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GEOTECHNICAL DESIGN REPORT

Meadow Brook Bridge Culvert Replacement
BRIDGE NO. 5856
MAINE DOT WIN 026442.00
Vassalboro, MAINE

November 2024
09.0026222.00

Prepared for:
Maine Department of Transportation
Augusta, Maine

Prepared by:
GZA GeoEnvironmental, Inc.
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VIA EMAIL

November 18, 2024
File No. 09.0026222.00

Ms. Laura Krusinski, P.E.
Maine Department of Transportation
16 State House Station
Augusta, Maine 04333-0016

Re: Geotechnical Design Report
Meadow Brook Bridge No. 5856 Culvert Replacement
Bog Road over Meadow Brook
Maine Department of Transportation WIN 026442.00
Vassalboro, Maine

Dear Laura:

We are pleased to provide this Geotechnical Design Report, which includes geotechnical design recommendations for the replacement of Meadow Brook Bridge Culvert, Bog Road over Meadow Brook in Vassalboro, Maine. Our work was completed in accordance with GZA GeoEnvironmental, Inc.'s (GZA's) August 19, 2020, Multi-PIN contract number 20200603000000000709 with the Maine Department of Transportation (MaineDOT) Bridge Program and Assignment Letter No. 15 dated February 5, 2024 for WIN 026442.00, and the attached *Limitations* contained in **Appendix A** of this report.

It has been a pleasure serving MaineDOT on this phase of the project, and we look forward to our continued work with you through project completion. If you have any questions regarding the report, please do not hesitate to contact the undersigned.

Very truly yours,

GZA GEOENVIRONMENTAL, INC.

Blaine M. Cardali, P.E.
Senior Project Manager

STATE OF MAINE
CHRISTOPHER L. SNOW
No. 7275
LICENSED PROFESSIONAL ENGINEER
11/18/2024

Andrew R. Blaisdell, P.E.
Consultant Reviewer

Christopher L. Snow, P.E.
Principal

BMC/ARB/CLS:idim
p:\09 jobs\0026200s\09.0026222.00 - medot - meadow brk bridge, vassalboro\report\26222.00 vassalboro meadow brk bridge culvert gdr 11.18.2024.docx

Attachment: Geotechnical Design Report

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1.0 INTRODUCTION

This report presents the results of the geotechnical evaluation by GZA GeoEnvironmental, Inc. (GZA) for the replacement of Meadow Brook Bridge No. 5856 Culvert in Vassalboro, Maine. Our work was completed in accordance with GZA GeoEnvironmental, Inc.'s (GZA's) August 19, 2020, Multi-PIN contract number 20200603000000000709 with the Maine Department of Transportation (MaineDOT) Bridge Program and Assignment Letter No. 15 dated February 5, 2024 for WIN 026442.00, and the attached *Limitations* contained in **Appendix A** of this report.

1.1 BACKGROUND

The project includes the replacement of Meadow Brook Bridge No. 5856 carrying Bog Road over Meadow Brook in Vassalboro, Maine, the location of which is shown in **Figure 1**. The bridge was originally constructed in 1911 and consists of a 16-foot-long, single span structure consisting of a cast-in-place deck slab bearing on stone masonry abutments capped with concrete. The original plans do not show the bearing elevation but indicate that the foundations were to be carried down to a solid foundation. In 1960, it was widened to its current width and the original railing was replaced with a concrete curb and W-beam guardrails. These were replaced again in 2005, with patching done to the bridge's wearing surface. Recent inspections have shown that the condition of the bridge is structurally deficient. The wearing surface has transverse and longitudinal cracking. The bridge deck portion that consists of the original 1911 slab has numerous areas of deterioration and exposed rebar. The widened portion of the deck from 1960 has areas of exposed rebar and spalling.

We understand plans are to construct a new 64-foot-long box culvert with a span of 17 feet and a rise of 7 feet. The culvert will have a sheet of waterproofing membrane lining the top, separating it from the subbase. The culvert will have 1-foot-tall precast headwalls and 2-foot-deep toe walls at the inlet and outlet. The box culvert invert will have 12 inches of special fill placed above the concrete base to create a natural streambed. The typical prepared subgrade is anticipated to consist of a 1-foot-thick layer of Underdrain backfill material placed on stabilization/reinforcement geotextile overlying the natural subgrade. The project is planned to maintain the current road alignment, as shown on **Figure 2**.

1.2 OBJECTIVES AND SCOPE OF SERVICES

The objectives of our work were to evaluate subsurface conditions and to provide geotechnical engineering recommendations for the proposed bridge replacement. To meet these objectives, GZA completed the following Scope of Services:

- Reviewed the results of two test borings and laboratory testing results completed by MaineDOT;
- Conducted final design phase geotechnical engineering analyses for:
  - soil and bedrock properties;
  - stability and settlement of approach embankments;
  - frost susceptibility and drainage of approach subgrade materials;
  - AASHTO LRFD load and resistance factors associated with geotechnical design elements;

  - spread footing design considerations, including bearing resistance, sliding resistance and settlement;
  - seismic design considerations;
- Developed geotechnical engineering recommendations including bearing resistance of soil, culvert backfill type and properties, earth pressures and seismic design parameters; geotechnical construction considerations; and
- Prepared this report summarizing our findings and design recommendations.

2.0 SUBSURFACE EXPLORATIONS

Two test borings were drilled and logged by MaineDOT between November 14 and 15, 2022 at the locations shown on **Figure 2, Boring Location Plan & Interpretive Subsurface Profile**. Boring BB-VMB-101 was drilled in the southwest portion of the existing bridge, through the bridge deck, in front of the abutment and BB-VMB-102 was drilled on the northeast approach, behind the existing abutment. The test borings were drilled using a CME-45C drill rig to depths ranging from approximately 25 to 32 feet below ground surface (bgs) and were terminated in the bedrock.

The borings were drilled using 3- and 4-inch driven casing and drive-and-wash drilling techniques. Standard penetration testing (SPT) and split-spoon sampling were performed at typical 5-foot intervals. Sampling was completed using a 24-inch-long, 1-3/8-inch inside-diameter sampler. The sampler was driven with a 140-lb calibrated automatic hammer with a 30-inch drop from a truck-mounted drill rig. The boring logs indicate a hammer efficiency factor at the time of drilling of 0.906. In situ field vane shear tests were conducted at typical 5- to 10-foot depth intervals in clay soils. Two vane shear tests were attempted at each test interval. One thin-walled tube sample was collected in BB-VMB-101 to provide a sample for use in laboratory compressibility testing. Approximately 10 feet of bedrock core was obtained in the borings using NQ2 coring equipment. At the completion of drilling, the borings were backfilled with cuttings and sand. The as-drilled locations and elevations were surveyed by MaineDOT.

Drafts of the logs were prepared in Geosystem Logdraft® by MaineDOT. GZA subsequently reviewed the logs and made edits to reflect laboratory soil test results and our interpretation of stratification. The final logs are provided in **Appendix B**.

3.0 LABORATORY TESTING

Soil testing was performed by MaineDOT Testing Laboratories in Bangor, Maine. The testing program included:

- Seven (7) gradation analysis with hydrometer / MaineDOT Frost Classification / Unified Soil Classification System (USCS) assessments;
- Four (4) sets of Atterberg Limits;
- Seven (7) moisture content tests; and
- One (1) 1-dimensional consolidation (compressibility) test.

Results of the testing are included in **Appendix D**.

4.0 SUBSURFACE CONDITIONS

4.1 SURFICIAL AND BEDROCK GEOLOGY

Based on available geologic mapping[1], the surficial unit in the vicinity of the bridge consists of Wetland Deposit, which is described as peat, muck, silt, and clay in poorly drained areas. An Esker deposit is mapped just south of the site and is described as sand and gravel deposited by glacial meltwater streams and Till, which consists of a poorly sorted, stratified mixture of sand, silt, and gravel-sized rock debris. Presumpscot Formation is mapped to the north and east of the bridge and described as glaciomarine silt, clay, and sand deposited on the late-glacial sea floor. The Presumpscot Formation includes an underlying ice-contact sediment, which is describes as areas of sand and gravel deposited as eskers and glaciomarine fans.

Bedrock mapping[2] in the vicinity of the site shows the bridge is mapped as the Mayflower Hill Formation. The Mayflower Hill Formation is described as thickly bedded metasandstone to very fine-grained quartzo-feldspathic schist. Furthermore, the bedrock can be medium dark grey to black fine to very fine-grained quartzo-feldspathic metawacke and very fine-grained quartz-plagioclase-biotite schist.

4.2 SUBSURFACE PROFILE

Four soil units were encountered in the test borings below surficial asphalt and above bedrock: Fill, Alluvium, Marine Clay, and Glacial Outwash. Approximately five inches of asphalt pavement was encountered in the test borings. The thicknesses and generalized descriptions of the soil units are presented in the following table in descending order from the ground surface. Detailed descriptions of the materials encountered at specific locations are provided in the boring logs in **Appendix B**. An interpretive subsurface profile based on the test boring results is presented on **Figure 2**.

---

[1] Syverson, Kent M., and Mans, David P., 2015, Surficial geology of the China Lake quadrangle, Maine: Maine Geological Survey, Open-File Map 15-18, map, scale 1:24,000. Maine Geological Survey Maps. 2033. http://digitalmaine.com/mgs_maps/2033

[2] Pollock, Stephen G., and Bowdoin, Wyeth., 2011, Bedrock geology of the China Lake quadrangle, Maine: Maine Geological Survey, Open-File Map 11-148, color map, scale 1:24,000. Maine Geological Survey Maps. 49. http://digitalmaine.com/mgs_maps/49

GENERALIZED SUBSURFACE CONDITIONS		
Subsurface Unit	**Approximate Encountered Thickness (ft)**	**Generalized Description**
Fill	9	Variable from: brown, gravelly SAND and GRAVEL to: Olive-grey, stiff, Silty Clay, some sand, little gravel, trace wood organics (USCS: SP-SM, SM, CL). MaineDOT Frost Classification = 0-IV *Encountered in BB-VMB-102 only, located on the approach.*
Alluvium	1	Olive-grey, wet, fine to coarse SAND, some gravel, little silt, (USCS: SM, SP-SM) *Encountered in BB-VMB-101 only, located in streambed*
Marine Clay	6 to 8	Light grey to dark grey, wet, very soft to medium stiff, Silty CLAY, trace sand, layer of wood organics noted in upper samples (USCS: CL) MaineDOT Frost Classification = III-IV *Encountered in both borings.*
Glacial Outwash	6 to 7	Variable from: Light grey, medium dense, Silty SAND, trace gravel to: Dark grey, medium dense, GRAVEL, little fine to coarse sand, trace silt, trace clay (USCS: SM, GP-GM) *Encountered in both borings.*
Top of Bedrock Elevation	Approximately El. 146.4 to 145.8 (25.4 to 32.4 feet bgs)	

4.2.1 Bedrock

Bedrock was cored in both test borings. Bedrock was described as hard, very fine to medium-grained, light to dark grey, METAWACKE. Joints are closely spaced, fresh and open. Additionally, bedrock included quartz/calcite stringers, and brecciated zones. The Rock Quality Designation in the core runs ranged from 20 to 83 percent, indicating very poor to good quality rock.

4.2.2 Groundwater

The groundwater level was measured in both BB-VMB-101 and -102 to be 4.7 feet bgs, which corresponds to El. 156.7 and 163.5. We note that these observations were made during drilling and may therefore have been influenced by drilling activities. Fluctuations in groundwater levels will occur due to variations in season, precipitation, brook levels and construction activity in the area. Consequently, water levels during and after construction are likely to vary from those encountered in the borings at the time the observations were made.

5.0 ENGINEERING EVALUATIONS

5.1 GENERAL

GZA has conducted geotechnical engineering evaluations in accordance with *2020 AASHTO LRFD Bridge Design Specifications, 9th Edition* (herein designated as AASHTO) and the *MaineDOT Bridge Design Guide, 2003 Edition*, with updates through 2018 (MaineDOT BDG). The sections that follow describe the evaluations and the geotechnical basis for each element. Supporting calculations are included in **Appendix E**.

5.2 APPROACH EMBANKMENTS

The proposed embankment will remain on the current horizontal alignment and vertical profile. Minor grading of the side slopes is anticipated to achieve the final slope angles of 2 horizontal to 1 vertical (2H:1V) or flatter.

We anticipate that the embankments will be reconstructed over loose to medium dense Fill overlying stiff to soft Marine Clay. Due to the embankment height of only 5 feet and since no raise in grade is proposed, embankment global stability and settlement of the approach roadway are judged to be acceptable for the project.

5.3 FOUNDATION TYPE

The culvert is proposed to consist of a box culvert with a span of 17 feet and a rise of 7 feet bearing on a 1-foot-thick layer of Underdrain Backfill Material, Type C (MaineDOT Pay Item 203.55 Culvert Bedding Stone), separated from the natural Marine Clay on the bottom and sides by Stabilization/Reinforcement Geotextile (MaineDOT Standard Specification 722.01).

5.4 LOAD AND RESISTANCE FACTORS

AASHTO LRFD load factors should be applied to horizontal earth pressure (EH), vertical earth pressure (EV), earth surcharge (ES), and live load surcharge (LS) loads, using the load factors for permanent loads (γ_p) provided in LRFD Table 3.4.1-2 for strength limit state foundation design.

The recommended LRFD resistance factors for strength limit state design of foundations were derived from LRFD Tables 10.5.5.2.2-1, 10.5.5.2.3-1 and 10.5.5.2.4-1 and are presented in the following table.

GEOTECHNICAL RESISTANCE FACTORS – STRENGTH LIMIT STATE			
Foundation Resistance Type	**Method/Condition**	**Resistance Factor (ϕ)**	**AASHTO Reference**
Bearing	Theoretical Method in Clay	0.50	10.5.5.2.2-1
Sliding	Precast Concrete Placed on Sand	0.90	10.5.5.2.2-1

Resistance factors for service and extreme limit state design should be taken as 1.0.

5.5 SPREAD FOOTING DESIGN CONSIDERATIONS

The bottom of the culvert and inlet and outlet walls will be underlain by 12 inches of Underdrain Backfill Material, resulting in excavation depths of approximately 13 to 14 feet below existing grades. At these depths, the exposed soils are anticipated to consist of a thin layer soft to medium stiff Marine Clay underlain by a medium dense Glacial Outwash. The following sections discuss settlement and bearing resistance for the proposed culvert.

5.5.1 Settlement

GZA evaluated the effective stress at the bearing elevation of the proposed box culvert under the existing conditions and the proposed conditions. The results indicate that the proposed construction will result in an increase in effective stress within the channel and between the existing abutments. Therefore, consolidation of the underlying 3 to 4 feet of medium stiff to soft Marine Clay is anticipated. Based on light overconsolidation of the clay interpreted from the consolidation test and the anticipated stress increase, we estimate the post-construction foundation settlement will be 1 inch or less including approximately the effects of primary consolidation and secondary compression. Calculations are presented in **Appendix E**.

5.5.2 Strength Bearing Resistance

The bearing resistance values for the strength condition were developed using the theoretical method (Munfakh et al., 2001) as shown in AASHTO Eq. 10.6.3.1.2a-1, which is based on an estimated shear strength of 600 psf for the Marine Clay. Bearing resistances were evaluated in accordance with Articles 10.6.3.1.1 and 10.6.3.1.2a of AASHTO LRFD.

The calculated bearing resistance values are presented in **Appendix D** and are presented in the table below.

5.5.3 Service Bearing Resistance

GZA evaluated the anticipated settlement for the service condition. We estimate it will include up to about 1/2 inch of primary consolidation plus an additional 1/2 inch or less of secondary compression, resulting in a total of approximately 1 inch over the first 15 years. Since the underlying Glacial Outwash is a granular material, we anticipate that any compression of that layer would occur elastically as the fill is placed and not contribute to post-construction settlement. Calculations are presented in **Appendix E**.

BEARING RESISTANCE VALUES FOR FOOTINGS ON SOIL				
Footing	**Footing Width (feet)**	**Nominal Bearing Resistance (ksf)**	**Factored Bearing Resistance, Strength Limit State (ksf)**	**Service Bearing Resistance (ksf)**
Precast Culvert	19	4.0	2.0	2.0

5.6 SEISMIC DESIGN CONSIDERATIONS

Per AASHTO LRFD Article 3.10.1, seismic analysis is not required for buried structures except where they cross active faults. The site is not located on a known fault; therefore, seismic design parameters are not required.

5.7 LATERAL EARTH PRESSURE

The precast culvert walls will be restrained from lateral movement at the top and bottom. Therefore, the box culvert walls should be designed for at-rest earth pressure conditions. Culvert inlet and outlet headwalls are a few feet high or shorter. These short walls should be also designed for at-rest earth pressure conditions. Inlet and Outlet Walls that extend beyond the box culvert and are independent of the box culvert are considered free to rotate and should be designed for Rankine active earth pressure with consideration for the design backslope, currently anticipated to be 2H:1V. The material properties will be controlled by the backfill material, which is anticipated to consist of BDG Type 4 soil. Soil properties for Type 4 soil are provided in **Section 6.2** of this report.

5.8 FROST PROTECTION

Marine Clay is anticipated to be present at the culvert bearing elevation, and new fill soils are anticipated to be present in the approach roadways, either as existing fill or imported backfill. Considering the Marine Clay is present at the bearing elevation, fine grained soils were considered for the frost penetration depth. Based on the MaineDOT BDG, Section 5.2.1, the Freezing Index for the site is 1,600, and with fine-grained soils with moisture content between 20 to 30 percent, the estimated depth of frost penetration is approximately 4.1 feet. However, the BDG does not specify frost embedment depth for culverts.

