Preliminary Geotechnical Design Report (PGDR)

Spaulding Brook Bridge No. 2790, Augusta, Maine (WIN 023126.00)

Submitted to:

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MaineDOT WIN 023126.00 / WSP 30900914.003

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1.0 INTRODUCTION

This Preliminary Geotechnical Design Report (PGDR) summarizes the results of WSP USA Inc. (WSP's) geotechnical investigation and preliminary recommendations for the replacement of the culvert carrying Maine Route (RT) 17 over Spaulding Brook in Augusta, Maine. Figure 1 shows the site location. The purpose of this report is to present soil and bedrock information for the culvert replacement project obtained from subsurface investigations and laboratory tests; present recommended geotechnical parameters for design; and provide preliminary geotechnical construction recommendations for the replacement culvert.

2.0 PROJECT BACKGROUND

WSP reviewed the As-Built Plans[1,2] and recent Inspection Report[3] for the existing structure. These plans indicate that the original structure was constructed in 1936 and replaced in 1989. The current in place structure consists of an 11 foot 7 inch by 7 foot 5 inch steel structural plate pipe arch culvert. The proposed replacement design consists of a precast concrete box culvert based on the Spaulding Brook bank full width of 13.5 feet[4].

3.0 GEOLOGIC SETTING

3.1 Regional Surficial Geology

The site lies within the Seaboard Lowland Section of the New England physiographic province, characterized by a topographic surface of low relief, that has been glaciated and eroded[5]. The site is mapped as lying within the Pleistocene-aged Presumpscot Formation, consisting of glaciomarine silt, clay and sand deposited on a late glacial sea floor. This formation often overlies older Pleistocene-aged glacial till, consisting of a loose to very dense, poorly sorted, massive to weakly stratified mixture of sand, silt, clay, and gravel-sized debris deposited directly by glacial ice. This unit includes lenses of water lain sand and gravel, along with occasional boulders. The till generally overlies intrusive igneous bedrock, described below. [6,7,8,9]

3.2 Regional Bedrock Geology

Bedrock beneath the site is mapped as Devonian-aged light gray, medium-grained, equigranular quartz monzonite with accessory biotite and muscovite mica, and pegmatite veins.[10,11] This unit was previously mapped

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1 Maine State Highway Commission, Bridge Division. Spaulding Bridge over Spaulding Brook in the city of Augusta, Kennebec Co. Dated November 1932 and February 1936.

2 State of Maine Department of Transportation. Thorne Bridge & Spaulding Bridge in the city of Augusta, Kennebec County. Dated January 1988.

3 Adams, Cy. Highway Bridge Inspection Report, BR# 2790 Spaulding Brook, RTE 17 over Spaulding Brook, Town: Augusta. Dated August 27, 2021.

4 Brady, Andrea F (MaineDOT). *Augusta 263126.00 Spaulding Brook Br (#2790) - preproposal input*, 27 December 2022.

5 Fenneman, N.M. and Johnson, D.W., 1946. Physical Divisions of the United States. U.S. Geological Survey, 1 sheet, scale 1:7,000,000.

6 USDA NRCS Web Soil Survey. https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx. Accessed September 28, 2022.

7 Thompson, Woodrow B., 2007, Surficial geology of the Togus Pond quadrangle: Maine Geological Survey, Open-File Map 07-101, map, scale 1:24,000. Maine Geological Survey Maps. 1754. http://digitalmaine.com/mgs_maps/1754

8 Thompson, Woodrow B. and Locke, Daniel B., 2005, Surficial materials of the Togus Pond quadrangle, Maine: Maine Geological Survey, Open-File Map 05-3, map, scale 1:24,000. Maine Geological Survey Maps. 1501. http://digitalmaine.com/mgs_maps/1501

9 Maine Geological Survey Water Well Database. https://www.maine.gov/dacf/mgs/pubs/digital/well.htm. Accessed September 28, 2022.

10 Osberg, P.H., Hussey, A.M., and Boone, G.M., 1985, Bedrock geologic map of Maine: Maine Geological Survey, scale 1:500,000. Digital Data – Maine Geological Survey. https://www.maine.gov/dacf/mgs/pubs/digital/bed500.htm

11 Marvinney, R.G. and Barker, D.S., 2012. Bedrock Geology of the Augusta Quadrangle, Maine Geological Survey Open-File Report No. 12-36, 1 sheet, scale 1:24,000.

as a biotite granodiorite, containing plagioclase feldspar, quartz, microcline feldspar, biotite and locally garnet or hornblende. The biotite forms a perceptible foliation in outcrops.[12]

4.0 SUBSURFACE INVESTIGATION

WSP completed two (2) geotechnical borings (BB-ASB-101 and BB-ASB-102) between April 7 and April 13, 2023. The as-drilled boring location coordinates and ground surface elevations, provided by MaineDOT, are summarized in Table 1. Boring locations with respect to existing site features are illustrated in the Boring Location Plan (Figure 2). Both borings were performed within the paved roadway of RT 17 on either side of the existing culvert at Spaulding Brook. The field program included Standard Penetration Testing (SPT) of predominantly fine-grained soils, in situ strength testing of unconsolidated materials, undisturbed Shelby tube sampling in the compressible clay strata, and recovery of rock core from the bedrock. A WSP geotechnical engineer monitored drilling activities, selected sampling intervals, logged subsurface conditions encountered, and obtained soil samples for use in visual descriptions and subsequent laboratory testing and classification.

WSP subcontracted Seaboard Drilling, LLC (Seaboard, formerly S.W. Cole Explorations, LLC) of Bangor, Maine to complete the borings using a B-48 Mobile track-mounted drill rig using cased wash boring techniques. To advance the borings, Seaboard drove 4-inch inside diameter casing in 5-foot lengths using an automatic safety hammer. Soil in the casing was washed out using a roller bit and water to the depth where samples were collected or where in situ field vane shear testing was performed. Boring BB-ASB-101 and BB-ASB-102 encountered bedrock at 30.5 feet and 31.5 feet below ground surface (bgs), respectively.

Seaboard performed SPT using a calibrated automatic hammer system and standard 2-inch split spoon sampler in general accordance with American Society for Testing and Materials (ASTM) D1586. Sampling was conducted at approximately 5-foot intervals. Seaboard drove split spoons for 24 inches with a 140-pound hammer dropped 30 inches and WSP recorded the number of hammer blows required to advance the sampler through each 6-inch increment. Measured, uncorrected N-values, calculated as the sum of the hammer blows to advance the sampler during the 6-inch to 18-inch interval, are provided in the boring logs in Appendix A. WSP used the calibrated hammer energy transfer ratio (91% for the Mobile B-48 Drill Rig as provided by Seaboard) to covert the measured N-values to N_{60} values for subsequent analyses. WSP collected and stored soil samples in sealed glass jars for later evaluation and laboratory testing.

Seaboard conducted in situ field vane shear tests in the cohesive soil deposit using a WSP-owned Geonor rectangular vane set. For each test or pair of tests, the borehole was advanced either 6-inches or 1 foot above the desired test depth, after which the vane was advanced the remaining distance by hand using dedicated vane rods. At the desired test depth, Seaboard rotated the vane with a calibrated torque wrench at a rate of approximately 90 degrees per minute to obtain the peak torque, used to estimate the peak undrained shear strength. The vane was then rotated rapidly at the same depth through 10 revolutions to remold the soil before being rotated again with a torque wrench at approximately 90 degrees per minute to obtain the residual torque, used to estimate the residual undrained shear strength. Results from vane shear testing are summarized in Table 2, including raw torque readings and calculated uncorrected undrained shear strengths, and provided on the boring logs in Appendix A.

[12] Osberg, P.H., 1968. Stratigraphy, Structural Geology, and Metamorphism of the Waterville-Vassalboro Area, Maine. Maine Geological Survey Bulletin No. 20, June 1968, 64 p., 1 sheet, scale 1:62,500.

Seaboard collected one (1) undisturbed Shelby tube sample in borehole BB-ASB-102 in general accordance with ASTM D6519 using a GUS sampler. Samples were sealed in the field using wax and transported back to the WSP office for subsequent laboratory testing assignment.

Seaboard collected up to 10 feet of rock core using NQ/NX size (1-7/8-inch diameter) diamond tipped core barrels in the two borings following either refusal of casing, or failure to advance the split spoon sampler or roller bit. Rock core samples were placed in wooden boxes and transported to the WSP office. WSP recorded the lithology, Total Core Recovery (TCR), Rock Quality Designation (RQD), and coring rates for each core run which are provided in the boring logs in Appendix A. A detailed summary of the rock core quality parameters for the recovered rock core is presented in Table 3 and photographs of the rock core are presented in Appendix B.

The boring logs provided in Appendix A present details of the sampling methods used, field data obtained, and soil and rock conditions encountered during the investigation. Soils were field categorized in accordance with ASTM D2488. WSP field characterized the bedrock lithology, and the descriptions were revised in the office. A description of the boring log symbols and terms used for the soil and rock descriptions precedes the boring logs.

5.0 LABORATORY TESTING PROGRAM

After reviewing the collected samples in the office, WSP transferred select samples to GeoTesting Express (GTX) of Acton, Massachusetts for geotechnical laboratory testing in accordance with applicable AASHTO and ASTM testing procedures. WSP selected representative SPT split spoon soil samples from the borings for geotechnical laboratory testing to assist in soil classification. The types and numbers of each of the laboratory tests conducted on soil samples are presented in Table 5-1. Measured index and classification test results from soil samples are summarized in Table 4 and include AASHTO and Unified Soil Classification System (USCS) classifications. Soil testing results are included on the boring logs in Appendix A. Measured strength and consolidation test results are summarized in Table 5. Complete laboratory testing results are provided in Appendix C.

Table 5-1: Summary of Laboratory Tests Performed

Laboratory Test	Test Standard	No. Tests
Moisture content	ASTM D 2216, AASHTO T267	2
Grain size analysis (coarse)	ASTM D 6913, AASHTO T88	2
Grainsize (fines)	ASTM D 7928, AASHTO T88	6
Atterberg Limits	ASTM D 4318, AASHTO T89	6
X-Ray Shelby Tube - Digital Imaging	ASTM D4452	1
Incremental Consolidation (ILC)	AASHTO T 216	1
Direct Simple Shear (DSS)	ASTM D6528	1

6.0 SUBSURFACE CONDITIONS

The soils encountered in the borings generally consist of fill materials placed during construction of the culvert and roadway, naturally occurring silt interpreted as Presumpscot Formation silt, clay interpreted as Presumpscot Formation clay, and sandy/silty gravel interpreted as glacial till. The boring logs in Appendix A provide detailed descriptions of the soil conditions encountered in the borings. Figure 3 provides WSP's Interpretive Subsurface Profile (ISP) along the centerline of the roadway. The following descriptions summarize the major stratigraphic units from the existing ground surface to depth.

Asphalt Pavement: Asphalt pavement thickness ranged from approximately 8.5 inches in boring BB-ASB-101 to 11 inches in boring BB-ASB-102.

Fill: A layer of fill was encountered between 0.7 feet to 5 feet below ground surface (bgs) in BB-ASB-101 and 0.9 feet to 5 feet bgs in BB-ASB-102. The fill consists of brown, dry, very dense gravel, with fine to coarse sand fractions, and little silt fractions. Laboratory classifications generally described the layer as GW-GM (USCS) and A-1-a (AASHTO). N_{60}-values ranged from 39 to 46 in the fill and generally decreased with depth. The fill layer transitions to the silty/ Presumpscot Formation silt layer at 5 feet bgs in both borings.

Presumpscot Formation Silt: The silt was encountered between 5 feet and 10 feet bgs in BB-ASB-101 and BB-ASB-102. This layer consists of brown to olive to grey, wet, very stiff to loose silt, with "some" fine sand fractions. This layer is generally described as ML (USCS) based on visual manual procedures[13]. Silt N_{60}-values ranged from 8 to 18. The silt layer transitions to the clay layer at approximately 10 feet bgs.

Presumpscot Formation Clay: A layer of silty clay was encountered between 10 feet and 31.5 feet bgs in BB-ASB-101 and 30 feet bgs in BB-ASB-102. The clay layer consists of olive to grey, wet, very soft to stiff, clay with "little" to "some" silt fractions. The layer is generally described as CL (USCS) and A-6 (AASHTO). N_{60}-values for the clay, corrected for hammer efficiency, ranged from 7 to 12. The undrained shear strength for the clay, determined from field vane shear measurements and corrected using plasticity index, ranged from 701 psf to 1036 psf, and the corrected remolded strength ranged from 140 psf to 252 psf. The clay layer overlies bedrock in BB-ASB-101 and transitions to glacial till in BB-ATB-102.

Glacial Till: A layer of gravel (interpreted as glacial till) was encountered in BB-ASB-102 from 30.0 to 31.1 feet bgs. The till consists of grey, wet, medium dense gravel with "some" silt, and "little" sand fractions. Laboratory classifications generally describe the layer as GM (USCS) and A-2-4 (AASHTO). The till lies directly on bedrock in BB-ASB-102.

Bedrock: Bedrock was cored from 31.5 feet to 41.5 feet bgs in BB-ASB-101 and from 31.1 feet to 32.6 feet bgs in BB-ASB-102. The bedrock consists of light gray to white, fresh to slightly weathered, (W1 to W2), strong to very strong (R3 to R4), moderately foliated quartz monzonite, with closely spaced fractures (0.5 inch to 9 inches). TCR ranged from 80% to 100%, and RQD ranged from 21% to 62% (i.e., very poor to fair). The lithology is consistent with the Devonian quartz monzonite described in Section 3.2.

Groundwater: Groundwater level was measured in boring BB-ASB-101 at 3.9 feet bgs upon returning to boring after a 6 day pause in drilling with casing installed to 32 feet bgs. Water level was not measured in BB-ATB-102 due to lack of time upon completion of the field program. Groundwater levels shown on the ISCS in Figure 3 were interpreted based on these water level measurements and on moisture content observed in the soil samples. We note that groundwater levels will fluctuate due to seasonal precipitation trends.

[13] ASTM D2488-17e1 Standard Practice for Description and Identification of Soils (Visual-Manual Procedures).

7.0 GEOTECHNICAL ANALYSES AND RECOMMENDATIONS

The base elevation of the proposed box culvert as specified in the project plans[14] will be founded within the Presumpscot clay deposit layer at EL. 169.9 feet and the precast toe walls will be located at EL. 167.9 feet. The culvert is proposed to be 76 feet long including the sloped wingwalls and 16 feet wide. The culvert location in plan is shown on the BLP (Figure 2) and in profile with respect to stratigraphy on the ISCS (Figure 3). Site soils at and adjacent to RT 17 will need to be excavated approximately 16 feet bgs to install the culvert, including an additional 1 foot of excavation below the base of the culvert and toe walls to accommodate the proposed Granular Borrow for Underwater Backfill (MaineDOT Standard Specification[15] Section 703.19).

Our analyses and recommendations are described in the subsections below. Calculations, references, and assumptions are provided in Appendix D.

7.1 Design Parameters

WSP evaluated the subsurface geotechnical data collected and developed geotechnical material design parameters to serve as a basis for calculations, analyses, and evaluations discussed herein. Table 7-1 provides a summary of design parameters for each in situ soil layer encountered (refer to Figure 3) and material properties for fills as identified in the MaineDOT Standard Specifications.[15]

Table 7-1: Recommended Geotechnical Design Parameters for In Situ Soils and Construction Fills

Soil Layer		γ (pcf)	ϕ (°)	Lateral Earth Pressure Coefficients[1]		
				K_0	K_a	K_p
In Situ Materials	Existing Fill	125	36	0.41	0.26	8.6
	Presumpscot Silt	120	33	0.46	0.29	6.0
	Presumpscot Clay	118	29	0.61	N/A	N/A
	Glacial Till	135	36	0.41	0.26	8.6
Construction Materials	Asphalt	140	N/A	N/A	N/A	N/A
	Granular Borrow (Section 703.19)	125	32	0.47	0.31	6.6
	Gravel Borrow (Section 703.20)	135	36	0.41	0.26	9.6
	Special Fill (Stream Bed) (Section 203.33)	135	N/A	N/A	N/A	N/A
	Stream Channel Rock	140	N/A	N/A	N/A	N/A
	Riprap (Section 703.26)	140	42	N/A	N/A	N/A

Notes: [1]Lateral earth pressure coefficients were determined using Rankine method for K_a and using AASHTO LRFD[16] Figure 3.11.5.4-1 for K_p. The term N/A indicates these parameters are not used in our evaluations.

[14] State of Maine Department of Transportation, Spaulding Brook Bridge, Spaulding Brook, Augusta, Kennebec County, (Sheets 1 - 16), Dated 11/2023 (WSP Draft plans).

[15] MaineDOT Standard Specifications, March 2020. https://www.maine.gov/mdot/contractors/publications/standardspec/docs/2020/2020%20Standard%20Specification.pdf

[16] AASHTO LRFD Bridge Design Specifications, 9th Ed. 2020.

Table 7-1 provides lateral earth pressure coefficients for subsurface and fill soils. For a non-yielding, stiff structure like the box culvert and wingwall system proposed for this project, an at-rest lateral earth pressure coefficient of 0.47 for Granular Borrow is recommended for design.

7.2 Bearing Resistance and Subgrade Modulus

WSP evaluated the bearing resistance of the underlying soils. We recommend a strength limit state bearing resistance factor of 0.45 and a strength limit state factored bearing resistance of 2.4 ksf be used for design. We recommend a service limit state bearing resistance factor of 1.0 and a factored presumptive bearing resistance of 2 ksf for the service limit state that limits settlement to 1 inch. These factored bearing resistances exceed the estimated bearing pressure of 1.6 ksf at the base of the proposed culvert that WSP determined as part of our settlement analysis.

We additionally evaluated the subgrade modulus using the corrected SPT N-values for the Presumpscot clay at the proposed culvert bearing elevation. We recommend a modulus of subgrade reaction of 2.5 pci (pounds per cubic inch) be used for structural design of the proposed culvert.

7.3 Settlement

We estimate a net increase in effective stress will occur in the soils below the proposed culvert following installation and roadway reconstruction compared to present stress conditions. Thus, we evaluated settlement below the proposed midpoint of the culvert where the stress changes will be the greatest. We considered elastic settlement of coarse-grained soils and primary consolidation settlement for the Presumpscot clay. The loads imposed by the proposed culvert and roadway fills were distributed through the subsurface soils using Boussinesq stress distribution theory for the given geometry. The subsurface soils were then discretized into layers less than 10 feet thick, and the effective stress, imposed stresses and other soil parameters were used to evaluate settlement within each layer. We estimated material properties for the cohesionless layers from the SPT N_{60} values (see Appendix A boring logs) and used the Hough Method to estimate immediate settlement in the glacial till. Material properties for the Presumpscot clay layer were based on results from one-dimensional consolidation laboratory tests performed on BB-ASB-102 Shelby tube and summarized in Table 5, and consolidation theory was used to estimate primary consolidation settlement. We estimated 1-inch of consolidation settlement below the center of the culvert.

Because the proposed final roadway embankment profile at this location is similar to the existing embankment configuration, we did not evaluate settlement at other locations along the culvert alignment. We expect limited settlement may occur in these areas due to construction activities.

7.4 Global Stability

WSP evaluated global stability transverse to RT 17 for a section with the greatest change in embankment geometry, specifically the northeastern slope at Station 109+50 northwest of the proposed box culvert. We performed the analyses using the two-dimensional limit equilibrium modeling software *Slide2* by Rocscience[17] for existing and post-construction static conditions. The embankment geometry is from the existing and proposed grades shown on the draft PDR plans[14] and subsurface stratigraphy is from the ISP (Figure 3).

[17] Rocscience Inc. Slide2 software package, Version 9.027, build date February 13, 2023.

We analyzed global stability using the Spencer method with auto refined search for circular failure surfaces and the Spencer Method with a Cuckoo search plus surface altering optimization for non-circular failure surfaces. The search algorithm that produced a lower factor of safety was selected, and the analyses show that non-circular surfaces govern potential slope failures. Per the MaineDOT Bridge Design Guide[18] Section 5.9.2, we used a minimum allowable design factor of safety (FS) of 1.3 for embankments to assess satisfactory global stability.

Results are summarized in Table 7-2. The existing embankment geometry at the northeastern slope produced adequate FS values. The proposed embankment geometry for northeastern slope produced FS values that meet the minimum allowable design FS.

Table 7-2: Summary of Global Stability Factors of Safety at Embankment Station 109+50.

Surface Type	Location	Condition	Static Factor of Safety
Non-Circular	Northeast Slope	Existing	1.64
Circular	Northeast Slope	Existing	1.65
Non-Circular	Northeast Slope	Proposed	1.64
Circular	Northeast Slope	Proposed	1.77

8.0 CONSTRUCTION CONSIDERATIONS

At the writing of this report, the sequence of the work and considerations for water diversion are unknown. However, construction activities will require soil excavation to below both the water table encountered during the geotechnical site investigation and the stream water level. Construction may require cofferdams and temporary earth support systems to support culvert and stream bed excavations and to control water flow. The design and maintenance of any temporary earth support systems must consider the weak nature of the subsurface Presumpscot silts and clays. The design of all temporary earth support systems should comply with Section 511 Cofferdams of the MaineDOT Standard Specifications[15] and OSHA requirements. Temporary dewatering of the stream and excavation may be required and should be performed to limit disturbance to the culvert bearing surfaces. Dewatering activities should comply with Section 656 Temporary Soil Erosion and Water Pollution Control of the MaineDOT Standard Specifications.[15] The contractor should additionally control groundwater and surface water infiltration so that construction can be completed under dry conditions.

When excavating the existing embankment for the culvert replacement, low strength, fine-grained silts and clays will be encountered. Care should be taken to minimize disturbance to these low strength soils during excavation. Low tire or track pressure machines are recommended for use when operating on these soils. Subgrade should be prepared with a smooth-edged bucket to minimize disturbance. Where groundwater is encountered during subgrade excavation, the Contractor should provide temporary dewatering of subgrade excavations such that fill or structure placement is performed in the dry. Vibratory compaction equipment should not be used on these soils, as they have the potential to liquefy in the short term and experience vibration-induced settlements in the

[18] Maine Department of Transportation, Bridge Design Guide, 2003 updated 2018. https://www.maine.gov/mdot/bdg/docs/BDGupdateJune2018.pdf

long-term. Other aspects related to subgrade preparation should be performed in accordance with Section 203.17 of the MaineDOT Standard Specifications.

Prior to placing the box culvert and wingwalls, we recommend undercutting the foundation 12 inches and placing a separation geotextile (Section 722.04) and 12 inches of Granular Borrow for Underwater Backfill to facilitate fine grading and dewatering for the installation of the culvert. The separation geotextile should fully encapsulate the Granular Borrow for Underwater Backfill and provide sufficient overlap under the box culvert such that the when the box culvert is installed the crushed stone remains in place and does not migrate into the Presumpscot clay.

Culvert bedding and backfill material should be placed systematically in horizontal layers not more than 8 inches in thickness prior to compaction, in accordance with Section 534.20 of the MaineDOT Standard Specifications. Cobbles larger than 4 inches should be removed from the fill prior to placement, in accordance with Section 534.02 of the MaineDOT Standard Specifications. Compaction equipment should preferably consist of large, self-propelled rollers. Hand-guided equipment, such as a small vibratory plate compactor, should be used within five feet of the box culvert structure as well as over the top until it is covered with at least 12 inches of backfill, in accordance with Section 534.20. Where hand-guided equipment is used, the loose lift thickness shall not exceed 6 inches. Culvert backfill material should consist of Granular Borrow for Underwater Backfill (MaineDOT Standard Specification Section 703.19), in accordance with Section 534.02 of the MaineDOT Standard Specifications.

Culvert bedding and backfill material should be compacted to a dry density of no less than 92% of the maximum dry density determined in accordance with AASHTO T-180, Method C. Embankment material placed beyond the limits of the culvert Granular Borrow bedding and backfill should be compacted in accordance with the applicable subsections of Section 203, Excavations and Embankment, of the MaineDOT Standard Specifications.

We recommend that both the culvert inlet and outlet be armored with riprap in accordance with MaineDOT Standard Details[19] and Standard Specifications.[15] We recommend the inlet and outlet include a 2-foot thick by 10-foot long Plain Riprap Apron (Detail 610(04)) comprised of Plain Riprap (Section 703.26) capped with a 2-foot-thick layer of Special Fill (Item No. 203.33, which will be specified later in a Special Provision). The riprap slope will be underlain by a Class 1 non-woven erosion control geotextile meeting the requirements of Section 722.03. The erosion control geotextile should encapsulate the riprap and extend up the sides of the embankment cut to prevent migration of the riprap into the Presumpscot clay.

9.0 REPORT AND EXPLORATION LIMITATIONS

This Preliminary Geotechnical Design Report (PGDR) was prepared for the exclusive use of MaineDOT for specific application to the proposed replacement of the culvert that passes RT 17 over Spaulding Brook in Augusta, Maine. We conducted our evaluations and compiled our recommendations in accordance with generally accepted soil and foundation engineering practices in this geographical area and under similar time and financial constraints. WSP makes no other warranty, either express or implied. If changes in the nature, design, or location of the proposed project are planned, WSP should be notified to review the appropriateness of our conclusions and recommendations, and to modify the recommendations as appropriate to reflect the changes in design. WSP should review the final plans and specifications to evaluate compliance with these recommendations.

[19] MaineDOT Standard Details, March 2020. https://www.maine.gov/mdot/contractors/publications/standarddetail/docs/2020/2020-STANDARD_DETAILS.pdf

Our analyses and recommendations are based, in part, on information obtained from the referenced subsurface explorations completed at the discrete locations described in the report. Variations in the nature and extent of subsurface conditions between explorations should be expected. WSP should be notified if conditions encountered during construction vary from those described in this report so that we may re-evaluate, and if necessary, revise the recommendations made in this report.

The professional services provided by WSP for this project include only the geotechnical aspects of the subsurface conditions at this site. The presence or implications of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this report and have not been investigated or addressed.

Signature Page

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https://wsponlinenam.sharepoint.com/sites/us-mainegeotech/shared documents/mainedot augusta spaulding brook culvert/06 deliverables/win 023126.00 spaulding brook pgdr wsp 20260226.docx

TABLES

Table 1: Subsurface Exploration Locations
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Boring Designation[1,2,3]	As-Drilled Locations[4]		Existing Ground Surface Elevation[4] (feet)	Maximum Depth of Investigation (feet bgs[5])
	Northing	Easting		
BB-ASB-101	535590.0554	1151640.8119	182.8	41.5
BB-ASB-102	535546.6736	1151667.6209	182.8	32.6

Notes:

1. Test boring locations are shown in Figure 2 - Boring Location Plan
2. Borings BB-ASB-101 & BB-ASB-102 were performed by Seaboard Drilling LLC (formerly S.W. Cole Explorations) in April 2023.
3. Boring logs are presented in Appendix A
4. As-drilled locations and elevations for boriings BB-ASB-101 & BB-ASB-102 are derived from the electronic file "CORRECTED BORINGS 17 AUG 23" recieved by WSP on August 17, 2023.
5. Depth below ground surface.

Prepared By: KMB
Checked By: ATM
Reviewed By: JRS

Table 2: In-Situ Vane Shear Testing Results
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Test Boring Designation[1]	Ground Surface Elevation[2] (feet)	Test Number	Test Depth Below Ground Surface (feet)	Approximate Test Elevation (feet)	Vane Size[3] (mm x mm)	Undisturbed		Remolded		Sensitivity S_t[6]
						Vane Reading Torque[4] (ft-lbs)	s_u from Vane Reading[5] (psf)	Vane Reading Torque[4] (ft-lbs)	s_{u-r} from Vane Reading[5] (psf)	
BB-ASB-101	182.80	V1	21.5	161.3	65 x 130	26	715	5.5	151	4.7
		V2	22.5	160.3	65 x 130	29	798	5	138	5.8
		V3	26.0	156.8	65 x 130	28	770	6	165	4.7
		V4	27.0	155.8	65 x 130	31	853	7	193	4.4
		V5	31.0	151.8	65 x 130	25	688	6	165	4.2
		V6	31.5	151.3	65 x 130	37	1018	9	248	4.1
BB-ASB-102	182.76	V1	21.0	161.8	65 x 130	33	908	8	220	4.1
		V2	22.0	160.8	65 x 130	31	853	7	193	4.4

Notes:
1. Test boring locations are shown in Figure 2 - Boring Location Plan
2. As-drilled locations and elevations for boriings BB-ASB-101 & BB-ASB-102 are derived from the electronic file "CORRECTED BORINGS 17 AUG 23" recieved by WSP on August 17,
3. Geonor Rectangular Vane, mm = millimeters
4. Raw torque readings are presented as ft-lbs for the 65 x 130 mm vane.
5. s_u and s_{u-r} are the calculated peak and remolded undrained shear strengths, respectively. Conversion from torque readings to shear strengths are based on data from Geonor. For the 65 x 130 mm vane, 1 ft-lb of torque corresponds to 27.5 psf.
6. Sensitivity, $S_t = s_u/s_{u-r}$
7. Vane shear test results are shown on the boring logs in Appendix A of the Preliminary Geotechnical Design Report.

Prepared By: ATM
Checked By: DEB
Reviewed By: JRS

Table 3: Summary of Rock Core Quality
Preliminary Geotechnical Design Report
Augusta Spaulding Brook Bridge No. 2790
MaineDOT WIN 023126.00

Test Boring Designation	Core Size [in]	Existing Ground Surface Elevation[1] [ft]	Run						TCR[2]		RQD[3]			Physical Rock Parameters			Lithologic, Rock Mass and Discontinuity Description[6]
			No.	Midpoint Depth Below Bedrock Surface [ft]	Depth Below Ground Surface [ft] Start	End	Midpoint	Length [ft]	Length [ft]	%	Length [ft]	%	Designation	Weathering[4]	Estimated Field Strength[4]	Rock Mass Rating [RMR][5]	
BB-ASB-101	NQ [1.875]	182.80	R1	1.13	31.50	33.75	32.63	2.3	2.3	100%	1.4	62%	Fair	Fresh (W1) to Slightly Weathered (W2)	Strong (R3) to Very strong (R4)	56	31.50 ft - 33.75 ft: Light grey to white, QUARTZ MONZONITE, strong (R3) to very strong (R4), fresh (W1) to slightly weathered (W2), fine-grained, moderately foliated, discontinuities low angle to moderately dipping (30 to 60 deg), fractures closely spaced (1-in to 7-in), fresh, tight to open, rough, average of 4 fractures per foot [DEVONIAN QUARTZ MONZONITE].
			R2	4.13	33.75	37.50	35.63	3.8	3.5	93%	2.2	58%	Fair	Fresh (W1) to Slightly Weathered (W2)	Strong (R3) to Very strong (R4)	57	33.75 ft - 37.50 ft: Light grey to white, QUARTZ MONZONITE, strong (R3) to very strong (R4), fresh (W1) to slightly weathered (W2), fine-grained, moderately foliated, discontinuities low angle to steeply dipping (60 deg), fractures closely spaced (0.5-in. to 8-in.), fresh, tight to open, rough to very rough, average of 3 fractures per foot [DEVONIAN QUARTZ MONZONITE].
			R3	6.71	37.50	38.92	38.21	1.4	1.4	100%	0.3	21%	Very Poor	Fresh (W1) to Slightly Weathered (W2)	Strong (R3) to Very strong (R4)	49	37.50 ft - 38.92 ft: Light grey to white, QUARTZ MONZONITE, strong (R3) to very strong (R4), fresh (W1) to slightly weathered (W2), fine-grained, moderately foliated, discontinuities low angle to steeply dipping (30 to 60 deg), fractures closely spaced (0.5-in to 4-in.), fresh, tight to open, rough to very rough, average of 5 fractures per foot [DEVONIAN QUARTZ MONZONITE].
			R4	8.95	38.92	41.98	40.45	3.1	3.1	100%	1.8	58%	Fair	Fresh (W1)	Strong (R3) to Very strong (R4)	58	38.92 ft - 41.98 ft: Light grey to white, QUARTZ MONZONITE, strong (R3) to very strong (R4), fresh (W1), fine-grained, moderately foliated, discontinuities low angle to steeply dipping (30 to 60 deg), fractures closely spaced (1-in. to 6-in.), fresh, tight to open, rough to very rough, average of 5 fractures per foot [DEVONIAN QUARTZ MONZONITE].
BB-ASB-102	NQ [1.875]	182.76	R1	0.75	31.10	32.60	31.85	1.5	1.2	80%	0.7	45%	Poor	Fresh (W1)	Strong (R3) to Very strong (R4)	56	31.10 ft - 32.60 ft: Light grey to white, QUARTZ MONZONITE, strong (R3) to very strong (R4), fresh (W1), fine-grained, moderately foliated, discontinuities low angle to steeply dipping (30 to 60 deg), fractures closely spaced (2-in. to 9-in.), fresh, tight to open, rough to very rough, average of 2 fractures per foot [DEVONIAN QUARTZ MONZONITE].

Notes:

1. As-drilled locations and elevations for boriings BB-ASB-101 & BB-ASB-102 are derived from the electronic file "CORRECTED BORINGS 17 AUG 23" recieved by WSP on August 17, 2023.
2. TCR = total core recovery. Total core recovery is the length of core recovered divided by the length of the run.
3. RQD = rock quality designation. RQD is the total length of intact, full diameter core pieces recovered with a length greater than or equal to twice the core diameter (i.e., length of 4 inches) measured along the core axis. The percent RQD is the total length of RQD measured versus the run length. Note that vertical discontinuities are not included in determination of RQD.
4. Weathering and Estimated Field Strength based on Tables II.4 and II.3 (respectively) in Willey, 2004 (based on ISRM, 1981).
5. Rock Mass Rating System (RMR; Bieniawski, 1989) assigns numerical ratings to six parameters, including the strength of the intact rock, the RQD, the discontinuity spacing, discontinuity conditions, groundwater conditions, and orientation of discontinuities. These ratings are summed to give the RMR value. As proposed foundations or tie-back designs are not complete, the rating adjustment for joint orientation was assigned a value of 0.
6. ft = feet, in = inches

Prepared by: KMB
Checked by: ATM
Reviewed by: JRS

Table 4: Summary of Soil Index and Classification Laboratory Testing Results
Preliminary Geotechnical Design Report
Spaulding Brook Culvert, Augusta, Maine
MaineDOT WIN 023126.00

Test Boring Designation [1]	Ground Surface Elevation (feet)[1,2]	Sample Number[3]	Sample Depth Below Ground Surface (feet)	Approximate Sample Elevation (feet)[2]	Laboratory Testing [3,4,5,6]						Soil Classification	
					Sieve Minus No. 200[4] (%)	Moisture Content[5] (%)	Liquid Limit[6]	Plastic Limit[6]	Plasticity Index[6]	Liquidity Index[6]	AASHTO[7,8]	USCS[7,8]
BB-ASB-101	182.80	S1	0.7 - 2.7	182.1 - 180.1	11.4	2.6	-	-	-	-	A-1-a (0)	GW-GM
		S4	10.0 - 12.0	172.8 - 170.8	N/A	26	33	20	13	0.5	-	CL
		S5	15.0 - 17.0	167.8 - 165.8	N/A	27	39	20	19	0.4	-	CL
		S6	20.0 - 22.0	162.8 - 160.8	N/A	39	39	22	17	1.0	-	CL
BB-ASB-102	182.76	S3	10.0 - 12.0	172.8 - 170.8	N/A	30	39	22	17	0.5	-	CL
		S5	20.0 - 22.0	162.8 - 160.8	N/A	35	39	19	20	0.8	-	CL
		1U	25.0 - 27.0	157.8 - 155.8	99.7	35	33	18	15	1.1	A-6 (15)	CL
		S6	30.0 - 31.1	152.8 - 151.7	34.1	-	-	-	-	-	A-2-4 (0)	GM

Notes:

1. Test boring locations are illustrated in Figure 2 - Boring Location Plan.
2. As-drilled elevations for borings BB-ATB-101 & BB-ATB-102 are derived from the electronic file "CORRECTED BORINGS 17 AUG 23" received by WSP on August 17, 2023.
3. Laboratory testing was performed by Geotesting Express of Acton, MA.
4. Particle size testing was performed in accordance with ASTM D6913, Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis.
5. Moisture content testing was performed in accordance with ASTM D2216, Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.
6. Atterberg Limits testing was performed in accordance with ASTM D4318, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
7. AASHTO and USCS symbols were assigned based on interpreted laboratory test results provided by Geotesting Express on May 3rd, 2023 and May 12th, 2023.
8. Complete laboratory test results for soil testing are provided in Appendix C.

