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MEMORANDUM

Date:	June 7, 2016 (*Revised June 16, 2016*)
To:	Office
From:	Lysandra Lincoln
Re:	EE Memo 4 – Diverted Flow in Drainage Net from Foundation Construction Wills Wharf, Baltimore, MD
File:	12582A-111

This memorandum summarizes the analysis of impedance to flow and changes in flow direction within the drainage net resulting from construction of foundations for the Wills Wharf development.

Exhibits

Calculation Set 1	Percent Obstruction to Flow within Drainage Net
Calculation Set 2	Assessment of Infiltration to Drainage Net
Table 1	Concrete Retaining Wall Pile Caps
Sketch SK-1	Location plan showing extents of parking lot with pavement surface cover
Sketch SK-2	Location plan showing surface runoff drainage net
Sketch SK-3	Drainage net above existing geomembrane
Sketch SK-4	Drainage net flowing towards concrete retaining wall pile caps
Sketch SK-5	Hydraulic gradient in Area A_2

Available Information

1. Drawing DDP F1.10 – Boring Location Plan
2. Drawing DDP F1.20 – Sheet Pile Barrier Wall Plan, dated April 29, 2016
3. Drawing DDP F1.20-2 – Sheet Pile Barrier Wall Plan, dated April 29, 2016
4. Drawing DDP F1.50 – Foundation Details and Sections, dated April 29, 2016

References

1. "Corrective Measures Implementation Construction Completion Report, Phase I: Soil-Bentonite Hydraulic Barrier Wall, Phase II: Final Remedial Construction" prepared by Black and Veatch, Volumes I and II, February 2000.
2. "Maryland Stormwater Design Manual, Appendix D.13", Maryland Department of the Environment (MDE), 2009.

Multimedia Cap

The Corrective Measures Implementation Report (CMI Report) by Black and Veatch details the construction and layering of the multimedia cap (MMC). The MMC includes a synthetic drainage net on the geomembrane. The MMC was constructed such that water that infiltrates the soil cover will flow away from the center of the cap through the drainage net and will not pond on the membrane. A contour of the surface of the geomembrane layer is presented in Ref. 1. The water flowing through the drainage net is discharged into the embankment along the waterside perimeter, and is collected in a toe drain that runs parallel to the Wills Street extension. The toe drain, which is outboard of the soil-bentonite barrier, conveys water to the embankment where it is allowed to permeate into the porous embankment fill. Since construction of the MMC the site has been largely unused, except for temporary parking. It is presumed that settlement has not created a negative slope of the drainage net and ponding does not occur.

Concrete Retaining Wall Foundations

The Wills Wharf development includes the extension of Wills Street. Wills Street will descend from the existing Plaza Garage at El. +28 south towards the water to El. +12, terminating just north of the promenade being constructed as part of the Project.

Wills Street will be constructed with pile supported concrete retaining walls running north-south and east-west. The north-south retaining wall will run for approximately 315 linear feet (lf) to the south (i.e., towards the water). The east-west retaining wall will run approximately the width of Wills Street. The Wills Wharf Office building wall will retain the street fill on the east side of Wills Street. The southern end of Wills Street will terminate with a vehicular turnaround before it approaches the pedestrian promenade and the harbor.

The piles supporting the concrete retaining wall will pass through the existing geomembrane. Each pile penetration will be sealed using a mechanical boot with stainless steel clamp and gasket system. Pile caps are designed to remain above the surrounding geomembrane. A geomembrane dam will be placed around each pile cap to isolate drainage net water from the pile cap excavation. This dam will be left in place after pile cap construction is completed.

Obstruction to Drainage Net Below Development Structures Analysis

Pile cap construction will isolate the pile cap and piles from the drainage net using a geomembrane dam at the perimeter of each excavation. Drainage net capacity to carry water between these flow obstructions is reviewed in this section. This analysis was performed on pile foundations known as of April 29, 2016.

Area 1 to the west of the Wills Street extension is covered by asphalt pavement and does not allow surface infiltration. Precipitation and water flowing over the ground surface will flow downslope as surface runoff to the existing infiltration trench at the southern waterside perimeter. Sketches SK-1 and SK-2 show the extents of this area and the drainage flow net for water at the ground surface.

Water that does permeate through the pavement surface cover will follow the contours of the existing geomembrane, as shown in Sketch SK-3. The majority of the drainage net will flow south to the existing infiltration trench. The drainage net flows east towards the existing perimeter toe drain along a 95 ft long segment of Wills Street, where five of the concrete retaining wall pile cap foundation dams will obstruct the drainage net.

Impedance to flow within the drainage net was quantified by computing the percentage of drainage net removed and not replaced. Sketch SK-4 divides the drainage area into three zones:

- A_1 – Area below proposed Wills Street extension. Surface water will be captured by storm drains and carried offsite.
- A_2 – Area to the west of the Wills Street extension where groundwater may flow east and be forced around the pile cap obstructions.
- A_3 – Area to the west of Wills Street extension where groundwater will flow to the south and will not encounter any obstructions.

