TECHNICAL MEMORANDUM

DATE August 13, 2024 **Project No.** 31404817.004

TO Laura Krusinski, PE
Bridge Division
Maine Department of Transportation

CC

FROM Melissa E. Landon, PhD, PE **EMAIL melissa.landon@wsp.com**

RE: GEOTECHNICAL SOIL CORROSIVITY FINDINGS – REV01
HOGAN ROAD BRIDGE REPLACEMENT, BANGOR, MAINE
WIN 018595.10

This updated Technical Memorandum summarizes the results of WSP USA, Inc.'s (WSP) testing and evaluation of the corrosion potential of in situ soils to support the design of proposed Hogan Road eastbound replacement bridge and evaluation of the existing condition of in-place Hogan Road westbound Bridge #5823 pile foundations relevant to this bridge's proposed bridge renovation in support of the geotechnical design for the Hogan Road Diverging Diamond Interchange bridges in Bangor, Maine.

WSP developed draft interpretive stratigraphic profiles (ISPs) along the centerline of the proposed new bridge and existing bridge as shown in Attachment 1 based on WSP's 2022 100-series borings, WSP's 2023 200-series and 300-series borings, and the 1979 historical borings used for design of the 1983 bridge that will be renovated. Boring locations are additionally shown in Attachment 1. We additionally included the depth and location of the 1983 bridge abutment and pier foundations from the historical plans and the depth and location of the proposed new bridge abutments and piers from the PDR plan set.

The draft ISP at the 1983 bridge shows that the bottom of the historical abutments encasing the steel H-piles are located in embankment fills above the water table, while the bottom of the historical Pier 1 is founded on the in situ silt and clay below the water table, likely with a thin layer of fill between the concrete and in situ soil. The piles for the existing abutments extend through the embankment fills into a layer of silty clay both above and below the interpreted water table.

The draft ISP for the proposed new bridge shows that the piles for the proposed abutments will be located in the existing fill and silty clay above and below the water table interpreted from the borings. For the northern piers on either side of I-95 southbound, the pier pile caps and piles will be founded in silty clay below the water table. For the southern piers on either side of I-95 northbound, the pier pile caps and piles will be founded in silty clay above the water table and piles will extend below the water table.

Corrosivity Testing

WSP completed corrosivity testing of 19 soil samples from 10 borings across the site: BB-BHR-101, -102, -103, -202, -203, -204, -205, -301, -302, and -303. This included the following tests recommended by AASHTO[1]:

- Chloride testing for 100-series borings in accordance with ASTM D512-12, Standard Test Methods for Chloride Ion in Water Method B and 200- and 300-series borings in accordance with AASHTO T 291-Chloride Method B.
- Sulfate testing for 100-series boring in accordance with ASTM D516-16, Standard Test Method for Sulfate Ion in Water and 200- and 300-series borings in accordance with AASHTO T290-Sulfates (Soluble).
- pH testing for 100-series borings in accordance with ASTM D4972, Standard Test Method for pH of Soils and 200- and 300-series borings in accordance with AASHTO T 289 for pH of Soils.
- Soil Resistivity testing was performed in accordance with ASTM G57, Standard Test Method for Measurement of Soil Resistivity Using the Wenner Four-Electrode Method for all borings.

Results of these laboratory tests are shown in Attachment 2. Attachment 2 additionally includes our evaluation of the corrosion potential with respect to the soil and groundwater conditions and our estimated steel section loss from corrosive soil conditions for the existing bridge piles with respect to relevant AASHTO[1,2], FHWA[3,4], and NCHRP[5] guidance for pile foundations. Results indicate that of the measured resistivity, pH, sulfate, and chloride values, only resistivity values are below the 2000 ohm-cm threshold in AASTHO[1] below which corrosive conditions may develop. These lower resistivity values were mainly encountered in near surface and shallow depths (less than 5 feet) at locations adjacent to I-95 northbound and southbound that would most be impacted by road salt and road salt runoff into the drainage ditches beside the highway. The highest measured resistivity values are located within the shallow subsurface soils on the Hogan Road western embankment for the north abutment.

As a result of the low resistivity values, AASHTO[2] indicates there is a possibility for severe macrocell corrosion in the existing soils at the water table and a low possibility of uniform corrosion. AASHTO[2] recommends using a corrosion probe to monitor macrocell corrosion. The presence of existing macrocell corrosion can be identified by excavation of the soils around the existing foundations to visually inspect the abutments, piers, and piles.

Assuming the measured soil corrosivity parameters are representative for similar areas (e.g., adjacent to I-95 or within the shallow subsurface), the corrosion potential with low resistivity conditions at or near the water table may create an environment where corrosion of steel piles is possible. We interpret corrosion potential is relevant to the piles at the abutments and Pier 1 near WSP's interpreted water table as road salt at the historical highway and

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[1] American Association of State Highway and Transportation Officials (AASHTO). LRFD Bridge Design Specifications. 9th Edition, dated 2020.

[2] AASHTO. Standard Practice for Assessment of Corrosion of Steel Piling for Non-Marine Applications. Specification R27-01 (2023). Technically Revised: 2001, Reviewed but Not Updated: 2023

[3] Federal Highway Administration (FHWA). GEC 012: Design and Construction of Driven Pile Foundations – Volume I. Publication No. FHWA-NHI-16-009. Dated July 2016

[4] FHWA. Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes. Publication No. FHWA-NHI-09-087. Dated November 2009

[5] National Cooperative Highway Research Program (NCHRP). Report 675: LRFD Metal Loss and Service-Life Strength Reduction Factors for Metal-Reinforced Systems. 2011

highway drainage level may have penetrated in situ soils between the time of the construction of I-95 through the construction of the 1983 bridge. We additionally interpret corrosion potential is relevant to the piles for each of the pier piles adjacent to I-95 northbound and southbound, and additionally to piles at the abutments at a similar elevation to the piers.

Evaluation of Existing Pile Sections

In July 2024, WSP and MaineDOT collaboratively performed a visual inspection of, and made dimensional measurements on, several exposed piles at the existing bridge to identify corrosion that may have occurred since the piles were installed. This entailed excavating test pits to examine one pile at Abutment 1 and two piles at Abutment 2 and Pier 5.

- We observed that Pier 5 piles were installed in the native silt and clay soils and showed no visual evidence of rust. Prior to measuring the piles at Pier 5 the piles were scraped clean of silt and clay and then were cleaned with a wire brush.
- We observed that the piles at Abutment 1 and Abutment 2 were installed in embankment fill and showed small areas of rust. Prior to measuring the piles at Abutment 1 and Abutment 2, cobbles mixed with sand and gravel stuck between the flanges of the piles were dislodged using a breaker bar and rock hammer. The piles were then cleaned with a wire brush.

The flange thicknesses were measured using two calipers accurate to 1/1000th of an inch. Flange width and flange depth were measured by WSP using a ruler accurate to 1/32nd of an inch and by MaineDOT using a tape measure accurate to 1/100th of a foot. Two sets of measurements were completed at different depths on the upper exposed pile section for each pile. For each set of measurements WSP made an “original” measurement and “repeat” measurement of each dimension and MaineDOT made a third measurement of each dimension. Table 1 provides the average measurements for each pile examined. Attachment 2 provides a full summary of the measurements made and Attachment 3 provides photos taken of the piles during the July 2024 field inspection.

