GEOTECHNICAL DESIGN REPORT

18-0952

November 5, 2018

Explorations and Geotechnical Engineering Services

Mast Arm Structures
Cumberland Mills Rotary (Route 25B)
Westbrook, Maine
WIN 018637.00

PREPARED FOR:
Maine Department of Transportation
Attention: Kate Maguire, P.E.
State House Station 16
Augusta, ME 04333-0016

PREPARED BY:
S. W. Cole Engineering, Inc.
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S.W.COLE ENGINEERING, INC.

- *Geotechnical Engineering*
- *Construction Materials Testing and Special Inspections*
- *GeoEnvironmental Services*
- *Test Boring Explorations*

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Attention: Kate Maguire, P.E.
State House Station 16
Augusta, ME 04333-0016

Subject: Geotechnical Design Report
Explorations and Geotechnical Engineering Services
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Dear Kate:

In accordance with our Proposal, dated July 24, 2018, and project Assignment Letter #9, dated July 27, 2018, we have made the requested subsurface explorations for the subject project. The purpose of our services was to obtain subsurface information in order to develop geotechnical parameters and recommendations to assist design of new mast arm signal pole structures. The services provided by S. W. Cole Engineering, Inc. (S.W.COLE) were conducted in accordance with our Multi-PIN Agreement with the Maine Department of Transportation (MaineDOT), No. 20150720000000000085, dated July 20, 2015. The contents of this report are subject to the limitations in Appendix A.

1.0 INTRODUCTION

1.1 Site and Proposed Construction

The project is located along Cumberland Mills Rotary (Route 25B) in Westbrook, Maine. The project location is shown on the *Site Location Map* attached in Appendix B.

Based on the provided Preliminary Plans, we understand fifteen new mast arm overhead sign/traffic signals (mast arms) are proposed as part of the intersection improvements and signalization of the Cumberland Mills Rotary. A list of the proposed mast arms location, approximate station and type are shown in the Table 1.

Table 1. Mast Arm Structures		
Location	**Approximate Station and Offset**	**Structure Type**
Cumberland Street	14+58, 4.2 ft Rt.	Traffic Signal
Cumberland Street	15+94, 30.4 ft Lt.	Overhead Sign
Cumberland Street	16+39, 30.3 ft Rt.	Traffic Signal
Cumberland Street	17+28, 17.1 ft Lt.	Traffic Signal
Cumberland Street	19+87, 26.3 ft Rt.	Overhead Sign
Cumberland Street	21+82, 20.6 ft Rt.	Traffic Signal
Main Street	33+06, 18.8 ft Rt.	Traffic Signal
Main Street	37+81, 33.2 ft Lt.	Overhead Sign
Main Street	42+39, 11.8 ft Lt.	Traffic Signal
Main Street	47+87, 31.5 ft Lt.	Traffic Signal
Main Street	47+93, 43.5 ft Rt.	Traffic Signal
Main Street	48+39, 40.8 ft Lt.	Traffic Signal
Main Street	48+54, 30.4 ft Rt.	Traffic Signal
Harnois Avenue	64+85, 20.6 ft Lt.	Overhead Sign
Harnois Avenue / Washington Street	86+42, 33.6 ft Rt.	Traffic Signal

We understand the mast arms will be either single or double arm structures supported on single drilled shaft foundations. Based on MaineDOT Standard Details Section 626, we understand the foundations may extend up to 20 feet below ground surface.

2.0 EXPLORATIONS AND TESTING

2.1 Explorations

Twelve test borings (HB-WBR-101 through HB-WBR-112) were made at the site from September 9 through September 12, 2018 by S. W. Cole Explorations, LLC using a track-mounted Diedrich D-50 drill rig. The exploration locations were selected by MaineDOT and established in the field by S.W.COLE using measurements from existing site features. The proposed borings were located as close as practicable to the proposed locations considering drill rig accessibility, the location of existing utilities and impacts to vehicular traffic prior to the start of drilling. The approximate exploration locations are shown on the *Boring Location Plans* attached in Appendix B. Logs of the test borings and a Key to Soil and Rock Descriptions and Terms used on the logs are attached in Appendix C.

2.2 Testing

The test borings were drilled using a combination of solid-stem auger and cased-wash boring, rock core drilling and rod probing techniques. The soils were sampled at 2 to 5-foot intervals using a split-spoon sampler and Standard Penetration Testing (SPT) methods using a calibrated automatic hammer.

The borings were advanced to a depth of about 20 feet below ground surface (bgs), or refusal. Upon encountering refusal, borings HB-WBR-107 and HB-WBR-111 were advanced about 5 feet into bedrock using NQ2 rock coring techniques. Borings in soft soils at a depth of about 20 feet were advanced to firm soils using rod probing techniques.

The drill rig was equipped with a calibrated automatic hammer to drive the split-spoon. Corrected N-values in this report were computed by applying an average energy transfer of 0.918 for the calibrated automatic hammer to the raw field N-values. Upon encountering cohesive soils Pocket Penetrometer Testing (PPT) and in-situ Vane Shear Testing (VST) were performed using the MaineDOT Geonor field vane kit to assess in-situ soil strength. The hammer efficiency factor (0.918), uncorrected SPT blow counts, raw field N-values, corrected N-values (N_{60}), PPT values, VST values, and rock core intervals are shown on the logs in Appendix C.

Soils samples recovered from the test borings were visually classified in our laboratory and transported to the MaineDOT Laboratory in Bangor, Maine for possible laboratory testing.

3.0 SUBSURFACE CONDITIONS

3.1 Surficial and Bedrock Geology

According to the Maine Geological Survey (MGS) mapping of the Portland West Quadrangle (Open-File 08-16), mapped surficial geology units within the site vicinity consist of Presumpscot Formation and Stream Alluvium. The Presumpscot Formation consist of silt, clay and minor sand and the Stream Alluvium consists of sand, silt, gravel and organic material. The subsurface conditions encountered were generally consistent with the mapped surficial geology; however, the explorations also encountered fill soils from previous site development and glacial till.

Bedrock in the site vicinity is mapped as fine-grained, quartz-plagioclase-biotite gneiss and granofels with minor calc-silicate gneiss or granofels of the Berwick Formation (MGS, Open-File 03-94). The bedrock cored at HB-WBR-107 and -111 consisted of hard, slightly-weathered biotite-mica schist with quartz and feldspar zoning.

3.2 Soil and Bedrock

The test borings encountered a soils profile generally consisting of a surface layer of pavement or topsoil overlying fill overlying Presumpscot Formation deposits overlying glacial till and refusal surfaces. The principal strata encountered in the explorations are summarized below; refer to the attached logs for more detailed subsurface information.

Pavement: Bituminous concrete and bituminous concrete over concrete were encountered at the ground surface in each boring except HB-WBR-102. The pavement thickness ranged from about 3 to 10.5 inches.

Topsoil: Topsoil was encountered at the ground surface in borings HB-WBR-102. The topsoil was generally about 0.8 feet thick and consisted of dark brown sandy silt, trace gravel with organics.

Fill: Below the topsoil and pavement, the borings encountered fill soils extending to depths of about 3 to 15.4 feet bgs. The fill soils generally consisted of:

- Brown, SAND, some to trace gravel, little to trace silt;
- Brown, Silty SAND, little gravel;
- Grey and brown, Gravelly SAND, trace silt;
- Brown, SAND, some to trace silt; and
- Grey-brown, Silty CLAY.

The fill varied from loose to very dense with SPT N_{60} values ranging from 5 to 57 blows per foot (bpf).

Organics (wood and wood fiber) was noted in the fills at HB-WBR-103 and HB-WBR-107 at depths of about 1.5 feet and 3 feet, respectively. Additionally, an approximately 20-inch void was noted within the fill in HB-WBR-107.

Presumpscot Formation Clay: Below the fill, the borings encountered Presumpscot Formation clay (marine clay) in each boring except HB-WBR-111. The marine clay extended to depths ranging from about 8.5 to 38 feet bgs. The clay deposit was generally about 3.5 to 33 feet thick. In general, the deposit consisted of:

- Grey-brown to grey, Silty CLAY.

The clay was generally stiff to very stiff becoming medium stiff to soft with depth. SPT N_{60} values ranged from weight of drill rods to 15 bpf. Pocket penetrometer tests performed on disturbed soil samples ranged from about 2,000 to 7,000 psf, correlating to approximate shear strengths of about 1,000 to 3,500 psf.

Vane shear tests completed in the softer Presumpscot Formation clay measured undisturbed undrained shear strengths ranging from about 220 to 879 pounds per square foot (psf), indicating the marine clay is soft to medium stiff in consistency. The remolded shear strengths ranged from about 27 to 192 psf. Based on the ratio of peak (undisturbed) to remolded shear strength, the marine clay has a sensitivity ranging from about 3 to 18 and classified as moderately to highly sensitive.

Presumpscot Formation Sand: Below the marine clay, Presumpscot Formation sand (marine sand) was encountered at boring HB-WBR-101. The sand extended to a depth of about 19.8 feet bgs. The marine sand deposit consisted of:

- Grey, fine SAND, trace silt.

Where sampled, the marine sand was generally medium dense with an SPT N_{60} value of 15 bpf.