6.0 RECOMMENDATIONS

6.1 EMBANKMENT DESIGN CONSIDERATIONS

Embankment side slopes should be designed with MaineDOT typical slope angles of 2H:1V or flatter for a loam and seed surface finish. Where a riprap surface treatment is used, a 1.75H:1V slope angle is acceptable. Riprap should also be provided for scour protection where the embankment side slopes will be near or below typical water levels in Meadow Brook. The extent and nature of scour countermeasures will be evaluated by others.

6.2 BOX CULVERT AND INLET AND OUTLET WALL DESIGN

- Backfill placed between the culvert and existing roadway approaches should consist of MaineDOT 703.19 Granular Borrow, MaineDOT BDG Type 4 soil. Recommended soil properties for Type 4 soils are as follows:
  - Internal Friction Angle of Soil = 32°
  - Soil Total Unit Weight = 125 pcf
  - At-rest Earth Pressure, K_o = 0.47 (use for design of box culvert walls and inlet and outlet headwalls)
  - Rankine Active Earth Pressure, K_a = 0.46 (use for design of culvert inlet and outlet walls unsupported from box and free to rotate, assumes slope of 2H:1V behind wall)
- Live load surcharge should be applied as a uniform lateral surcharge pressure using the equivalent fill height (H_{eq}) values developed in accordance with LRFD Section 3.11.6.4, based on the culvert/inlet and outlet wall height and distance from the wall backface to the edge of traffic. A minimum H_{eq} of 2 feet is recommended.

6.3 RECOMMENDATIONS FOR FOUNDATIONS

- The existing masonry abutments should be removed to at least 1 foot below the bottom of the proposed culvert bearing elevation.

- The proposed box culvert and footings should be supported on 12 inches of MaineDOT 703.22 Underdrain Backfill Material, Type C separated on the bottom and sides by Stabilization/Reinforcement Geotextile installed over undisturbed stiff to medium stiff Marine Clay, except for the precast concrete toe walls, which should bear directly on the undisturbed stiff to medium stiff Marine Clay. Culvert bearing pressures should be checked to confirm that they are less than the bearing resistance values presented in **Section 5.5** of this report.

- In order to limit seepage beneath the culvert, the Underdrain Backfill material should not extend upstream or downstream beyond the limits of the cutoff walls on the base. The cutoff walls and culvert ends should bear directly on natural Marine Clay.
- The culvert subgrade surfaces should be cleaned of any soil loosened by the excavation process prior to placement of Underdrain Backfill Material. Bearing surface preparation should be in accordance with **Section 7.2**.
- The Underdrain Backfill Material, Type C bedding for the culvert should be placed in maximum 6-inch lifts and densified with several passes of a walk-behind roller or large plate compactor.
- The base resistance against sliding was evaluated in accordance with AASHTO Article 10.6.3.4 using ϕ_f' = 32 degrees and C = 0.8 for the culvert (precast concrete). Nominal sliding resistance coefficient for culvert was calculated as C*tan ϕ_f' and is equal to 0.50. The factored sliding resistance coefficient for the strength condition is 0.45 for the culvert and inlet/outlet walls, based on a resistance factor ($\phi\tau$) of 0.9 for the strength limit state.
- Passive resistance on the toe of footings should be neglected when evaluating sliding and overturning.

7.0 CONSTRUCTION CONSIDERATIONS

This section provides guidance regarding quality control during excavation, dewatering, and foundation subgrade preparation and protection. These items are discussed in the paragraphs that follow.

7.1 EXCAVATION, TEMPORARY LATERAL SUPPORT AND DEWATERING

Excavations for culvert foundations are anticipated to extend approximately 13 feet below existing grade and at least 5 feet below Q 1.1 (El. 160.4). We anticipate that either sheet-pile-supported or open cut excavation techniques may be suitable for this project.

Damming and diversion coupled with temporary dewatering are anticipated to be necessary to control groundwater and/or stream inflow in excavations. Depending on permitting and water levels at the time of construction, we anticipate that it would be possible to dam the stream with sandbags and an impermeable membrane and temporarily divert the flow through a pipe so the contractor can construct foundations in the dry. It may also be necessary to employ localized pumping from sumps to maintain dewatering. Where the excavations are at/near measured groundwater levels, it is anticipated that inflow of surface water or runoff to excavations can be handled by open pumping from sumps installed at the bottoms of excavations. Sumps should be fitted with geotextile or sand filters to prevent loss of subgrade fines during pumping. Dewatering discharge should be managed in accordance with the contractor's Stormwater Prevention Plan and MaineDOT Best Management Practices.

7.2 SUBGRADE PREPARATION

Even with damming and diversion, excavation bases may be wet. If the exposed surface of the Marine Clay is wet, Stabilization/Reinforcement Geotextile (MaineDOT Standard Specification 722.01) should be placed directly on the subgrade, and then the first lift of Underdrain Backfill, Type C may be placed prior to commencing compaction. The surface of the Type C material may then be densified as previously described. Compaction should be completed in a manner at which the subgrade does not exhibit weaving or rutting.

TABLES

TABLE 1
Summary of Subsurface Explorations
Meadow Brook Bridge #5856 carries Bog Road over Meadow Brook
Vassalboro, Maine
GZA job#: 09.0026222.00

Boring ID	Station	Offset	Ground Surface El. (ft)	Top of Stratum Elevation						Stratum Thickness					Depth to Bedrock (ft)	Top of Rock Elevation (ft)	Bottom of Boring Depth (ft)	Bottom of Boring El. (ft)	Groundwater	
				Asphalt	Fill	Alluvium	Marine Clay	Glacical Outwash	Bedrock	Asphalt	Fill	Alluvium	Marine Clay	Glacical Outwash					El. (ft)	Depth (ft)
BB-VMB-101	103+66.2	5.6' Rt.	161.4	NE	NE	161.4	160.4	152.4	146.4	NE	NE	1.0	8.0	6.0	15.0	146.4	25.4	136.0	156.7	4.7
BB-VMB-102	103+89.9	9.7' Lt.	168.2	168.2	167.8	NE	159.2	152.7	145.8	0.4	8.6	NE	6.5	6.9	22.4	145.8	32.4	135.8	163.5	4.7

El. = Elevation, NE = Not Encountered, NM = Not Measured, NP = Not Penetrated, > = Boring Terminated in Stratum

Notes:
1. Refer to the boring logs in Appendix B for additional information.
2. Project elevation datum is North American Vertical Datum (NAVD 88), unless noted otherwise.
3. As-drilled locations were surveyed by MaineDOT.
4. Stratum depths, thickness and elevations are rounded to the nearest 0.1 foot as interpreted on the boring logs, but this does not represent the precision of the data.

FIGURES

USGS QUADRANGLE LOCATION

N W E S

SOURCE : THIS MAP CONTAINS THE ESRI ARCGIS ONLINE USA TOPOGRAPHIC MAP SERVICE, PUBLISHED DECEMBER 12, 2009 BY ESRI ARCIMS SERVICES AND UPDATED AS NEEDED. THIS SERVICE USES UNIFORM NATIONALLY RECOGNIZED DATUM AND CARTOGRAPHY STANDARDS AND A VARIETY OF AVAILABLE SOURCES FROM SEVERAL DATA PROVIDERS. THIS MAP ALSO CONTAINS THE ESRI ARCGIS ONLINE USA COUNTIES WHICH PROVIDES DETAILED BOUNDARIES THAT ARE CONSISTENT WITH THE TRACT, BLOCK GROUP, AND STATE DATA SETS AND ARE EFFECTIVE AT REGIONAL AND STATE LEVELS.

0 1,000 2,000 4,000 6,000

SCALE IN FEET

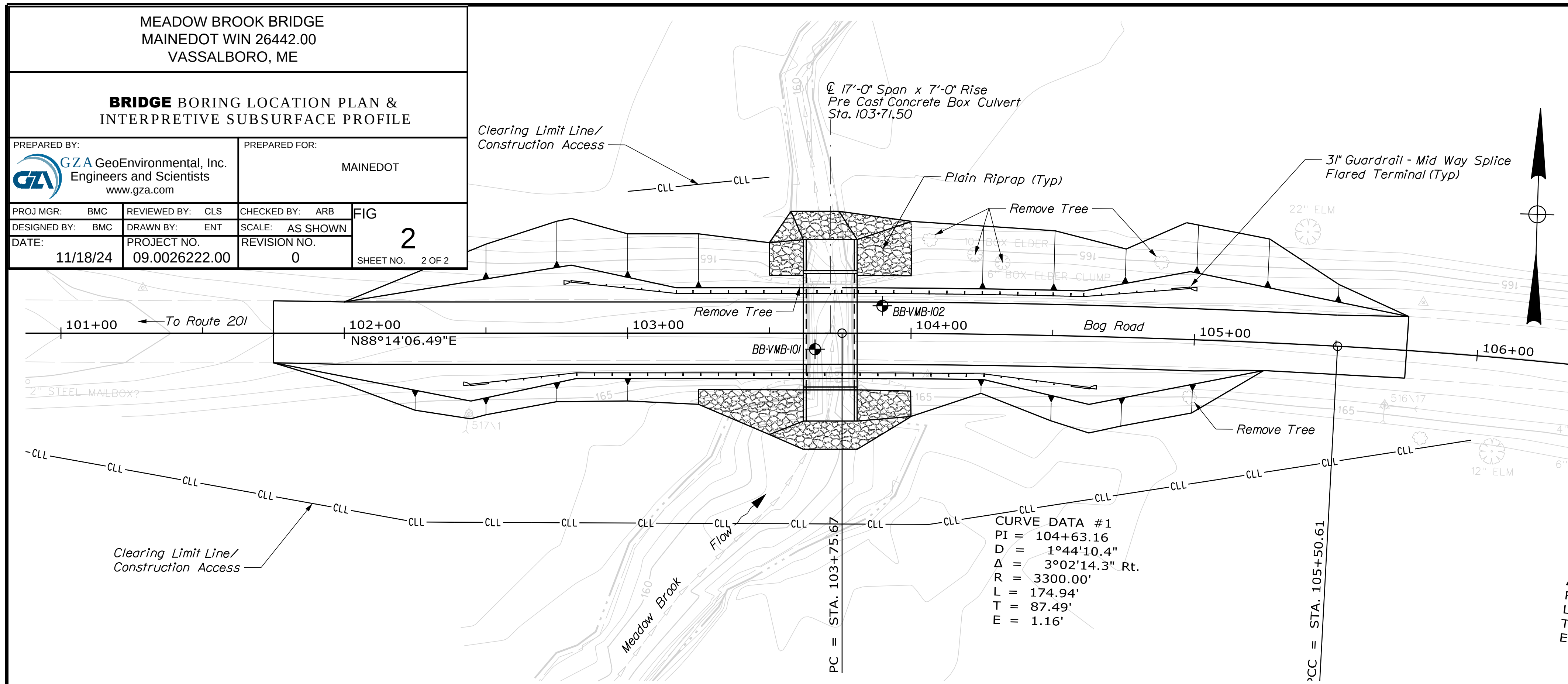
Data Supplied by :

PROJ. MGR.: BMC DESIGNED BY: EAF REVIEWED BY: BMC OPERATOR: EAF DATE: 10-09-2024	**LOCUS PLAN**	JOB NO. 09.0026222.00
	MEADOW BROOK BRIDGE NO. 5856 VASSALBORO, MAINE	FIGURE NO. 1

MEADOW BROOK BRIDGE
MAINEDOT WIN 26442.00
VASSALBORO, ME

BRIDGE BORING LOCATION PLAN &
INTERPRETIVE SUBSURFACE PROFILE

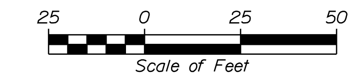
PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com			PREPARED FOR: MAINEDOT	
PROJ MGR: BMC	REVIEWED BY: CLS	CHECKED BY: ARB	FIG 2	
DESIGNED BY: BMC	DRAWN BY: ENT	SCALE: AS SHOWN		
DATE: 11/18/24	PROJECT NO. 09.0026222.00	REVISION NO. 0	SHEET NO. 2 OF 2	



Legend

Location and designation of BB-VMB-101 and BB-VMB-102 Series borings drilled by MaineDOT between November 14 and 15, 2022.

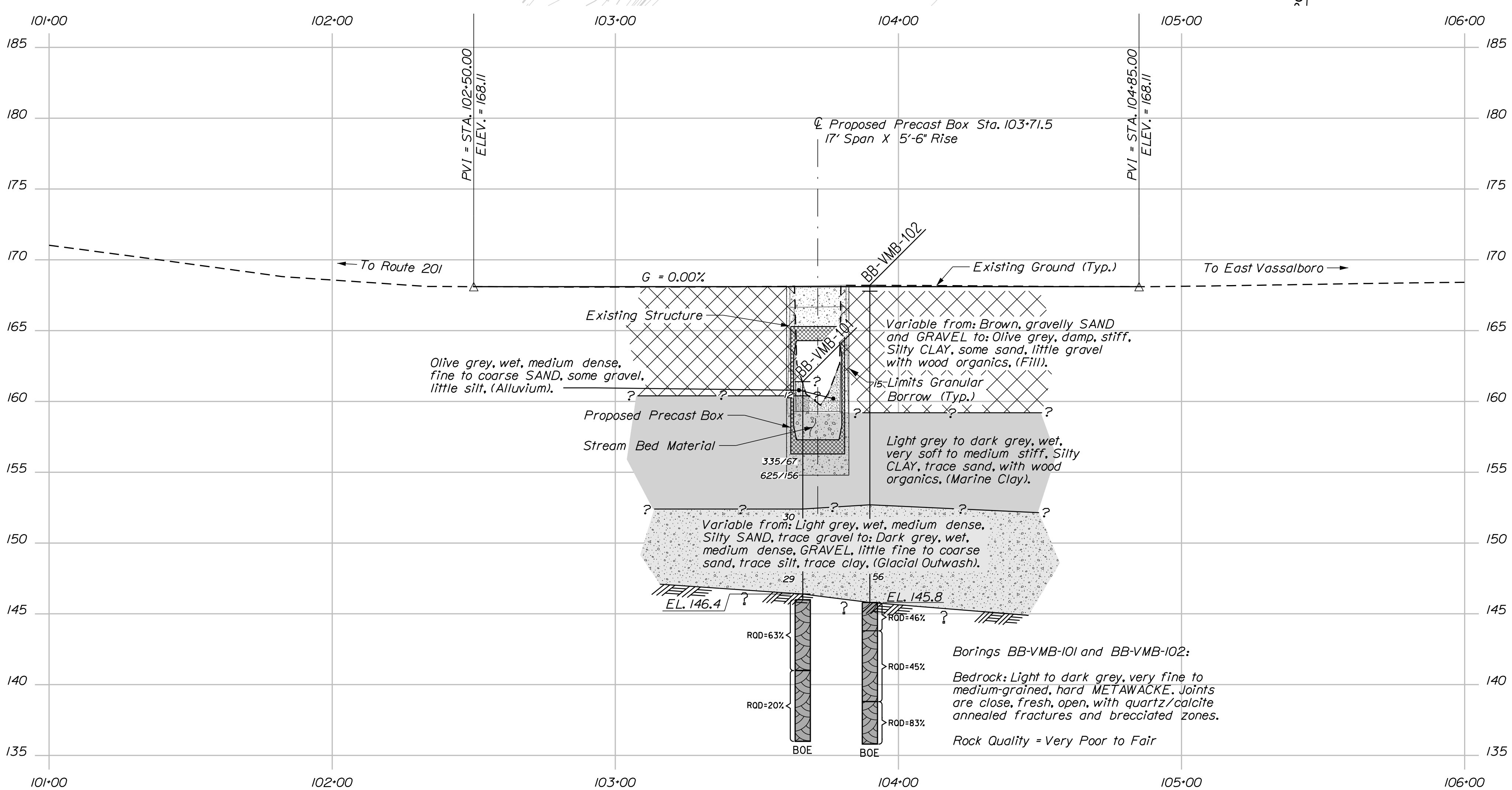
PLAN



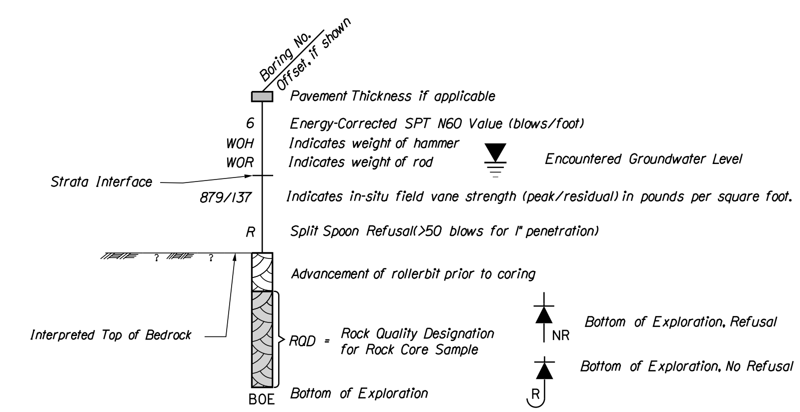
Notes:

1) Base map developed from elecatronic files (alignments.dgn, Bridge.dgn, contours.dgn, topo.dgn and text.dgn) provide by MaineDOT.

2) The as-drilled locations of BB-VMB-101 and BB-VMB-102 test borings were measured from existing site features to the approximate locations shown on this plan by MaineDOT personnel and provided as a hand sketch on November 22, 2022. This data should be considered accurate only to the degree implied by the method used.



LEGEND



PROFILE

Notes:

1) Base Profile developed from electronic file (Profile.dgn) provide by MaineDOT.