Table 1: Summary of Pile Measurements

Structure	Pile Location[1]	Flange Thickness, t_{f1} (inches)	Flange Thickness, t_{f2} (inches)	Flange Width, b_f (inches)	Depth, d (inches)	Web Thickness[2], t_w (inches)
Pier 5	Pile 7	0.475	0.490	10.447	9.757	-
	Pile 14	0.456	0.480	10.210	9.823	-
Abutment 1	Pile 1	0.435	0.447	10.202	9.770	0.437
Abutment 2	Pile 16	0.441	0.443	10.120	9.853	0.490
	Pile 18	0.428	0.454	10.120	9.719	-
HP 10x42 Intact Section		0.420	0.420	10.100	9.700	0.415

Notes: 1. Pile location number corresponds to the numbering provided in WSP’s Geotechnical Evaluation of Existing Bridge Piles – REV01 Technical Memorandum dated 8/13/2024. 2. - indicates measurements could not be made due to difficulty of maneuvering around the exposed pile.

The measured dimensions of the five selected piles were not less than the nominal dimensions for HP 10x42 piles. This indicates that the soil environment surrounding the measured piles is such that corrosion does not occur or results in a slower rate of corrosion. This is consistent with the laboratory data discussed above, where results indicate that of the measured resistivity, pH, sulfate, and chloride values, only resistivity values are below the 2000 ohm-cm threshold in AASTHO[1] below which corrosive conditions may develop.

Potential Corrosion Recommendations

Because of the presence of some rust on the three exposed abutment piles and measured resistivity that could lead to corrosion, WSP recommends corrosion section loss be part of the evaluation of the pile structural resistance for the bridge renovation. In an email[6] dated July 26, 2024, WSP was directed by MaineDOT's Laura Krusinski and Tim Aguilar to consider section loss for the existing bridge for the future 50-year design life for the lesser of either 1/16th of an inch or WSP's calculated section loss over 50 years.

WSP estimated the loss of steel section based on the FHWA[3] and NCHRP[5] linear methods and the FHWA[4] non-linear method to account for potential section loss during an additional 50 year design life for the bridge. The loss of section for these three methods ranged between 0.05 inches and 0.15 inches per steel face over the next 50 years, assuming no section loss from 1983 to present. WSP's recommendation is the use of the non-linear section loss method value of 0.05 inches of steel loss from each face of the pile over 50 years as described in Attachment 4, which may be used to decrease the pile section to estimate the capacity of the existing HP 10x42 piles. For the proposed bridge pile foundations, we recommend accounting for non-linear section loss for the pile design.

We look forward to your review of our evaluation and future discussion about the potential for corrosion of the existing bridge piles.

WSP USA, Inc.

Melissa E. Landon, PhD, PE
Lead Consultant, Geotechnical Engineering

Christopher C. Benda, PE
Vice President, Geotechnical Engineering

MEL/CCB

Distribution: Jeffrey D. Lloyd, PE, WSP

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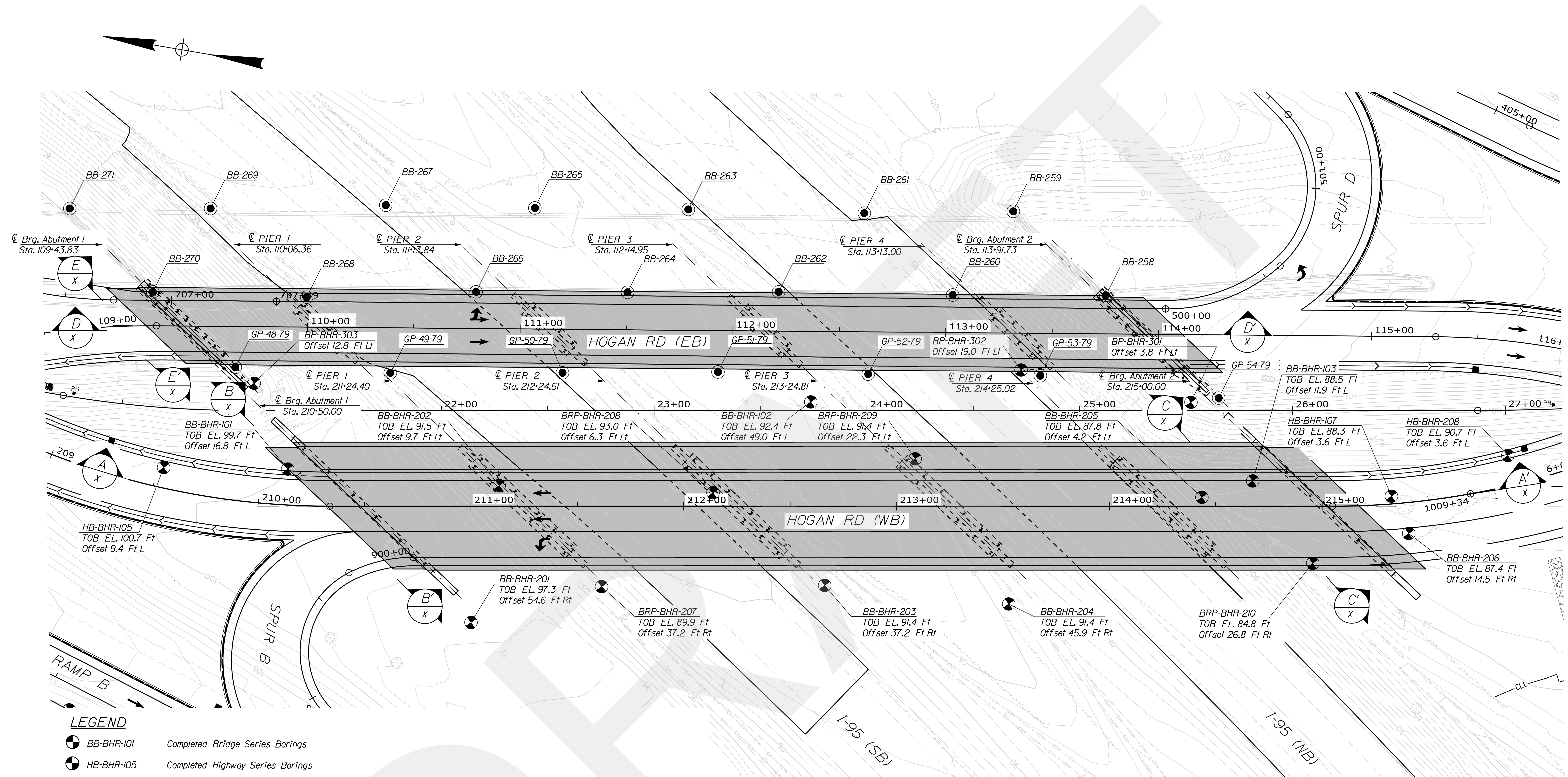
6 Krusinski, Laura "RE: Bangor Hogan Road - 1983 Bridge Updated Geotechnical Pile Resistance – Corrosion" Received by Melissa Landon, July 26, 2024

Attachment: 1: Draft Interpretive Stratigraphic Profiles and Boring Location Plan
2: Pile Measurements Summary
3: Pile Photos from Field Investigation
4: Soil Corrosivity Evaluation for Bridge Foundations

https://wsponlinenam.sharepoint.com/sites/gld-157336/project files/6 deliverables/memo-corrosion/win 018595.10 hogan road bridge - soil corrosivity findings revised 20240813.docx



LEGEND

BB-BHR-101	Completed Bridge Series Borings
HB-BHR-105	Completed Highway Series Borings
B-268, GP-48-79	Old Borings
TOB EL. 99.7	Elevation of Top of Boring

NOTES:

1. As Drilled Boring Locations for the Shown Borings Derived from an Electronic File "Borings.dgn" Provided to WSP GOLDER by Maine DOT on May 24, 2022.
2. Basemap Elements Shown Derived from a group of Electronic Files "WIN 18595.10-Bangor" Provided to WSP GOLDER by VHB on May 26, 2022 and from Maine DOT Drawing Titled "Bridge_12-3-2022.dwg" Received on May 5, 2022.
3. Proposed Stationing Provided to WSP GOLDER by VHB on May 26, 2022 in an Electronic File "Alignments.dgn".
4. For Detailed Lithologic Descriptions see Boring Logs in Appendix A Bridge Borings (BB-Series) and Highway Borings (HB-Series).
5. For Complete Laboratory Data see Laboratory Reports Appendix C (BB-Series).
6. Groundwater Surface is Interpreted From Localized Surface Water Levels and Measurements Taken During the Subsurface Exploration Programs. For Details of the Subsurface Exploration Programs see Boring Logs in Appendix A Bridge Borings (BB-Series) and Highway Borings (HB-Series).
7. This Generalized Subsurface Profile is Intended to Convey Trends in Subsurface Conditions. The Boundaries Between Strata are Approximate and Idealized and Have Been Developed Based on Interpretations of Widely Spaced Explorations. Actual Soil and Rock Transitions may Vary and are Probably More Erratic. For More Specific Information, Refer to Boring Logs in Appendix A (BB-Series) and (HB-Series).
8. Proposed Abutment Details Interpreted From Electronic File Name "Bridge_12-3-2020" Provided to WSP GOLDER by MAINE DOT on May 5, 2022.