Glacial Till: Below the marine clay, borings HB-WBR-111 and -112 encountered glacial till generally consisting of:

- Grey, Sandy SILT some gravel; and
- Grey, Gravelly SAND, little silt.

Where sampled, the glacial till was generally very dense with SPT N_{60} values ranging from 89 bpf to refusal (greater than 50 blows per 6 inch increment of drive).

Refusal: Refusal surfaces were encountered at each boring except HB-WBR-109 at depths ranging from about 7.5 to 38.1 feet bgs. The nature of the refusal surface was not determined in borings HB-WBR-101 through -106, -108, -110 and -112. Bedrock was encountered and sampled in borings HB-WBR-107 and -111 at depths of about 7.5 and 8 feet bgs, respectively. The sampled bedrock consisted of dark grey, hard, slight weathered, biotite-mica-SCHIST with quartz and feldspar zones of the Berwick Formation (Berwick Formation). Joints are generally moderate dipping to low angle, very close to close and closed. Rock quality designation (RQD) values for the bedrock ranged from was 0 to 70 percent correlating to a Rock Mass Quality (RMQ) of very poor to fair.

3.3 Groundwater

The soils encountered at the test borings were damp to moist from the ground surface. Measured water levels immediately after drilling ranged from about 2 to 8 feet bgs. Water was introduced into the borings during drilling; therefore, stabilized groundwater levels were not measured. Long term groundwater information is not available. It should be anticipated that groundwater levels will fluctuate seasonally, particularly in response to periods of snowmelt and precipitation and changes in site use.

4.0 EVALUATION AND RECOMMENDATIONS

S.W.COLE conducted geotechnical engineering evaluations for foundation length requirements for fifteen proposed mast arms at intersections around the Cumberland Mills Rotary. Evaluations to determine foundation length were made using the design charts in the November 2014 edition of the MaineDOT Standard Details Section 626.

Geotechnical engineering calculations and reference documents used to support the recommendations within this memorandum are provided in Appendix D.

4.1 General Findings

Below a surface layer of topsoil or pavement, the soils encountered generally included fill overlying Presumpscot Formation clays overlying marine sands, glacial till and areas of shallow bedrock. The Presumpscot Formation clay generally consist of a stiffer crust becoming soft to medium stiff with depth. Based on the subsurface findings, drilled shafts appear suitable for foundation support of the proposed mast arm structures. Drilled shaft foundations with specific geotechnical considerations include:

- Based on the minimum foundation lengths provided on the design charts, bedrock sockets or dowels into bedrock should be anticipated for the structure near Station (Sta) 33+06.

- The structure near Sta 64+85 is located between borings HB-WBR-111 and HB-WBR-112 with varying subsurface conditions. HB-WBR-111 encountered fill overlying glacial till overlying shallow bedrock at a depth of about 7 feet bgs and HB-WBR-112 encountered fill overlying stiff, silty clay overlying glacial till at a depth of about 15 feet bgs. Considering the thin overburden soils encountered in boring HB-WBR-111, bedrock sockets or dowels into bedrock may be needed for the structure near Sta 64+85.

- The remaining 13 structures are anticipate to be founded on standard drilled shaft foundations.

4.2 Frost Considerations

Based on the Maine Design Freezing Index Map[1], the design freezing index for the Westbrook, Maine area is approximately 1,250 freezing degree-days. Based on Section 5.2.1 of the MaineDOT BDG and subsurface findings, the maximum seasonal frost penetration is estimated to be on the order of about 6.25 feet. We recommend foundations not on bedrock have at least 6.25 feet of soil cover to provide frost protection.

4.3 Design Soil Parameters

The MaineDOT Standard Details Section 626 includes design charts for determining the minimum length of foundations for various foundation diameters (30 to 60 inches) based on a range of applied loads (moment and torsion) and soil properties for granular soils (ϕ = 28 to 34 degrees) and cohesive soils (s_u = 400 to 1,200 psf). The design charts were developed assuming uniform soil profiles consisting entirely of either granular (friction angle, ϕ) or cohesive (undrained shear strength, s_u) soil.

Site specific soil parameters within the upper 25 feet were evaluated in accordance with AASHTO LRFD Section 10.4.6.2, MaineDOT BDG Table 3.3 and in situ field testing. Site-specific structural design of the foundations should be completed in accordance with

[1] Maine Department of Transportation, Bridge Design Guide (BDG), August 2003, with Revisions through 2014, Figure 5-1.

based on MaineDOT Standard Details Section 626(04), using the recommended soil parameters in Table 2.

Table 2. Recommended Mast Arm Foundation Design Soil Parameters

Location	Approximate Station and Offset	Structure Type	Applicable Exploration	Friction Angle[3] ϕ (deg)	Shear Strength[3] s_u (psf)
Cumberland Street	14+58, 4.2 ft Rt.	Traffic Signal	HB-WBR-101	-	1,200
Cumberland Street	15+94, 30.4 ft Lt.	Overhead Sign	HB-WBR-102	-	400
Cumberland Street	16+39, 30.3 ft Rt.	Traffic Signal	HB-WBR-103	-	400
Cumberland Street	17+28, 17.1 ft Lt.	Traffic Signal	HB-WBR-104	-	400
Cumberland Street	19+87, 26.3 ft Rt.	Overhead Sign	HB-WBR-105	-	600
Cumberland Street	21+82, 20.6 ft Rt.	Traffic Signal	HB-WBR-106	-	600
Main Street	33+06, 18.8 ft Rt.	Traffic Signal	HB-WBR-107[2]	-	800
Main Street	37+81, 33.2 ft Lt.	Overhead Sign	HB-WBR-108	28	-
Main Street	42+39, 11.8 ft Lt.	Traffic Signal	HB-WBR-106	-	600
Main Street	47+87, 31.5 ft Lt.	Traffic Signal	HB-WBR-109/110	-	400
Main Street	47+93, 43.5 ft Rt.	Traffic Signal	HB-WBR-109/110	-	400
Main Street	48+39, 40.8 ft Lt.	Traffic Signal	HB-WBR-109/110	-	400
Main Street	48+54, 30.4 ft Rt.	Traffic Signal	HB-WBR-109/110	-	400
Harnois Avenue	64+85, 20.6 ft Lt.[1]	Overhead Sign	HB-WBR-111[2]/112	-	800
Harnois Ave/Washington St	86+42, 33.6 ft Rt.	Traffic Signal	HB-WBR-112	-	1,200

Notes:
1. Structure at Sta 64+85 is located between HB-WBR-111 and HB-WBR-112.
2. Bedrock encountered about 8.5 feet bgs in HB-WBR-107 and 7 feet bgs in HB-WBR-111.
3. The provided Friction Angle and Shear Strength values refer to the design charts from MaineDOT Standard Details 626(04).

4.4 Bearing Resistance

The mast arm structures will be founded below frost on drilled shaft foundations. Based on the subsurface conditions encountered and described herein, the factored bearing resistance at strength and service limit states shall not exceed the factored bearing resistances shown in Table 3.

Table 3. Design Factored Bearing Resistance		
Recommended Mast Arm Foundation Design Soil Parameter	**Factored Bearing Resistance (ksf)**	
	Strength Limit State[1]	**Service Limit State[2]**
s_u = 400 psf	1.1	1.0
s_u = 600 psf	1.5	1.0
s_u = 800 psf	2.0	2.0
s_u = 1,200 psf	2.9	3.0
ϕ = 28 degrees	2.3	3.0

Notes: 1. Resistance Factor of ϕ_f = 0.45 for Strength Limit State based on AASHTO LRFD Table 10.5.5.2.2-1
2. Services Limit State Bearing Resistance based on AASHTO LRFD Table C10.6.2.6.1-1.

The design of drilled shafts should be in accordance with AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (2015, 6th Ed.), MaineDOT Standard Detail 626 for the idealized soils parameters. Structural design should consider both geotechnical lateral and axial resistance, although lateral resistance will likely control.

4.5 Construction Considerations

Drilled shafts shall be uncased (concrete cast against soil) except within the top 3 feet. Temporary casing used during construction shall be removed following placement of concrete. Backfill used to repair disturbed areas around the drilled shafts should consist of MaineDOT Specification 703.19 “Granular Borrow for Embankment Construction” and grading adjacent to the shafts should direct surface water runoff away from the structures.

Please note each test boring was drilled as close as practicable to the requested boring locations provided by MaineDOT. The final boring locations were determined by S.W.COLE considering drill rig accessibility, the location of existing utilities and impacts to pedestrian and vehicular traffic prior to the start of drilling.

It should be anticipated that subsurface conditions will vary and that bedrock at the proposed mast arm locations may be higher or lower than that encountered in the test borings. We recommend language to this affect be included in the Contract Documents and that adjustments to mast arm foundation lengths and modifications to the bedrock “pinning” detail (whether it is needed or not) may be necessary and require re-evaluation during construction.

5.0 CLOSURE

We trust this information meets your present needs. Please contact us if you have any questions or need further assistance.

