.15	0.00
6.86	0.85	1.56	0.00
7.39	0.93	2.04	0.00
7.92	0.76	2.50	0.00
8.44	0.34	2.80	0.00
8.97	-0.33	2.82	0.00
9.50	-1.25	2.41	0.00
10.03	-2.39	1.45	0.00
10.56	-3.05	0.02	0.00

$\delta_{max} = 0$ ∴ Ok, By inspection

```
   Moment  (M/Mmax)

   -1.0           -0.5            0.0           0.5             1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0                              :
  0.5                              :
  1.1                              :
  1.6                              :
  2.1                              :
  2.6                              |:
  3.2                              |:
  3.7                              |:
  4.2                              | :
  4.8                              |   :
  5.3                              |     :
  5.8                              |        :
  6.3                              |           :
  6.9                              |                :
  7.4                              |                     :
  7.9                              |                          :
  8.4                              |                             :
  9.0                              |                             :
  9.5                              |                         :
 10.0                              |              :
 10.6                              |:

   Shear  (V/Vmax)

   -1.0           -0.5            0.0           0.5             1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0                              :
  0.5                              :
  1.1                              :
  1.6                              :
  2.1                              :
  2.6                              |:
  3.2                              |:
  3.7                              | :
  4.2                              | :
  4.8                              |  :
  5.3                              |   :
  5.8                              |     :
  6.3                              |      :
  6.9                              |       :
  7.4                              |        :
  7.9                              |      :
  8.4                              |  :
  9.0                          :   |
  9.5                 :            |
 10.0      :                       |
 10.6:                             |
```

SHEET ____ OF ____

FILE 12582B

MUESER RUTLEDGE CONSULTING ENGINEERS

MADE BY ZM DATE 1/6/2016

PROJECT WILLS WHARF OFFICE/HOTEL

CHECKED BY ____ DATE ____

SUBJECT WILLS STREET WHARF BULKHEAD - PROPOSED

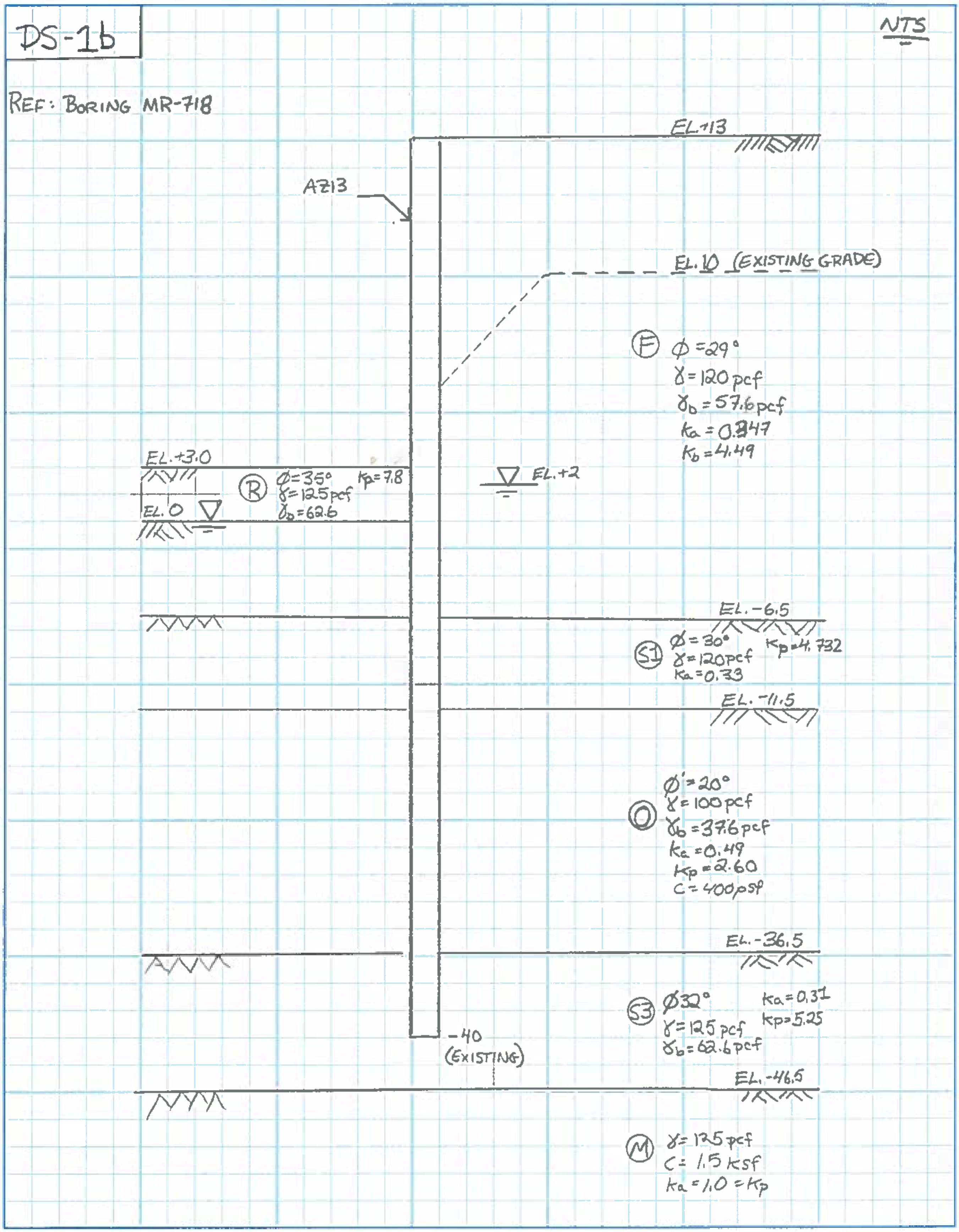


TABLE 1

Ultimate Friction Factors and Adhesion for Dissimilar Materials

Interface Materials	Friction factor, tan [delta]	Friction angle [delta] degrees
Mass concrete on the following foundation materials:		
Clean sound rock......................................	0.70	35
Clean gravel, gravel-sand mixtures, coarse sand...	0.55 to 0.60	29 to 31
Clean fine to medium sand, silty medium to coarse sand, silty or clayey gravel..................	0.45 to 0.55	24 to 29
Clean fine sand, silty or clayey fine to medium sand..	0.35 to 0.45	19 to 24
Fine sandy silt, nonplastic silt.................	0.30 to 0.35	17 to 19
Very stiff and hard residual or preconsolidated clay...	0.40 to 0.50	22 to 26
Medium stiff and stiff clay and silty clay........	0.30 to 0.35	17 to 19
(Masonry on foundation materials has same friction factors.)		
Steel sheet piles against the following soils:		
Clean gravel, gravel-sand mixtures, well-graded rock fill with spalls..........................	0.40	22
Clean sand, silty sand-gravel mixture, single size hard rock fill................................	0.30	17
Silty sand, gravel or sand mixed with silt or clay	0.25	14
Fine sandy silt, nonplastic silt.................	0.20	11
Formed concrete or concrete sheet piling against the following soils:		
Clean gravel, gravel-sand mixture, well-graded rock fill with spalls..........................	0.40 to 0.50	22 to 26
Clean sand, silty sand-gravel mixture, single size hard rock fill................................	0.30 to 0.40	17 to 22
Silty sand, gravel or sand mixed with silt or clay	0.30	17
Fine sandy silt, nonplastic silt.................	0.25	14
Various structural materials:		
Masonry on masonry, igneous and metamorphic rocks:		
Dressed soft rock on dressed soft rock..........	0.70	35
Dressed hard rock on dressed soft rock..........	0.65	33
Dressed hard rock on dressed hard rock..........	0.55	29
Masonry on wood (cross grain)....................	0.50	26
Steel on steel at sheet pile interlocks...........	0.30	17

Interface Materials (Cohesion)	Adhesion c+a, (psf)
Very soft cohesive soil (0 - 250 psf)	0 - 250
Soft cohesive soil (250 - 500 psf)	250 - 500
Medium stiff cohesive soil (500 - 1000 psf)	500 - 750
Stiff cohesive soil (1000 - 2000 psf)	750 - 950
Very stiff cohesive soil (2000 - 4000 psf)	950 - 1,300

REDUCTION FACTOR (R) OF Kp FOR VARIOUS RATIOS OF $-\delta/\phi$

ϕ \ δ/ϕ	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0.0
10	.978	.962	.946	.929	.912	.898	.881	.864
15	.961	.934	.907	.881	.854	.830	.803	.775
20	.939	.901	.862	.824	.787	.752	.716	.678
25	.912	.860	.808	.759	.711	.666	.620	.574
30	.878	.811	.746	.686	.627	.574	.520	.467
35	.836	.752	.674	.603	.536	.475	.417	.362
40	.783	.682	.592	.512	.439	.375	.316	.262
45	.718	.600	.500	.414	.339	.276	.221	.174

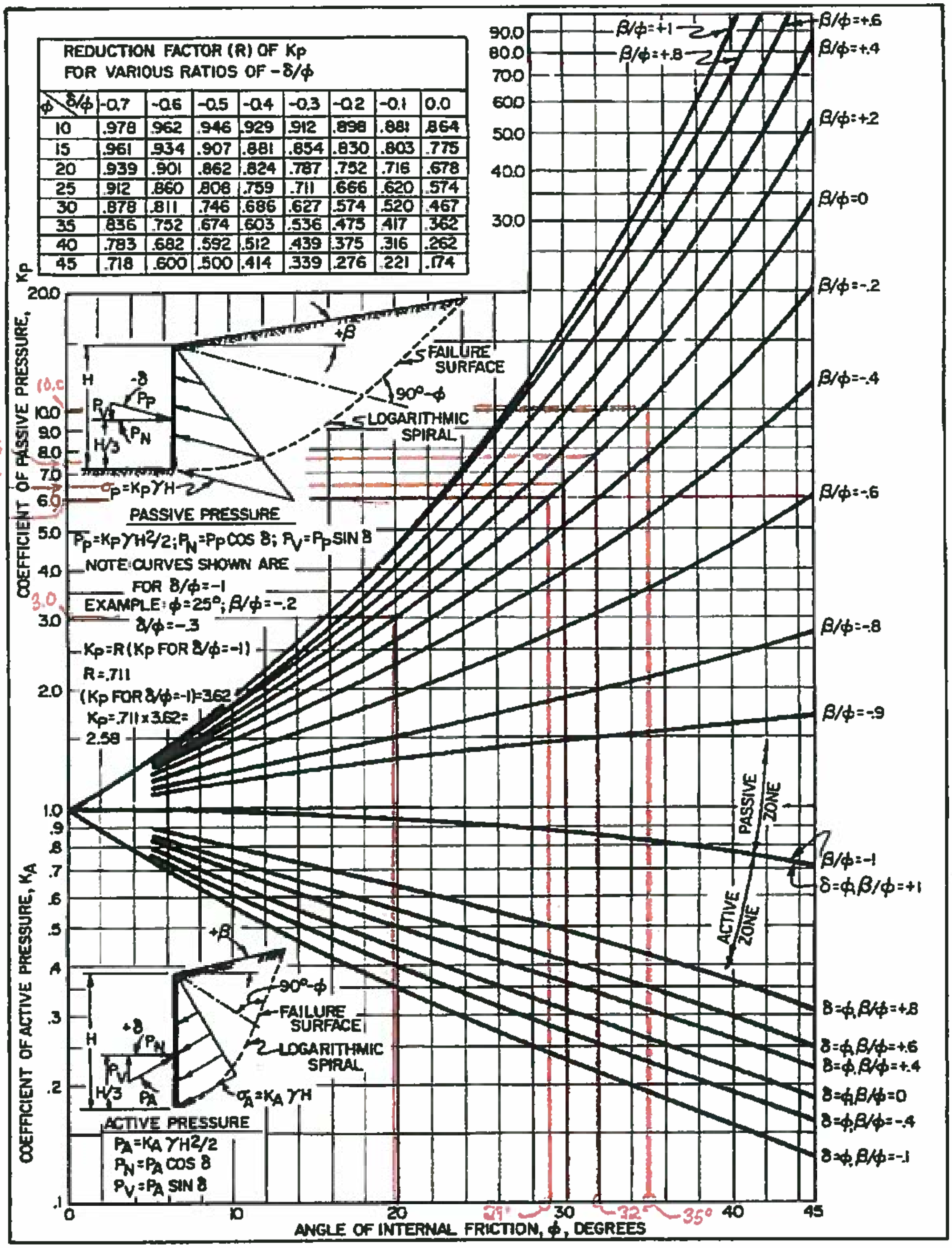


FIGURE 6
Active and Passive Coefficients with Wall Friction
(Sloping Backfill)

SUBJECT: **PASSIVE PRESSURE COEFFICIENTS WITH WALL FRICTION**

Fill (F): $\phi := 29\cdot deg$ $\delta := 14deg$ $\frac{\delta}{\phi} = 0.48$ Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of subgrade $\beta := 0\cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 6.0$

From reduction factor (R) table, $\phi_1 := 25\cdot deg$ $\phi_2 := 30\cdot deg$

For $\frac{\delta}{\phi} = 0.48$ Reduction factor $r_{25} := 0.759 + \frac{\left(\frac{\delta}{\phi} - 0.4\right)\cdot(0.808 - 0.759)}{(0.5 - 0.4)}$ $r_{25} = 0.8$

For $\frac{\delta}{\phi} = 0.48$ Reduction factor $r_{30} := 0.686 + \frac{\left(\frac{\delta}{\phi} - 0.4\right)\cdot(0.746 - 0.686)}{(0.5 - 0.4)}$ $r_{30} = 0.736$

Thus, Reduction factor $r_{29} := r_{25} - \left[\frac{(\phi - \phi_1)\cdot(r_{25} - r_{30})}{(\phi_2 - \phi_1)}\right]$ $r_{29} = 0.748$

Therefore, effective Kp with wall friction is: $K_p := (r_{29})\cdot(K_p)$ $\boxed{K_p = 4.49}$

Medium Sands (S1): $\phi := 30\cdot deg$ $\delta := 14deg$ $\frac{\delta}{\phi} = 0.47$ Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of grade $\beta := 0\cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 6.5$

For $\frac{\delta}{\phi} = 0.47$ Reduction factor $r_{30} := 0.686 + \frac{\left(\frac{\delta}{\phi} - 0.4\right)\cdot(0.746 - 0.686)}{(0.5 - 0.4)}$ $r_{30} = 0.73$

Therefore effective Kp with wall friction is: $K_p := (r_{30})\cdot(K_p)$ $\boxed{K_p = 4.719}$

MUESER RUTLEDGE CONSULTING ENGINEERS

File 12582A

Made By ZM Date 01/06/16

FOR Harbor Point Development

Checked By ________ Date ________

SUBJECT: **PASSIVE PRESSURE COEFFICIENTS WITH WALL FRICTION**

Silty Sands (S3):

$\phi := 32 \cdot deg \quad \delta := 14deg \quad \frac{\delta}{\phi} = 0.44$

Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of subgrade $\beta := 0 \cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 7.75$

From reduction factor (R) table, $\phi_1 := 30 \cdot deg \quad \phi_2 := 35 \cdot deg$

For $\frac{\delta}{\phi} = 0.44$ Reduction factor $r_{30} := 0.686 + \frac{\left(\frac{\delta}{\phi} - 0.4\right) \cdot (.746 - .686)}{(0.5 - 0.4)}$ $r_{30} = 0.709$

For $\frac{\delta}{\phi} = 0.44$ Reduction factor $r_{35} := 0.603 + \frac{\left(\frac{\delta}{\phi} - 0.4\right) \cdot (.674 - .603)}{(0.5 - 0.4)}$ $r_{35} = 0.630$

Thus, Reduction factor $r_{32} := r_{30} - \left[\frac{(\phi - \phi_1) \cdot (r_{30} - r_{35})}{(\phi_2 - \phi_1)}\right]$ $r_{32} = 0.677$

Therefore, effective Kp with wall friction is: $K_p := (r_{32}) \cdot (K_p)$ $\boxed{K_p = 5.25}$

Organic Silt (O):

$\phi := 20 \cdot deg \quad \delta := 11deg \quad \frac{\delta}{\phi} = 0.55$

Friction angle for Sheet piles on fine sandy silt, nonplastic silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of grade $\beta := 0 \cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 3.0$

For $\frac{\delta}{\phi} = 0.55$ Reduction factor $r_{20} := 0.862 + \frac{\left(\frac{\delta}{\phi} - 0.5\right) \cdot (0.901 - 0.862)}{(0.6 - 0.5)}$ $r_{20} = 0.88$

Therefore effective Kp with wall friction is: $K_p := (r_{20}) \cdot (K_p)$ $\boxed{K_p = 2.6}$

MUESER RUTLEDGE CONSULTING ENGINEERS

File 12582A

Made By ZM Date 01/06/16

FOR Harbor Point Development

Checked By ________ Date ________

SUBJECT: **PASSIVE PRESSURE COEFFICIENTS WITH WALL FRICTION**

RIP RAP (R):

$\phi := 35 \cdot deg \quad \delta := 22deg \quad \frac{\delta}{\phi} = 0.63$

Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of grade $\beta := 0 \cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 10.0$

For $\frac{\delta}{\phi} = 0.63$ Reduction factor $r_{35} := 0.752 + \frac{\left(\frac{\delta}{\phi} - 0.6\right) \cdot (0.836 - 0.752)}{(0.7 - 0.6)}$ $r_{35} = 0.78$

Therefore effective Kp with wall friction is: $K_p := (r_{35}) \cdot (K_p)$ $\boxed{K_p = 7.8}$

SUBJECT: **STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-1b)**

Lateral Earth Pressures:

DRIVING FORCES													RESISTING FORCES											
Layer	Elev.	H	γ	σ_v	ϕ	k_a	c	R_a	Active Pressures	Surcharge*	Sidewalk Surcharge	Net Water Pressures	Layer	Elev.	H	γ	σ_v	k_p	R_p	c	ϕ	Passive Pressures	Total Pressures	Elev.
	(ft.)	(ft.)	(pcf)	(psf)	°		(psf)		(psf)	(psf)		(psf)		(ft.)	(ft.)	(pcf)	(psf)			(psf)	°	(psf)	(psf)	(ft.)
	13	0	0	0	29	1.000	0	1.0	0	240	0	0											240	13
	10	3	120	360	29	0.347	0	1.0	125	240	0	0											365	10
	7.5	2.5	120	660	29	0.347	0	1.0	229	240	0	0											469	7.5
	3	4.5	120	1200	29	0.347	0	1.0	416	240	0	0											656	3
	3	0	120	1200	29	0.347	0	1.0	416	100	0	0		3	0	125	0	7.80	1.000	0	35	0	516	3
	2	1	120	1320	29	0.347	0	1.0	458	100	0	0	R	2	1	125	125	7.80	1.000	0	35	-975	-417	2
	2	0	57.6	1320	29	0.347	0	1.0	458	100	0	0		2	0	125	125	7.80	1.000	0	35	-975	-417	2
F	0	2	57.6	1435	29	0.347	0	1.0	498	100	0	125		0	2	125	375	7.80	1.000	0	35	-2925	-2202	0
	0	0	57.6	1435	29	0.347	0	1.0	498	100	0	125		0	0	57.6	375	4.49	1.000	0	29	-1684	-961	0
	-3	3	57.6	1608	29	0.347	0	1.0	558	100	0	125		-3	3	57.6	548	4.49	1.000	0	29	-2460	-1677	-3
	-3	0	57.6	1608	29	0.347	0	1.0	558	0	0	125		-3	0	57.6	548	4.49	1.000	0	29	-2460	-1777	-3
	-5	2	57.6	1723	29	0.347	0	1.0	598	0	0	125	F	-5	2	57.6	663	4.49	1.000	0	29	-2977	-2254	-5
	-5	0	57.6	1723	29	0.347	0	1.0	598	0	0	125		-5	0	57.6	663	4.49	1.000	0	29	-2977	-2254	-5
	-6.5	1.5	57.6	1810	29	0.347	0	1.0	628	0	0	125		-6.5	1.5	57.6	749	4.49	1.000	0	29	-3365	-2812	-6.5
	-6.5	0	57.6	1810	30	0.333	0	1.0	603	0	0	125		-6.5	0	57.6	749	4.72	1.000	0	30	-3536	-2808	-6.5
S1	-10	3.5	57.6	2011	30	0.333	0	1.0	670	0	0	125	S1	-10	3.5	57.6	951	4.72	1.000	0	30	-4488	-3693	-10
	-10	0	57.6	2011	30	0.333	0	1.0	670	0	0	125		-10	0	57.6	951	4.72	1.000	0	30	-4488	-3693	-10
	-11.5	1.5	57.6	2098	30	0.333	0	1.0	699	0	0	125		-11.5	1.5	57.6	1037	4.72	1.000	0	30	-4895	-4071	-11.5
	-11.5	0	37.6	2098	0	1.000	400	1.0	1298	0	0	125		-11.5	0	37.6	1037	2.64	1.000	400	0	-4039	-2616	-11.5
O	-12.5	1	37.6	2135	0	1.000	400	1.0	1335	0	0	125	O	-12.5	1	37.6	1075	2.64	1.000	400	0	-4138	-2678	-12.5
	-12.5	0	37.6	2135	0	1.000	400	1.0	1335	0	0	125		-12.5	0	37.6	1075	2.64	1.000	400	0	-4138	-2678	-12.5
	-36.5	24	37.6	3038	0	1.000	400	1.0	2238	0	0	125		-36.5	24	37.6	1977	2.64	1.000	400	0	-6520	-4158	-36.5
	-36.5	0	62.6	3038	32	0.307	0	1.0	933	0	0	125		-36.5	0	62.6	1977	5.25	1.000	0	32	-10381	-9323	-36.5
S3	-40	3.5	62.6	3257	32	0.307	0	1.0	1001	0	0	125	S3	-40	3.5	62.6	2197	5.25	1.000	0	32	-11532	-10406	-40
	-46.5	6.5	62.6	3664	32	0.307	0	1.0	1126	0	0	125		-46.5	6.5	62.6	2603	5.25	1.000	0	32	-13668	-12417	-46.5
	-46.5	0	57.6	3664	0	1.000	1500	1.0	664	0	0	125		-46.5	0	57.6	2603	1.00	1.000	1.5	0	-2606	-1818	-46.5
M	-50	3.5	57.6	3865	0	1.000	1500	1.0	865	0	0	125	M	-50	3.5	57.6	2805	1.00	1.000	1.5	0	-2808	-1818	-50
	-50	0	57.6	3865	0	1.000	1500	1.0	865	0	0	125		-50	0	57.6	2805	1.00	1.000	1.5	0	-2808	-1818	-50

At rest Pressures: $\sigma_a = \gamma \cdot H \cdot k_a - 2C\sqrt{k_a}$ $k_a = \tan^2\left(45 - \frac{\phi}{2}\right)$