2) The as-drilled locations of BB-VMB-101, and -102 test borings were measured from existing site features to the approximate locations shown on this plan by MaineDOT personnel and provided as a hand sketch on November 22, 2022. This data should be considered accurate only to the degree implied by the method used.

3) This generalized interpretive soil profile is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and have been developed by interpretations of widely spaced explorations and samples. Actual soil and bedrock transitions may vary and are probably more erratic. For more specific information refer to the exploration logs.

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

2644200

WIN 26442.00

BRIDGE PLANS

BRIDGE NO. 5856

	BY	DATE
PROJ. MANAGER		
DESIGN-DETAILED	R. NADUS	J. BRUNELLE 10/22
CHECKED-REVIEWED		11/22
DESIGN2-DETAILED2	B. CARDALI	T. WHITE NOV 2024
DESIGN3-DETAILED3		
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE

P.E. NUMBER

DATE

MEADOW BROOK BRIDGE
MEADOW BROOK
VASSALBORO KENNEBEC COUNTY

BORING LOCATION PLAN &
INTERPRETIVE SUBSURFACE PROFILE

SHEET NUMBER
6
OF _

Filename: ...\GEOTECH\MSTA\006_BLP&ISP1.dgn Division: GEOTECH Username: Terry.White Date:11/15/2024

APPENDIX A – LIMITATIONS

GEOTECHNICAL LIMITATIONS

Use of Report

1. GZA GeoEnvironmental, Inc. (GZA) prepared this report on behalf of, and for the exclusive use of our Client for the stated purpose(s) and location(s) identified in the Proposal for Services and/or Report. Use of this report, in whole or in part, at other locations, or for other purposes, may lead to inappropriate conclusions; and we do not accept any responsibility for the consequences of such use(s). Further, reliance by any party not expressly identified in the contract documents, for any use, without our prior written permission, shall be at that party's sole risk, and without any liability to GZA.

Standard of Care

2. GZA's findings and conclusions are based on the work conducted as part of the Scope of Services set forth in Proposal for Services and/or Report, and reflect our professional judgment. These findings and conclusions must be considered not as scientific or engineering certainties, but rather as our professional opinions concerning the limited data gathered during the course of our work. If conditions other than those described in this report are found at the subject location(s), or the design has been altered in any way, GZA shall be so notified and afforded the opportunity to revise the report, as appropriate, to reflect the unanticipated changed conditions .

3. GZA's services were performed using the degree of skill and care ordinarily exercised by qualified professionals performing the same type of services, at the same time, under similar conditions, at the same or a similar property. No warranty, expressed or implied, is made.

4. In conducting our work, GZA relied upon certain information made available by public agencies, Client and/or others. GZA did not attempt to independently verify the accuracy or completeness of that information. Inconsistencies in this information which we have noted, if any, are discussed in the Report.

Subsurface Conditions

5. The generalized soil profile(s) provided in our Report are based on widely-spaced subsurface explorations and are intended only to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and were based on our assessment of subsurface conditions. The composition of strata, and the transitions between strata, may be more variable and more complex than indicated. For more specific information on soil conditions at a specific location refer to the exploration logs. The nature and extent of variations between these explorations may not become evident until further exploration or construction. If variations or other latent conditions then become evident, it will be necessary to reevaluate the conclusions and recommendations of this report.

6. In preparing this report, GZA relied on certain information provided by the Client, state and local officials, and other parties referenced therein which were made available to GZA at the time of our evaluation. GZA did not attempt to independently verify the accuracy or completeness of all information reviewed or received during the course of this evaluation.

7. Water level readings have been made in test holes (as described in this Report) and monitoring wells at the specified times and under the stated conditions. These data have been reviewed and interpretations have been made in this Report. Fluctuations in the level of the groundwater however occur due to temporal or spatial variations in areal recharge rates, soil heterogeneities, the presence of subsurface utilities, and/or natural or artificially induced perturbations. The water table encountered in the course of the work may differ from that indicated in the Report.

8. GZA's services did not include an assessment of the presence of oil or hazardous materials at the property. Consequently, we did not consider the potential impacts (if any) that contaminants in soil or groundwater may have on construction activities, or the use of structures on the property.

9. Recommendations for foundation drainage, waterproofing, and moisture control address the conventional geotechnical engineering aspects of seepage control. These recommendations may not preclude an environment that allows the infestation of mold or other biological pollutants.

Compliance with Codes and Regulations

10. We used reasonable care in identifying and interpreting applicable codes and regulations. These codes and regulations are subject to various, and possibly contradictory, interpretations. Compliance with codes and regulations by other parties is beyond our control.

Cost Estimates

11. Unless otherwise stated, our cost estimates are only for comparative and general planning purposes. These estimates may involve approximate quantity evaluations. Note that these quantity estimates are not intended to be sufficiently accurate to develop construction bids, or to predict the actual cost of work addressed in this Report. Further, since we have no control over either when the work will take place or the labor and material costs required to plan and execute the anticipated work, our cost estimates were made by relying on our experience, the experience of others, and other sources of readily available information. Actual costs may vary over time and could be significantly more, or less, than stated in the Report.

Additional Services

12. GZA recommends that we be retained to provide services during any future: site observations, design, implementation activities, construction and/or property development/redevelopment. This will allow us the opportunity to: i) observe conditions and compliance with our design concepts and opinions; ii) allow for changes in the event that conditions are other than anticipated; iii) provide modifications to our design; and iv) assess the consequences of changes in technologies and/or regulations.

APPENDIX B – TEST 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

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):

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

*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))

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

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: Meadow Brook Bridge #5856 carries Bog Road over Meadow Brook Location: Vassalboro, Maine	Boring No.: BB-VMB-101 WIN: 26442.00

Driller:	MaineDOT	**Elevation (ft.)**	161.4	**Auger ID/OD:**	N/A
Operator:	Daggett/Brook	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. Manahan	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	11/15/2022; 08:45-15:00	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	103+66.2, 5.6 ft Rt.	**Casing ID/OD:**	HW-4" & NW-3"	**Water Level*:**	4.7 ft bgs.
Hammer Efficiency Factor:	0.906	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:	R = Rock Core Sample	S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf)	T_v = Pocket Torvane Shear Strength (psf)
D = Split Spoon Sample	SSA = Solid Stem Auger	$S_{u(lab)}$ = Lab Vane Undrained Shear Strength (psf)	WC = Water Content, percent
MD = Unsuccessful Split Spoon Sample Attempt	HSA = Hollow Stem Auger	q_p = Unconfined Compressive Strength (ksf)	LL = Liquid Limit
U = Thin Wall Tube Sample	RC = Roller Cone	N-uncorrected = Raw Field SPT N-value	PL = Plastic Limit
MU = Unsuccessful Thin Wall Tube Sample Attempt	WOH = Weight of 140lb. Hammer	Hammer Efficiency Factor = Rig Specific Annual Calibration Value	PI = Plasticity Index
V = Field Vane Shear Test, PP = Pocket Penetrometer	WOR/C = Weight of Rods or Casing	N_{60} = SPT N-uncorrected Corrected for Hammer Efficiency	G = Grain Size Analysis
MV = Unsuccessful Field Vane Shear Test Attempt	WO1P = Weight of One Person	N_{60} = (Hammer Efficiency Factor/60%)*N-uncorrected	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	24/7	0.00 - 2.00	4/5/3/2	8	12	a31	160.4		Olive grey, wet, medium dense, fine to coarse SAND, some gravel, little silt, (Alluvium). 1.0	
							a19				
							a15				
	2D	24/24	3.00 - 5.00	WOH/WOH/WOH/WOH	---		OPEN HOLE			Light grey, wet, very soft, Silty CLAY, trace sand, layer of wood organics, (Marine Clay).	G#303227 A-6, CL WC=30.9% LL=32 PL=19 PI=13
5	1U	24/24	5.00 - 7.00	WOR/WOR/WOR/WOR	---					Grey, varved, very soft, Silty CLAY, trace sand (Marine Clay).	G,C#303226 A-4, CL-ML WC=23.5% LL=21 PL=15 PI=6
	3D V1	24/21	7.00 - 9.00 7.63 - 8.00	WOR/WOR/WOR/WOH Su=335/67 psf	---					Light grey, wet, medium stiff, Silty CLAY, trace sand, (Marine Clay). 55x110 mm vane raw torque readings: V1: 7.5/1.5 ft-lbs	
	V2		8.63 - 9.00	Su=625/156 psf				152.4		V2: 14.0/3.5 ft-lbs Last 1/2" of V2 much harder to push. 9.0	G#303228 A-4, CL-ML WC=26.3% LL=23 PL=19 PI=4
	4D	24/8	9.00 - 11.00	4/10/10/14	20	30					
10										Light grey, wet, medium dense, Silty SAND, trace gravel, (Glacial Outwash). Drove NW Casing to 20.0 ft bgs.	
	5D	24/7	13.00 - 15.00	17/9/10/17	19	29				Dark grey, wet, medium dense, GRAVEL, little fine to coarse sand, trace silt, trace clay, (Glacial Outwash).	
15								146.4		15.0	
	R1	60/60	15.40 - 20.40	RQD = 63%			NQ-2			Top of Bedrock at Elev. 146.4 ft. Roller Coned ahead, to 15.4 ft. bgs. and set up to core. R1: Bedrock: Light to dark grey, very fine to medium-grained, hard, METAWACKE, fresh and quartz/calcite annealed fractures, brecciated zones. [Mayflower Hill Formation] Rock Quality = Fair 100% Recovery R1: Core Times (min:sec) 15.4-16.4 ft (1:37) 16.4-17.4 ft (1:18) 17.4-18.4 ft (1:45) no water return 18.4-19.4 ft (2:01) 19.4-20.4 ft (2:51)	
20	R2	60/60	20.40 - 25.40	RQD = 20%						R2: Bedrock: Similar to R1. Rock Quality = Very Poor 100% Recovery R2: Core Times (min:sec) 20.4-21.4 ft (1:26) 21.4-22.4 ft (1:19) 22.4-23.4 ft (1:21)	
25											

Remarks:

7.0 ft from Bridge Deck to bottom of Stream.
a HW-4" Casing.

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: Meadow Brook Bridge #5856 carries Bog Road over Meadow Brook
Location: Vassalboro, Maine

Boring No.: BB-VMB-101
WIN: 26442.00

Driller:	MaineDOT	**Elevation (ft.)**	161.4	**Auger ID/OD:**	N/A
Operator:	Daggett/Brook	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. Manahan	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	11/15/2022; 08:45-15:00	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	103+66.2, 5.6 ft Rt.	**Casing ID/OD:**	HW-4" & NW-3"	**Water Level*:**	4.7 ft bgs.
Hammer Efficiency Factor:	0.906	**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.
25							V	136.0		23.4-24.4 ft (4:12) 24.4-25.4 ft (3:04)	
										25.4	
										Bottom of Exploration at 25.4 feet below ground surface.	
30											
35											
40											
45											
50											

Remarks:

7.0 ft from Bridge Deck to bottom of Stream.
a HW-4" Casing.

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: Meadow Brook Bridge #5856 carries Bog Road over Meadow Brook

Location: Vassalboro, Maine

Boring No.: BB-VMB-102

WIN: 26442.00

Driller:	MaineDOT	**Elevation (ft.)**	168.2	**Auger ID/OD:**	5" Solid Stem
Operator:	Daggett/Brook	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. Manahan	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	11/14/2022; 09:15-13:30	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	103+89.9, 9.7 ft Lt.	**Casing ID/OD:**	HW-4" & NW-3"	**Water Level*:**	4.7 ft bgs.
Hammer Efficiency Factor:	0.906	**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							SSA	167.8		5" HMA. 0.4 Brown sand and gravel cuttings, (Fill).	
5	1D	24/23	5.00 - 7.00	7/5/5/3	10	15				Olive grey, damp, stiff, Silty CLAY, some sand, little gravel, trace wood organics, (Fill).	G#303229 A-4, CL WC=20.0%
								159.2		9.0	
10	2D	24/24	10.00 - 12.00	WOH/WOH/WOH/ WOH	---		1			Light grey, moist, very soft, Silty CLAY, trace fine sand, (Marine Clay).	G#303230 A-6, CL WC=29.8% LL=34 PL=19 PI=15
							5				
							6				
							6				
							7				
15	3D MV	6/4	15.00 - 15.50	WOR	---		20	152.7		Grey, wet, Silty CLAY, trace fine sand, (Marine Clay). 15.5 Failed 55x110 mm vane attempt, vane refusal.	G#303231 A-4, CL WC=23.9%
							30				
							56				
							67				
							70				
20	4D	21.6/21.6	20.00 - 21.80	14/23/14/33(3.6)	37	56	53			Light brown, damp, hard, Silty CLAY, some sand, trace gravel, (Glacial Outwash).	G#303232 A-4, CL WC=16.7%
							78			a95 blows for 0.4 ft.	
	R1	24/19	22.40 - 24.40	RQD = 46%			a95	145.8		22.4 Top of Bedrock at Elev. 145.8 ft.	
							NQ-2			R1: Bedrock: light to dark grey, very fine to medium-grained, hard, METAWACKE, fresh, open joints, close. [Mayflower Hill Formation]	
	R2	60/60	24.40 - 29.40	RQD = 45%							
25											

Remarks:

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: Meadow Brook Bridge #5856 carries Bog Road over Meadow Brook
Location: Vassalboro, Maine

Boring No.: BB-VMB-102

WIN: 26442.00

Driller:	MaineDOT	**Elevation (ft.)**	168.2	**Auger ID/OD:**	5" Solid Stem
Operator:	Daggett/Brook	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. Manahan	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	11/14/2022; 09:15-13:30	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	NQ-2"
Boring Location:	103+89.9, 9.7 ft Lt.	**Casing ID/OD:**	HW-4" & NW-3"	**Water Level*:**	4.7 ft bgs.
Hammer Efficiency Factor:	0.906	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
D = Split Spoon Sample
MD = Unsuccessful Split Spoon 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.
25										Rock Quality = Poor. 79% Recovery R1: Core Times (min:sec) 22.4-23.4 ft (1:05) 23.4-24.4 ft (0:48) R2: Bedrock: Similar to R1, except with quartz/calcite annealed fractures. [Mayflower Hill Formation] Rock Quality = Poor. 100% Recovery R2: Core Times (min:sec) 24.4-25.4 ft (2:03) 25.4-26.4 ft (1:51) 26.4-27.4 ft (1:45) 27.4-28.4 ft (1:47) 28.4-29.4 ft (2:19)	
	R3	36/34	29.40 - 32.40	RQD = 83%							
30											
								135.8		R3: Bedrock: Similar to R1. [Mayflower Hill Formation] Rock Quality = Good. 94% Recovery R3: Core Times (min:sec) 29.4-30.4 ft (1:40) 30.4-31.4 ft (2:28) 31.4-32.4 ft (2:30)	
35										32.4 **Bottom of Exploration at 32.4 feet below ground surface.**	
40											
45											
50											

Remarks:

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.

APPENDIX C – CORE PHOTO LOG

Meadow Brook Bridge No. 5856
MaineDOT WIN 26442.00, Vassalboro, Maine
Rock Core Photographs

Boring No.	Run	Depth (ft)	Recovery (in)	Recovery (%)	RQD (in)	RQD (%)	Rock Type	Box Row
BB-VMB-102	R1	22.4 - 24.4	19	79	11	46	Metawacke	1
BB-VMB-102	R2	24.4 - 29.4	60	100	27	45	Metawacke	1&2
BB-VMB-102	R3	29.4 - 32.4	34	94	30	83	Metawacke	2
BB-VMB-101	R1	22.4 - 27.4	60	100	38	63	Metawacke	3
BB-VMB-101	R2	27.4 - 32.4	60	100	12	20	Metawacke	4

Notes: 1. Box row corresponds to the core box section in which the rock core sample is contained; Row 1=Top, Row 4=Bottom.
2. Photo is dry, no wet photo was provided.

APPENDIX D – LABORATORY TEST RESULTS

State of Maine - Department of Transportation

Laboratory Testing Summary Sheet

Town(s): Vassalboro   Work Number: 26442.00

Boring & Sample Identification Number	Station (Feet)	Offset (Feet)	Depth (Feet)	Reference Number	G.S.D.C. Sheet	W.C. %	L.L.	P.I.	Classification		
									Unified	AASHTO	Frost
BB-VMB-101, 2D	103+66.2	5.6 Rt.	3.0-5.0	303227	1	30.9	32	13	CL	A-6	III
*BB-VMB-101, 1U	103+66.2	5.6 Rt.	5.0-7.0	303226	1	23.5	21	6	CL-ML	A-4	IV
BB-VMB-101, 3D	103+66.2	5.6 Rt.	7.0-9.0	303228	1	26.3	23	4	CL-ML	A-4	IV
BB-VMB-102, 1D	103+89.9	9.7 Lt.	5.0-7.0	303229	2	20.0			CL	A-4	IV
BB-VMB-102, 2D	103+89.9	9.7 Lt.	10.0-12.0	303230	2	29.8	34	15	CL	A-6	III
BB-VMB-102, 3D	103+89.9	9.7 Lt.	15.0-15.5	303231	2	23.9			CL	A-4	IV
BB-VMB-102, 4D	103+89.9	9.7 Lt.	20.0-21.8	303232	2	16.7			CL	A-4	IV

* See Geotechnical Test Reports for Consolidation (T 216) and Vane Shear Test on Shelby Tubes (Maine DOT).

Classification of these soil samples is in accordance with AASHTO Classification System M-145-40. This classification is followed by the "Frost Susceptibility Rating" from zero (non-frost susceptible) to Class IV (highly frost susceptible). The "Frost Susceptibility Rating" is based upon the MaineDOT and Corps of Engineers Classification Systems.