Sincerely,

S. W. Cole Engineering, Inc.

Michael St. Pierre, P.E.
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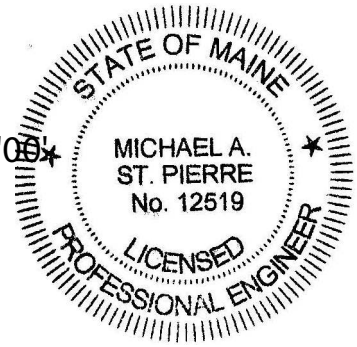


Michael A. St. Pierre, P.E.
Geotechnical Engineer

MAS:tjm-rec

S.W.COLE ENGINEERING, INC.

APPENDIX A

Limitations

This report has been prepared for the exclusive use of the Maine Department of Transportation for specific application to the proposed Mast Arm Structures as part of the Cumberland Mills Rotary Signalization and Improvements Project (MaineDOT WIN 018637.00) in Westbrook, Maine. S. W. Cole Engineering, Inc. (S.W.COLE) has endeavored to conduct our services in accordance with generally accepted soil and foundation engineering practices. No warranty, expressed or implied, is made.

The soil profiles described in the report are intended to convey general trends in subsurface conditions. The boundaries between strata are approximate and are based upon interpretation of exploration data and samples.

The analyses performed during this investigation and recommendations presented in this report are based in part upon the data obtained from subsurface explorations made at the site. Variations in subsurface conditions may occur between explorations and may not become evident until construction. If variations in subsurface conditions become evident after submission of this report, it will be necessary to evaluate their nature and to review the recommendations of this report.

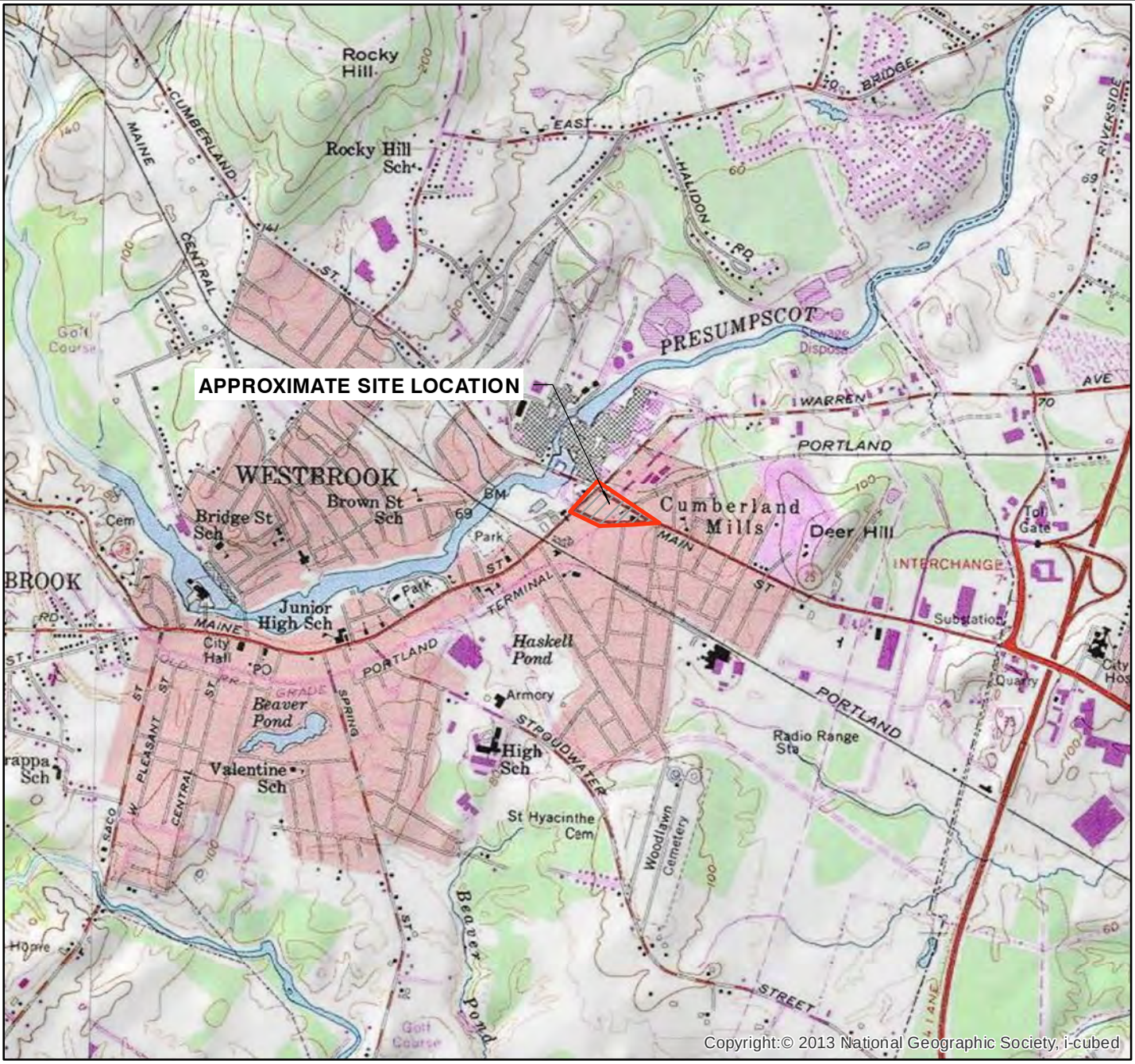
Observations have been made during exploration work to assess site groundwater levels. Fluctuations in water levels will occur due to variations in rainfall, temperature, and other factors.

Recommendations contained in this report are based substantially upon information provided by others regarding the proposed project. In the event that any changes are made in the design, nature, or location of the proposed project, S.W.COLE should review such changes as they relate to analyses associated with this report. Recommendations contained in this report shall not be considered valid unless the changes are reviewed by S.W.COLE.

S.W.COLE ENGINEERING, INC.

APPENDIX B

Figures



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Scale in Feet

S.W.COLE ENGINEERING, INC.

MAINE DEPARTMENT OF TRANSPORTATION

SITE LOCATION MAP

MAST ARM STRUCTURES
CUMBERLAND MILLS ROTARY (ROUTE 25B)
WESTBROOK, MAINE
WIN 018637.00

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Date:	10/17/2018	Sheet	1

NOTE:
SITE LOCATION MAP PREPARED FROM ESRI ArcGIS ONLINE AND DATA PARTNERS INCLUDING USGS AND © 2007 NATIONAL GEOGRAPHIC SOCIETY.

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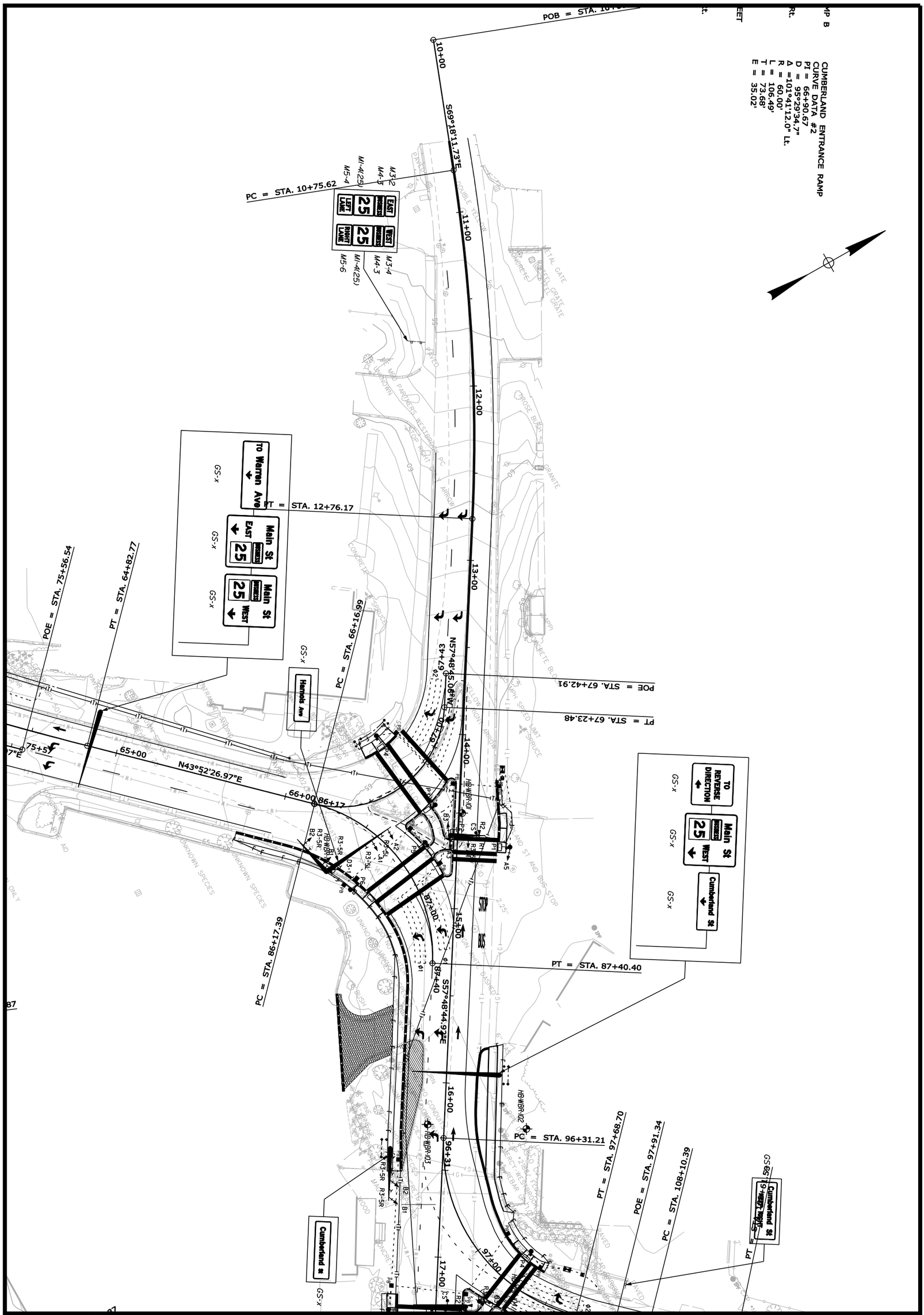