Passive Pressures: $\sigma_p = \gamma \cdot H \cdot k_p + 2C\sqrt{k_p}$

Reduction Factors applied below subgrade:

Ra = bf/s = 1.000

Rp = 3*Ra = 1.000

Undrained Clay Strength Ratio:

c/p Ra 0.2

Wall Type: Continous

MUESER RUTLEDGE CONSULTING ENGINEERS

Sheet No. ________ Of ________

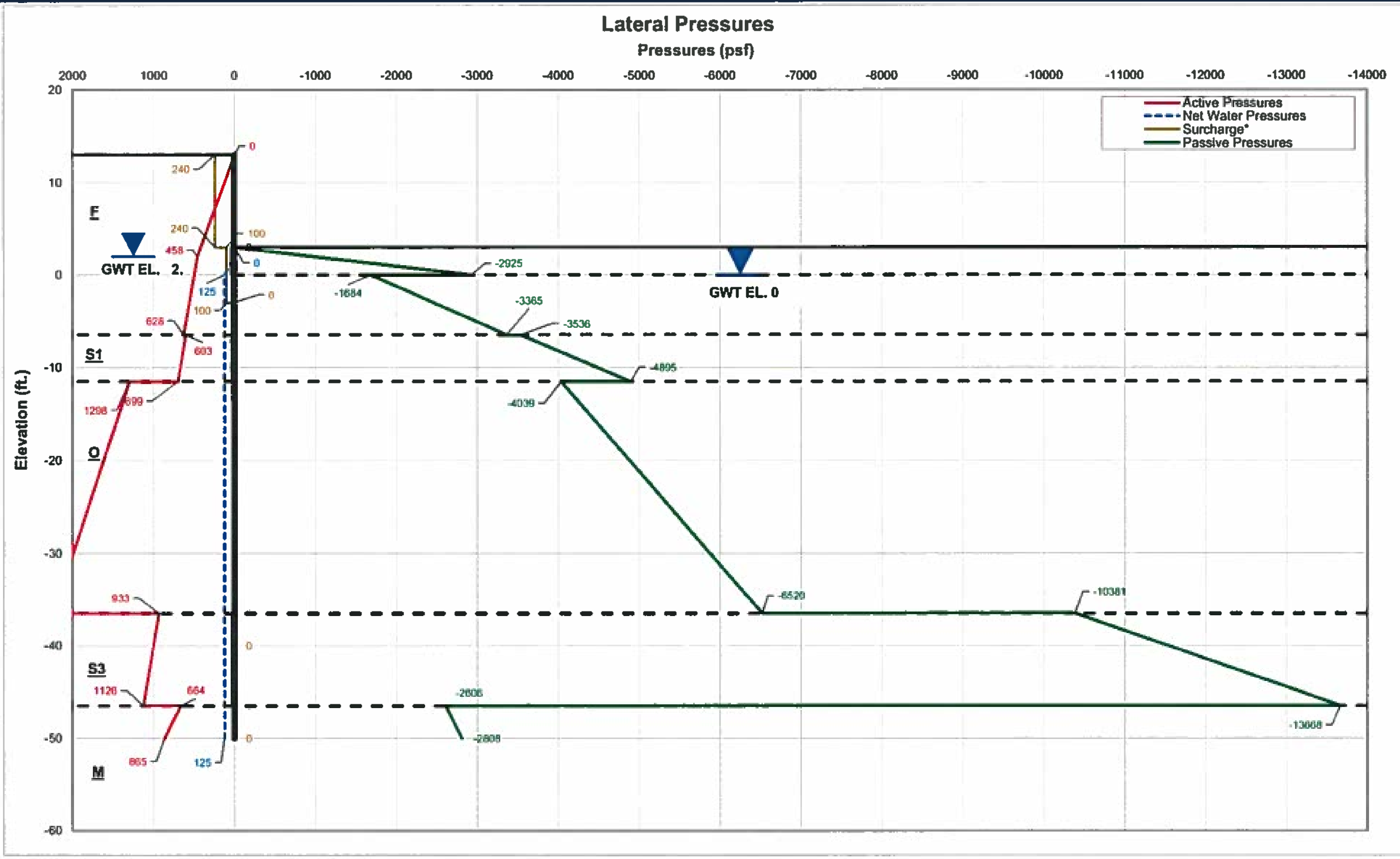
FILE 12582B

FOR : **Wills Wharf Office / Hotel**

MADE BY ZM DATE 01/06/16

CHECKED BY DATE

SUBJECT: **STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-1b)**



F:\125\12582\12582B\Task 130 - Retaining Wall Design\SSP Bulkhead Analysis\Staging Analysis AREA 2 - Cantilevered

MUESER RUTLEDGE CONSULTING ENGINEERS

Sheet No. ________ Of ________

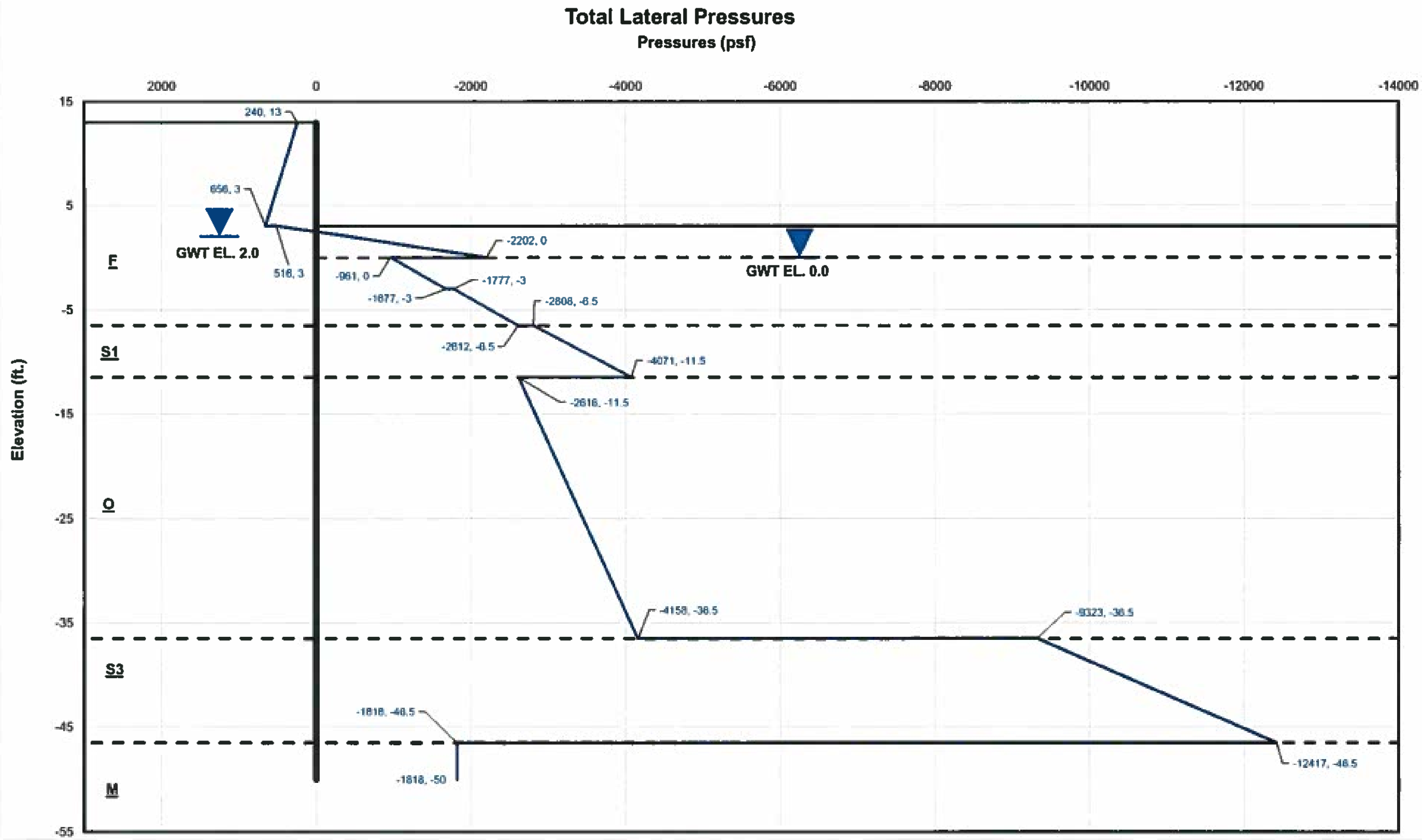
FILE 12582B

FOR : Wills Wharf Office / Hotel

MADE BY ZM DATE 01/06/16

CHECKED BY ______ DATE ______

SUBJECT: STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-1b)



F:\125\12582\12582B\Task 130 - Retaining Wall Design\SSP Bulkhead Analysis\Staging Analysis AREA 2 - Cantilevered

MUESER RUTLEDGE CONSULTING ENGINEERS

Cantilever v3.0 BETA for Windows, 32-bit

Subject: DS-1b

INPUT

P	Q	Interval Lengths
0.240	0.656	10.000
0.516	-0.417	1.000
-0.417	-2.202	2.000
-0.961	-1.677	3.000
-1.777	-2.612	3.500

Passive pressure at subgrade : 2.808
Passive pressure slope : .251
Flexural rigidity : 19374

OUTPUT

At end of int. 1, Shear= 4.48, Moment= 18.93
At end of int. 2, Shear= 4.53, Moment= 23.52
At end of int. 3, Shear= 1.91, Moment= 30.55
At end of int. 4, Shear= -2.05, Moment= 30.88
At end of int. 5, Shear= -9.73, Moment= 11.13

D= 1.00 embedment below subgrade with F.S.= 1

$D(FOS=1.2) = 1.44(3ft + 6.5ft + 1.0ft) = 15.12'$ [EL. -12.12]

Total Length of sheetpile is 20.50

Depth of max. moment= 14.65

Max. moment= 32.22

$M_{all} = 0.60(50ksi)(16.13 in^3/ft)(1'/12") = 40.32$ k-ft

$M_{max} < M_{all}$ ∴ OK

Depth of max. shear= 20.50
Max. shear= 12.66

X	V	M	Defl.
0.00	0.00	0.00	0.22
1.03	0.27	0.13	0.20
2.05	0.58	0.56	0.19
3.08	0.93	1.34	0.17
4.10	1.33	2.50	0.15
5.13	1.78	4.09	0.14
6.15	2.26	6.15	0.12
7.18	2.79	8.74	0.10
8.20	3.37	11.89	0.09
9.23	3.98	15.66	0.07
10.25	4.58	20.07	0.06
11.28	4.38	24.74	0.05
12.30	3.23	28.73	0.04
13.33	1.59	31.12	0.03
14.35	0.40	32.16	0.02
15.38	-1.04	31.85	0.01
16.40	-2.78	29.92	0.01
17.43	-4.82	26.05	0.00
18.45	-7.12	19.95	0.00
19.48	-9.66	11.37	0.00
20.50	-12.66	-0.04	0.00

$\delta_{max} = 0.22' \left(12''/1'\right) = 2.64 \text{ in}$ ∴ OK

```
   Moment   (M/Mmax)

   -1.0           -0.5            0.0           0.5             1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0                              :
  1.0                              |:
  2.1                              |:
  3.1                              |:
  4.1                              | :
  5.1                              |   :
  6.2                              |     :
  7.2                              |       :
  8.2                              |          :
  9.2                              |              :
 10.3                              |                  :
 11.3                              |                      :
 12.3                              |                          :
 13.3                              |                            :
 14.4                              |                             :
 15.4                              |                             :
 16.4                              |                           :
 17.4                              |                       :
 18.5                              |                  :
 19.5                              |          :
 20.5                             :|
```

```
   Shear   (V/Vmax)

   -1.0           -0.5            0.0           0.5             1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0                              :
  1.0                              |:
  2.1                              |:
  3.1                              | :
  4.1                              |  :
  5.1                              |   :
  6.2                              |    :
  7.2                              |      :
  8.2                              |       :
  9.2                              |        :
 10.3                              |          :
 11.3                              |         :
 12.3                              |       :
 13.3                              |   :
 14.4                              |:
 15.4                           :  |
 16.4                       :      |
 17.4                  :           |
 18.5             :                |
 19.5       :                      |
 20.5:                             |
```

MUESER RUTLEDGE CONSULTING ENGINEERS

SHEET ____ OF ____
FILE 12582B
MADE BY ZM DATE 1/6/2016
CHECKED BY ____ DATE ____

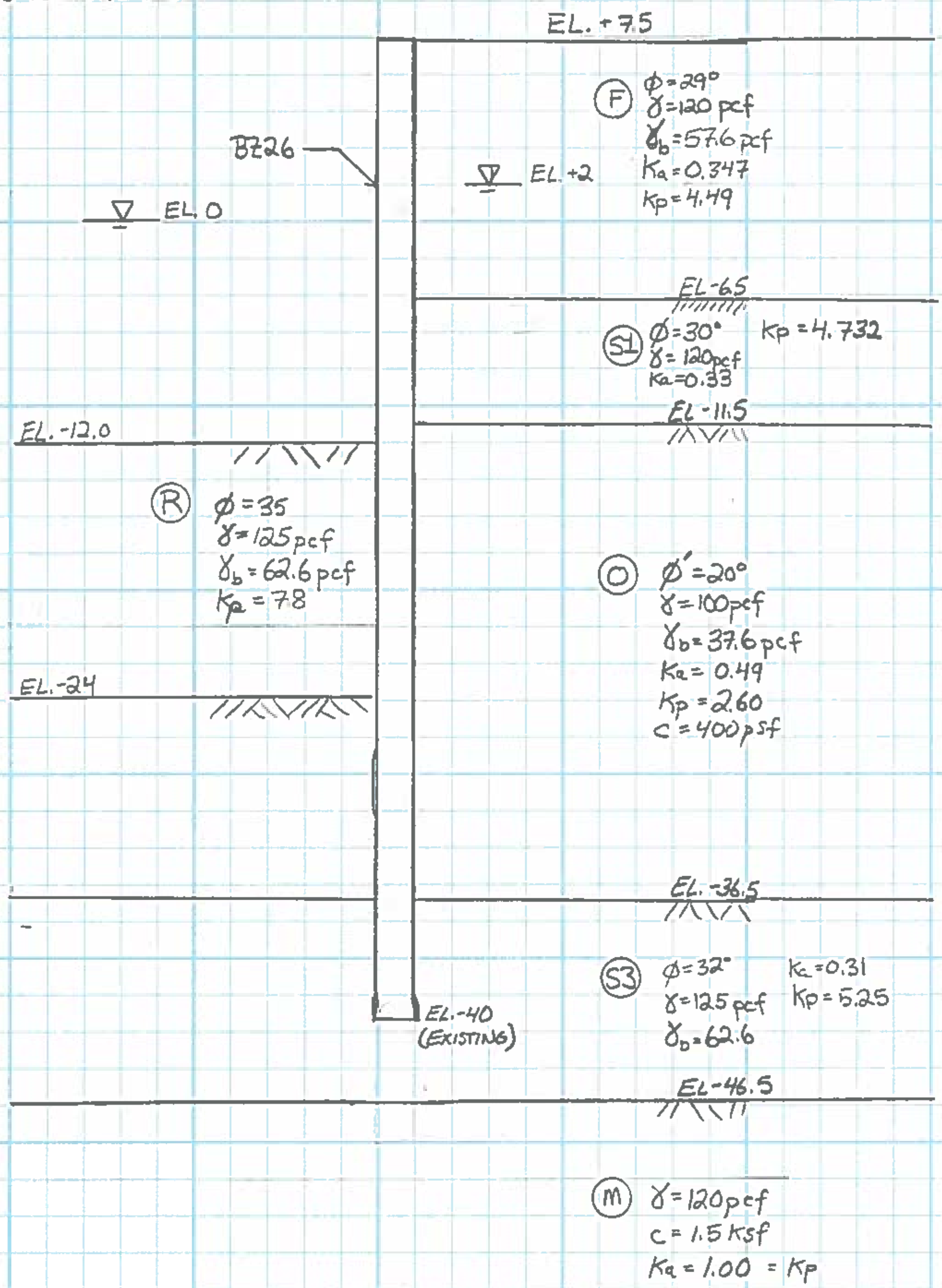
PROJECT: WILLS WHARF OFFICE / HOTEL

SUBJECT: WILLS STREET WHARF BULKHEAD - EXISTING

DS-2a

N.T.S

REF: BORING No. MR-718



SUBJECT: **SSP - Flexural Rigidity**

Section: BZ-26

Moment of Inertia of Section: $I_{pile} := 331.9 \dfrac{in^4}{ft}$

Section Modulus of Section: $S_{pile} := 48.2 \dfrac{in^3}{ft}$

Young's Modulus: $E := 29000ksi$

Thickness of Flange: $t_f := 0.520in$

Thickness of Web: $t_w := 0.394in$

Total Corrosion Thickness Loss: $t_{loss} := \dfrac{1}{8} in$

Corroded Section Modulus: $S_{red} := S_{pile} \cdot \left(\dfrac{\min(t_f, t_w) - t_{loss}}{\min(t_f, t_w)} \right) = 32.91 \cdot \dfrac{in^3}{ft}$

Corroded Moment of Inertia: $I_{red} := I_{pile} \cdot \left(\dfrac{\min(t_f, t_w) - t_{loss}}{\min(t_f, t_w)} \right) = 226.6 \cdot \dfrac{in^4}{ft}$

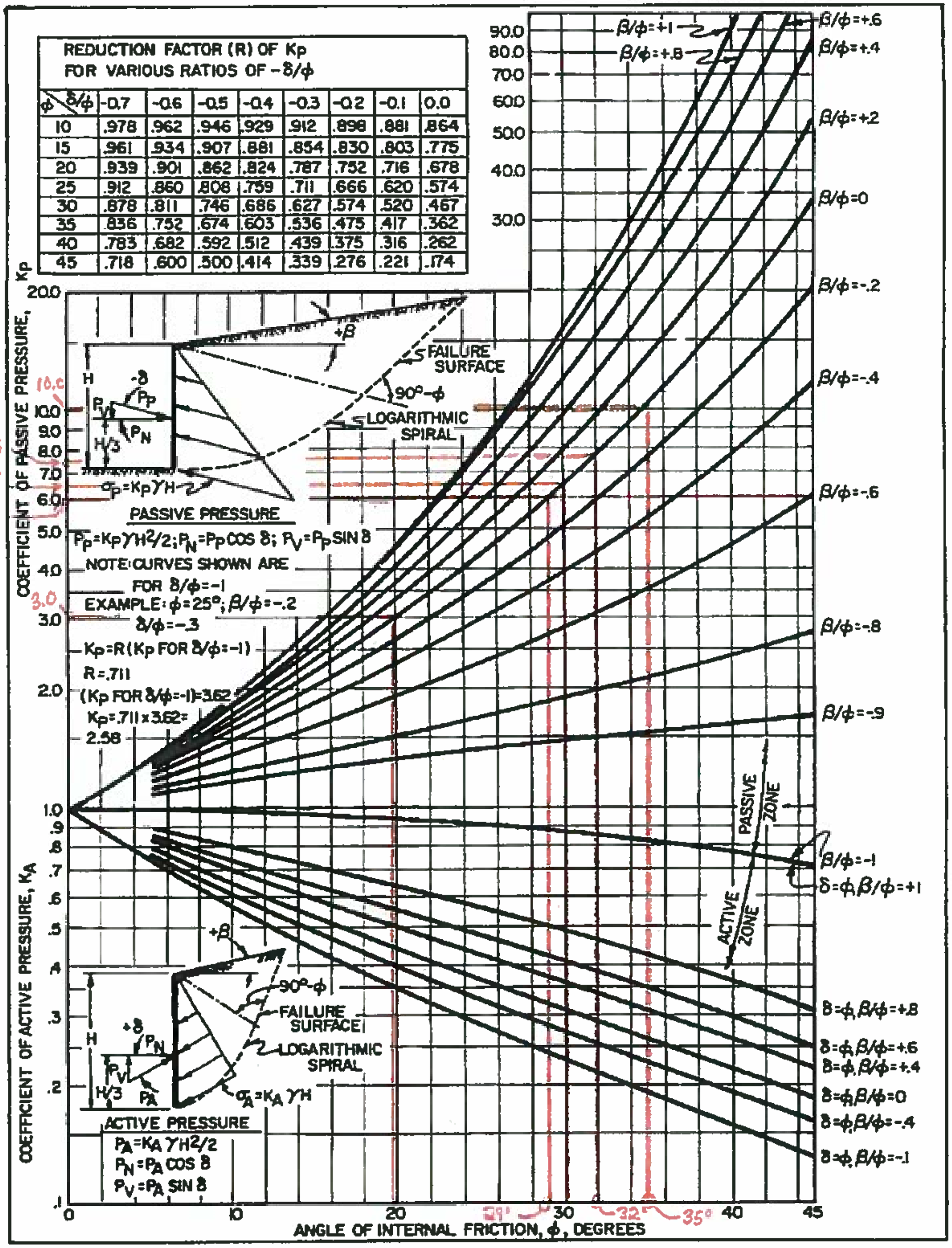
Corroded Flexural Rigidity: $R_e := E \cdot I_{red}$ $R_e = 45635.08 \dfrac{1}{ft} \cdot kip \cdot ft^2$

Initial Flexural Rigidity: $R_{ei} := E \cdot I_{pile}$ $R_{ei} = 66840.97 \dfrac{1}{ft} \cdot kip \cdot ft^2$

TABLE 1
Ultimate Friction Factors and Adhesion for Dissimilar Materials

Interface Materials	Friction factor, tan [delta]	Friction angle [delta] degrees
Mass concrete on the following foundation materials:		
Clean sound rock	0.70	35
Clean gravel, gravel-sand mixtures, coarse sand	0.55 to 0.60	29 to 31
Clean fine to medium sand, silty medium to coarse sand, silty or clayey gravel	0.45 to 0.55	24 to 29
Clean fine sand, silty or clayey fine to medium sand	0.35 to 0.45	19 to 24
Fine sandy silt, nonplastic silt	0.30 to 0.35	17 to 19
Very stiff and hard residual or preconsolidated clay	0.40 to 0.50	22 to 26
Medium stiff and stiff clay and silty clay	0.30 to 0.35	17 to 19
(Masonry on foundation materials has same friction factors.)		
Steel sheet piles against the following soils:		
Clean gravel, gravel-sand mixtures, well-graded rock fill with spalls	0.40	22
Clean sand, silty sand-gravel mixture, single size hard rock fill	0.30	17
Silty sand, gravel or sand mixed with silt or clay	0.25	14
Fine sandy silt, nonplastic silt	0.20	11
Formed concrete or concrete sheet piling against the following soils:		
Clean gravel, gravel-sand mixture, well-graded rock fill with spalls	0.40 to 0.50	22 to 26
Clean sand, silty sand-gravel mixture, single size hard rock fill	0.30 to 0.40	17 to 22
Silty sand, gravel or sand mixed with silt or clay	0.30	17
Fine sandy silt, nonplastic silt	0.25	14
Various structural materials:		
Masonry on masonry, igneous and metamorphic rocks:		
Dressed soft rock on dressed soft rock	0.70	35
Dressed hard rock on dressed soft rock	0.65	33
Dressed hard rock on dressed hard rock	0.55	29
Masonry on wood (cross grain)	0.50	26
Steel on steel at sheet pile interlocks	0.30	17