BORING LOCATION PLAN 5 SPAN ALTERNATE

25 0 25 50
1" = 25 Feet

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

18595.10

WIN 18595.10
BRIDGE PLANS
BRIDGE NO. 5823

	BY	DATE
PROJ. MANAGER	M. LANDON	
DESIGN-DETAILED	MEL	WEG	XXX
CHECKED-REVIEWED	CCB		XXX
DESIGN2-DETAILED2		
DESIGN3-DETAILED3		
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

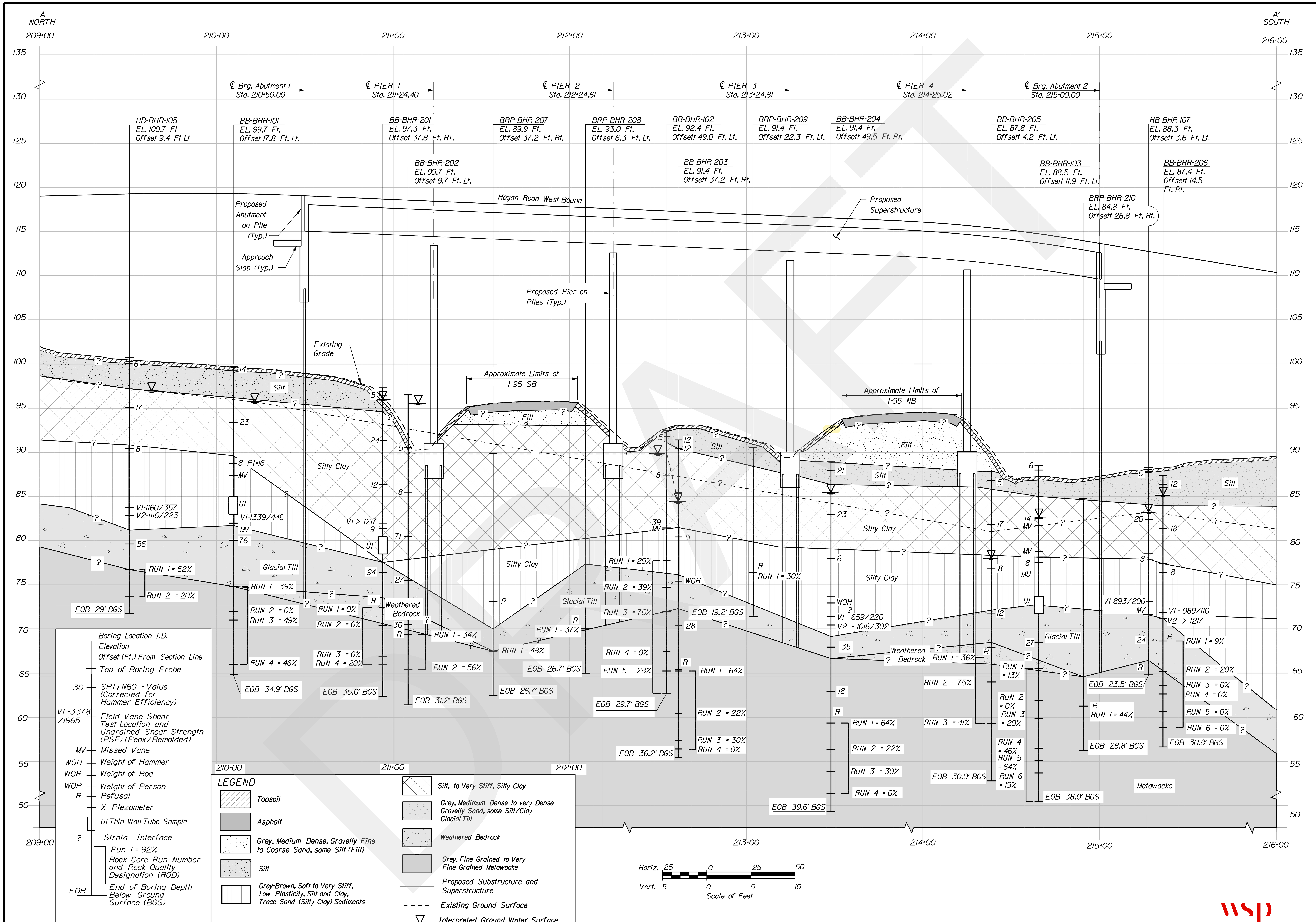
SIGNATURE
P.E. NUMBER
DATE

I-95 HOGAN ROAD BRIDGE
REPLACEMENT #5823 (EXIT 187)
BANGOR MAINE

BORING LOCATION PLAN

SHEET NUMBER
X
OF X

Filename: ...\MSTA\GeoProfile_5Span_wb.dgn
Division: BRIDGE
Username:
Date:2/1/2024



STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

18595.10

WIN 18595.10

BRIDGE PLANS

BRIDGE No. 5823

	BY	DATE
PROJ. MANAGER	M. LANDON	
DESIGN-DETAILED	NVW	XXX
CHECKED-REVIEWED	WEG XXX	XXX
DESIGN2-DETAILED2		
DESIGN3-DETAILED3		
REVISIONS 1	XXX	XXX
REVISIONS 2	XXX	XXX
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE

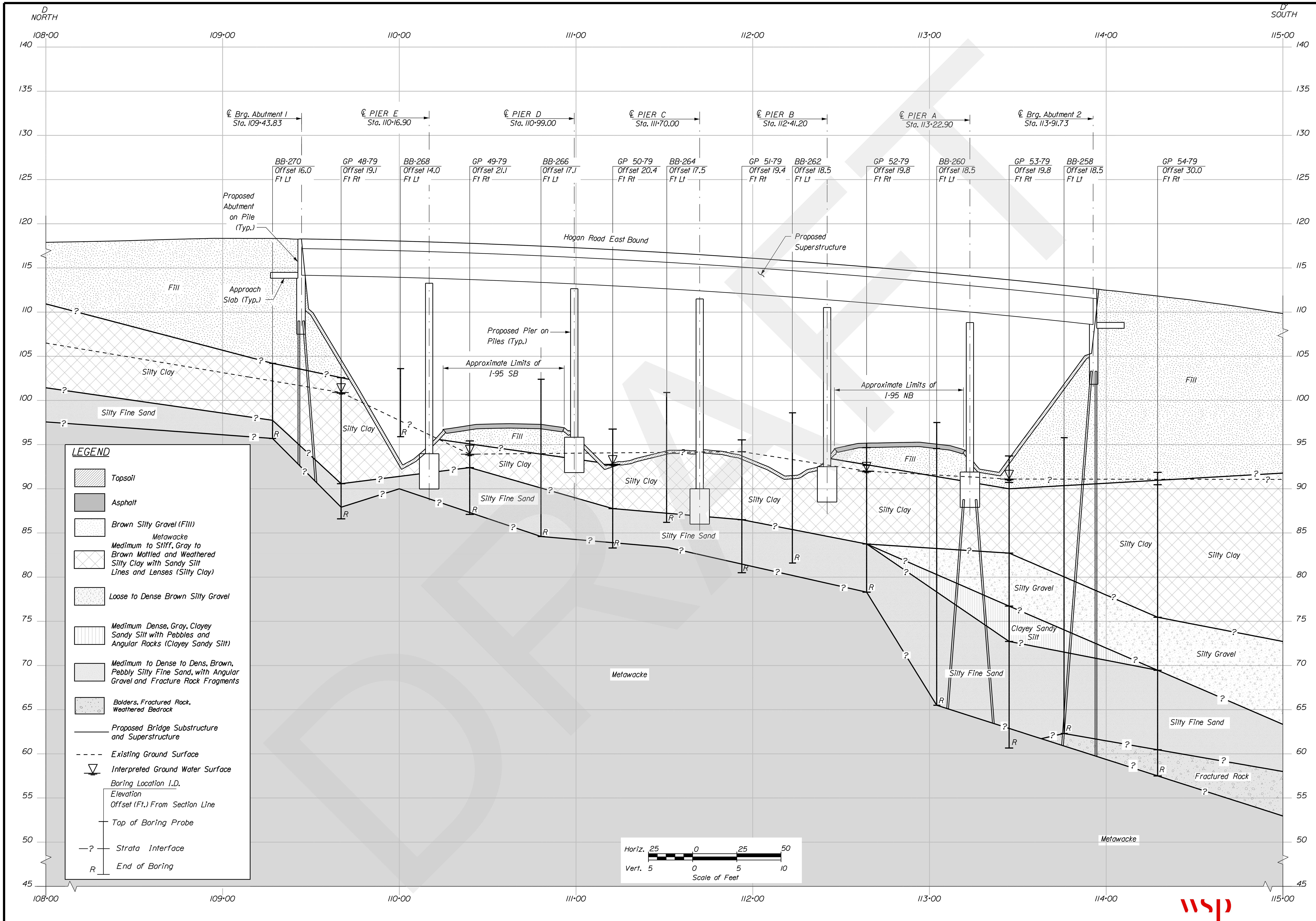
P.E. NUMBER

DATE

I-95 HOGAN ROAD BRIDGE
REPLACEMENT #5823 (EXIT 187)
BANGOR MAINE

INTERPRETIVE SUBSURFACE PROFILE A-A'

SHEET NUMBER
X
OF X



Date:2/6/2024

Username:

Division: BRIDGE

Filename: ...\MSTA\GeoProfile_5Span_eb.dgn

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

18595.10

WIN 18595.10

BRIDGE PLANS

BRIDGE No. 5823

	BY	DATE
PROJ. MANAGER	M. LANDON	
DESIGN-DETAILED	WEG	NVW	XXX
CHECKED-REVIEWED	CCB	XXX	XXX
DESIGN2-DETAILED2			
DESIGN3-DETAILED3			
REVISIONS 1	XXX		XXX
REVISIONS 2	XXX		XXX
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE

P.E. NUMBER

DATE

I-95 HOGAN ROAD BRIDGE
REPLACEMENT #5823 (EXIT 187)
BANGOR MAINE

INTERPRETIVE SUBSURFACE PROFILE D-D'

SHEET NUMBER
X
OF X

wsp

Date:	7/29/2024	**Made by:**	ATM
Project No.:	31404817.004	**Checked by:**	RJN
Subject:	Field Inspection of Pier 5 Piles - Measurement Summary	**Reviewed by:**	CCB
Project Title:	MaineDOT Hogan Road Bridge Replacement		

Objective

Summarize the field measurements of the existing Pier 5 piles made by WSP and MaineDOT on Monday July 22, 2024.

Method

The flange thicknesses were measured by WSP and MaineDOT with separate digital calipers accurate to 1/1000th of an inch. Flange width and depth were measured by WSP using a ruler accurate to 1/32nd of an inch and by MaineDOT using a tape measure accurate to 1/100th of a foot. Prior to measuring the piles, any silt and clay stuck to the piles was scarped off using a paint scraper and then the piles were cleaned with a wire brush. Figure 1 shown below, depicts the location of the piles measured at Pier 5. Figure 2 shows a typical H-Pile section with the labels for the dimensions that were measured in the field.

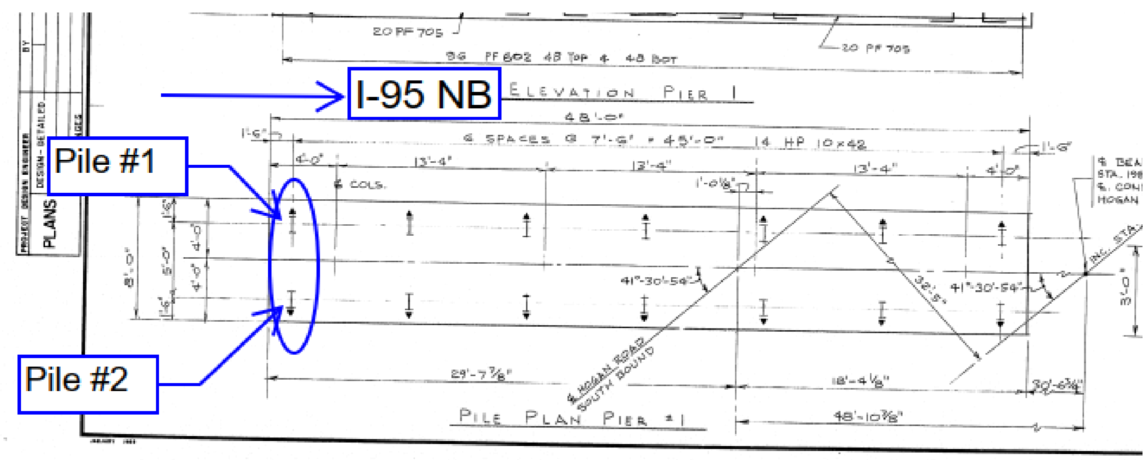


Figure 1

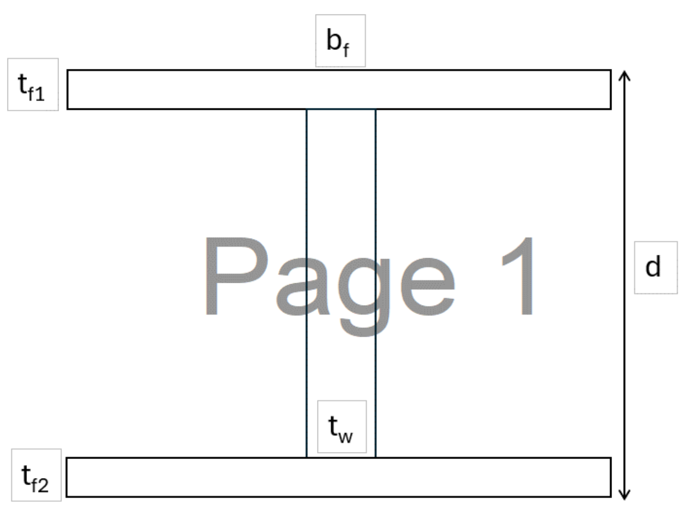


Figure 2

Observations

No rust was observed on either pile measured at Pier 5. The pile cap was installed on a silty clay layer. Groundwater was observed seeping in to the excavation approximately 1-foot below the pile cap.