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STATE OF MAINE
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WIN 018637.00 HIGHWAY PLANS

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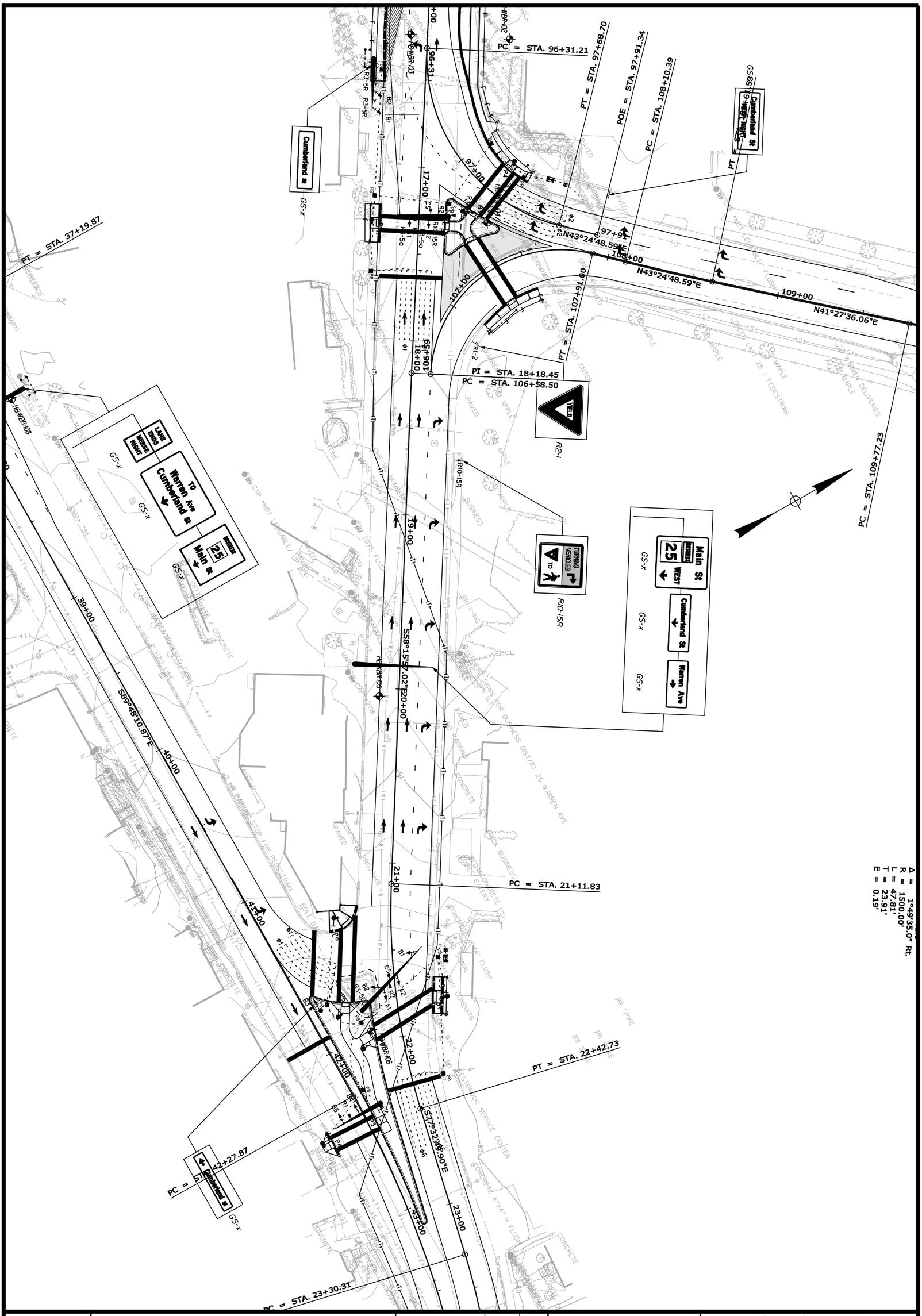

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WESTBROOK
CUMBERLAND ROTARY

BORING LOCATION PLAN

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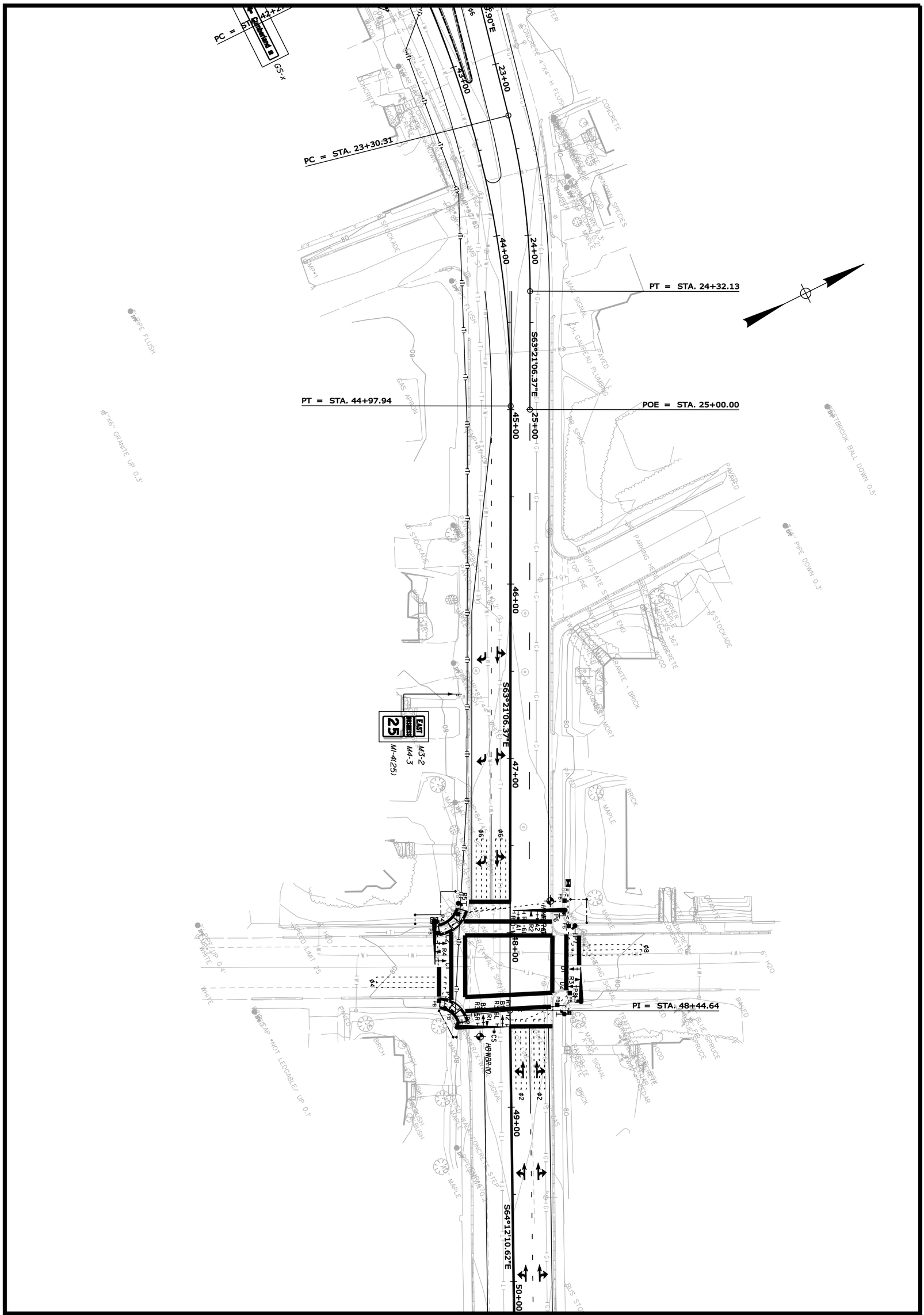