Prepared By: KMB / KAR
Checked By: ATM
Reviewed By: JRS

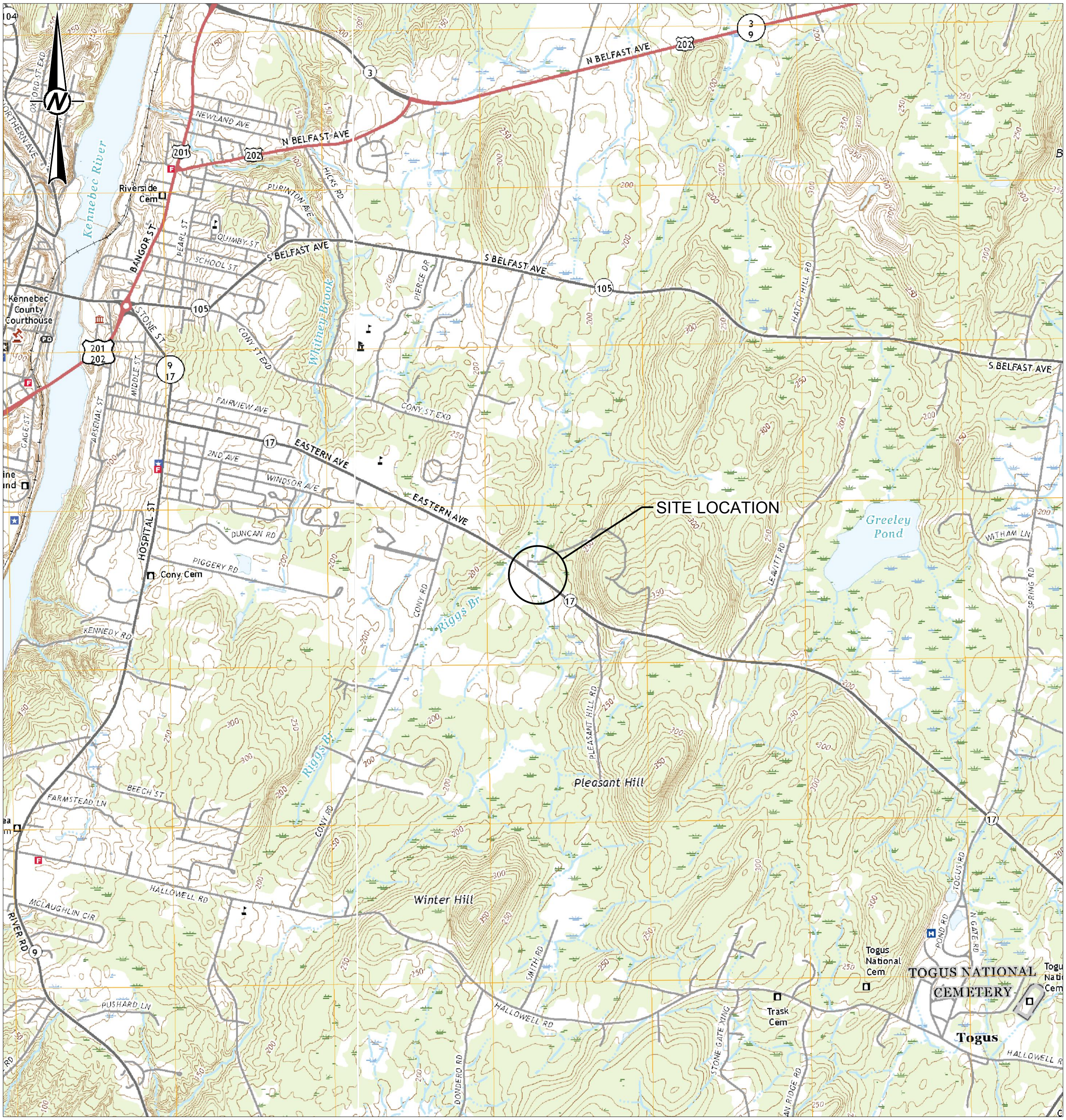
Table 5: Summary of Soil Engineering Laboratory Testing Results
Preliminary Geotechnical Design Report
Augusta Spaulding Brook Bridge #2183 Replacement, Augusta, Maine
MaineDOT WIN 023126.00

Test Boring Designation[1] (-)	Ground Surface Elevation[2] (feet)	Sample Number[3] (-)	Depth Below Ground Surface (feet)	Approximate Sample Elevation (feet)	Tube X-ray (-)	Test Type[4,5] (-)	Test No. (-)	unit weight, γ[6] (pcf)	Void Ratio, e (-)	σ'_{v0}[7] (psf)	σ'_{vc}[8] (psf)	s_u[9] (psf)	s_u/σ'_{vc} (-)	σ'_p[10] (psf)	OCR[11] (-)	C_c[12] (-)	C_r[12] (-)	c_v[13] (ft^2/day)
BB-ASB-102	182.76	U-1	25.0 - 27.0	157.8 - 155.8	Y	ILC	IP-1	117.6	0.97	1744	-	-	-	2440	1.4	0.25	0.032	0.12
						DSS-R	DSS-1	118.4	-		1720	400	0.23	-	-	-	-	-

Notes:
1. Test boring locations are shown on Figure 2 - Boring Location Plan.
2. As-drilled elevation for boring BB-ASB-102 derived from the electronic file "CORRECTED BORINGS 17 AUG 23" received by WSP on August 17,2023.
3. Laboratory testing was performed by Geotesting Express of Acton, MA.
4. ILC = Incremental Load Consolidation, DSS-R = Direct Simple Shear - Recompression
5. DSS-R tests were performed using the recompression method, where the sample was consolidated to the estimated in situ effective stress before shear.
6. γ = bulk unit weight. Values were measured during engineering property testing. Refer to Appendix C for more detailed laboratory results.
7. σ'_{v0} is the in situ vertical effective stress for each sample was estimated using the interpreted engineering profiles, average water table, and estimates or measurements of unit weight for each soil type in the profile.
8. σ'_{vc} is the vertical effective stress state at the end of consolidation, also known as the pre-shear effective stress.
9. s_u = undrained shear strength determined as the peak of the stress vs. strain plot resulting from direct simple shear (DSS) tests.
10. σ'_p is the preconsolidation stress. Preconsolidation stress determined using the Casagrande Construction method on stress vs. void ratio plots from ILC tests.
11. Overconsolidation ratio (OCR) = σ'_p/σ'_{v0} for ILC tests.
12. Recompression and compression indices were determined by interpretation of stress vs. strain plots from ILC tests.
13. Coefficient of consolidation values reported are from the ILC tests.
14. Secondary compression and recompression indices were determined by interpretation of strain vs. log time plots from ILC test.
15. Complete laboratory test results for soil testing are provided in Appendix C.

Prepared By: DEB
Checked By: ATM
Reviewed By: MEL

FIGURES



REFERENCE(S)

BASE MAP TAKEN FROM U.S.G.S. 7.5 MINUTE QUADRANGLES OF AUGUSTA AND TOGUS POND, MAINE DATED 2021.

0 1500 3000
1" = 3000' FEET

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

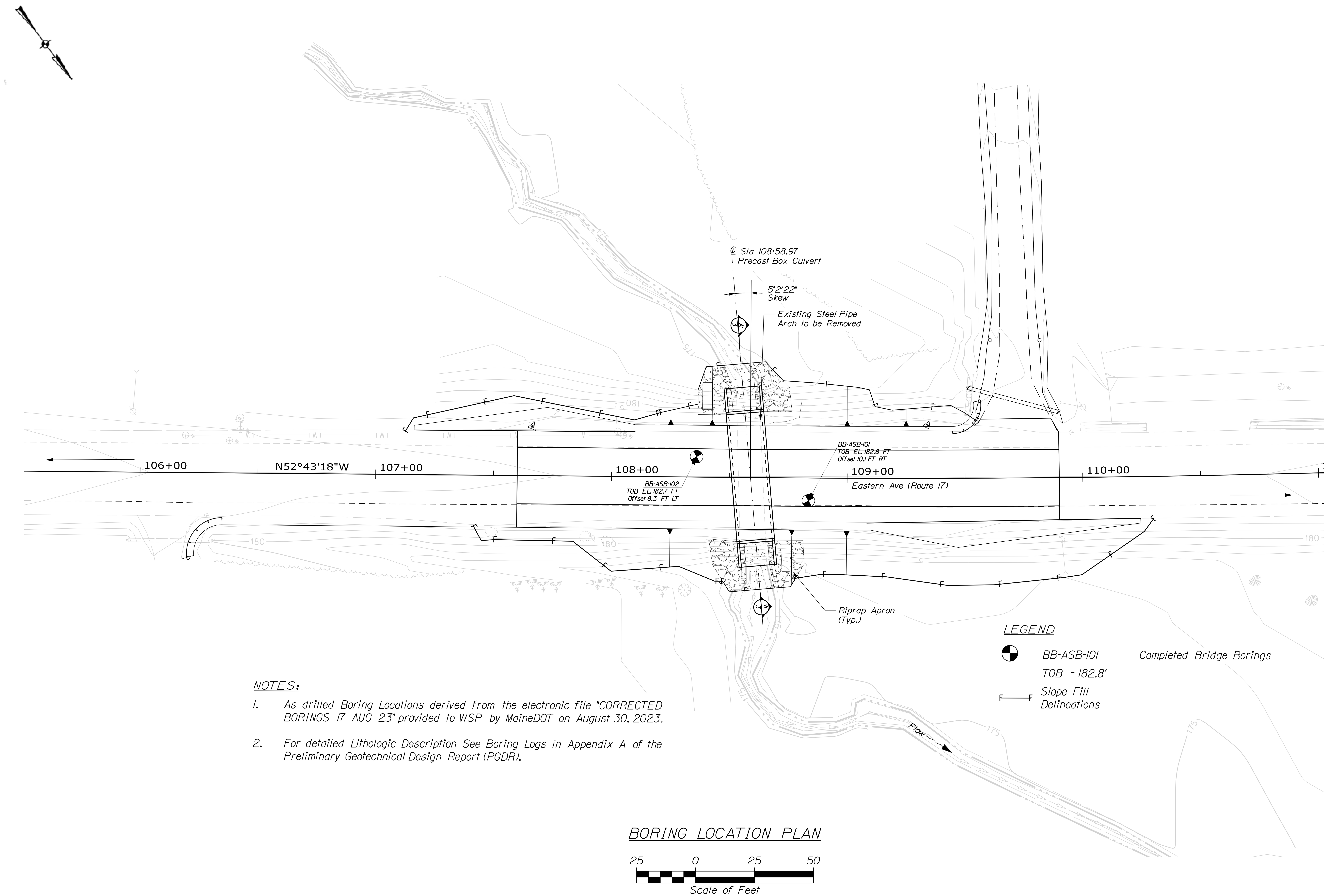
PROJECT
SPAULDING BROOK BRIDGE No. 2790
AUGUSTA, MAINE (WIN 023126.00)

CONSULTANT

YYYY-MM-DD	2023-11-15
DESIGNED	DB
PREPARED	AM
REVIEWED	MEL
APPROVED	CCB

TITLE
SITE LOCATION MAP

PROJECT NO.	CONTROL	REV.	FIGURE
30900914.003	0001-001	0	1



BORING LOCATION PLAN

NOTES:

1. As drilled Boring Locations derived from the electronic file "CORRECTED BORINGS 17 AUG 23" provided to WSP by MaineDOT on August 30, 2023.
2. For detailed Lithologic Description See Boring Logs in Appendix A of the Preliminary Geotechnical Design Report (PGDR).

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

BRIDGE NO. 2790
WIN
023126.00
BRIDGE PLANS

		BY	DATE
PROJ. MANAGER	B. NICHOLS		
DESIGN-DETAILED	E. CARON	W. GERHOLD	11/2023
CHECKED-REVIEWED	T. POLSON	E. CARON	11/2023
CHECKED-REVIEWED	D. BURGESS	C. BENDA	11/2023
DESIGN3-DETAILED3	$designer3$	$detailer3$	$prjdate3$
REVISIONS 1			$revdate1$
REVISIONS 2	$revision2$		$revdate2$
REVISIONS 3	$revision3$		$revdate3$
REVISIONS 4	$revision4$		$revdate4$
FIELD CHANGES	$fieldchange$		$fielddate$

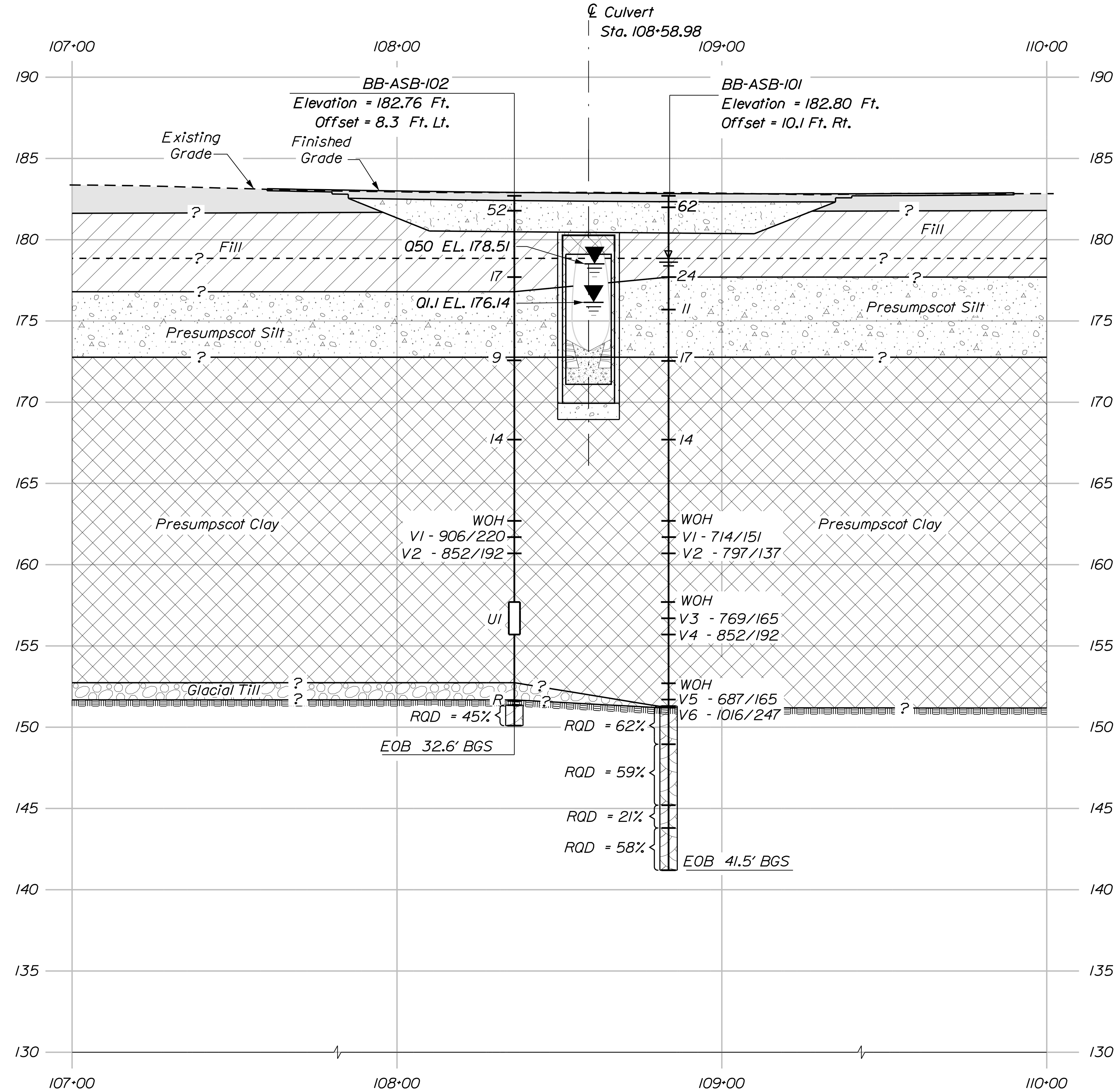
SIGNATURE
P.E. NUMBER
DATE

SPAULDING BROOK BRIDGE
ROUTE 17
AUGUSTA KENNEBEC COUNTY

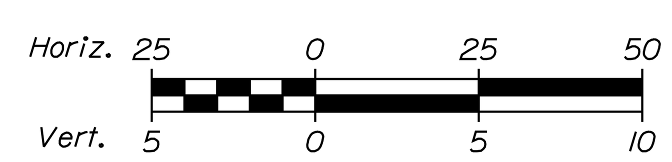
BORING LOCATION PLAN

SHEET NUMBER
2
OF 3

Filename: ...\BRIDGE\MSTA\002_BorLoc.dgn Division: BRIDGE Username: Date:11/16/2023



INTERPRETIVE SUBSURFACE PROFILE



LEGEND

- Brown, Dry to Moist, Very Dense, Fine To Coarse Sand, Fine to Coarse Gravel, Little Silt (Fill).
- Brown with Olive to Dark Grey, Moist To Wet, stiff to very Stiff, Silt, Trace Clay, Trace Fine Sand (Presumpscot Silt).
- Olive with Brown to Grey, Wet very Stiff to very Soft, Silty Clay, Slightly Plastic, Interbedded Silt Lenses (Presumscot Clay).
- Grey, Wet, Fine to Medium Sand, Fine to Coarse Gravel, Little Silt (Glacial Till).
- Light Grey to White, Fine Grained, Quatrz Monozonite, Strong to very Strong, Fresh to Slightly Weathered (Bedrock).
- Existing Ground Surface
- Existing Groundwater Elevations
- Interpreted Ground Water Surface At Boring Locations At The Time Of Drilling
- Design Water Level
- Boring Location I.D. / Elevation / Offset (Ft.) From ℄ of Roadway
- Top of Boring
- 30 — SPT; N60 - Value (Corrected for Hammer Efficiency)
- V1 - 906/220 — Field Vane Shear Test Location and Undrained Shear Strenght (PSF) Peak/Remolded)
- MS — Missed Sample
- U1 Thin Wall Tube Sample
- —? Strata Interface
- Run 1 = 92% Core Run Number and Rock Quality Designation (RQD)
- EOB — End of Boring Depth Below Ground Surface (BGS)

NOTES:

1. As drilled Boring Locations Derived from the Electronic file "CORRECTED BORINGS 17 AUG 23" Provided to WSP by MaineDOT on August 17, 2024.
2. For Detailed Lithologic Descriptions see Boring Logs in Appendix A of the Preliminary Geotechnical Design Report (PGDR).
3. For Complete Laboratory Data, see Laboratory Results in Appendix C of the Preliminary Geotechnical Design Report (PGDR).
4. Groundwater Surface is Interpreted from Localized Water Levels and Measurements Taken During the Subsurface Exploration Program, see the Preliminary Geotechnical Design Report (PGDR) and Boring Logs in Appendix A.
5. 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 may be Erratic.

wsp

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

BRIDGE PLANS
WIN 02312600
BRIDGE No 2790

	BY	DATE
PROJ. MANAGER	B. NICHOLS	
DESIGN-DETAILED	E. CARON	W. GERHOLD	11/2023
CHECKED-REVIEWED	T. POLSON	E. CARON	11/2023
DESIGN2-DETAILED3	D. BURGESS	C. BENDA	11/2023

SIGNATURE
P.E. NUMBER
DATE

SPAULDING BROOK BRIDGE
ROUTE 17
AUGUSTA KENNEBEC COUNTY
INTERPRETIVE SUBSURFACE PROFILE

SHEET NUMBER
3
OF 3

Filename: ...\BRIDGE\MSTA\003_GeoProfile.dgn Division: BRIDGE Username: Date:2/23/2026

APPENDIX A

Boring Logs

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS (more than half of material is larger than No. 200 sieve size)	GRAVELS (more than half of coarse fraction is larger than No. 4 sieve size)	CLEAN GRAVELS (little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
			GP	Poorly-graded gravels, gravel sand mixtures, little or no fines.
		GRAVEL WITH FINES (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures.
	SANDS (more than half of coarse fraction is smaller than No. 4 sieve size)	CLEAN SANDS (little or no fines)	SW	Well-graded sands, Gravelly sands, little or no fines
			SP	Poorly-graded sands, Gravelly sand, little or no fines.
		SANDS WITH FINES (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures.
FINE-GRAINED SOILS (more than half of material is smaller than No. 200 sieve size)	SILTS AND CLAYS (liquid limit less than 50)		ML	Inorganic silts and very fine sands, rock flour, Silty or Clayey fine sands, or Clayey silts with slight plasticity.
			CL	Inorganic clays of low to medium plasticity, Gravelly clays, Sandy clays, Silty clays, lean clays.
			OL	Organic silts and organic Silty clays of low plasticity.
	SILTS AND CLAYS (liquid limit greater than 50)		MH	Inorganic silts, micaceous or diatomaceous fine Sandy or Silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays.
			OH	Organic clays of medium to high plasticity, organic silts.
	HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.

Desired Soil Observations (in this order, if applicable):
Color (Munsell color chart)
Moisture (dry, damp, moist, wet)
Density/Consistency (from above right hand side)
Texture (fine, medium, coarse, etc.)
Name (Sand, Silty Sand, Clay, etc., including portions - trace, little, etc.)
Gradation (well-graded, poorly-graded, uniform, etc.)
Plasticity (non-plastic, slightly plastic, moderately plastic, highly plastic)
Structure (layering, fractures, cracks, etc.)
Bonding (well, moderately, loosely, etc.,)
Cementation (weak, moderate, or strong)
Geologic Origin (till, marine clay, alluvium, etc.)
Groundwater level

Maine Department of Transportation
Geotechnical Section
Key to Soil and Rock Descriptions and Terms
Field Identification Information

MODIFIED BURMISTER SYSTEM

Descriptive Term	Portion of Total (%)
trace	0 - 10
little	11 - 20
some	21 - 35
adjective (e.g. Sandy, Clayey)	36 - 50

TERMS DESCRIBING DENSITY/CONSISTENCY

Coarse-grained soils (more than half of material is larger than No. 200 sieve): Includes (1) clean gravels; (2) Silty or Clayey gravels; and (3) Silty, Clayey or Gravelly sands. Density is rated according to standard penetration resistance (N-value).

Density of Cohesionless Soils	Standard Penetration Resistance N_{60}-Value (blows per foot)
Very loose	0 - 4
Loose	5 - 10
Medium Dense	11 - 30
Dense	31 - 50
Very Dense	> 50

Fine-grained soils (more than half of material is smaller than No. 200 sieve): Includes (1) inorganic and organic silts and clays; (2) Gravelly, Sandy or Silty clays; and (3) Clayey silts. Consistency is rated according to undrained shear strength as indicated.

Consistency of Cohesive soils	SPT N_{60}-Value (blows per foot)	Approximate Undrained Shear Strength (psf)	Field Guidelines
Very Soft	WOH, WOR, WOP, <2	0 - 250	Fist easily penetrates
Soft	2 - 4	250 - 500	Thumb easily penetrates
Medium Stiff	5 - 8	500 - 1000	Thumb penetrates with moderate effort
Stiff	9 - 15	1000 - 2000	Indented by thumb with great effort
Very Stiff	16 - 30	2000 - 4000	Indented by thumbnail
Hard	>30	over 4000	Indented by thumbnail with difficulty

Rock Quality Designation (RQD):

$$\text{RQD (\%)} = \frac{\text{sum of the lengths of intact pieces of core* > 4 inches}}{\text{length of core advance}}$$

*Minimum NQ rock core (1.88 in. OD of core)

Rock Quality Based on RQD

Rock Quality	RQD (%)
Very Poor	≤25
Poor	26 - 50
Fair	51 - 75
Good	76 - 90
Excellent	91 - 100

Desired Rock Observations (in this order, if applicable):
Color (Munsell color chart)
Texture (aphanitic, fine-grained, etc.)
Rock Type (granite, schist, sandstone, etc.)
Hardness (very hard, hard, mod. hard, etc.)
Weathering (fresh, very slight, slight, moderate, mod. severe, severe, etc.)
Geologic discontinuities/jointing:
- -dip (horiz - 0-5 deg., low angle - 5-35 deg., mod. dipping - 35-55 deg., steep - 55-85 deg., vertical - 85-90 deg.)
- -spacing (very close - <2 inch, close - 2-12 inch, mod. close - 1-3 feet, wide - 3-10 feet, very wide >10 feet)
- -tightness (tight, open, or healed)
- -infilling (grain size, color, etc.)

Formation (Waterville, Ellsworth, Cape Elizabeth, etc.)
RQD and correlation to rock quality (very poor, poor, etc.)
ref: ASTM D6032 and FHWA NHI-16-072 GEC 5 - Geotechnical Site Characterization, Table 4-12
Recovery (inch/inch and percentage)
Rock Core Rate (X.X ft - Y.Y ft (min:sec))

Sample Container Labeling Requirements:

WIN	Blow Counts
Bridge Name / Town	Sample Recovery
Boring Number	Date
Sample Number	Personnel Initials
Sample Depth	

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: MaineDOT RTE-17 Augusta Spaulding Brook Bridge No. 2790 Replacement
Location: Augusta, Maine

Boring No.: BB-ASB-101

WIN: 023126.00

Driller:	M. Bussey	**Elevation (ft.)**	182.80	**Auger ID/OD:**	4.25-in (ID) 4.5-in (OD)
Operator:	M. Bussey	**Datum:**	NAVD88	**Sampler:**	Split Spoon
Logged By:	D. Burgess	**Rig Type:**	B-48 Mobile Drill	**Hammer Wt./Fall:**	140 lbs/ 30-in
Date Start/Finish:	4/7/2023 - 4/13/2023	**Drilling Method:**	SSA & Drive and Wash	**Core Barrel:**	NQ
Boring Location:	N: 535590.055, E: 1151640.812	**Casing ID/OD:**	4-in (ID) 4.5-in (OD)	**Water Level*:**	3.85 ft bgs at 8:40 4/13/2023
Hammer Efficiency Factor: 0.91		**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
D = Split Spoon Sample
MD = Unsuccessful Split Spoon Sample Attempt
U = Thin Wall Tube Sample
MU = Unsuccessful Thin Wall Tube Sample Attempt
V = Field Vane Shear Test, PP = Pocket Penetrometer
MV = Unsuccessful Field Vane Shear Test Attempt
R = Rock Core Sample
SSA = Solid Stem Auger
HSA = Hollow Stem Auger
RC = Roller Cone
WOH = Weight of 140lb. Hammer
WOR/C = Weight of Rods or Casing
WO1P = Weight of One Person
S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf)
$S_{u(lab)}$ = Lab Vane Undrained Shear Strength (psf)
q_p = Unconfined Compressive Strength (ksf)
N-uncorrected = Raw Field SPT N-value
Hammer Efficiency Factor = Rig Specific Annual Calibration Value
N_{60} = SPT N-uncorrected Corrected for Hammer Efficiency
N_{60} = (Hammer Efficiency Factor/60%)*N-uncorrected
T_v = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
G = Grain Size Analysis
C = Consolidation Test

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0	1D	24/17	0.71 - 2.71	24-22-19-18	41	62	SSA	182.1		ASPHALT (8.5 in) —0.7— Brown, moist, very dense, sandy GRAVEL, little silt, well-graded [FILL].	WC = 2.6% Fines = 11.4% A-1-a(0), GW-GM
5	2D	24/16	5.00 - 7.00	3-6-10-5	16	24	44	177.8		—5.0— 5-6.5 ft: Brown/olive, moist, very stiff, SILT, trace fine sand [PRESUMPSCOT CLAYEY SILT]. Color change from olive to dark grey at 6.5 feet bgs q_p = 7 ksf (pocket penetrometer)	
							55				
	3D	24/10	7.00 - 9.00	3-3-4-5	7	11	21			6.5-9.0 ft: Dark grey, darker lenses, wet, loose, SILT, trace fine sand, darker lenses [PRESUMPSCOT CLAYEY SILT].	
							26				
							47				
10	4D	24/20	10.00 - 12.00	4-5-6-6	11	17	63	172.8		—10.0— Olive with brown, wet, very stiff,CLAY, trace fine sand, slightly plastic [PRESUMPSCOT CLAY]. q_p = 3.5 ksf to 5 ksf (pocket penetrometer)	WC = 26% LL = 33 PL = 20 PI = 13 LI = 0.5 CL
							58				
							59				
							67				
							70				
15	5D	24/9	15.00 - 17.00	3-4-5-4	9	14	71			Olive, wet, stiff, CLAY, slightly plastic [PRESUMPSCOT CLAY]. q_p = 5.5 ksf to 6.0 ksf (pocket penetrometer)	WC = 27% LL = 39 PL = 20 PI = 19 LI = 0.4 CL
							84				
							33				
							29				
							26				
20	6D	24/24	20.00 - 22.00	WOH(24")	--		38			Grey, wet, medium stiff, CLAY, slightly plastic, interbedded silt lenses [PRESUMPSCOT CLAY]. 65x130 mm vane raw torque readings: V1: 26/5.5 ft-lbs V2: 29/5 ft-lbs	WC = 39% LL = 39 PL = 22 PI = 17 LI = 1 CL
	V1			S_u=714/151 psf			36				
	V2			S_u=797/137 psf			43				
							44				
							49				
25	7D	24/24	25.00 - 27.00	WOH(24")	--		47			Grey, wet,medium stiff, CLAY, with interbedded silt lenses [PRESUMPSCOT CLAY]. 65x130 mm vane raw torque readings: V3: 28/6 ft-lbs V4: 31/7 ft-lbs	
	V3			S_u=769/165 psf			43				
	V4			S_u=852/192 psf			47				
							50				
30							48				

Remarks:

1. Hammer efficiency factor provided by S.W. Cole and taken from "Standard Penetration Test Measurement Calibration: Track Rig Mobile Drill B-48 with automatic Hammer" by Geoscience Testing and Research Inc., dated 11/04/2022.
2.As-drilled boring locations and ground surface elevations were provided by MaineDOT, and are derived from the electronic file "CORRECTED BORINGS 17 AUG 23" received by WSP on May 17, 2023.
3. Water level reading was taken at 8:40 am on 4/13/2023 after a six day pause in drilling with casing at 32 feet bgs. 4. Station 108+83, Offset 10.1 feet RT.

Stratification lines represent approximate boundaries between soil types; transitions may be gradual.

* Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: MaineDOT RTE-17 Augusta Spaulding Brook Bridge No. 2790 Replacement
Location: Augusta, Maine

Boring No.: BB-ASB-101
WIN: 023126.00

Driller:	M. Bussey	**Elevation (ft.)**	182.80	**Auger ID/OD:**	4.25-in (ID) 4.5-in (OD)
Operator:	M. Bussey	**Datum:**	NAVD88	**Sampler:**	Split Spoon
Logged By:	D. Burgess	**Rig Type:**	B-48 Mobile Drill	**Hammer Wt./Fall:**	140 lbs/ 30-in
Date Start/Finish:	4/7/2023 - 4/13/2023	**Drilling Method:**	SSA & Drive and Wash	**Core Barrel:**	NQ
Boring Location:	N: 535590.055, E: 1151640.812	**Casing ID/OD:**	4-in (ID) 4.5-in (OD)	**Water Level*:**	3.85 ft bgs at 8:40 4/13/2023
Hammer Efficiency Factor:	0.91	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
D = Split Spoon Sample
MD = Unsuccessful Split Spoon Sample Attempt
U = Thin Wall Tube Sample
MU = Unsuccessful Thin Wall Tube Sample Attempt
V = Field Vane Shear Test, PP = Pocket Penetrometer
MV = Unsuccessful Field Vane Shear Test Attempt
R = Rock Core Sample
SSA = Solid Stem Auger
HSA = Hollow Stem Auger
RC = Roller Cone
WOH = Weight of 140 lb. Hammer
WOR/C = Weight of Rods or Casing
WO1P = Weight of One Person
S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf)
$S_{u(lab)}$ = Lab Vane Undrained Shear Strength (psf)
q_p = Unconfined Compressive Strength (ksf)
N-uncorrected = Raw Field SPT N-value
Hammer Efficiency Factor = Rig Specific Annual Calibration Value
N_{60} = SPT N-uncorrected Corrected for Hammer Efficiency
N_{60} = (Hammer Efficiency Factor/60%)*N-uncorrected
T_V = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
G = Grain Size Analysis
C = Consolidation Test

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
30	8D	19/18	30.00 - 31.58	WOH(18")-50/1"	--						
	V5/V6	27/27	31.50 - 33.75	Su=687/165 psf Su=1016/247 psf			NQ	151.3		65x130 mm vane raw torque readings: V5: 25/6 ft-lbs V6: 37/9 ft-lbs 31.5	
	R1			RQD = 62%							
	R2	45/42	33.75 - 37.50	RQD = 59%						Roller bit refusal at 31.5 ft bgs, probable bedrock. Top of bedrock Elev. 151.3 ft.	
35											
	R3	17/17	37.50 - 38.92	RQD = 21%							
	R4	31/31	38.90 - 41.48	RQD = 58%							
40								141.3			
45											
50											
55											
60											

R1: Light grey to white, QUARTZ MONZONITE, strong (R3) to very strong (R4), fresh (W1) to slightly weathered (W2), fine-grained, moderately foliated, discontinuities low angle to moderately dipping (30 to 60 deg), fractures closely spaced (1-in to 7-in), fresh, tight to open, rough, average of 4 fractures per foot [DEVONIAN QUARTZ MONZONITE]
Rock Mass Designation = Fair (RQD 62%)
100% Recovery
Rock Coring Rate (min:sec/ft)
31.5-32.5 ft (5:40)
32.5-33.75 ft (5:58)
R2: Light grey to white, QUARTZ MONZONITE, strong (R3) to very strong (R4), fresh (W1) to slightly weathered (W2), fine-grained, moderately foliated, discontinuities low angle to steeply dipping (60 deg), fractures closely spaced (0.5-in. to 8-in.), fresh, tight to open, rough to very rough, average of 3 fractures per foot [DEVONIAN QUARTZ MONZONITE]
Rock Mass Designation = Fair (RQD = 59%)
93% Recovery
Rock Coring Rate (min:sec/ft)
33.75-34.5 ft (3:12)
34.5-35.5 ft (4:14)
35.5-36.5 ft (4:59)
36.5-37.5 ft (4:00)
R3: Light grey to white, QUARTZ MONZONITE, strong (R3) to very strong (R4), fresh (W1) to slightly weathered (W2), fine-grained, moderately foliated, discontinuities low angle to steeply dipping (30 to 60 deg), fractures closely spaced (0.5-in to 4-in.), fresh, tight to open, rough to very rough, average of 5 fractures per foot [DEVONIAN QUARTZ MONZONITE]
Rock Mass Designation = Very Poor (RQD = 21%)
100% Recovery
Rock Coring Rate (min:sec/ft)
37.5-38.5ft (4:07)
38.5-38.9 ft (1:06)
R4: Light grey to white, QUARTZ MONZONIT E, strong (R3) to very strong (R4), fresh (W1), fine-grained, moderately foliated, discontinuities low angle to steeply dipping (30 to 60 deg), fractures closely spaced (1-in. to 6-in.), fresh, tight to open, rough to very rough, average of 5 fractures per foot [DEVONIAN QUARTZ MONZONITE]
Rock Mass Designation = Fair (RQD = 58%)
Rock Core Rate (min:sec/ft)
38.9-39.5 ft (1:35)
39.5-40.5 ft (3:36)
40.5-41.5 ft (3:12)

Remarks:

1. Hammer efficiency factor provided by S.W. Cole and taken from "Standard Penetration Test Measurement Calibration: Track Rig Mobile Drill B-48 with automatic Hammer" by Geoscience Testing and Research Inc., dated 11/04/2022.
2. As-drilled boring locations and ground surface elevations were provided by MaineDOT, and are derived from the electronic file "CORRECTED BORINGS 17 AUG 23" received by WSP on May 17, 2023.

Stratification lines represent approximate boundaries between soil types; transitions may be gradual.

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: MaineDOT RTE-17 Augusta Spaulding Brook Bridge No. 2790 Replacement
Location: Augusta, Maine

Boring No.: BB-ASB-101
WIN: 023126.00

Driller:	M. Bussey	**Elevation (ft.)**	182.80	**Auger ID/OD:**	4.25-in (ID) 4.5-in (OD)
Operator:	M. Bussey	**Datum:**	NAVD88	**Sampler:**	Split Spoon
Logged By:	D. Burgess	**Rig Type:**	B-48 Mobile Drill	**Hammer Wt./Fall:**	140 lbs/ 30-in
Date Start/Finish:	4/7/2023 - 4/13/2023	**Drilling Method:**	SSA & Drive and Wash	**Core Barrel:**	NQ
Boring Location:	N: 535590.055, E: 1151640.812	**Casing ID/OD:**	4-in (ID) 4.5-in (OD)	**Water Level*:**	3.85 ft bgs at 8:40 4/13/2023
Hammer Efficiency Factor:	0.91	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
D = Split Spoon Sample
MD = Unsuccessful Split Spoon Sample Attempt
U = Thin Wall Tube Sample
MU = Unsuccessful Thin Wall Tube Sample Attempt
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R = Rock Core Sample
SSA = Solid Stem Auger
HSA = Hollow Stem Auger
RC = Roller Cone
WOH = Weight of 140 lb. Hammer
WOR/C = Weight of Rods or Casing
WO1P = Weight of One Person
S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf)
$S_{u(lab)}$ = Lab Vane Undrained Shear Strength (psf)
q_p = Unconfined Compressive Strength (ksf)
N-uncorrected = Raw Field SPT N-value
Hammer Efficiency Factor = Rig Specific Annual Calibration Value
N_{60} = SPT N-uncorrected Corrected for Hammer Efficiency
N_{60} = (Hammer Efficiency Factor/60%)*N-uncorrected
T_v = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
G = Grain Size Analysis
C = Consolidation Test

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
60										41.5 **Bottom of Exploration at 41.5 feet below ground surface.** Boring backfilled with bentonite chips to bottom of pavement then cold patch to top of pavement.	
65											
70											
75											
80											
85											
90											

Remarks:

1. Hammer efficiency factor provided by S.W. Cole and taken from "Standard Penetration Test Measurement Calibration: Track Rig Mobile Drill B-48 with automatic Hammer" by Geoscience Testing and Research Inc., dated 11/04/2022.
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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: MaineDOT RTE-17 Augusta Spaulding Brook Bridge No. 2790 Replacement
Location: Augusta, Maine

Boring No.: BB-ASB-102
WIN: 023126.00

Driller:	M. Bussey	**Elevation (ft.)**	182.76	**Auger ID/OD:**	4.25-in (ID) 4.5-in (OD)
Operator:	M. Bussey	**Datum:**	NAVD88	**Sampler:**	Split Spoon
Logged By:	D. Burgess	**Rig Type:**	B-48 Mobile Drill	**Hammer Wt./Fall:**	140 lbs/ 30-in
Date Start/Finish:	4/14/2023 - 4/14/2023	**Drilling Method:**	SSA & Drive and Wash	**Core Barrel:**	NQ
Boring Location:	N: 535546.674, E: 1151667.621	**Casing ID/OD:**	4-in (ID) 4.5-in (OD)	**Water Level*:**	
Hammer Efficiency Factor:	0.91	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
D = Split Spoon Sample
MD = Unsuccessful Split Spoon Sample Attempt
U = Thin Wall Tube Sample
MU = Unsuccessful Thin Wall Tube Sample Attempt
V = Field Vane Shear Test, PP = Pocket Penetrometer
MV = Unsuccessful Field Vane Shear Test Attempt
R = Rock Core Sample
SSA = Solid Stem Auger
HSA = Hollow Stem Auger
RC = Roller Cone
WOH = Weight of 140lb. Hammer
WOR/C = Weight of Rods or Casing
WO1P = Weight of One Person
S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf)
$S_{u(lab)}$ = Lab Vane Undrained Shear Strength (psf)
q_p = Unconfined Compressive Strength (ksf)
N-uncorrected = Raw Field SPT N-value
Hammer Efficiency Factor = Rig Specific Annual Calibration Value
N_{60} = SPT N-uncorrected Corrected for Hammer Efficiency
N_{60} = (Hammer Efficiency Factor/60%)*N-uncorrected
T_v = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
G = Grain Size Analysis
C = Consolidation Test

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0	1D	24/10	0.92 - 2.92	34-20-14-15	34	52	SSA			ASPHALT (11 in)	
								181.8		0.9 — Brown, dry, very dense, fine to coarse sandy GRAVEL, little silt [FILL].	
							27				
							41				
							28				
5	2D	24/4	5.00 - 7.00	19-7-4-6	11	17	63				
							51	176.8		6.0 — Olive, wet, stiff, SILT, trace fine sand, trace clay [PRESUMPSCOT CLAYEY SILT].	
							86				
							94				
							82				
10	3D	24/10	10.00 - 12.00	19-3-3-3	6	9	80	172.8		10.0 — Grey to olive, wet, medium stiff, CLAY, trace fine sand, slightly plastic [PRESUMPSCOT CLAY]. q_p = 3 to 4 ksf (pocket penetrometer)	WC = 30% LL = 39 PL = 22 PI=17 LI = 0.4 CL
							70				
							71				
							75				
							74				
15	4D	24/16	15.00 - 17.00	17-5-4-4	9	14	49			Grey, wet, stiff, CLAY [PRESUMPSCOT CLAY].	
							40				
							44				
							45				
							45				
20	5D	24/24	20.00 - 22.00	WOH(24")	--		33			Grey, wet, medium stiff,CLAY, slightly plastic [PRESUMPSCOT CLAY]. 65x130 mm vane raw torque readings: V1: 33/8 ft-lbs V2: 31/7 ft-lbs	WC = 35% LL = 39 PL = 19 PI = 20 LI = 0.8 CL
	V1			S_u=906/220 psf			35				
	V2			S_u=852/192 psf			38				
							39				
							36				
25	1U	24/22	25.00 - 27.00				29			Shelby Tube: CLAY, slightly plastic.	WC=35% Fines=99.7% LL=33 PL=18 PI=15 LI=1.1 A-6(15), CL
							29				
							33				
							32				
30							32				

Remarks:

1. Hammer efficiency factor provided by S.W. Cole and taken from "Standard Penetration Test Measurement Calibration: Track Rig Mobile Drill B-48 with automatic Hammer" by Geoscience Testing and Research Inc., dated 11/04/2022.
2. As-drilled boring locations and ground surface elevations were provided by MaineDOT, and are derived from the electronic file "CORRECTED BORINGS 17 AUG 23" received by WSP on May 17, 2023.
3. Station 108+36, Offset 8.3 feet LT

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: MaineDOT RTE-17 Augusta Spaulding Brook Bridge No. 2790 Replacement
Location: Augusta, Maine

Boring No.: BB-ASB-102
WIN: 023126.00

Driller:	M. Bussey	**Elevation (ft.)**	182.76	**Auger ID/OD:**	4.25-in (ID) 4.5-in (OD)
Operator:	M. Bussey	**Datum:**	NAVD88	**Sampler:**	Split Spoon
Logged By:	D. Burgess	**Rig Type:**	B-48 Mobile Drill	**Hammer Wt./Fall:**	140 lbs/ 30-in
Date Start/Finish:	4/14/2023 - 4/14/2023	**Drilling Method:**	SSA & Drive and Wash	**Core Barrel:**	NQ
Boring Location:	N: 535546.674, E: 1151667.621	**Casing ID/OD:**	4-in (ID) 4.5-in (OD)	**Water Level*:**	
Hammer Efficiency Factor:	0.91	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
D = Split Spoon Sample
MD = Unsuccessful Split Spoon Sample Attempt
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MU = Unsuccessful Thin Wall Tube Sample Attempt
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SSA = Solid Stem Auger
HSA = Hollow Stem Auger
RC = Roller Cone
WOH = Weight of 140 lb. Hammer
WOR/C = Weight of Rods or Casing
WO1P = Weight of One Person
S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf)
$S_{u(lab)}$ = Lab Vane Undrained Shear Strength (psf)
q_p = Unconfined Compressive Strength (ksf)
N-uncorrected = Raw Field SPT N-value
Hammer Efficiency Factor = Rig Specific Annual Calibration Value
N_{60} = SPT N-uncorrected Corrected for Hammer Efficiency
N_{60} = (Hammer Efficiency Factor/60%)*N-uncorrected
T_v = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
G = Grain Size Analysis
C = Consolidation Test

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
30	6D	13/10	30.00 - 31.08	1-6-50/1"	R			152.8		30.0 Grey, wet, very dense, fine to medium sand, GRAVEL, some silt, little sand [GLACIAL TILL].	Fines=34% A-2-4(0), GM
	R1	18/14	31.10 - 32.60	RQD = 45%			NQ	151.7		31.1 Roller bit refusal at 31.1 ft bgs. Top of bedrock Elev. 151.7 ft.	
								150.2		R1: Light grey to white, QUARTZ MONZONITE, strong (R3) to very strong (R4), fresh (W1), fine-grained, moderately foliated, discontinuities low angle to steeply dipping (30 to 60 deg), fractures closely spaced (2-in. to 9-in.), fresh, tight to open, rough to very rough, average of 2 fractures per foot [DEVONIAN QUARTZ MONZONITE] Rock Mass Designation = Poor (RQD = 45%) 80% Recovery Rock Coring Rate (min:sec/ft) 31.1-32.1 ft (5:04) 32.1-32.6 ft (4:45) Core barrel would not advance beyond 32.6 ft bgs. Upon inspection of the core barrel, the outer barrel separated and remained in the borehole, and was abandoned in place. 32.6	
35										**Bottom of Exploration at 32.6 feet below ground surface.** Boring backfilled with bentonite chips to 6 feet bgs, then gravel to the bottom of pavement, then cold patch to top of pavement.	
40											
45											
50											
55											
60											

Remarks:

1. Hammer efficiency factor provided by S.W. Cole and taken from "Standard Penetration Test Measurement Calibration: Track Rig Mobile Drill B-48 with automatic Hammer" by Geoscience Testing and Research Inc., dated 11/04/2022.
2. As-drilled boring locations and ground surface elevations were provided by MaineDOT, and are derived from the electronic file "CORRECTED BORINGS 17 AUG 23" received by WSP on May 17, 2023.