Data Summary

Structure	Pile Location	Depth below pile cap	Measurement	Flange Thickness, t_{f1}	Flange Thickness, t_{f2}	Flange Width, b_f	Depth, d	Web Thickness, t_w
Pier 5	Pile #1	6	WSP - Original	0.498	0.518	10.270	9.799	-
			WSP - Repeat	0.480	0.508	10.415	9.625	-
			MaineDOT	0.485	0.473	10.740	9.840	-
		11	WSP - Original	0.485	0.478	10.404	9.813	-
			WSP - Repeat	0.451	0.484	10.594	9.688	-
			MaineDOT	0.448	0.478	10.260	9.780	-
	Pile #2	7	WSP - Original	0.462	0.475	10.125	9.875	-
			WSP - Repeat	0.456	0.477	10.063	9.875	-
			MaineDOT	0.445	0.454	10.320	9.780	-
		12	WSP - Original	0.456	0.491	10.125	9.813	-
			WSP - Repeat	0.446	0.495	10.188	9.813	-
			MaineDOT	0.473	0.488	10.440	9.780	-

Note: All measurements shown are in inches

Structure	Pile Location	Depth below pile cap	Average Measurement	Flange Thickness, t_{f1}	Flange Thickness, t_{f2}	Flange Width, b_f	Depth, d	Web Thickness, t_w
Pier 5	Pile #1	6	WSP	0.489	0.513	10.343	9.712	-
			WSP and MaineDOT	0.488	0.500	10.475	9.755	-
		11	WSP	0.468	0.481	10.499	9.750	-
			WSP and MaineDOT	0.461	0.480	10.419	9.760	-
		Combined	Avg. for Pile	0.475	0.490	10.447	9.757	
	Pile #2	7	WSP	0.459	0.476	10.094	9.875	-
			WSP and MaineDOT	0.454	0.469	10.169	9.843	-
		12	WSP	0.451	0.493	10.156	9.813	-
			WSP and MaineDOT	0.458	0.491	10.251	9.802	-
		Combined	Avg. for Pile	0.456	0.480	10.210	9.823	-
	Avg. for Structure			**0.465**	**0.485**	**10.329**	**9.790**	

Note: All measurements shown are in inches

CALCULATIONS

Date:	7/30/2024	**Made by:**	RJN
Project No.:	31404817.004	**Checked by:**	ATM
Subject:	Field Inspection of Abutment 1 Piles - Measurement Summary	**Reviewed by:**	CCB
Project Title:	MaineDOT Hogan Road Bridge Replacement		

Objective

Summarize the field measurements of the existing Abutment 1 piles made by WSP and MaineDOT on Tuesday July 23, 2024.

Method

The flange thicknesses were measured by WSP and MaineDOT with separate digital calipers accurate to 1/1000th of an inch. Flange width and depth were measured by WSP using a ruler accurate to 1/32nd of an inch and by MaineDOT using a tape measure accurate to 1/100th of a foot. Prior to measuring the piles, any sands/gravels and cobbles stuck between the flanges of the pile were dislodged using a rock hammer and then the piles were cleaned with a wire brush. Figure 1 shown below, depicts the location of the pile measured at Abutment 1. Figure 2 shows a typical H-Pile section with the labels for the dimensions that were measured in the

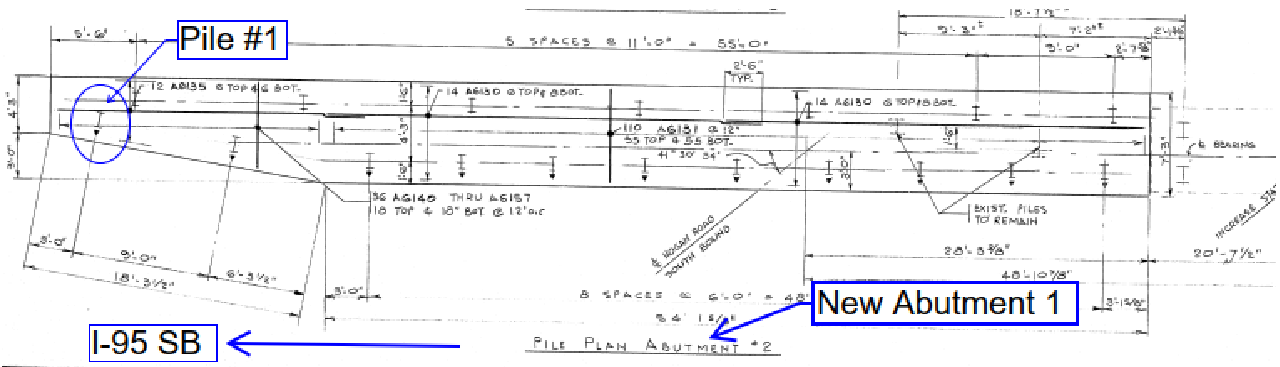


Figure 1

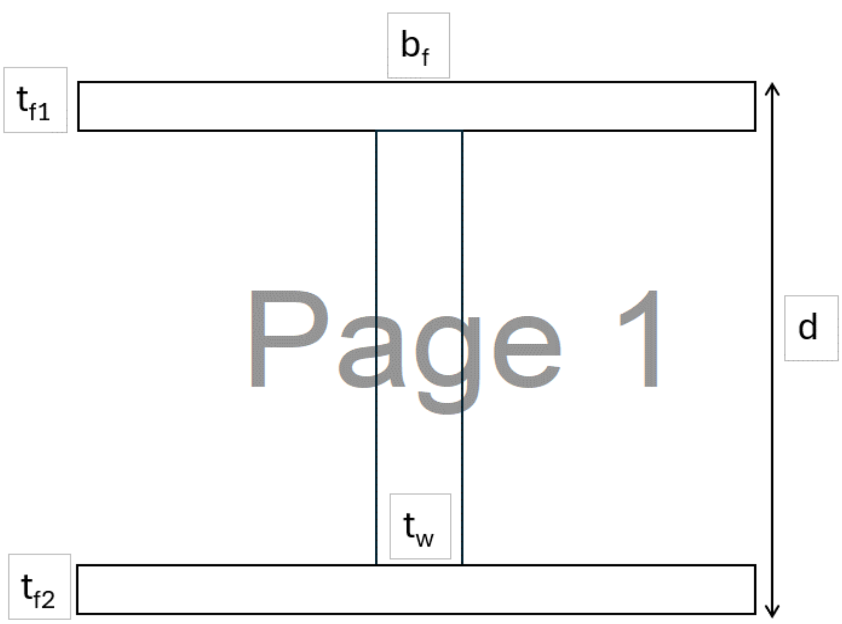


Figure 2

Observations

Small spots of rust were observed on the pile, otherwise the pile was in good condition. Pile cap installed in the fill layer. No Groundwater observed during excavation of the piles.

Data Summary

Structure	Pile Location	Depth below pile cap	Measurement	Flange Thickness, t_{f1}	Flange Thickness, t_{f2}	Flange Width, b_f	Depth, d	Web Thickness, t_w
Abutment 1	Pile #1	10	WSP - Original	0.429	0.430	10.188	9.750	0.421
			WSP - Repeat	0.433	0.437	10.188	9.750	-
			MaineDOT	0.475	0.475	10.200	9.840	-
		18	WSP - Original	0.427	0.433	10.188	9.750	0.452
			WSP - Repeat	0.424	0.431	10.188	9.750	-
			MaineDOT	0.420	0.475	10.260	9.780	-

Note: All measurements shown are in inches

Structure	Pile Location	Depth below pile cap	Average Measurement	Flange Thickness, t_{f1}	Flange Thickness, t_{f2}	Flange Width, b_f	Depth, d	Web Thickness, t_w
Abutment 1	Pile #1	10	WSP	0.431	0.434	10.188	9.750	0.421
			WSP and MaineDOT	0.446	0.447	10.192	9.780	-
		18	WSP	0.425	0.432	10.188	9.750	0.452
			WSP and MaineDOT	0.424	0.446	10.212	9.760	-
	Avg. for Structure			**0.435**	**0.447**	**10.202**	**9.770**	**0.437**

Note: All measurements shown are in inches

Date:	7/30/2024	**Made by:**	RJN
Project No.:	31404817.004	**Checked by:**	ATM
Subject:	Field Inspection of Abutment 2 Piles - Measurement Summary	**Reviewed by:**	CCB
Project Title:	MaineDOT Hogan Road Bridge Replacement		

Objective

Summarize the field measurements of the existing Abutment 2 piles made by WSP and MaineDOT on Monday July 22, 2024.