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CUMBERLAND ROTARY

BORING LOCATION PLAN

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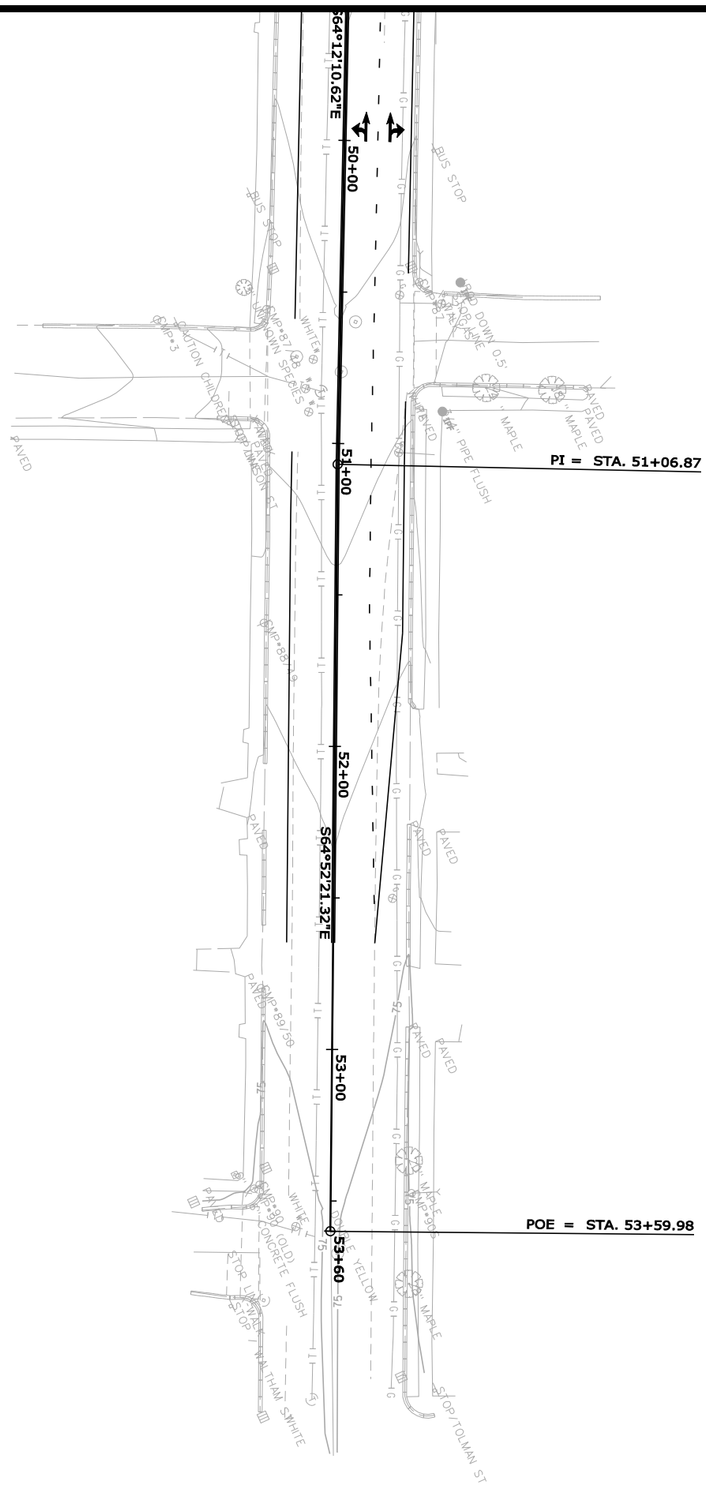
HIGHWAY PLANS



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MAIN STREET
CURVE DATA #6
PI = 51+06.87
Δ = 0°40'10.7" Lt.

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WESTBROOK
CUMBERLAND ROTARY

BORING LOCATION PLAN

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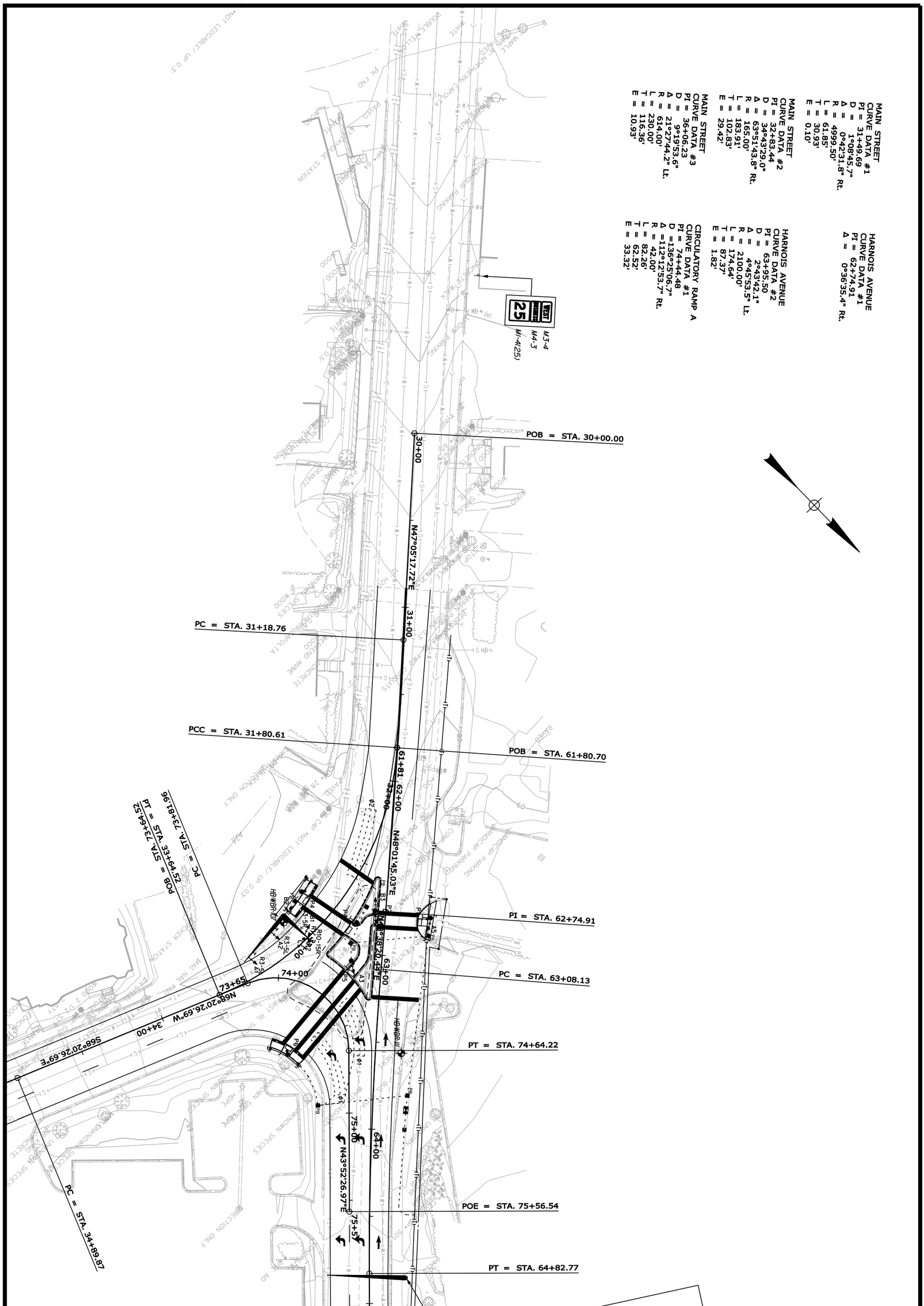
HIGHWAY PLANS