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APPENDIX B

Rock Core Photographs

APPENDIX B
ROCK CORE PHOTOGRAPHS
SPAULDING BROOK CULVERT REPLACEMENT BRIDGE #2790, AUGUSTA, MAINE
MAINEDOT WIN 023126.00

Boring	Run	Depth Below Surface Feet			Recovery Feet			Recovery %	RQD Feet			RQD %	Rock Type	Box Row	Date Cored
BB-ASB-101	R1	31.5	-	33.8	2.3	/	2.3	100	1.4	/	2.3	61	QUARTZ MONZONITE	1	4/13/2023
	R2	33.8	-	37.5	3.5	/	3.8	92	2.2	/	3.8	58	QUARTZ MONZONITE	1, 2	4/13/2023
	R3	37.5	-	38.9	1.4	/	1.4	100	0.3	/	1.4	21	QUARTZ MONZONITE	2,3	4/13/2023
	R4	38.9	-	41.5	2.6	/	2.6	100	1.5	/	2.6	58	QUARTZ MONZONITE	3	4/13/2023
BB-ASB-102	R2	31.1	-	32.6	1.2	/	1.5	80	0.7	/	1.5	45	QUARTZ MONZONITE	4	4/14/2023

Notes: 1. "Box row" indicates the section of the box where the core is contained: 1 = top, 4 = bottom.
2. Top of each core run is on the left and increases with depth to the right.

Prepared By: KMB
Checked By: ATM
Reviewed By: MEL

APPENDIX C

Laboratory Results

Client:	WSP USA, Inc.				
Project:	ME DOT Augusta Spaulding Brook Culvert				
Location:	Augusta, ME			Project No:	GTX-317120
Boring ID:	BB-ASB-101	Sample Type:	jar	Tested By:	ckg
Sample ID:	S-1	Test Date:	05/03/23	Checked By:	ank
Depth :	0.7'-2.7'	Test Id:	713541		

Test Comment: ---
Visual Description: Moist, dark grayish brown gravel with silt and sand
Sample Comment: ---

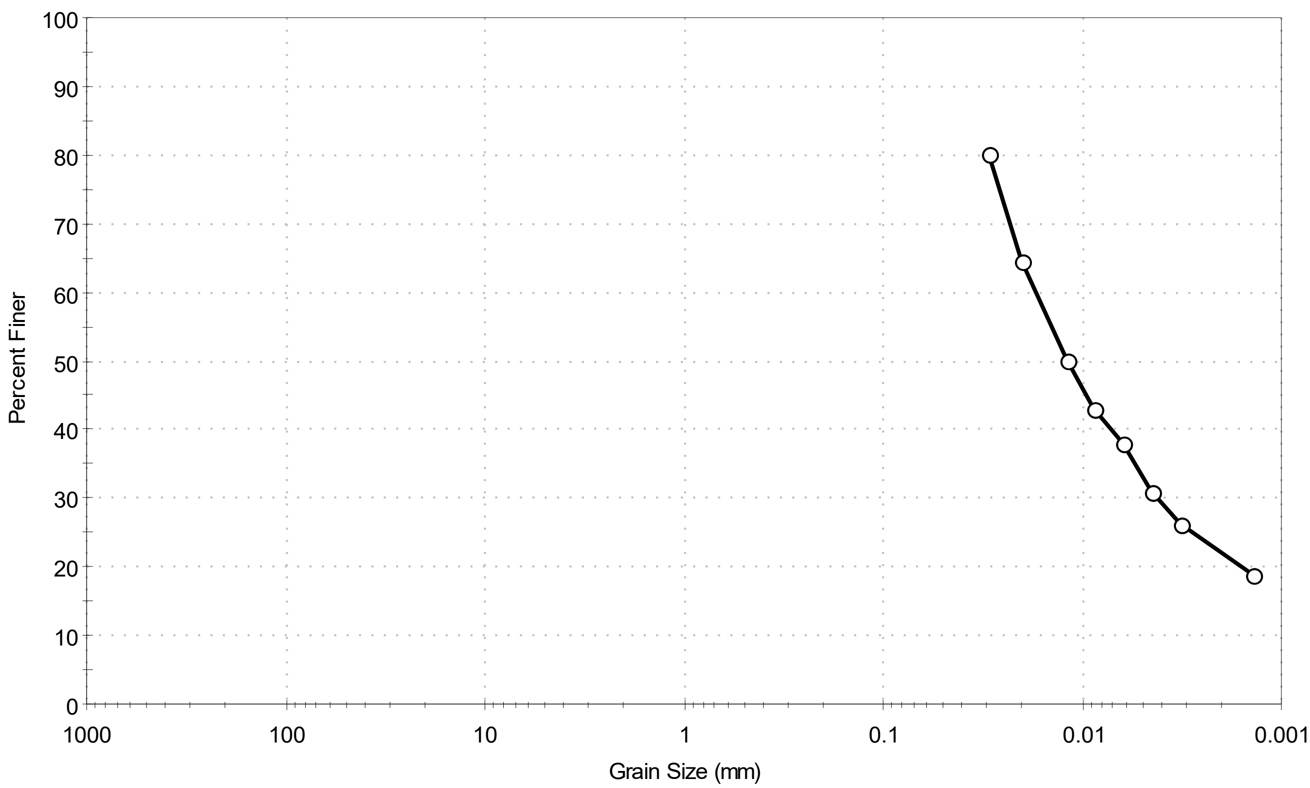
Moisture Content of Soil and Rock - ASTM D2216

Boring ID	Sample ID	Depth	Description	Moisture Content,%
BB-ASB-101	S- 1	0.7'-2.7'	Moist, dark grayish brown gravel with silt and sand	2.6

Notes: Temperature of Drying : 110º Celsius

Client:	WSP USA, Inc.		
Project:	ME DOT Augusta Spaulding Brook Culvert		
Location:	Augusta, ME	Project No:	GTX-317120
Boring ID: BB-ASB-101	Sample Type: jar	Tested By:	ckg
Sample ID: S-4	Test Date: 05/03/23	Checked By:	ank
Depth : 10'-12'	Test Id: 713533		
Test Comment:	---		
Visual Description:	Moist, light olive brown clay		
Sample Comment:	---		

Particle Size Analysis - ASTM D7928



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	—	—	—

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0293	80		
---	0.0202	65		
---	0.0120	50		
---	0.0087	43		
---	0.0062	38		
---	0.0045	31		
---	0.0032	26		
---	0.0014	19		

Coefficients

D_{85} =N/A　　D_{30} =0.0042 mm

D_{60} =0.0172 mm　　D_{15} =N/A

D_{50} =0.0120 mm　　D_{10} =N/A

C_u =N/A　　C_c =N/A

Classification

ASTM N/A

AASHTO ()

Sample/Test Description

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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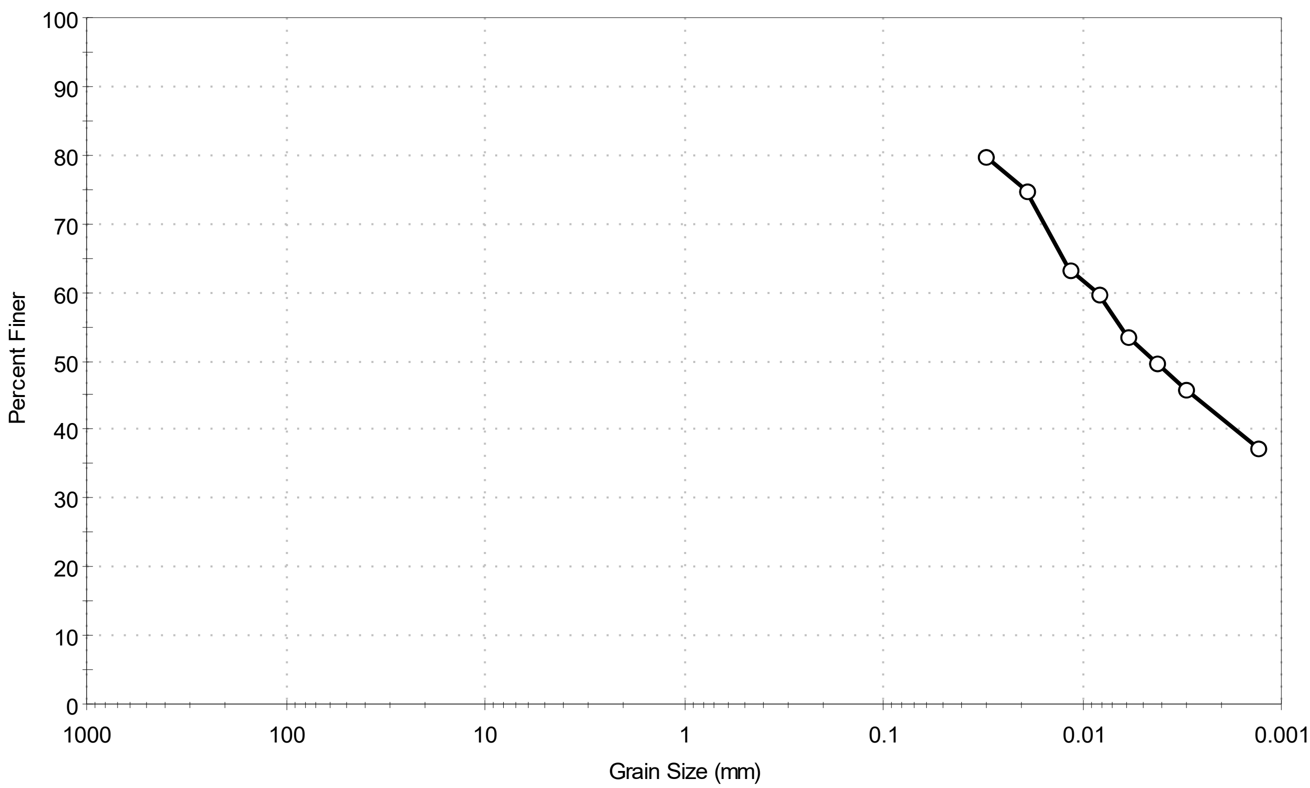
Client:	WSP USA, Inc.		
Project:	ME DOT Augusta Spaulding Brook Culvert		
Location:	Augusta, ME	Project No:	GTX-317120
Boring ID: BB-ASB-101	Sample Type: jar	Tested By:	ckg
Sample ID: S-5	Test Date: 05/03/23	Checked By:	ank
Depth : 15'-17'	Test Id: 713537		
Test Comment:	---		
Visual Description:	Moist, dark gray clay		
Sample Comment:	---		

Particle Size Analysis - ASTM D7928



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	—	—	—

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0314	80		
---	0.0194	75		
---	0.0117	64		
---	0.0083	60		
---	0.0060	54		
---	0.0043	50		
---	0.0031	46		
---	0.0013	37		

Coefficients

D_{85} =N/A | D_{30} =N/A
D_{60} =0.0085 mm | D_{15} =N/A
D_{50} =0.0043 mm | D_{10} =N/A
C_u =N/A | C_c =N/A

Classification

ASTM N/A

AASHTO ()

Sample/Test Description

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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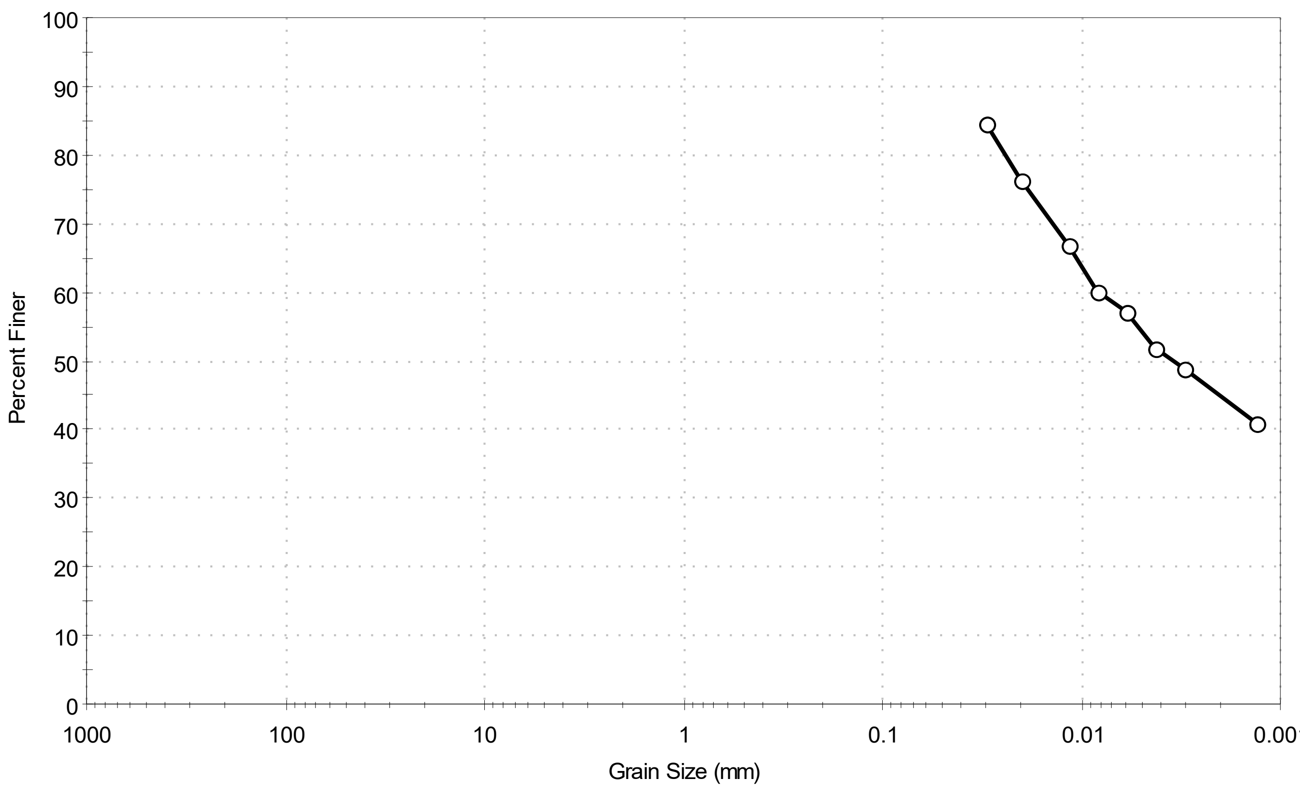
Client:	WSP USA, Inc.		
Project:	ME DOT Augusta Spaulding Brook Culvert		
Location:	Augusta, ME	Project No:	GTX-317120
Boring ID: BB-ASB-101	Sample Type: jar	Tested By:	ckg
Sample ID: S-6	Test Date: 05/03/23	Checked By:	ank
Depth : 20'-22'	Test Id: 713538		
Test Comment:	---		
Visual Description:	Moist, dark gray clay		
Sample Comment:	---		

Particle Size Analysis - ASTM D7928



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	—	—	—

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0305	85		
---	0.0201	76		
---	0.0118	67		
---	0.0085	60		
---	0.0060	57		
---	0.0043	52		
---	0.0031	49		
---	0.0013	41		

Coefficients

D_{85} =N/A
D_{30} =N/A
D_{60} =0.0084 mm
D_{15} =N/A
D_{50} =0.0034 mm
D_{10} =N/A
C_u =N/A
C_c =N/A

Classification

ASTM N/A

AASHTO ()

Sample/Test Description

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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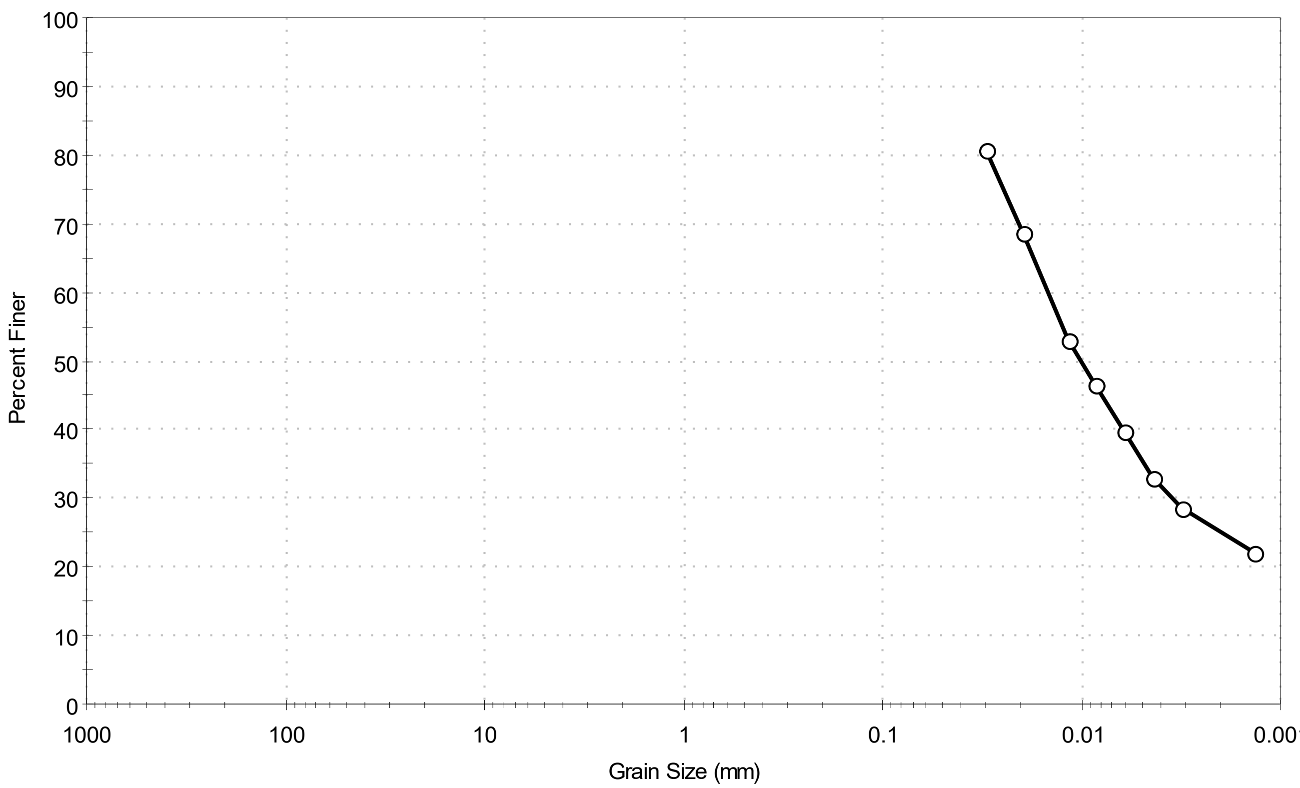
Client:	WSP USA, Inc.				
Project:	ME DOT Augusta Spaulding Brook Culvert				
Location:	Augusta, ME			Project No:	GTX-317120
Boring ID:	BB-ASB-102	Sample Type:	jar	Tested By:	ckg
Sample ID:	S-3	Test Date:	05/03/23	Checked By:	ank
Depth :	10'-12'	Test Id:	713534		
Test Comment:	---				
Visual Description:	Moist, dark gray clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D7928



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	—	—	—

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0302	81		
---	0.0196	69		
---	0.0118	53		
---	0.0085	46		
---	0.0061	40		
---	0.0044	33		
---	0.0032	29		
---	0.0014	22		

Coefficients

D_{85} =N/A
D_{30} =0.0035 mm
D_{60} =0.0148 mm
D_{15} =N/A
D_{50} =0.0101 mm
D_{10} =N/A
C_u =N/A
C_c =N/A

Classification

ASTM N/A

AASHTO ()

Sample/Test Description

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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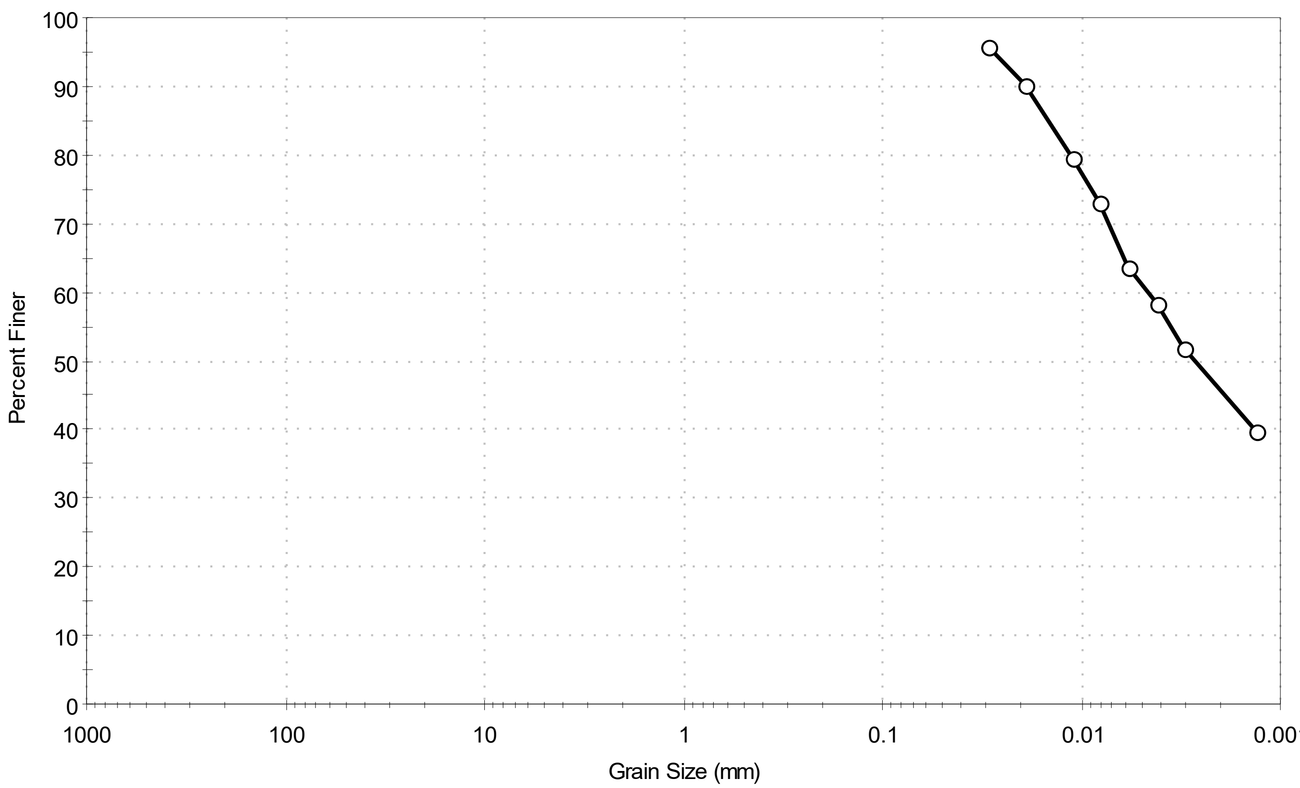
GeoTesting EXPRESS

Client:	WSP USA, Inc.				
Project:	ME DOT Augusta Spaulding Brook Culvert				
Location:	Augusta, ME			Project No:	GTX-317120
Boring ID:	BB-ASB-102	Sample Type:	jar	Tested By:	ckg
Sample ID:	S-5	Test Date:	05/03/23	Checked By:	ank
Depth :	20'-22'	Test Id:	713535		

Test Comment: ---
Visual Description: Moist, dark gray clay
Sample Comment: ---

Particle Size Analysis - ASTM D7928



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	—	—	—

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0298	96		
---	0.0191	90		
---	0.0113	80		
---	0.0081	73		
---	0.0059	64		
---	0.0042	58		
---	0.0030	52		
---	0.0013	40		

Coefficients

D_{85} =0.0146 mm　　D_{30} =N/A
D_{60} =0.0047 mm　　D_{15} =N/A
D_{50} =0.0027 mm　　D_{10} =N/A
C_u =N/A　　C_c =N/A

Classification

ASTM　N/A

AASHTO　()

Sample/Test Description

Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Est. Specific Gravity : 2.65
Separation of Sample: #200 Sieve

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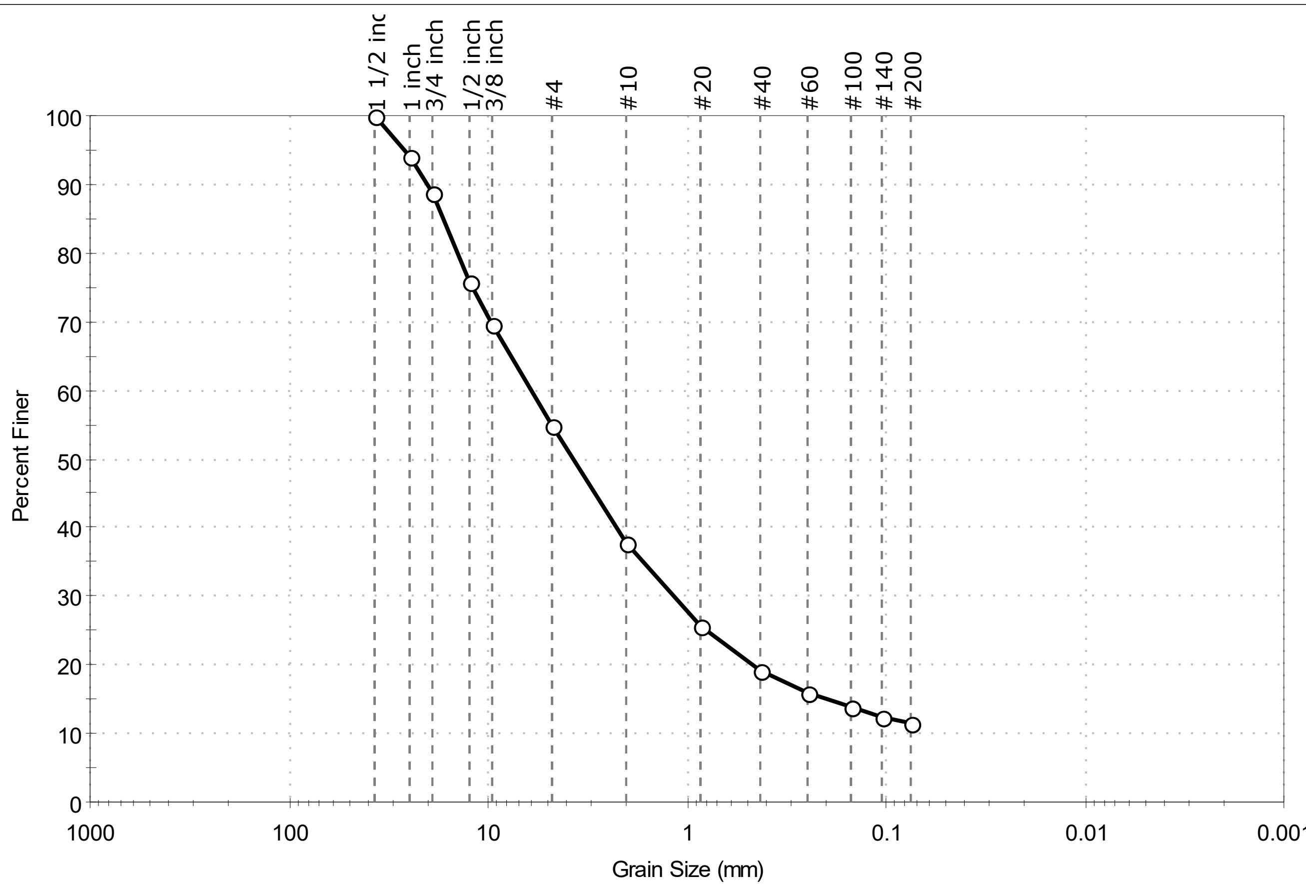
Client:	WSP USA, Inc.		
Project:	ME DOT Augusta Spaulding Brook Culvert		
Location:	Augusta, ME	Project No:	GTX-317120
Boring ID:	BB-ASB-101	Sample Type: jar	Tested By: ckg
Sample ID:	S-1	Test Date: 05/01/23	Checked By: ank
Depth :	0.7'-2.7'	Test Id: 713539	
Test Comment:	---		
Visual Description:	Moist, dark grayish brown gravel with silt and sand		
Sample Comment:	---		

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	45.2	43.4	11.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 1/2 inch	37.50	100		
1 inch	25.00	94		
3/4 inch	19.00	89		
1/2 inch	12.50	76		
3/8 inch	9.50	70		
#4	4.75	55		
#10	2.00	38		
#20	0.85	26		
#40	0.42	19		
#60	0.25	16		
#100	0.15	14		
#140	0.11	13		
#200	0.075	11		

Coefficients

D_{85} =16.8029 mm
D_{30} =1.1569 mm
D_{60} =6.0397 mm
D_{15} =0.1965 mm
D_{50} =3.7124 mm
D_{10} =N/A
C_u =N/A
C_c =N/A

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-a (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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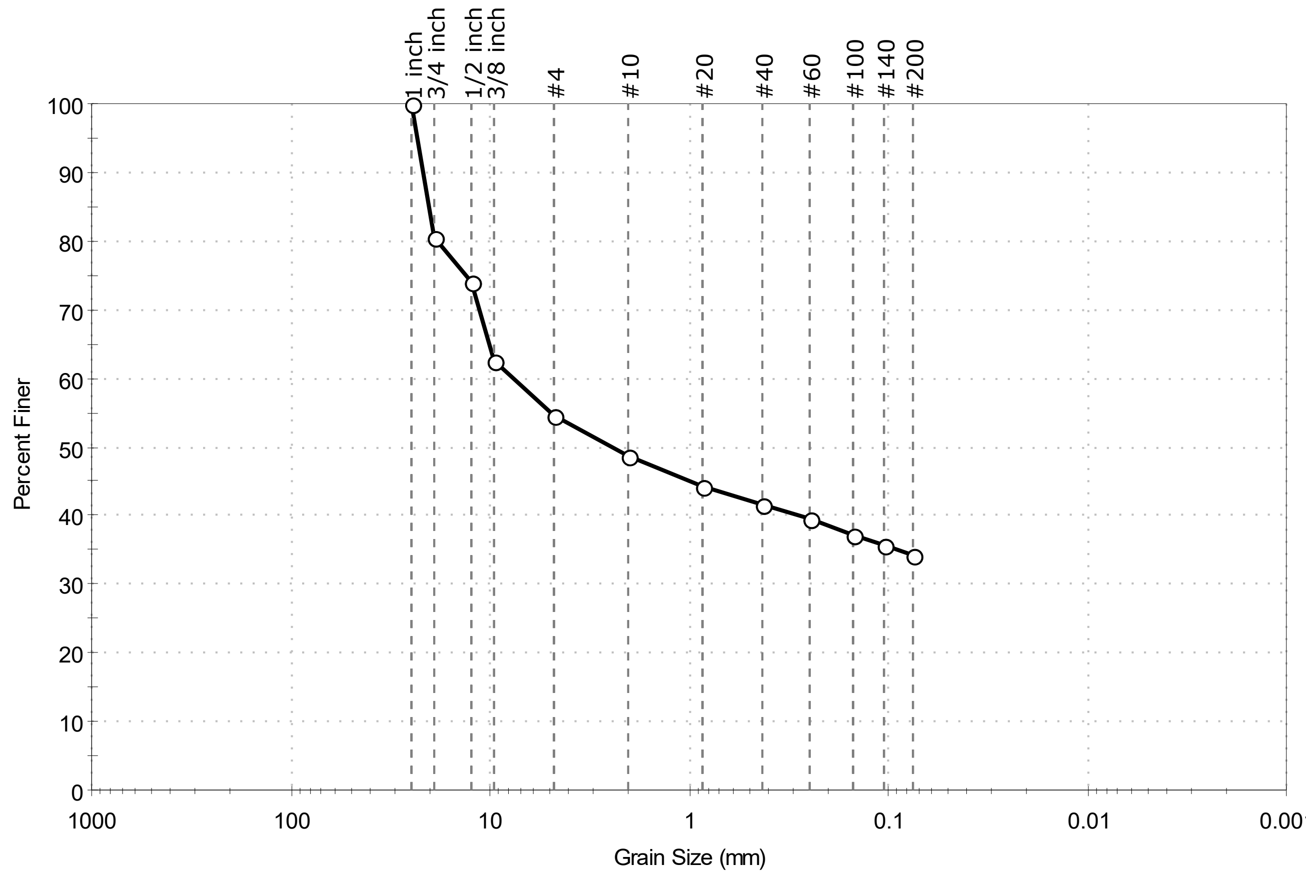
Client:	WSP USA, Inc.		
Project:	ME DOT Augusta Spaulding Brook Culvert		
Location:	Augusta, ME	Project No:	GTX-317120
Boring ID:	BB-ASB-102	Sample Type: jar	Tested By: ckg
Sample ID:	S-6	Test Date: 04/28/23	Checked By: ank
Depth :	30'-31.1'	Test Id: 713540	
Test Comment:	---		
Visual Description:	Moist, gray clayey gravel with sand		
Sample Comment:	---		

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	45.5	20.4	34.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 inch	25.00	100		
3/4 inch	19.00	80		
1/2 inch	12.50	74		
3/8 inch	9.50	62		
#4	4.75	55		
#10	2.00	49		
#20	0.85	44		
#40	0.42	41		
#60	0.25	39		
#100	0.15	37		
#140	0.11	36		
#200	0.075	34		