Method

The flange thicknesses were measured by WSP and MaineDOT with separate digital calipers accurate to 1/1000th of an inch. Flange width and depth were measured by WSP using a ruler accurate to 1/32nd of an inch and by MaineDOT using a tape measure accurate to 1/100th of a foot. Prior to measuring the piles, any sands/gravels and cobbles stuck between the flanges of the pile were dislodged using a rock hammer and then the piles were cleaned with a wire brush. Figure 1 shown below, depicts the location of the piles measured at Abutment 2. Figure 2 shows a typical H-Pile section with the labels for the dimensions that were measured in the field.

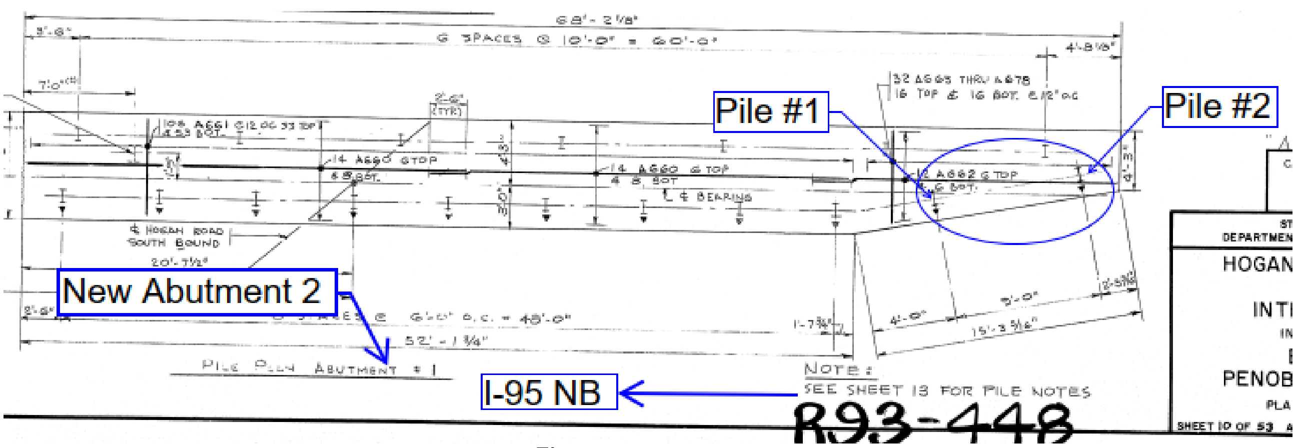


Figure 1

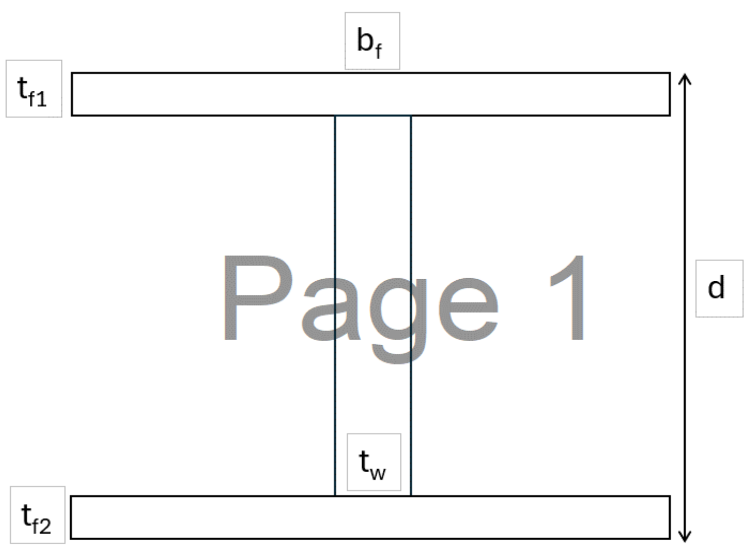


Figure 2

Observations

Small spots of rust were observed on the pile, otherwise the pile was in good condition. Pile cap installed in the fill layer. No Groundwater observed during excavation of the piles.

Data Summary

Structure	Pile Location	Depth below pile cap	Measurement	Flange Thickness, t_{f1}	Flange Thickness, t_{f2}	Flange Width, b_f	Depth, d	Web Thickness, t_w
Abutment 2	Pile #1	6	WSP - Original	0.457	0.450	10.125	9.813	0.49
			WSP - Repeat	0.468	0.436	10.063	9.875	-
			MaineDOT	0.462	0.455	10.140	9.840	-
		12	WSP - Original	0.421	0.446	10.125	9.875	-
			WSP - Repeat	0.418	0.441	10.125	9.875	-
			MaineDOT	0.419	0.428	10.140	9.840	-
	Pile #2	5	WSP - Original	0.443	0.450	10.063	9.688	-
			WSP - Repeat	0.415	0.473	10.125	9.625	-
			MaineDOT	0.436	0.456	10.140	9.720	-
		10	WSP - Original	0.420	0.455	10.125	9.750	-
			WSP - Repeat	0.423	0.453	10.125	9.813	-
			MaineDOT	0.430	0.436	10.140	9.720	-

Note: All measurements shown are in inches

Structure	Pile Location	Depth below pile cap	Average Measurement	Flange Thickness, t_{f1}	Flange Thickness, t_{f2}	Flange Width, b_f	Depth, d	Web Thickness, t_w
Abutment 2	Pile #1	6	WSP	0.463	0.443	10.094	9.844	0.49
			WSP and MaineDOT	0.462	0.447	10.109	9.843	-
		12	WSP	0.420	0.444	10.125	9.875	-
			WSP and MaineDOT	0.419	0.438	10.130	9.863	-
		Combined	Avg. for Pile	0.441	0.443	10.120	9.853	0.49
	Pile #2	5	WSP	0.429	0.462	10.094	9.656	-
			WSP and MaineDOT	0.431	0.460	10.109	9.678	-
		10	WSP	0.422	0.454	10.125	9.781	-
			WSP and MaineDOT	0.424	0.448	10.130	9.761	-
		Combined	Avg. for Pile	0.428	0.454	10.120	9.719	-
	Avg. for Structure			**0.434**	**0.448**	**10.120**	**9.786**	0.49

Note: All measurements shown are in inches

Abutment 1 Pile #1

Abutment 2 Pile #1

Abutment 2 Pile #2

Pier 5 Pile #1

Pier 5 Pile #2

CALCULATIONS

Date:	8/1/2024	**Made by:**	KAR
Project No.:	31404817.004	**Checked by:**	DEB
Subject:	Soil Corrosivity Evaluation for Bridge Foundations	**Reviewed by:**	CCB
Project Title:	MaineDOT Hogan Rd Bridge Phase II		

OBJECTIVE

Estimate the corrosion that the existing Hogan Road Bridge HP10x42 piles may experience over the desired remaining service life of 50 years.

METHOD

Use references from AASHTO, FHWA, and NCHRP to determine potential corrosion rates based on the results of pH, electrical resistivity, chloride, and sulfate laboratory testing on soil samples obtained during the subsurface investigation at site.

REFERENCES

1. GeoTesting Express. Laboratory test results for bridge and highway 100- and 200-series borings and 300-series hand probes. Received by WSP on May 26, 2022, May 31, 2022, January 3, 2024, and March 5, 2024. Summarized in Table 4 and included in Appendix C of the WSP Geotechnical Design Report.