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WESTBROOK
CUMBERLAND ROTARY

BORING LOCATION PLAN

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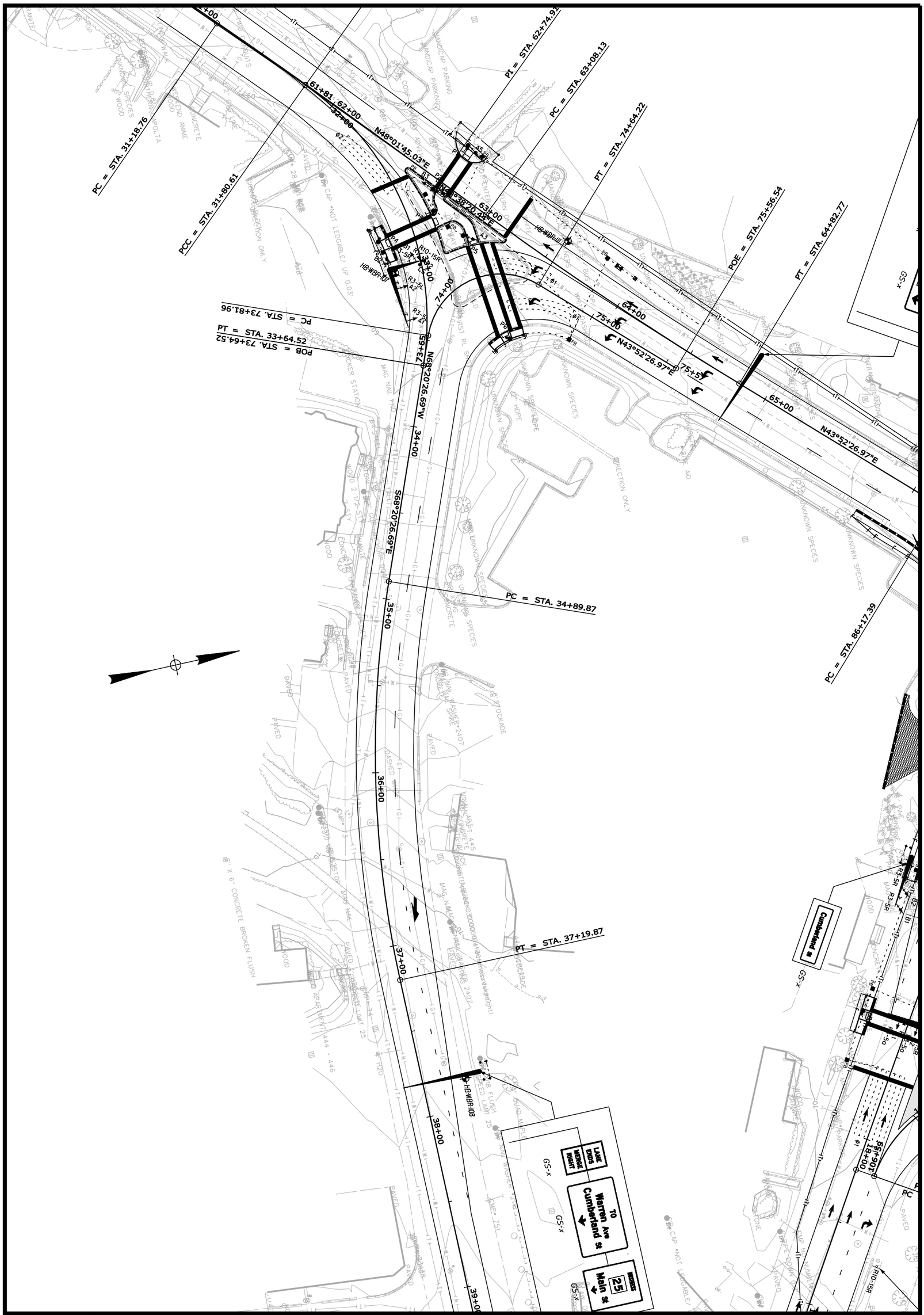

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WESTBROOK
CUMBERLAND ROTARY

BORING LOCATION PLAN

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STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

STP-1863(700)

WIN 018637.00 HIGHWAY PLANS

S.W.COLE ENGINEERING, INC.

APPENDIX C

Boring Logs & Key to Soil and Rock Descriptions and Terms

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS (more than half of material is larger than No. 4 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-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-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 (%) = sum of the lengths of intact pieces of core* > 4 inches / length of core advance

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

Correlation of RQD to Rock Mass Quality

Rock Mass 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 mass quality (very poor, poor, etc.)
ref: ASTM D6032 and AASHTO Standard Specification for Highway Bridges, 17th Ed. Table 4.4.8.1.2A
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
Bridge Name / Town
Boring Number
Sample Number
Sample Depth
Blow Counts
Sample Recovery
Date
Personnel Initials

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-101
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	65.5	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-09-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 14+45.1, 2.0' L Cumberland Street	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±7 ft (after drilling)
Hammer Efficiency Factor: 0.918		**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

Sample Information

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	24/14	0.90 - 2.90	8/8/4/4	12	18	SSA	65.3		3" of Pavement.	
										0.3	
										Brown, damp, medium dense, SAND, little gravel, trace silt, fine to medium sand, (Fill).	
	2D	24/10	2.90 - 4.90	4/4/3/3	7	11					
										Brown, damp, medium dense, SAND, trace gravel, trace silt, fine to medium sand, (Fill).	
5	3D	24/18	5.00 - 7.00	3/2/2/3	4	6	24	60.1		3D(A): Similar to above.	
										5.4	
							30			3D(B): Grey-brown, moist, medium stiff, Silty CLAY, (Presumpscot Formation). PP=4.0-5.0 ksf	
							44				
							42				
							41				
10	MV/4D	24/24	10.00 - 12.00	3/2/3/4	5	8	52			Failed 55x110 mm vane attempt. Grey-brown, wet, medium stiff, Silty CLAY, (Presumpscot Formation). PP=4.5-5.5 ksf	
							56				
							50				
							38				
							60				
15	5D	24/17	15.00 - 17.00	5/6/4/2	10	15	59			5D(A): Grey, wet, very stiff, Silty CLAY, (Presumpscot Formation).	
								49.5		16.0	
							60			5D(B): Grey, wet, medium dense, SAND, trace silt, (Presumpscot Formation).	
							58				
							23/7"			Casing refusal on cobble at ±18.7 ft bgs.	
	MD	1/0	19.70 - 19.78	50-1"	- -			45.7		No recovery.	
20										19.8	
										Bottom of Exploration at 19.8 feet below ground surface. Sampler Refusal.	
25											

Remarks:

Autohammer SN 367
bgs = below ground surface

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: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-102
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	68.2	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-12-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 16+24.3, 47.2' L Cumberland Street	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±3.5 ft (after drilling)
Hammer Efficiency Factor: 0.918		**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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MV = Unsuccessful Field Vane Shear Test Attempt
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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
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G = Grain Size Analysis
C = Consolidation Test

Sample Information

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0	1D	24/10	0.00 - 2.00	2/3/3/2	6	9	SSA	67.4		Dark brown, damp, stiff, Sandy SILT, trace gravel, with organics (Topsoil).	
										0.8	
	2D	24/20	2.00 - 4.00	5/10/12/10	22	34				2D(A): Brown, damp, dense, Silty SAND, little gravel, (Fill).	
5	3D	24/24	5.00 - 7.00	2/2/3/4	5	8	30	63.2		5.0 Grey-brown, moist, medium stiff, Silty CLAY, blocky structure, (Presumpscot Formation). PP=4.0-5.5 ksf	
							31				
							35				
							39				
							46				
10	4D	24/24	10.00 - 12.00	1/1/1/1	2	3	42			Grey-brown, wet, soft, Silty CLAY, (Presumpscot Formation). PP=1.0-2.0 ksf	
							48				
							51				
							49				
							52				
15	5D	24/24	15.00 - 17.00	WOR-12"/WO1P-12"	---		50			Grey, wet, soft to medium stiff, Silty CLAY, (Presumpscot Formation).	
	V1		15.63 - 16.00	Su=494/27 psf						55x110 mm raw torque readings:	
	V2		16.63 - 17.00	Su=577/55 psf			53			V1: 18.0/1.0 ft-lbs V2: 21.0/2.0 ft-lbs	
							52				
							49				
							54				
20	6D	24/24	20.00 - 22.00	WOR/WO1P-18"	---		PROBE			Similar to above.	
										Advanced by hydraulic pushed rod probe from 22 to 24.5 feet.	
25								43.7		24.5	

Remarks:

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-102
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	68.2	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-12-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 16+24.3, 47.2' L Cumberland Street	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±3.5 ft (after drilling)
Hammer Efficiency Factor:	0.918	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
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SSA = Solid Stem Auger
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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 Information: 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										**Bottom of Exploration at 24.5 feet below ground surface.** Rod Probe Refusal.	
30											
35											
40											
45											
50											

Remarks:

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-103
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	67.6	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-12-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 16+24.3, 9.5' R Cumberland Street	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±3 ft (after drilling)
Hammer Efficiency Factor: 0.918		**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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D = Split Spoon Sample
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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
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Depth (ft.)	Sample Information: 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	24/19	0.80 - 2.80	36/11/9/6	20	31	SSA	67.0		7.5" of Pavement.	
										0.6	
										1D(A): Grey, damp, dense, Gravelly SAND, trace silt, (Fill - Road Gravels).	
										1D(B): 5" of Wood at ±1.5 ft bgs.	
	2D	24/14	2.80 - 4.80	8/8/7/5	15	23				1D(C): Brown, damp, medium dense, Silty SAND, little gravel, (Fill).	
										2D(A): Brown, damp, medium dense, SAND, some silt, fine to medium sand, (Fill).	
								64.0		3.6	
5										2D(B): Grey-brown, moist, stiff, Silty CLAY, blocky structure, (Presumpscot Formation).	
	3D	24/24	5.00 - 7.00	3/4/5/6	9	14	40			Similar to above. PP=5.0-7.0 ksf	
							42				
							48				
							53				
							44				
10	4D	24/24	10.00 - 12.00	1/1/1/2	2	3	40			4D(A) (10.0-10.8 ft): Similar to above except grey and medium stiff to stiff. PP=2.5-4.0 ksf	
							38			4D(B) (10.8-12.0 ft): Grey, wet, medium stiff to soft, Silty CLAY, (Presumpscot Formation).	
							44				
							46				
							51				
15	5D	24/24	15.00 - 17.00	WOR-12"/WO1P-12"	---		52			Grey, wet, soft to medium stiff, Silty CLAY, (Presumpscot Formation).	
	V1		15.63 - 16.00	Su=330/27 psf						55x110 mm raw torque readings: V1: 12.0/1.0 ft-lbs	
	V2		16.63 - 17.00	Su=577/82 psf			48			V2: 21.0/3.0 ft-lbs	
							53				
							56				
							43				
20	6D	24/24	20.00 - 22.00	WO1P-24"	---		PROBE			Similar to above.	
										Advanced by hydraulic pushed rod probe from 22 to 27.1 ft bgs.	
25											