Interface Materials (Cohesion)	Adhesion c+a, (psf)
Very soft cohesive soil (0 - 250 psf)	0 - 250
Soft cohesive soil (250 - 500 psf)	250 - 500
Medium stiff cohesive soil (500 - 1000 psf)	500 - 750
Stiff cohesive soil (1000 - 2000 psf)	750 - 950
Very stiff cohesive soil (2000 - 4000 psf)	950 - 1,300



REDUCTION FACTOR (R) OF Kp FOR VARIOUS RATIOS OF −δ/φ

φ \ δ/φ	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0.0
10	.978	.962	.946	.929	.912	.898	.881	.864
15	.961	.934	.907	.881	.854	.830	.803	.775
20	.939	.901	.862	.824	.787	.752	.716	.678
25	.912	.860	.808	.759	.711	.666	.620	.574
30	.878	.811	.746	.686	.627	.574	.520	.467
35	.836	.752	.674	.603	.536	.475	.417	.362
40	.783	.682	.592	.512	.439	.375	.316	.262
45	.718	.600	.500	.414	.339	.276	.221	.174

FIGURE 6
Active and Passive Coefficients with Wall Friction
(Sloping Backfill)

SUBJECT: **PASSIVE PRESSURE COEFFICIENTS WITH WALL FRICTION**

Fill (F): $\phi := 29\cdot deg$ $\delta := 14 deg$ $\frac{\delta}{\phi} = 0.48$ Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of subgrade $\beta := 0\cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 6.0$

From reduction factor (R) table, $\phi_1 := 25\cdot deg$ $\phi_2 := 30\cdot deg$

For $\frac{\delta}{\phi} = 0.48$ Reduction factor $r_{25} := 0.759 + \frac{\left(\frac{\delta}{\phi} - 0.4\right)\cdot(0.808 - 0.759)}{(0.5 - 0.4)}$ $r_{25} = 0.8$

For $\frac{\delta}{\phi} = 0.48$ Reduction factor $r_{30} := 0.686 + \frac{\left(\frac{\delta}{\phi} - 0.4\right)\cdot(0.746 - 0.686)}{(0.5 - 0.4)}$ $r_{30} = 0.736$

Thus, Reduction factor $r_{29} := r_{25} - \left[\frac{(\phi - \phi_1)\cdot(r_{25} - r_{30})}{(\phi_2 - \phi_1)}\right]$ $r_{29} = 0.748$

Therefore, effective Kp with wall friction is: $K_p := (r_{29})\cdot(K_p)$ $\boxed{K_p = 4.49}$

Medium Sands (S1): $\phi := 30\cdot deg$ $\delta := 14 deg$ $\frac{\delta}{\phi} = 0.47$ Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of grade $\beta := 0\cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 6.5$

For $\frac{\delta}{\phi} = 0.47$ Reduction factor $r_{30} := 0.686 + \frac{\left(\frac{\delta}{\phi} - 0.4\right)\cdot(0.746 - 0.686)}{(0.5 - 0.4)}$ $r_{30} = 0.73$

Therefore effective Kp with wall friction is: $K_p := (r_{30})\cdot(K_p)$ $\boxed{K_p = 4.719}$

SUBJECT: **PASSIVE PRESSURE COEFFICIENTS WITH WALL FRICTION**

Silty Sands (S3):

$\phi := 32\cdot deg \quad \delta := 14deg \quad \frac{\delta}{\phi} = 0.44$

Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of subgrade $\beta := 0\cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 7.75$

From reduction factor (R) table, $\phi_1 := 30\cdot deg \quad \phi_2 := 35\cdot deg$

For $\frac{\delta}{\phi} = 0.44$ Reduction factor $r_{30} := 0.686 + \frac{\left(\frac{\delta}{\phi} - 0.4\right)\cdot(.746 - .686)}{(0.5 - 0.4)}$ $\quad r_{30} = 0.709$

For $\frac{\delta}{\phi} = 0.44$ Reduction factor $r_{35} := 0.603 + \frac{\left(\frac{\delta}{\phi} - 0.4\right)\cdot(.674 - .603)}{(0.5 - 0.4)}$ $\quad r_{35} = 0.630$

Thus, Reduction factor $r_{32} := r_{30} - \left[\frac{(\phi - \phi_1)\cdot(r_{30} - r_{35})}{(\phi_2 - \phi_1)}\right]$ $\quad r_{32} = 0.677$

Therefore, effective Kp with wall friction is: $K_p := (r_{32})\cdot(K_p)$ $\quad \boxed{K_p = 5.25}$

Organic Silt (O):

$\phi := 20\cdot deg \quad \delta := 11deg \quad \frac{\delta}{\phi} = 0.55$

Friction angle for Sheet piles on fine sandy silt, nonplastic silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of grade $\beta := 0\cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 3.0$

For $\frac{\delta}{\phi} = 0.55$ Reduction factor $r_{20} := 0.862 + \frac{\left(\frac{\delta}{\phi} - 0.5\right)\cdot(0.901 - 0.862)}{(0.6 - 0.5)}$ $\quad r_{20} = 0.88$

Therefore effective Kp with wall friction is: $K_p := (r_{20})\cdot(K_p)$ $\quad \boxed{K_p = 2.6}$

Sheet No.________ Of ________

MUESER RUTLEDGE CONSULTING ENGINEERS

File 12582A

Made By ZM Date 01/06/16

FOR Harbor Point Development

Checked By ____________ Date ________

SUBJECT: **PASSIVE PRESSURE COEFFICIENTS WITH WALL FRICTION**

RIP RAP (R):

$\phi := 35 \cdot deg \quad \delta := 22deg \quad \frac{\delta}{\phi} = 0.63$

Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of grade $\beta := 0 \cdot deg$

From DM 7.02, Figure 5 (attached), $K_p := 10.0$

For $\frac{\delta}{\phi} = 0.63$ Reduction factor $r_{35} := 0.752 + \frac{\left(\frac{\delta}{\phi} - 0.6\right) \cdot (0.836 - 0.752)}{(0.7 - 0.6)}$ $r_{35} = 0.78$

Therefore effective Kp with wall friction is: $K_p := (r_{35}) \cdot (K_p)$ $\boxed{K_p = 7.8}$

MUESER RUTLEDGE CONSULTING ENGINEERS

Sheet No. ______ Of ______

FOR : **Wills Wharf Office / Hotel**

FILE 12582B

MADE BY ZM DATE 01/05/16

CHECKED BY ______ DATE ______

SUBJECT: **STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-2a)**

Lateral Earth Pressures:

DRIVING FORCES													RESISTING FORCES											
Layer	Elev.	H	γ	σ_v	φ	k_a	c	R_a	Active Pressures	Surcharge*	Sidewalk Surcharge	Net Water Pressures	Layer	Elev.	H	γ	σ_v	k_p	R_p	c	φ	Passive Pressures	Total Pressures	Elev.
	(ft.)	(ft.)	(pcf)	(psf)	°		(psf)		(psf)	(psf)		(psf)		(ft.)	(ft.)	(pcf)	(psf)			(psf)	°	(psf)	(psf)	(ft.)
F	7.5	0	120	0	29	0.347	0	1.0	0	0	0	0											0	7.5
	4.5	3	120	360	29	0.347	0	1.0	125	0	0	0											125	4.5
	4.5	0	120	360	29	0.347	0	1.0	125	0	0	0											125	4.5
	2	2.5	120	660	29	0.347	0	1.0	229	0	0	0											229	2
	2	0	57.6	660	29	0.347	0	1.0	229	0	0	0											229	2
	0	2	57.6	775	29	0.347	0	1.0	269	0	0	125											394	0
	0	0	57.6	775	29	0.347	0	1.0	269	0	0	125											394	0
	-2.5	4.5	57.6	1034	29	0.347	0	1.0	359	0	0	125											484	-2.5
	-2.5	0	57.6	1034	29	0.347	0	1.0	359	0	0	125											484	-2.5
	-5	2.5	57.6	1178	29	0.347	0	1.0	409	0	0	125											534	-5
	-5	0	57.6	1178	29	0.347	0	1.0	409	0	0	125											534	-5
	-6.5	1.5	57.6	1265	29	0.347	0	1.0	439	0	0	125											564	-6.5
S1	-6.5	0	57.6	1265	30	0.333	0	1.0	422	0	0	125											546	-6.5
	-11.5	5	57.6	1553	30	0.333	0	1.0	518	0	0	125											642	-11.5
O	-11.5	0	37.6	1553	0	1.000	400	1.0	753	0	0	125											878	-11.5
	-12	0.5	37.6	1572	0	1.000	400	1.0	772	0	0	125											896	-12
	-12	0	37.6	1572	0	1.000	400	1.0	772	0	0	125	R	-12	0	62.6	0	7.80	1.000	0	35	0	896	-12
	-24	12	37.6	2023	0	1.000	400	1.0	1223	0	0	125		-24	12	62.6	751	7.80	1.000	0	35	-5859	-4512	-24
	-24	0	37.6	2023	0	1.000	400	1.0	1223	0	0	125	O	-24	0	37.6	751	2.64	1.000	400	0	-3283	-1935	-24
	-36.5	12.5	37.6	2493	0	1.000	400	1.0	1693	0	0	125		-36.5	12.5	37.6	1221	2.64	1.000	400	0	-4524	-2706	-36.5
S3	-36.5	0	62.6	2493	32	0.307	0	1.0	766	0	0	125	S3	-36.5	0	62.6	1221	5.25	1.000	0	32	-6411	-5521	-36.5
	-40	3.5	62.6	2712	32	0.307	0	1.0	833	0	0	125		-40	3.5	62.6	1440	5.25	1.000	0	32	-7562	-6604	-40
	-46.5	6.5	62.6	3119	32	0.307	0	1.0	958	0	0	125		-46.5	6.5	62.6	1847	5.25	1.000	0	32	-9698	-8615	-46.5
M	-46.5	0	57.6	3119	0	1.000	1500	1.0	119	0	0	125	M	-46.5	0	57.6	1847	1.00	1.000	1.5	0	-1850	-1607	-46.5
	-50	3.5	57.6	3320	0	1.000	1500	1.0	320	0	0	125		-50	3.5	57.6	2049	1.00	1.000	1.5	0	-2052	-1607	-50
	-50	0	57.6	3320	0	1.000	1500	1.0	320	0	0	125		-50	0	57.6	2049	1.00	1.000	1.5	0	-2052	-1607	-50

$\sigma_a = \gamma \cdot H \cdot k_a - 2C\cdot\sqrt{k_a}$ $k_a = \tan^2\left(45 - \frac{\phi}{2}\right)$

At rest Pressures:

$\sigma_p = \gamma \cdot H \cdot k_p + 2C\cdot\sqrt{k_p}$

Passive Pressures:

Reduction Factors applied below subgrade:

Ra = bf/s = 1.000

Rp = 3*Ra = 1.000

Undrained Clay Strength Ratio:

c/p Ra 0.2

Wall Type: Continous

MUESER RUTLEDGE CONSULTING ENGINEERS

Sheet No. ______ Of ______

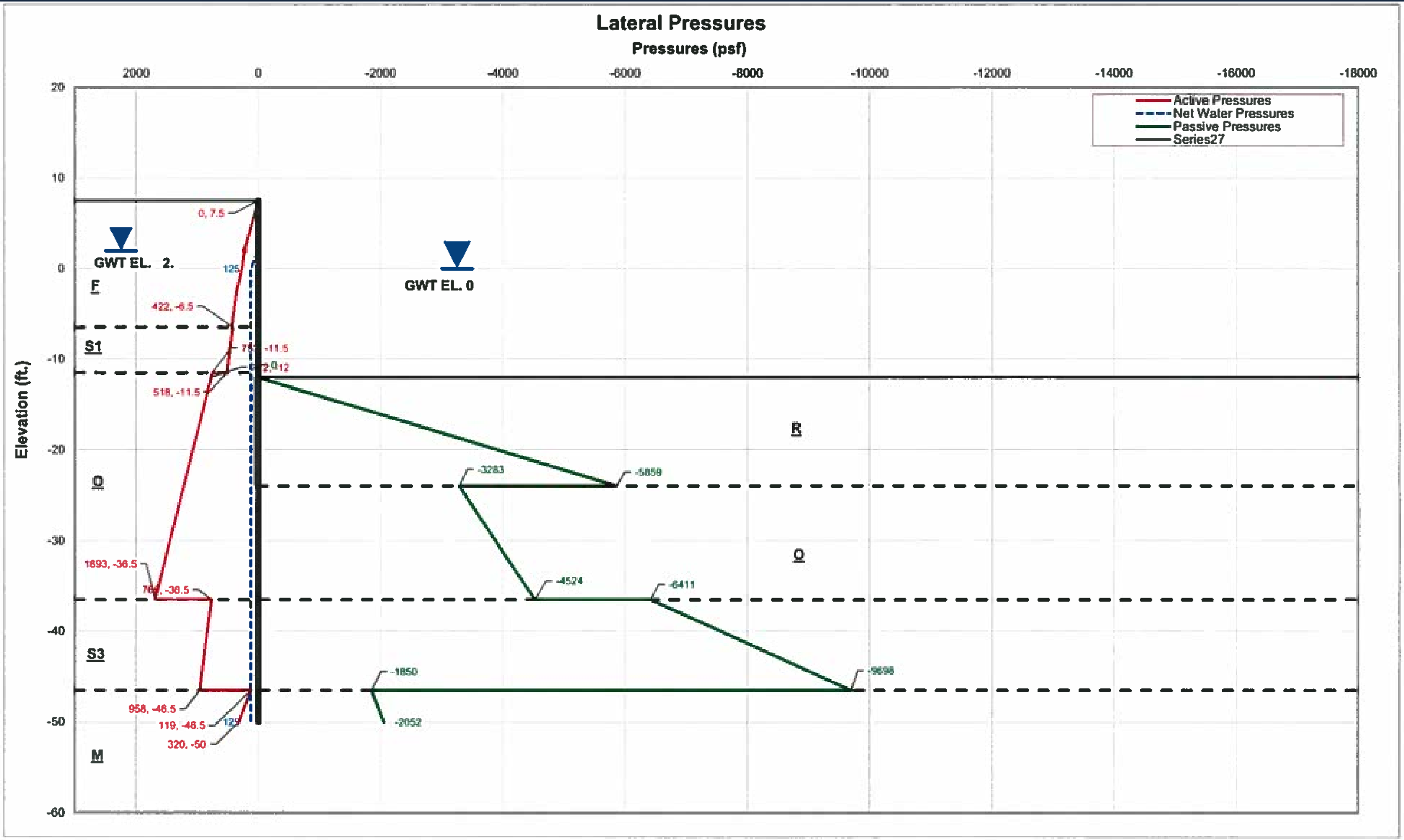
FILE 12582B

FOR : Wills Wharf Office / Hotel

MADE BY ZM DATE 01/05/16

CHECKED BY ______ DATE ______

SUBJECT: STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-2a)



DS-2a

F:\125\12582\12582B\Task 130 - Retaining Wall Design\SSP Bulkhead Analysis\Staging Analysis AREA 2 - Cantilevered

MUESER RUTLEDGE CONSULTING ENGINEERS

Sheet No. ______ Of ______

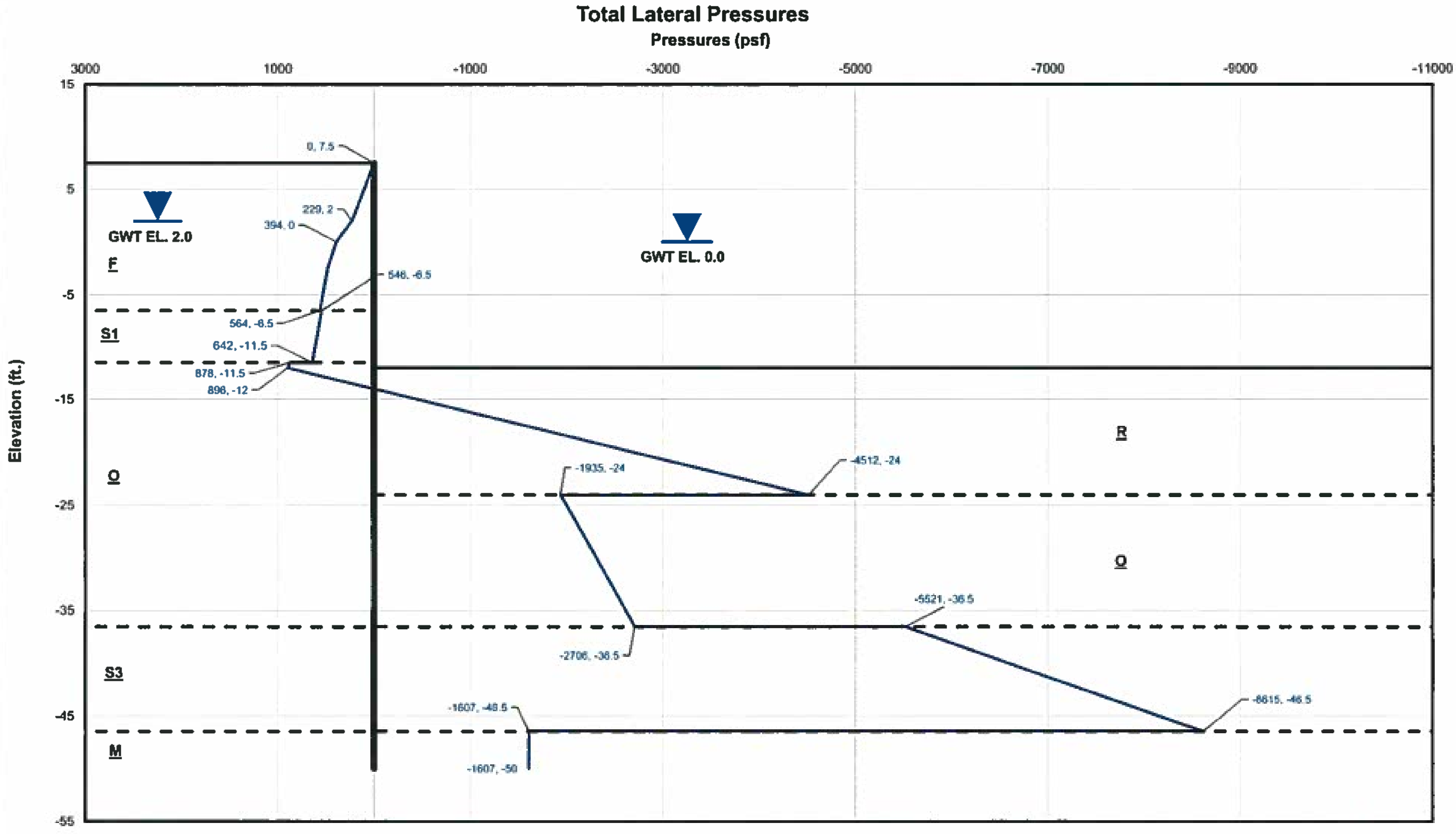
FOR : **Wills Wharf Office / Hotel**

FILE 12582B

MADE BY ZM DATE 01/05/16

CHECKED BY ______ DATE ______

SUBJECT: **STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-2a)**



MUESER RUTLEDGE CONSULTING ENGINEERS

Cantilever v3.0 BETA for Windows, 32-bit

Subject: DS-2a

INPUT

P	Q	Interval Lengths
0.000	0.229	5.500
0.229	0.394	2.000
0.394	0.564	6.500
0.546	0.642	5.000
0.878	0.896	0.500

Passive pressure at subgrade : .896
Passive pressure slope : .45
Flexural rigidity : 45635

OUTPUT

At end of int. 1, Shear= 0.63, Moment= 1.15
At end of int. 2, Shear= 1.25, Moment= 2.98
At end of int. 3, Shear= 4.37, Moment= 20.65
At end of int. 4, Shear= 7.34, Moment= 49.70
At end of int. 5, Shear= 7.78, Moment= 53.48

D= 10.46 embedment below subgrade with F.S.= 1   D (FOS = 1.2) = 1.44(10.46 ft) = 15.06 ft [EL. -27.06]

Total Length of sheetpile is 29.96

Depth of max. moment= 23.72
Max. moment= 72.70

M_{all} = 0.6(50 ksi)(32.9 in³/ft)(1'/12") = 82.25 k-ft
M_{max} < M_{all} ∴ OK

Depth of max. shear= 29.96
Max. shear= 26.20

X	V	M	Defl.
0.00	0.00	0.00	0.40
1.50	0.05	0.02	0.37
3.00	0.19	0.19	0.35
4.49	0.42	0.63	0.32
5.99	0.75	1.49	0.29
7.49	1.25	2.97	0.26
8.99	1.87	5.30	0.23
10.49	2.55	8.59	0.21
11.98	3.28	12.95	0.18
13.48	4.08	18.46	0.15
14.98	4.91	25.19	0.13
16.48	5.78	33.18	0.10
17.97	6.69	42.52	0.08
19.47	7.76	53.27	0.06
20.97	5.98	63.71	0.04
22.47	3.14	70.67	0.03
23.97	-0.71	72.61	0.01
25.46	-5.57	68.03	0.01
26.96	-11.44	55.42	0.00
28.46	-18.31	33.27	0.00
29.96	-26.20	0.05	0.00

```
   Moment   (M/Mmax)


   -1.0           -0.5            0.0           0.5            1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0                              :
  1.5                              |:
  3.0                              |:
  4.5                              |:
  6.0                              |:
  7.5                              |:
  9.0                              | :
 10.5                              |   :
 12.0                              |    :
 13.5                              |       :
 15.0                              |         :
 16.5                              |             :
 18.0                              |                 :
 19.5                              |                     :
 21.0                              |                         :
 22.5                              |                            :
 24.0                              |                             :
 25.5                              |                           :
 27.0                              |                      :
 28.5                              |             :
 30.0                              |:

   Shear   (V/Vmax)


   -1.0           -0.5            0.0           0.5            1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0                              :
  1.5                              |:
  3.0                              |:
  4.5                              |:
  6.0                              |:
  7.5                              |:
  9.0                              | :
 10.5                              |  :
 12.0                              |   :
 13.5                              |    :
 15.0                              |     :
 16.5                              |      :
 18.0                              |       :
 19.5                              |        :
 21.0                              |      :
 22.5                              |   :
 24.0                             :|
 25.5                       :      |
 27.0                :             |
 28.5         :                    |
 30.0:                             |
```