The percent of the A_2 drainage net area reduction after pile cap construction is 6.7%. However, A_2 only accounts for 20% of the total drainage net area ($A_1 + A_2 + A_3$).

Water infiltration to the drainage net in area A_2 was calculated for the design rainfall event (100-year storm). This infiltration flow volume is equal to 0.01425 ft^3/sec and accounts for the demand on drainage net flow to the concrete retaining wall interface on the west side of the Wills Street extension. The drainage net flow capacity was calculated using the hydraulic conductivity of the drainage net, hydraulic gradient across area A_2, and the cross-sectional area of the drainage net at the retaining wall interface. Before the pile cap construction, the flow capacity is equal to 0.0406 ft^3/sec. After the pile cap construction, the flow capacity is reduced to 0.0305 ft^3/sec. The factor of safety against potential head build up above the geomembrane is calculated as the drainage net flow capacity / infiltration to the drainage net. Before pile cap construction, the factor of safety is $FS_I = 2.85$. With the pile cap obstructions, the factor of safety is reduced to $FS_F = 2.14$, a 25% reduction in the factor of safety.

<u>Summary</u>

The obstruction to the drainage net due to pile cap blockage occurs only at Area A_2. The 6.7% reduction in A_2 drainage net area results in a 25% reduction in drainage flow capacity. This reduction is acceptable, as the capacity of the drainage net with obstructions is sufficient to manage water infiltration during the design rainfall event without head build up. Infiltration to Area A_1 is prevented by surface drainage improvements, reducing water volume in drainage net downstream of Area A_2; this should increase the rate of flow towards the toe drain for water from Area A_2 entering Area A_1. Water in Area A_3 will continue to flow south to the existing toe drains and independently discharges to the embankment without flowing through pile obstructions.

By: ______________________
Lysandra Lincoln

SHEET ____ OF ____

MUESER RUTLEDGE CONSULTING ENGINEERS

FILE 12582A

MADE BY LL DATE 6/6/16

PROJECT WILLS WHARF

CHECKED BY ____ DATE ____

SUBJECT OBSTRUCTIONS TO FLOW WITHIN DRAINAGE NET

PURPOSE: ASSESS THE TOTAL AREA OF OBSTRUCTED FLOW IN DRAINAGE NET FROM PILE CAP CONSTRUCTION.

ASSUMPTIONS:

1. DRAINAGE NET IS REMOVED WITHOUT REPLACEMENT AT PILE CAPS FOR CONCRETE RETAINING WALL, AS SHOWN ON SK-3 AND SK-4

CALCULATIONS:

AREA OF DRAINAGE NET WITH POTENTIAL TO FLOW EAST AROUND PILE CAPS

$= A_2 = (65\ FT)(160\ FT)$

$= 10{,}400\ FT^2$

AREA OF PILE CAP OBSTRUCTIONS (SEE TABLE 1)

$= 696\ FT^2$

PERCENT OF A_2 DRAINAGE NET REDUCTION

$$= \left(\frac{10400 - 696}{10400}\right) = 0.933$$

OR 6.7% REDUCTION

PERCENT OF TOTAL DRAINAGE NET AREA REDUCED

$$= (6.7\%)\frac{A_2}{A_1 + A_2 + A_3}$$

$$= (6.7\%)\frac{10400}{53125}$$

$= 1.3\%$ REDUCTION IN TOTAL DRAINAGE NET AREA

SHEET 1 OF ____

FILE 12582A

MUESER RUTLEDGE CONSULTING ENGINEERS

MADE BY LL DATE 6/16/16

PROJECT WILLS WHARF

CHECKED BY PWD DATE 6/16/16

SUBJECT ASSESSMENT OF INFILTRATION TO DRAINAGE NET

PURPOSE: COMPARE THE DESIGN FLOW CAPACITY WITHIN THE IMPEDED DRAINAGE LAYER TO THE EXPECTED FLOW BASED ON SITE CONDITIONS AND INFILTRATION FROM THE DESIGN RAINFALL EVENT.

ASSUMPTIONS:

1. DESIGN RAINFALL EVENT = 100-YR STORM: TOTAL PRECIPITATION OVER 24-HRS DURING 100-YR. STORM = P = 7.1 IN/24 HR
   = 0.592 FT/24 HR

2. DRAINAGE NET PROPERTIES:
   THICKNESS t = 0.25 IN
   TRANSMISSIVITY $T = 2.8 * 10^{-3}\ m^2/SEC$
   $= 0.0305\ FT^2/SEC$
   * ASSUMING GRADIENT OF 0.1 AND CONFINING PRESSURE OF 2,000 psf

3. SOURCES OF WATER:
   WATER INFILTRATES THROUGH COVER SOIL IN AREA 2 AND IS CARRIED BY DRAINAGE NET TO THE WILLS ST RETAINING WALL.