Coefficients

D_{85} =20.2672 mm　　D_{30} =N/A

D_{60} =7.6474 mm　　D_{15} =N/A

D_{50} =2.4638 mm　　D_{10} =N/A

C_u =N/A　　C_c =N/A

Classification

ASTM　N/A

AASHTO　Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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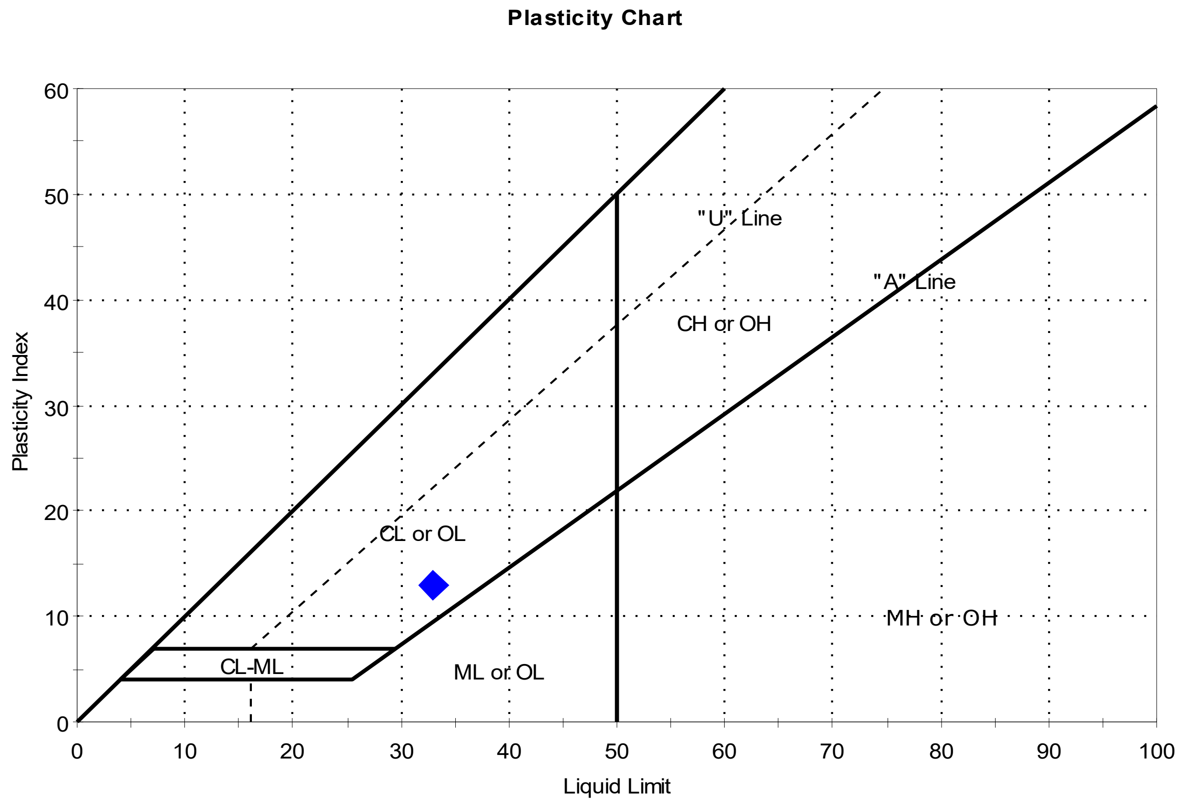
Client:	WSP USA, Inc.				
Project:	ME DOT Augusta Spaulding Brook Culvert				
Location:	Augusta, ME			Project No:	GTX-317120
Boring ID:	BB-ASB-101	Sample Type:	jar	Tested By:	GA
Sample ID:	S-4	Test Date:	05/03/23	Checked By:	ank
Depth :	10'-12'	Test Id:	713527		
Test Comment:	---				
Visual Description:	Moist, light olive brown clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-4	B-ASB-10	10'-12'	26	33	20	13	0.5	

Sample Prepared using the WET method

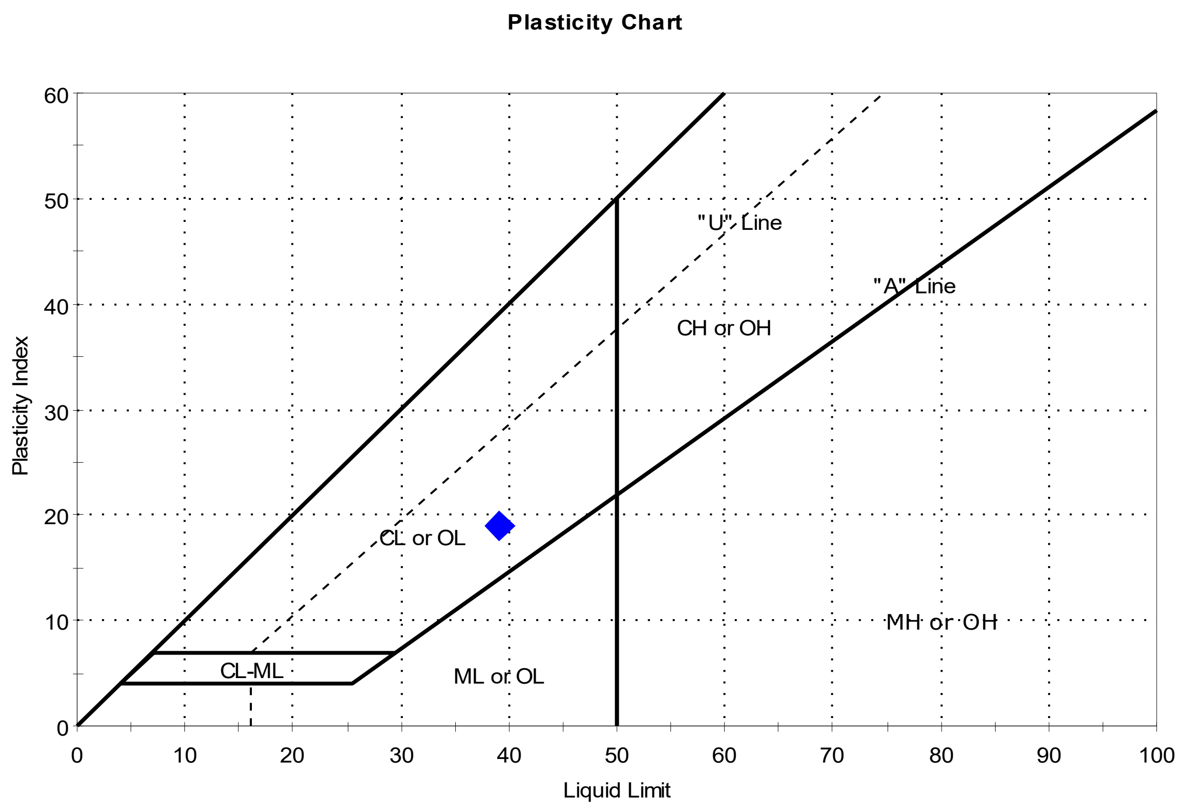
Dry Strength: HIGH

Dilatancy: SLOW

Toughness: MEDIUM

Client:	WSP USA, Inc.		
Project:	ME DOT Augusta Spaulding Brook Culvert		
Location:	Augusta, ME	Project No:	GTX-317120
Boring ID: BB-ASB-101	Sample Type: jar	Tested By:	GA
Sample ID: S-5	Test Date: 05/03/23	Checked By:	ank
Depth : 15'-17'	Test Id: 713531		
Test Comment:	---		
Visual Description:	Moist, dark gray clay		
Sample Comment:	---		

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-5	B-ASB-10	15'-17'	27	39	20	19	0.4	

Sample Prepared using the WET method

Dry Strength: HIGH

Dilatancy: SLOW

Toughness: MEDIUM

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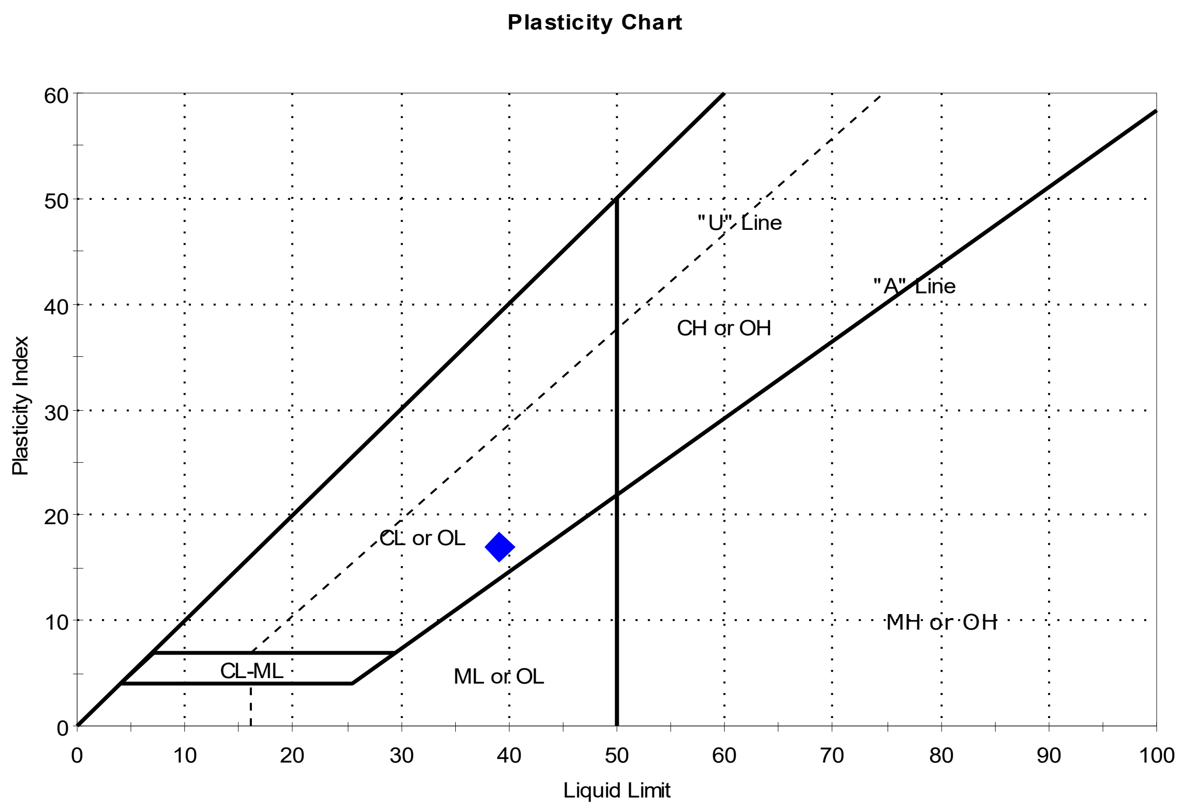
Client:	WSP USA, Inc.				
Project:	ME DOT Augusta Spaulding Brook Culvert				
Location:	Augusta, ME			Project No:	GTX-317120
Boring ID:	BB-ASB-101	Sample Type:	jar	Tested By:	cam
Sample ID:	S-6	Test Date:	05/02/23	Checked By:	ank
Depth :	20'-22'	Test Id:	713532		

Test Comment: ---
Visual Description: Moist, dark gray clay
Sample Comment: ---

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-6	B-ASB-10	20'-22'	39	39	22	17	1	

Sample Prepared using the WET method

Dry Strength: VERY HIGH
Dilatancy: SLOW
Toughness: LOW

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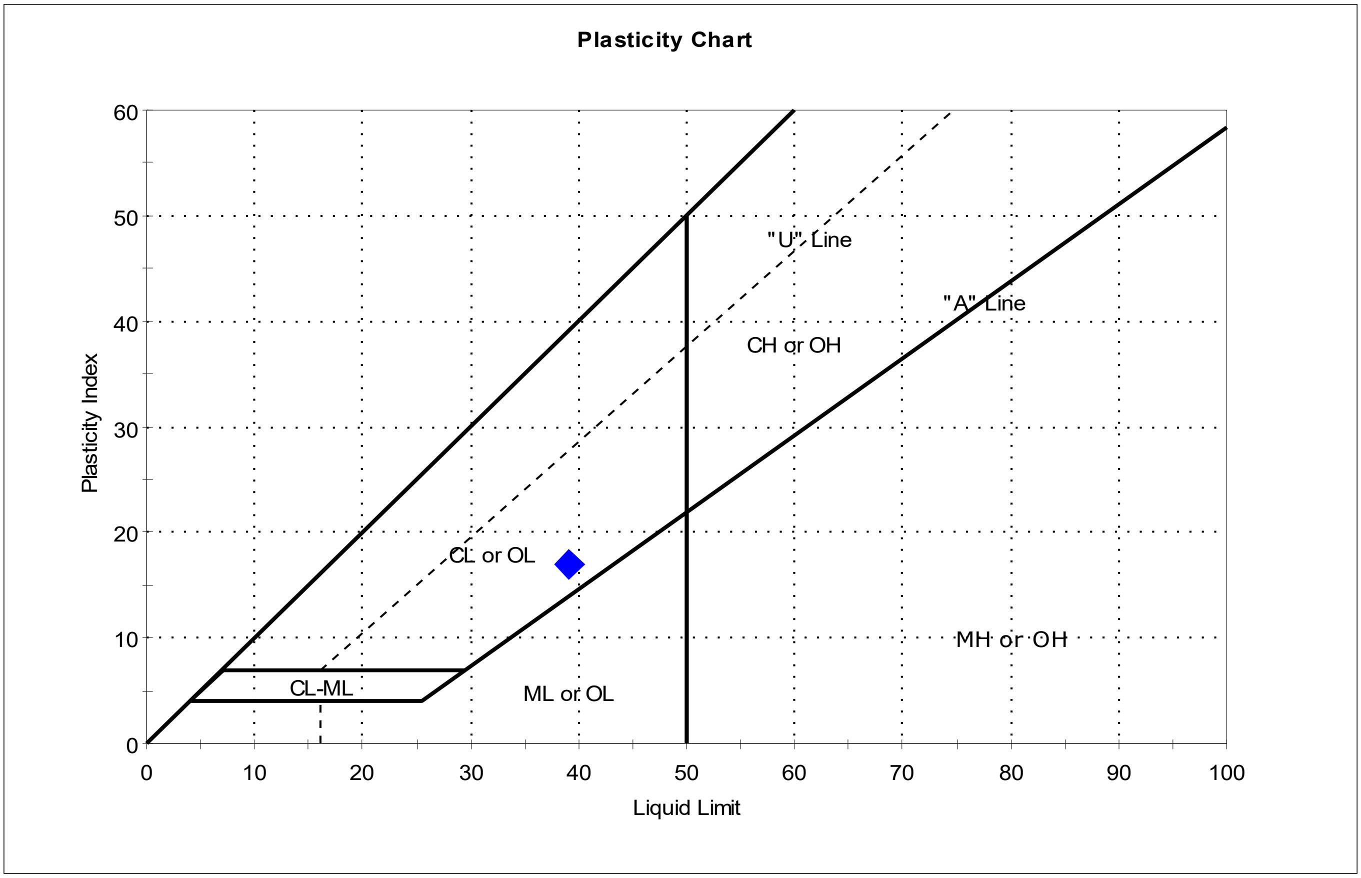
Client:	WSP USA, Inc.		
Project:	ME DOT Augusta Spaulding Brook Culvert		
Location:	Augusta, ME	Project No:	GTX-317120
Boring ID: BB-ASB-102	Sample Type: jar	Tested By:	cam
Sample ID: S-3	Test Date: 05/02/23	Checked By:	ank
Depth : 10'-12'	Test Id: 713528		
Test Comment:	---		
Visual Description:	Moist, dark gray clay		
Sample Comment:	---		

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-3	B-ASB-10	10'-12'	30	39	22	17	0.4	

Sample Prepared using the WET method

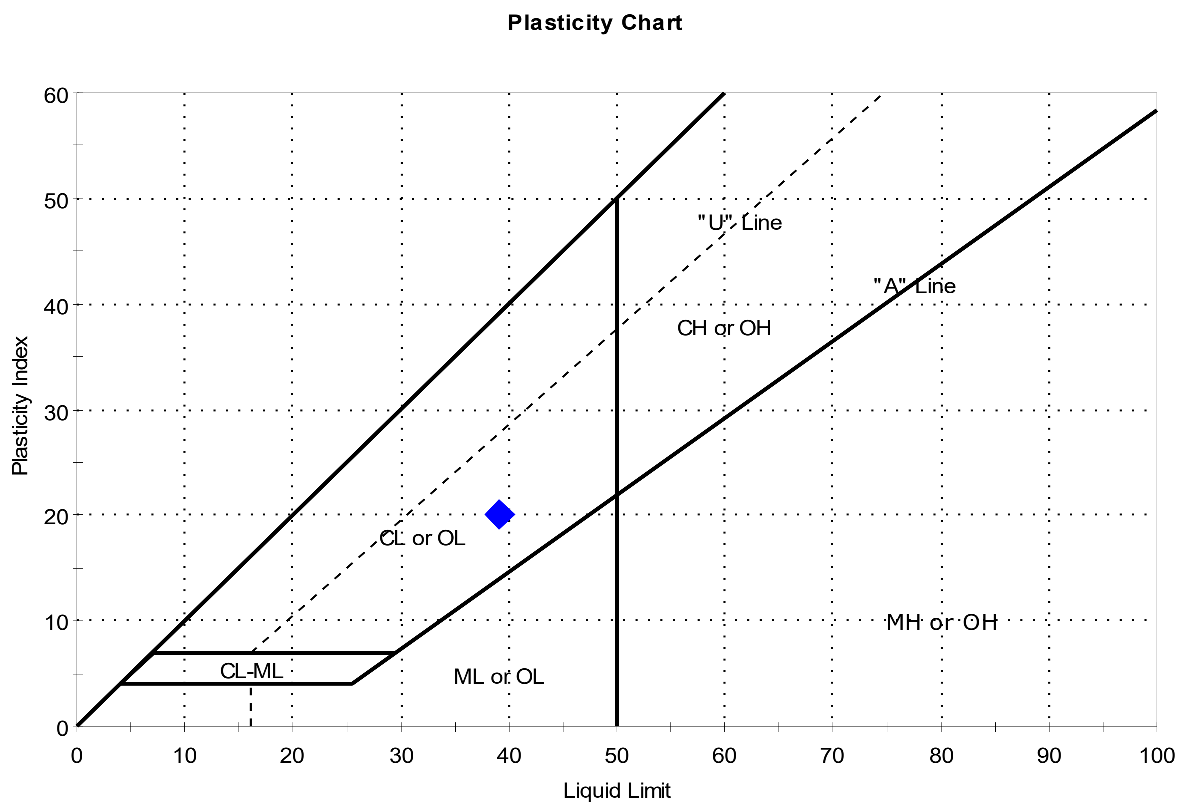
Dry Strength: VERY HIGH

Dilatancy: SLOW

Toughness: LOW

Client:	WSP USA, Inc.				
Project:	ME DOT Augusta Spaulding Brook Culvert				
Location:	Augusta, ME			Project No:	GTX-317120
Boring ID:	BB-ASB-102	Sample Type:	jar	Tested By:	GA
Sample ID:	S-5	Test Date:	05/03/23	Checked By:	ank
Depth :	20'-22'	Test Id:	713529		
Test Comment:	---				
Visual Description:	Moist, dark gray clay				
Sample Comment:	---				

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	S-5	B-ASB-10	20'-22'	35	39	19	20	0.8	

Sample Prepared using the WET method

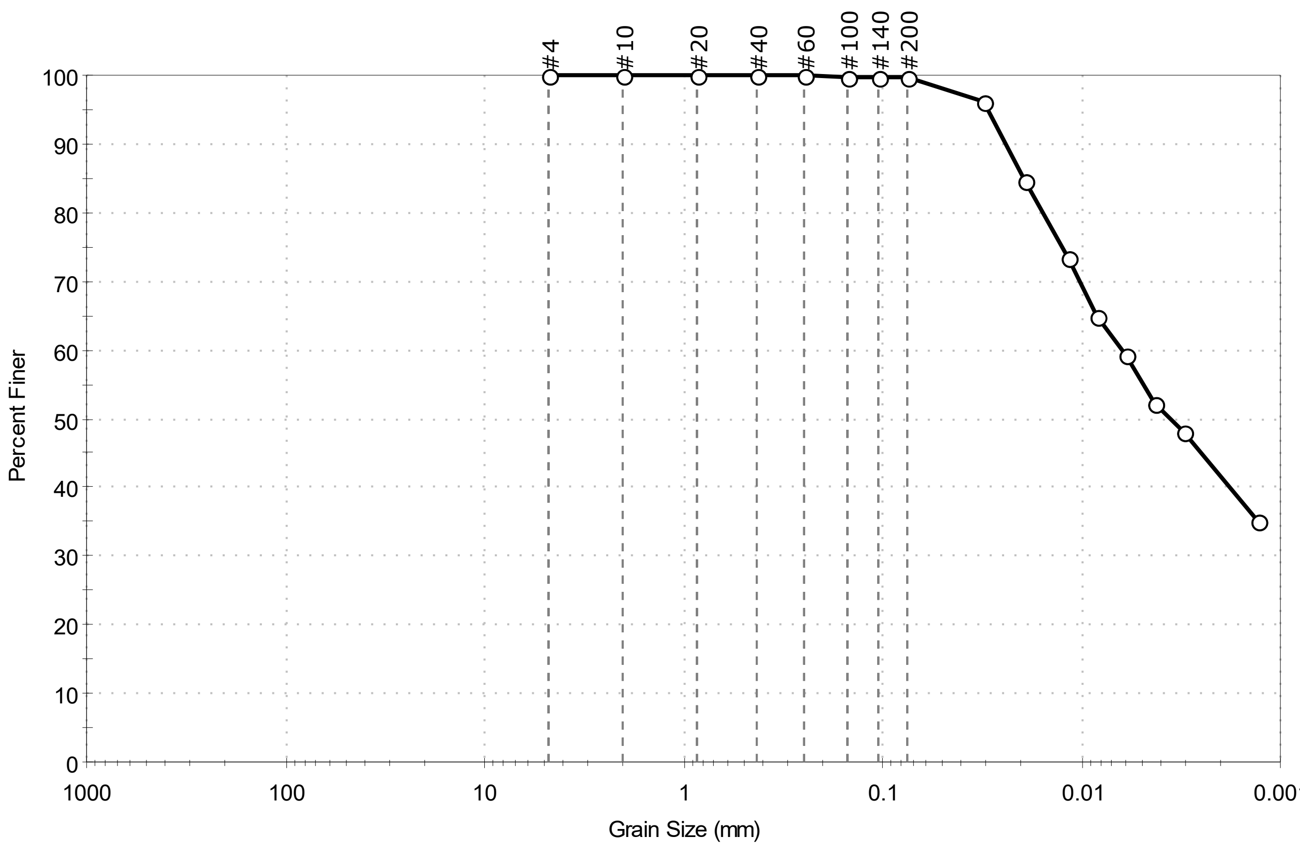
Dry Strength: HIGH

Dilatancy: SLOW

Toughness: MEDIUM

Client:	WSP USA, Inc.		
Project:	ME DOT Augusta Spaulding Brook Culvert		
Location:	Augusta, ME	Project No:	GTX-317120
Boring ID: BB-ASB-102	Sample Type: tube	Tested By:	ckg
Sample ID: U-1	Test Date: 05/12/23	Checked By:	ank
Depth : 25'-27'	Test Id: 714430		
Test Comment:	---		
Visual Description:	Moist, dark gray clay		
Sample Comment:	---		

Particle Size Analysis - ASTM D6913/D7928



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.3	99.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#140	0.11	100		
#200	0.075	100		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0311	96		
---	0.0191	85		
---	0.0117	73		
---	0.0084	65		
---	0.0060	59		
---	0.0043	52		
---	0.0031	48		
---	0.0013	35		

Coefficients

D_{85} =0.0193 mm — D_{30} =N/A

D_{60} =0.0063 mm — D_{15} =N/A

D_{50} =0.0036 mm — D_{10} =N/A

C_u =N/A — C_c =N/A

Classification

ASTM Lean CLAY (CL)

AASHTO Clayey Soils (A-6 (15))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Dispersion Device : Apparatus A - Mech Mixer

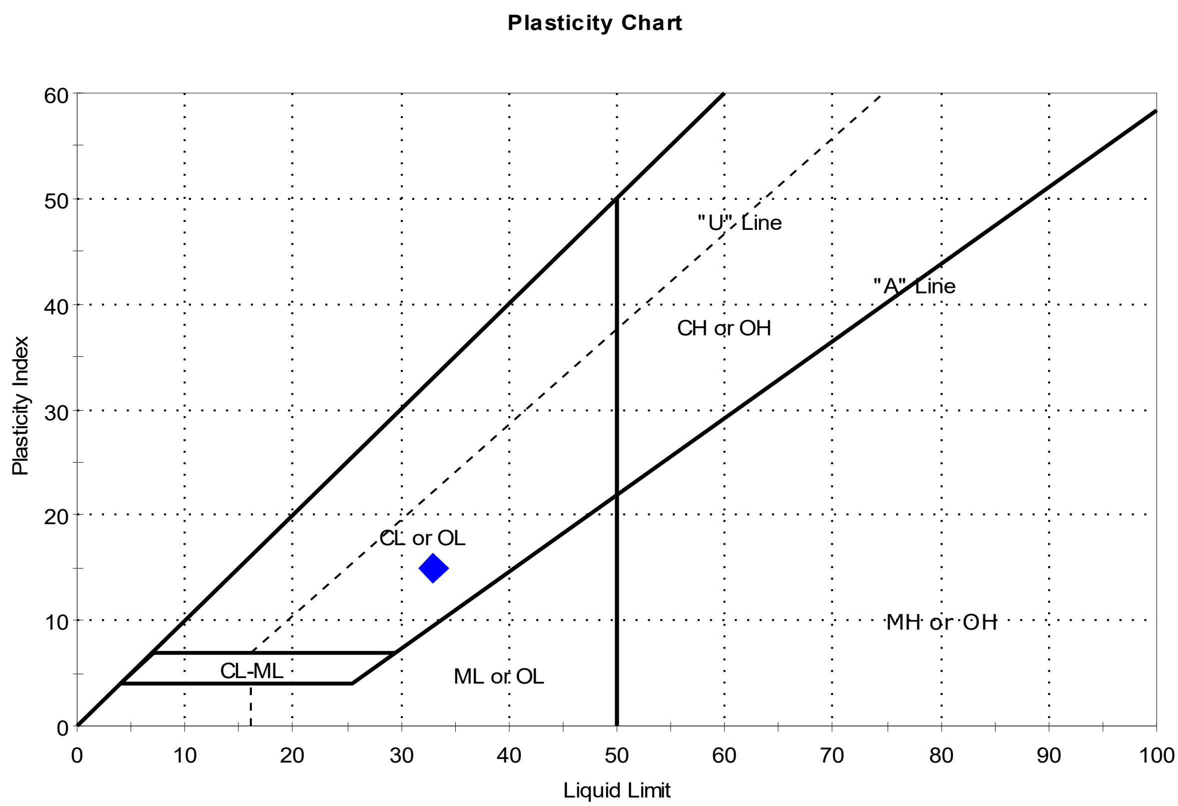
Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

Client:	WSP USA, Inc.		
Project:	ME DOT Augusta Spaulding Brook Culvert		
Location:	Augusta, ME	Project No:	GTX-317120
Boring ID: BB-ASB-102	Sample Type: tube	Tested By:	GA
Sample ID: U-1	Test Date: 05/12/23	Checked By:	ank
Depth : 25'-27'	Test Id: 714429		
Test Comment:	---		
Visual Description:	Moist, dark gray clay		
Sample Comment:	---		

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content,%	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	U-1	B-ASB-10	25'-27'	35	33	18	15	1.1	Lean CLAY (CL)

Sample Prepared using the WET method

0% Retained on #40 Sieve

Dry Strength: HIGH

Dilatancy: SLOW

Toughness: MEDIUM

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GeoTesting EXPRESS

Consolidated Undrained Direct Simple Shear Testing of Cohesive Soils by ASTM D6528

Client:	WSP USA, Inc.	GTX#:	303721
Project Name:	ME DOT Augusta Spaulding Brook Culvert	Test Date:	5/15/23
Project Location:	Augusta, ME		

Boring ID: BB-ASB-102
Sample ID: U-1
Depth, ft: 25-27

Visual Description: Moist, dark gray clay

Test Equipment: Top and bottom box (circular) = 2.50 in diameter. Load cells and LVDT's connected to data acquisition system for shear force, normal load, horizontal and vertical displacement; surface area = 4.91 in^2, soil height = 1 inch. Stacked rings used. Set up included porous stones with pins.

Test Condition: Inundated prior to consolidating to 1,720 psf.

Sample Type and Preparation: density — Extruded from tube, cut, trimmed and placed into apparatus at as-received and moisture content.

Parameter	Point 1	Point 2	Point 3	Point 4	Point 5
Test No.	DSS-1				
Initial Moisture Content, %	33.6				
Initial Dry Density, pcf	88.6				
Nominal Rate of Shear Strain, %/hr	5.0				
Maximum Vertical Consolidation Stress, psf	1,720				
Vertical Consolidation Stress at time of shear, psf	1,720				
Final Moisture Content, %	34.4				
Measured Peak Shear Stress, psf	427				
Shear Strain at Peak Shear Stress, %	3.0				
Membrane Correction, psf	27				
Corrected Peak Shear Stress, psf	400				
S_u / σ'_{vc}	0.23				

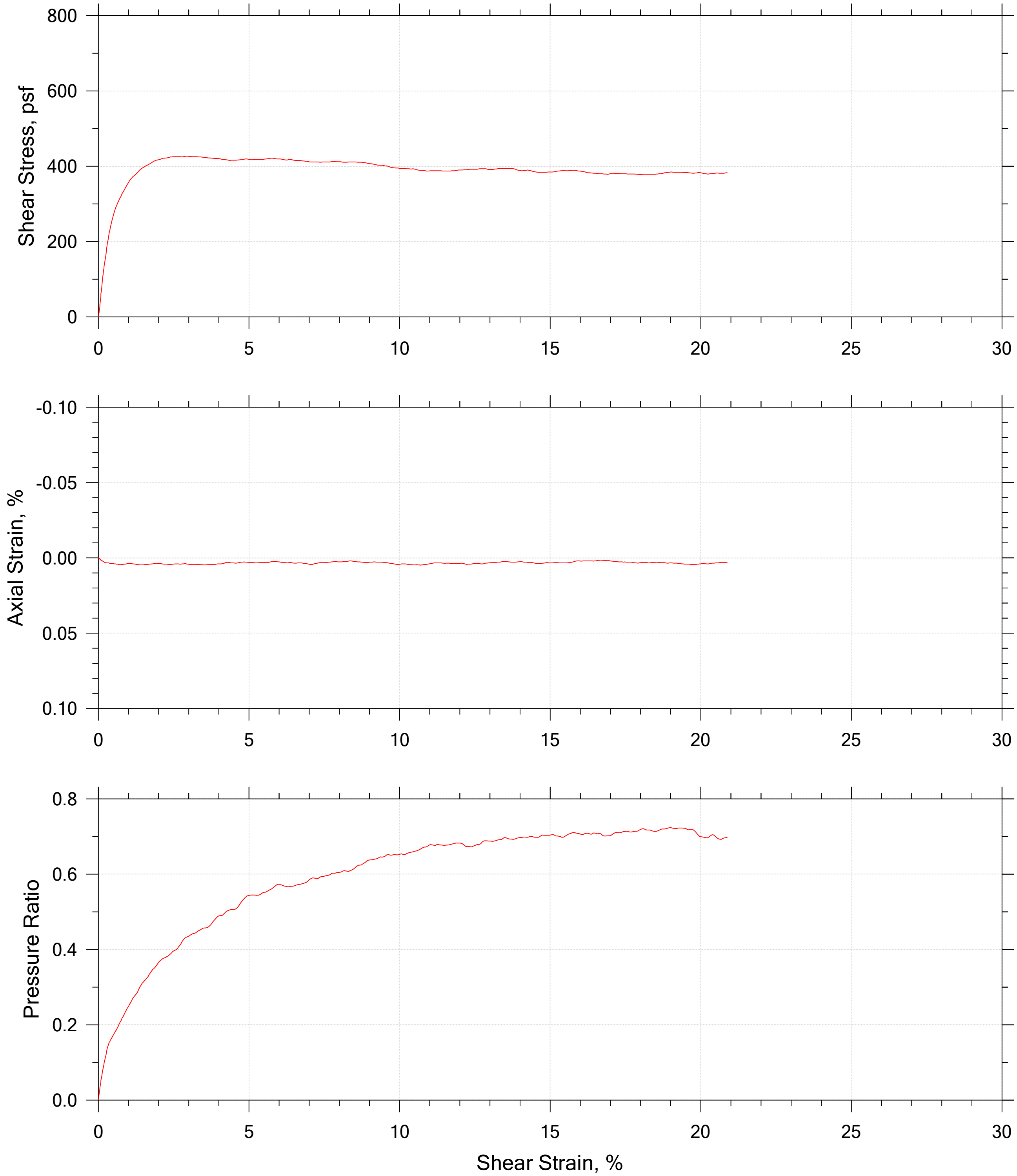
Comments:

Tested By: jlw

Checked By: njh

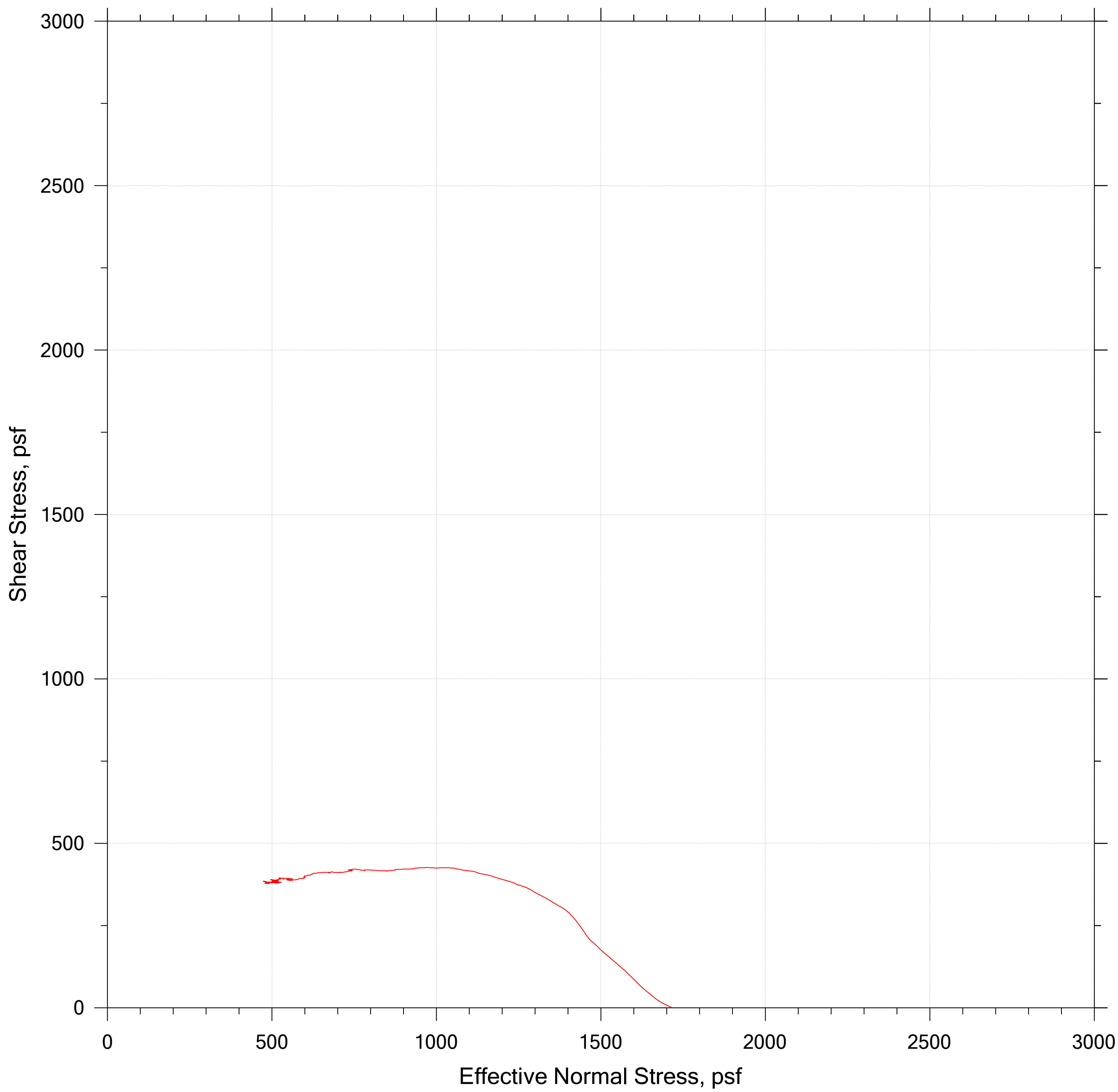
Notes: These results apply only to the sample tested for the specific test conditions. The test procedures employed follow accepted industry practice and the indicated test method. GeoTesting Express has no specific knowledge as to conditioning, origin, sampling procedure or intended use of the material.