2. American Association of State Highway and Transportation Officials (AASHTO). LRFD Bridge Design Specifications. 9th Edition, dated 2020.

3. AASHTO. Standard Practice for Assessment of Corrosion of Steel Piling for Non-Marine Applications. Specification R 27-01 (2023). Technically Revised: 2001, Reviewed but Not Updated: 2023

4. Federal Highway Administration (FHWA). GEC 012: Design and Construction of Driven Pile Foundations – Volume I. Publication No. FHWA-NHI-16-009. Dated July 2016.

5. National Cooperative Highway Research Program (NCHRP). Report 675: LRFD Metal Loss and Service-Life Strength Reduction Factors for Metal-Reinforced Systems. 2011.

6. FHWA. Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes. Publication No. FHWA-NHI-09-087. Dated November 2009.

7. Carroll E. Taylor & Associates for MaineDOT. As-Built Plans: Hogan Road Bridge over Interstate 95 in the city of Bangor, Penobscot County. Dated 1983.

8. AISC Shapes Database v15.0. November 2017. https://www.aisc.org/globalassets/aisc/manual/v15.0-shapes-database/aisc-shapes-database-v15.0.xlsx

ASSUMPTIONS

1. Based on field measurements and observations made in the field by WSP and MaineDOT field engineers on July 22nd and July 23rd, 2024, assume no section loss due to corrosion has occurred from pile installation to present.

ATTACHMENTS

1. Summary table of corrosivity laboratory test results for bridge and highway 100- and 200-series borings and 300-series hand probes

2. Draft boring location plan for bridge and highway 100- and 200-series borings and 300-series hand probes in the vicinity of the existing and proposed bridges

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CALCULATION

A. Use the corrosivity laboratory test results for the soil at site (Ref. 1, also included as Attachment 1) to determine the corrosion potential at the existing piles.

Per AASHTO LRFD Article 10.7.5 (Ref. 2), the following soil or water conditions should be considered as indicative of a potential pile deterioration or corrosion situation:

- Resistivity less than 2,000 ohm-cm
- pH less than 5.5
- pH between 5.5 and 8.5 in soils with high organic content
- Sulfate concentration greater than 1,000 ppm (soil) or 500 ppm (water)
- Chloride content greater than 500 ppm

The corrosivity laboratory test results for the soil at site (Ref. 1) are compared to these conditions:

Condition	Range from lab test results	Median from lab test results	Meets condition?
Resistivity less than 2,000 ohm-cm	1,038 ohm-cm to 7,666 ohm-cm	2,212 ohm-cm	Yes*
pH less than 5.5	6.4 to 8.2	7.5	No
pH between 5.5 and 8.5 in soils with high organic content	0.5% to 0.7% organic content	0.6% organic content	No
Sulfate concentration greater than 1,000 ppm (soil) or 500 ppm (water)	<10 ppm to 30 ppm	10 ppm	No
Chloride content greater than 500 ppm	<10 ppm to 120 ppm	48 ppm	No

*While the median value is above the 2,000 ohm-cm threshold, a sufficient number of test results are below 2,000 ohm-cm to warrant further consideration.

Since the lab test results only indicate a marginal potential for pile deterioration due to corrosion, the AASHTO Standard Practice for Assessment of Corrosion of Steel Piling for Non-Marine Applications (Ref. 3) is used to further assess corrosion potential.

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B. Use the flowcharts from the AASHTO Standard Practice (Ref. 3) to determine the potential corrosion situation at the existing piles.

Step 1: use AASHTO flowchart Figure 3 (Ref. 3) and the corrosivity laboratory test results for the soil at site (Ref. 1) to determine the possibility of macrocell and uniform corrosion of the existing piles.

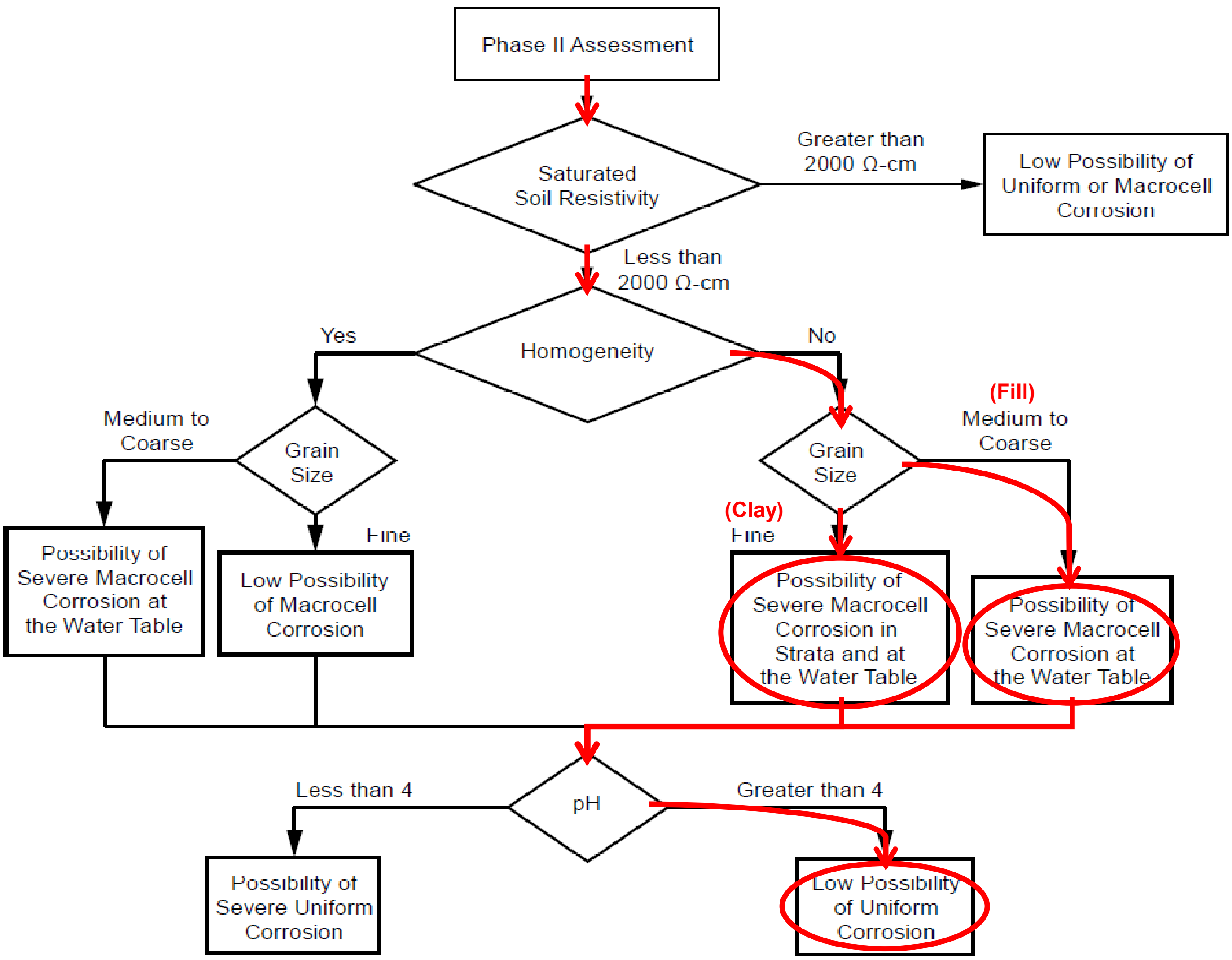

Figure 3—Determination of the Possibility for General and/or Macrocell Corrosion Based on Soil Analysis

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Step 2: use AASHTO flowchart Figure 4 (Ref. 3) to determine the recommended corrosion assessment procedure for the existing piles.