Remarks:

Autohammer SN 367
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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: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-103
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	67.6	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-12-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 16+24.3, 9.5' R Cumberland Street	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±3 ft (after drilling)
Hammer Efficiency Factor: 0.918		**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
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$S_{u(lab)}$ = Lab Vane Undrained Shear Strength (psf)
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N-uncorrected = Raw Field SPT N-value
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Depth (ft.)	Sample Information: 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								40.5		27.1	
								40.0		Hammer driven rod probe. 27.1-27.6 ft: 50 blows/6 inches.	
										27.6 **Bottom of Exploration at 27.6 feet below ground surface.** Rod Probe Refusal.	
30											
35											
40											
45											
50											

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-104
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	68.7	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-11-2018/09-12-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 17+30.1, 39.3' L Cumberland Street	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±3 ft (after drilling)
Hammer Efficiency Factor: 0.918		**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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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	68.0		8" of Pavement. 0.7	
	1D	24/6	1.00 - 3.00	8/11/12/9	23	35				Brown, damp, dense, Gravelly SAND, trace silt, (Fill).	
	2D	24/15	3.00 - 5.00	9/9/10/8	19	29				Brown, moist, medium dense, SAND, trace silt, (Fill).	
5	3D	24/22	5.00 - 7.00	3/3/3/4	6	9	25	63.7		5.0	
							26			3D(A): Grey-brown, moist, stiff to very stiff, Silty CLAY, blocky structure, (Presumpscot Formation). PP=3.5-5.5 ksf	
							26			3D(B) (5.8-7.0 ft): Grey, moist, medium stiff, Silty CLAY, (Presumpscot Formation). PP=1.0-2.5 ksf	
							24				
							20				
10	4D	24/24	10.00 - 12.00	WOR-12"/WO1P-12"	---		22			Grey, wet, very soft, Silty CLAY, (Presumpscot Formation).	
							30				
							32				
							31				
							34				
15	5D	24/24	15.00 - 17.00	WOR-12"/WO1P-12"	---		37			Grey, wet, very soft to soft, Silty CLAY, (Presumpscot Formation).	
	V1		15.63 - 16.00	Su=220/27 psf						55x110 mm raw torque readings: V1: 8.0/1.0 ft-lbs V2: 16.0/2.0 ft-lbs	
	V2		16.63 - 17.00	Su=439/55 psf			30				
							29				
							25				
							24				
20	6D	24/24	20.00 - 22.00	WOR-12"/WO1P-12"	---		PROBE			Similar to above, except soft to medium stiff.	
	V3		20.63 - 21.00	Su=384/27 psf						55x110 mm raw torque readings: V3: 14.0/1.0 ft-lbs V4: 20.0/3.0 ft-lbs	
	V4		21.63 - 22.00	Su=549/82 psf						Advanced by hydraulic pushed rod probe from 22 to 29.4 ft bgs.	
25											

Remarks:

Autohammer SN 367
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Stratification lines represent approximate boundaries between soil types; transitions may be gradual.

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-104
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	68.7	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-11-2018/09-12-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 17+30.1, 39.3' L Cumberland Street	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±3 ft (after drilling)
Hammer Efficiency Factor:	0.918	**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 Information: 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											
								39.3		29.4	
30										Hammer driven rod probe. 29.4-30.4 ft: 29 blows 30.4-31.4 ft: 20 blows 31.4-32.4 ft: 12 blows 32.4-33.3 ft: 50 blows/8 inches.	
								35.4		33.3	
										Bottom of Exploration at 33.3 feet below ground surface. Rod Probe Refusal.	
35											
40											
45											
50											

Remarks:

Autohammer SN 367
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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-105
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	73.4	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-11-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 20+04.6, 11.3' R Cumberland	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±4 ft (after drilling)
Hammer Efficiency Factor: 0.918		**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	72.8		3" of Pavement over 4.5" of Concrete.	
										0.6	
	1D	24/12	1.00 - 3.00	5/7/5/4	12	18				Dark brown, damp, medium dense, SAND, some gravel, trace silt, (Fill).	
										2D(A): Brown, damp, medium dense, SAND, trace silt, (Fill).	
	2D	24/12	3.00 - 5.00	5/5/5/5	10	15		69.7		3.8	
										2D(B) (3.8-5.0 ft): Grey-brown, moist, stiff to very stiff, Silty CLAY, blocky structure, (Presumpscot Formation).	
5	3D	24/24	5.00 - 7.00	4/5/5/7	10	15	37			Similar to above except wet. PP=4.5-6.5 ksf	
							62				
							70				
							62				
							42				
10	4D	24/24	10.00 - 12.00	1/2/2/2	4	6	50			Grey, wet, medium stiff to soft, Silty CLAY, (Presumpscot Formation). PP=0.5-1.0 ksf	
							52				
							43				
							46				
							39				
15	5D	24/24	15.00 - 17.00	WOR-12"/WO1P-12"	---		35			Similar to above.	
	MV		15.63 - 16.00							55x110 mm raw torque readings: MV: No reading - Read Error V1: 29.0/4.0 ft-lbs	
	V1		16.63 - 17.00	Su=796/110 psf			45				
							41				
							51				
							52				
20	6D	24/24	20.00 - 22.00	WOR-12"/WO1P-12"	---		PROBE			Similar to above except medium stiff.	
	V2		20.63 - 21.00	Su=879/137 psf						55x110 mm raw torque readings: V2: 32.0/5.0 ft-lbs V3: 26.0/5.0 ft-lbs	
	V3		21.63 - 22.00	Su=714/137						Advanced by hydraulic pushed rod probe from 22 to 28.3 ft bgs.	
25											

Remarks:

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-105
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	73.4	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-11-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 20+04.6, 11.3' R Cumberland	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±4 ft (after drilling)
Hammer Efficiency Factor:	0.918	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
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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 Information: 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								45.1		28.3	
										Hammer driven rod probe. 28.3-29.3 ft: 12 blows 29.3-30.3 ft: 19 blows 30.3-31.3 ft: 9 blows 31.3-32.2 ft: 50 blows/11 inches.	
30											
								41.2		32.2	
										Bottom of Exploration at 32.2 feet below ground surface. Rod Probe Refusal.	
35											
40											
45											
50											

Remarks:

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-106
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	79.1	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-10-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 21+93.9, 17.4' R Cumberland	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±4.5 ft (during drilling)
Hammer Efficiency Factor: 0.918		**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0	1D	24/10	0.60 - 2.60	11/17/20/9	37	57	SSA	78.5		7.5" of Pavement.	
										0.6 Brown, damp, very dense, Gravelly SAND, trace silt, (Fill).	
	MD	24/0	2.60 - 4.60	7/6/6/5	12	18				No recovery.	
5	2D	24/24	5.00 - 7.00	2/2/2/4	4	6	37	74.1		5.0 Brown-grey, wet, medium stiff, Silty CLAY, (Presumpscot Formation). PP=3.0-4.0 ksf	
							37				
							43				
							38				
							34				
10	3D	24/23	10.00 - 12.00	2/1/1/2	2	3	41			Grey, wet, soft, Silty CLAY, (Presumpscot Formation). PP=0.5-1.0 ksf	
							42				
							43				
							43				
							45				
15	4D	24/24	15.00 - 17.00	WOR-12"/1/2	---		PROBE			Similar to above.	
	V1		15.63 - 16.00	Su=577/110						55x110 mm raw torque readings: V1: 21.0/4.0 ft-lbs	
	V2		16.63 - 17.00	Su=522/110 psf						V2: 19.0/4.0 ft-lbs Advanced by hydraulic pushed rod probe from 17 to 38 ft bgs.	
20											
25											

Remarks:

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-106
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	79.1	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-10-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 21+93.9, 17.4' R Cumberland	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±4.5 ft (during drilling)
Hammer Efficiency Factor:	0.918	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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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 Information: 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											
30											
35											
								41.0		Hammer driven rod probe. 38.0-38.1 ft: 50 blows/1 inch.	
								38.1		**Bottom of Exploration at 38.1 feet below ground surface.** Rod Probe Refusal.	
40											
45											
50											

Remarks:

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-107
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	59.3	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-10-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	NQ2
Boring Location:	Sta. 33+08.5, 15.7' R Main Street	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±4.3 ft (after drilling)
Hammer Efficiency Factor: 0.918		**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
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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