Direct Simple Shear Test



GeoTesting EXPRESS			
	Project Name: MEDOT Augusta Spaulding	Location: Augusta, ME	Project Number: GTX- 317120
	Boring Number: BB-ASB-102	Tester: jlw	Checker: njh
	Sample Number: U-1	Test Date: 5/15/23	Depth: 25-27
	Test Number: DSS-1	Preparation: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: CST-001		
			Page 2 of 3

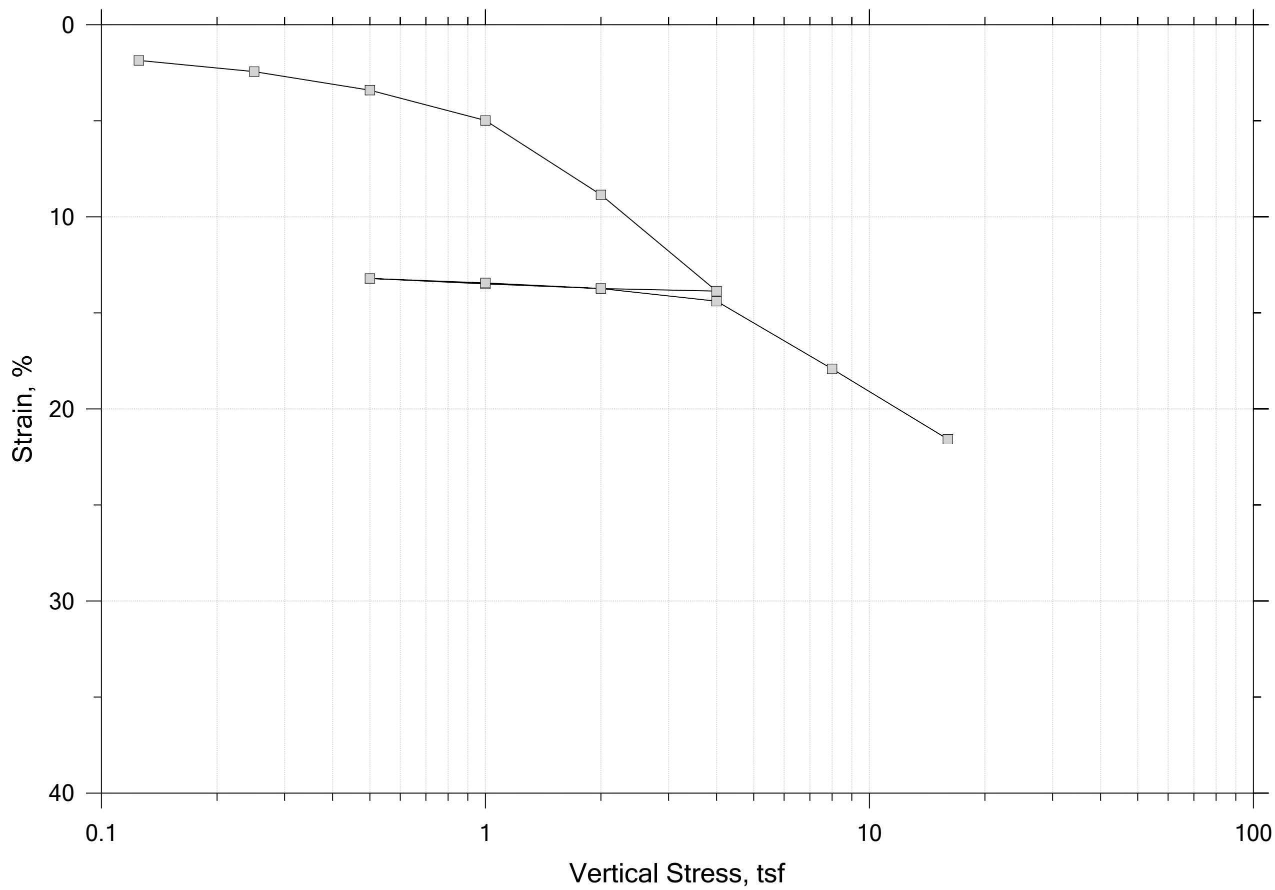
Direct Simple Shear Test

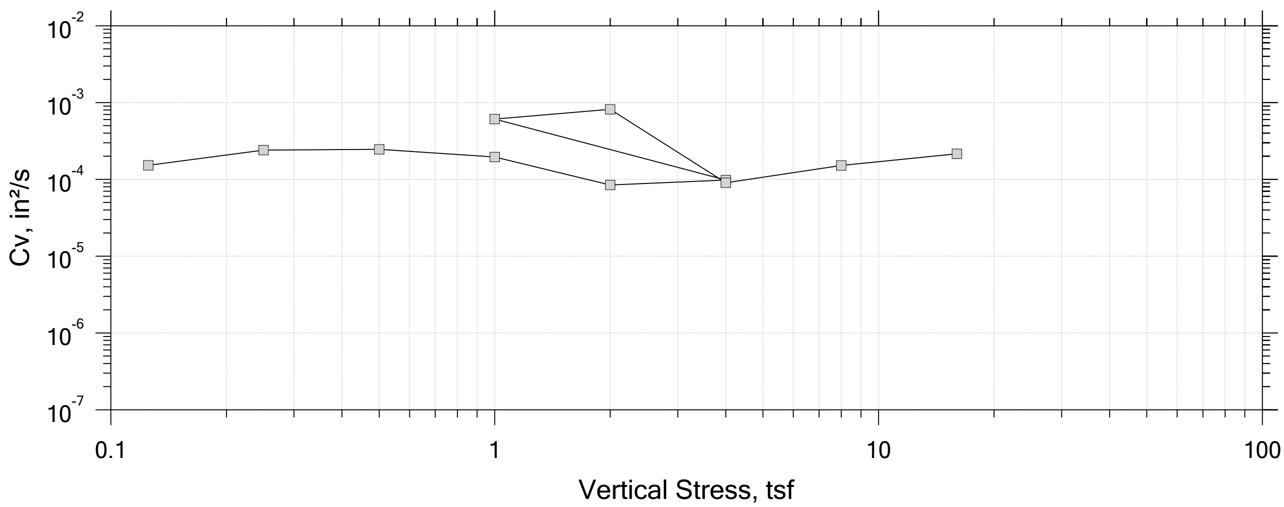


GeoTesting EXPRESS	Project Name: MEDOT Augusta Spaulding	Location: Augusta, ME	Project Number: GTX- 317120
	Boring Number: BB-ASB-102	Tester: jlw	Checker: njh
	Sample Number: U-1	Test Date: 5/15/23	Depth: 25-27
	Test Number: DSS-1	Preparation: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: CST-001		

One-Dimensional Consolidation by ASTM D2435 - Method B

Summary Report





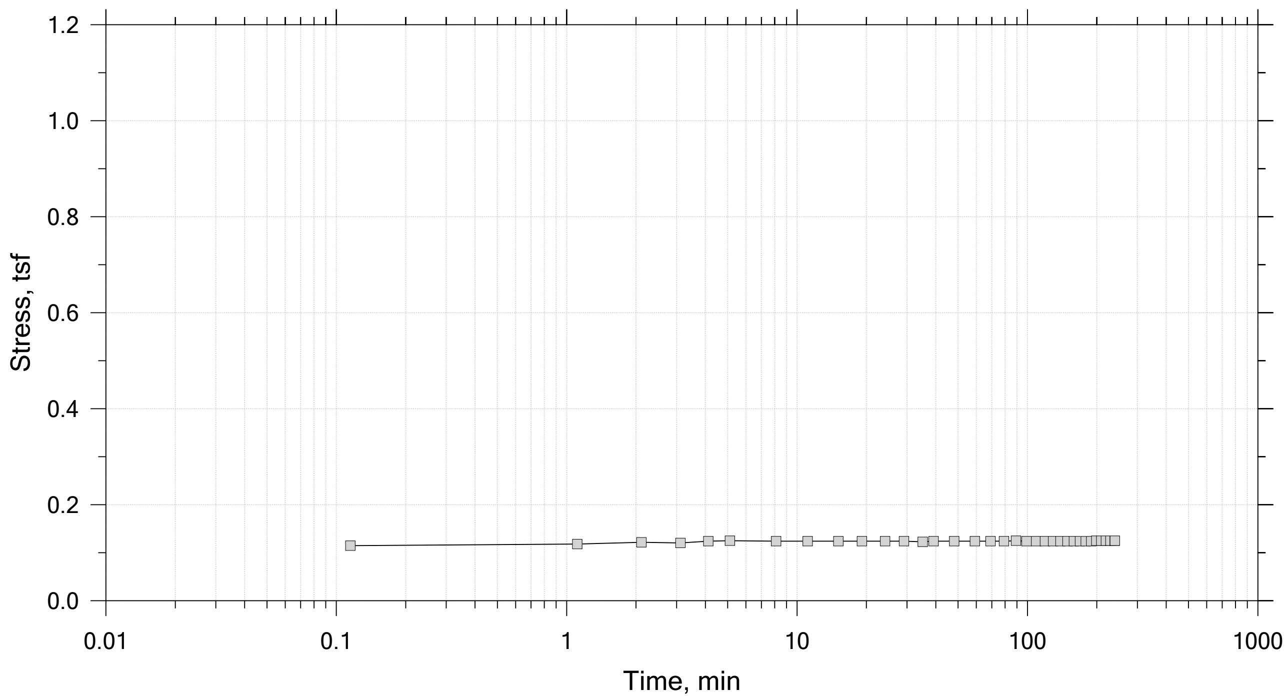
GeoTesting EXPRESS	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		
	Displacement at End of Increment		

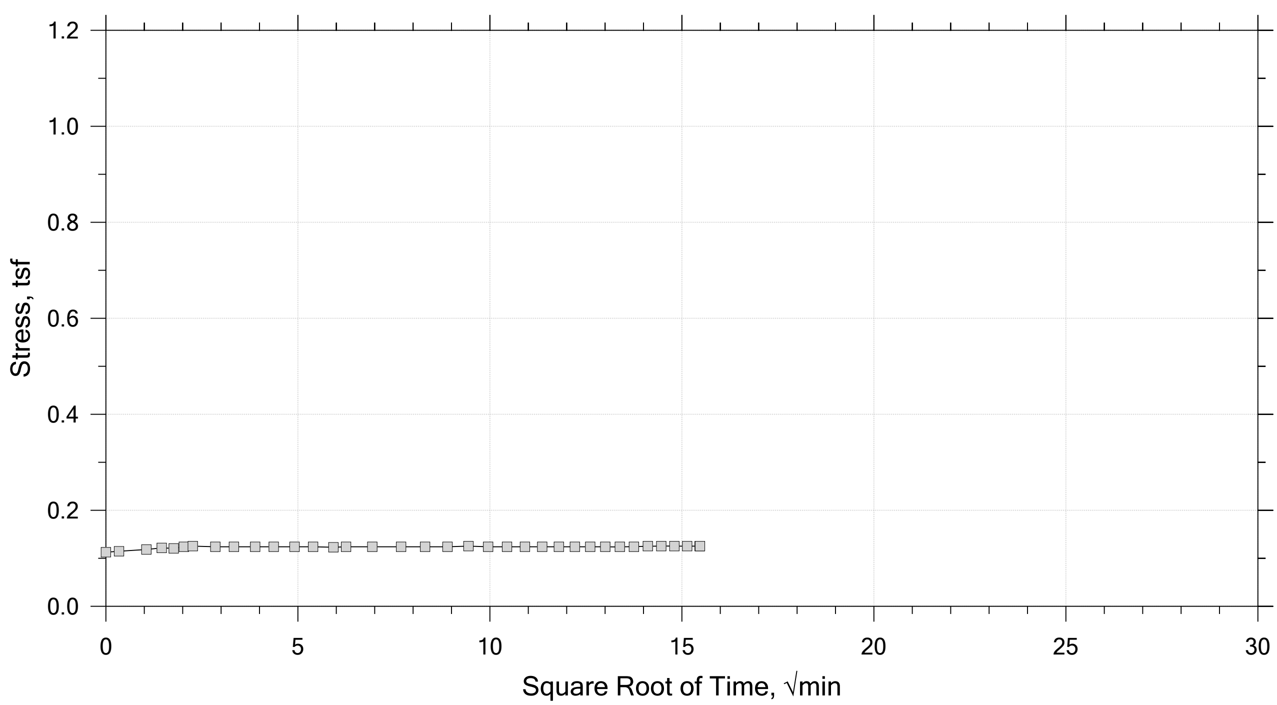
One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 1 of 14

Constant Volume Step

Stress: 0.125 tsf





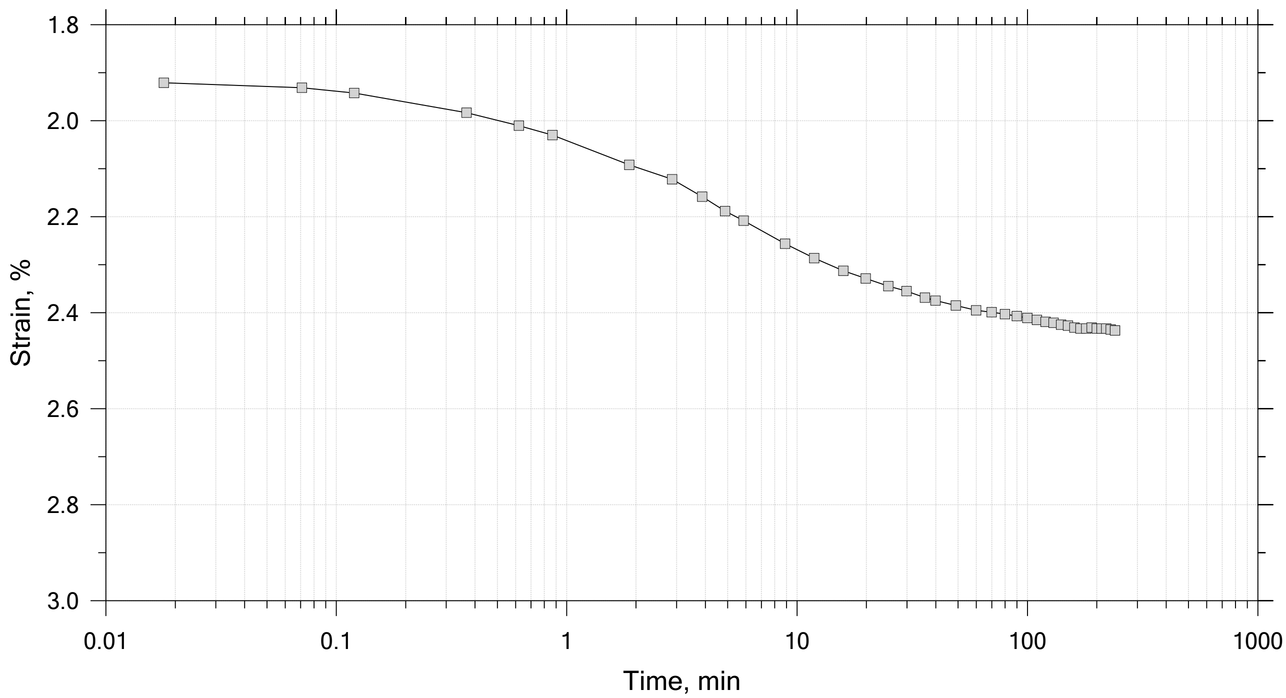
GeoTesting EXPRESS	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

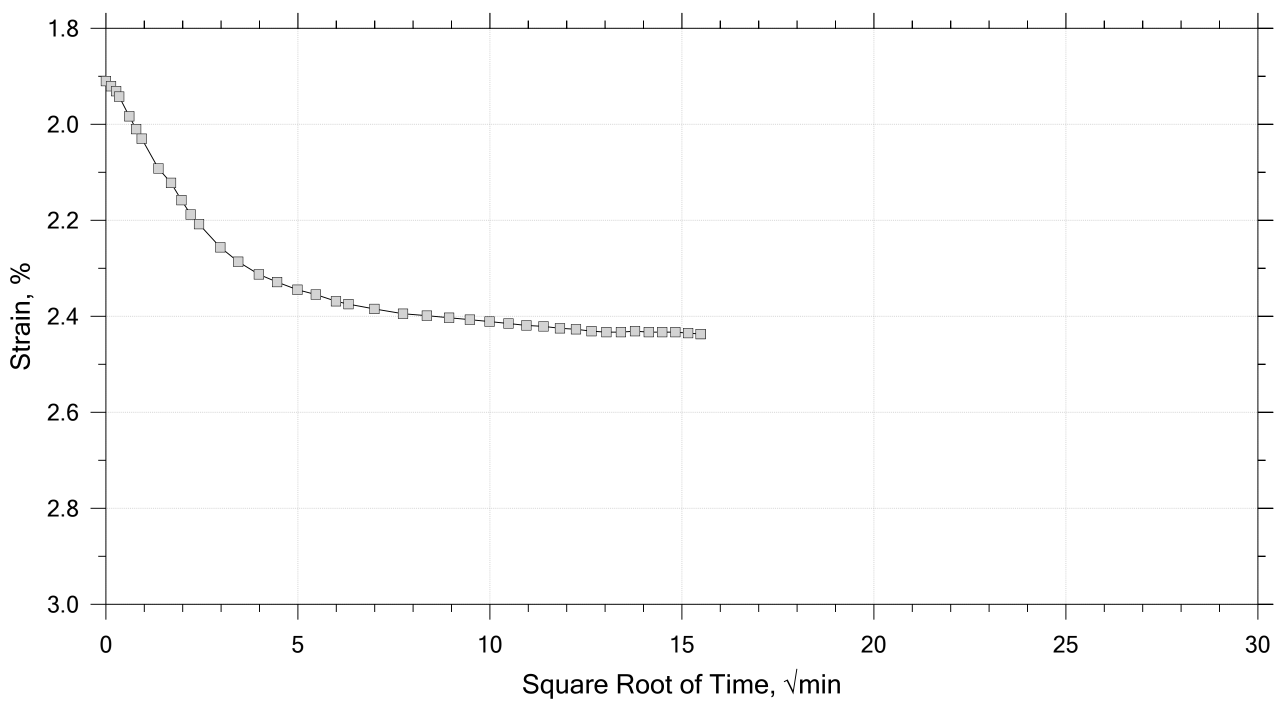
One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 2 of 14

Constant Load Step

Stress: 0.25 tsf





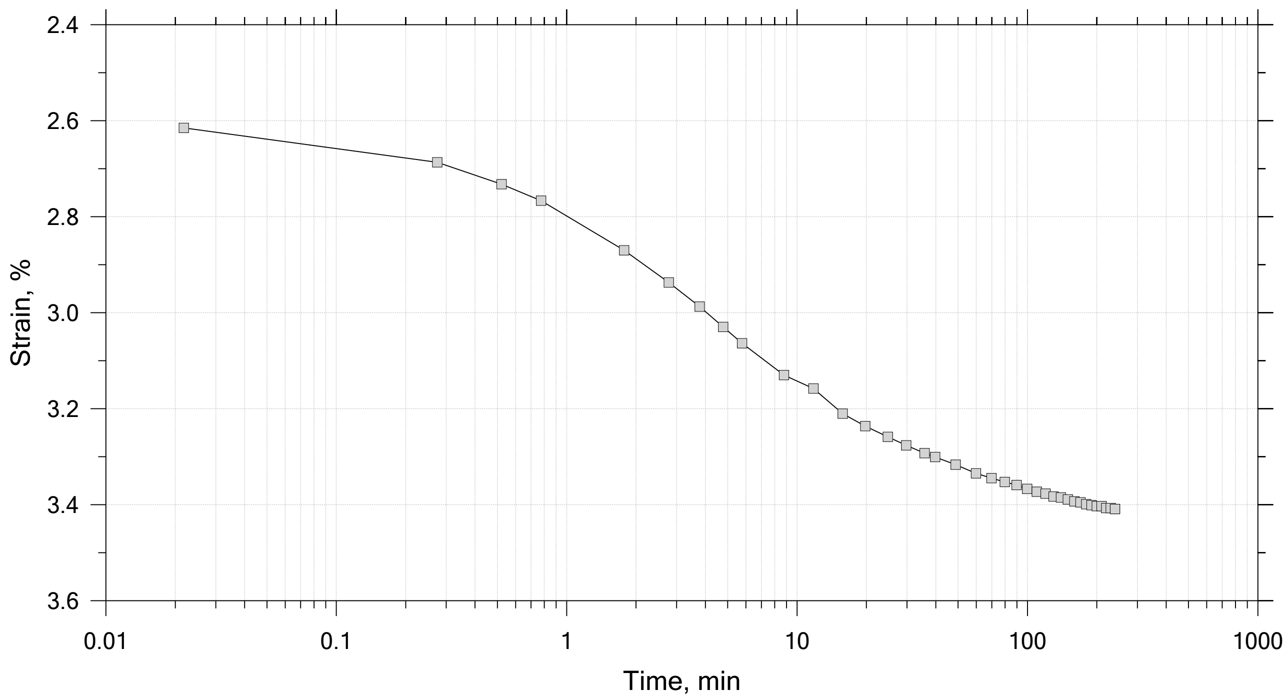
GeoTesting EXPRESS			
	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

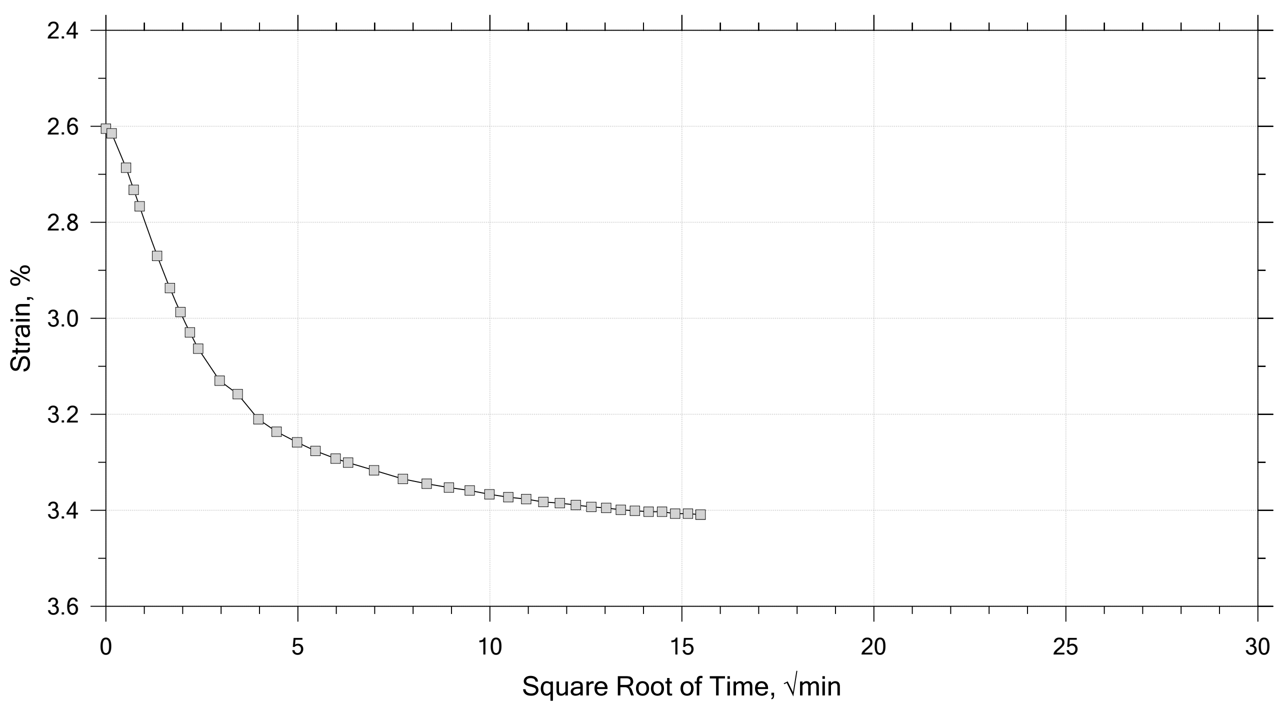
One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 3 of 14

Constant Load Step

Stress: 0.5 tsf





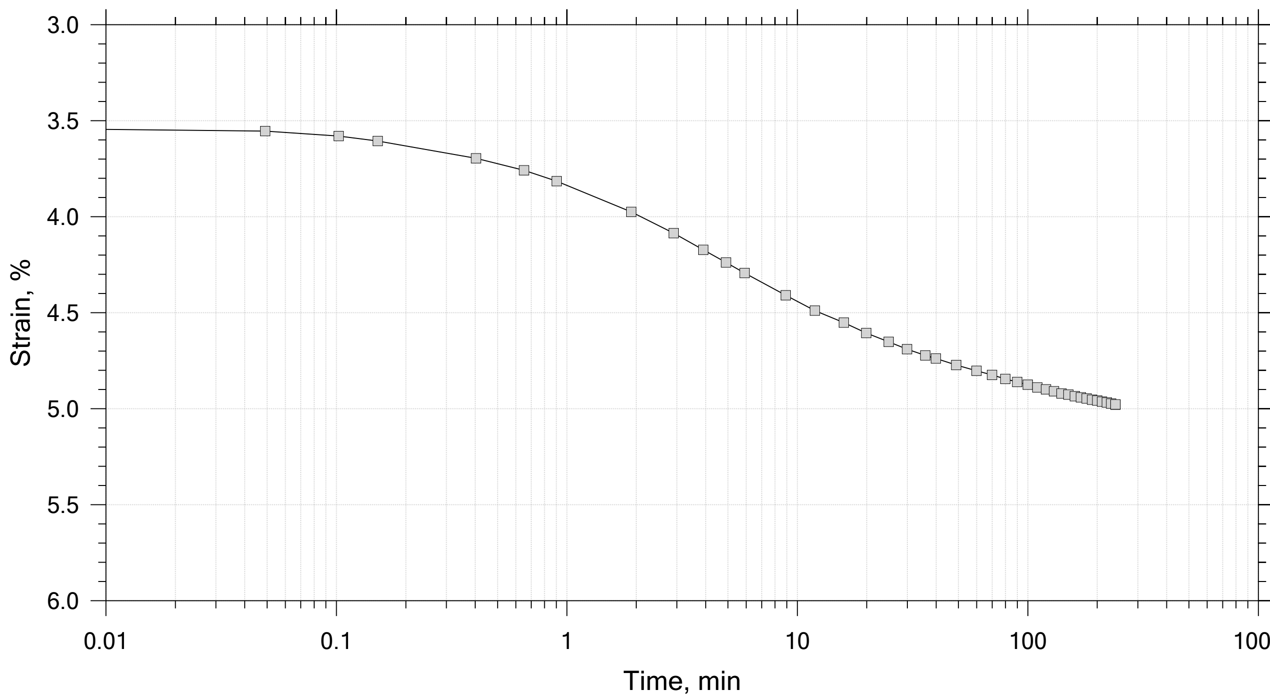
GeoTesting EXPRESS			
	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

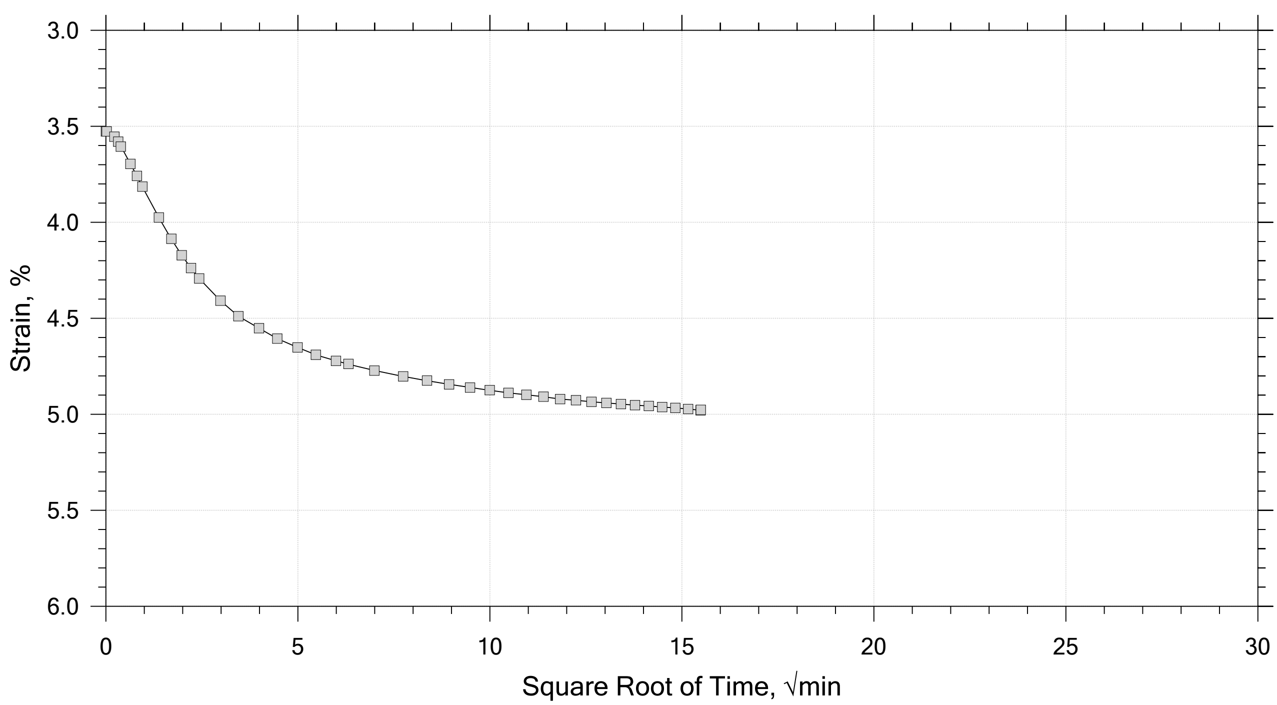
One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 4 of 14

Constant Load Step

Stress: 1 tsf





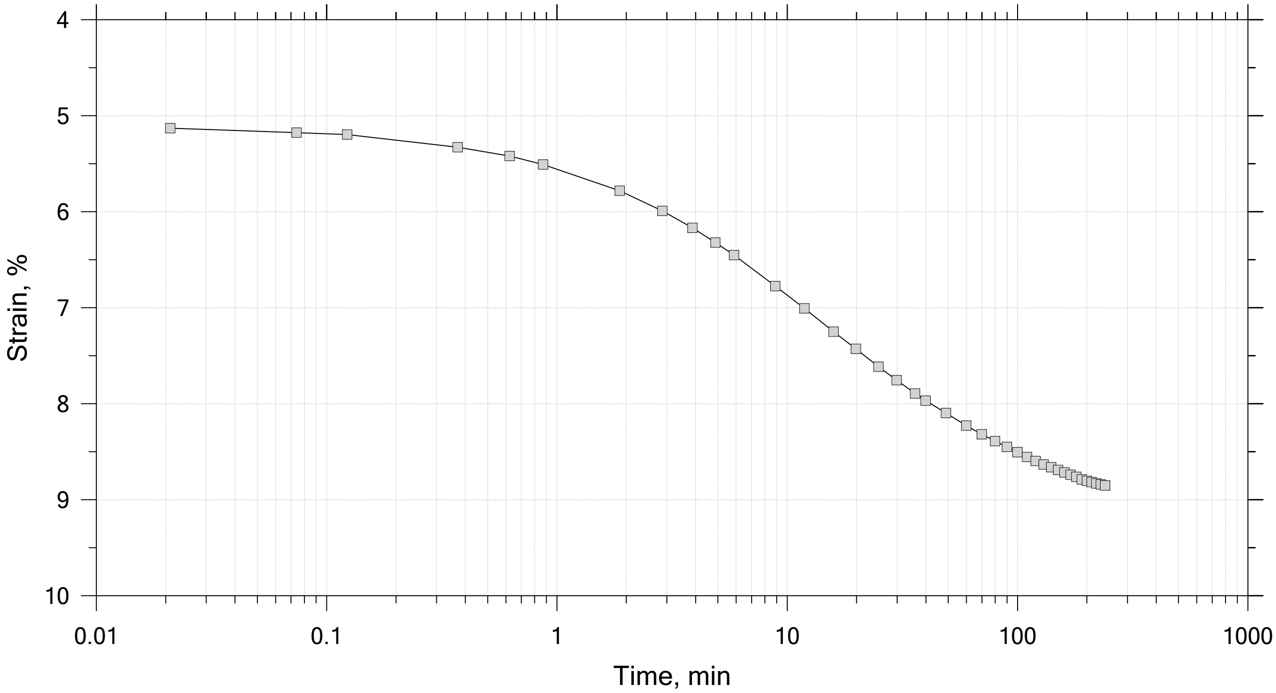
GeoTesting EXPRESS	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

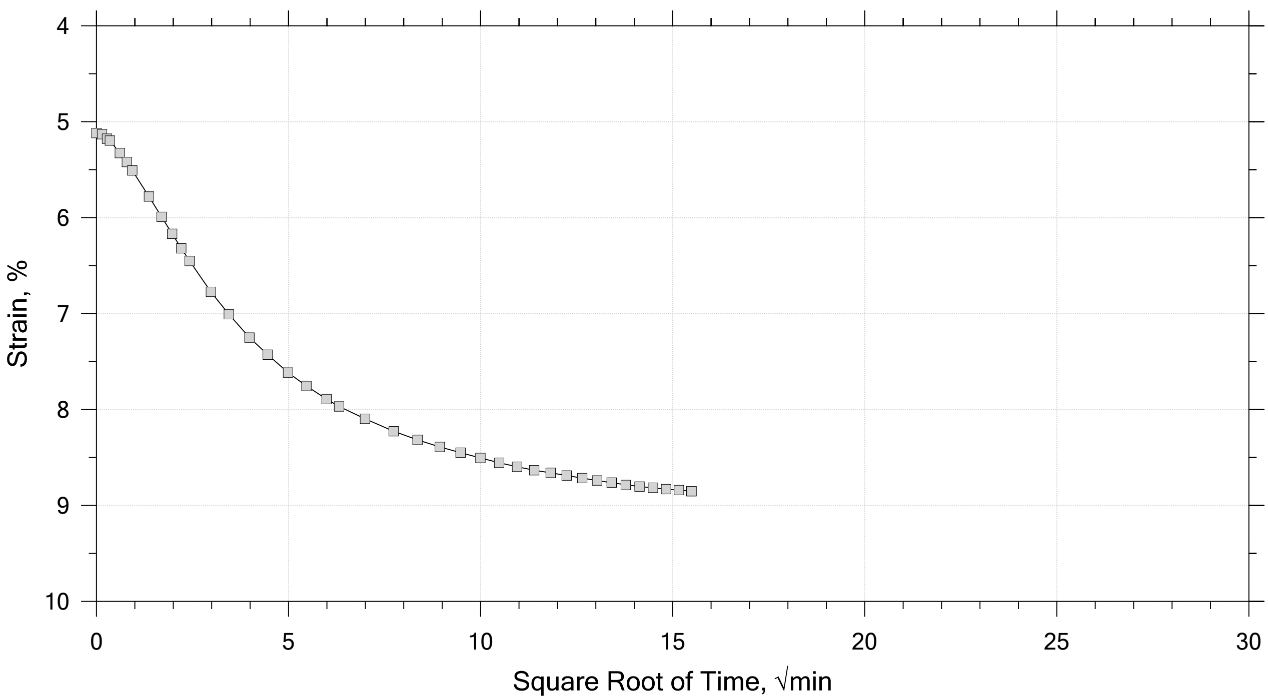
One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 5 of 14

Constant Load Step

Stress: 2 tsf





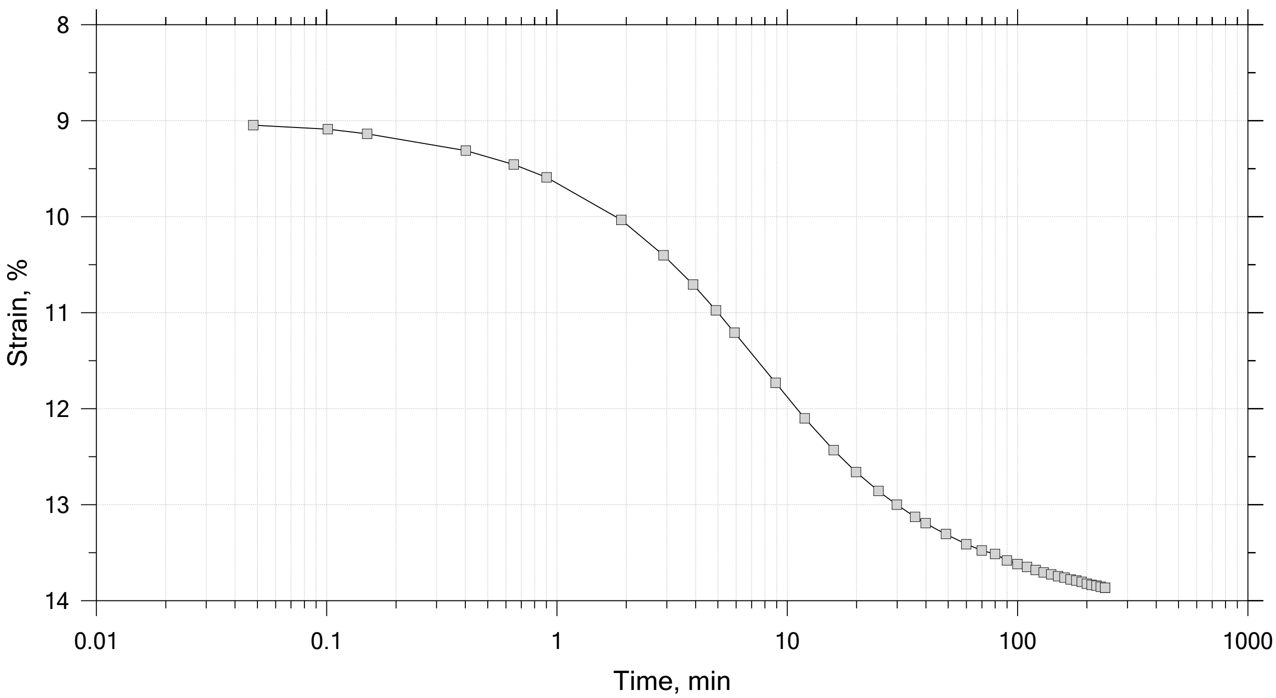
GeoTesting EXPRESS	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

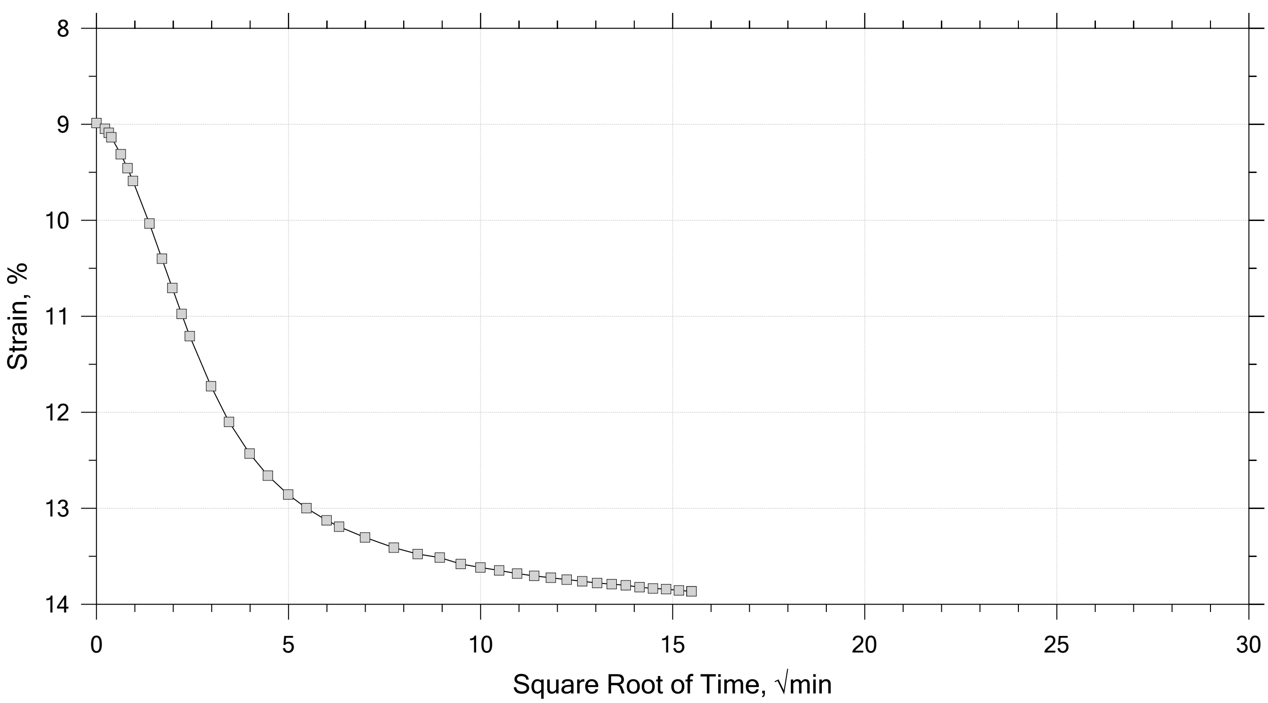
One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 6 of 14