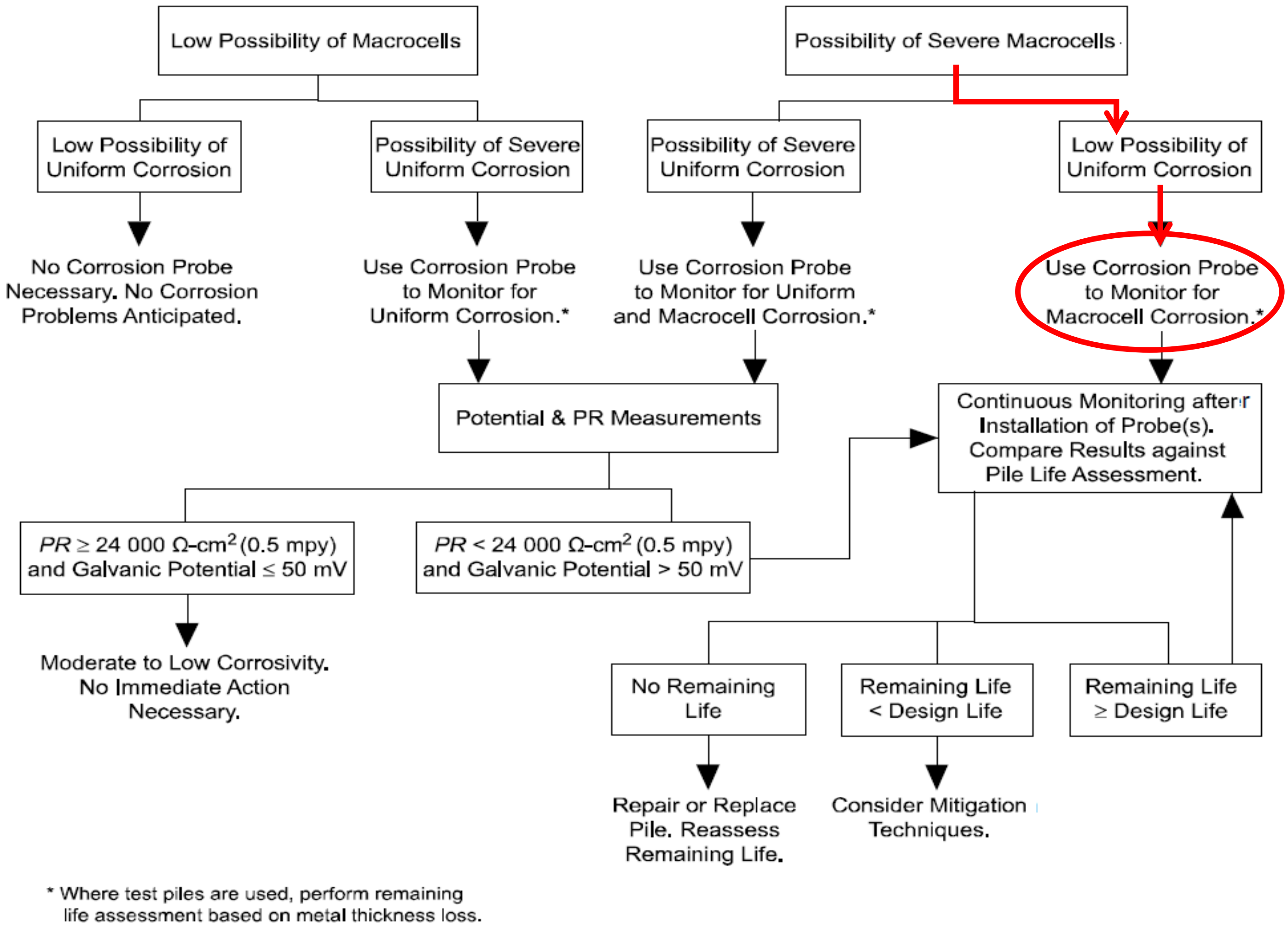

Figure 4—Determination of the Necessity for Electrochemical Testing, Corrosion Monitoring, and Mitigation

Based on the corrosivity lab test results, the AASHTO Standard Practice recommends using a corrosion probe to monitor for macrocell corrosion.

Since a corrosion probe is not currently installed at site, several approximate corrosion rates from FHWA and NCHRP will be used to estimate corrosion loss of the existing piles.

CALCULATIONS

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C. Estimate corrosion loss of the pile steel and calculate the resulting reduced pile section area.

Linear methods:

Per FHWA GEC-12 Driven Pile Foundations (Ref. 4), Section 6.12.1.1, for steel piles buried in fill or disturbed natural soils, a conservative estimate of the corrosion rate is 0.003 inches per year.

Corrosion loss per year = 0.003 inches

Per NCHRP Report 675 LRFD Metal Loss (Ref 5), Figure 8, for plain steel elements and soil resistivity less than 3,000 ohm-cm, an average corrosion rate is 13.5 μm/yr = 0.0005 in/yr.

Corrosion loss per year = 0.0005 inches

Corrosion loss per year with FS of 2 = 0.0011 inches

Estimate the total corrosion loss that the existing piles may experience over the desired remaining service life of 50 years:

Desired remaining service life = 50 years (2024 to 2074)

	NCHRP	FHWA		
Linear rate of corrosion loss =	0.0011	0.003	inches per year	per steel face or side
Future corrosion loss =	0.05	0.15	inches over 50 years	

Non-linear methods:

Per FHWA Corrosion of Soil Reinforcements (Ref. 6), Section 2.4.a, a general conclusion of studies on underground corrosion is that the rate of corrosion is greatest in the first few years of burial and then levels off to a steady but significantly lower rate. Thus, both Ref. 5 and Ref. 6 suggest a non-linear model of steel corrosion loss:

$$x = kt^n$$ (Ref. 5, Equation 1)

in which *x* is the loss of steel thickness per side, *k* is a constant dependent on soil conditions (i.e., soil corrosivity), *t* is time in years, and *n* is a constant dependent on steel conditions (i.e., galvanized or plain).

k = 50 μm (Ref. 5, Table 5, for pH > 5 and resistivity between 700 and 2,000 ohm-cm)

n = 0.8 (Ref. 5 Eq. 3 for plain steel elements; Ref. 6 pg. 2-25 for non-galvanized steel)

t =	50	years
x =	1143	μm over the next 50 years
x =	0.05	inches over the next 50 years
	(future)	

CALCULATIONS

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Pile section loss:

Using the non-linear total corrosion loss per side = 0.05 inches over the next 50 years

Pile size: HP 10x42 (Ref. 7, Sheet 10)

	Intact Section				Corroded Section	
Depth, d =	9.70	in (Ref. 8)		Depth, d =	9.60	in
Width, b_f =	10.1	in (Ref. 8)		Width, b_f =	10.0	in
Web thickness, t_w =	0.415	in (Ref. 8)		Web thickness, t_w =	0.315	in
Flange thickness, t_f =	0.420	in (Ref. 8)		Flange thickness, t_f =	0.320	in
Fillet area =	0.2	in^2		Fillet area =	0.2	in^2
Section area, A =	12.4	in^2 (Ref. 8)		Section area, A =	9.4	in^2

CONCLUSIONS

Based on the corrosivity lab test results, the AASHTO Standard Practice recommends using a corrosion probe to monitor for macrocell corrosion. Since a corrosion probe is not currently installed at site, several approximate corrosion rates from FHWA and NCHRP were used to estimate corrosion loss of the existing piles. Using a non-linear corrosion loss of 0.05 inches per side over the next 50 years (desired future life), the estimated corroded section area of the HP 10x42 piles would be 9.4 in^2, representing 76% of the intact section area. Per the AASHTO Standard Practice, the anticipated corrosion pattern is macrocell rather than uniform, so this estimated corroded section area may vary throughout the pile length.