MUESER RUTLEDGE CONSULTING ENGINEERS

SHEET ____ OF ____

FILE 12582B

MADE BY ZM DATE 1/6/2016

CHECKED BY ____ DATE ____

PROJECT Harbor Point Development

SUBJECT Wills Street Wharf Bulkhead - Proposed (Anchored Option)

DS-2b

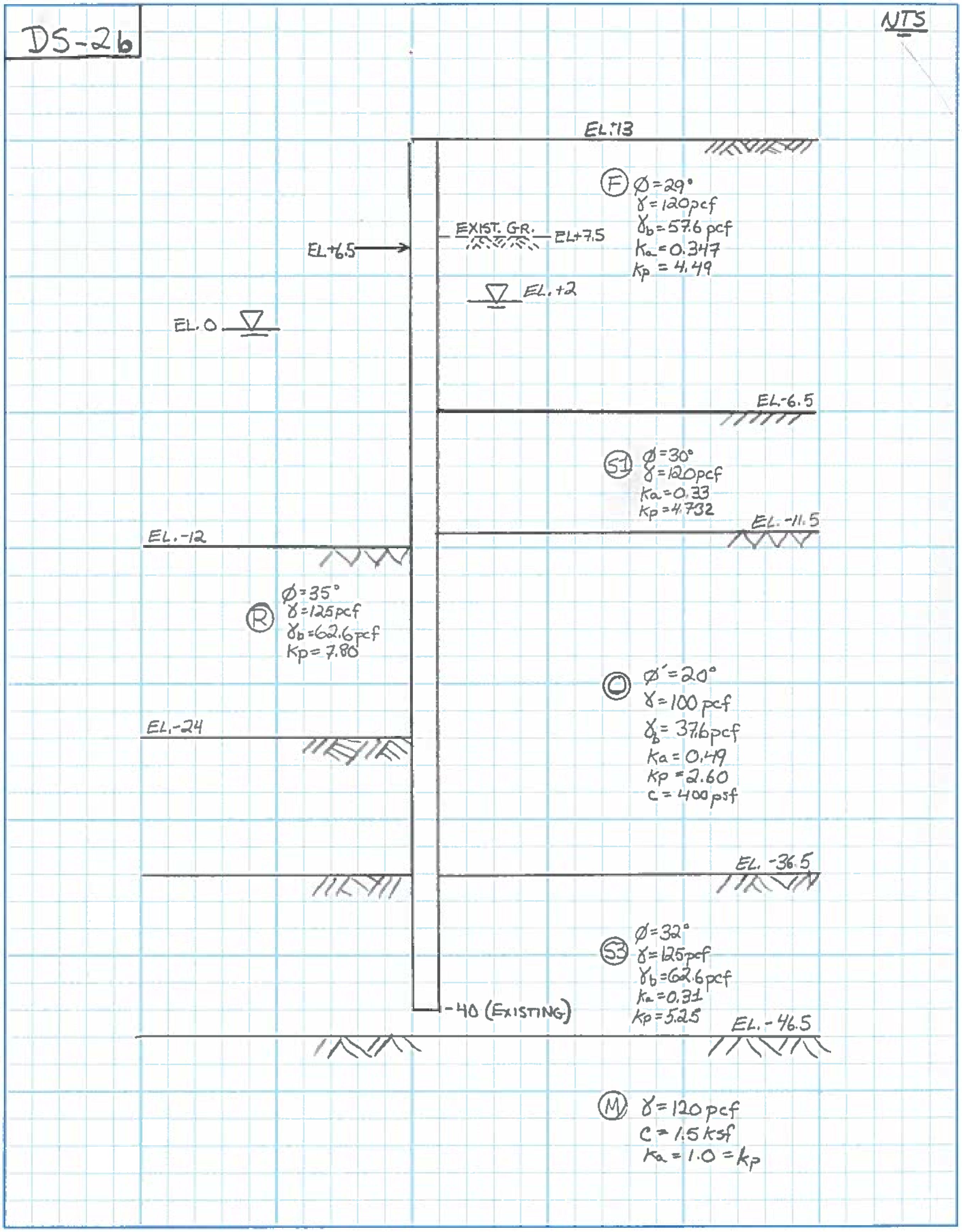
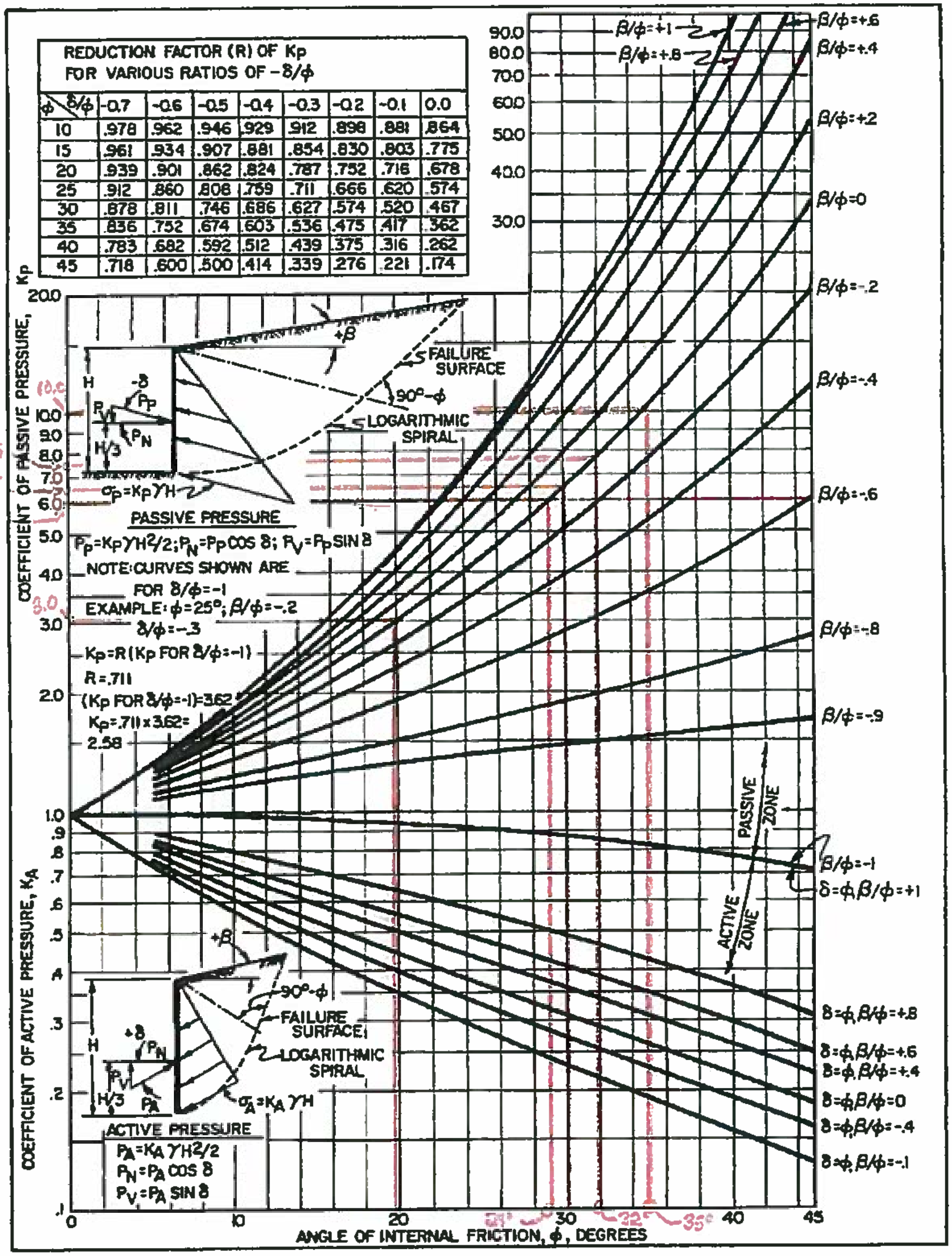


TABLE 1
Ultimate Friction Factors and Adhesion for Dissimilar Materials

Interface Materials	Friction factor, tan [delta]	Friction angle [delta] degrees
Mass concrete on the following foundation materials:		
Clean sound rock..................................	0.70	35
Clean gravel, gravel-sand mixtures, coarse sand...	0.55 to 0.60	29 to 31
Clean fine to medium sand, silty medium to coarse sand, silty or clayey gravel....................	0.45 to 0.55	24 to 29
Clean fine sand, silty or clayey fine to medium sand...	0.35 to 0.45	19 to 24
Fine sandy silt, nonplastic silt..................	0.30 to 0.35	17 to 19
Very stiff and hard residual or preconsolidated clay...	0.40 to 0.50	22 to 26
Medium stiff and stiff clay and silty clay........	0.30 to 0.35	17 to 19
(Masonry on foundation materials has same friction factors.)		
Steel sheet piles against the following soils:		
Clean gravel, gravel-sand mixtures, well-graded rock fill with spalls..........................	0.40	22
Clean sand, silty sand-gravel mixture, single size hard rock fill.................................	0.30	17
Silty sand, gravel or sand mixed with silt or clay	0.25	14
Fine sandy silt, nonplastic silt..................	0.20	11
Formed concrete or concrete sheet piling against the following soils:		
Clean gravel, gravel-sand mixture, well-graded rock fill with spalls..........................	0.40 to 0.50	22 to 26
Clean sand, silty sand-gravel mixture, single size hard rock fill.................................	0.30 to 0.40	17 to 22
Silty sand, gravel or sand mixed with silt or clay	0.30	17
Fine sandy silt, nonplastic silt..................	0.25	14
Various structural materials:		
Masonry on masonry, igneous and metamorphic rocks:		
Dressed soft rock on dressed soft rock..........	0.70	35
Dressed hard rock on dressed soft rock..........	0.65	33
Dressed hard rock on dressed hard rock..........	0.55	29
Masonry on wood (cross grain).....................	0.50	26
Steel on steel at sheet pile interlocks...........	0.30	17

Interface Materials (Cohesion)	Adhesion c+a, (psf)
Very soft cohesive soil (0 - 250 psf)	0 - 250
Soft cohesive soil (250 - 500 psf)	250 - 500
Medium stiff cohesive soil (500 - 1000 psf)	500 - 750
Stiff cohesive soil (1000 - 2000 psf)	750 - 950
Very stiff cohesive soil (2000 - 4000 psf)	950 - 1,300



REDUCTION FACTOR (R) OF Kp FOR VARIOUS RATIOS OF −δ/φ

φ \ δ/φ	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0.0
10	.978	.962	.946	.929	.912	.898	.881	.864
15	.961	.934	.907	.881	.854	.830	.803	.775
20	.939	.901	.862	.824	.787	.752	.716	.678
25	.912	.860	.808	.759	.711	.666	.620	.574
30	.878	.811	.746	.686	.627	.574	.520	.467
35	.836	.752	.674	.603	.536	.475	.417	.362
40	.783	.682	.592	.512	.439	.375	.316	.262
45	.718	.600	.500	.414	.339	.276	.221	.174

FIGURE 6
Active and Passive Coefficients with Wall Friction
(Sloping Backfill)

SUBJECT: **PASSIVE PRESSURE COEFFICIENTS WITH WALL FRICTION**

Fill (F): $\phi := 29 \cdot deg$ $\delta := 14deg$ $\frac{\delta}{\phi} = 0.48$ Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of subgrade $\beta := 0 \cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 6.0$

From reduction factor (R) table, $\phi_1 := 25 \cdot deg$ $\phi_2 := 30 \cdot deg$

For $\frac{\delta}{\phi} = 0.48$ Reduction factor $r_{25} := 0.759 + \frac{\left(\frac{\delta}{\phi} - 0.4\right) \cdot (0.808 - 0.759)}{(0.5 - 0.4)}$ $r_{25} = 0.8$

For $\frac{\delta}{\phi} = 0.48$ Reduction factor $r_{30} := 0.686 + \frac{\left(\frac{\delta}{\phi} - 0.4\right) \cdot (0.746 - 0.686)}{(0.5 - 0.4)}$ $r_{30} = 0.736$

Thus, Reduction factor $r_{29} := r_{25} - \left[\frac{(\phi - \phi_1) \cdot (r_{25} - r_{30})}{(\phi_2 - \phi_1)}\right]$ $r_{29} = 0.748$

Therefore, effective Kp with wall friction is: $K_p := (r_{29}) \cdot (K_p)$ $\boxed{K_p = 4.49}$

Medium Sands (S1): $\phi := 30 \cdot deg$ $\delta := 14deg$ $\frac{\delta}{\phi} = 0.47$ Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of grade $\beta := 0 \cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 6.5$

For $\frac{\delta}{\phi} = 0.47$ Reduction factor $r_{30} := 0.686 + \frac{\left(\frac{\delta}{\phi} - 0.4\right) \cdot (0.746 - 0.686)}{(0.5 - 0.4)}$ $r_{30} = 0.73$

Therefore effective Kp with wall friction is: $K_p := (r_{30}) \cdot (K_p)$ $\boxed{K_p = 4.719}$

Sheet No.________ Of________

MUESER RUTLEDGE CONSULTING ENGINEERS File 12582A

Made By ZM Date 01/06/16

FOR Harbor Point Development Checked By ________ Date ________

SUBJECT: **PASSIVE PRESSURE COEFFICIENTS WITH WALL FRICTION**

Silty Sands (S3): $\phi := 32 \cdot deg \quad \delta := 14deg \quad \frac{\delta}{\phi} = 0.44$

Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of subgrade $\beta := 0 \cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 7.75$

From reduction factor (R) table, $\phi_1 := 30 \cdot deg \quad \phi_2 := 35 \cdot deg$

For $\frac{\delta}{\phi} = 0.44$ Reduction factor $r_{30} := 0.686 + \frac{\left(\frac{\delta}{\phi} - 0.4\right) \cdot (.746 - .686)}{(0.5 - 0.4)}$ $r_{30} = 0.709$

For $\frac{\delta}{\phi} = 0.44$ Reduction factor $r_{35} := 0.603 + \frac{\left(\frac{\delta}{\phi} - 0.4\right) \cdot (.674 - .603)}{(0.5 - 0.4)}$ $r_{35} = 0.630$

Thus, Reduction factor $r_{32} := r_{30} - \left[\frac{(\phi - \phi_1) \cdot (r_{30} - r_{35})}{(\phi_2 - \phi_1)}\right]$ $r_{32} = 0.677$

Therefore, effective Kp with wall friction is: $K_p := (r_{32}) \cdot (K_p)$ $\boxed{K_p = 5.25}$

Organic Silt (O): $\phi := 20 \cdot deg \quad \delta := 11deg \quad \frac{\delta}{\phi} = 0.55$

Friction angle for Sheet piles on fine sandy silt, nonplastic silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of grade $\beta := 0 \cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 3.0$

For $\frac{\delta}{\phi} = 0.55$ Reduction factor $r_{20} := 0.862 + \frac{\left(\frac{\delta}{\phi} - 0.5\right) \cdot (0.901 - 0.862)}{(0.6 - 0.5)}$ $r_{20} = 0.88$

Therefore effective Kp with wall friction is: $K_p := (r_{20}) \cdot (K_p)$ $\boxed{K_p = 2.6}$

MUESER RUTLEDGE CONSULTING ENGINEERS

File 12582A

Made By ZM Date 01/06/16

FOR Harbor Point Development

Checked By ____________ Date ____________

SUBJECT: **PASSIVE PRESSURE COEFFICIENTS WITH WALL FRICTION**

RIP RAP (R):

$\phi := 35 \cdot deg \quad \delta := 22deg \quad \frac{\delta}{\phi} = 0.63$

Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of grade $\beta := 0 \cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 10.0$

For $\frac{\delta}{\phi} = 0.63$ Reduction factor $r_{35} := 0.752 + \frac{\left(\frac{\delta}{\phi} - 0.6\right) \cdot (0.836 - 0.752)}{(0.7 - 0.6)}$ $r_{35} = 0.78$

Therefore effective Kp with wall friction is: $K_p := (r_{35}) \cdot (K_p)$ $\boxed{K_p = 7.8}$

MUESER RUTLEDGE CONSULTING ENGINEERS

Sheet No. ________ Of ________

FILE 12582B

FOR : Wills Wharf Office / Hotel

MADE BY ZM DATE 01/06/16

CHECKED BY ______ DATE ______

SUBJECT: **STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-2b)**

Lateral Earth Pressures:

DRIVING FORCES												RESISTING FORCES											
Layer	Elev. (ft.)	H (ft.)	γ (pcf)	σ_v (psf)	ϕ (°)	k_a	c (psf)	R_a	Active Pressures (psf)	Surcharge* (psf)	Sidewalk Surcharge	Net Water Pressures (psf)	Layer	Elev. (ft.)	H (ft.)	γ (pcf)	σ_v (psf)	k_p	R_p	c (psf)	ϕ (°)	Passive Pressures (psf)	Total Pressures (psf)	Elev. (ft.)
F	13	0	120	0	29	0.347	0	1.0	0	240		0											240	13
	4.5	8.5	120	1020	29	0.347	0	1.0	354	240	0	0											594	4.5
	4.5	0	120	1020	29	0.347	0	1.0	354	240	0	0											594	4.5
	3	1.5	120	1200	29	0.347	0	1.0	416	240	0	0											656	3
	3	0	57.6	1200	29	0.347	0	1.0	416	100	0	0											516	3
	2	1	57.6	1258	29	0.347	0	1.0	436	100	0	0											536	2
	2	0	57.6	1258	29	0.347	0	1.0	436	100	0	0											536	2
	0	2	57.6	1373	29	0.347	0	1.0	476	100	0	125											701	0
	0	0	57.6	1373	29	0.347	0	1.0	476	100	0	125											701	0
	-3	6	57.6	1718	29	0.347	0	1.0	596	100	0	125											821	-3
	-3	0	57.6	1718	29	0.347	0	1.0	596	0	0	125											721	-3
	-5	2	57.6	1834	29	0.347	0	1.0	636	0	0	125											761	-5
	-5	0	57.6	1834	29	0.347	0	1.0	636	0	0	125											761	-5
	-6.5	1.5	57.6	1920	29	0.347	0	1.0	666	0	0	125											791	-6.5
S1	-6.5	0	57.6	1920	30	0.333	0	1.0	640	0	0	125											765	-6.5
	-11.5	5	57.6	2208	30	0.333	0	1.0	736	0	0	125											861	-11.5
	-11.5	0	37.6	2208	0	1.000	400	1.0	1408	0	0	125											1533	-11.5
	-12	0.5	37.6	2227	0	1.000	400	1.0	1427	0	0	125											1552	-12
O	-12	0	37.6	2227	0	1.000	400	1.0	1427	0	0	125	R	-12	0	62.6	0	7.80	1.000	0	35	0	1552	-12
	-24	12	37.6	2678	0	1.000	400	1.0	1878	0	0	125		-24	12	62.6	751	7.80	1.000	0	35	-5859	-3857	-24
	-24	0	37.6	2678	0	1.000	400	1.0	1878	0	0	125	O	-24	0	37.6	751	2.64	1.000	400	0	-3283	-1280	-24
	-36.5	12.5	37.6	3148	0	1.000	400	1.0	2348	0	0	125		-36.5	12.5	37.6	1221	2.64	1.000	400	0	-4524	-2051	-36.5
	-36.5	0	62.6	3148	32	0.307	0	1.0	967	0	0	125		-36.5	0	62.6	1221	5.25	1.000	0	32	-6411	-5319	-36.5
S3	-40	3.5	62.6	3367	32	0.307	0	1.0	1035	0	0	125	S3	-40	3.5	62.6	1440	5.25	1.000	0	32	-7562	-6402	-40
	-46.5	6.5	62.6	3774	32	0.307	0	1.0	1160	0	0	125		-46.5	6.5	62.6	1847	5.25	1.000	0	32	-9698	-8413	-46.5
	-46.5	0	57.6	3774	0	1.000	1500	1.0	774	0	0	125		-46.5	0	57.6	1847	1.00	1.000	1.5	0	-1850	-951	-46.5
M	-50	3.5	57.6	3976	0	1.000	1500	1.0	976	0	0	125	M	-50	3.5	57.6	2049	1.00	1.000	1.5	0	-2052	-951	-50
	-50	0	57.6	3976	0	1.000	1500	1.0	976	0	0	125		-50	0	57.6	2049	1.00	1.000	1.5	0	-2052	-951	-50

At rest Pressures: $\sigma_a = \gamma \cdot H \cdot k_a - 2C\cdot\sqrt{k_a}$ $k_a = \tan^2\left(45 - \frac{\phi}{2}\right)$

Passive Pressures: $\sigma_p = \gamma \cdot H \cdot k_p + 2C\cdot\sqrt{k_p}$

Reduction Factors applied below subgrade:

Ra = bf/s = 1.000

Rp = 3*Ra = 1.000

Undrained Clay Strength Ratio:

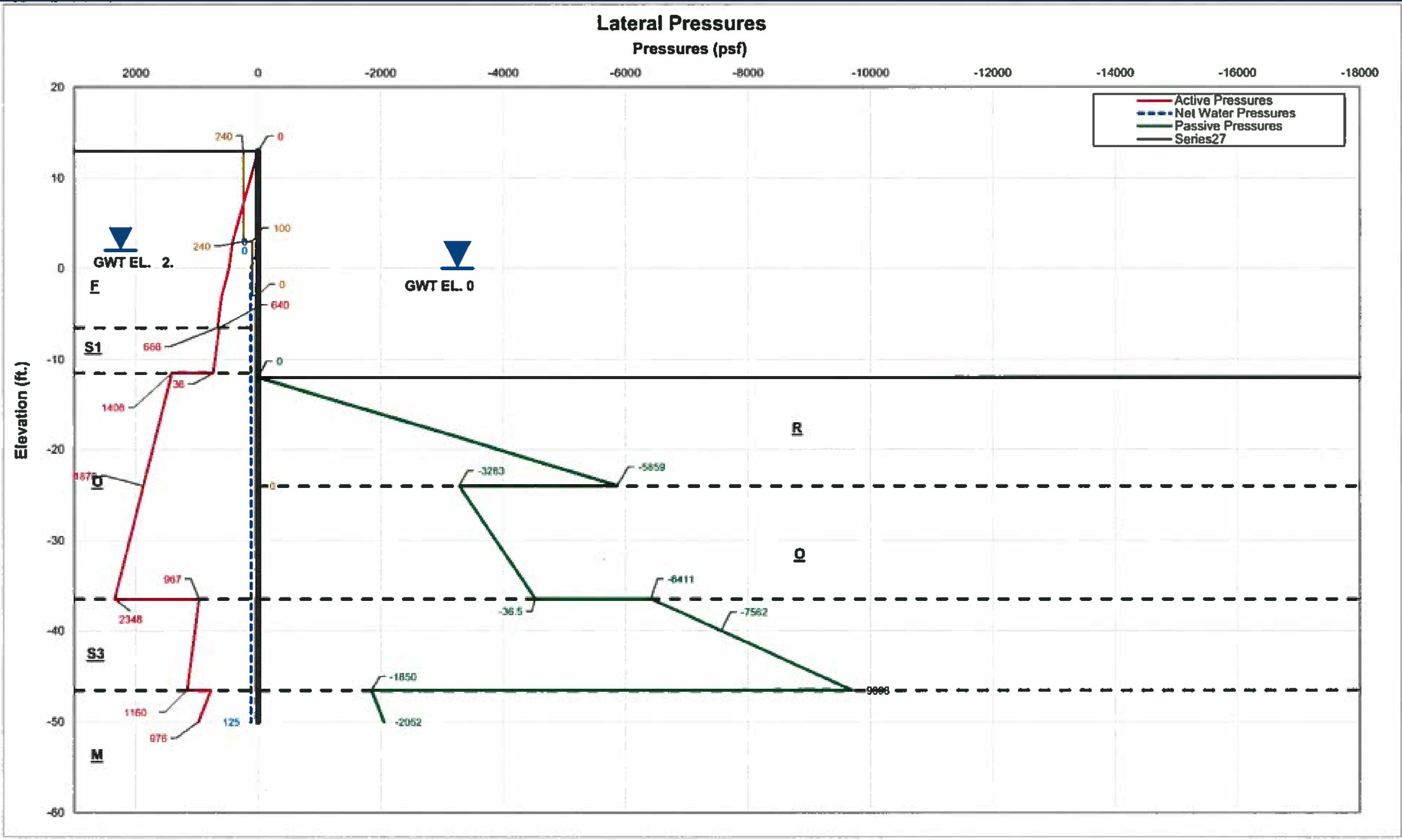
c/p Ra 0.2

Wall Type: Continous

FOR : **Wills Wharf Office / Hotel**

MADE BY ZM DATE 01/06/16
CHECKED BY ______ DATE ______

SUBJECT: **STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-2b)**



F:\125\12582\12582B\Task 130 - Retaining Wall Design\SSP Bulkhead Analysis\Staging Analysis AREA 2 - Cantilevered

MUESER RUTLEDGE CONSULTING ENGINEERS

Sheet No. ________ Of ________

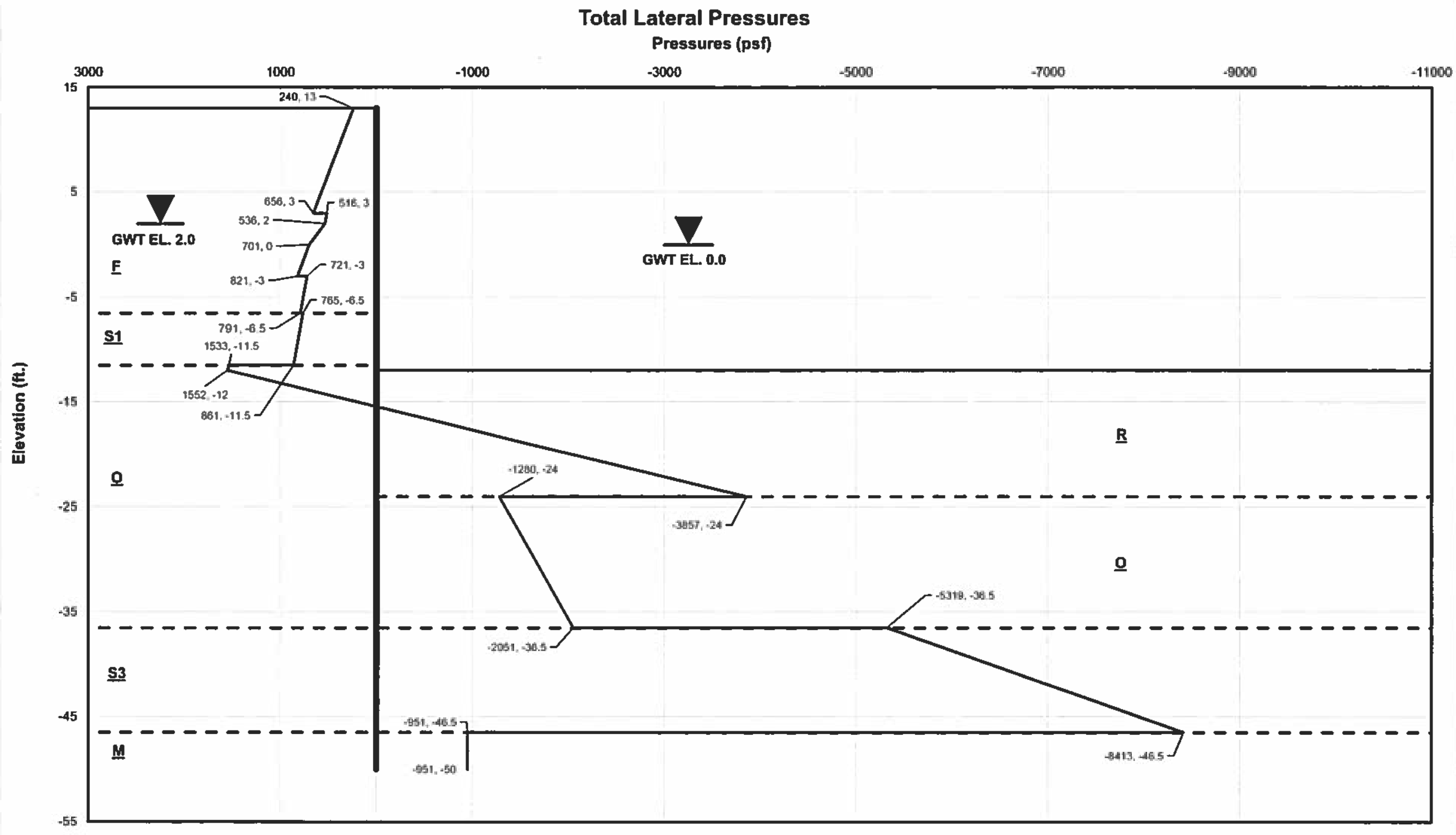
FOR : **Wills Wharf Office / Hotel**

FILE 12582B

MADE BY ZM DATE 01/06/16

CHECKED BY ________ DATE ________

SUBJECT: **STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-2b)**



F:\125\12582\12582B\Task 130 - Retaining Wall Design\SSP Bulkhead Analysis\Staging Analysis AREA 2 - Cantilevered

MUESER RUTLEDGE CONSULTING ENGINEERS

Cantilever v3.0 BETA for Windows, 32-bit

Subject: DS-2b

INPUT

P	Q	Interval Lengths
0.240	0.656	10.000
0.516	0.536	1.000
0.536	0.701	2.000
0.701	0.821	3.000
0.721	0.791	3.500
0.765	0.861	5.000
1.533	1.552	0.500
1.552	-3.857	12.000
-1.280	-2.051	12.500

Passive pressure at subgrade : 5.319
Passive pressure slope : .309
Flexural rigidity : 45635.08

OUTPUT

At end of int. 1, Shear= 4.48, Moment= 18.93
At end of int. 2, Shear= 5.01, Moment= 23.67
At end of int. 3, Shear= 6.24, Moment= 34.87
At end of int. 4, Shear= 8.53, Moment= 56.93
At end of int. 5, Shear= 11.17, Moment= 91.33
At end of int. 6, Shear= 15.24, Moment= 157.15
At end of int. 7, Shear= 16.01, Moment= 164.97
At end of int. 8, Shear= 2.18, Moment= 338.99
At end of int. 9, Shear= -18.64, Moment= 246.14

D= 6.47 embedment below subgrade with F.S.= 1 $D(FOS=1.2) = 1.44(12\,ft + 11.5\,ft + 6.47\,ft) = 43.17\,ft$ [EL.-55]

Total Length of sheetpile is 55.97

Depth of max. moment= 38.64

Max. moment= 340.80 $M_{ALL} = 0.6(50\,ksi)(32.91\,in^3/ft)(1'/12") = 82.28$ k-ft

Depth of max. shear= 55.97 $M_{max} \gg M_{all}$ ∴ NG
Max. shear= 59.55

X	V	M	Defl.
0.00	0.00	0.00	7.50
2.80	0.83	1.09	6.93
5.60	2.00	4.98	6.36
8.40	3.48	12.56	5.79
11.19	5.11	24.66	5.22
13.99	6.96	41.42	4.66
16.79	9.10	63.91	4.11
19.59	11.24	92.35	3.56
22.39	13.46	126.88	3.04
25.19	16.29	168.00	2.53
27.99	18.63	217.70	2.06
30.79	17.44	269.01	1.61
33.58	12.72	312.04	1.22
36.38	4.47	336.93	0.87
39.18	-0.76	340.59	0.60
41.98	-4.96	332.70	0.37
44.78	-9.64	312.37	0.21
47.58	-14.81	278.26	0.09
50.38	-23.42	227.73	0.03
53.17	-40.27	139.17	0.00
55.97	-59.55	0.05	0.00

δ_{max} = 7.50 ft ∴ NG, Excessive

```
   Moment  (M/Mmax)

   -1.0           -0.5            0.0           0.5             1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0                              :
  2.8                              |:
  5.6                              |:
  8.4                              |:
 11.2                              | :
 14.0                              |   :
 16.8                              |     :
 19.6                              |       :
 22.4                              |          :
 25.2                              |              :
 28.0                              |                  :
 30.8                              |                       :
 33.6                              |                          :
 36.4                              |                             :
 39.2                              |                             :
 42.0                              |                            :
 44.8                              |                           :
 47.6                              |                       :
 50.4                              |                   :
 53.2                              |           :
 56.0                              |:

   Shear  (V/Vmax)

   -1.0           -0.5            0.0           0.5             1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0                              :
  2.8                              |:
  5.6                              |:
  8.4                              | :
 11.2                              |  :
 14.0                              |  :
 16.8                              |    :
 19.6                              |     :
 22.4                              |      :
 25.2                              |       :
 28.0                              |        :
 30.8                              |        :
 33.6                              |     :
 36.4                              | :
 39.2                             :|
 42.0                           :  |
 44.8                         :    |
 47.6                      :       |
 50.4                  :           |
 53.2         :                    |
 56.0:                             |
```

MUESER RUTLEDGE CONSULTING ENGINEERS

Anchored Wall Analysis V2.1 for Windows

Subject:

FREE EARTH METHOD
For an anchored wall with the following input:

p (ksf)	q (ksf)	interval (ft)
0.240	0.656	10.00
0.516	0.536	1.00
0.536	0.701	2.00
0.701	0.821	3.00
0.721	0.791	3.50
0.765	0.861	5.00
1.533	1.552	0.50

Pressure at slope (ksf): -1.552
Pressure slope (ksf/ft): 0.45

Flexural rigidity of wall [EI} (k-ft^2): 45635

Distance from top of wall to anchor (ft): 6.5

Results from analysis:

d = 9.09 ft embedment below z = 25.00 $D(FOS=1.2) = 1.2(9.09\,ft) = 10.9'$ [EL. -23]
with FS=1.0

Total wall length = 34.09 ft

Anchor Pull = 11.54 k/ft
Moment at anchor = 6.97 k-ft/ft
Shear at anchor = 9.10 k/ft

Maximum positive moment = 58.72 k-ft/ft

Maximum moment = 58.72 k-ft/ft $M_{ALL} = 0.6(50\,ksi)(32.91\,in^3/ft)(1'/12'') = 82.3\,k\text{-}ft$ OK
Location of maximum moment = 19.98 ft below top of wall

Maximum shear = 9.10 k/ft

Maximum load = -2.54 ksf/ft
Maximum defl. = -1.15 in at 20.45 ft below top of wall

$\delta_{max} = 1.15$ ∴ OK

X (ft)	P (ksf/ft)	V (k/ft)	M (k-ft/ft)	DEF (in)
0.00	0.24	0.00	0.00	0.83
1.70	0.31	0.47	-0.38	0.61
3.41	0.38	1.06	-1.67	0.40
5.11	0.45	1.77	-4.06	0.18
6.82	0.52	-8.93	-4.12	-0.04
8.52	0.59	-7.98	10.31	-0.26
10.23	0.52	-6.94	23.02	-0.48
11.93	0.61	-6.00	34.07	-0.68
13.63	0.73	-4.84	43.33	-0.84
15.34	0.79	-3.54	50.49	-0.99
17.04	0.74	-2.25	55.40	-1.08
18.75	0.78	-0.95	58.14	-1.15
20.45	0.78	0.37	58.63	-1.15
22.16	0.82	1.74	56.85	-1.13
23.86	0.85	3.15	52.69	-1.05
25.56	1.30	5.28	45.70	-0.94
27.27	0.53	6.83	35.19	-0.78
28.97	-0.24	7.09	23.14	-0.61
30.68	-1.00	6.03	11.78	-0.41
32.38	-1.77	3.67	3.33	-0.21
34.09	-2.54	0.00	0.01	0.00

```
                              Pressure    (P/Pmax)

    1.0            0.5            0.0            -.5           -1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0                           *  |
  1.7                          *   |
  3.4                         *    |
  5.1                         *    |
  6.8                        *     |
  8.5                       *      |
 10.2                        *     |
 11.9                       *      |
 13.6                     *        |
 15.3                     *        |
 17.0                     *        |
 18.7                     *        |
 20.5                     *        |
 22.2                    *         |
 23.9                    *         |
 25.6               *              |
 27.3                        *     |
 29.0                              |  *
 30.7                              |           *
 32.4                              |                    *
 34.1                              |                             *
```

```
                           Moment    (M/Mmax)

    1.0            0.5            0.0            -.5           -1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0                              *
  1.7                              *
  3.4                             *|
  5.1                            * |
  6.8                            * |
  8.5                              |    *
 10.2                              |           *
 11.9                              |                *
 13.6                              |                     *
 15.3                              |                         *
 17.0                              |                           *
 18.7                              |                             *
 20.5                              |                             *
 22.2                              |                            *
 23.9                              |                          *
 25.6                              |                      *
 27.3                              |                 *
 29.0                              |           *
 30.7                              |     *
 32.4                              | *
 34.1                              *
```

```
                            Shear    (V/Vmax)

    1.0            0.5            0.0            -.5           -1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0                              *
  1.7                              | *
  3.4                              |  *
  5.1                              |     *
  6.8  *                           |
  8.5     *                        |
 10.2        *                     |
 11.9           *                  |
 13.6               *              |
 15.3                   *          |
 17.0                        *     |
 18.7                            * |
 20.5                              |*
 22.2                              |     *
 23.9                              |         *
 25.6                              |                *
 27.3                              |                      *
 29.0                              |                      *
 30.7                              |                   *
 32.4                              |           *
 34.1                              *
```

```
                    Deflection    (DELTA/DELTAmax)

    1.0            0.5            0.0            -.5           -1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0        *                     |
  1.7              *               |
  3.4                    *         |
  5.1                         *    |
  6.8                              |*
  8.5                              |      *
 10.2                              |           *
 11.9                              |                 *
 13.6                              |                     *
 15.3                              |                         *
 17.0                              |                           *
 18.7                              |                             *
 20.5                              |                             *
 22.2                              |                            *
 23.9                              |                          *
 25.6                              |                       *
 27.3                              |                   *
 29.0                              |               *
 30.7                              |          *
 32.4                              |    *
 34.1                              *
```

MUESER RUTLEDGE CONSULTING ENGINEERS

SHEET ____ OF ____

FILE 12582B

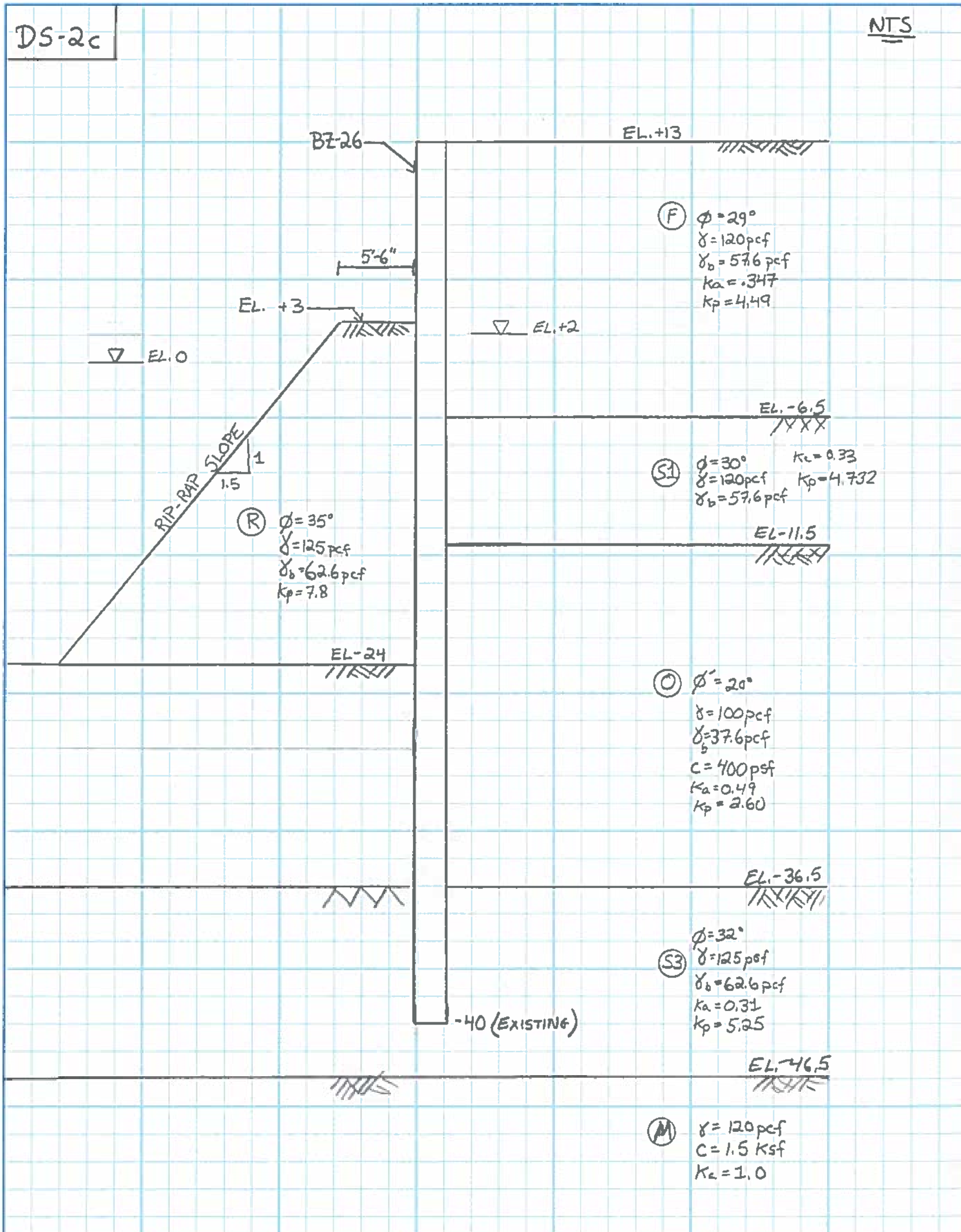
MADE BY ZM DATE 1/11/2016

CHECKED BY ____ DATE ____

PROJECT Wills Wharf Office / Hotel

SUBJECT WILLS STREET BULKHEAD - PROPOSED (RIP RAP OPTION)