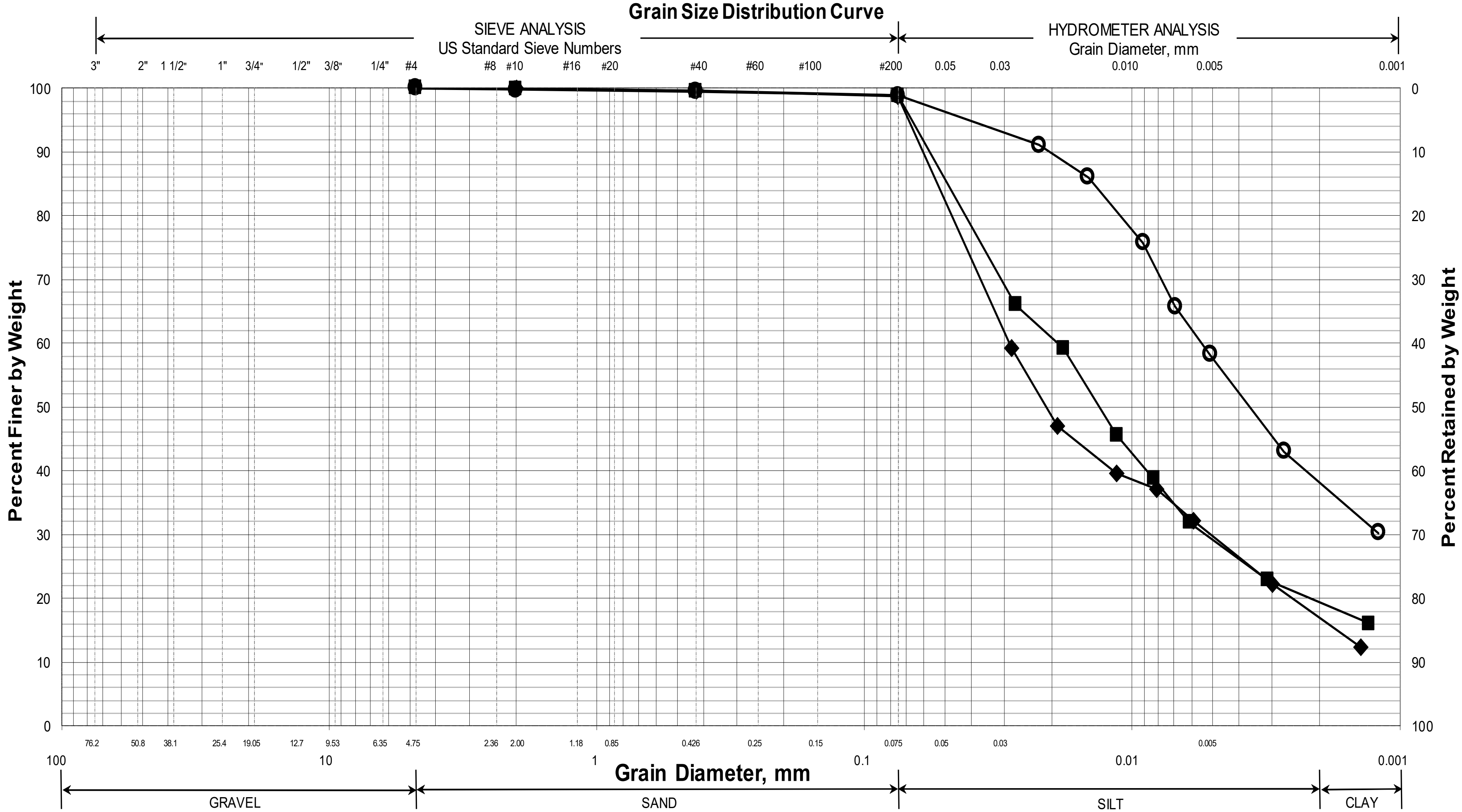
GSDC = Grain Size Distribution Curve as determined by AASHTO T 88-93 (1996) and/or ASTM D 422-63 (Reapproved 1998)

WC = water content as determined by AASHTO T 265-93 and/or ASTM D 2216-98

LL = Liquid limit as determined by AASHTO T 89-96 and/or ASTM D 4318-98   NP = Non Plastic

PI = Plasticity Index as determined by AASHTO 90-96 and/or ASTM D4318-98

Maine Department of Transportation
Grain Size Distribution Curve



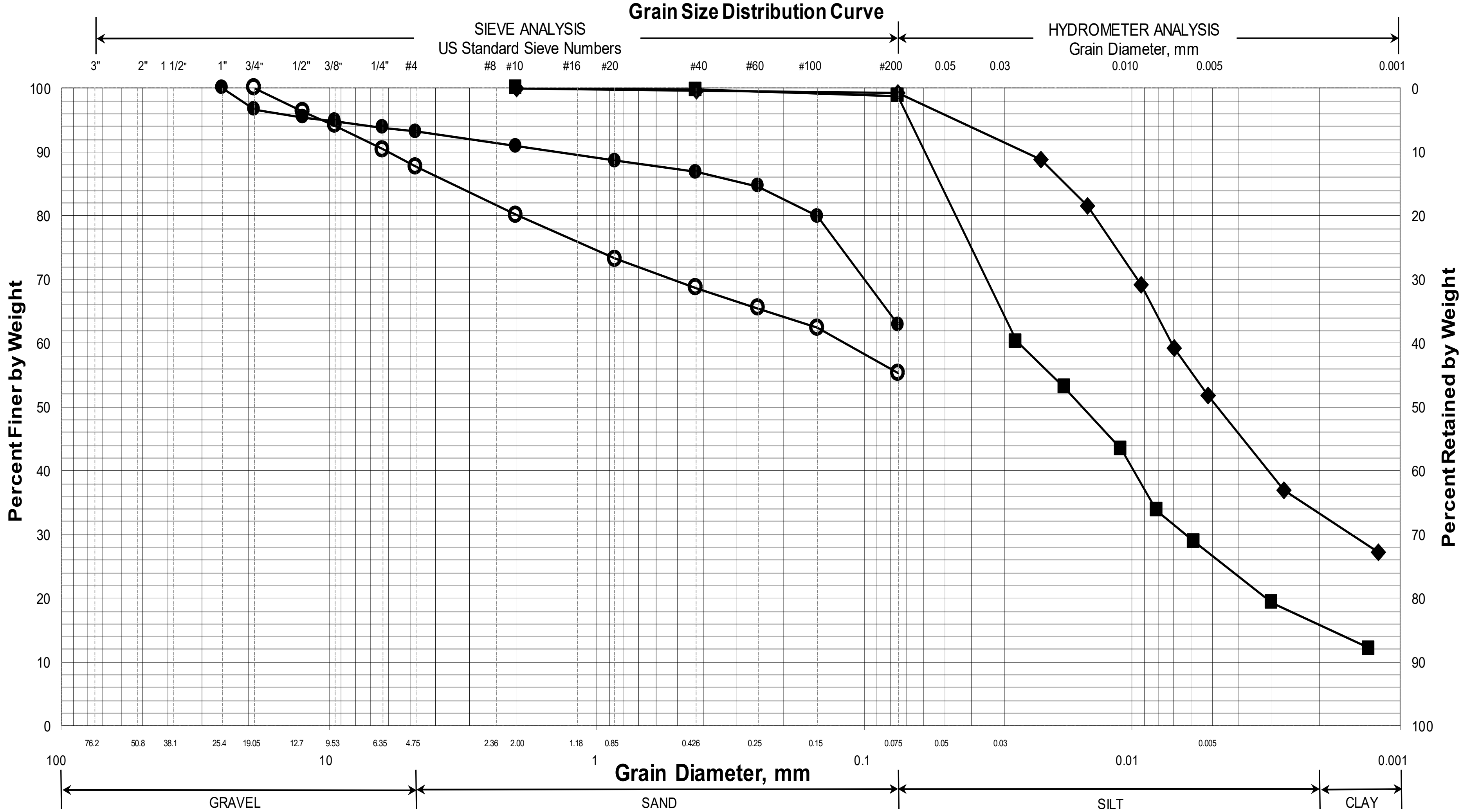
UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
○	BB-VMB-101/2D	103+66.2	5.6 RT	3.0-5.0	Clayey SILT, trace sand.	30.9	32	19	13
◆	BB-VMB-101/1U	103+66.2	5.6 RT	5.0-7.0	SILT, little clay, trace sand.	23.5	21	15	6
■	BB-VMB-101/3D	103+66.2	5.6 RT	7.0-9.0	SILT, little clay, trace sand.	26.3	23	19	4
●									
▲									
×									

WIN	
026442.00	
Town	
Vassalboro	
Reported by/Date	
WHITE, TERRY A	3/21/2023

SHEET 1

Maine Department of Transportation
Grain Size Distribution Curve



UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
○	BB-VMB-102/1D	103+89.9	9.7 LT	5.0-7.0	SILT, some sand, little gravel.	20			
◆	BB-VMB-102/2D	103+89.9	9.7 LT	10.0-12.0	SILT, some clay, trace sand.	29.8	34	19	15
■	BB-VMB-102/3D	103+89.9	9.7 LT	15.0-15.5	SILT, little clay, trace sand.	23.9			
●	BB-VMB-102/4D	103+89.9	9.7 LT	20.0-21.8	SILT, some sand, trace gravel.	16.7			
▲									
×									

WIN
026442.00
Town
Vassalboro
Reported by/Date
WHITE, TERRY A 1/9/2023

SHEET 2

GEOTECHNICAL TEST REPORT
Central Laboratory

SAMPLE INFORMATION

Reference No.	Boring No./Sample No.	Sample Description	Sampled	Received
303227	**BB-VMB-101/2D**	**GEOTECHNICAL (DISTURBED)**	**11/15/2022**	**12/7/2022**

Sample Type: **GEOTECHNICAL** Location: Station: **103+66.2** Offset, ft: **5.6 RT** Dbfg, ft: **3.0-5.0**

WIN/Town **026442.00 - VASSALBORO** Sampler: **JAMES MANAHAN**

TEST RESULTS

Sieve Analysis (T 88)

Wash Method

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	
¾ in. [19.0 mm]	
½ in. [12.5 mm]	
⅜ in. [9.5 mm]	
¼ in. [6.3 mm]	
No. 4 [4.75 mm]	**100.0**
No. 10 [2.00 mm]	**99.8**
No. 20 [0.850 mm]	
No. 40 [0.425 mm]	**99.5**
No. 60 [0.250 mm]	
No. 100 [0.150 mm]	
No. 200 [0.075 mm]	**98.9**
[0.0223 mm]	**91.1**
[0.0146 mm]	**86.0**
[0.0091 mm]	**75.8**
[0.0069 mm]	**65.8**
[0.0051 mm]	**58.2**
[0.0027 mm]	**43.0**
[0.0012 mm]	**30.3**

Miscellaneous Tests

Test	Result
Liquid Limit @ 25 blows (T 89), %	**32**
Plastic Limit (T 90), %	**19**
Plasticity Index (T 90), %	**13**
Specific Gravity, Corrected to 20°C (T 100)	**2.74**
Loss on Ignition, % (T 267)	
Water Content (T 265), %	**30.9**

Consolidation (T 216)

Trimmings, Water Content, %

	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In. U. Shear tons/ft²	3 In. Remold tons/ft²	6 In. U. Shear tons/ft²	6 In. Remold tons/ft²	Water Content, %	Description of Material Sampled at the Various Tube Depths

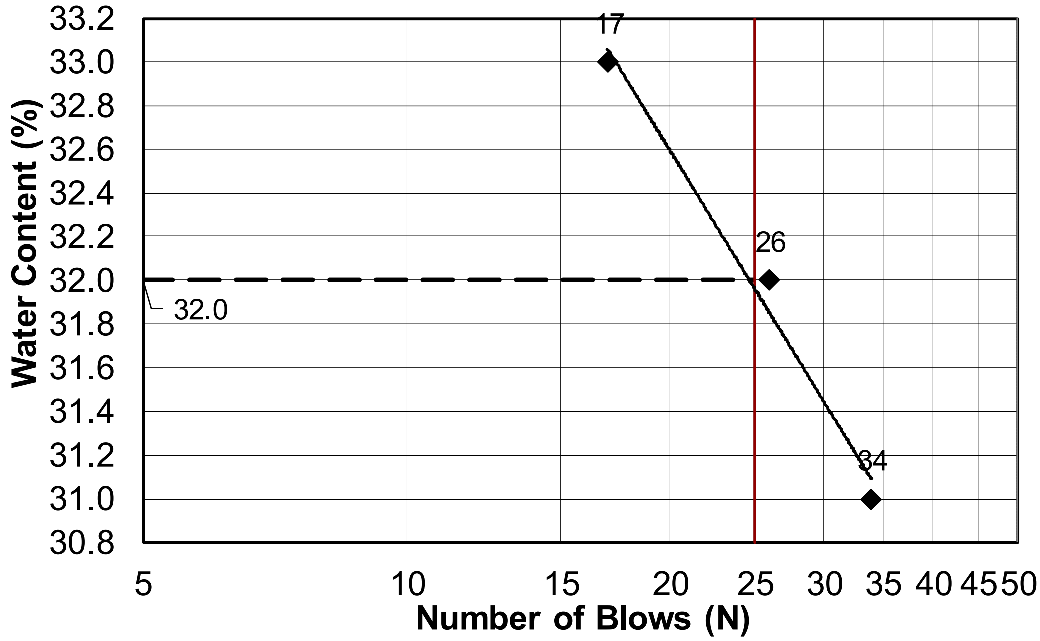
Comments:

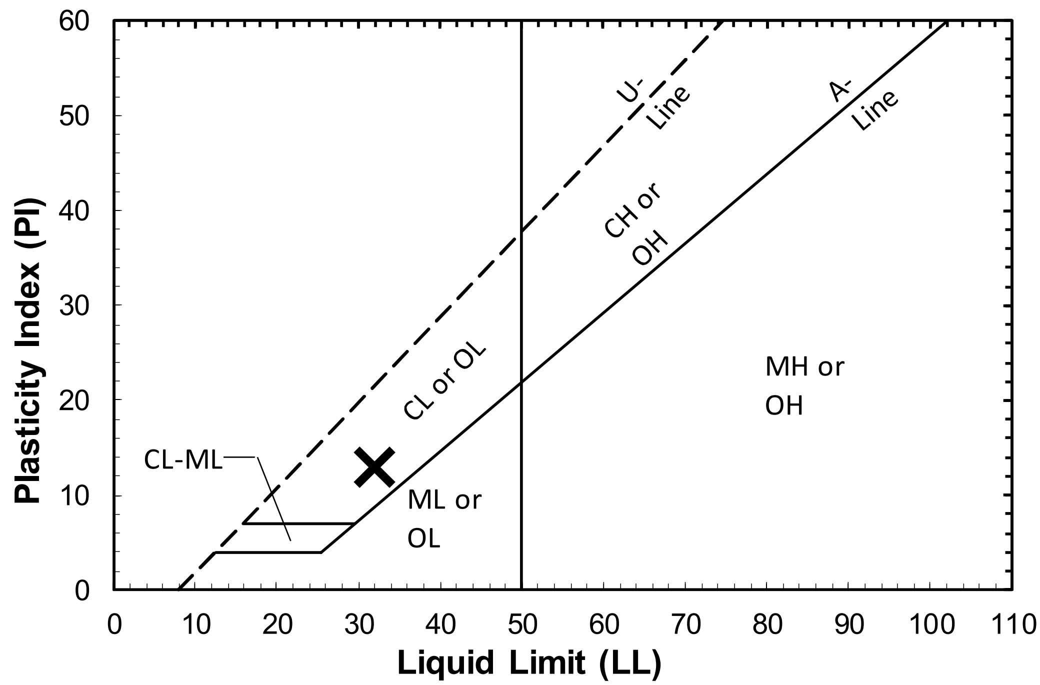
AUTHORIZATION AND DISTRIBUTION

Reported by: **GREGORY LIDSTONE** Date Reported: **1/4/2023**

Paper Copy: Lab File; Project File; Geotech File

TOWN	Vassalboro	Reference No.	303227
WIN	026442.00	Water Content, %	30.9
Sampled	11/15/2022	Liquid Limit @ 25 blows (T 89), %	32
Boring No./Sample No.	BB-VMB-101/2D	Plastic Limit (T 90), %	19
Station	103+66.2	Plasticity Index (T 90), %	13
Depth	3.0-5.0	Tested By	BBURR





GEOTECHNICAL TEST REPORT
Central Laboratory

SAMPLE INFORMATION

Reference No.	Boring No./Sample No.	Sample Description	Sampled	Received
303226	**BB-VMB-101/1U**	**GEOTECHNICAL (UNDISTURBED)**	**11/15/2022**	**12/7/2022**

Sample Type: **GEOTECHNICAL** Location: Station: **103+66.2** Offset, ft: **5.6** **RT** Dbfg, ft: **5.0-7.0**

WIN/Town **026442.00 - VASSALBORO** Sampler: **JAMES MANAHAN**

TEST RESULTS

Sieve Analysis (T 88)

Wash Method

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	
¾ in. [19.0 mm]	
½ in. [12.5 mm]	
⅜ in. [9.5 mm]	
¼ in. [6.3 mm]	
No. 4 [4.75 mm]	
No. 10 [2.00 mm]	**100.0**
No. 20 [0.850 mm]	
No. 40 [0.425 mm]	**99.7**
No. 60 [0.250 mm]	
No. 100 [0.150 mm]	
No. 200 [0.075 mm]	**98.8**
[0.0281 mm]	**59.3**
[0.0190 mm]	**47.0**
[0.0114 mm]	**39.6**
[0.0081 mm]	**37.1**
[0.0059 mm]	**32.1**
[0.0030 mm]	**22.2**
[0.0014 mm]	**12.4**

Miscellaneous Tests

Test	Result
Liquid Limit @ 25 blows (T 89), %	**21**
Plastic Limit (T 90), %	**15**
Plasticity Index (T 90), %	**6**
Specific Gravity, Corrected to 20°C (T 100)	**2.71**
Loss on Ignition, % (T 267)	
Water Content (T 265), %	**23.5**

Consolidation (T 216)

Trimmings, Water Content, % **29.6**

	Initial	Final		Void Ratio	% Strain
Water Content, %	**33.71**	**22.18**	Pmin		
Dry Density, lbs/ft³	**89.583**	**105.66**	Pp		
Void Ratio	**0.889**	**0.601**	Pmax		
Saturation, %	**102.81**	**100**	Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In. U. Shear tons/ft²	3 In. Remold tons/ft²	6 In. U. Shear tons/ft²	6 In. Remold tons/ft²	Water Content, %	Description of Material Sampled at the Various Tube Depths
0.0-0.5	0.115	0	0.084	0	26.6	Alternating layers of light to dark grey clay, silt lines at 0.75" and 2". Black line runs from 3.75" on left to 4.5" on right.
0.75-1.25	0.084	0	0.094	0	32.7	Alternating layers of light to dark grey clay, black line runs from 9" on left to 10.5" on right.
1.25-1.75	0.105	0	0.136	0.01	32.3	Alternating layers of light to dark grey clay, silt line at 17.25".
1.75-2.0	0.167	0.031			32.3	Alternating layers of light to dark grey clay.