CALCULATIONS:

DRAINAGE AREA $A_2 = 10400\ FT^2$
RAINFALL INTENSITY $I = 0.592\ FT/24\ HR$
RUNOFF COEFFICIENT $C = 0.80$ (80% OF RAINFALL WILL BE CARRIED AWAY BY SURFACE RUNOFF)

VOLUME OF WATER INFILTRATING INTO DRAINAGE NET:

$W_I = (1-0.8)(10400\ FT^2)(0.592\ FT/24\ HRS)$

$W_I = 1231.4\ FT^3/24\ HRS = 0.01425\ FT^3/SEC$

(INITIAL) DRAINAGE NET FLOW CAPACITY:

$Q = kiA$ WHERE k = HYDRAULIC CONDUCTIVITY $= \frac{\text{TRANSMISSIVITY}}{\text{THICKNESS}}$

$= 1.464\ FT/SEC$

i = GRADIENT = 0.014
(SEE SKETCH SK-5)

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SUBJECT INFILTRATION TO DRAINAGE NET (CONT.)

A_I = FLOW CROSS SECTIONAL AREA (BEFORE PILE CAP CONSTR.)
= (95 FT) (0.25 IN)

$A_I = 1.98\ FT^2$

$Q_I = (1.464\ FT/SEC)(0.014)(1.98\ FT^2)$

$Q_I = 0.0406\ FT^3/SEC$

(FINAL) DRAINAGE NET FLOW CAPACITY :

$A_F = (95 - (3*3.5\ FT) - (2*6.5\ FT)) * (0.25\ IN)$

$= (71.5\ FT)(0.25\ IN)$

$A_F = 1.49\ FT^2$

$Q_F = (1.464\ FT/SEC)(0.014)(1.49\ FT^2)$

$Q_F = 0.0305\ FT^3/SEC$

FACTOR OF SAFETY

BEFORE PILE CAP CONSTRUCTION :

$FS_I = \frac{\text{DRAINAGE NET FLOW CAPACITY}}{\text{INFILTRATION TO DRAINAGE NET}}$

$= \frac{Q_I}{W_I} = 0.0406/0.01425$

$FS_I = \underline{\underline{2.85}}$ ✓

AFTER PILE CAP CONSTRUCTION :

$FS_F = Q_F/W_I = 0.0305/0.01425$

$FS_F = \underline{\underline{2.14}}$ ✓

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File No.: 12582A-111

Made by: LL Date: 6/6/16

FOR: Wills Wharf Checked by: Date:

SUBJECT: Table 1: Concrete Retaining Wall Pile Cap Areas

Pile Cap	Number of Piles	Excavation Subgrade Elevation	Excavation Subgrade Below MMC	Pile Cap Edge to Drainage Dam, B (ft)	Length of Pile Cap (ft)	Width of Pile Cap (ft)	Area Without Drainage Net (ft^2)
1	4	4.0	8.0	3.0	7	7	169
2	4	4.0	8.0	3.0	7	7	169
3	4	4.0	8.5	3.0	7	7	169
4	3	4.5	7.5	3.0	6.5	7	163
5	3	4.5	7.5	3.0	6.5	7	163
6	3	4.5	7.5	3.0	6.5	7	163
7*	3	4.5	7.5	3.0	6.5	7	163
8*	3	4.5	7.0	3.0	6.5	7	163
9*	2	4.5	7.0	3.0	7	3.5	124
10*	2	4.5	7.0	3.0	7	3.5	124
11*	2	4.5	6.5	3.0	7	3.5	124
12	2	4.5	6.5	3.0	7	3.5	124
13	2	4.5	6.5	3.0	7	3.5	124
14	2	4.5	6.0	3.0	7	3.5	124
15	2	4.5	6.0	3.0	7	3.5	124
16	2	4.5	5.5	3.0	7	3.5	124
17	2	4.5	5.5	3.0	7	3.5	124
18	2	4.5	5.5	3.0	7	3.5	124