Constant Load Step

Stress: 4 tsf





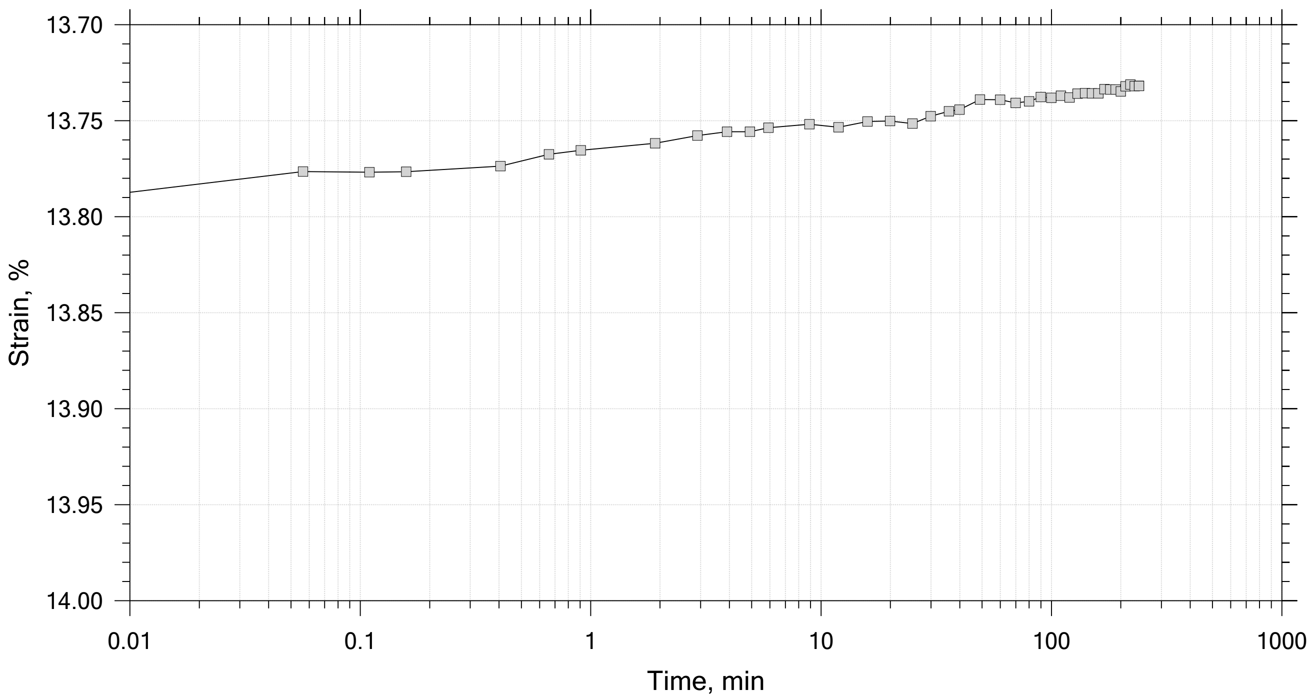
GeoTesting EXPRESS	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

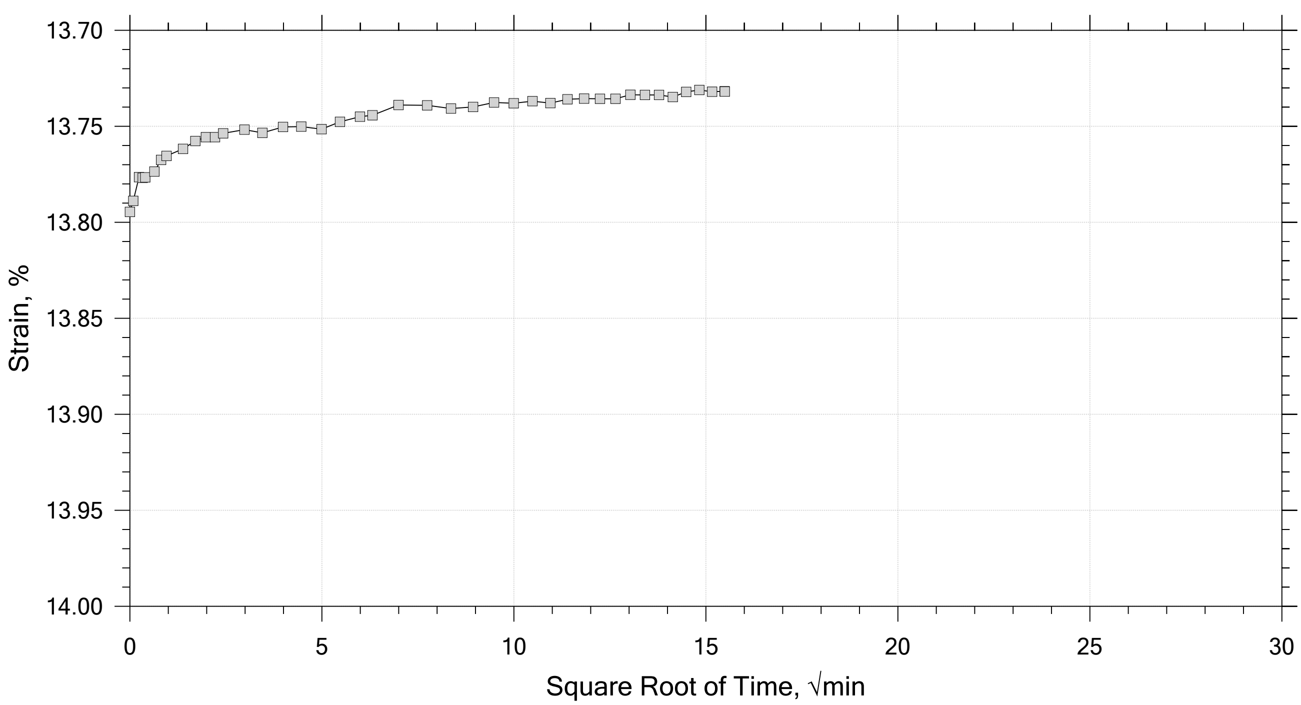
One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 7 of 14

Constant Load Step

Stress: 2 tsf

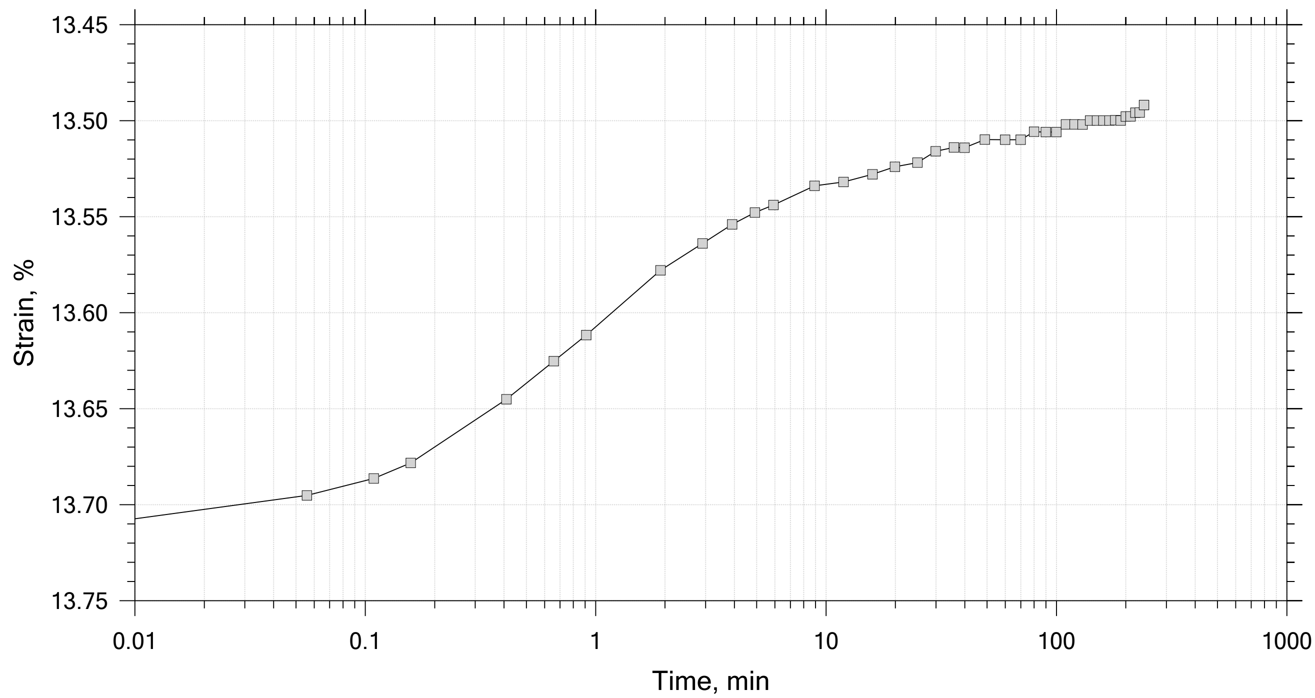


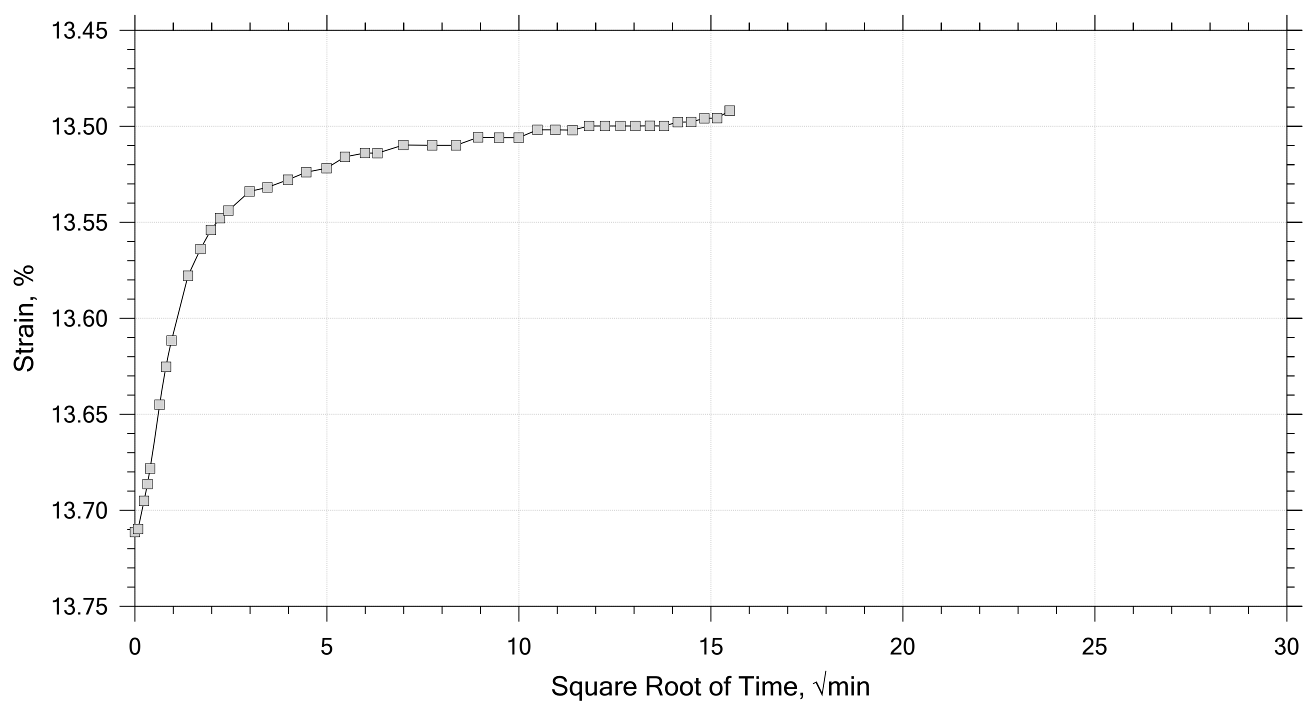


GeoTesting EXPRESS	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 8 of 14
Constant Load Step
Stress: 1 tsf





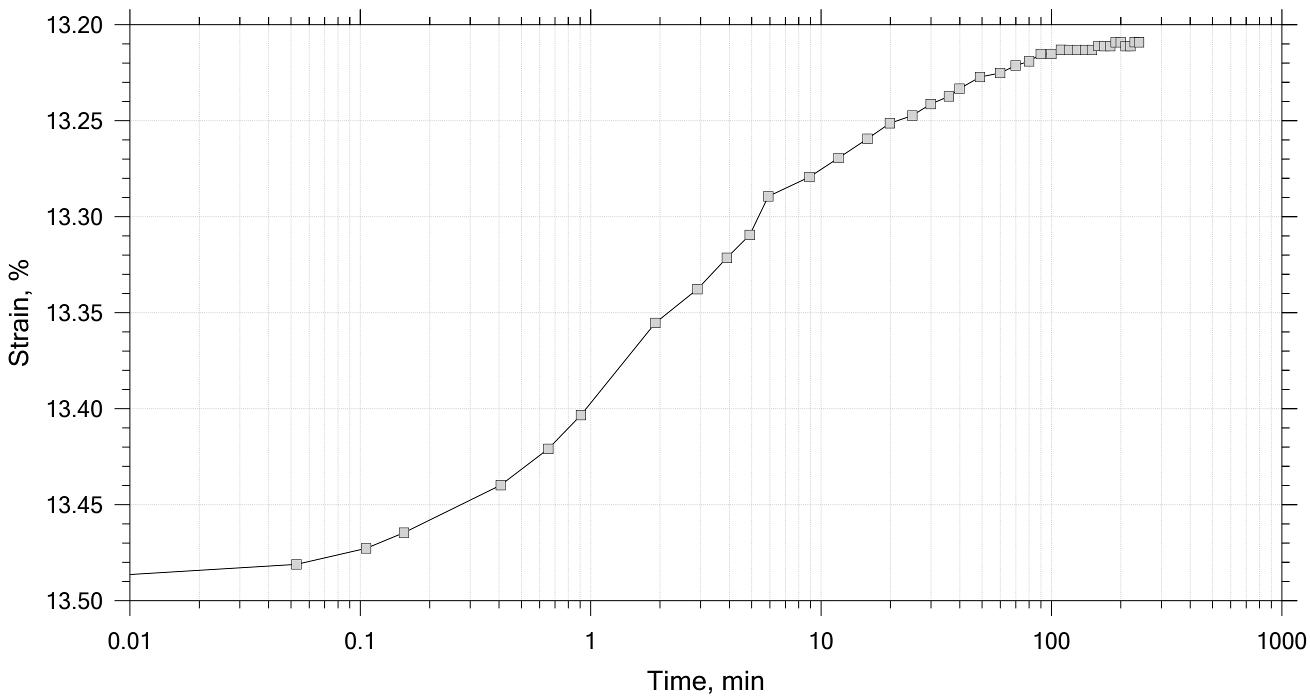
GeoTesting EXPRESS	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

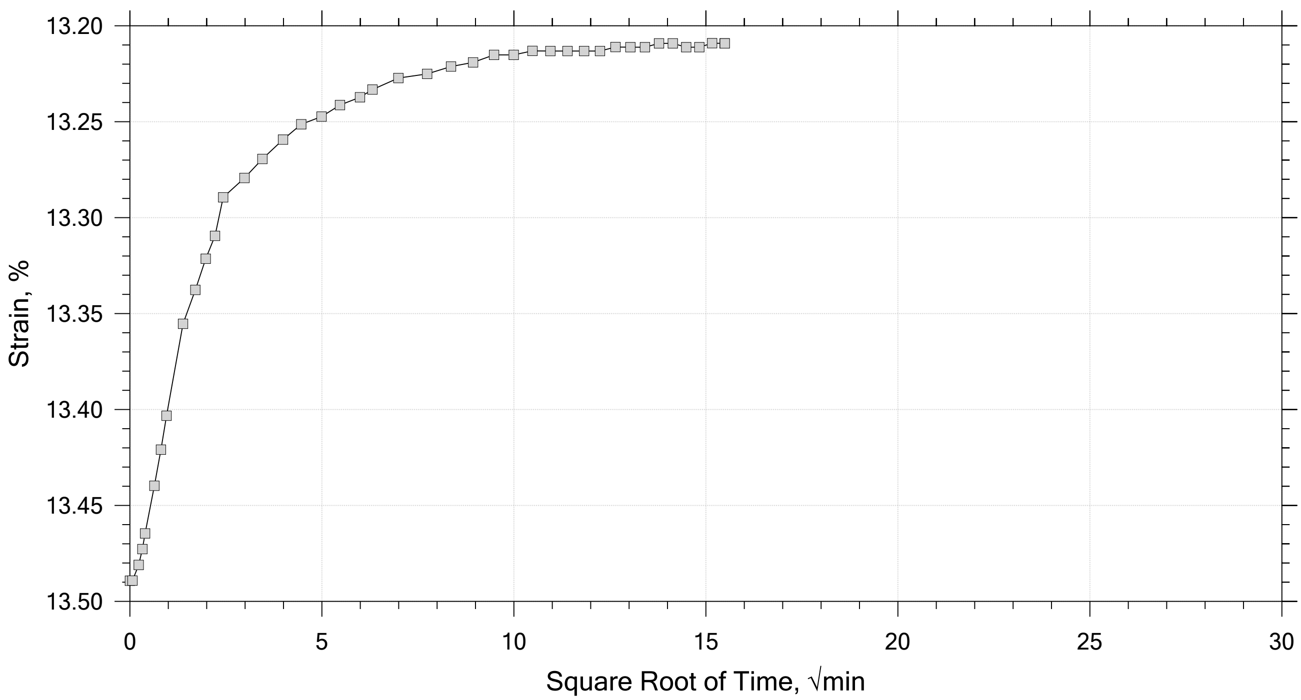
One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 9 of 14

Constant Load Step

Stress: 0.5 tsf





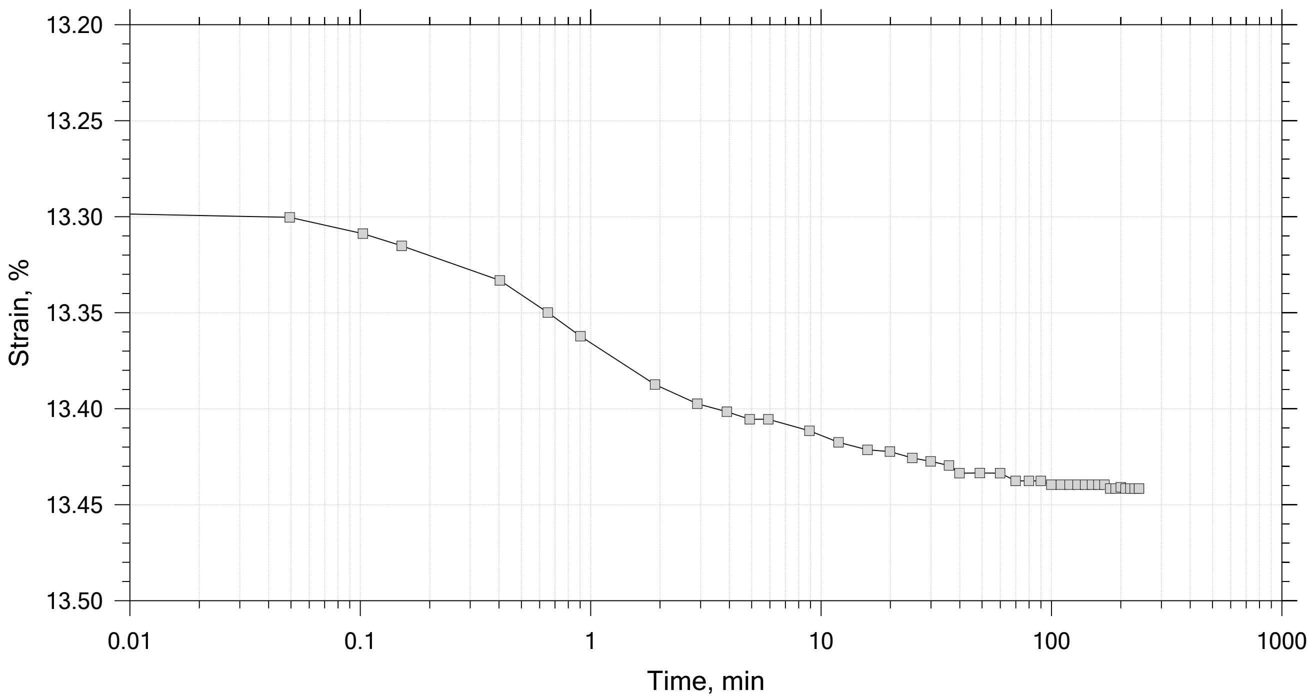
GeoTesting EXPRESS			
	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

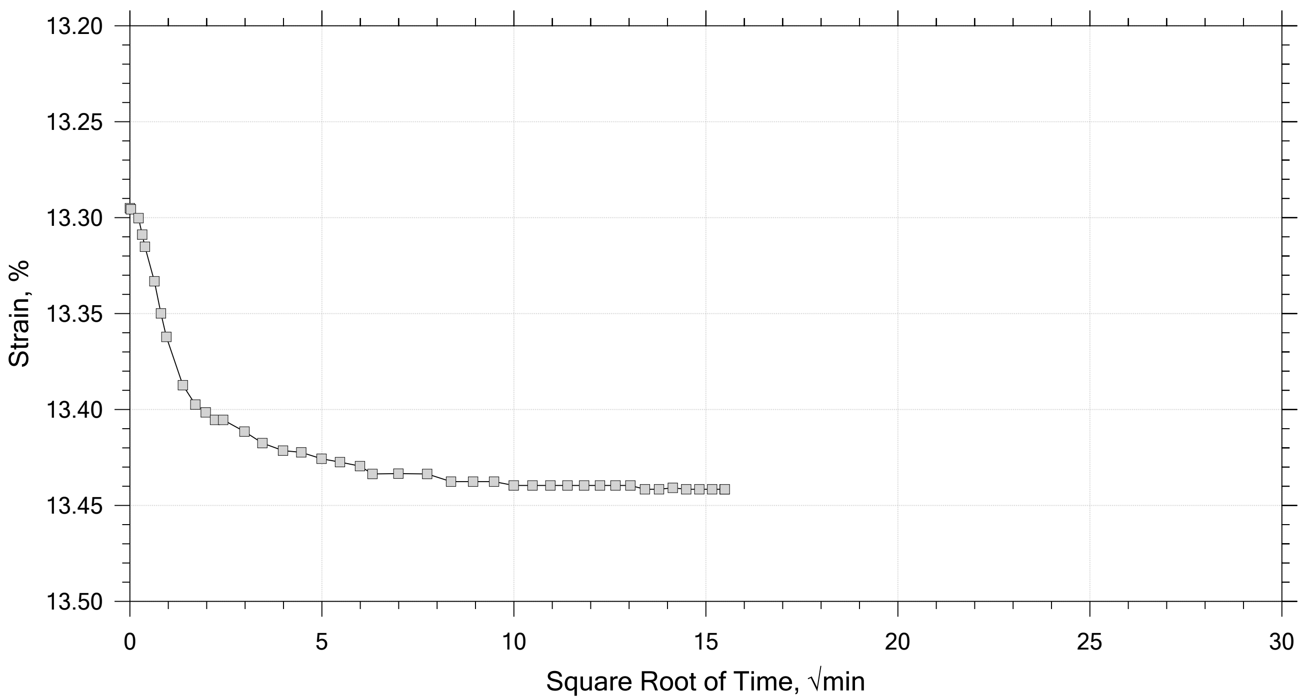
One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 10 of 14

Constant Load Step

Stress: 1 tsf

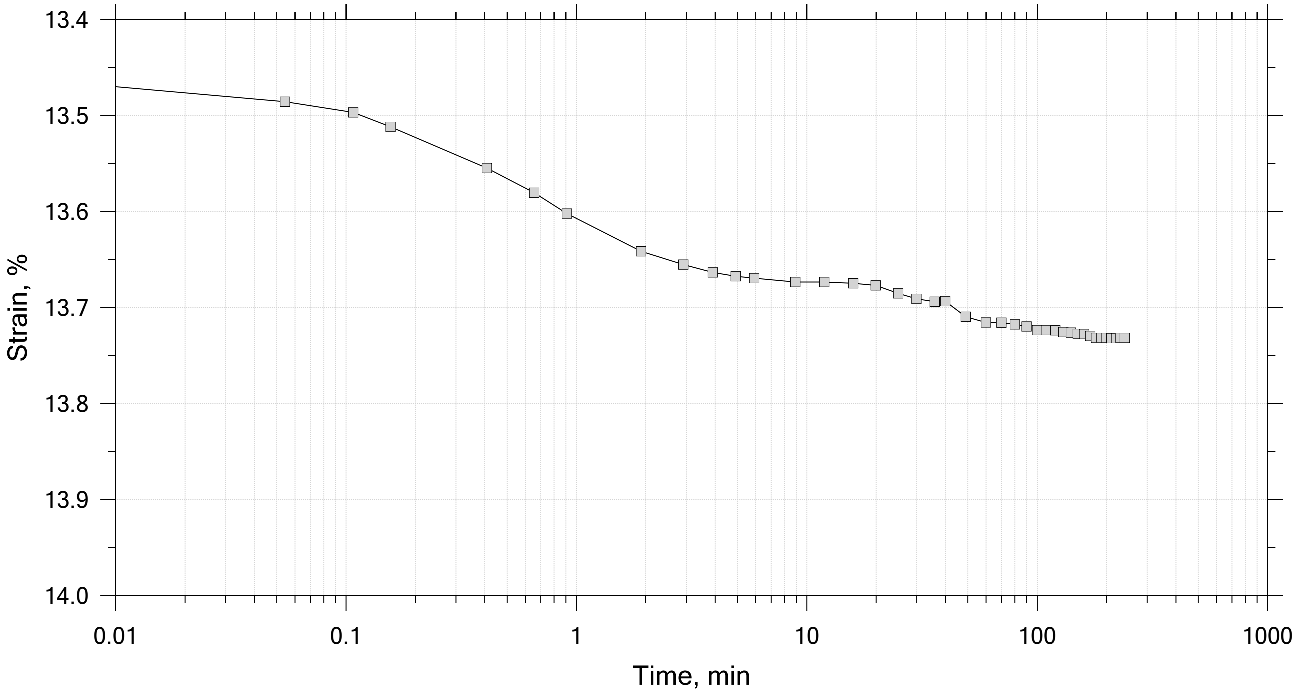


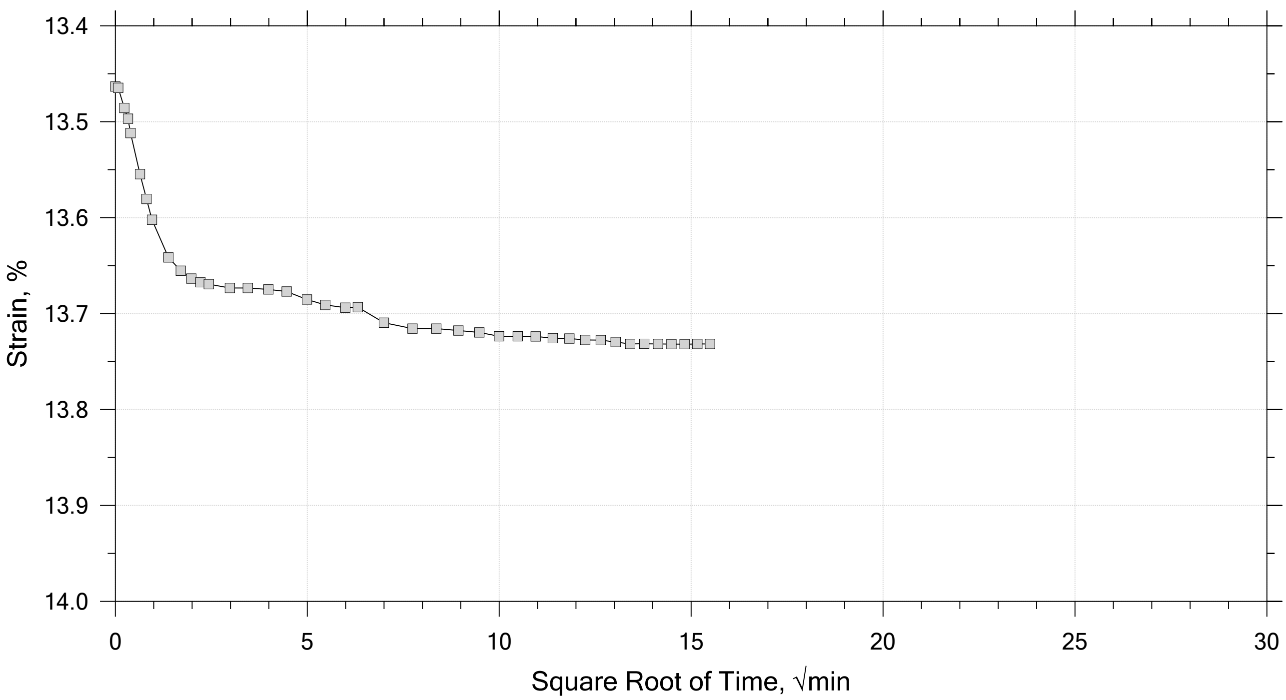


GeoTesting EXPRESS	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 11 of 14
Constant Load Step
Stress: 2 tsf

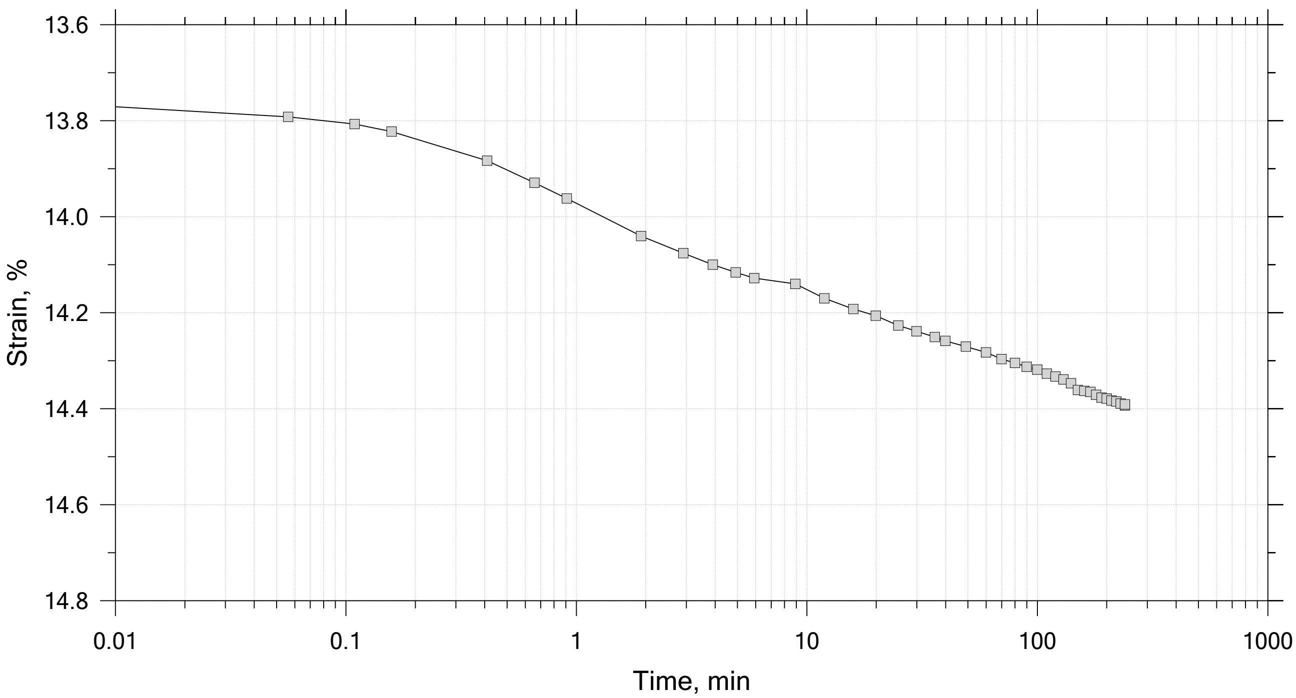


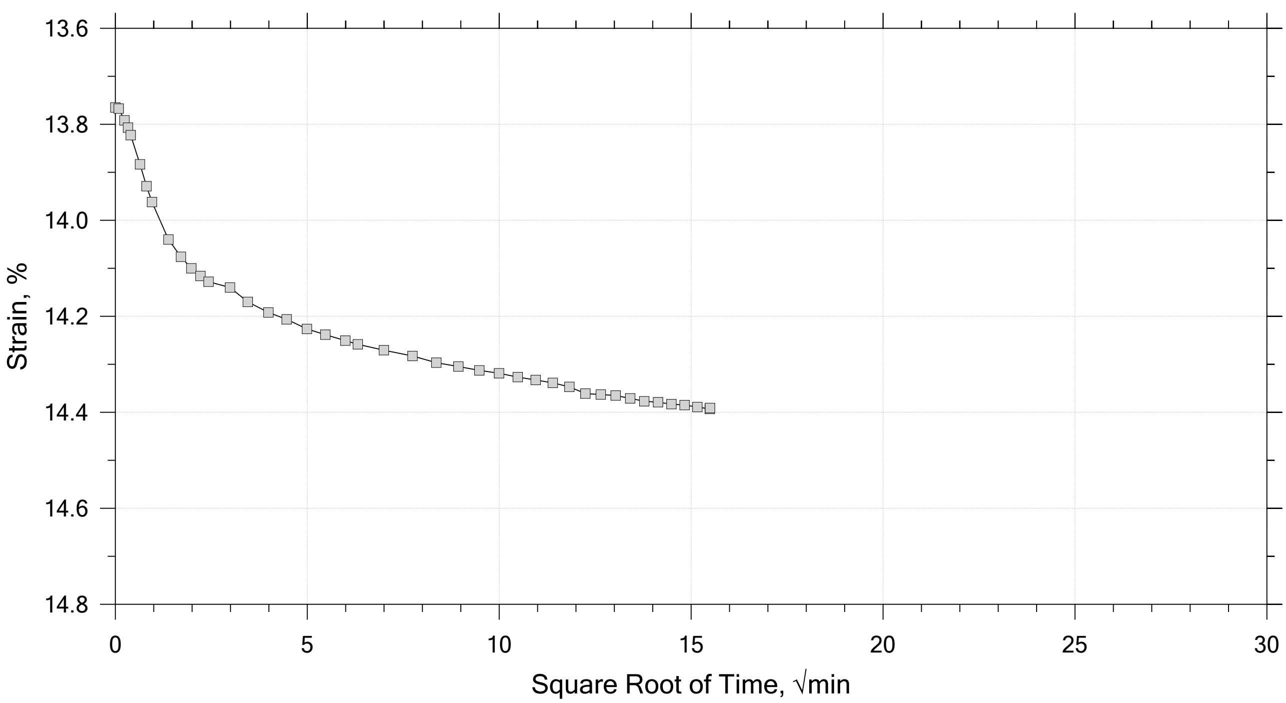


GeoTesting EXPRESS	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 12 of 14
Constant Load Step
Stress: 4 tsf





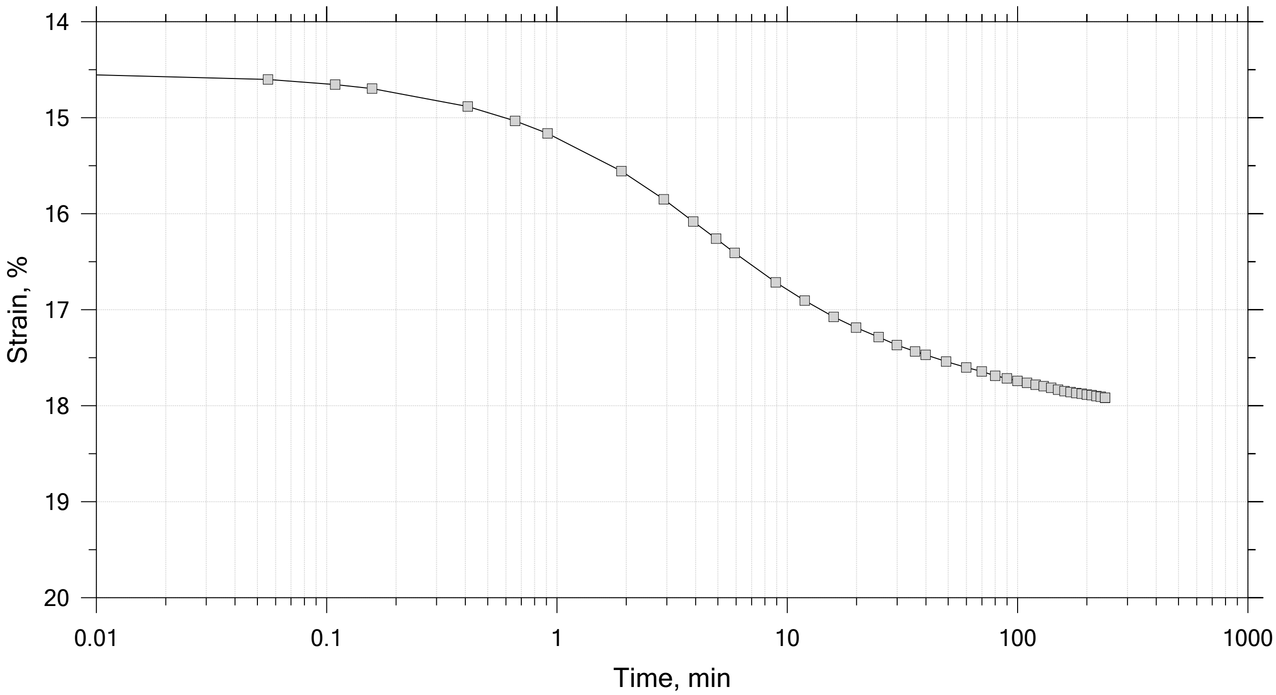
GeoTesting EXPRESS	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

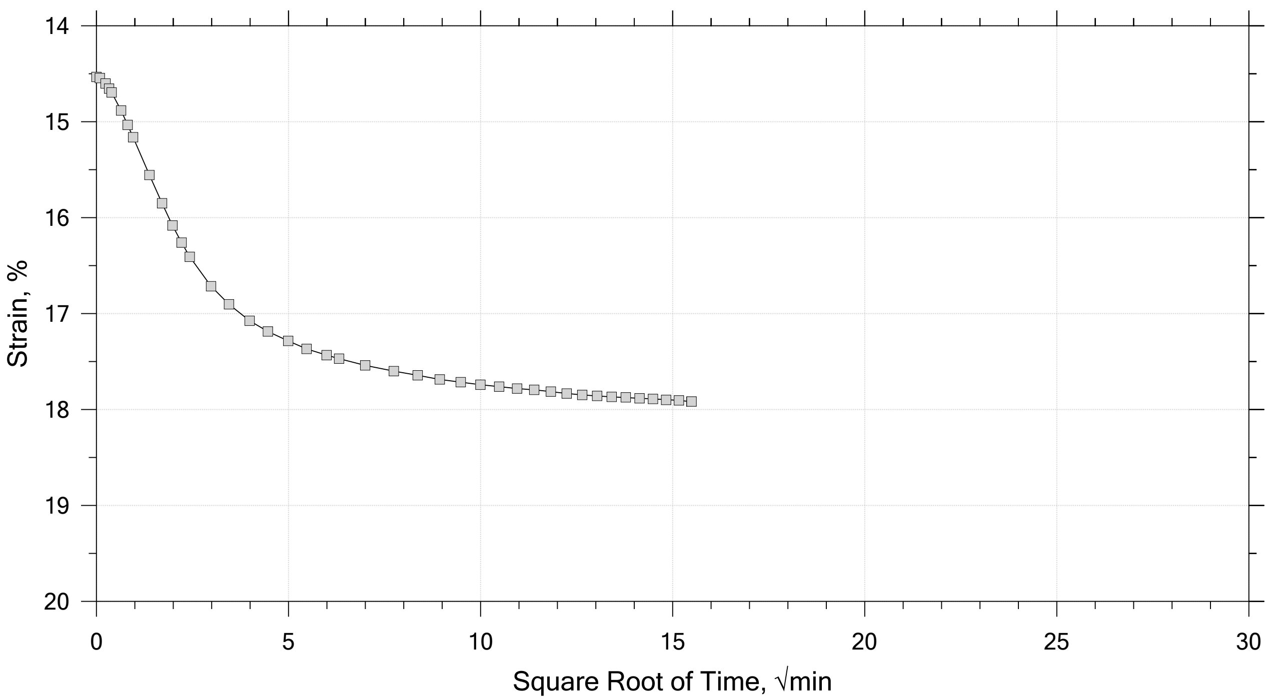
One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 13 of 14