DS-2c



SHEET ____ OF ____

MUESER RUTLEDGE CONSULTING ENGINEERS

FILE 12582B

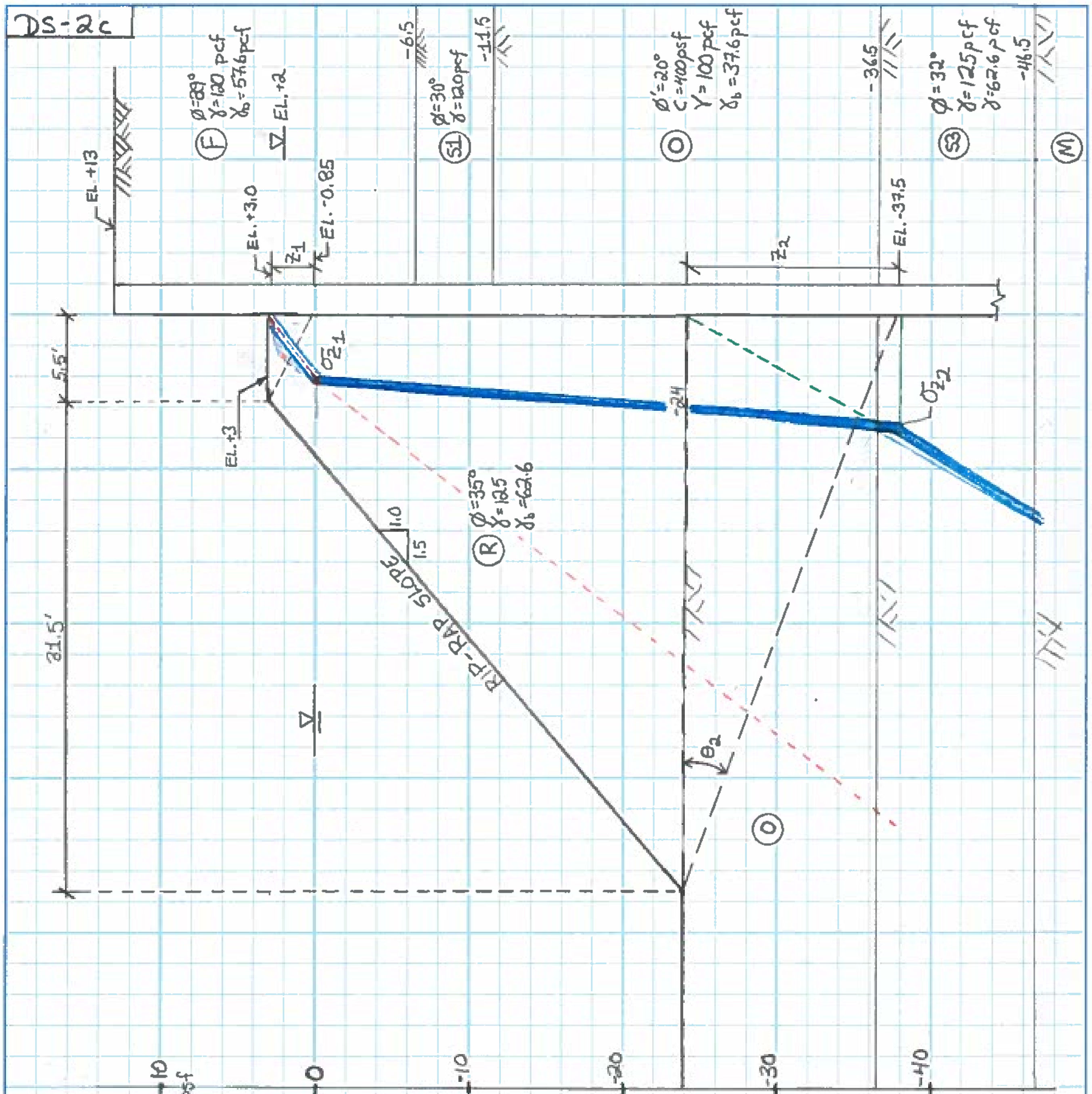
PROJECT: Harbor Point Development

MADE BY: ZM DATE: 1/11/2016

CHECKED BY: ____ DATE: ____

SUBJECT: Wills St. Wharf Bulkhead – Rip Rap Berm Option

DS-2c



$\theta_1 = 45 - \frac{35}{2} = 27.5°$

$\theta_2 = 45 - \frac{20}{2} = 35°$

$Z_1 = 5.5' \tan(35°) = 3.85'$

$Z_2 = (31.5' + 5.5') \tan(20°) = 13.5'$

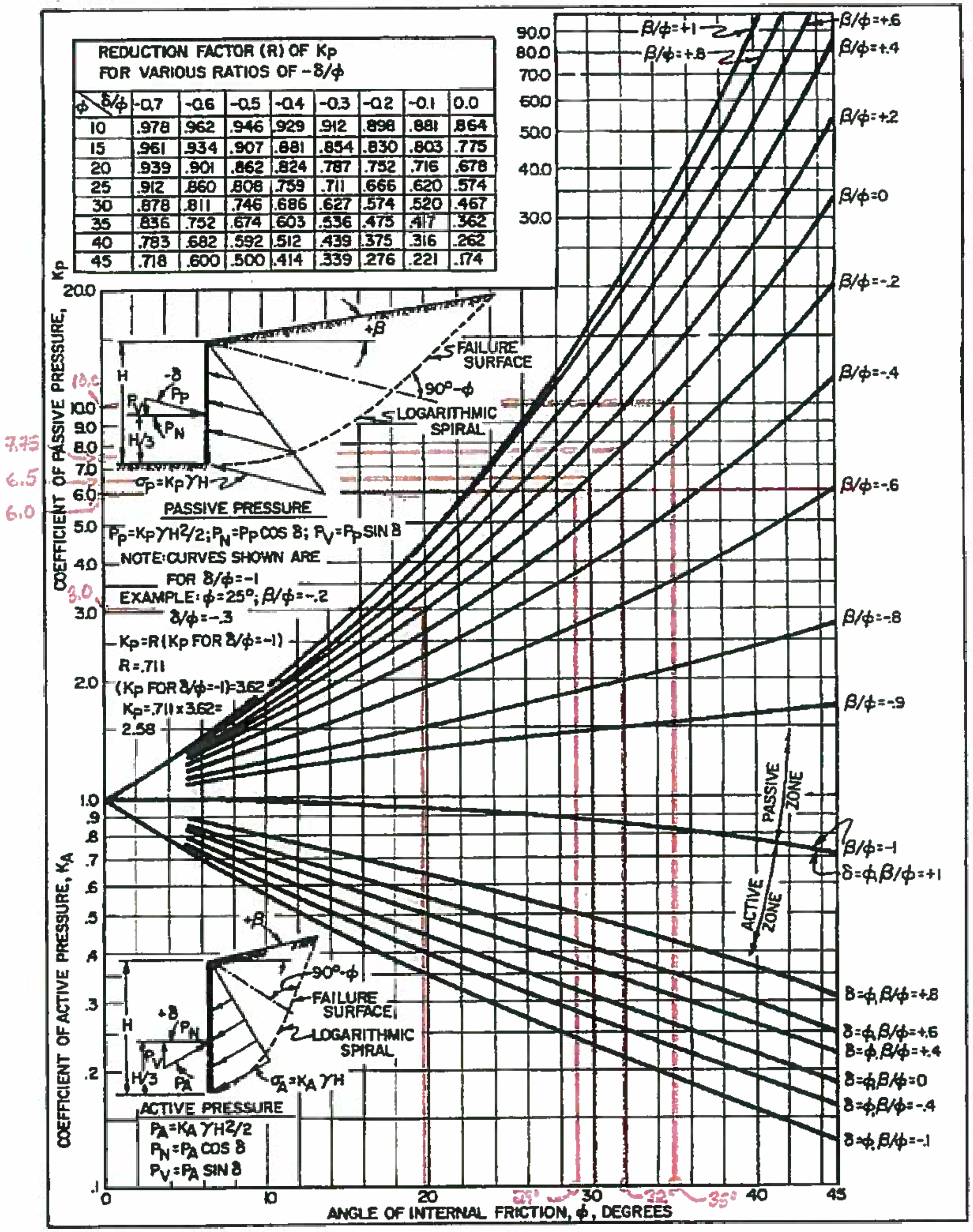
$\sigma_{z1} = 3.85'(125 pcf) = 481.25 psf$

$\sigma_{z2} = 12.5'(37.6) + 1'(62.6) = 532.6 psf$

TABLE 1
Ultimate Friction Factors and Adhesion for Dissimilar Materials

Interface Materials	Friction factor, tan [delta]	Friction angle [delta] degrees
Mass concrete on the following foundation materials:		
Clean sound rock................................	0.70	35
Clean gravel, gravel-sand mixtures, coarse sand...	0.55 to 0.60	29 to 31
Clean fine to medium sand, silty medium to coarse sand, silty or clayey gravel....................	0.45 to 0.55	24 to 29
Clean fine sand, silty or clayey fine to medium sand...	0.35 to 0.45	19 to 24
Fine sandy silt, nonplastic silt..................	0.30 to 0.35	17 to 19
Very stiff and hard residual or preconsolidated clay..	0.40 to 0.50	22 to 26
Medium stiff and stiff clay and silty clay........	0.30 to 0.35	17 to 19
(Masonry on foundation materials has same friction factors.)		
Steel sheet piles against the following soils:		
Clean gravel, gravel-sand mixtures, well-graded rock fill with spalls..........................	0.40	22
Clean sand, silty sand-gravel mixture, single size hard rock fill................................	0.30	17
Silty sand, gravel or sand mixed with silt or clay	0.25	14
Fine sandy silt, nonplastic silt..................	0.20	11
Formed concrete or concrete sheet piling against the following soils:		
Clean gravel, gravel-sand mixture, well-graded rock fill with spalls..........................	0.40 to 0.50	22 to 26
Clean sand, silty sand-gravel mixture, single size hard rock fill................................	0.30 to 0.40	17 to 22
Silty sand, gravel or sand mixed with silt or clay	0.30	17
Fine sandy silt, nonplastic silt..................	0.25	14
Various structural materials:		
Masonry on masonry, igneous and metamorphic rocks:		
Dressed soft rock on dressed soft rock..........	0.70	35
Dressed hard rock on dressed soft rock..........	0.65	33
Dressed hard rock on dressed hard rock..........	0.55	29
Masonry on wood (cross grain).....................	0.50	26
Steel on steel at sheet pile interlocks...........	0.30	17

Interface Materials (Cohesion)	Adhesion c+a, (psf)
Very soft cohesive soil (0 - 250 psf)	0 - 250
Soft cohesive soil (250 - 500 psf)	250 - 500
Medium stiff cohesive soil (500 - 1000 psf)	500 - 750
Stiff cohesive soil (1000 - 2000 psf)	750 - 950
Very stiff cohesive soil (2000 - 4000 psf)	950 - 1,300



REDUCTION FACTOR (R) OF Kp FOR VARIOUS RATIOS OF -δ/φ

φ \ δ/φ	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0.0
10	.978	.962	.946	.929	.912	.898	.881	.864
15	.961	.934	.907	.881	.854	.830	.803	.775
20	.939	.901	.862	.824	.787	.752	.716	.678
25	.912	.860	.808	.759	.711	.666	.620	.574
30	.878	.811	.746	.686	.627	.574	.520	.467
35	.836	.752	.674	.603	.536	.475	.417	.362
40	.783	.682	.592	.512	.439	.375	.316	.262
45	.718	.600	.500	.414	.339	.276	.221	.174

FIGURE 6
Active and Passive Coefficients with Wall Friction
(Sloping Backfill)

Sheet No.______ Of______

MUESER RUTLEDGE CONSULTING ENGINEERS

File 12582A

Made By ZM Date 01/06/16

FOR Harbor Point Development

Checked By ______ Date ______

SUBJECT: **PASSIVE PRESSURE COEFFICIENTS WITH WALL FRICTION**

Fill (F): $\phi := 29 \cdot deg$ $\delta := 14deg$ $\frac{\delta}{\phi} = 0.48$ Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of subgrade $\beta := 0 \cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 6.0$

From reduction factor (R) table, $\phi_1 := 25 \cdot deg$ $\phi_2 := 30 \cdot deg$

For $\frac{\delta}{\phi} = 0.48$ Reduction factor $r_{25} := 0.759 + \frac{\left(\frac{\delta}{\phi} - 0.4\right) \cdot (0.808 - 0.759)}{(0.5 - 0.4)}$ $r_{25} = 0.8$

For $\frac{\delta}{\phi} = 0.48$ Reduction factor $r_{30} := 0.686 + \frac{\left(\frac{\delta}{\phi} - 0.4\right) \cdot (0.746 - 0.686)}{(0.5 - 0.4)}$ $r_{30} = 0.736$

Thus, Reduction factor $r_{29} := r_{25} - \left[\frac{(\phi - \phi_1) \cdot (r_{25} - r_{30})}{(\phi_2 - \phi_1)}\right]$ $r_{29} = 0.748$

Therefore, effective Kp with wall friction is: $K_p := (r_{29}) \cdot (K_p)$ $\boxed{K_p = 4.49}$

Medium Sands (S1): $\phi := 30 \cdot deg$ $\delta := 14deg$ $\frac{\delta}{\phi} = 0.47$ Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of grade $\beta := 0 \cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 6.5$

For $\frac{\delta}{\phi} = 0.47$ Reduction factor $r_{30} := 0.686 + \frac{\left(\frac{\delta}{\phi} - 0.4\right) \cdot (0.746 - 0.686)}{(0.5 - 0.4)}$ $r_{30} = 0.73$

Therefore effective Kp with wall friction is: $K_p := (r_{30}) \cdot (K_p)$ $\boxed{K_p = 4.719}$

Sheet No.________ Of ________

MUESER RUTLEDGE CONSULTING ENGINEERS

File 12582A

Made By ZM Date 01/06/16

FOR Harbor Point Development

Checked By ________ Date ________

SUBJECT: **PASSIVE PRESSURE COEFFICIENTS WITH WALL FRICTION**

Silty Sands (S3): $\phi := 32\cdot deg$ $\delta := 14deg$ $\frac{\delta}{\phi} = 0.44$

Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of subgrade $\beta := 0\cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 7.75$

From reduction factor (R) table, $\phi_1 := 30\cdot deg$ $\phi_2 := 35\cdot deg$

For $\frac{\delta}{\phi} = 0.44$ Reduction factor $r_{30} := 0.686 + \frac{\left(\frac{\delta}{\phi} - 0.4\right)\cdot(.746 - .686)}{(0.5 - 0.4)}$ $r_{30} = 0.709$

For $\frac{\delta}{\phi} = 0.44$ Reduction factor $r_{35} := 0.603 + \frac{\left(\frac{\delta}{\phi} - 0.4\right)\cdot(.674 - .603)}{(0.5 - 0.4)}$ $r_{35} = 0.630$

Thus, Reduction factor $r_{32} := r_{30} - \left[\frac{(\phi - \phi_1)\cdot(r_{30} - r_{35})}{(\phi_2 - \phi_1)}\right]$ $r_{32} = 0.677$

Therefore, effective Kp with wall friction is: $K_p := (r_{32})\cdot(K_p)$ $\boxed{K_p = 5.25}$

Organic Silt (O): $\phi := 20\cdot deg$ $\delta := 11deg$ $\frac{\delta}{\phi} = 0.55$

Friction angle for Sheet piles on fine sandy silt, nonplastic silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of grade $\beta := 0\cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 3.0$

For $\frac{\delta}{\phi} = 0.55$ Reduction factor $r_{20} := 0.862 + \frac{\left(\frac{\delta}{\phi} - 0.5\right)\cdot(0.901 - 0.862)}{(0.6 - 0.5)}$ $r_{20} = 0.88$

Therefore effective Kp with wall friction is: $K_p := (r_{20})\cdot(K_p)$ $\boxed{K_p = 2.6}$

Sheet No.________ Of________

MUESER RUTLEDGE CONSULTING ENGINEERS

File 12582A

Made By ZM Date 01/06/16

FOR Harbor Point Development

Checked By ________ Date ________

SUBJECT: **PASSIVE PRESSURE COEFFICIENTS WITH WALL FRICTION**

RIP RAP (R): $\phi := 35\cdot deg$ $\delta := 22deg$ $\frac{\delta}{\phi} = 0.63$ Friction angle for Sheet piles on silty sand or sands mixed with silt [Table 1 DM7.2-63]

Assuming wall friction for K_p

Slope of grade $\beta := 0\cdot deg$ From DM 7.02, Figure 5 (attached), $K_p := 10.0$

For $\frac{\delta}{\phi} = 0.63$ Reduction factor $r_{35} := 0.752 + \frac{\left(\frac{\delta}{\phi} - 0.6\right)\cdot(0.836 - 0.752)}{(0.7 - 0.6)}$ $r_{35} = 0.78$

Therefore effective Kp with wall friction is: $K_p := (r_{35})\cdot(K_p)$ $\boxed{K_p = 7.8}$

MUESER RUTLEDGE CONSULTING ENGINEERS

Sheet No. ______ Of ______

FOR : **Wills Wharf Office / Hotel**

FILE 12582B

MADE BY ZM DATE 01/11/16

CHECKED BY ______ DATE ______

SUBJECT: **STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-2c)**

Lateral Earth Pressures:

DRIVING FORCES												RESISTING FORCES												
Layer	Elev.	H	γ	σ_v	φ	k_a	c	R_a	Active Pressures	Surcharge*	Sidewalk Surcharge	Net Water Pressures	Layer	Elev.	H	γ	σ_v	k_p	R_p	c	φ	Passive Pressures	Total Pressures	Elev.
	(ft)	(ft)	(pcf)	(psf)	°		(psf)		(psf)	(psf)		(psf)		(ft)	(ft)	(pcf)	(psf)			(psf)	°	(psf)	(psf)	(ft)
F	13	0	120	0	29	0.347	0	1.0	0	240		0											240	13
	4.5	8.5	120	1020	29	0.347	0	1.0	354	240	0	0											594	4.5
	4.5	0	120	1020	29	0.347	0	1.0	354	240	0	0											594	4.5
	3	1.5	120	1200	29	0.347	0	1.0	416	240	0	0											656	3
	3	0	57.6	1200	29	0.347	0	1.0	416	100	0	0	R	3	0	125	0	7.80	1.000	0	35	0	516	3
	2	1	57.6	1258	29	0.347	0	1.0	436	100	0	0		2	1	125	125	7.80	1.000	0	35	-975	-439	2
	2	0	57.6	1258	29	0.347	0	1.0	436	100	0	0		2	0	125	125	7.80	1.000	0	35	-975	-439	2
	0	2	57.6	1373	29	0.347	0	1.0	476	100	0	125		0	2	125	375	7.80	1.000	0	35	-2925	-2224	0
	0	0	57.6	1373	29	0.347	0	1.0	476	100	0	125		0	0	62.6	375	7.80	1.000	0	35	-2925	-2224	0
	-0.85	0.85	57.6	1422	29	0.347	0	1.0	493	100	0	125		-0.85	0.85	62.6	481.0	7.80	1.000	0	35	-3752	-3034	-0.85
	-3	2.15	57.6	1546	29	0.347	0	1.0	536	100	0	125		-3	2.15	62.6	484.0	7.80	1.000	0	35	-3775	-3014	-3
	-3	0	57.6	1546	29	0.347	0	1.0	536	0	0	125		-3	0	62.6	484.0	7.80	1.000	0	35	-3775	-3114	-3
	-6.5	3.5	57.6	1747	29	0.347	0	1.0	606	0	0	125		-6.5	3.5	62.6	489.0	7.80	1.000	0	35	-3814	-3083	-6.5
S1	-6.5	0	57.6	1747	30	0.333	0	1.0	582	0	0	125		-6.5	0	62.6	489.0	7.80	1.000	0	35	-3814	-3107	-6.5
	-11.5	5	57.6	2035	30	0.333	0	1.0	678	0	0	125		-11.5	5	62.6	496.0	7.80	1.000	0	35	-3869	-3066	-11.5
O	-11.5	0	37.6	2035	0	1.000	400	1.0	1235	0	0	125		-11.5	0	62.6	496.0	7.80	1.000	0	35	-3869	-2509	-11.5
	-12	0.5	37.6	2054	0	1.000	400	1.0	1254	0	0	125		-12	0.5	62.6	496.7	7.80	1.000	0	35	-3874	-2495	-12
	-12	0	37.6	2054	0	1.000	400	1.0	1254	0	0	125		-12	0	62.6	496.7	7.80	1.000	0	35	-3874	-2495	-12
	-24	12	37.6	2505	0	1.000	400	1.0	1705	0	0	125		-24	12	62.6	513.6	7.80	1.000	0	35	-4006	-2176	-24
	-24	0	37.6	2505	0	1.000	400	1.0	1705	0	0	125	O	-24	0	37.6	513.6	2.64	1.000	400	0	-2656	-826	-24
	-36.5	12.5	37.6	2975	0	1.000	400	1.0	2175	0	0	125		-36.5	12.5	37.6	531.2	2.64	1.000	400	0	-2702	-402	-36.5
S3	-36.5	0	62.6	2975	32	0.307	0	1.0	914	0	0	125	S3	-36.5	0	62.6	531.2	5.25	1.000	0	32	-2789	-1750	-36.5
	-37.5	1	62.6	3038	33	0.295	1	1.0	894	0	0	125		-37.5	1	62.6	532.6	5.25	1.000	0	33	-2796	-1778	-37.5
	-40	3.5	62.6	3194	32	0.307	0	1.0	981	0	0	125		-40	3.5	62.6	750	5.25	1.000	0	32	-3939	-2833	-40
	-46.5	6.5	62.6	3601	32	0.307	0	1.0	1106	0	0	125		-46.5	6.5	62.6	1157	5.25	1.000	0	32	-6075	-4844	-46.5
M	-46.5	0	57.6	3601	0	1.000	1500	1.0	601	0	0	125	M	-46.5	0	57.6	1157	1.00	1.000	1.5	0	-1160	-434	-46.5
	-50	3.5	57.6	3803	0	1.000	1500	1.0	803	0	0	125		-50	3.5	57.6	1359	1.00	1.000	1.5	0	-1362	-434	-50
	-50	0	57.6	3803	0	1.000	1500	1.0	803	0	0	125		-50	0	57.6	1359	1.00	1.000	1.5	0	-1362	-434	-50

$$\sigma_a = \gamma \cdot H \cdot k_a - 2C\cdot\sqrt{k_a} \qquad k_a = \tan^2\left(45 - \frac{\phi}{2}\right)$$

At rest Pressures:

$$\sigma_p = \gamma \cdot H \cdot k_p + 2C\cdot\sqrt{k_p}$$

Passive Pressures:

Reduction Factors applied below subgrade:

Ra = b/s = 1.000

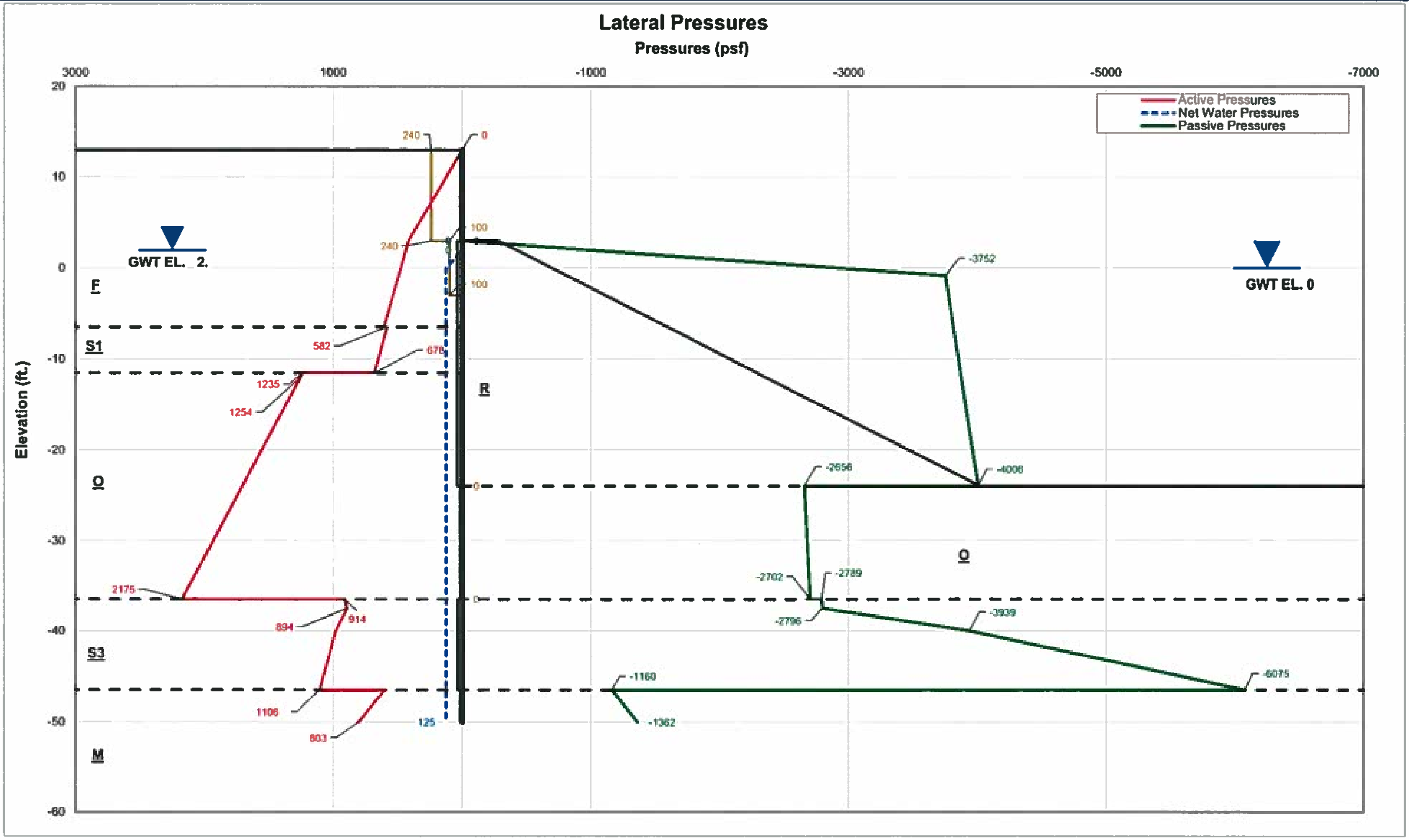
Rp = 3*Ra = 1.000

Undrained Clay Strength Ratio:

c/p Ra 0.2

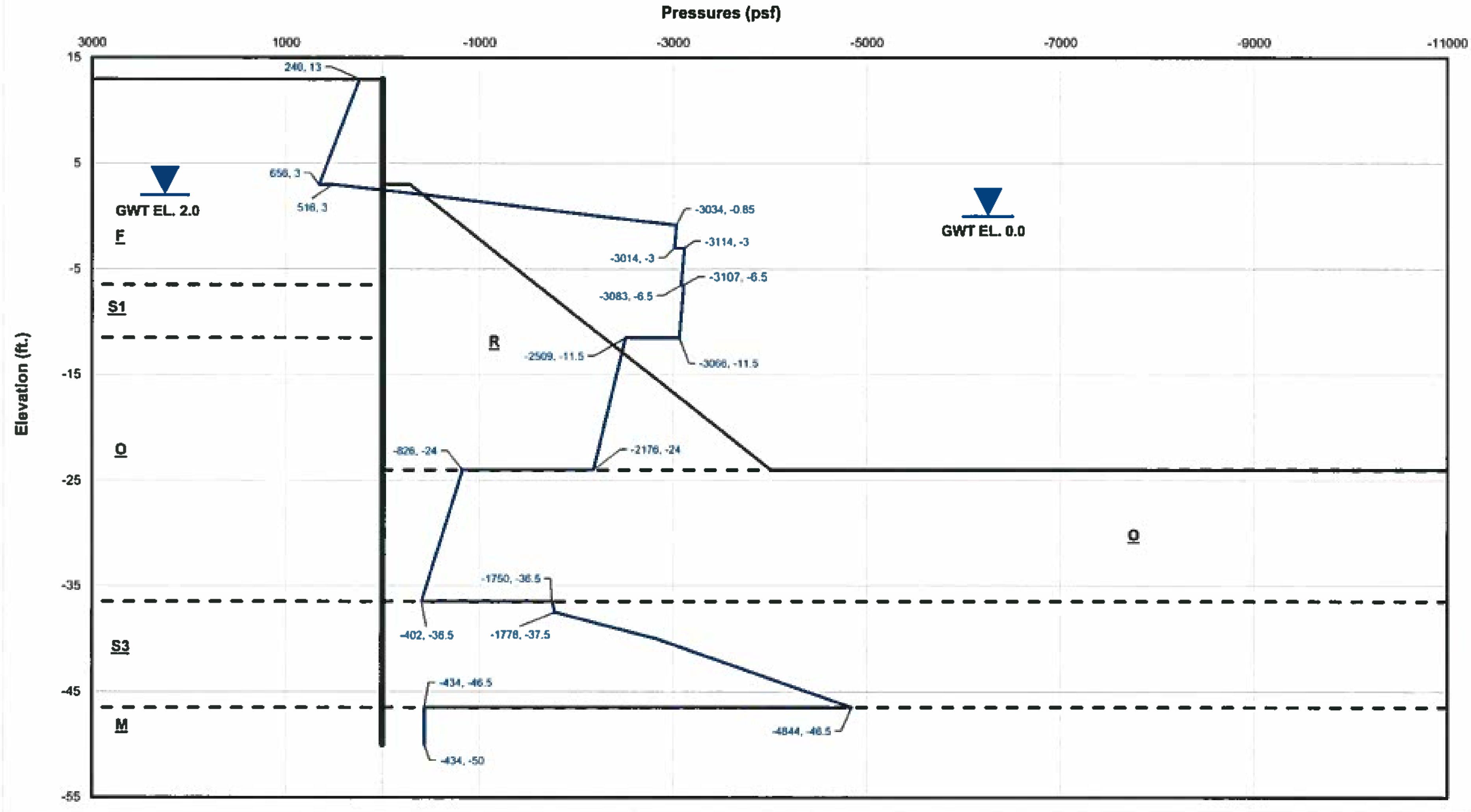
Wall Type: Continous

SUBJECT: **STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-2c)**



SUBJECT: **STAGING ANALYSIS - SHEET PILE WALL South of Wills St. Wharf Building (DS-2c)**

Total Lateral Pressures



MUESER RUTLEDGE CONSULTING ENGINEERS

Cantilever v3.0 BETA for Windows, 32-bit

Subject: DS-2c

INPUT

P	Q	Interval Lengths
0.240	0.656	10.000
0.516	-0.439	1.000
-0.439	-3.034	2.850
-3.034	-3.014	2.150

Passive pressure at subgrade : 3.114
Passive pressure slope :-.009
Flexural rigidity : 45635.08

OUTPUT

At end of int. 1, Shear= 4.48, Moment= 18.93
At end of int. 2, Shear= 4.52, Moment= 23.51
At end of int. 3, Shear= -0.43, Moment= 31.09
At end of int. 4, Shear= -6.93, Moment= 23.17

D= 2.22 embedment below subgrade with F.S.= 1 D(FOS=1.2) = 1.44(3.85'+2.15'+2.22') = 11.83ft [EL. -8.8]

Total Length of sheetpile is 18.22

Depth of max. moment= 13.70

Max. moment= 31.13 k-ft

Depth of max. shear= 18.22

Max. shear= 13.83

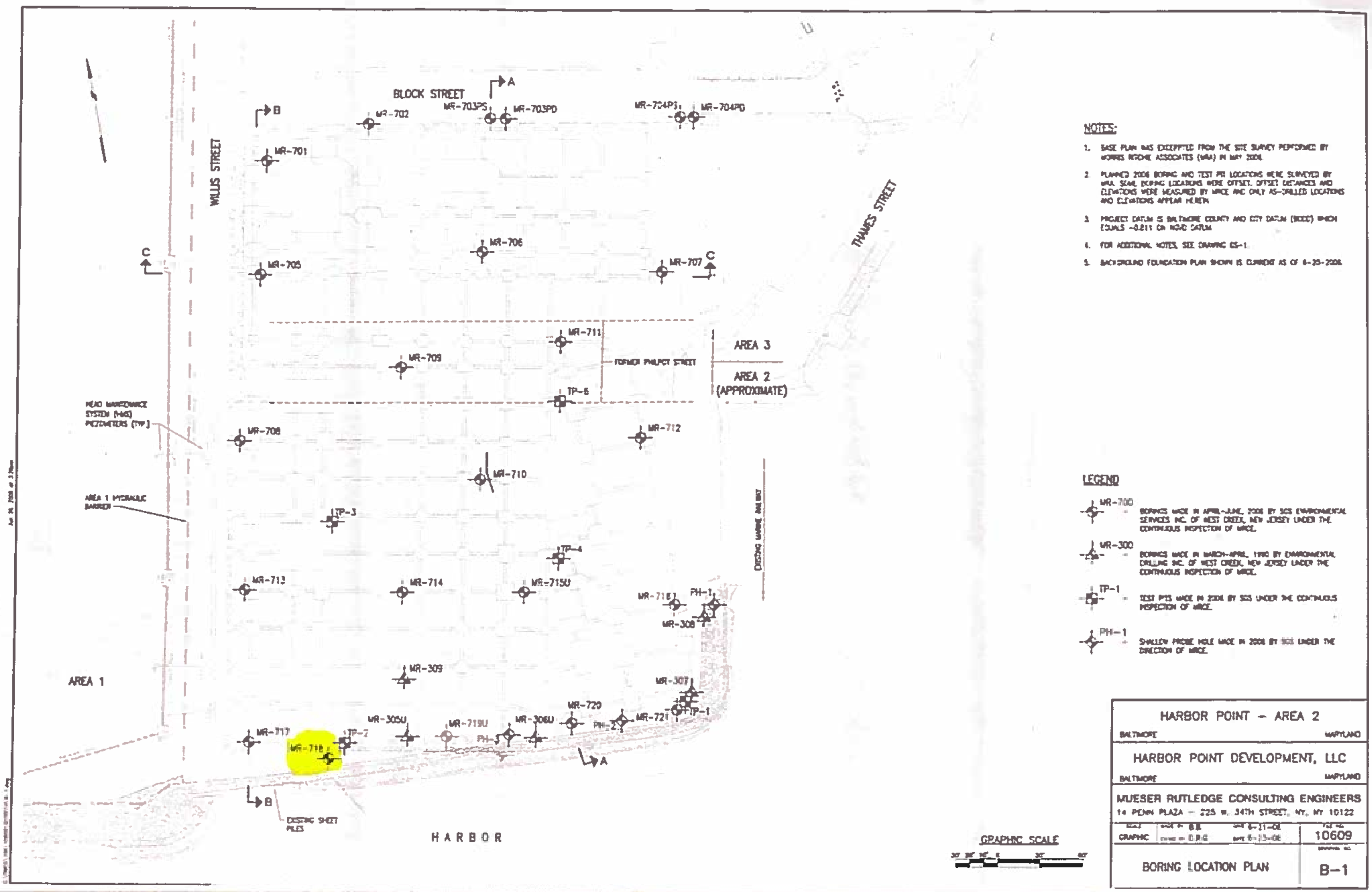
$M_{ALL} = 0.6(50\ ksi)(32.91\ in^3/ft)(1'/12") = 82.3$ k-ft

$M_{max} < M_{ALL}$ ∴ OK

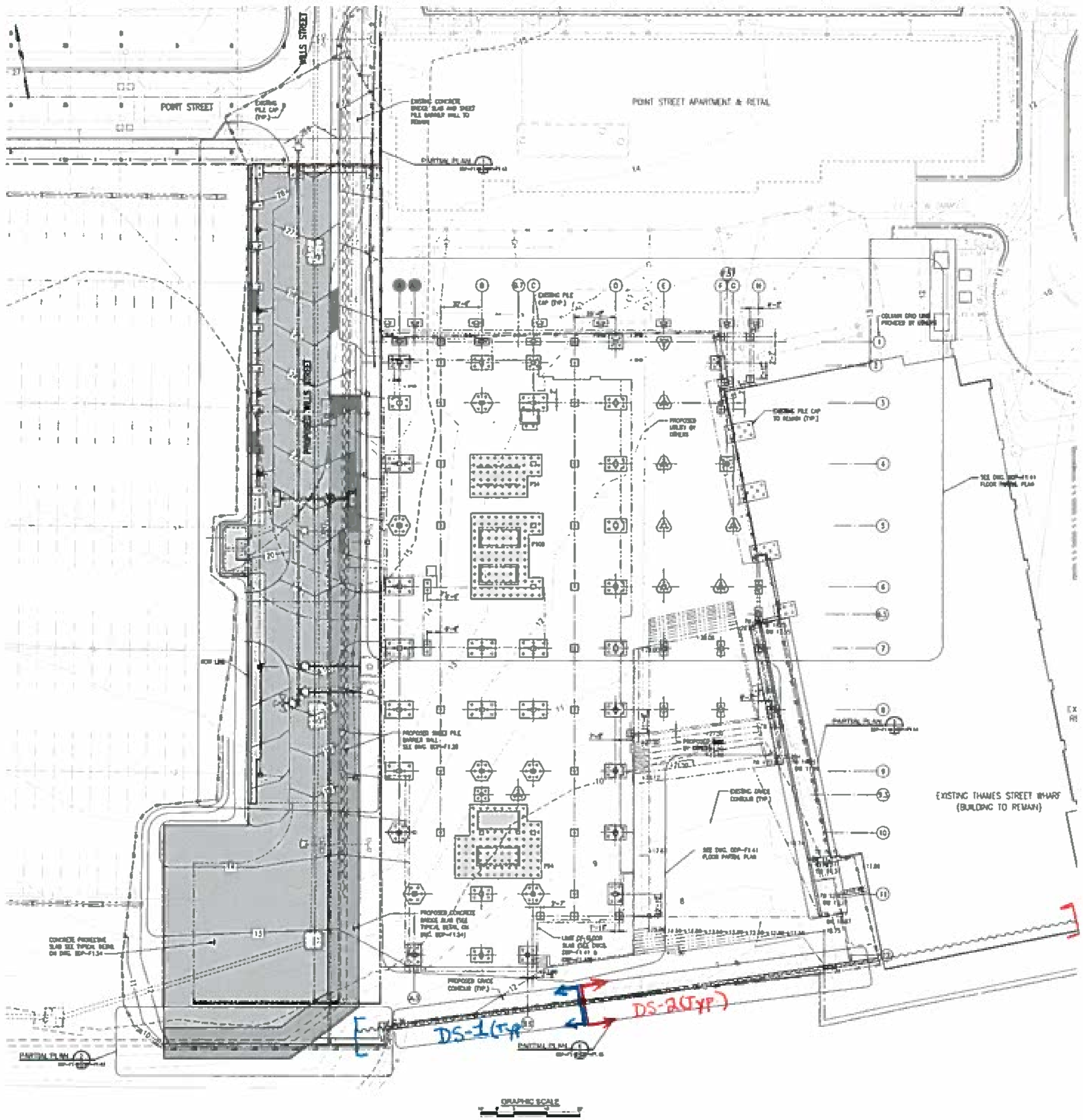
X	V	M	Defl.
0.00	0.00	0.00	0.07
0.91	0.24	0.10	0.06
1.82	0.51	0.44	0.06
2.73	0.81	1.04	0.05
3.64	1.15	1.93	0.05
4.56	1.52	3.15	0.04
5.47	1.93	4.72	0.04
6.38	2.38	6.68	0.03
7.29	2.85	9.06	0.03
8.20	3.37	11.89	0.02
9.11	3.91	15.21	0.02
10.02	4.49	19.03	0.02
10.93	4.55	23.21	0.01
11.84	3.82	27.08	0.01
12.76	2.34	29.95	0.01
13.67	0.11	31.12	0.00
14.58	-2.64	29.98	0.00
15.49	-5.39	26.32	0.00
16.40	-8.18	20.15	0.00
17.31	-11.01	11.41	0.00
18.22	-13.83	0.10	0.00

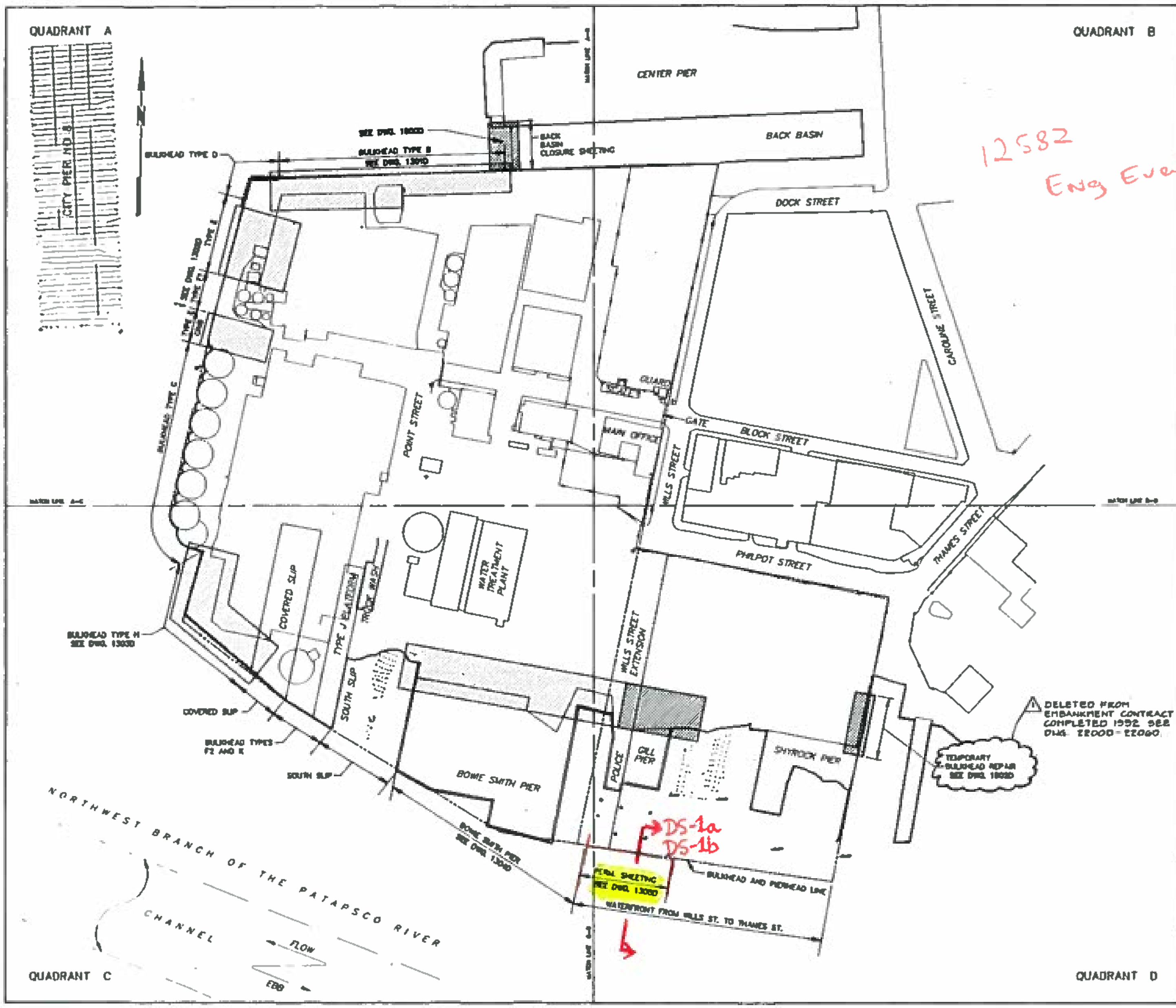
```
   Moment   (M/Mmax)

   -1.0           -0.5            0.0           0.5             1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0                              :
  0.9                              |:
  1.8                              |:
  2.7                              |:
  3.6                              | :
  4.6                              |  :
  5.5                              |    :
  6.4                              |     :
  7.3                              |        :
  8.2                              |          :
  9.1                              |              :
 10.0                              |                 :
 10.9                              |                     :
 11.8                              |                         :
 12.8                              |                            :
 13.7                              |                             :
 14.6                              |                            :
 15.5                              |                        :
 16.4                              |                  :
 17.3                              |          :
 18.2                              |:

   Shear   (V/Vmax)

   -1.0           -0.5            0.0           0.5             1.0
X(ft)+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  0.0                              :
  0.9                              |:
  1.8                              |:
  2.7                              | :
  3.6                              | :
  4.6                              |  :
  5.5                              |   :
  6.4                              |    :
  7.3                              |     :
  8.2                              |      :
  9.1                              |       :
 10.0                              |         :
 10.9                              |         :
 11.8                              |       :
 12.8                              |    :
 13.7                              |:
 14.6                        :     |
 15.5                  :           |
 16.4            :                 |
 17.3      :                       |
 18.2:                             |
```

Boring Map


BLOCK STREET
WILLIS STREET
THAMES STREET
MR-701
MR-702
MR-703PS
MR-703PD
MR-704PS
MR-704PD
MR-705
MR-706
MR-707
MR-708
MR-709
MR-710
MR-711
MR-712
MR-713
MR-714
MR-715U
MR-716
MR-717
MR-718
MR-719U
MR-720
MR-721
MR-305U
MR-306U
MR-307
MR-308
MR-309
TP-1
TP-2
TP-3
TP-4
TP-5
PH-1
PH-2
PH-3
FORMER PHILPOT STREET
AREA 3
AREA 2 (APPROXIMATE)
AREA 1
HEAD MAINTENANCE SYSTEM (HMS) PIEZOMETERS (TYP.)
AREA 1 HYDRAULIC BARRIER
EXISTING MARINE RAILWAY
EXISTING SHEET PILES
HARBOR
NOTES:
1. BASE PLAN WAS EXCERPTED FROM THE SITE SURVEY PERFORMED BY MORRIS RITCHIE ASSOCIATES (MRA) IN MAY 2006.
2. PLANNED 2006 BORING AND TEST PIT LOCATIONS WERE SURVEYED BY MRA. SOME BORING LOCATIONS WERE OFFSET. OFFSET DISTANCES AND ELEVATIONS WERE MEASURED BY MRCE AND ONLY AS-DRILLED LOCATIONS AND ELEVATIONS APPEAR HEREIN.
3. PROJECT DATUM IS BALTIMORE COUNTY AND CITY DATUM (BCCD) WHICH EQUALS -0.811 ON NGVD DATUM.
4. FOR ADDITIONAL NOTES, SEE DRAWING GS-1.
5. BACKGROUND FOUNDATION PLAN SHOWN IS CURRENT AS OF 6-23-2006.
LEGEND
MR-700 BORINGS MADE IN APRIL-JUNE, 2006 BY SGS ENVIRONMENTAL SERVICES INC. OF WEST CREEK, NEW JERSEY UNDER THE CONTINUOUS INSPECTION OF MRCE.
MR-300 BORINGS MADE IN MARCH-APRIL, 1990 BY ENVIRONMENTAL DRILLING INC. OF WEST CREEK, NEW JERSEY UNDER THE CONTINUOUS INSPECTION OF MRCE.
TP-1 TEST PITS MADE IN 2006 BY SGS UNDER THE CONTINUOUS INSPECTION OF MRCE.
PH-1 SHALLOW PROBE HOLE MADE IN 2006 BY SGS UNDER THE DIRECTION OF MRCE.
GRAPHIC SCALE
HARBOR POINT - AREA 2
BALTIMORE
MARYLAND
HARBOR POINT DEVELOPMENT, LLC
BALTIMORE
MARYLAND
MUESER RUTLEDGE CONSULTING ENGINEERS
14 PENN PLAZA - 225 W. 34TH STREET, NY, NY 10122
GRAPHIC
10609
BORING LOCATION PLAN
B-1

Design Section Location Plan





GENERAL SHEETING AND SHORING NOTES:

1. See Drawing 1101D for General Notes, Site Legend, and bulkhead, slip and pier designations.
2. Work staging areas are shown on Drawing 1102D. Materials shall be stored on barges or in the designated work staging areas.
3. Construction surcharge loading is not permitted within 30 ft of the bulkhead until Embankment Fill is placed to Elev. −10 adjacent to the bulkhead.
4. Steel H-Piles, steel sheeting, and structural steel installed outboard of the bulkhead shall be transported to and from the site by barge.
5. Used steel will be accepted for temporary sheeting and shoring. New steel is required for permanent sheeting east of Wills St. and the Back Basin closure sheeting. All used steel shall be free of structural defects caused by, scaling, flaking, rusting or pitting. Contractor may substitute stronger sections.
6. Actual location of temporary shoring structures outboard of the bulkhead will be determined by the Contractor and approved by the Owner prior to installation.
7. Batter piles shall be driven to the capacity shown as determined from the penetration resistance using the Engineering News formula or to the minimum tip elevation shown, whichever is deeper.
8. Vertical piles shall be driven to the minimum tip elevation shown.
9. Batter piles shall be cut true to the surface and ground smooth for full contact with vertical piles.
10. Temporary structures shall be removed after the embankment fill is at Elev. −10 adjacent to the bulkhead:
    - A. H-Piles, sheeting, and structural steel outboard of the bulkhead shall be extracted as indicated, and shall be washed upon extraction with a high pressure jet.
    - B. If requested, small pieces of steel shall be removed from the steel members after extraction and washing, and provided to the Owner for chemical testing.
11. Steel sections and pieces shall not be dropped into the Harbor waters. Clean materials, cut steel sections, and supplies shall be collected and removed from the site.