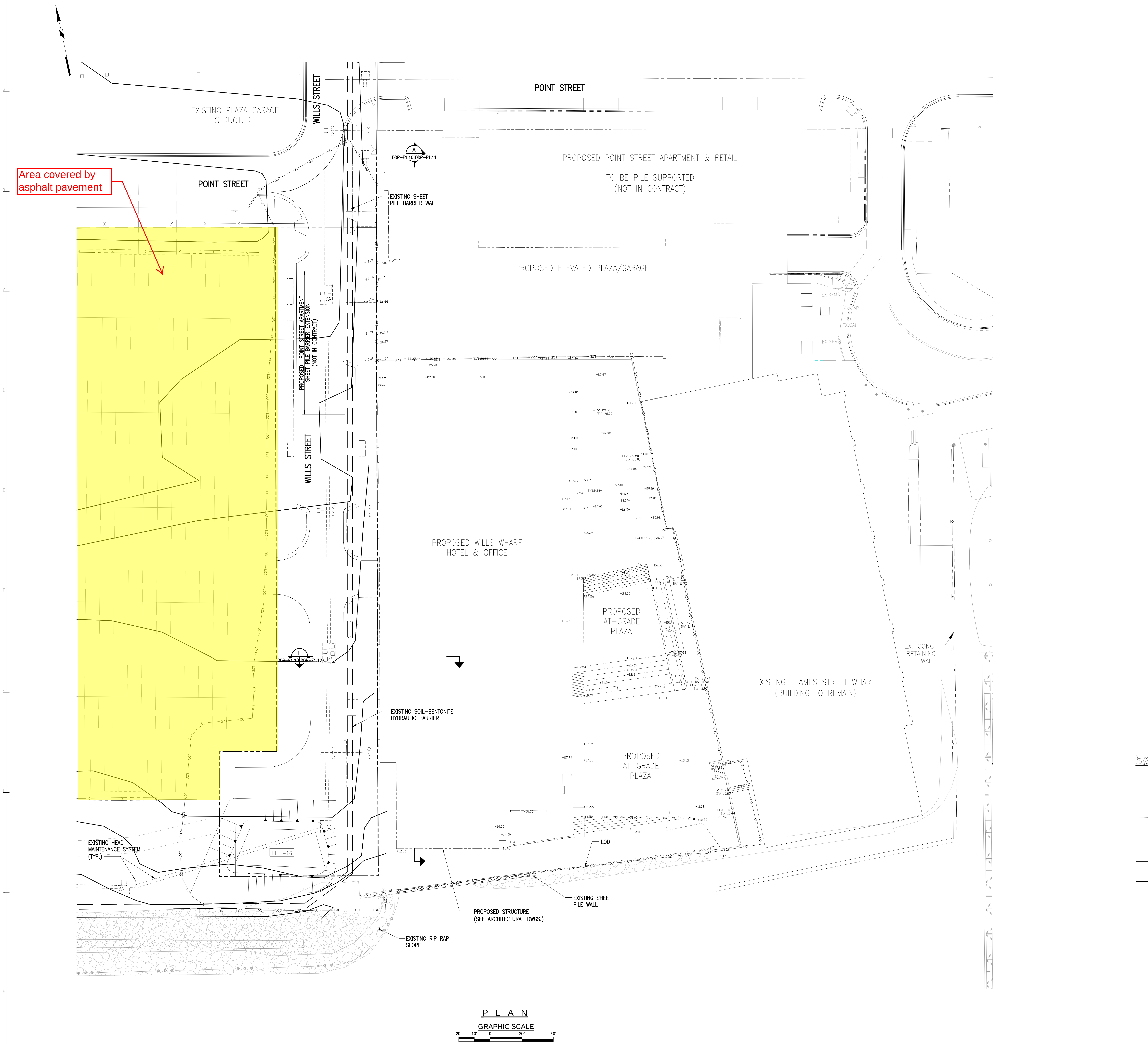
*Pile caps that cause obstructions to flow

Total: 2,555

Total Area of pile cap obstructions: 696

Pile Caps dimensions

# of piles	Comments	Dim 1 (ft)	Dim 2 (ft)
2		7.0	3.5
3	Triangular	6.5	7.0
4		7.0	7.0



P L A N

GRAPHIC SCALE

20' 10' 0 20' 40'

General Notes:

1. For General and TechnicaL notes, see drawings DDP–F1.01, DDP–F1.02 and DDP–F1.03.
2. Borings shown are those which are within 50 feet of proposed development and extend into or through Stratum M.
3. Borings identified with the prefix "MR–" were drilled under inspection of MRCE. Other borings are available. MRCE makes no representation as to the accuracy of borings by others.
4. Limits of compressible stratum shown are based on widely spaced borings and historical shoreline information and as such are approximate. Actual conditions may vary.

References:

Reports by MRCE:

1. "Summary of the 1988 Subsurface Investigation for Perimeter Cutoff Wall Evaluation," Mueser Rutledge Consulting Engineers, New York, New York 1988.
2. "Condition Survey of Waterfront Structures," Mueser Rutledge Consulting Engineers, New York, NY 1990.
3. "Summary of the 1989–1990 Subsurface Investigation for Perimeter Embankment and Cut–Off Wall Design," Mueser Rutledge Consulting Engineers, New York, New York 1990.
4. "Existing Subsurface Structures Review and Documentation," Mueser Rutledge Consulting Engineers, New York, New York 1992.
5. "Summary of Subsurface Information Along the Hydraulic Barrier," Mueser Rutledge Consulting Engineers, New York, New York 1994.
6. "Geotechnical Data Report Harbor Point Areas 2 and 3 – Philpot and Block Sts Between Wills & Thames," Mueser Rutledge Consulting Engineers, New York, New York 2006.

Reports by Others:

7. "Baltimore Works Remedial Investigation Report," NUS Corporation, Gaithersburg, Maryland 1986.
8. "Summary of Aquifer Testing Completed at the Baltimore Works," Geraghty and Miller, Annapolis, Maryland 1989.
9. "Corrective Measures Implementation Report: Phase I Construction," Black and Veatch Waste Science Technology, Philadelphia, Pennsylvania 1993.
10. "Sidney Meyer Property Investigation Results," Black and Veatch Waste Science Technology, Philadelphia, Pennsylvania 1993.
11. "Construction Completion Report, Phase II: Soil–Bentonite Hydraulic Barrier Wall and Phase III: Final Remedial Construction," Black and Veatch Waste Science Technology, Philadelphia, Pennsylvania 2000.