Constant Load Step

Stress: 8 tsf

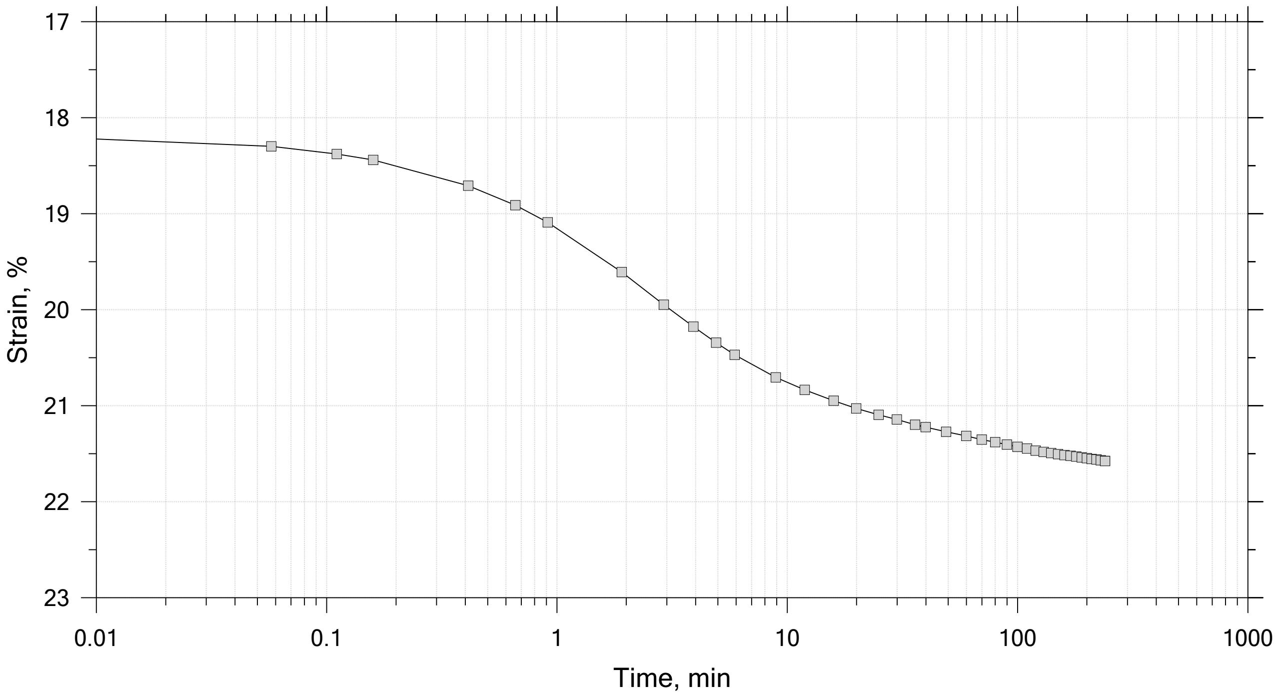


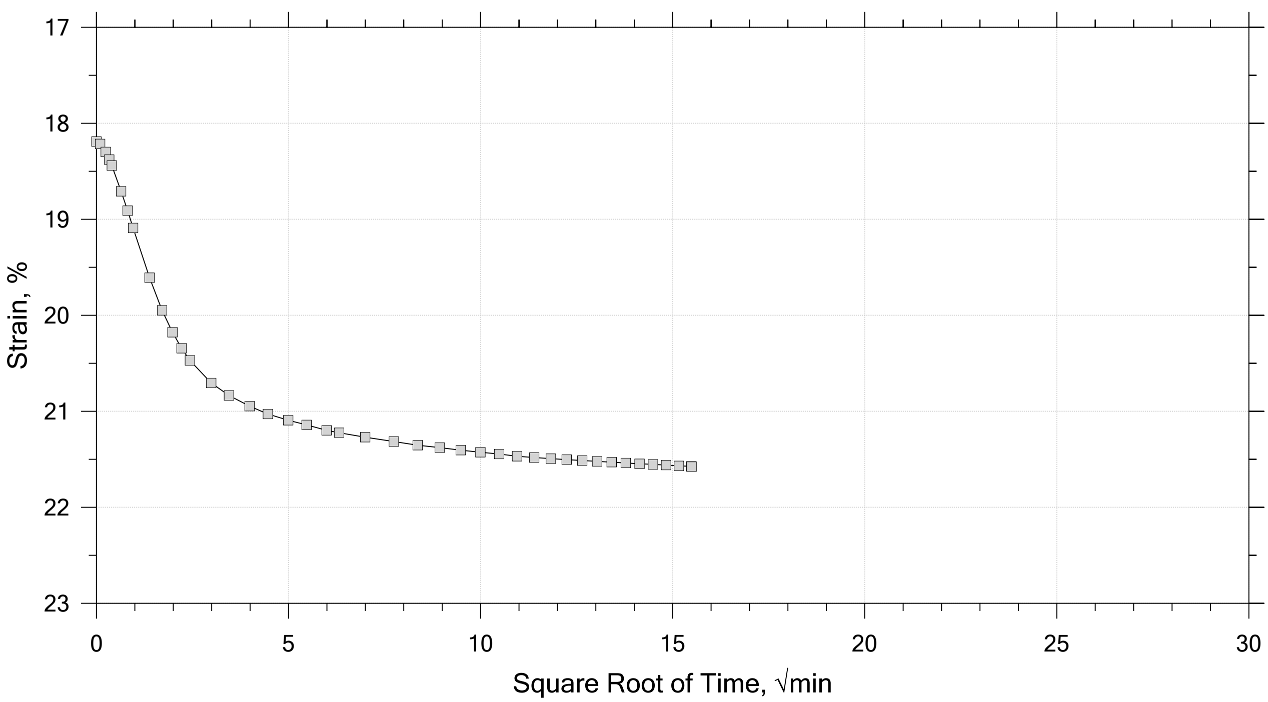


GeoTesting EXPRESS	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

One-Dimensional Consolidation by ASTM D2435 - Method B

Time Curve 14 of 14
Constant Load Step
Stress: 16 tsf





GeoTesting EXPRESS	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

One-Dimensional Consolidation by ASTM D2435 - Method B

Specimen Diameter: 2.50 in	Estimated Specific Gravity: 2.74	Liquid Limit: 33
Initial Height: 1.00 in	Initial Void Ratio: 0.966	Plastic Limit: 18
Final Height: 0.79 in	Final Void Ratio: 0.553	Plasticity Index: 15

	Before Test Trimmings	Before Test Specimen	After Test Specimen	After Test Trimmings
Container ID	E6727	RING		E7500
Mass Container, gm	8.91	111.07	111.07	8.44
Mass Container + Wet Soil, gm	144.12	262.64	246	144.88
Mass Container + Dry Soil, gm	109.42	223.37	223.37	122
Mass Dry Soil, gm	100.51	112.3	112.3	113.56
Water Content, %	34.52	34.96	20.15	20.15
Void Ratio	---	0.97	0.55	---
Degree of Saturation, %	---	99.36	100.00	---
Dry Unit Weight, pcf	---	87.157	110.32	---

Note: Specific Gravity and Void Ratios are calculated assuming the degree of saturation equals 100% at the end of the test.
Therefore, values may not represent actual values for the specimen.

GeoTesting EXPRESS	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		

One-Dimensional Consolidation by ASTM D2435 - Method B

Square Root of Time Coefficients

Step	Applied Stress tsf	Final Displacement in	Void Ratio	Strain at End %	Sq.Rt. T90 min	Cv in²/s	Mv 1/tsf	k ft/day
1	0.125	0.01859	0.929	1.86	22.711	1.53e-04	1.49e-01	4.25e-04
2	0.250	0.02437	0.918	2.44	14.108	2.40e-04	4.63e-02	2.08e-04
3	0.500	0.03409	0.899	3.41	13.531	2.46e-04	3.89e-02	1.79e-04
4	1.00	0.04977	0.868	4.98	16.566	1.96e-04	3.14e-02	1.15e-04
5	2.00	0.08852	0.792	8.85	36.242	8.45e-05	3.88e-02	6.13e-05
6	4.00	0.1386	0.693	13.9	28.306	9.81e-05	2.51e-02	4.60e-05
7	2.00	0.1373	0.696	13.7	46.130	5.69e-05	6.65e-04	7.09e-07
8	1.00	0.1349	0.701	13.5	4.590	5.75e-04	2.40e-03	2.58e-05
9	0.500	0.1321	0.706	13.2	8.045	3.30e-04	5.65e-03	3.49e-05
10	1.00	0.1344	0.702	13.4	4.358	6.09e-04	4.65e-03	5.30e-05
11	2.00	0.1373	0.696	13.7	3.237	8.15e-04	2.90e-03	4.43e-05
12	4.00	0.1439	0.683	14.4	28.933	9.02e-05	3.30e-03	5.57e-06
13	8.00	0.1792	0.614	17.9	16.409	1.51e-04	8.81e-03	2.50e-05
14	16.0	0.2158	0.542	21.6	10.563	2.15e-04	4.58e-03	1.85e-05

GeoTesting EXPRESS			
	Project: ME DOT Augusta Spaulding	Location: Augusta, ME	Project No.: GTX-317120
	Boring No.: BB-ASB-102	Tested By: jlw	Checked By: anm
	Sample No.: U-1	Test Date: 5/2/23	Depth: 25'-27'
	Test No.: IP-1	Sample Type: intact	Elevation: ---
	Description: Moist, dark gray clay		
	Remarks: System LTIII-F, Swell Pressure = 0.125 tsf		
	Displacement at End of Increment		

APPENDIX D

Calculations

CALCULATIONS

Date:	11/9/2023	**Made by:**	LMP
Project No.:	30900914.003	**Checked by:**	DEB
Subject:	Lateral Earth Pressure	**Reviewed by:**	CCB
Project Short Title:	Spaulding Brook Bridge No. 2790, Augusta, Maine		

OBJECTIVE
Determine lateral earth pressure acting on the proposed box culvert and wingwalls.

REFERENCES

1. Das, Braja M. 2011. Principles of Foundation Engineering, 7th ed. Cengage Learning, Stamford, CT.
2. WSP geotechnical test boring logs (Appendix A, Preliminary Geotechnical Design Report, dated November 2023).
3. Guertin Elkerton & Associates for Maine Department of Transportation. Bridge Design Guide. Dated August 2003 with 2018 updates.
4. Holtz, R.D. , Kovacs, W.D., and Sheahan, T.C. 2010. An Introduction to Geotechnical Engineering, 2nd ed. Pearson Education, Hoboken, NJ.
5. WSP Summary of Soil Engineering Laboratory Testing Results (Table 5, Preliminary Geotechnical Design Report, dated November, 2023).
6. AASHTO LRFD Bridge Design Specifications, 9th Ed. 2020.

ASSUMPTIONS
1. The backfill surface behind the wingwalls is assumed to be horizontal.

2. The design friction angles for the in-situ soil layers are based on correlation (Ref. 1, Equation 18.15) to the average N60-values encountered in all borings for each layer (Ref. 2). The design friction angle for the Fill material is based on the standard MaineDOT practice (Ref. 3). The design friction angle for the Presumpscot Clay is based on correlation to OCR and Plasticity Index (PI) (Ref. 4, Figure 12.50 and Equation 12.14).The design friction angles are:

ϕ_{Fill} = 36 degrees

$\phi_{Presump.\ Silt}$ = 33 degrees

$\phi_{Presump.\ Clay}$ = 29 degrees

$\phi_{Glacial\ Till}$ = 36 degrees

3. The design friction angles for the proposed fill construction materials (Reference 3), based on MaineDOT standard practice, are:

$\phi_{Granular\ Borrow}$ = 32 degrees

$\phi_{Gravel\ Borrow}$ = 36 degrees

4. Over consolidation ratio (OCR) from ILC test (Ref. 5).

$OCR_{Presump.\ Clay}$ = 1.4 -

CALCULATION

1. Calculate the at-rest lateral earth pressure coefficient.

$$K_0 = 1 - \sin\phi$$ (Ref. 1, Eqn. 13.5) For coarse-grained soils

$$K_0 = (1 - \sin\phi)\ OCR^{\sin\phi}$$ (Ref. 4, Eqn. 12.14) For over consolidated clays (Applicable to Presumpscot Clay)

where:

ϕ = internal friction angle of soil

	K_0 =	
	0.41	Existing Fill
	0.46	Presumpscot Silt - In Situ
	0.61	Presumpscot Clay- In Situ
	0.41	Glacial Till - In Situ
	0.47	Granular Borrow - Fill
	0.41	Gravel Borrow - Fill

CALCULATIONS

Date:	11/9/2023	**Made by:**	LMP
Project No.:	30900914.003	**Checked by:**	DEB
Subject:	Lateral Earth Pressure	**Reviewed by:**	CCB
Project Short Title:	Spaulding Brook Bridge No. 2790, Augusta, Maine		

2. Calculate the full active earth pressure coefficients using Rankine theory.

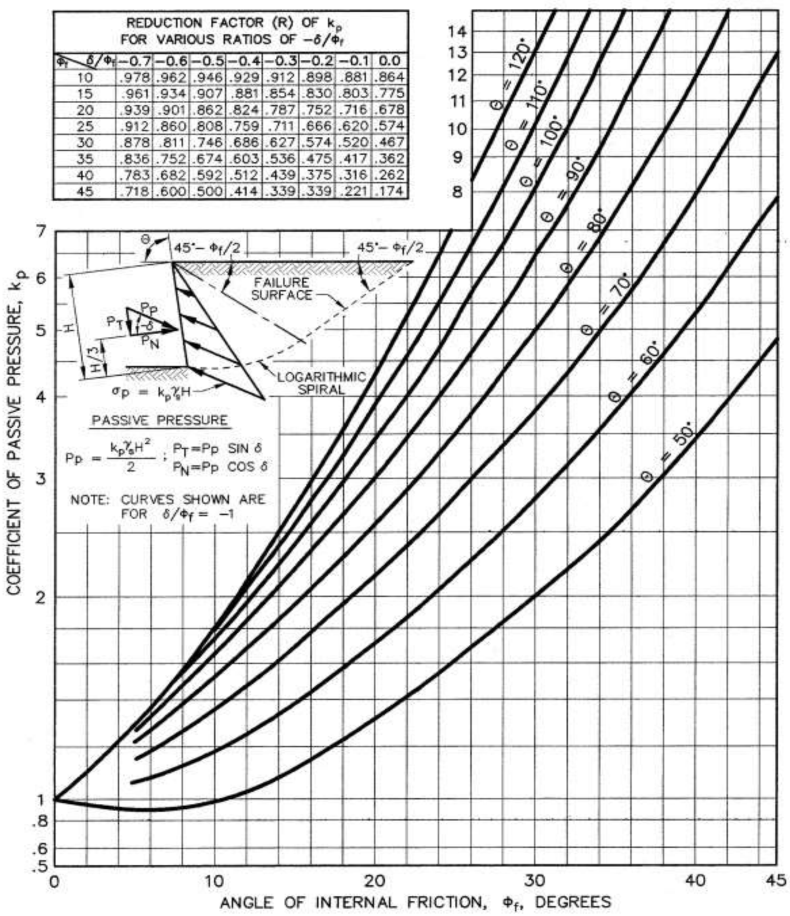
$$K_a = \tan^2\left(45° - \frac{\phi}{2}\right)$$ (Ref. 3, page 3-7)

for horizontal backfill surface, where:
ϕ = internal friction angle of soil

K_a =	0.26	Existing Fill
	0.29	Presumpscot Silt - In Situ
	0.26	Glacial Till - In Situ
	0.31	Granular Borrow - Fill
	0.26	Gravel Borrow - Fill

3. Calculate the full passive earth pressure coefficients.

Per the MaineDOT Bridge Design Guide Section Chapter 3, section 3.6.6 (Ref. 3), Values of the coefficient of passive lateral earth pressure, K_p, may be taken from Figures 3.11.5.4-1 and 2 in AASHTO LRFD (Ref. 6).



ϕ_f \ δ/ϕ_f	−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	.339	.221	.174

Figure 3.11.5.4-1—Computational Procedures for Passive Earth Pressures for Vertical and Sloping Walls with Horizontal Backfill (U.S. Department of the Navy, 1982a)

for horizontal backfill surface, where:

θ = angle of wall from horizontal = 90 degrees

δ = Friction angle between fill and culvert (Ref. 3, Table 3-3)

R = Reduction Factor of K_p (Ref. 6 Figure 3.11.5.4-1)

Material	φ (degrees)	δ (degrees)	$\frac{-\delta}{\phi}$	Uncorrected K_p	R	K_p
Exisitng Fill	36	24	-0.67	11.6	0.74	8.6
Presumpscot Silt - In Situ	33	19	-0.58	8.5	0.70	6.0
Glacial Till -In Situ	36	24	-0.67	11.6	0.74	8.6
Granular Borrow	32	24	-0.75	7.7	0.86	6.6
Gravel Borrow	36	27	-0.75	11.6	0.83	9.6

CONCLUSIONS

For a non-yielding, stiff structure like the box culvert and wingwall system proposed for this project, an at-rest lateral earth pressure coefficient of 0.47 is recommended for design.

CALCULATIONS

Date:	9/9/2024	**Created:**	TJ/RJN
Project No.:	30900914.003	**Checked:**	DEB/KAR
Subject:	Bearing Resistance at Proposed Culvert	**Reviewed:**	CCB/MEL
Project Short Title:	MaineDOT Spaulding Brook Culvert, Augusta, ME		

OBJECTIVE

Calculate the bearing resistance of the proposed culvert for the strength limit state and the service limit state at a location where the culvert invert is within a 20-feet deep Presumpscot Clay layer at the roadway centerline at Station 109+58.

REFERENCES

1. WSP interpreted subsurface cross-section at Sta. 108+58.97. (State of Maine Department of Transportation, Spaulding Brook Bridge, Augusta, Kennebec County, Route 17, Sheet 3)
2. WSP Boring Logs (Appendix A, Preliminary Geotechnical Design Report, dated November 2023).
3. Typical Box Details and Cross Sections (State of Maine Department of Transportation, Spaulding Brook Bridge, Augusta, Kennebec County, Route 17 as shown on the Interpretive Subsurface Profile in the PGDR.
4. AASHTO LRFD Bridge Design Specifications, 9th Edition, 2020.
5. FHWA. 2002. Geotechnical Engineering Circular No. 6: Shallow Foundations. Report No. FHWA-SA-02-054.
6. WSP settlement analysis (Appendix D, Preliminary Geotechnical Design Report, dated December 2023).
7. NAVFAC Design Manual 7.2 Foundations and Earth Structures, dated May 1982.
8. MaineDOT Geotechnical Section, Key to Soil and Rock Descriptions and Terms, dated May 2024.

ASSUMPTIONS

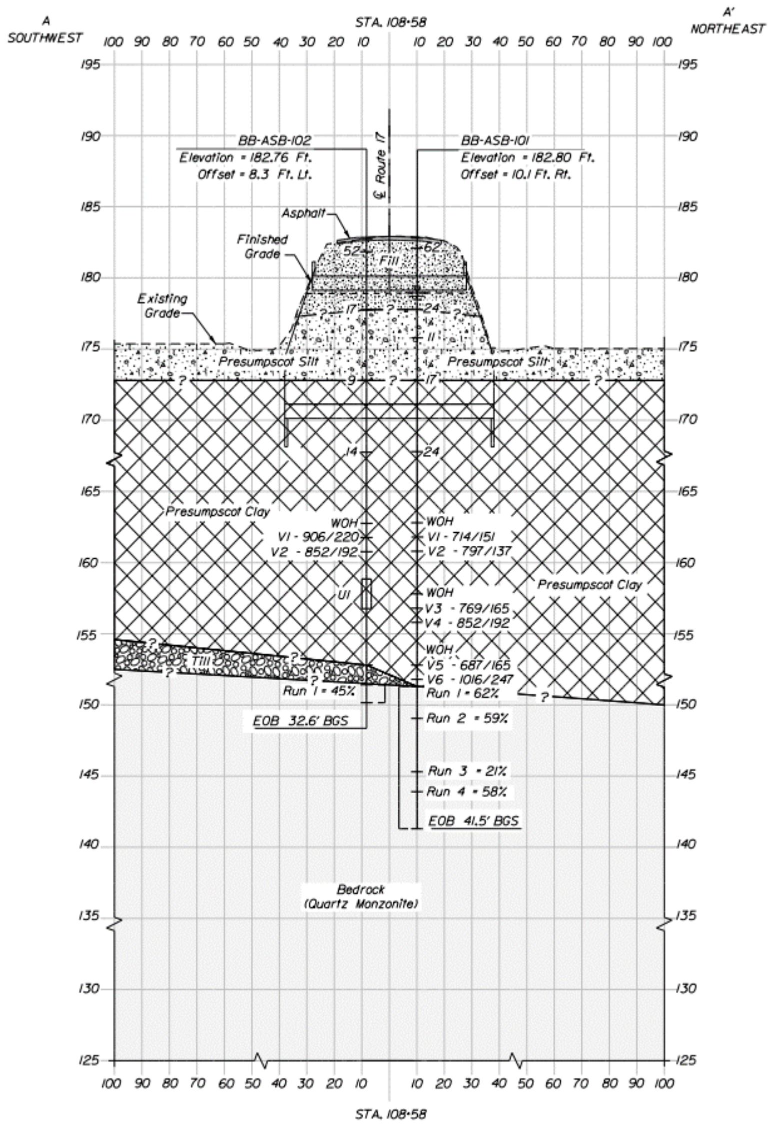
1. The undrained shear strength for the Presumpscot Clay was calculated as the 33 percentile of the corrected undrained strength measured with the field vane shear tests (Reference 2):	$s_{u,33\%}$	0.793	ksf
2. The proposed finish grade elevation and proposed culvert invert elevation at the location of analysis are (Reference 3):	El. finish grade =	182.9	ft
	El. proposed invert =	171.1	ft
3. Based on Reference 3 and information provided by the WSP structures team, the proposed culvert wall thickness and the proposed thickness of excavation/fill beneath the culvert are estimated to be:	Proposed culvert wall thickness =	1.2	ft
	Excavation/fill thickness beneath culvert =	1.0	ft
4. The interpreted water table elevation, based on measurements taken during the subsurface exploration program in boring BB-ASB-101 (Reference 2):	WL elev. =	178.8	ft

5. Bearing resistance is based on the Presumpscot Clay below the fill and Presumpscot Silt layer.

CALCULATIONS

Date:	9/9/2024	**Created:**	TJ/RJN
Project No.:	30900914.003	**Checked:**	DEB/KAR
Subject:	Bearing Resistance at Proposed Culvert	**Reviewed:**	CCB/MEL
Project Short Title:	MaineDOT Spaulding Brook Culvert, Augusta, ME		

Location of Analysis:



(Reference 1)

CALCULATIONS

Date:	9/9/2024	**Created:**	TJ/RJN
Project No.:	30900914.003	**Checked:**	DEB/KAR
Subject:	Bearing Resistance at Proposed Culvert	**Reviewed:**	CCB/MEL
Project Short Title:	MaineDOT Spaulding Brook Culvert, Augusta, ME		

CALCULATION

A. Determine the bearing resistance at the strength limit state. Use Article 10.6.3, Strength Limit Design, from the AASHTO LRFD Bridge Design Specifications.

Based on Reference 1, the proposed culvert invert will be founded within the Presumpscot Clay layer.

1. Calculate the nominal bearing resistance.

$$q_n = cN_{cm} + \gamma_q D_f N_{qm} C_{wq} + 0.5\gamma_f B N_{\gamma m} C_{w\gamma}$$ (Ref. 4, Eqn. 10.6.3.1.2a-1)

where:

c = cohesion, ksf — c = 0.793 ksf

γ = total unit weight of soil, kcf — γ = 0.118 kcf

Since the same design unit weight is used for the soil above and below the bearing depth of the footing, $\gamma_q = \gamma_f$.

D_f = footing embedment depth, ft — D_f = 13.0 ft

$N_{cm} = N_c s_c i_c$ (Ref. 4, Eqn. 10.6.3.1.2a-2) — N_{cm} = 5.4

N_c = Cohesion term — N_c = 5.14 (Table 10.6.3.1.2a-1)

S_c = footing shape correct factor (cohesion) — S_c = 1.04 Ref. 4, Table 10.6.3.1.2a-3

B = footing width, ft — B = 16 ft (Ref. 3, Sheet 5)

L = footing length, ft — L = 78 ft (Ref. 3, Sheet 17)

$$i_c = 1 - \left(\frac{nH}{cBLN_c}\right)$$ i_c = 1.0 (Eqn. 10.6.3.1.2a-5)

i_c = load inclination factor (neglected as per Ref. 4, Article C10.6.3.1.2a)

$N_{qm} = N_q s_q d_q i_q$ (Ref. 4, Eqn. 10.6.3.1.2a-3) — N_{qm} = 1.0

N_q = surcharge term (undrained) — N_q = 1.0

S_q = footing shape correction factor (cohesion) — S_q = 1.0 Ref. 4, Table 10.6.3.1.2a-3

d_q = depth correction factor — d_q = 1.0 Neglected as per Ref. 4,

i_q = load inclination factor — i_q = 1.0 Article C10.6.3.1.2a

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ (Ref. 5, Eqn. 10.6.3.1.2a-4) — $N_{\gamma m}$ = 0.0

N_γ = unit weight factor — N_γ = 0.0 (Table 10.6.3.1.2a-1)

(Ref. 5, Table 10.6.3.1.2a-3) — s_γ = 1.00

i_γ = load inclination factor (neglected as per Ref. 5, Article C10.6.3.1.2a)

Since in Reference 4 C_{wq} and $C_{w\gamma}$ are determined based on D_w using Table 10.6.3.1.2a-2, which does not contain the value of D_w determined in this analysis, the equations in Reference 5 will be used instead.

$$C_{wq} = 0.5 + 0.5\left(\frac{D_w}{D_f}\right) \le 1.0$$ C_{wq} = 0.66

D_w = groundwater depth, ft — D_w = 4.1 ft

q_n = 5.2 ksf

Date:	9/9/2024	**Created:**	TJ/RJN
Project No.:	30900914.003	**Checked:**	DEB/KAR
Subject:	Bearing Resistance at Proposed Culvert	**Reviewed:**	CCB/MEL
Project Short Title:	MaineDOT Spaulding Brook Culvert, Augusta, ME		

2. Apply resistance factor.

$q_R = \varphi_b q_n$ (Ref. 4, Eqn. 10.6.3.1.1-1)

φ_b = resistance factor specified in LRFD 10.5.5.2.2 φ_b = 0.45 (Table 10.5.5.2.2-1)

Semi-empirical methods, all soils

q_R = 2.4 ksf

B. Determine the bearing resistance at the service limit state.

Use AASHTO LRFD Table C10.6.2.5.1-1 (Ref. 4) and NAVFAC 7.2 Table 1 (Ref. 7) to determine the presumptive bearing resistance at the service limit state.

Undrained shear strength for the Presumpcot Clay = 793 psf (Assumption 1)

Calculated as the 33 percentile of the corrected undrained strength measured with the field vane shear tests (Ref. 2).

Based on the MaineDOT Geotechnical Section soil key (Ref. 8), this undrained shear strength corresponds to a soil consistency of "medium stiff".

From AASHTO LRFD Table C10.6.2.5.1-1 (Ref. 4) and NAVFAC 7.2 Table 1 (Ref. 7):

Type of Bearing Material:	Homogeneous inorganic clay, sandy or silty clay (CL, CH)	
Consistency in Place:	medium stiff	
Bearing Resistance Ordinary Range:	2 to 6 ksf	(for medium stiff to stiff soils)
Bearing Resistance Selected Value:	2 ksf	(lower end of range, for medium stiff soils)

Note: This bearing resistance is settlement limited (1 inch) and applies only at the service limit state.

Resistance factor for the service limit state = 1.0 (Ref. 4, Article 10.5.5.1)

Factored bearing resistance = 2.0 ksf

C. Confirm that the calculated bearing resistance satisfies the estimated bearing pressure.

Note: the bearing pressure was estimated in the settlement calculations (Ref. 6).

Bearing pressure = 1.6 ksf

Bearing Pressure			Factored Bearing Resistance			
1.6	ksf	<	2.4	ksf	(STR)	OK
1.6	ksf	<	2.0	ksf	(SRV)	OK

CONCLUSIONS

For the proposed culvert, the recommended nominal bearing resistance is 5.2 ksf. A resistance factor of 0.45 is recommended for use at the strength limit state and a resistance factor of 1.0 is recommended for use at the service limit state. The factored bearing resistance for the strength limit state is estimated to be 2.4 ksf and the factored presumptive bearing resistance for the service limit state is estimated to be 2.0 ksf. The factored bearing resistance at both the strength limit state and the service limit state was determined to be higher than the estimated bearing pressure.

Date:	11/20/2023	**Made by:**	DEB
Project No.:	30900914.003	**Checked by:**	TJ
Subject:	Modulus of Subgrade Reaction	**Reviewed by:**	CCB
Project Short Title:	Spaulding Brook Bridge No. 2790, Augusta, ME		

OBJECTIVE

Determine the modulus of subgrade reaction in the Presumpscot clay deposit.

REFERENCES

1. Das, Braja M. 2011. Principles of Foundation Engineering, 8th ed. Cengage Learning, Stamford, CT.
2. WSP geotechnical test boring logs (Appendix A, Preliminary Geotechnical Design Report, dated November 2023).
3. Typical Box Details and Cross Sections (State of Maine Department of Transportation, Spaulding Brook Bridge, Augusta, Kennebec County, Route 17 (Sheets 1 - 16), Dated 11/2023 (WSP Draft plans)).

ASSUMPTIONS

1. Proposed box culvert bearing El. (Ref 3.)	Invert El.=	171.1	feet
	Bottom Thickness =	1.2	feet
	Bearing El. =	169.9	feet
4. Average cohesive consistency at bearing elevation (Ref 2.)	Consistency =	Stiff	
5. Proposed box culvert width (Ref. 3).	B =	16	feet

CALCULATION

1. Determine Modulus of Subgrade Reaction.

Determine Modulus of Subgrade Reaction (K) using Eqn. 8.47b (Ref. 1), based on Table 8.2 below. Consistency of stiff cohesive soil based on SPT N-value of 9 to 15 (Ref 2). Based on the average SPT N-value of 9 (Ref. 2) in the Presumpscot clay at the approximate bearing elevation of 169.9 feet, the lower bound of the stiff clay range for k_1 was used in Table 8.2.

Table 8.2 Typical Subgrade Reaction Values, $k_{0.3}(k_1)$

Soil type	$k_{0.3}(k_1)$ MN/m^3	$k_{0.3}(k_1)$ lb/in.^{3}
Dry or moist sand:		
Loose	8–25	30–90
Medium	25–125	90–450
Dense	125–375	450–1350
Saturated sand:		
Loose	10–15	35–55
Medium	35–40	125–145
Dense	130–150	475–550
Clay:		
Stiff	10–25	40–90
Very stiff	25–50	90–185
Hard	>50	>185

Date:	11/20/2023	**Made by:**	DEB
Project No.:	30900914.003	**Checked by:**	TJ
Subject:	Modulus of Subgrade Reaction	**Reviewed by:**	CCB
Project Short Title:	Spaulding Brook Bridge No. 2790, Augusta, ME		

$$k = k_1(\frac{1}{B})$$ (lb/in^3) Eqn. 8.47b (Ref. 1)

k_1 = 40 (lb/in^3) (Table 8.2, Ref. 1)

k = 2.5 (lb/in^3)

CONCLUSIONS

The modulus of subgrade reaction (K) has been determined using the average SPT N-value of the Presumpscot clay at the proposed bearing elevation of the box culvert. The modulus of subgrade reaction value of k = 2.5 lb/in^3 will be recommended in the Preliminary Geotechnical Design Report (PGDR).

CALCULATIONS

Date:	12/27/2023	**Made by:**	LMP
Project No.:	30900914.003	**Checked by:**	DEB
Subject:	Settlement of Proposed Culvert	**Reviewed by:**	CCB
Project:	Spaulding Brook Bridge No. 2790, Augusta, Maine		

OBJECTIVE

Calculate the primary settlement beneath the proposed culvert after construction, at the location where the Presumpscot Clay is thickest (Station 108+83 along the proposed culvert centerline).

REFERENCES

1. Holtz, Robert D. and Kovacs, William D. An Introduction to Geotechnical Engineering, 1st Ed. Prentice-Hall, 1981.
2. GEOTECHNICAL ENGINEERING CIRCULAR NO. 6: Shallow Foundations. FHWA: September 2002. (FHWA)
3. Das, Braja M. 2011. Principles of Foundation Engineering, 7th ed. Cengage Learning, Stamford, CT.
4. FHWA. 2002. Geotechnical Engineering Circular No. 6: Shallow Foundations. Report No. FHWA-SA-02-054.
5. WSP boring logs, included as Appendix A of the Preliminary Geotechnical Design Report.
6. WSP Interpretive Subsurface Profile A-A', included as Sheet 3 Preliminary Geotechnical Design Report.
7. GeoTesting Express laboratory testing results, included as Appendix C and summarized in Table 5 of the Preliminary Geotechnical Design Report.
8. State of Maine Department of Transportation, Spaulding Brook Bridge, Augusta, Kennebec County, Route 17 (Sheets 1 - 16), Dated 11/2023 (WSP Draft plans).
9. Guertin Elkerton & Associates for Maine Department of Transportation. Bridge Design Guide. Dated August 2003 with 2018 updates.
10. State of Maine Department of Transportation, Thorne Bridge and Spaulding Bridge in the city of Augusta, Kennebec County, General Plan (sheets 1 and 2), dated Jan. 1988. Marked as as-built-1989.

ASSUMPTIONS

1. The existing stratigraphy and water table surface are estimated from samples and groundwater measurements encountered during drilling at location (Reference 5 and 6).	GS EL =	182.9	feet
	Water table EL. =	178.8	feet
2. Clay consolidation parameters for the Presumpscot layer are based on laboratory test results for boring BB-ASB-102 reported on Reference 7:	C_c =	0.25	
	C_r =	0.032	
	e_0 =	0.97	
	OCR =	1.4	
3. N60-values for the soil layers, based on correlation (Reference 3, Equation 18.5) to the measured N values are:	$N_{60\ \text{Existing Fill}}$ =	42	
	$N_{60\ \text{Presump. Silt}}$ =	13	
	$N_{60\ \text{Glacial till}}$ =	100	
4. The proposed road grade elevation and proposed culvert invert elevation at the location of analysis are (Reference 8, Sheet 5):	Road EL =	182.9	feet
	Proposed invert EL =	171.1	feet
5. Based on Reference 8, Sheet 5, the proposed culvert wall thickness and the proposed thickness of excavation/fill beneath the culvert are estimated to be:	Proposed culvert wall thickness =	1.2	feet
	Excavation/fill thickn. beneath culvert =	1	feet
6. Based on Reference 8, Sheet 5, the culvert interior will be filled with Stream Channel Rock and Special Fill with a thickness of:	Stone fill thickness =	2.4	feet
7. The unit weight for the proposed fill construction material (Reference 9), based on MaineDOT standard practice, are:	Unit weight - Granular Borrow =	125	pcf
	Unit weight - Gravel Borrow =	136	pcf
	Unit weight - Agg. Subbase =	136	pcf
8. Unit weights for concrete and steel are assumed based on local engineering experience:	Unit weight - Concrete =	150	pcf
	Unit weight - Steel =	490	pcf

CALCULATIONS

Date:	12/27/2023	**Made by:**	LMP
Project No.:	30900914.003	**Checked by:**	DEB
Subject:	Settlement of Proposed Culvert	**Reviewed by:**	CCB
Project:	Spaulding Brook Bridge No. 2790, Augusta, Maine		

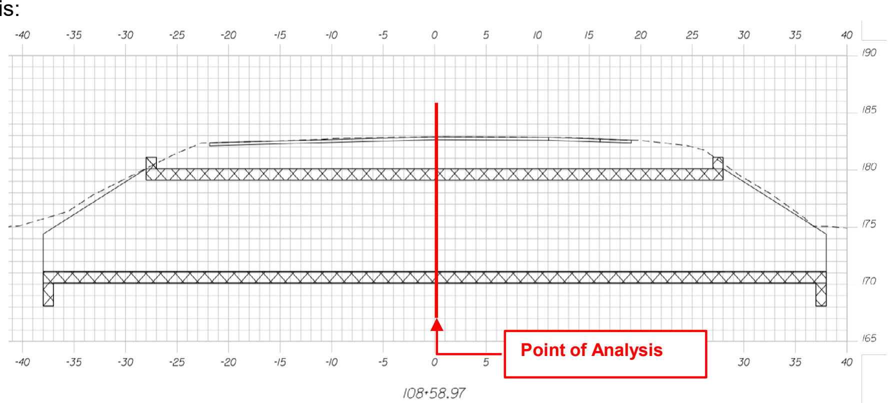
9. The stream elevation within the culvert is assumed to be the groundwater elevation measured at Boring BB-ASB-101. The loading from this groundwater elevation includes anticipated increased flow from spring thaw.