Comments:

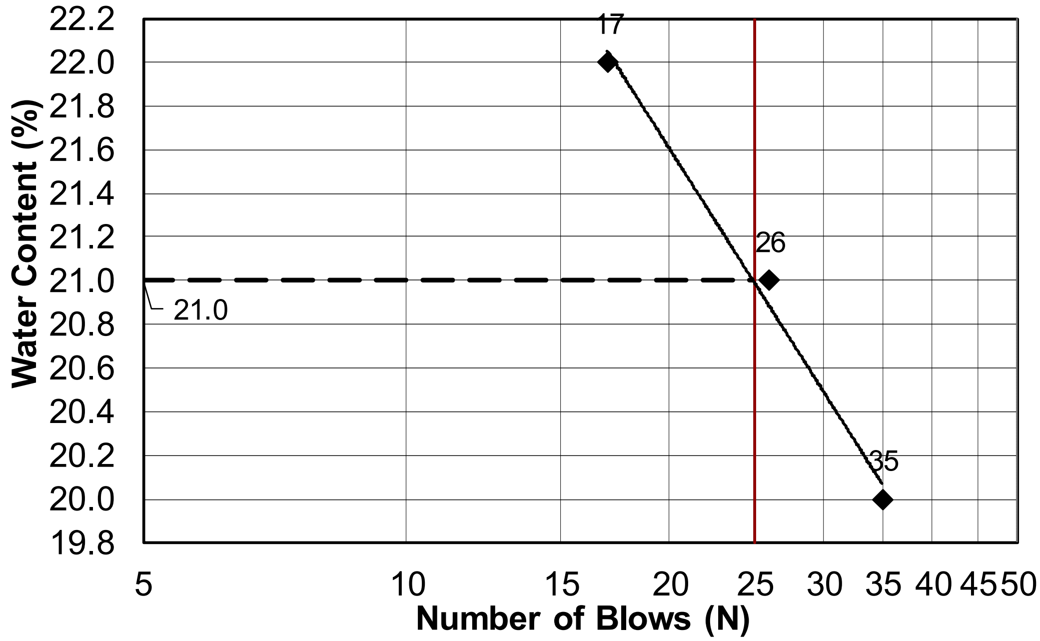
Tube labeled 12-14'. Maine Sensitive loading sequence.

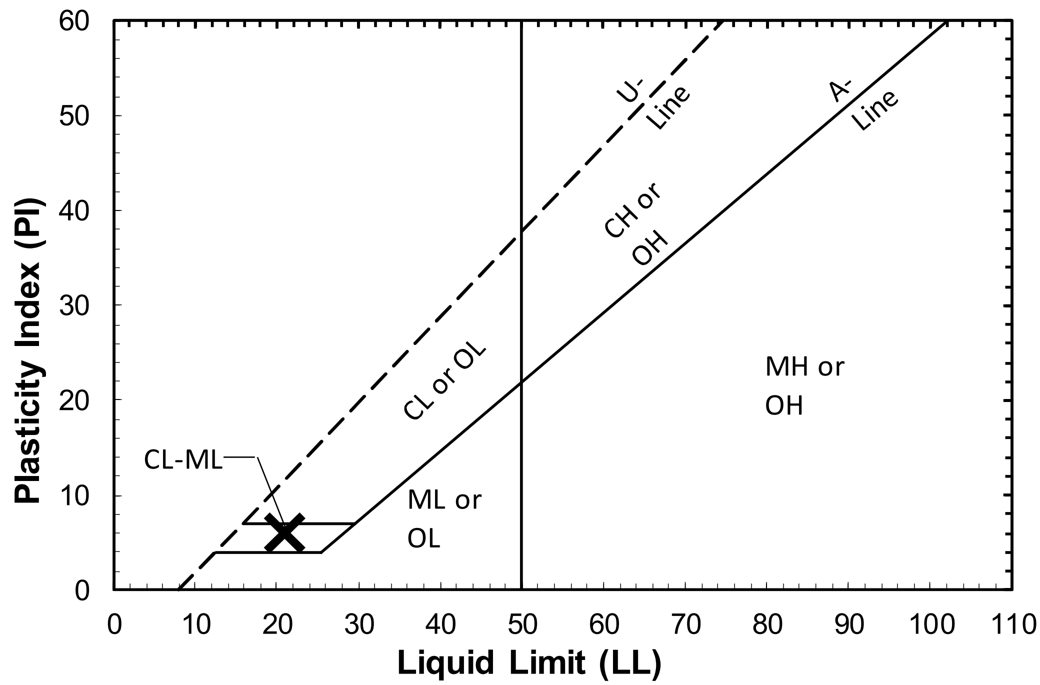
AUTHORIZATION AND DISTRIBUTION

Reported by: **GREGORY LIDSTONE** Date Reported: **1/25/2023**

Paper Copy: Lab File; Project File; Geotech File

TOWN	Vassalboro	Reference No.	303226
WIN	026442.00	Water Content, %	23.5
Sampled	11/15/2022	Liquid Limit @ 25 blows (T 89), %	21
Boring No./Sample No.	BB-VMB-101/1U	Plastic Limit (T 90), %	15
Station	103+66.2	Plasticity Index (T 90), %	6
Depth	5.0-7.0	Tested By	BBURR





GEOTECHNICAL TEST REPORT
Central Laboratory

SAMPLE INFORMATION

Reference No.	Boring No./Sample No.	Sample Description	Sampled	Received
303228	**BB-VMB-101/3D**	**GEOTECHNICAL (DISTURBED)**	**11/15/2022**	**12/7/2022**

Sample Type: **GEOTECHNICAL** Location: Station: **103+66.2** Offset, ft: **5.6 RT** Dbfg, ft: **7.0-9.0**

WIN/Town **026442.00 - VASSALBORO** Sampler: **JAMES MANAHAN**

TEST RESULTS

Sieve Analysis (T 88)

Wash Method

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	
¾ in. [19.0 mm]	
½ in. [12.5 mm]	
⅜ in. [9.5 mm]	
¼ in. [6.3 mm]	
No. 4 [4.75 mm]	**100.0**
No. 10 [2.00 mm]	**99.9**
No. 20 [0.850 mm]	
No. 40 [0.425 mm]	**99.6**
No. 60 [0.250 mm]	
No. 100 [0.150 mm]	
No. 200 [0.075 mm]	**98.9**
[0.0272 mm]	**66.0**
[0.0181 mm]	**59.2**
[0.0114 mm]	**45.6**
[0.0083 mm]	**38.8**
[0.0061 mm]	**31.9**
[0.0031 mm]	**22.8**
[0.0013 mm]	**16.0**

Miscellaneous Tests

Test	Result
Liquid Limit @ 25 blows (T 89), %	**23**
Plastic Limit (T 90), %	**19**
Plasticity Index (T 90), %	**4**
Specific Gravity, Corrected to 20°C (T 100)	**2.72**
Loss on Ignition, % (T 267)	
Water Content (T 265), %	**26.3**

Consolidation (T 216)

Trimmings, Water Content, %

	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In. U. Shear tons/ft²	3 In. Remold tons/ft²	6 In. U. Shear tons/ft²	6 In. Remold tons/ft²	Water Content, %	Description of Material Sampled at the Various Tube Depths

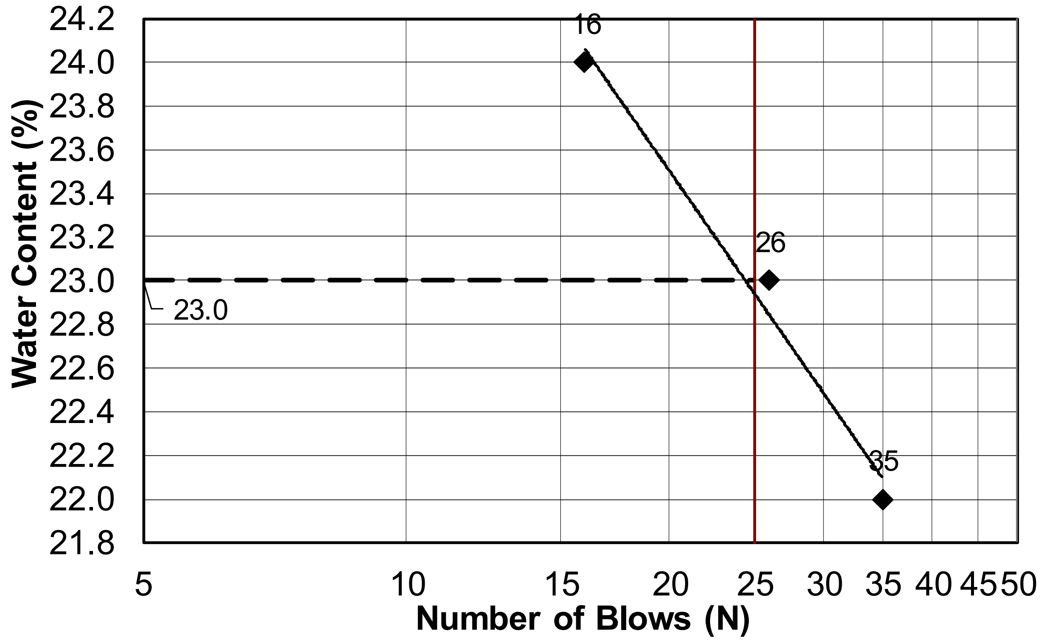
Comments:

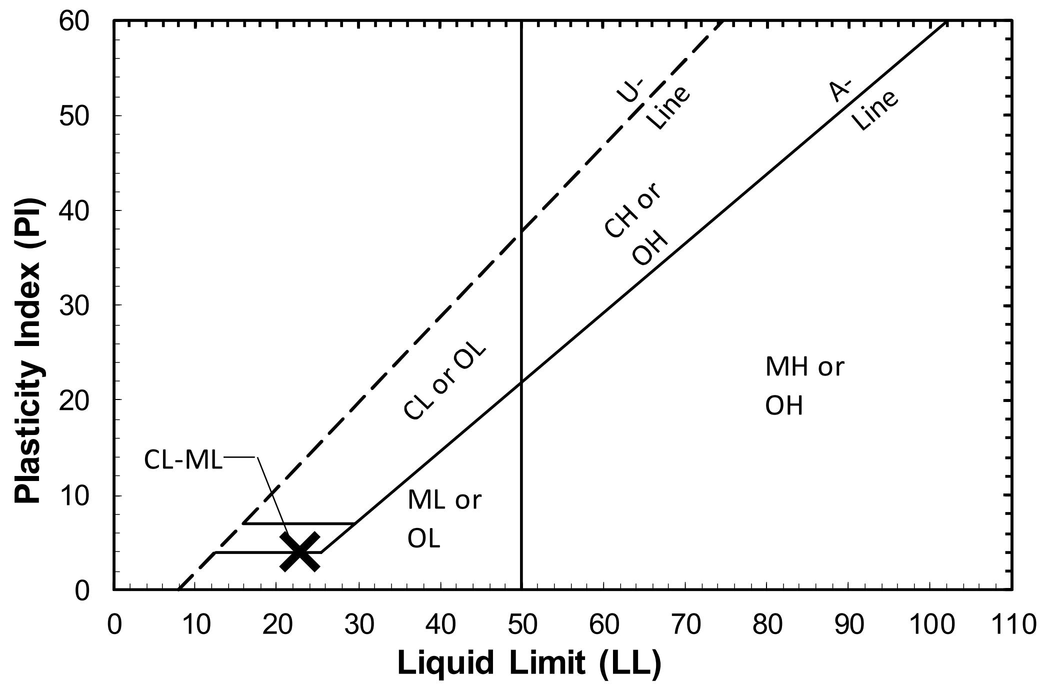
AUTHORIZATION AND DISTRIBUTION

Reported by: **GREGORY LIDSTONE** Date Reported: **1/4/2023**

Paper Copy: Lab File; Project File; Geotech File

TOWN	Vassalboro	Reference No.	303228
WIN	026442.00	Water Content, %	26.3
Sampled	11/15/2022	Liquid Limit @ 25 blows (T 89), %	23
Boring No./Sample No.	BB-VMB-101/3D	Plastic Limit (T 90), %	19
Station	103+66.2	Plasticity Index (T 90), %	4
Depth	7.0-9.0	Tested By	BBURR





GEOTECHNICAL TEST REPORT
Central Laboratory

SAMPLE INFORMATION

Reference No.	Boring No./Sample No.	Sample Description	Sampled	Received
303229	BB-VMB-102/1D	GEOTECHNICAL (DISTURBED)	11/14/2022	12/7/2022

Sample Type: **GEOTECHNICAL** Location: Station: **103+89.9** Offset, ft: **9.7** **LT** Dbfg, ft: **5.0-7.0**

WIN/Town **026442.00 - VASSALBORO** Sampler: **JAMES MANAHAN**

TEST RESULTS

Sieve Analysis (T 27, T 11)

Wash Method: Procedure A

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	
¾ in. [19.0 mm]	100.0
½ in. [12.5 mm]	96.3
⅜ in. [9.5 mm]	94.2
¼ in. [6.3 mm]	90.4
No. 4 [4.75 mm]	87.7
No. 10 [2.00 mm]	80.1
No. 20 [0.850 mm]	73.2
No. 40 [0.425 mm]	68.7
No. 60 [0.250 mm]	65.5
No. 100 [0.150 mm]	62.4
No. 200 [0.075 mm]	55.3

Miscellaneous Tests

Test	Result
Liquid Limit @ 25 blows (T 89), %	
Plastic Limit (T 90), %	
Plasticity Index (T 90), %	
Specific Gravity, Corrected to 20°C (T 100)	
Loss on Ignition, % (T 267)	
Water Content (T 265), %	20.0

Consolidation (T 216)

Trimmings, Water Content, %

	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In. U. Shear tons/ft²	3 In. Remold tons/ft²	6 In. U. Shear tons/ft²	6 In. Remold tons/ft²	Water Content, %	Description of Material Sampled at the Various Tube Depths

Comments:

AUTHORIZATION AND DISTRIBUTION

Reported by: **GREGORY LIDSTONE** Date Reported: **12/13/2022**

Paper Copy: Lab File; Project File; Geotech File

GEOTECHNICAL TEST REPORT
Central Laboratory

SAMPLE INFORMATION

Reference No.	Boring No./Sample No.	Sample Description	Sampled	Received
303230	**BB-VMB-102/2D**	**GEOTECHNICAL (DISTURBED)**	**11/14/2022**	**12/7/2022**

Sample Type: **GEOTECHNICAL** Location: Station: **103+89.9** Offset, ft: **9.7** **LT** Dbfg, ft: **10.0-12.0**

WIN/Town **026442.00 - VASSALBORO** Sampler: **JAMES MANAHAN**

TEST RESULTS

Sieve Analysis (T 88)

Wash Method

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	
¾ in. [19.0 mm]	
½ in. [12.5 mm]	
⅜ in. [9.5 mm]	
¼ in. [6.3 mm]	
No. 4 [4.75 mm]	
No. 10 [2.00 mm]	**100.0**
No. 20 [0.850 mm]	
No. 40 [0.425 mm]	**99.6**
No. 60 [0.250 mm]	
No. 100 [0.150 mm]	
No. 200 [0.075 mm]	**99.2**
[0.0220 mm]	**88.9**
[0.0147 mm]	**81.5**
[0.0093 mm]	**69.1**
[0.0070 mm]	**59.3**
[0.0052 mm]	**51.9**
[0.0027 mm]	**37.0**
[0.0012 mm]	**27.2**

Miscellaneous Tests

Test	Result
Liquid Limit @ 25 blows (T 89), %	**34**
Plastic Limit (T 90), %	**19**
Plasticity Index (T 90), %	**15**
Specific Gravity, Corrected to 20°C (T 100)	**2.79**
Loss on Ignition, % (T 267)	
Water Content (T 265), %	**29.8**

Consolidation (T 216)

Trimmings, Water Content, %

	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In.		6 In.		Water Content, %	Description of Material Sampled at the Various Tube Depths
	U. Shear tons/ft²	Remold tons/ft²	U. Shear tons/ft²	Remold tons/ft²		