Surcharge Notes:

1. For Details of Surcharge Fill 2 see Phase II Construction Completion Report prepared by Black & Veatch dated February 2000.
2. Fill area extents as shown by hatching with slopes graded between 2H:1V and 1H:1V.
3. Surcharge Fill Placement: Placed to surcharge Baltimore City Pier at the foot of Wills Street.
4. Strip Drains were installed with a triangular spacing at approximately 5'.

Legend:

MR–101 – Borings made in previous MRCE subsurface investigations

– Borings made by others

Area where organic deposits encountered

Approximate limits of organic deposits encountered in borings

11 Existing ground surface elevation

EL. ... Elev. Historic of Surcharge

Top of slope

Toe of slope

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key

NORTH

project
WILLS WHARF
OFFICE/HOTEL

HARBOR POINT
BALTIMORE, MARYLAND

seal

issued	date	description

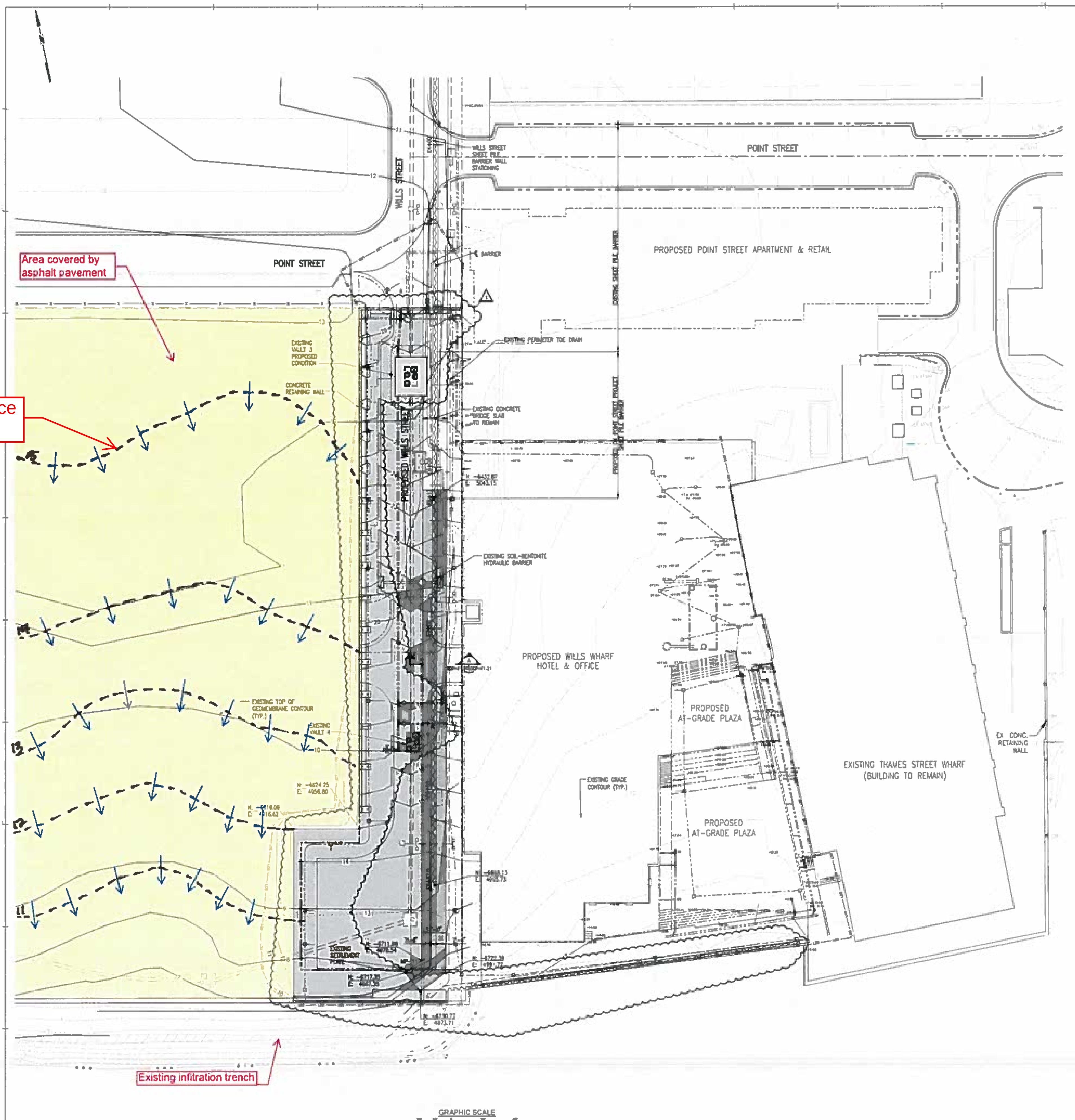
title
BORING LOCATION PLAN

drawn by: E.C.
checked by: A.M.D.
scale: AS SHOWN
project number: MRCE - 12582
scaled inch

sheet number

SK-1

DDP-F1.10



NOTES:

1. For General and Technical notes, see drawings DDP-F1.01, DDP-F1.02 and DDP-F1.03.
2. See note 1 under sheet pile notes on drawing DDP-F1.02.
3. For Typical sheet pile barrier see drawing DDP-F1.22.
4. Top of concrete bridge slab will vary depending on top of the soil-bentonite hydraulic barrier. See Section A on the drawing DDP-F1.21 and drawing DDP-F1.53 for detail.
5. Top of concrete protective slab elevation will vary depending on elevation of existing grade. Adjacent to retaining wall footings and utilities place protective slab on a slope similar to that shown on section A on drawing DDP-F1.21. See DDP-F1.53 for typical concrete protective slab detail.
6. For partial plan and section of concrete retaining wall see drawing DDP-F1.43 and DDP-F1.52.
7. For partial plan, section and detail of concrete cap see drawing DDP-F1.43, DDP-F1.50 and DDP-F1.51.
8. For partial plan of concrete pile supported platform see drawing DDP-F1.44.
4. For plan and section of proposed condition at vault 3 see drawing DDP-F1.53.
5. For plan and section of pile cap see drawings DDP-F1.51.

LEGEND:

- Proposed concrete protective slab
- Proposed concrete bridge slab
- Proposed concrete retaining wall, concrete cap beam.

Table 1: Sheet Pile Elevations

Sheet Pile Stationing	Proposed Sheet Pile Top Elevation	Proposed Sheet Pile Tip Elevation
E6+17 to E7+00	+ 7*	-67
E7+00 to E7+60	+ 7*	-68
E7+60 to E8+00	+ 7*	-69
E8+00 to E8+30	+ 7*	-68
E8+30 to E8+57	+ 7*	-70

* - Sheet Pile Cutoff Elevation may vary. Top of Sheetpile to be 6 inches below geomembrane. Confirm Elevation in field.

← Flow of surface runoff

Area covered by asphalt

BHC ARCHITECTS

BEATTY HARVEY COCO ARCHITECTS, LLP

WILLS WHARF OFFICE/HOTEL

HARBOR POINT BALTIMORE, MARYLAND

SHEET PILE BARRIER WALL PLAN

SK-2

DDP-F1.20

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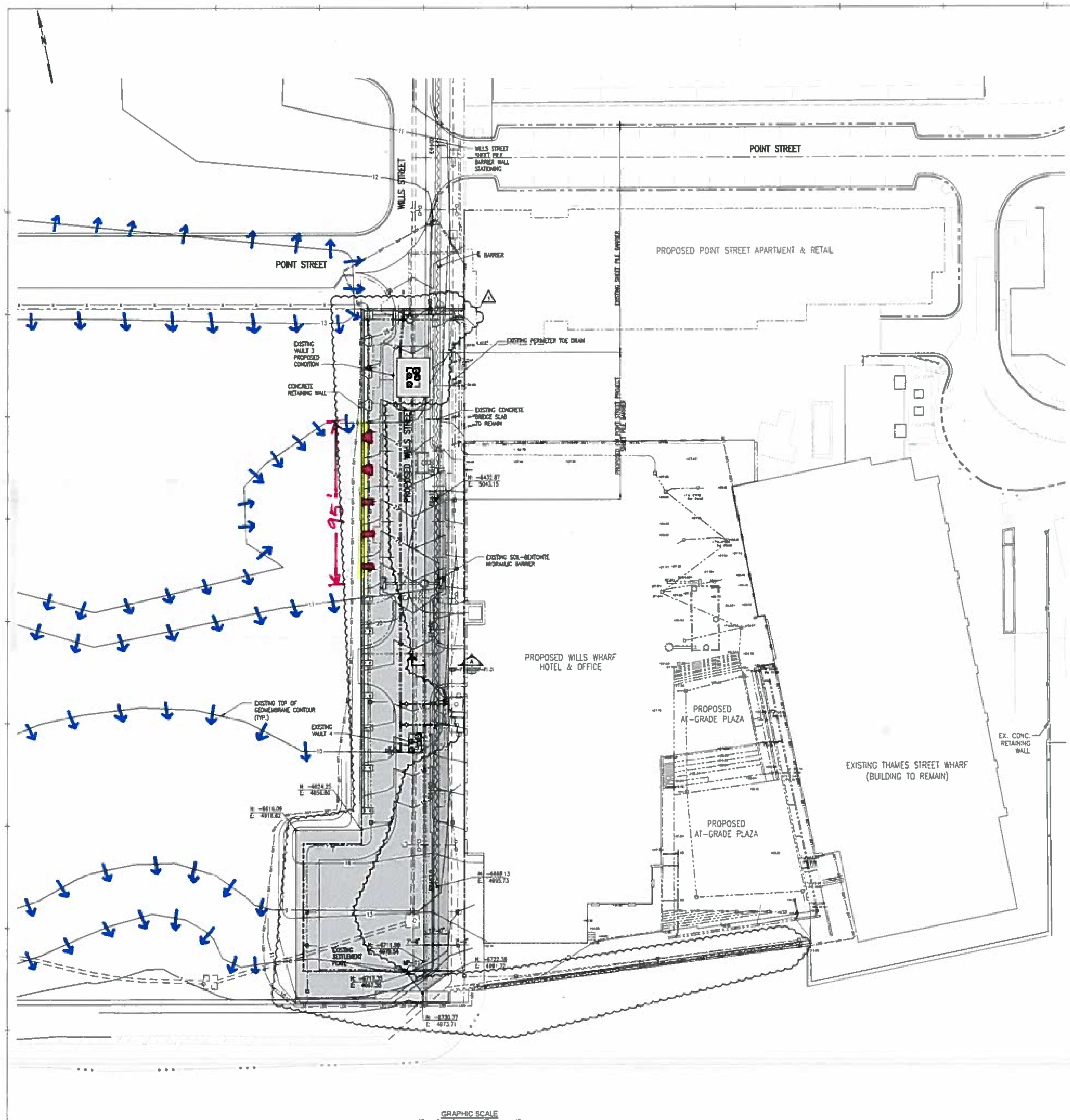