Stream EL above Stream Channel Fill =	178.8	feet

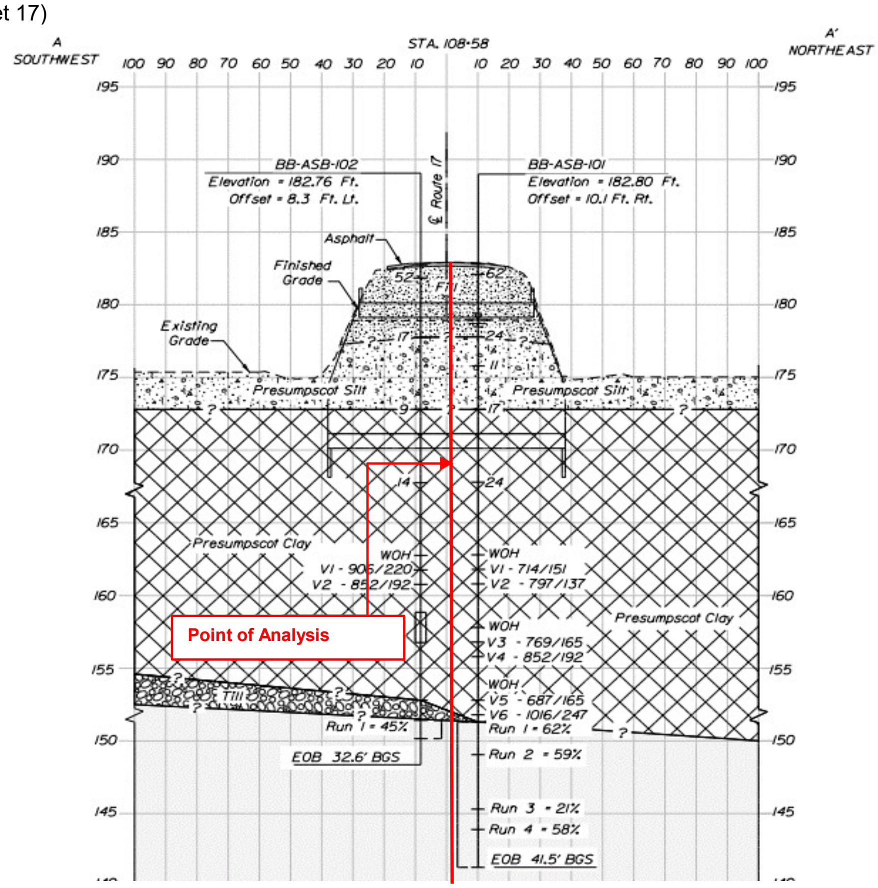
10.The stress will be uniformly distributed over the culvert box length. Localized stress concentration is not considered for the analysis.

11. Primary consolidation settlement is assumed to be based on a preconsolidation stress calculated using the existing effective stress outside of the existing culvert area, to reflect the pre-construction maximum past pressure in the Presumpscot clay.

Location of the Analysis:



(Reference 8, Sheet 17)



(Reference 6)

CALCULATIONS

Date:	12/27/2023	**Made by:**	LMP
Project No.:	30900914.003	**Checked by:**	DEB
Subject:	Settlement of Proposed Culvert	**Reviewed by:**	CCB
Project:	Spaulding Brook Bridge No. 2790, Augusta, Maine		

CALCULATION `

A. Determine the change in effective stress state within the soil beneath the proposed culvert to identify if settlement or heave will occur. Calculate the vertical stress change beneath the proposed culvert due to culvert construction.

The change in effective stress state due to the excavation of the existing steel culvert and the construction of the proposed concrete box culvert is determined at the lower limit of the proposed excavation for the concrete box culvert along the culvert centerline: elevation 168.9 ft (culvert invert elevation 171.1 ft minus culvert base thickness 1.2 ft and excavation/fill thickness 1.0 ft). Based on Reference 6, the excavation limit will be founded within the Presumpscot Clay layer.

1. Load from existing steel culvert, per linear foot (Ref. 10):

	Width (ft)	Height (ft)	Area (ft^2)	Unit weight of steel (pcf)	Weight per linear foot of culvert (lb/ft)	Distributed weight per linear foot (psf)
External dimensions	11.6	7.4	85.9			
Internal dimensions	11.6	7.4	85.5			
		Culvert steel:	0.436	490	213.9	18.5

2. Load from proposed culvert concrete, per linear foot (Ref. 8):

	Width (ft)	Height (ft)	Area (ft^2)	Unit weight of concrete (pcf)	Weight per linear foot of culvert (lb/ft)	Distributed weight per linear foot (psf)
External dimensions	16.0	10.4	166.4			
Internal dimensions (Ref. 8, Sheet 5)	14.0	8.0	112.0			
		Culvert concrete:	54.4	150	8160.0	510.0

3. Existing conditions outside of the existing culvert (Ref. 5 & 6) for preconsolidation stress calculation:

Layer	Unit weight (pcf)	Elevation (ft)		Thickness (ft)	Vertical Stress Contribution of Layer (psf)	Vertical Effective Stress Contribution of Layer (psf)
		Top	Bottom			
Pavement	140	182.9	182.1	0.8	112	112
Fill	125	182.1	177.8	4.3	537	475
Presumpscot Silt	120	177.8	172.8	5.0	600	288
Presumpscot Clay	118	172.8	168.9	3.9	460	217
				Total =	1710	1092

CALCULATIONS

Date:	12/27/2023	**Made by:**	LMP
Project No.:	30900914.003	**Checked by:**	DEB
Subject:	Settlement of Proposed Culvert	**Reviewed by:**	CCB
Project:	Spaulding Brook Bridge No. 2790, Augusta, Maine		

4. Current conditions at the center of the existing steel arch culvert (Ref. 6 & 10):

Layer	Unit weight (pcf)	Elevation (ft)		Thickness (ft)	Vertical Stress Contribution of Layer (psf)	Vertical Effective Stress Contribution of Layer (psf)
		Top	Bottom			
Pavement	140	182.9	182.1	0.8	112	N/A
Fill	125	182.1	181.2	0.9	113	N/A
Existing Culvert	N/A	181.2	173.8	7.4	18	N/A
Granular Borrow Fill	125	173.8	168.9	4.9	613	307
				Total =	855	

5. Proposed conditions at the center of the proposed concrete box culvert after construction (Ref. 8):

Layer	Unit weight (pcf)	Elevation (ft)		Thickness (ft)	Vertical Stress Contribution of Layer (psf)	Vertical Effective Stress Contribution of Layer (psf)
		Top	Bottom			
Pavement	140	182.9	182.4	0.5	70	N/A
Aggregate Subbase	135	182.4	180.3	2.1	284	N/A
Culvert	N/A	180.3	169.9	10.4	510	N/A
Stream Above Fill (inside)	62.4	178.8	173.5	5.3	331	N/A
Stream Channel Rock and Special Fill (inside)	140	173.5	171.1	2.4	336	N/A
Granular Borrow Backfill	125	169.9	168.9	1.0	125	63
				Total =	1655	

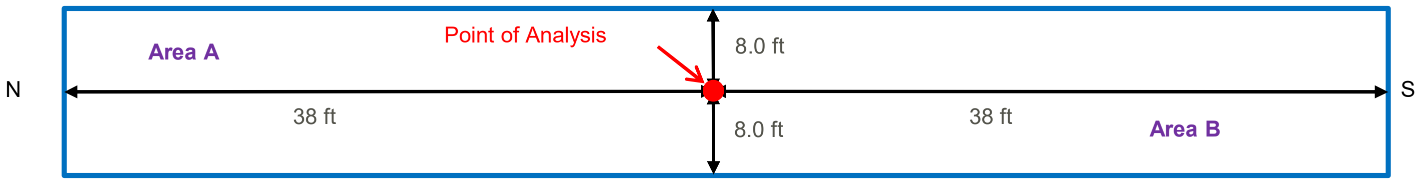
6. Calculate the increase or decrease in effective stress as a result of construction.

	σv at Elev. 168.9 ft (psf)	σ'v at Elev. 168.9 ft (psf)	Δσ'v at Elev. 168.9ft (psf)	Result
Current site conditions at existing steel culvert	855	550	1043	Settlement
After proposed construction	1655	1593		

Date:	12/27/2023	**Made by:**	LMP
Project No.:	30900914.003	**Checked by:**	DEB
Subject:	Settlement of Proposed Culvert	**Reviewed by:**	CCB
Project:	Spaulding Brook Bridge No. 2790, Augusta, Maine		

B. Subdivide the subsurface soils into layers no larger than 10 ft thick and to a depth of either twice the footing width or to bedrock. Calculate the vertical stress increase at each layer, assuming the Boussinesq stress distribution method for stress under the corner of a rectangular load.

Assumed Loading (plan view):



$$\sigma_z = q_0 \times I$$ Reference 1, Eqn. 8-30

$$m = x/z$$ Reference 1, Figure 8.21

$$n = y/z$$ Reference 1, Figure 8.21

where:	Area A	Area B		
σ_z = half of the vertical stress increase, psf	(each half of the culvert width is calculated separately for each area)			
q_0 = net stress applied by culvert	1043		psf	(Part A)
x = half of the width of the loading area, ft	8.0	8.0	ft	(Ref. 8, Sheet 5)
y = length of the loading area, ft	38	38	ft	(Ref. 8, Sheet 17)
z = depth to midpoint of layer, ft	(z_{max} = twice the footing width = 32 ft)			

Area A:

Layer		Depth below lower limit of excavation (ft)	Layer Thickness (ft)	z (ft)	m	n	I	Stress Increase $\sigma_z \times 2$ (psf)
Presumpscot Clay	1	0-10	10.0	5.0	1.6	7.6	0.233	486.0
Presumpscot Clay	2	10-17.6	7.6	13.8	0.6	2.8	0.156	325.4
Glacial Till	3	17.6-18.7	1.1	18.1	0.4	2.1	0.113	235.7

Note: The stratigraphy for the analysis considers the thickest section of the Presumpscot Clay encountered in BB-ASB-101 and the thickness of the Glacial till encountered in BB-ASB-102.

Area B:

Layer		Depth below lower limit of excavation (ft)	Layer Thickness (ft)	z (ft)	m	n	I	Stress Increase $\sigma_z \times 2$ (psf)
Presumpscot Clay	1	0-10	10.0	5.0	1.6	7.6	0.233	486.0
Presumpscot Clay	2	10-17.6	7.6	13.8	0.6	2.8	0.156	325.4
Glacial Till	3	17.6-18.7	1.1	18.1	0.4	2.1	0.113	235.7

Note: The stratigraphy for the analysis considers the thickest section of the Presumpscot Clay encountered in BB-ASB-101 and the thickness of the Glacial till encountered in BB-ASB-102.

Area A + Area B:

Layer		Depth below lower limit of excavation (ft)	Increase σ_z (psf)
Presumpscot Clay	1	0-10	972
Presumpscot Clay	2	10-17.6	651
Glacial Till	3	17.6-18.7	471

C. Use consolidation theory to estimate settlement of the Presumpscot Clay layer beneath the proposed culvert (Layers 1 and 2); use the Hough method to estimate settlement of the Glacial Till beneath the proposed culvert (Layer 3).

1 Calculate $\sigma'_{v0\text{-}E}$ based on pre-construction stratigraphy outside of the existing steel culvert area for use in determining the preconsolidated stress in the clay layers, based on the initial pre-construction effective stress state.

σ'v at Elev. 168.9 ft (psf)	1092	(Part A)

Layer		(pcf)	Depth below lower limit of	Thickness (ft)	z (ft)	σ'_{v0}	σ'_{v0}
Presumpscot Clay	1	118	0-10	10.0	5.0	1370	65.6
Presumpscot Clay	2	118	10-17.6	7.6	13.8	1859	89.0
Glacial Till	3	135	17.6-18.7	1.1	18.1	2110	101.0

2 Calculate $\sigma'_{v0\text{-}Prop}$ based on proposed new culvert construction stratigraphy at the center of the proposed culvert for use in determining the proposed construction final stress state.

σ'v at Elev. 168.9 ft (psf)	550	(Part A)

Layer		Unit weight (pcf)	Depth below lower limit of excavation (ft)	Layer Thickness (ft)	z (ft)	σ'_{v0} (psf)	σ'_{v0} (kPa)
Presumpscot Clay	1	118	0-10	10.0	5.0	828	39.6
Presumpscot Clay	2	118	10-17.6	7.6	13.8	1317	63.0
Glacial Till	3	135	17.6-18.7	1.1	18.1	1568	75.1

3 Calculate the total settlement of the Presumpscot Clay layer (Layers 1 and 2) using the consolidation theory:

CALCULATIONS

Date:	12/27/2023	**Made by:**	LMP
Project No.:	30900914.003	**Checked by:**	DEB
Subject:	Settlement of Proposed Culvert	**Reviewed by:**	CCB
Project:	Spaulding Brook Bridge No. 2790, Augusta, Maine		

General Equation (Das, Eqn 1.61, 1.63, 1.65)

$$\Delta H_i = C_{r\varepsilon} H_c \log \frac{\sigma'_p}{\sigma'_{v0}} + C_{c\varepsilon} H_c \log \frac{\sigma'_{v0} + \Delta\sigma_v}{\sigma'_p}$$

for underconsolidated clay, $\sigma'_{v0} + \Delta\sigma_v > \sigma'_p$

$$\Delta H_i = C_{r\varepsilon} H_c \log \frac{\sigma'_{v0} + \Delta\sigma_v}{\sigma'_{v0}}$$

for overconsolidated clay, $\sigma'_{v0} + \Delta\sigma_v \le \sigma'_p$

$$\Delta H_i = C_{c\varepsilon} H_c \log \frac{\sigma'_{v0} + \Delta\sigma_v}{\sigma'_{v0}}$$

for normally consolidated clay

where:			Layer 1 - Presump. Clay	Layer 2 - Presump. Clay		
H_c	initial height of layer i, ft		10.0	7.60		
$\Delta\sigma_v$	surcharge load, psf		972	651		
$\sigma'_{v0\text{-Prop}}$	Proposed in situ vertical effective stress, psf		828	1317		
$\sigma'_{v0\text{-P}} + \Delta\sigma_v = \sigma'_f$	check against σ'_p to select eqn.		1800	1968		
$\sigma'_{v0\text{-E}}$	Existing in situ vertical effective stress, psf		1370	1859		
OCR	Overconsolidation Ratio (laboratory test data)		1.4	1.4		
σ'_p	Preconsolidated stress, psf calculated using existing vertical effective stress		1918	2603		
$C_{r\varepsilon}$	modified recompression index		0.02	0.02		
$C_{c\varepsilon}$	modified compression index		0.13	0.13		
ΔH_i		ft	0.055	0.022	0.02	0.003
		in	0.658	0.258	0.231	0.037

Note: Settlement determined for the stress increase between $\sigma'_{v0\text{-E}}$ and σ'_p

4 Determine C' and σ'_{v0} for in situ existing soil. Use FHWA Figures 5-18 and 5-19 to obtain N' and C' for Layer 3,

Layer		Layer Thickness (ft)	Unit Weight of Layer (pcf)	σ'_{v0} at layer midpoint (psf)	σ'_{v0} at layer midpoint (kPa)	N_{60}	N'	C'
Presumpscot Clay	1	10.0	118	828	40	Not required, for clay consolidation analysis		
Presumpscot Clay	2	7.6	118	1317	63			
Glacial Till	3	1.1	135	1568	75	100.0	113	300

CALCULATIONS

Date:	12/27/2023	**Made by:**	LMP
Project No.:	30900914.003	**Checked by:**	DEB
Subject:	Settlement of Proposed Culvert	**Reviewed by:**	CCB
Project:	Spaulding Brook Bridge No. 2790, Augusta, Maine		

5 Calculate the total settlement of the Glacial Till (Layer 3) using the Hough method:

General Equation (Ref. 2, Eqn 5-24)

$$\Delta H_i = H_c \frac{1}{C'} \log\left(\frac{\sigma'_{v0} + \Delta\sigma_v}{\sigma'_{v0}}\right)$$

where:

ΔH_i	settlement in each layer, ft
H_c	initial height of layer i, ft
C'	bearing capacity index from Ref. 5, Figure 5-19
$\Delta\sigma_v$	vertical stress increase, ksf

ΔH_i (Layer 1)	ft	0.000
	in	0.005

	Settlement Based on Calculated Loading Stress
Layer	ΔH_i (in)
PRESUMP. CLAY, 1	0.658
PRESUMP. CLAY, 2	0.258
GLACIAL TILL, 3	0.005
Total Settlement (in)	0.92

CONCLUSIONS

The primary consolidation settlement under the center of the proposed culvert is estimated to be 1 inch.

CALCULATIONS

Date:	12/18/2023	**Made by:**	LMP
Project No.:	30900914.003	**Checked by:**	TJ
Subject:	Global Stability Analysis	**Reviewed by:**	CCB
Project Short	Spaulding Brook Bridge No. 2790, Augusta, Maine		

OBJECTIVE

Determine the factor of safety for existing and proposed conditions for Sta. 109+50 at Spaulding, Augusta, Maine.

REFERENCES

1. WSP geotechnical test boring logs (Appendix A, Preliminary Geotechnical Design Report, dated November 2023).

2. WSP Corrected N_{60}-value to friction angle correlation titled "MaineDOT Spaulding Brook Material Properties.xlsx"

3. State of Maine Department of Transportation, Spaulding Brook Bridge, Spualding Brook, Augusta, Kennebec County (Sheets 1 - 16), Dated 11/2023 (WSP Draft plans).

4. Maine Department of Transportation. Bridge Design Guide. August 2003.

5. Rocscience Slide2 Software Package Version 9.027 64-bit, build date 02/13/2023.

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

ATTACHMENTS

1. Slide2 material properties.
2. Slide2 output figures for model with current conditions.
3. Slide2 output figures for model with proposed final loading.

ASSUMPTIONS

1. Circular surface searches were analyzed using the Spencer method. Non-circular surfaces searches were analyzed using the Spencer method and cuckoo search with surface altering optimization.

2. As per AASHTO LRFD Article 11.6.3.7 and Article C11.6.3.7 (Ref. 6) a minimum allowable factor of safety (FS) of 1.3 for overall stability of earth slopes with and without foundations.

3. As per Maine Department of Transportation, the load applied by the road and traffic for final design conditions is modeled as a 2-foot equivalent load of soil (Ref. 4, Table 3-4): 2 x 125 pcf (granular borrow) = 250 psf.

4. A FS ≥ 1.3 for static loading is recommended for potential failure surfaces on the embankment slope.

5. The water table elevation below the road was estimated from levels measured during the drilling at location BB-ASB-101 (Ref. 1). At the toe of the slope, the water table was assumed to be 1 foot below the ground surface, as ponded water was not observed during drilling at the toe of the slope. The water table on the embankment slope was based off grading and boundary conditions at the top and toe of the slope.

6. Ground surface elevations for the current and proposed final conditions were taken from the Proposed Plans (Ref. 3).

7. Subsurface profile at Sta. 109+50 was estimated based on the results from the nearest boring location, BB-ASB-101 (Ref. 1).

CALCULATIONS

Date:	12/18/2023	**Made by:**	LMP
Project No.:	30900914.003	**Checked by:**	TJ
Subject:	Global Stability Analysis	**Reviewed by:**	CCB
Project Short	Spaulding Brook Bridge No. 2790, Augusta, Maine		

CALCULATION

1. Global slope stability analysis based on the current site conditions (Ref. 3) at Sta. 109+50.

a. The material properties selected for use in the Slide2 models are shown in the table below and in the Attachment 1 figures.

b. The unit weight properties for most of the in-situ soils, excluding the Presumpscot Clay, were determined using Figure 12.14 in Holtz, Kovacs, and Sheahan (2011), and the final design unit weights were determined using engineering judgement and knowledge gained from previous experience. The unit weight of the Presumpscot Clay layer was determined using consolidation test results.

c. The friction angles for the in-situ soils were correlated to friction angles using Peck, Hanson, & Thornburn (1974), as provided in Das (2011) Friction Angle = $27.1 + 0.3*N_{60} - 0.00054*(N_{60})^2$ (Ref. 2).

d. The undrained strength from the Presumpscot Clay was calculated as the 33 percentile of the corrected undrained strength measured with the field vane shear test from boring locations BB-ASB-101 and BB-ASB-102.

Material Name	Unit Weight (pcf)	Strength Type	Cohesion (psf)	Friction Angle (°)
Pavement	140	Mohr-Coulomb	0	45
Fill (Granular)	125	Mohr-Coulomb	0	32
Fill (Existing)	125	Mohr-Coulomb	0	36
Presumpscot Silt	120	Mohr-Coulomb	0	33
Presumpscot Clay	118	Undrained	793	-
Bedrock (Quartz Monzonite)	170	Infinite Strength	-	-

The soil layer properties shown above were used to analyze circular surfaces using Spencer method and non-circular surfaces using the Spencer method.

The results of the Slide2 stability analyses are summarized in the following table.

Station	Surface Type	Failure Surface Location	Factor of Safety	Figure # (Attach. 1)	Condition
109+50	Circular (Right)	Global	1.65	2A	Existing slope geometry
	Non-Circular (Right)	Global	1.64	2B	

Date:	12/18/2023	**Made by:**	LMP
Project No.:	30900914.003	**Checked by:**	TJ
Subject:	Global Stability Analysis	**Reviewed by:**	CCB
Project Short	Spaulding Brook Bridge No. 2790, Augusta, Maine		

The soil layer properties shown above were used to analyze circular surfaces using Spencer method and non-circular surfaces using the Spencer method.

The results of the Slide2 stability analyses are summarized in the following table.

Station	Surface Type	Failure Surface Location	Factor of Safety	Figure # (Attach. 2)	Condition
109+50	Circular (Right)	Global	1.77	3A	Proposed slope geometry
	Non-Circular (Right)	Global	1.64	3B	

Conclusions

1) The analyzed existing conditions at Sta. 109+50 have a computed factor of safety that meet the requirement of FS ≥ 1.3 for circular and non-circular potential slope failure surfaces.

2) The analyzed proposed conditions at Sta. 109+50 have a computed factor of safety that meet the requirement of FS ≥ 1.3 for circular and non-circular potential slope failure surfaces.

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type	Allow Sliding	Water Surface	Hu Type	Hu
Pavement		140	Mohr-Coulomb	0	45			Water Surface	Custom	1
Fill (Existing)		125	Mohr-Coulomb	0	36			Water Surface	Custom	1
Fill (Granular)		125	Mohr-Coulomb	0	32			Water Surface	Custom	1
Presump. Silt		120	Mohr-Coulomb	0	33			Water Surface	Custom	1
Presump. Clay		118	Undrained	793		Constant		Water Surface	Custom	0
Bedrock (Quartz Monzonite)		170	Infinite strength				No	Water Surface	Custom	0

280
260
240
220

-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60

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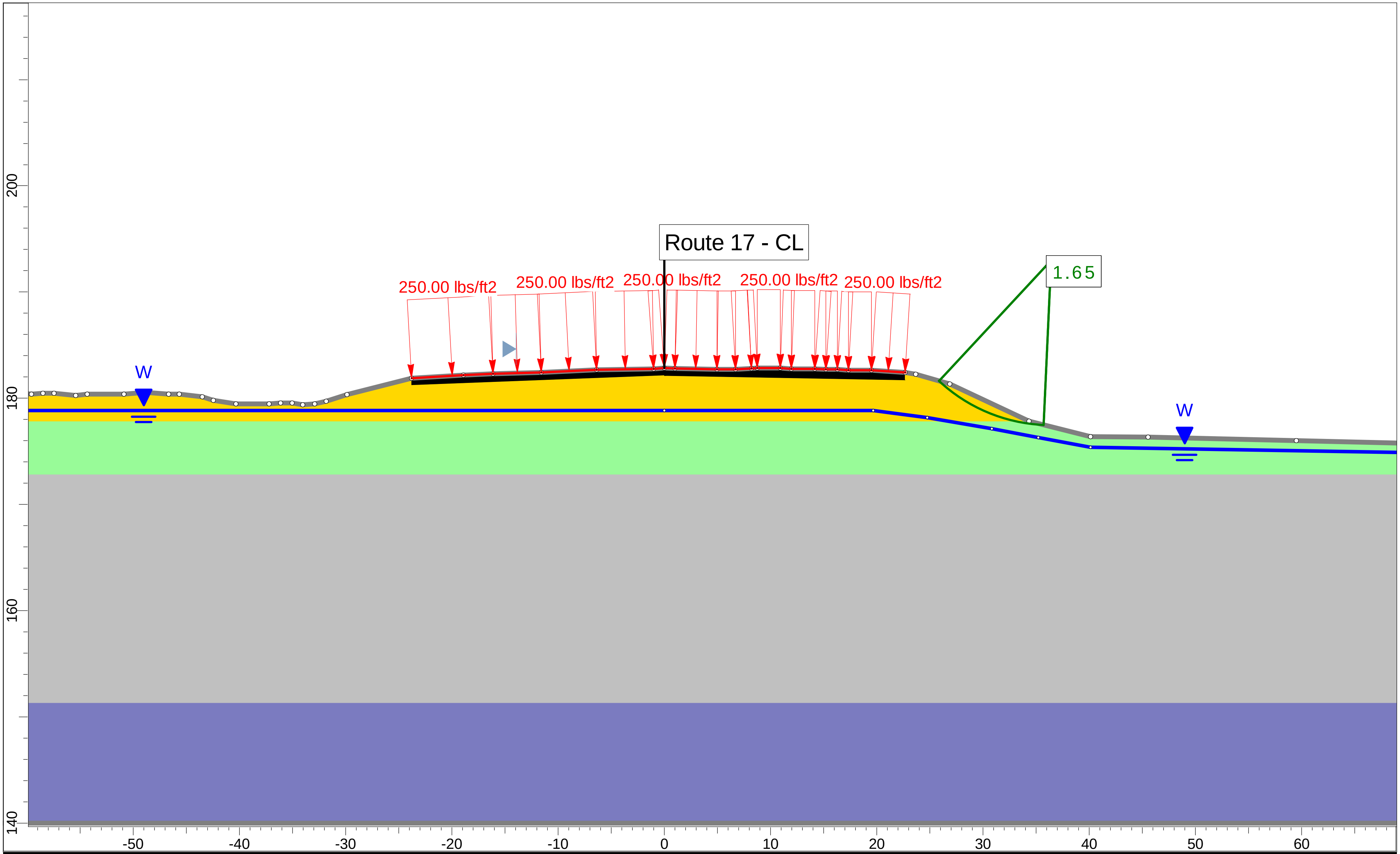
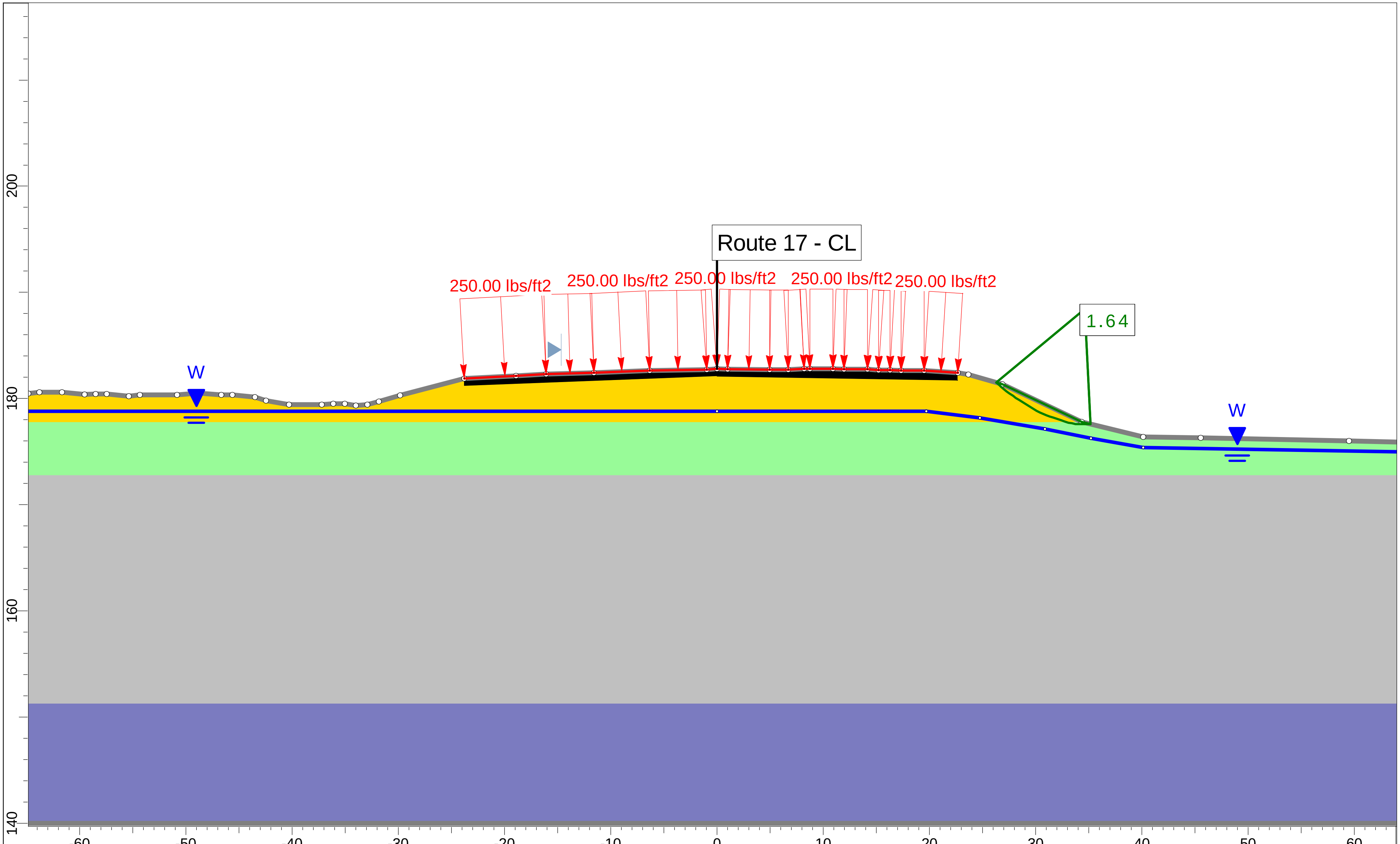
Project	MaineDOT Spaulding Brook Bridge No. 2790
Analysis Description	Material Properties Sta. 109+50
Drawn By	LMP
Checked By	TJ
Reviewed By	CCB
Scale	N/A
Date	12/14/2023
File Name	Sta.109+50Right.slmd

Figure 1



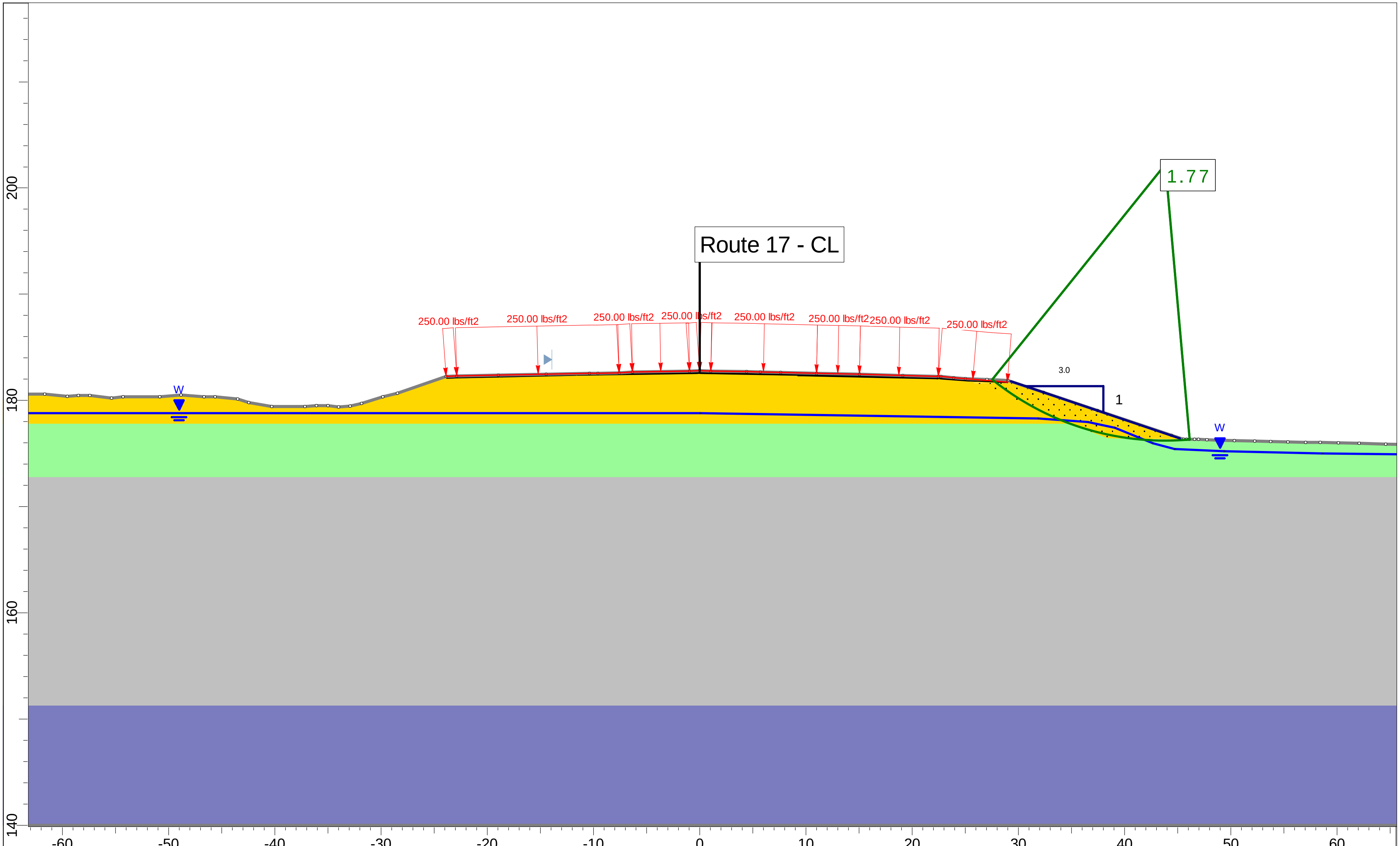
Project	MaineDOT Spaulding Brook Bridge No. 2790			
Analysis Description	Sta. 109+50 Existing Conditions (Right) - Circular			
Drawn By LMP	Checked By TJ	Reviewed By CCB	Scale 1:150	Figure 2A
Date 12/14/2023	File Name Sta.109+50Right.slmd			

SLIDEINTERPRET 9.020

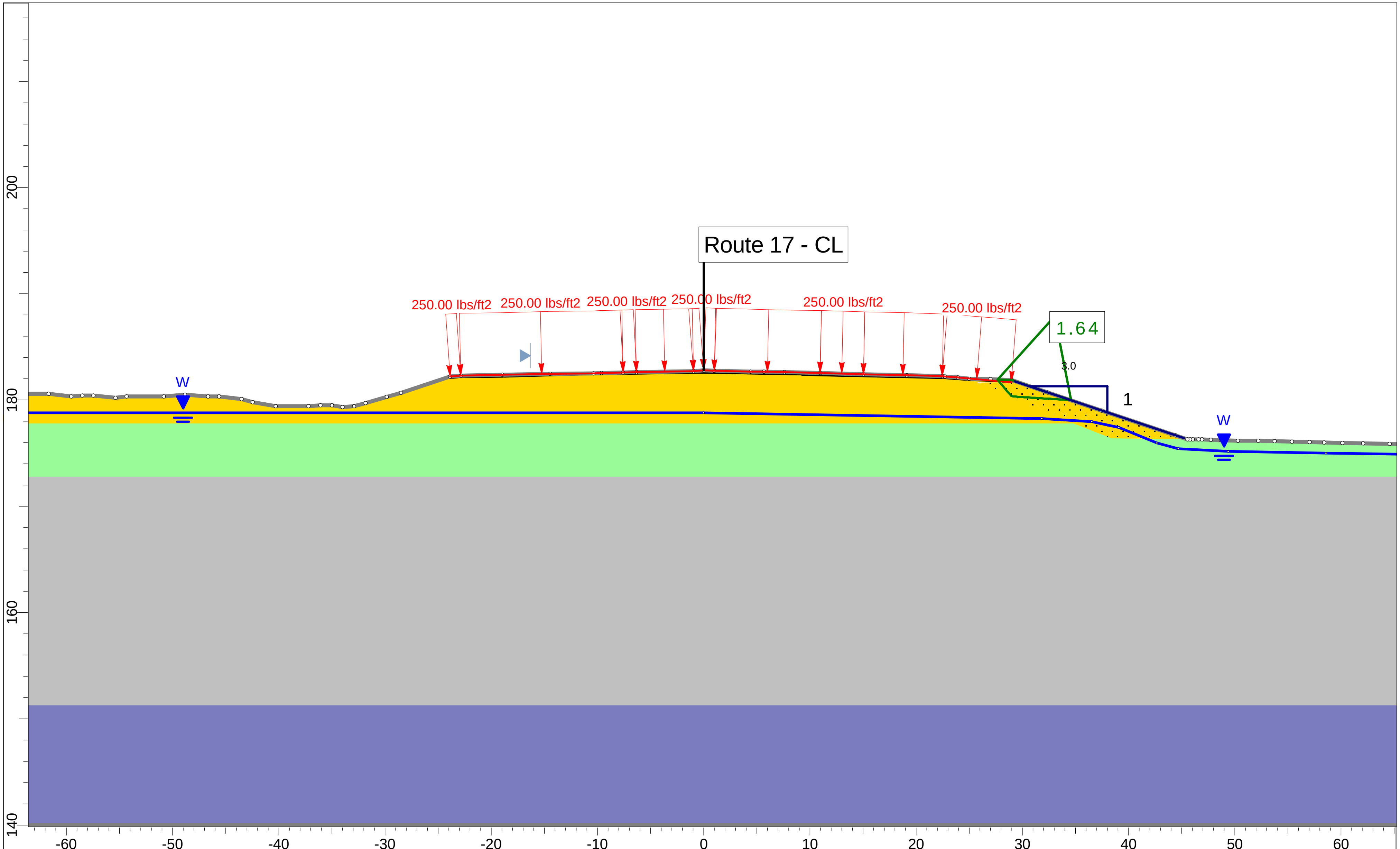


Project	MaineDOT Spaulding Brook Bridge No. 2790			
Analysis Description	Sta. 109+50 Existing Conditions (Right) - Non-Circular			
Drawn By LMP	*Checked By* TJ	*Reviewed By* CCB	*Scale* 1:150	Figure 2B
Date 12/14/2023	*File Name* Sta.109+50Right.slmd			

SLIDEINTERPRET 9.020



	Project	MaineDOT Spaulding Brook Bridge No. 2790					
	Analysis Description	Sta. 109+50 Proposed Conditions (Right) - Circular					
	Drawn By LMP	*Checked By* TJ	*Reviewed By* CCB	*Scale* 1:150		Figure 3A	
SLIDEINTERPRET 9.020	*Date* 12/14/2023	*File Name* Sta.109+50Right.slmd					



Project	MaineDOT Spaulding Brook Bridge No. 2790
Analysis Description	Sta. 109+50 Proposed Conditions (Right) - Non-Circular
Drawn By	LMP
Checked By	TJ
Reviewed By	CCB
Scale	1:150
Date	12/18/2023
File Name	Sta.109+50Right.slmd
	Figure 3B

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