LEGEND

AREA OF TEMPORARY CONSTRUCTION

AREA OF PERMANENT CONSTRUCTION

80' 40' 0 80' 160'

GRAPHIC SCALE

NO.	DESCRIPTION	DATE	BY
	RECORD DRAWING	4/25/??	PD
△	CONSTRUCTED CONDITION NOTED	[illegible]	PD
	RECORD DRAWING-DRAFT	1/14/??	JR
0	ISSUE FOR BID PURPOSES	[illegible]	[illegible]

MUESER RUTLEDGE CONSULTING ENGINEERS
708 THIRD AVENUE, NEW YORK, N.Y. 10017

FILE NO. 6909

CONSULTING ENGINEERS
PHILADELPHIA, PENNSYLVANIA

PROJECT NO. 04190

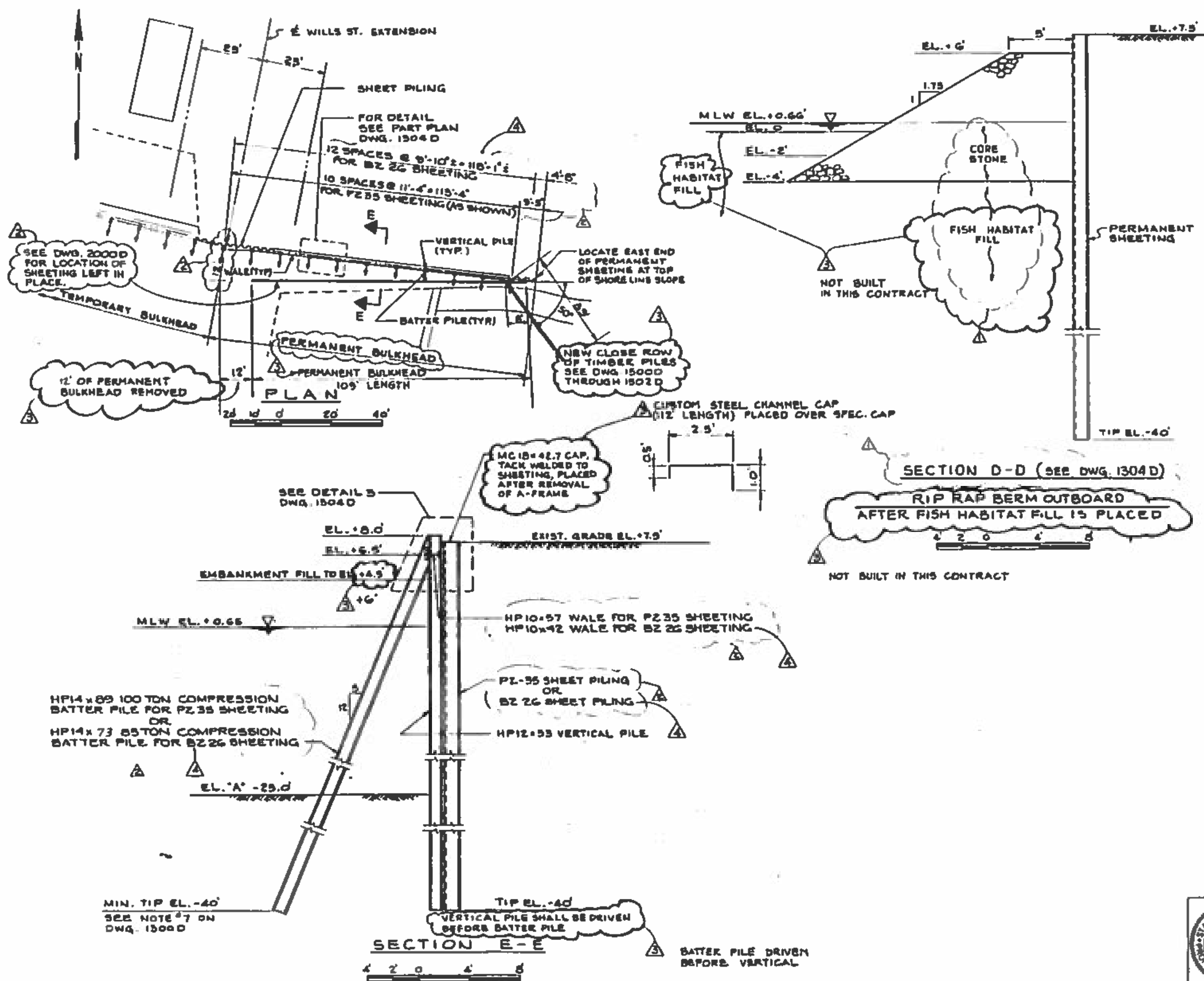
AlliedSignal
ENGINEERED MATERIALS SECTOR
ENGINEERING DEPARTMENT

31831-60
LOCATION BALTIMORE

BALTIMORE WORKS REMEDIATION

SHEETING AND SHORING
GENERAL PLAN

DRAWING NO. 1300D
SHEET 8 OF 75



NOTES:

1. See Drawing 1300D for General Sheeting and Shoring Notes and location of w'pt.
2. See Drawings 1200D, 1203D, and 1303D for pier demolition.
3. See Drawings 1500D through 1502D for Fish Habitat Construction of close row piles.
4. Timber piles which interfere with driving new steel piles shall be pulled before driving new piles. Contractor shall locate existing pier piling in plan and space sheeting and batter pile bents to clear the maximum number of timber pile bents. Align New H-Piles with new sheeting.
5. Contractor may temporarily re-align the tops of vertical piles up to 12 inches to permit driving and cutting of batter piles.
6. Temporary shoring east of Wills St. shall be removed after the Fish Habitat fill is placed to Elev. -2 adjacent to the sheeting.
7. Rip Rap and Core Stone fill shall be placed under Embankment Construction Section 02210 and Drawings 1617D through 1623D as shown after placing Fish Habitat fill. See Drawing 1500D for Fish Habitat Construction.
8. Payment for core stone and rip rap shown on Section D-D will be made for the measured volume placed from the top of Fish Habitat Fill to the final grades shown.

△5 NOT BUILT IN THIS CONTRACT

NO.	DESCRIPTION	DATE	BY	CHK	APP	APP	APP
	RECORD DRAWING	12/3/92	PD	HK	[illegible]	[illegible]	[illegible]
	RECORD DRAWING - DRAFT	1/14/92	JR	HK	[illegible]		
5	BZ SHEETING OPTION INSTALLED	7/9/91	JR	HK			
4	CONSTRUCTED CONDITION NOTED	7/9/91	JR	HK			
3	REVISED FOR ARBED SHEETING	[illegible]	[illegible]	[illegible]	[illegible]		
1	PAYMENT NOTE 8 AND SECTION D-D LABEL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0	ISSUE FOR BID PURPOSES	5/9/90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

WEBER RUTLEDGE CONSULTING ENGINEERS
FILE NO. 6909

CONSULTING ENGINEERS PHILADELPHIA, PENNSYLVANIA
PROJECT NO. 04190

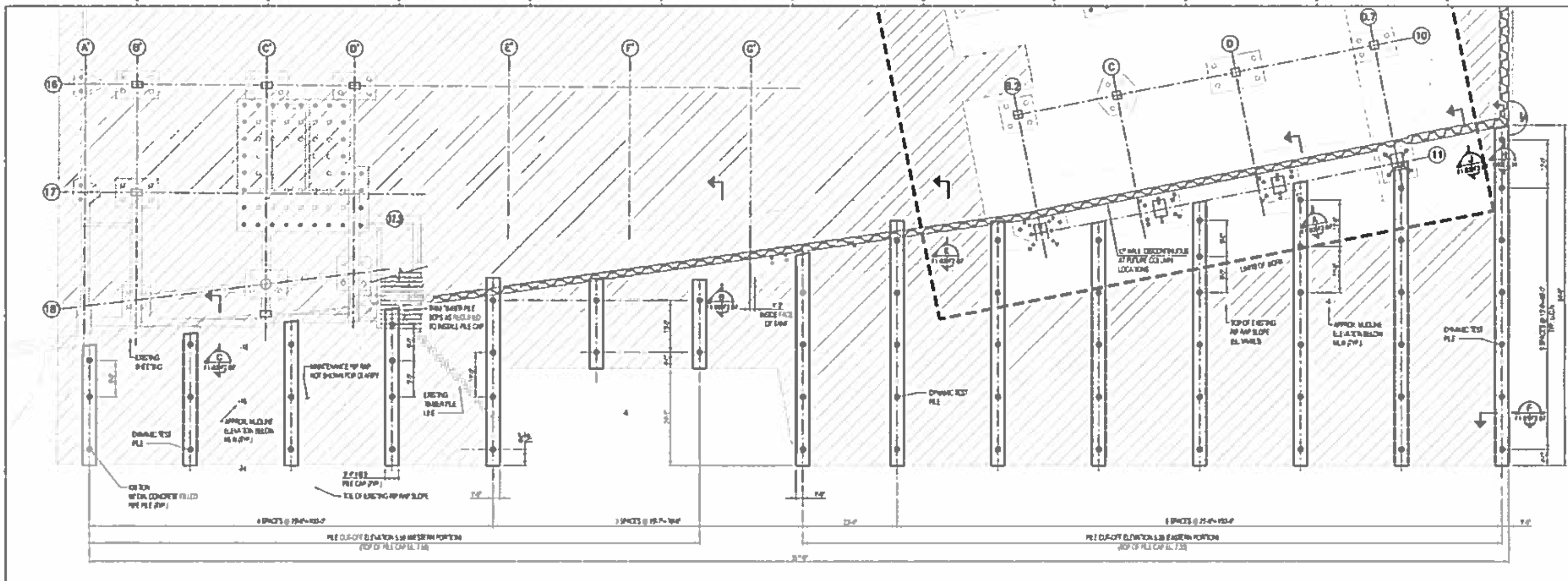
Allied Signal
ENGINEERED MATERIALS SECTOR
ENGINEERING DEPARTMENT
PROJECT NUMBER 31691-60
LOCATION BALTIMORE

BALTIMORE WORKS REMEDIATION

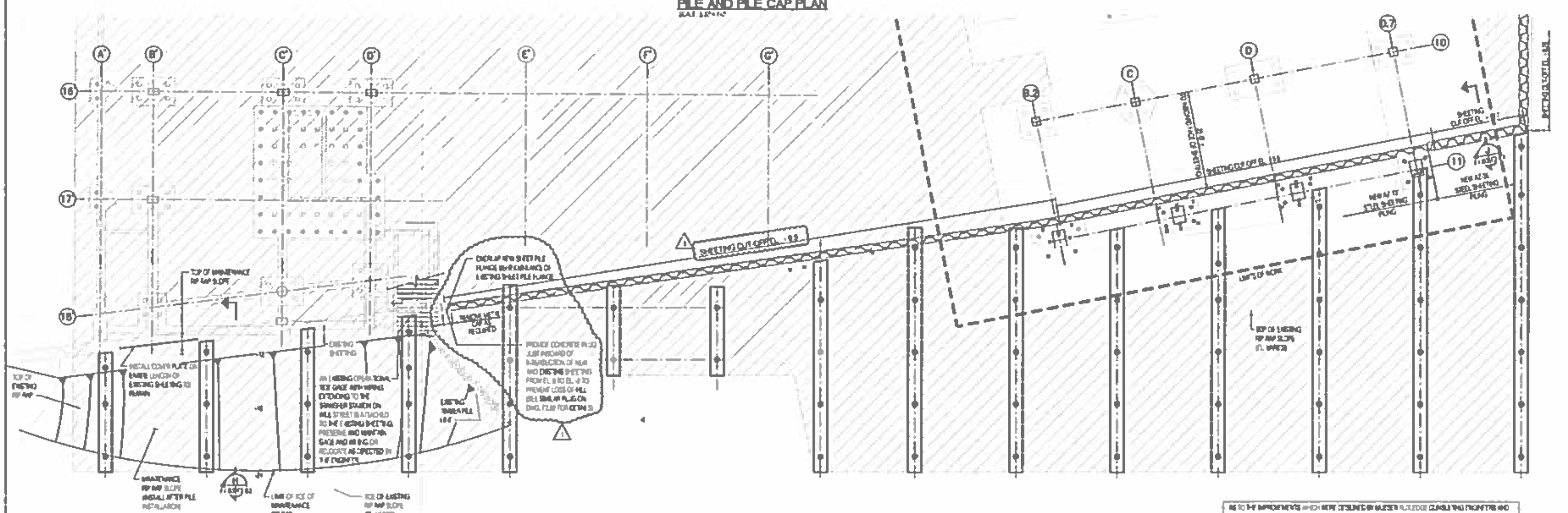
PERMANENT SHEETING EAST OF WILLS ST.

DRAWING NO. 1305D

MRCE 10609



PILE AND PILE CAP PLAN



SHEETING PLAN

PROMENADE MARINE PILE SCHEDULE (16 INCH DIA.)					
Zone	Cut-off Elev.	Estimated Tip Elev.	Estimated Length [ft]	Quantity	Estimated Total Length [ft]
Eastern Portion	5.33	-55	60.33	44	2655
Western Portion	5.58	-55	60.58	21	1272
			Total	65	3927

LEGEND:

NOTES:

GRAPHIC SCALE

HARBOR POINT

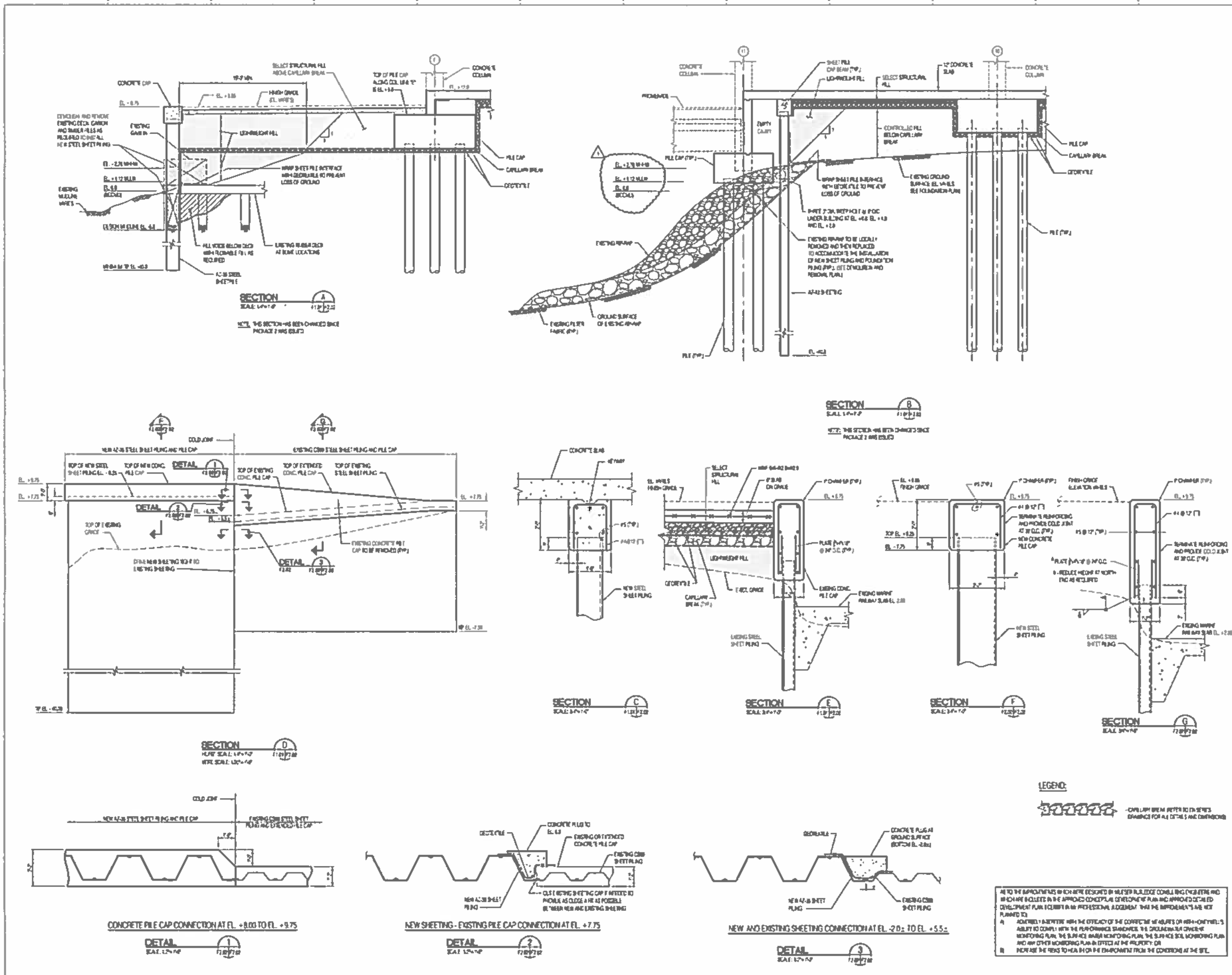
Thames Street Wharf
Office Building + Garage
1300 Thames Street
Baltimore, Maryland 21231

PACKAGE 3

AYERS SAINT GROSS
ARCHITECTS + PLANNERS

PROMENADE AND SHEETING PLAN

F1.03



HARBORPOINT

Thames Street Wharf
Office Building + Garage
Baltimore, Maryland 21231

PACKAGE 3

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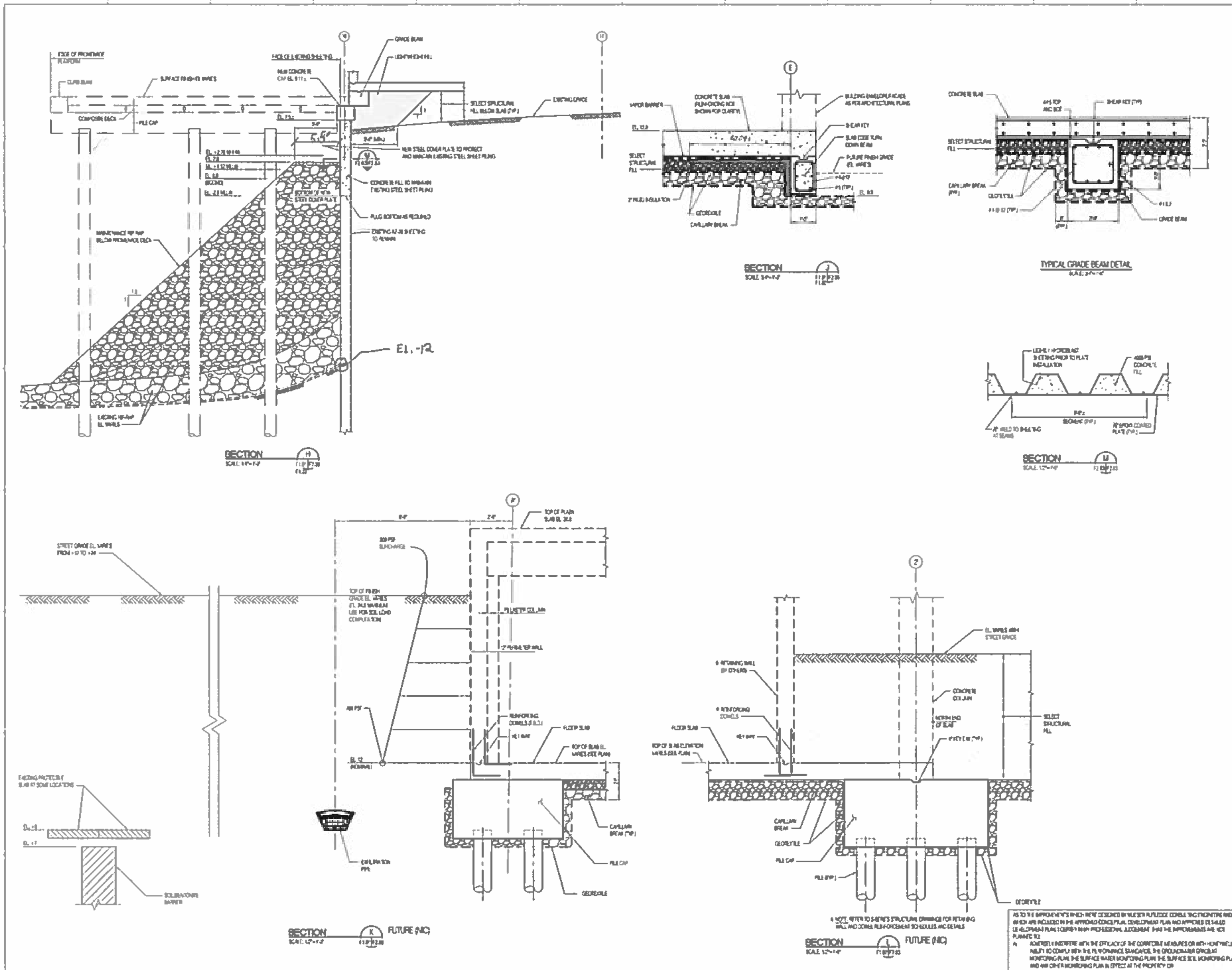
ARCHITECTS + PLANNERS

SECTIONS AND DETAILS

F2.02



HARBORPOINT

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ARCHITECTS + PLANNERS

SECTIONS AND DETAILS

F2.03