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EA Group, Inc

Brayton Hughes Design Studios

Cini Little International, Inc

Gerald Waldman Associates

Core Studio Design

Jensen Hughes

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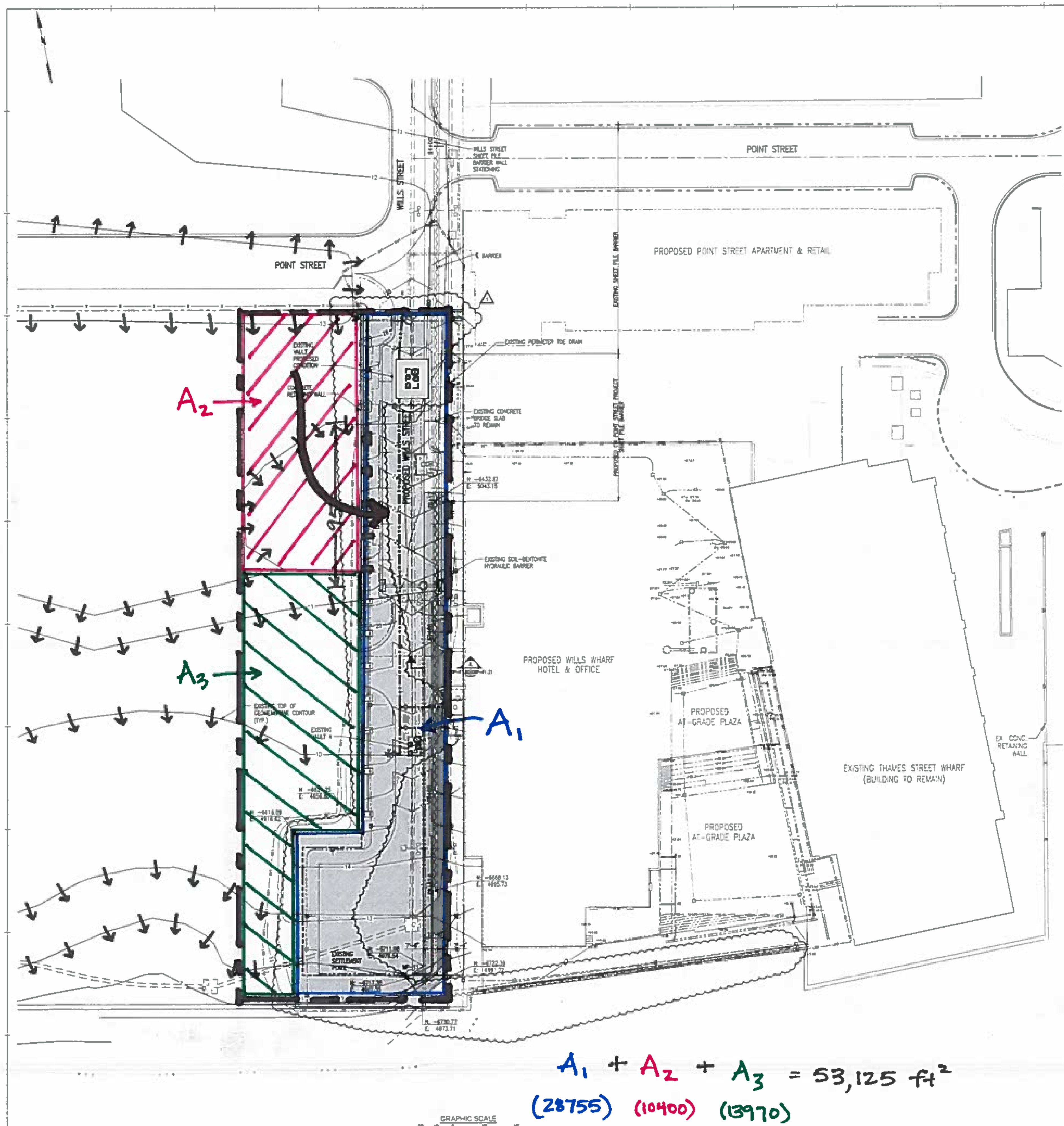
HARBOR POINT BALTIMORE, MARYLAND