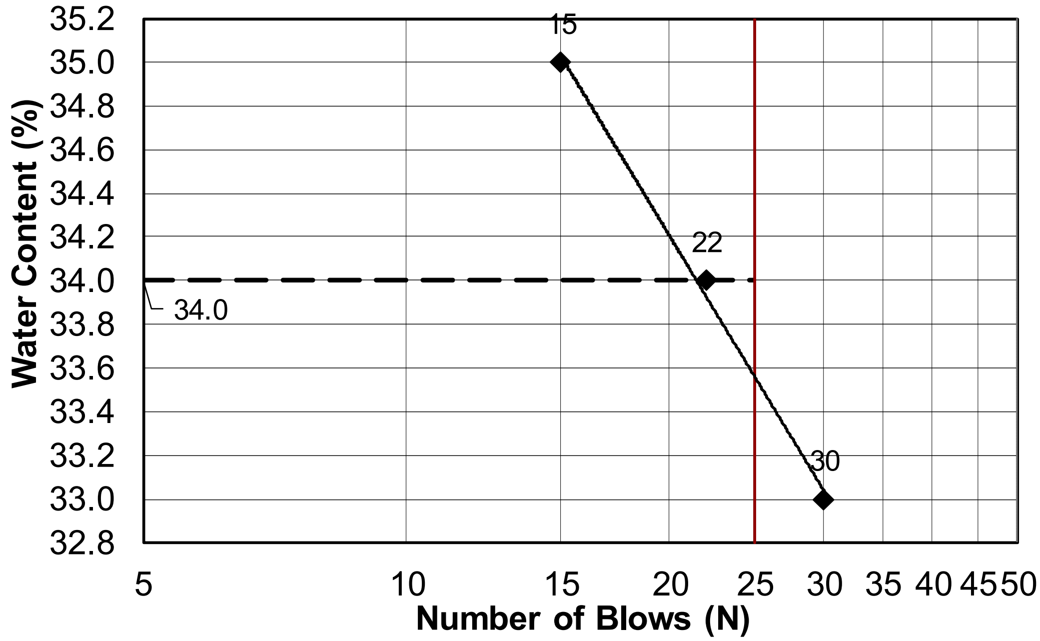
Comments:

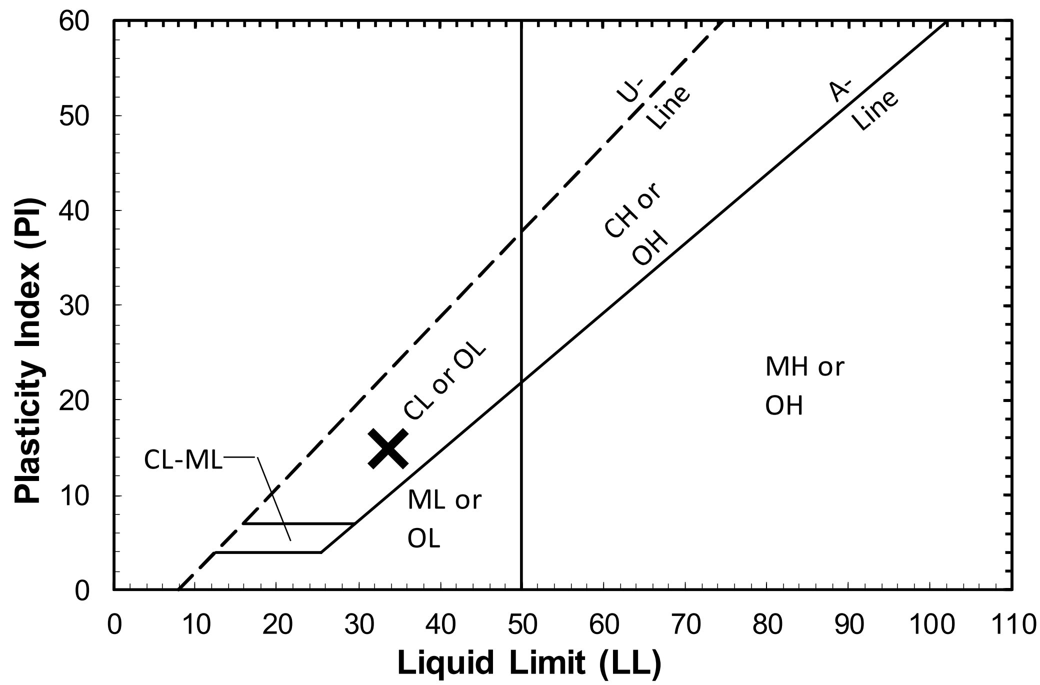
AUTHORIZATION AND DISTRIBUTION

Reported by: **GREGORY LIDSTONE** Date Reported: **1/4/2023**

Paper Copy: Lab File; Project File; Geotech File

TOWN	Vassalboro	Reference No.	303230
WIN	026442.00	Water Content, %	29.8
Sampled	11/14/2022	Liquid Limit @ 25 blows (T 89), %	34
Boring No./Sample No.	BB-VMB-102/2D	Plastic Limit (T 90), %	19
Station	103+89.9	Plasticity Index (T 90), %	15
Depth	10.0-12.0	Tested By	BBURR





GEOTECHNICAL TEST REPORT
Central Laboratory

SAMPLE INFORMATION

Reference No.	Boring No./Sample No.	Sample Description	Sampled	Received
303231	BB-VMB-102/3D	GEOTECHNICAL (DISTURBED)	11/14/2022	12/7/2022

Sample Type: **GEOTECHNICAL** Location: Station: **103+89.9** Offset, ft: **9.7 LT** Dbfg, ft: **15.0-15.5**

WIN/Town **026442.00 - VASSALBORO** Sampler: **JAMES MANAHAN**

TEST RESULTS

Sieve Analysis (T 88)

Wash Method

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	
¾ in. [19.0 mm]	
½ in. [12.5 mm]	
⅜ in. [9.5 mm]	
¼ in. [6.3 mm]	
No. 4 [4.75 mm]	
No. 10 [2.00 mm]	100.0
No. 20 [0.850 mm]	
No. 40 [0.425 mm]	99.8
No. 60 [0.250 mm]	
No. 100 [0.150 mm]	
No. 200 [0.075 mm]	98.8
[0.0271 mm]	60.3
[0.0179 mm]	53.1
[0.0110 mm]	43.4
[0.0081 mm]	33.8
[0.0059 mm]	28.9
[0.0030 mm]	19.3
[0.0013 mm]	12.1

Miscellaneous Tests

Test	Result
Liquid Limit @ 25 blows (T 89), %	
Plastic Limit (T 90), %	
Plasticity Index (T 90), %	
Specific Gravity, Corrected to 20°C (T 100)	2.77
Loss on Ignition, % (T 267)	
Water Content (T 265), %	23.9

Consolidation (T 216)

Trimmings, Water Content, %

	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In. U. Shear tons/ft²	3 In. Remold tons/ft²	6 In. U. Shear tons/ft²	6 In. Remold tons/ft²	Water Content, %	Description of Material Sampled at the Various Tube Depths

Comments:

Insufficient material for Atterburg Limits.

AUTHORIZATION AND DISTRIBUTION

Reported by: **GREGORY LIDSTONE** Date Reported: **1/4/2023**

Paper Copy: Lab File; Project File; Geotech File

GEOTECHNICAL TEST REPORT
Central Laboratory

SAMPLE INFORMATION

Reference No.	Boring No./Sample No.	Sample Description	Sampled	Received
303232	**BB-VMB-102/4D**	**GEOTECHNICAL (DISTURBED)**	**11/14/2022**	**12/7/2022**

Sample Type: **GEOTECHNICAL** Location: Station: **103+89.9** Offset, ft: **9.7 LT** Dbfg, ft: **20.0-21.8**

WIN/Town **026442.00 - VASSALBORO** Sampler: **JAMES MANAHAN**

TEST RESULTS

Sieve Analysis (T 27, T 11)

Wash Method

Procedure A

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	**100.0**
¾ in. [19.0 mm]	**96.7**
½ in. [12.5 mm]	**95.4**
⅜ in. [9.5 mm]	**94.9**
¼ in. [6.3 mm]	**93.8**
No. 4 [4.75 mm]	**93.2**
No. 10 [2.00 mm]	**90.9**
No. 20 [0.850 mm]	**88.6**
No. 40 [0.425 mm]	**86.8**
No. 60 [0.250 mm]	**84.6**
No. 100 [0.150 mm]	**79.9**
No. 200 [0.075 mm]	**62.9**

Miscellaneous Tests

Test	Result
Liquid Limit @ 25 blows (T 89), %	
Plastic Limit (T 90), %	
Plasticity Index (T 90), %	
Specific Gravity, Corrected to 20°C (T 100)	
Loss on Ignition, % (T 267)	
Water Content (T 265), %	**16.7**

Consolidation (T 216)

Trimmings, Water Content, %	

	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In.		6 In.		Water Content, %	Description of Material Sampled at the Various Tube Depths
	U. Shear tons/ft²	Remold tons/ft²	U. Shear tons/ft²	Remold tons/ft²		

Comments:

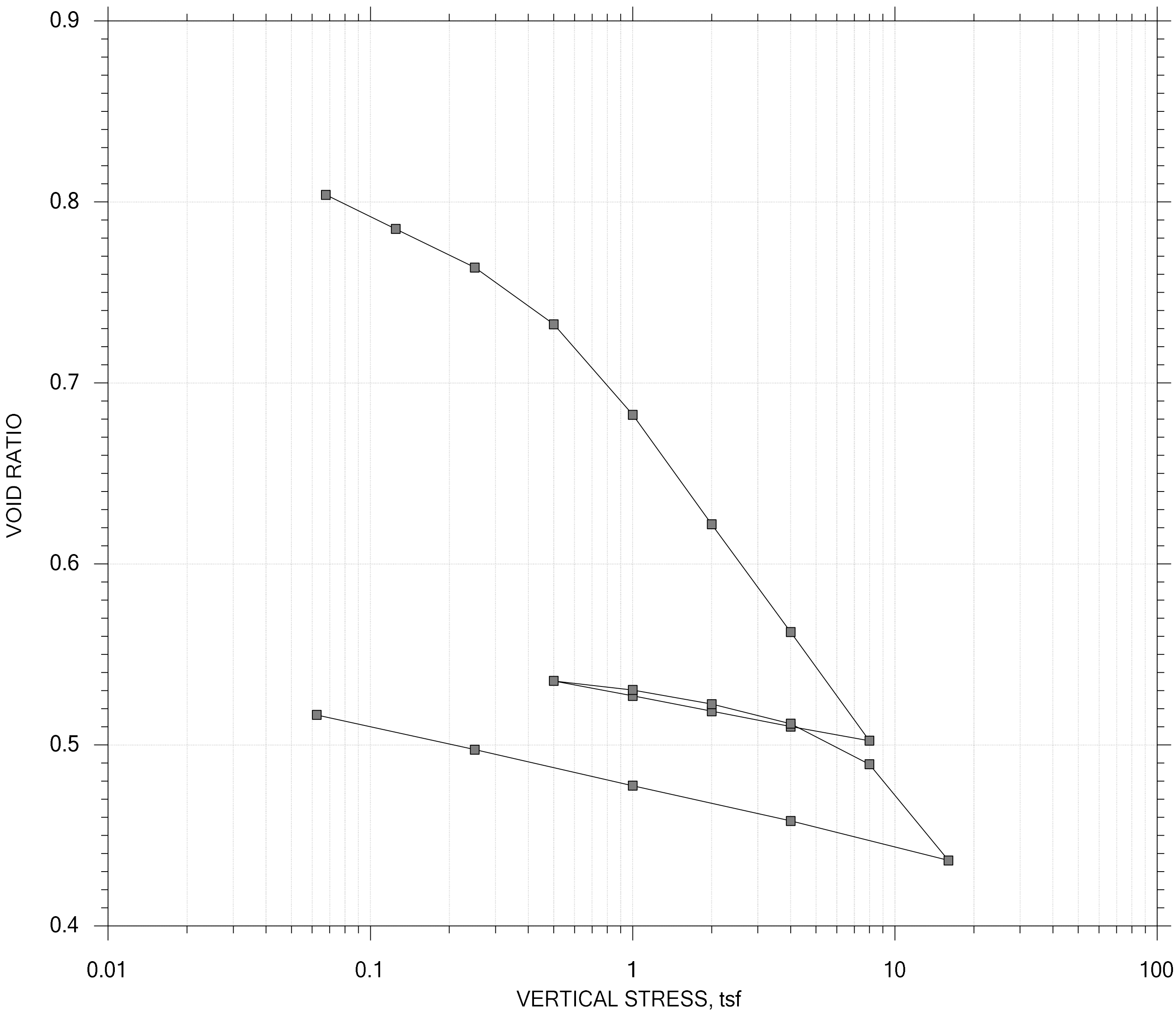
AUTHORIZATION AND DISTRIBUTION

Reported by: **GREGORY LIDSTONE** Date Reported: **12/13/2022**

Paper Copy: Lab File; Project File; Geotech File

One-Dimensional Consolidation by ASTM D2435 - Method B

SUMMARY REPORT

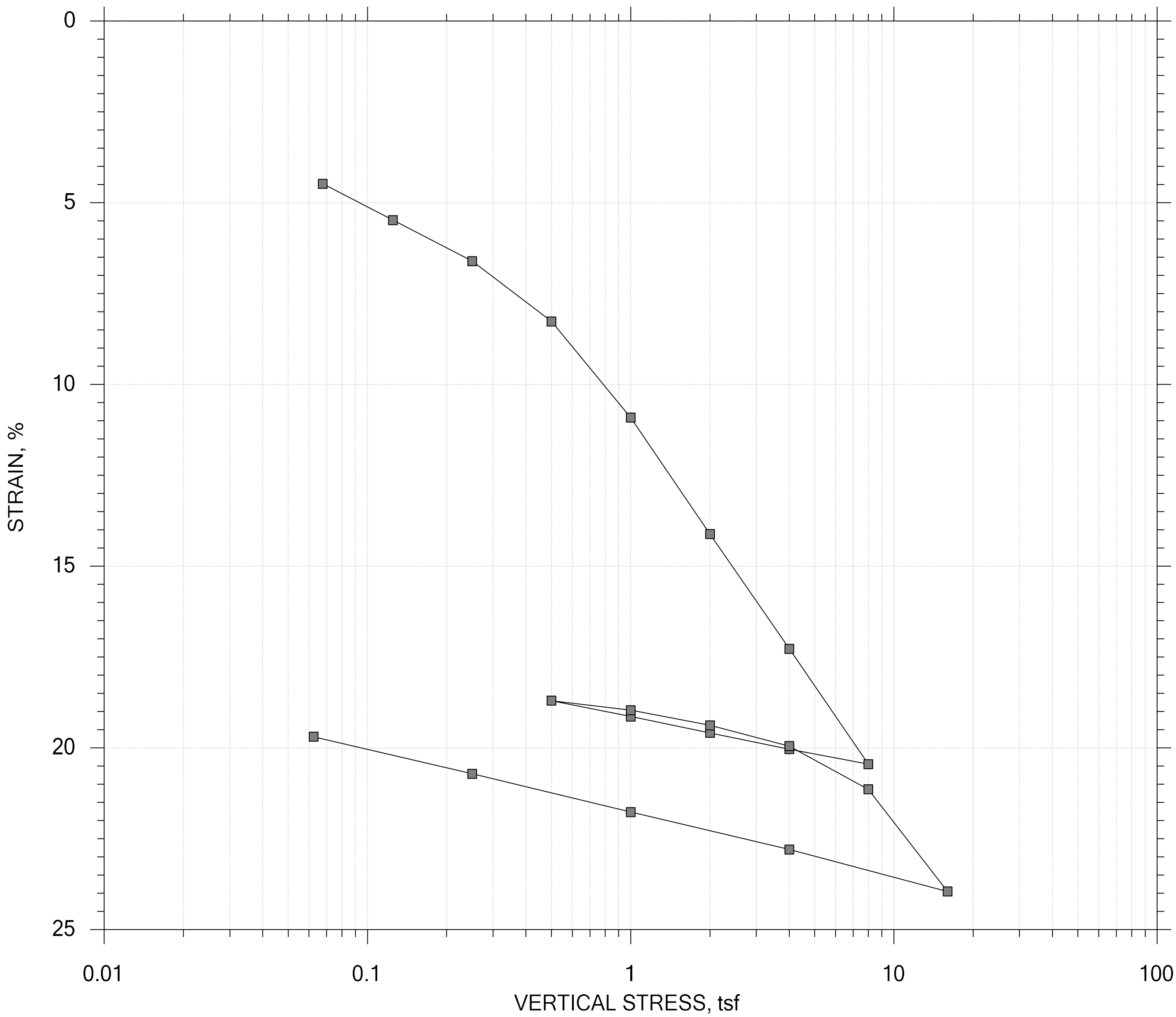


					Before Test	After Test
Current Vertical Effective Stress: ---				Water Content, %	33.71	22.18
Preconsolidation Stress: ---				Dry Unit Weight, pcf	89.583	105.66
Compression Ratio: ---				Saturation, %	102.81	100.00
Diameter: 2.495 in		Height: 1.002 in		Void Ratio	0.89	0.60
LL: 21	PL: 15	PI: 6	GS: 2.71			

	Project: Vassalboro	Location: --	Project No.: 26442.00
	Boring No.: BB-VMB-101	Tested By: GSL	Checked By: --
	Sample No.: 1U	Test Date: 1/5/2023	Test No.: 303226
	Depth: 5.0-7.0 FT	Sample Type: Intact	Elevation: --
	Description: Grey Clay		
	Remarks: Maine Sensitive Loading/Unloading Sequence		
	Displacement at End of Increment		

One-Dimensional Consolidation by ASTM D2435 - Method B

SUMMARY REPORT



					Before Test	After Test
Current Vertical Effective Stress: ---				Water Content, %	33.71	22.18
Preconsolidation Stress: ---				Dry Unit Weight, pcf	89.583	105.66
Compression Ratio: ---				Saturation, %	102.81	100.00
Diameter: 2.495 in		Height: 1.002 in		Void Ratio	0.89	0.60
LL: 21	PL: 15	PI: 6	GS: 2.71			

	Project: Vassalboro	Location: --	Project No.: 26442.00
	Boring No.: BB-VMB-101	Tested By: GSL	Checked By: --
	Sample No.: 1U	Test Date: 1/5/2023	Test No.: 303226
	Depth: 5.0-7.0 FT	Sample Type: Intact	Elevation: --
	Description: Grey Clay		
	Remarks: Maine Sensitive Loading/Unloading Sequence		
	Displacement at End of Increment		

One-Dimensional Consolidation by ASTM D2435 - Method B

Project: Vassalboro	Location: --	Project No.: 26442.00
Boring No.: BB-VMB-101	Tested By: GSL	Checked By: --
Sample No.: 1U	Test Date: 1/5/2023	Depth: 5.0-7.0 FT
Test No.: 303226	Sample Type: Intact	Elevation: --

Soil Description: Grey Clay
Remarks: Maine Sensitive Loading/Unloading Sequence

Measured Specific Gravity: 2.71	Liquid Limit: 21	Specimen Diameter: 2.50 in
Initial Void Ratio: 0.889	Plastic Limit: 15	Initial Height: 1.00 in
Final Void Ratio: 0.601	Plasticity Index: 6	Final Height: 0.85 in

	Before Consolidation		After Consolidation	
	Trimmings	Specimen+Ring	Specimen+Ring	Trimmings
Container ID	173	RING	RING & BASE	208
Wt. Container + Wet Soil, gm	104.51	416.06	402.78	204.12
Wt. Container + Dry Soil, gm	92.600	377.23	377.23	178.81
Wt. Container, gm	52.290	262.03	262.03	64.700
Wt. Dry Soil, gm	40.310	115.20	115.20	114.11
Water Content, %	29.55	33.71	22.18	22.18
Void Ratio	---	0.889	0.601	---
Degree of Saturation, %	---	102.81	100.00	---
Dry Unit Weight, pcf	---	89.583	105.66	---

One-Dimensional Consolidation by ASTM D2435 - Method B

Project: Vassalboro
Boring No.: BB-VMB-101
Sample No.: 1U
Test No.: 303226

Location: --
Tested By: GSL
Test Date: 1/5/2023
Sample Type: Intact

Project No.: 26442.00
Checked By: --
Depth: 5.0-7.0 FT
Elevation: --

Soil Description: Grey Clay
Remarks: Maine Sensitive Loading/Unloading Sequence

Displacement at End of Increment

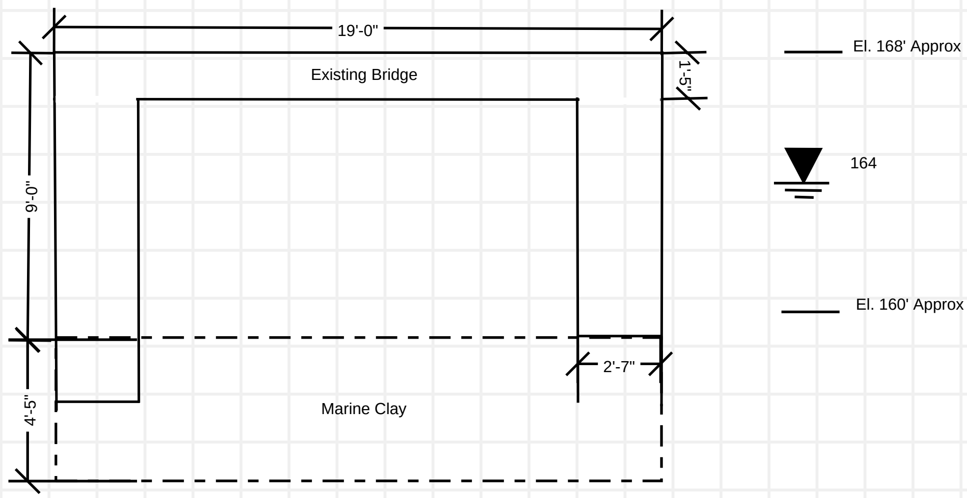
	Applied Stress tsf	Final Displacement in	Void Ratio	Strain at End %	Sq.Rt T90 min	Cv ft²/sec	Mv 1/tsf	k ft/day
1	0.0676	0.04485	0.804	4.48	17.847	1.32e-006	6.62e-001	2.36e-003
2	0.125	0.05486	0.785	5.48	6.989	3.18e-006	1.74e-001	1.49e-003
3	0.250	0.06617	0.764	6.60	7.943	2.74e-006	9.03e-002	6.67e-004
4	0.500	0.08281	0.732	8.26	7.511	2.81e-006	6.64e-002	5.03e-004
5	1.00	0.1093	0.682	10.9	7.512	2.68e-006	5.30e-002	3.83e-004
6	2.00	0.1414	0.622	14.1	6.416	2.94e-006	3.20e-002	2.54e-004
7	4.00	0.1730	0.562	17.3	3.343	5.24e-006	1.58e-002	2.23e-004
8	8.00	0.2049	0.502	20.4	2.080	7.80e-006	7.94e-003	1.67e-004
9	4.00	0.2007	0.510	20.0	0.204	7.69e-005	1.03e-003	2.15e-004
10	2.00	0.1962	0.519	19.6	0.422	3.75e-005	2.23e-003	2.26e-004
11	1.00	0.1917	0.527	19.1	0.780	2.05e-005	4.51e-003	2.50e-004
12	0.500	0.1874	0.535	18.7	2.643	6.13e-006	8.70e-003	1.44e-004
13	1.00	0.1900	0.530	19.0	1.653	9.82e-006	5.27e-003	1.39e-004
14	2.00	0.1941	0.523	19.4	0.596	2.70e-005	4.14e-003	3.02e-004
15	4.00	0.1999	0.512	20.0	0.495	3.21e-005	2.87e-003	2.49e-004
16	8.00	0.2118	0.489	21.1	1.920	8.10e-006	2.97e-003	6.49e-005
17	16.0	0.2400	0.436	23.9	1.357	1.09e-005	3.51e-003	1.03e-004
18	4.00	0.2284	0.458	22.8	1.344	1.08e-005	9.63e-004	2.79e-005
19	1.00	0.2181	0.478	21.8	0.769	1.93e-005	3.44e-003	1.79e-004
20	0.250	0.2075	0.497	20.7	3.168	4.82e-006	1.40e-002	1.83e-004
21	0.0625	0.1973	0.517	19.7	10.276	1.53e-006	5.42e-002	2.23e-004

	Applied Stress tsf	Final Displacement in	Void Ratio	Strain at End %	Log T50 min	Cv ft²/sec	Mv 1/tsf	k ft/day	Ca %
1	0.0676	0.04485	0.804	4.48	2.291	2.39e-006	6.62e-001	4.26e-003	0.00e+000
2	0.125	0.05486	0.785	5.48	1.897	2.72e-006	1.74e-001	1.28e-003	0.00e+000
3	0.250	0.06617	0.764	6.60	1.975	2.56e-006	9.03e-002	6.23e-004	0.00e+000
4	0.500	0.08281	0.732	8.26	1.889	2.60e-006	6.64e-002	4.65e-004	0.00e+000
5	1.00	0.1093	0.682	10.9	1.985	2.36e-006	5.30e-002	3.37e-004	0.00e+000
6	2.00	0.1414	0.622	14.1	1.207	3.63e-006	3.20e-002	3.13e-004	0.00e+000
7	4.00	0.1730	0.562	17.3	0.698	5.83e-006	1.58e-002	2.48e-004	0.00e+000
8	8.00	0.2049	0.502	20.4	0.448	8.40e-006	7.94e-003	1.80e-004	0.00e+000
9	4.00	0.2007	0.510	20.0	0.000	0.00e+000	1.03e-003	0.00e+000	0.00e+000
10	2.00	0.1962	0.519	19.6	0.000	0.00e+000	2.23e-003	0.00e+000	0.00e+000
11	1.00	0.1917	0.527	19.1	0.198	1.88e-005	4.51e-003	2.29e-004	0.00e+000
12	0.500	0.1874	0.535	18.7	0.484	7.77e-006	8.70e-003	1.82e-004	0.00e+000
13	1.00	0.1900	0.530	19.0	0.000	0.00e+000	5.27e-003	0.00e+000	0.00e+000
14	2.00	0.1941	0.523	19.4	0.130	2.88e-005	4.14e-003	3.22e-004	0.00e+000
15	4.00	0.1999	0.512	20.0	0.120	3.08e-005	2.87e-003	2.39e-004	0.00e+000
16	8.00	0.2118	0.489	21.1	0.177	2.04e-005	2.97e-003	1.63e-004	0.00e+000
17	16.0	0.2400	0.436	23.9	0.213	1.61e-005	3.51e-003	1.53e-004	0.00e+000
18	4.00	0.2284	0.458	22.8	0.000	0.00e+000	9.63e-004	0.00e+000	0.00e+000
19	1.00	0.2181	0.478	21.8	0.211	1.64e-005	3.44e-003	1.52e-004	0.00e+000
20	0.250	0.2075	0.497	20.7	1.083	3.28e-006	1.40e-002	1.24e-004	0.00e+000
21	0.0625	0.1973	0.517	19.7	4.134	8.82e-007	5.42e-002	1.29e-004	0.00e+000

APPENDIX E – CALCULATIONS

Objective: Calculate the net pressure from the existing culverts and the proposed culvert at the elevation of the bottom of the proposed bearing pad.

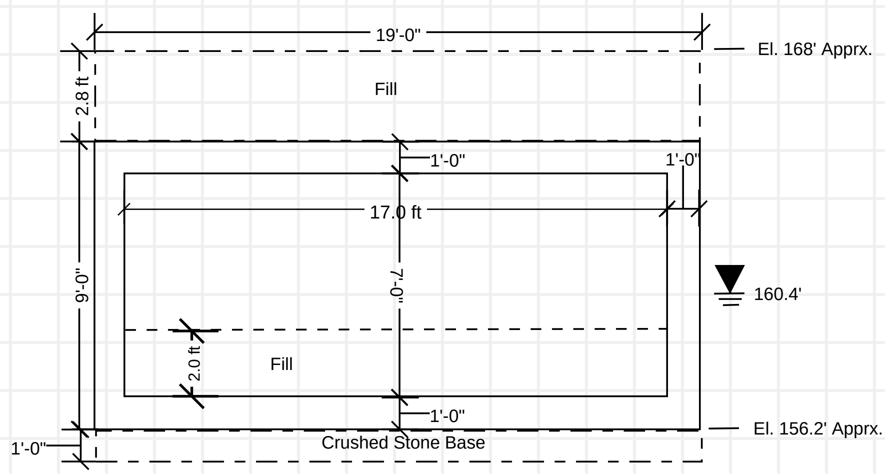
Existing Bridge Sketch and Pressure Calculation:



The plans indicate that the footings should be extended to a suitable foundation layer. The plans do not indicate the as-built elevations or bearing stratum. However, the recent boring drilled through the bridge and in the stream indicates Marine clay is present. The existing structure spans the marine clay, whereas the proposed structure will partially bear directly on the clay. Therefore the existing effective stress at the bearing elevation is based on the soils between the existing abutments.

Average effective stress in channel = (120 pcf - 62.4 pcf) x 4.5') = 260 psf

Proposed Box Culvert Sketch and Pressure Calculation:



Area of open box culvert = 7' x 17' = 119 sf

Weight of Concrete = [(2(18+8)) x 1 x150 pcf]/ 19 feet = 411 psf

Weight of Fill above, Fill in (2'), and Crushed Stone below box = (2.8' x 125 pcf) + (2' x 125 pcf) + (1' x (115 pcf - 62.4pcf)) = 653 psf

Weight of Concrete and Soil = 411 psf + 528 psf = 1064 psf

Conclusion:

The net pressure at the base of the bearing pad below the proposed culvert is approximately 804 psf greater than the existing, therefore consolidation of the thin layer of underlying clay should be checked.

Meadow Brook Bridge - Vassalboro	
SETTLEMENT due to proposed Fill/culvert	
Vassalboro, ME	
GZA File No. 09.0026222.00	
Calc By: B.Cardali	10/28/2024
Check By: C. Snow	11/13/2024

Secondary		
First paving cycle 15 yrs Post construction	t2 (days) :	5475
	t	0.848
	U	0.90

Layer	Depth (ft) top/mid/bot (below bot of load)	Thick. (ft)	Original Embankment Stress Influence (psf)	In-Situ Stress (psf)	Final Stress (psf)	Max. Prev. Stress (psf)	RR	CR	RECOMPRESSION SETTLEMENT RR H log(Po+dP/Po) (in)	VIRGIN COMPR. SETTLEMENT CR H log(Po+dP/Pmax) (in)	TOTAL CONSOL. SETTLEMENT (in)	Stress Ratio	Calpha	Second Settlement (in) **Per cycle**	thickness (ft)	Cv (ft^2/day)	t90 (primary) (days)	t2/t1	log(t2/t1) (cycles) 15 yr	Ss (in)
	0																			
Clay	1.65	3.3	0	260	1064	1180	0.017	0.13	0.41	0.00	0.41	0.90	0.004	0.16	3.3	0.7	3	1660.04	3.22	0.51
	3.3			(See Net Pressure Calc)																
Total Clay Thickness	*3.3*																			
TOTAL		3.3							0.00	0.00	0.41			0.16						0.51

Notes 1. Use Bousinessq stress bulb to apply influence factor at the midpoint of each cohesive layer for the footing load. Apply full fill surcharge from fill (no stress re
2. Initial and Final stress calculated in net pressure calculation, (see Appendix E) and are directly input into the calculation.

Reference Ladd Figure 4-2, Portsmouth NH Sensitive Clay (below)
Use the Stress Ratio for LADD Fig

		Settlement (in)
Primary (Sc)		0.41
Secondary	15 yr	0.51
Total		0.92

Primary is anticipated to occur prior to final paving, therefore post construction settlement is anticipated to be 0.5 inches or less.

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Engineers and Scientists

Objective

Calculate soil bearing resistance for a culvert bearing on naturally deposited marine clay over glacial outwash. Evaluate strength and service bearing resistance at the top of the clay.

References

1. American Association of State Highway and Transportation Officials, AASHTO LRFD Bridge Design Specifications: Customary U.S. Units, 9th edition, 2020, (AASHTO LRFD), Articles 10.5.5.2.2 and 10.6.3.1.
2. Terzaghi, Peck & Mesri, Soil Mechanics in Engineering Practice, Third Edition, 1996.

Soil Properties and Geotechnical Inputs

$\phi_f := 0\text{deg}$ Internal friction angle

$\phi_b := .5$ Bearing resistance factor as specified in Table 10.5.5.2.2-1 (Theoretical Method, SPT Data, Strength Limit, Spread Footing)

$c := .6\text{ksf}$ Cohesion of the Marine Clay (base), taken as undrained shear strength

$\gamma := 118\text{pcf}$ Unit weight of soil above or below the bearing depth of the footing

$N_c := 5.14$ Cohesion term bearing capacity factor as specified in Table 10.6.3.1.2a-1

$N_q := 1$ Surcharge term bearing capacity factor as specified in Table 10.6.3.1.2a-1

$N_\gamma := 0$ Total unit weight term bearing capacity factor as specified in Table 10.6.3.1.2a-1

$C_{wq}, C_{w\gamma}:=$ Correction factors to account for the location of the groundwater table as specified in Table 10.6.3.1.2a-2

Depth to water table at or below depth of footing (D_f) $C_{wq} := 0.5$ $C_{w\gamma} := 0.5$

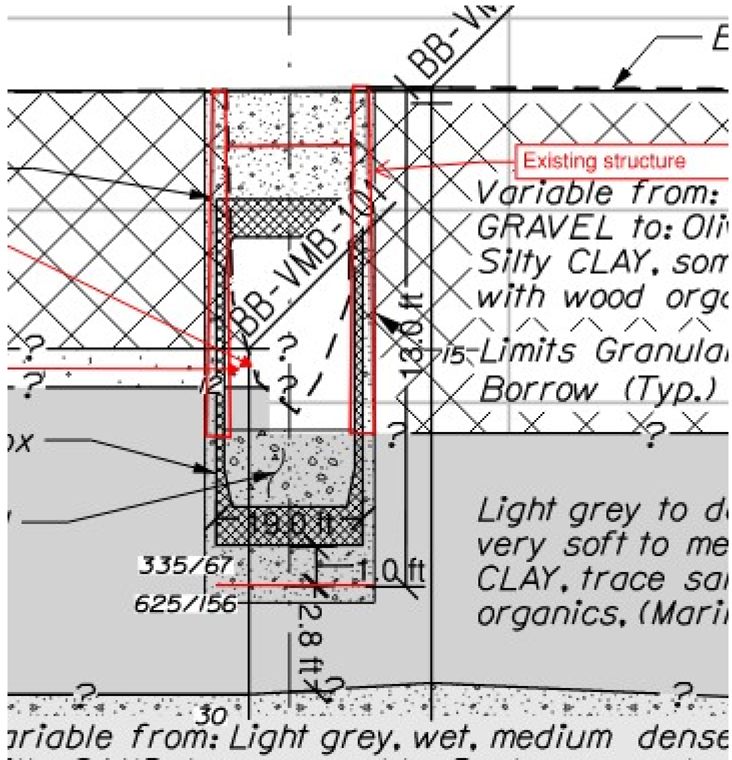
Footing Dimensions

$B_{1.max} := 19 \cdot ft$ Maximum Footing Width at top of clay (Plans show a 19' wide culvert)

$B_1 := 15 \cdot ft, 17 \cdot ft .. B_{1.max}$ Range of effective footing widths considered (includes eccentricity)

$L_1 := 64ft$ Length of culvert Base

$D_f := 12ft$ Footing embedment depth



Strength Limit Design

$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + 0.5 \gamma B N_{\gamma m} C_{w\gamma}$ Nominal Bearing Resistance Formula

$q.D = \phi_b \times q_n$ Factored Bearing Resistance Formula

Correction Factors

$d_{qtable}(B_1) := \frac{D_f}{B_1}$

$d_{qtable}(B_1)$ Using Table 10.6.3.1.2a-4

$d_q := 1$ dq assumed soil above footing less competent than soil below footing.