SHEET PILE BARRIER WALL PLAN

SK-3

DDP-F1.20



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SK-4

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Mahan Rykiel Associates

EBA Group, Inc

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Core Studio Design

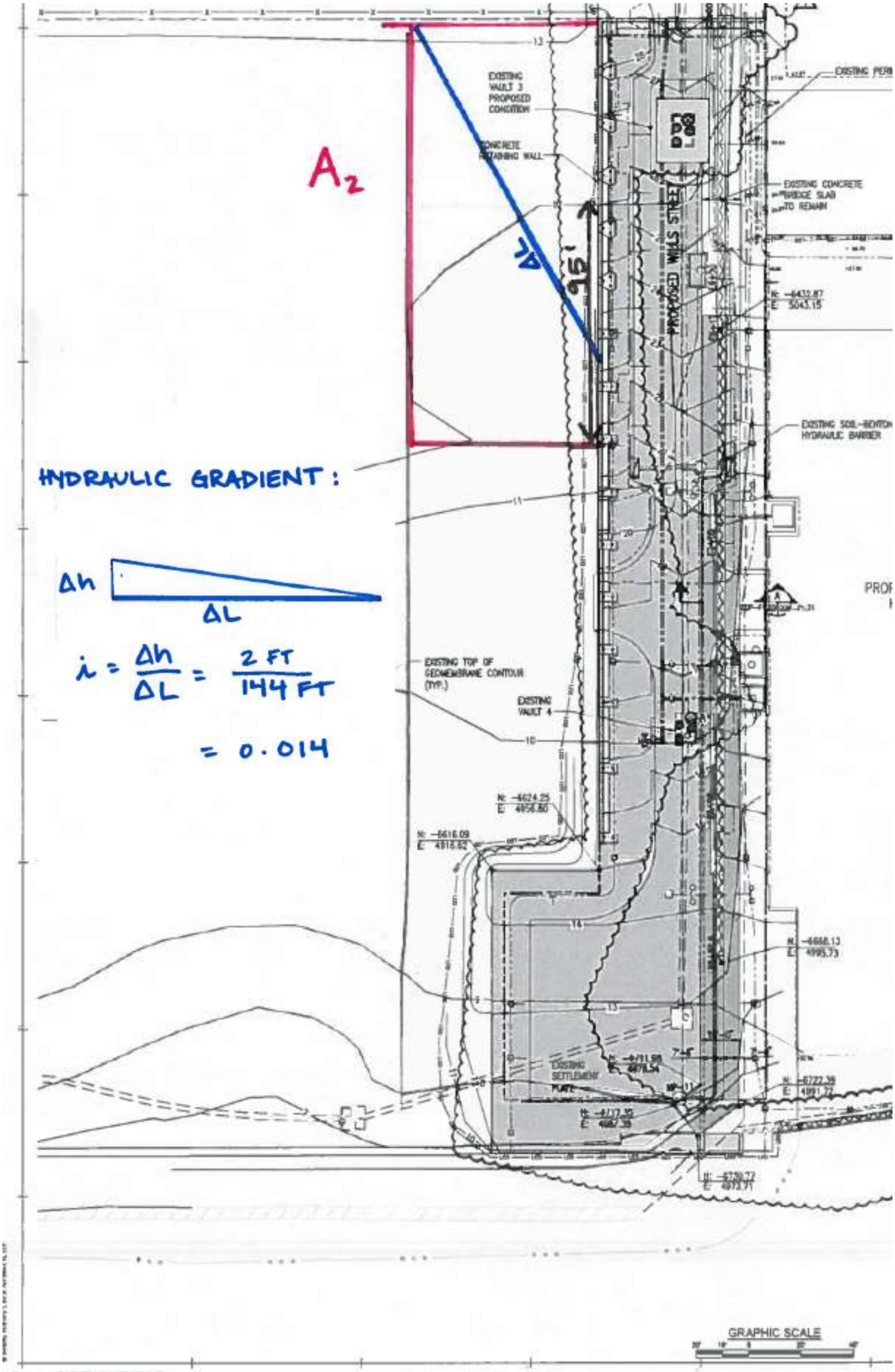
Jensen Hughes

WILLS WHARF OFFICE/HOTEL

HARBOR POINT BALTIMORE, MARYLAND

SHEET PILE BARRIER WALL PLAN

DDP-F1.20


A2
95'
EXISTING VAULT 3 PROPOSED CONDITION
CONCRETE RETAINING WALL
EXISTING CONCRETE BRIDGE SLAB TO REMAIN
PROPOSED WALL STEEL
EXISTING SOIL-BENTONITE HYDRAULIC BARRIER
N: -6432.87
E: 5043.15
HYDRAULIC GRADIENT:
Δh
ΔL
i = Δh/ΔL = 2 FT / 144 FT
= 0.014
EXISTING TOP OF GEOMEMBRANE CONTOUR (TYP.)
EXISTING VAULT 4
N: -6624.25
E: 4956.80
N: -6616.09
E: 4916.82
N: -6668.13
E: 4995.73
EXISTING SETTLEMENT PLATE
N: -6722.39
E: 4991.72
N: -6739.72
E: 4973.71
GRAPHIC SCALE

SK-5