$s_c(B_1) := 1 + \left(\frac{B_1}{L_1}\right)\left(\frac{N_q}{N_c}\right)$

$s_q(B_1) := 1 + \left(\frac{B_1}{L_1} \tan(\phi_f)\right)$

$s_\gamma(B_1) := 1 - 0.4\left(\frac{B_1}{L_1}\right)$

$s_c(B_1) =$	$s_q(B_1) =$	$s_\gamma(B_1) =$
1.05	1	0.91
1.05	1	0.89
1.06	1	0.88

Bearing Capacity Factors

$N_{cm}(B_1) := N_c \cdot s_c(B_1)$ $\quad N_{cm}(B_1) = \begin{bmatrix} 5.37 \\ 5.41 \\ 5.44 \end{bmatrix}$

$N_{qm}(B_1) := N_q \cdot s_q(B_1) \cdot d_q$ $\quad N_{qm}(B_1) = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$

$N_{\gamma m}(B_1) := N_\gamma \cdot s_\gamma(B_1)$ $\quad N_{\gamma m}(B_1) = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$

Nominal Bearing Resistance

$$q_n(B_1) := \overrightarrow{\left(c \cdot N_{cm}(B_1) + \gamma \cdot D_f \cdot N_{qm}(B_1) \cdot C_{wq} + 0.5 \cdot \gamma \cdot B_1 \cdot N_{\gamma m}(B_1) \cdot C_{w\gamma}\right)}$$

$q_n(B_1) = \begin{bmatrix} 3.9 \\ 4 \\ 4 \end{bmatrix} \cdot ksf$

Factored Bearing Resistance - Strength Limit State

$q_D(B_1) := \phi_b \cdot q_n(B_1)$

$q_D(B_1) = \begin{bmatrix} 2 \\ 2 \\ 2 \end{bmatrix} \cdot ksf$ $\quad$ for $\quad B_1 = \begin{bmatrix} 15 \\ 17 \\ 19 \end{bmatrix} \cdot ft$

Service Limit Design

GZA calculated the proposed and existing effective stress at the proposed culvert base elevation (see calculation in Appendix E). The proposed construction will result in an increase in pressure. GZA's settlement calculation estimates up to 1 inch of post-construction settlement.

AASHTO provides Table C10.6.2.5.1-1 (attached) of presumptive bearing resistances of spread footings when a settlement limited bearing resistance is required. This table may be used with sufficient knowledge of the geological conditions present at the site. Considering GZA's experience with the underlying Presumpscot formation clay, GZA recommends utilizing a service bearing resistance of 2 ksf, based on a homogeneous inorganic clay, sandy or silty clay (CL,CH) that is medium stiff.

Type of Bearing Material	Consistency in Place	Bearing Resistance (ksf)	
		Ordinary Range	Recommended Value
Homogeneous Inorganic clay, sandy or silty clay (CL,CH)	Medium stiiff to stiff	2 - 6	2

Table C10.6.2.5.1-1—Presumptive Bearing Resistance for Spread Footing Foundations at the Service Limit State Modified after U.S. Department of the Navy (1982)

Type of Bearing Material	Consistency in Place	Bearing Resistance (ksf) Ordinary Range	Bearing Resistance (ksf) Recommended Value of Use
Massive crystalline igneous and metamorphic rock: granite, diorite, basalt, gneiss, thoroughly cemented conglomerate (sound condition allows minor cracks)	Very hard, sound rock	120–200	160
Foliated metamorphic rock: slate, schist (sound condition allows minor cracks)	Hard sound rock	60–80	70
Sedimentary rock: hard cemented shales, siltstone, sandstone, limestone without cavities	Hard sound rock	30–50	40
Weathered or broken bedrock of any kind, except highly argillaceous rock (shale)	Medium hard rock	16–24	20
Compaction shale or other highly argillaceous rock in sound condition	Medium hard rock	16–24	20
Well-graded mixture of fine- and coarse-grained soil: glacial till, hardpan, boulder clay (GW-GC, GC, SC)	Very dense	16–24	20
Gravel, gravel-sand mixture, boulder-gravel mixtures (GW, GP, SW, SP)	Very dense Medium dense to dense Loose	12–20 8–14 4–12	14 10 6
Coarse to medium sand, and with little gravel (SW, SP)	Very dense Medium dense to dense Loose	8–12 4–8 2–6	8 6 3
Fine to medium sand, silty or clayey medium to coarse sand (SW, SM, SC)	Very dense Medium dense to dense Loose	6–10 4–8 2–4	6 5 3
Fine sand, silty or clayey medium to fine sand (SP, SM, SC)	Very dense Medium dense to dense Loose	6–10 4–8 2–4	6 5 3
Homogeneous inorganic clay, sandy or silty clay (CL, CH)	Very dense Medium dense to dense Loose	6–12 2–6 1–2	8 4 1
Inorganic silt, sandy or clayey silt, varved silt-clay-fine sand (ML, MH)	Very stiff to hard Medium stiff to stiff Soft	4–8 2–6 1–2	6 3 1

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707 Sable Oaks Drive
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South Portland, Maine 04106
207-879-9190
Fax 207-879-0099

Engineers and Scientists

Table 10.6.3.1.2a-1—Bearing Capacity Factors N_c (Prandtl, 1921), N_q (Reissner, 1924), and N_γ (Vesic, 1975)

ϕ_f	N_c	N_q	N_γ	ϕ_f	N_c	N_q	N_γ
0	5.14	1.0	0.0	23	18.1	8.7	8.2
1	5.4	1.1	0.1	24	19.3	9.6	9.4
2	5.6	1.2	0.2	25	20.7	10.7	10.9
3	5.9	1.3	0.2	26	22.3	11.9	12.5
4	6.2	1.4	0.3	27	23.9	13.2	14.5
5	6.5	1.6	0.5	28	25.8	14.7	16.7
6	6.8	1.7	0.6	29	27.9	16.4	19.3
7	7.2	1.9	0.7	30	30.1	18.4	22.4
8	7.5	2.1	0.9	31	32.7	20.6	26.0
9	7.9	2.3	1.0	32	35.5	23.2	30.2
10	8.4	2.5	1.2	33	38.6	26.1	35.2
11	8.8	2.7	1.4	34	42.2	29.4	41.1
12	9.3	3.0	1.7	35	46.1	33.3	48.0
13	9.8	3.3	2.0	36	50.6	37.8	56.3
14	10.4	3.6	2.3	37	55.6	42.9	66.2
15	11.0	3.9	2.7	38	61.4	48.9	78.0
16	11.6	4.3	3.1	39	67.9	56.0	92.3
17	12.3	4.8	3.5	40	75.3	64.2	109.4
18	13.1	5.3	4.1	41	83.9	73.9	130.2
19	13.9	5.8	4.7	42	93.7	85.4	155.6
20	14.8	6.4	5.4	43	105.1	99.0	186.5
21	15.8	7.1	6.2	44	118.4	115.3	224.6
22	16.9	7.8	7.1	45	133.9	134.9	271.8

Table 10.6.3.1.2a-2—Coefficients C_{wq} and $C_{w\gamma}$ for Various Groundwater Depths

D_w	C_{wq}	$C_{w\gamma}$
0.0	0.5	0.5
D_f	1.0	0.5
$>1.5B + D_f$	1.0	1.0

Where the position of groundwater is at a depth less than 1.5 times the footing width below the footing base, the bearing resistance is affected. The highest anticipated groundwater level should be used in design.

Table 10.6.3.1.2a-3—Shape Correction Factors s_c, s_γ, s_q

Factor	Friction Angle	Cohesion Term (s_c)	Unit Weight Term (s_γ)	Surcharge Term (s_q)

Shape Factors s_c, s_γ, s_q	$\phi_f = 0$	$1+\left(\frac{B}{5L}\right)$	1.0	1.0
	$\phi_f > 0$	$1+\left(\frac{B}{L}\right)\left(\frac{N_q}{N_c}\right)$	$1-0.4\left(\frac{B}{L}\right)$	$1+\left(\frac{B}{L}\tan\phi_f\right)$

Table 10.6.3.1.2a-4—Depth Correction Factor d_q

Friction Angle, ϕ_f (degrees)	D_f/B	d_q
32	1	1.20
	2	1.30
	4	1.35
	8	1.40
37	1	1.20
	2	1.25
	4	1.30
	8	1.35
42	1	1.15
	2	1.20
	4	1.25
	8	1.30

The depth correction factor should be used only when the soils above the footing bearing elevation are as competent as the soils beneath the footing level; otherwise, the depth correction factor should be taken as 1.0.

Linear interpolations may be made for friction angles in between those values shown in Table 10.6.3.1.2a-4.

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Engineers and Scientists

JOB: 09.0026222.00 Vassalboro - Meadow Brook Bridge
SUBJECT: Lateral Earth Pressures
SHEET: 1 OF 1
CALCULATED BY B.Cardali 10/28/24
CHECKED BY S.Snow 10/28/24

Subject:

Evaluate lateral earth pressure coefficients for a precast box culvert walls, inlet and outlet walls.

References:

1. MaineDOT Bridge Design Guide, Chapter 3
2. AASHTO LRFD Bridge Design Specifications, 9th Edition (2020)
3. U.S. Army Corps of Engineers Engineer Manual 1110-2-2502, Retaining and Flood Walls

Input Parameters:

$\phi := 32deg$ Effective angle of internal friction *(Granular borrow, Soil Type 4, BDG Table 3-3)*

$\delta_f := 19.5deg$ Average value, precast concrete against clean sand/silty sand-gravel mixture *(AASHTO LRFD Table 3.11.5.3-1)*

$\beta := 26.6deg$ Angle of backfill to the horizontal (Sheets 23 & 24, PIC Plans 2022-10-12)

$\theta := 90 \cdot deg$ Angle of back face of wall to the horizontal

Earth Pressure Coefficients:

Outlet Walls Fixed to Box Culvert:

Assume translation and rotation of culvert with inlet and outlet walls is inadequate to achieve active earth pressure. Therefore, design for at-rest earth pressure.

$\boxed{K_o := 1 - \sin(\phi) = 0.47}$ At-rest Earth Pressure Coefficient, Level Ground

Outlet Walls free to rotate:

The earth pressure is applied to a plane extedning vertically up from the heel of the wall base, and the weight of the soil on the inside of the vertical plane is considereed as part of the wall weight. The failure sliding surface is not restricted by the top of the wall or back face of wall. Use Rankine theory for active earth pressure.

For unsupported culvert walls extending beyond the box, with horizontal backslope:

$$K_{ar} := \tan\left(45deg - \frac{\phi}{2}\right)^2 \qquad \boxed{K_{ar} = 0.31}$$

For a sloped 2H:1V backfill:

$$K_{ar} := \cos(\beta) \cdot \frac{\left[\cos(\beta) - \sqrt{(\cos(\beta))^2 - (\cos(\phi))^2}\right]}{\left[\cos(\beta) + \sqrt{(\cos(\beta))^2 - (\cos(\phi))^2}\right]} \qquad \boxed{K_{ar} = 0.31}$$

March 2014

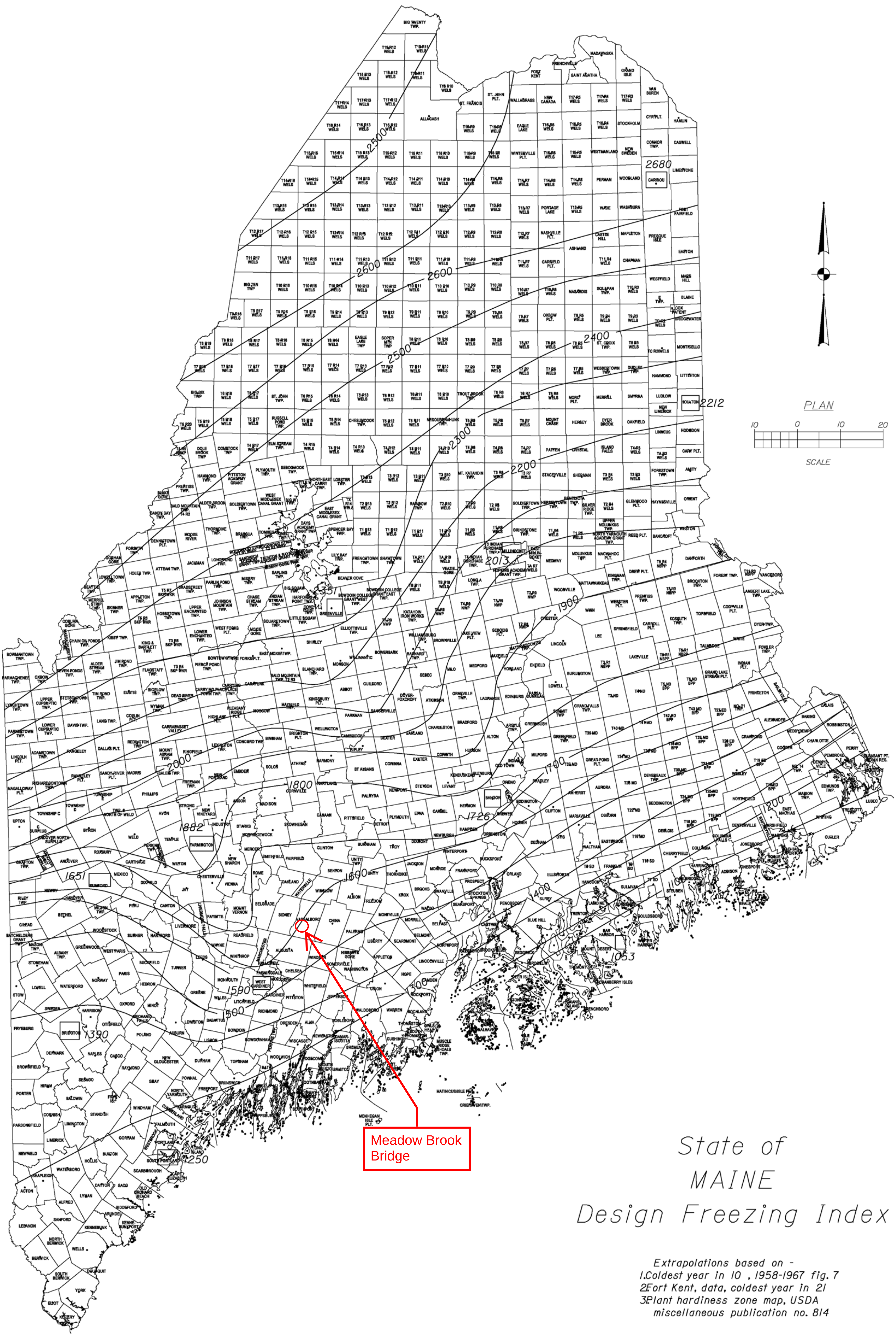

Figure 5-1 Maine Design Freezing Index Map

Table 5-1 Depth of Frost Penetration

Design Freezing Index	Frost Penetration (in)					
	Coarse Grained			Fine Grained		
	w=10%	w=20%	w=30%	w=10%	w=20%	w=30%
1000	66.3	55.0	47.5	47.1	40.7	36.9
1100	69.8	57.8	49.8	49.6	42.7	38.7
1200	73.1	60.4	52.0	51.9	44.7	40.5
1300	76.3	63.0	54.3	54.2	46.6	42.2
1400	79.2	65.5	56.4	56.3	48.5	43.9
1500	82.1	67.9	58.4	58.3	50.2	45.4
1600	84.8	70.2	60.3	60.2	51.9	46.9
1700	87.5	72.4	62.2	62.2	53.5	48.4
1800	90.1	74.5	64.0	64.0	55.1	49.8
1900	92.6	76.6	65.7	65.8	56.7	51.1
2000	95.1	78.7	67.5	67.6	49.4" = 4.1'	[illegible]5
2100	97.6	80.7	69.2	69.3	59.7	53.8
2200	100.0	82.6	70.8	71.0	61.1	55.1
2300	102.3	84.5	72.4	72.7	62.5	56.4
2400	104.6	86.4	74.0	74.3	63.9	57.6
2500	106.9	88.2	75.6	75.9	65.2	58.8
2600	109.1	89.9	77.1	77.5	66.5	60.0

Notes: 1. w = water content
2. Where the Freezing Index and/or water content is between the presented values, linear interpretation may be used to determine the frost penetration.

Marine Clay is anticipated near the culvert bearing elevation and have an average water content of 20 to 30 percent. Based on the MaineDOT BDG, Section 5.2.1 and a Freezing index of 1,600 the estimated depth of frost penetration is 4.1 feet.