Sample Information

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	58.7		7" of Pavement.	
										0.6	
	1D	24/4	1.00 - 3.00	3/2/1-12"	3	5				1D(A) (1.0-1.3 ft): Brown, moist, loose, SAND, little silt, little gravel, (Fill).	
										20" Void.	
	2D	24/4	3.00 - 5.00	0-20"/1	---						
5								54.3		Brown, wet, loose, SAND, some silt, with wood fiber, (Fill).	
	3D	24/24	5.00 - 7.00	2/2/3/11	5	8				5.0	
							30			Grey-brown, wet, medium stiff, Silty CLAY, (Presumpscot Formation). PP=6.0-6.5 ksf	
							60				
							88	50.8		8.5	
	R1	52/51	9.00 - 13.33	RQD = 25%			NQ2			Top of Bedrock at Elev 50.8 feet. Advanced by rollercone from 8.5 to 9 ft bgs. R1:Bedrock: Dark grey, metamorphic, biotite-mica-SCHIST with quartz and feldspar, hard, slight weathering, joints are moderate dipping (35-55 degrees) with low angle (10-30 degrees) areas, very close to close and closed, (Berwick Formation). Rock Mass Quality = Very Poor. R1:Core Times (min:sec) 9.0-10.0 ft (4.25) 10.0-11.0 ft (2:17) 11.0-12.0 ft (3:07) 12.0-13.0 ft (3:14) 13.0-13.3 ft (4:12) 98% Recovery.	
10								46.0		13.3	
15										**Bottom of Exploration at 13.3 feet below ground surface.**	
20											
25											

Remarks:

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-108
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	71.2	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-10-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 37+83.0, 24.6' L Main Street	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±8 ft (after drilling)
Hammer Efficiency Factor: 0.918		**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			5" of Pavement over 5.5" of Concrete.	
								70.3		0.9	
	1D	24/10	1.00 - 3.00	3/2/1/2	3	5				1D(A): Brown, damp, loose, SAND, some gravel, trace silt, (Fill). 1D(B): Grey-brown, damp, medium stiff, Silty CLAY, (Presumpscot Formation).	
	2D	24/20	3.00 - 5.00	3/3/3/3	6	9				Similar to above. PP=2.0 ksf	
5	3D	24/20	5.00 - 7.00	3/4/4/5	8	12	25			3D(A): Similar to above, except moist. 3D(B): Brown, moist, medium dense, Silty SAND, (Fill).	
							32				
							38				
							36				
							29				
10	4D	24/8	10.00 - 12.00	2/1/1/1	2	3	32			Brown, wet, very loose, SAND, some silt, (Fill).	
							28				
							23				
							22				
							35				
15	5D	24/17	15.00 - 17.00	16/6/4/6	10	15	87	55.8		Concrete fragments, (Fill).	
										15.4	
							56			5D(B): Brown-grey, wet, stiff, Silty CLAY, (Presumpscot Formation).	
							58				
							61				
							57				
20	6D	24/24	20.00 - 22.00	WOH-12"/1/2	1	2	PROBE			Similar to above, except soft.	
										Advanced by hydraulic pushed rod probe from 22 to 29.5 ft bgs.	
25											

Remarks:

Autohammer SN 367
bgs = below ground surface

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

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-108
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	71.2	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-10-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 37+83.0, 24.6' L Main Street	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±8 ft (after drilling)
Hammer Efficiency Factor:	0.918	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
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MV = Unsuccessful Field Vane Shear Test 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 Information: 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											
								41.7		29.5	
30								41.2		Hammer driven rod probe. 29.5-30.0 ft: 50 blows/6 inch. 30.0 **Bottom of Exploration at 30.0 feet below ground surface.** Rod Probe Refusal.	
35											
40											
45											
50											

Remarks:

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-109
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	79.1	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-11-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 47+81.7, 23.0' L Main Street	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±3.3 ft (after drilling)
Hammer Efficiency Factor: 0.918		**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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SSA = Solid Stem Auger
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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
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WC = Water Content, percent
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
G = Grain Size Analysis
C = Consolidation Test

Sample Information

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	24/15	0.70 - 2.70	10/11/11/9	22	34	SSA	78.4		8" of Pavement.	
										0.7	
										Brown, damp, dense, SAND, some gravel, trace silt, (Fill).	
	2D	24/3	2.70 - 4.70	7/5/5/5	10	15				Brown, moist, medium dense, SAND, little gravel, trace silt, (Fill).	
5	3D	24/9	5.00 - 7.00	4/2/5/6	7	11	32			Similar to above, except wet.	
							97				
							58				
							52				
							42				
10	4D	24/24	10.00 - 12.00	WOH-12"/1-12"	---		39	69.1		10.0	
							34			Grey, wet, very soft, Silty CLAY, (Presumpscot Formation).	
							34				
							36				
							37				
15	5D	24/24	15.00 - 17.00	WOR-12"/3/3	---		36			5D(A) Grey, wet, soft to medium stiff, SILT CLAY, with 5D(B) SAND, trace silt, fine sand seams, (Presumpscot Formation).	
	V1		15.63 - 16.00	Su=384/55 psf						55x110 mm raw torque readings:	
	V2		16.63 - 17.00	Su=659/192 psf			34			V1: 14.0/2.0 ft-lbs	
							42			V2: 24.0/7.0 ft-lbs	
							46				
							37				
20	6D	24/18	20.00 - 22.00	1/WOH/2/4	2	3				Similar to above.	
								57.1		22.0	
										Bottom of Exploration at 22.0 feet below ground surface. No Refusal.	
25											

Remarks:

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-110
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	79.0	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-11-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 48+59.3, 17.4' R Main Street	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±2 ft (after drilling)
Hammer Efficiency Factor: 0.918		**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
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MV = Unsuccessful Field Vane Shear Test Attempt
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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 Information: 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	24/14	0.80 - 2.80	11/10/11/11	21	32	SSA	78.4		7.5" of Pavement.	
										0.6	
										Brown, damp, dense, SAND, some gravel, trace silt, (Fill).	
	2D	24/20	2.80 - 4.80	4/5/5/5	10	15					
								76.0		2D(A): Brown, damp, medium dense, SAND, trace silt, (Fill).	
										3.0	
										2D(B): Grey-brown, moist, stiff, Silty CLAY, (Presumpscot Formation). PP=2.5-3.5 ksf	
5	3D	24/21	5.00 - 7.00	2/3/4/15	7	11	22			Brown, wet, medium dense, SAND, some silt, fine sand, (Presumpscot Formation).	
							40				
							48				
							45				
							20				
10	4D	24/24	10.00 - 12.00	WOR-12"/WO1P-12"	---		29			4D(B): Grey, wet, very soft, Silty CLAY, with 4D(B) SAND, trace silt, fine sand seams, (Presumpscot Formation).	
							27				
							36				
							42				
							36				
15	5D	24/24	15.00 - 17.00	WOH/2/1/1	3	5	42			Similar to above except soft to medium stiff.	
							38				
							35				
							35				
							39				
20	6D	24/19	20.00 - 22.00	1/1/1/1	2	3	PROBE			Brown, wet, very loose, SAND, some silt, (Presumpscot Formation).	
	V3		20.63 - 21.00	Su=384/27 psf						55x110 mm raw torque readings: V3: 14.0/1.0 ft-lbs V4: 20.0/3.0 ft-lbs	
	V4		21.63 - 22.00	Su=549/82 psf						Advanced by hydraulic pushed rod probe from 22 to 29.4 ft bgs.	
25											

Remarks:

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-110
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	79.0	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-11-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 48+59.3, 17.4' R Main Street	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±2 ft (after drilling)
Hammer Efficiency Factor:	0.918	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
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MV = Unsuccessful Field Vane Shear Test Attempt
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SSA = Solid Stem Auger
HSA = Hollow Stem Auger
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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
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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
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G = Grain Size Analysis
C = Consolidation Test

Depth (ft.)	Sample Information: 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											
								49.6		29.4	
30										Hammer driven rod probe. 29.4-30.4 ft: 29 blows 30.4-31.4 ft: 20 blows 31.4-32.4 ft: 12 blows 32.4-33.3 ft: 50 blows/8 inches.	
								45.7		33.3	
										Bottom of Exploration at 33.3 feet below ground surface. Rod Probe Refusal.	
35											
40											
45											
50											

Remarks:

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-111
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	60.0	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-09-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	NQ2
Boring Location:	Sta. 63+55.6, 14.9' L Harnois Avenue	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±4 ft (after drilling)
Hammer Efficiency Factor: 0.918		**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
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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

Sample Information

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	24/12	0.80 - 2.80	7/5/3/3	8	12	SSA	59.3		8.5" of Pavement.	
										0.7	
								58.7		1D(A): Dark brown, damp, medium dense, SAND, some gravel trace silt, (Fill - Base Gravel).	
	2D	24/8	2.80 - 4.80	7/4/3/4	7	11				1.3 1D(B): Brown, moist, medium dense, Sandy SILT. Similar to above.	
5								55.0		5.0	
	3D	13/13	5.00 - 6.08	2/72/50-1"	---		29			Brown, wet, very dense, Sandy SILT, some gravel, (Glacial Till).	
							46				
	R1	35/32	7.30 - 10.22	RQD = 70%			85 NQ2	53.0		7.0 Top of Bedrock at Elev 53.0 feet. Advanced by rollercone from 7.0 to 7.3 ft bgs. R1:Bedrock: Dark grey, metamorphic, biotite-mica-SCHIST with quartz and feldspar, hard, slight weathering, joints are moderate dipping (35-55 degrees) with low angle (10-30 degrees) areas, very close to close and closed, (Berwick Formation). Rock Mass Quality = Fair. R1:Core Times (min:sec) 7.3-8.3 ft (4:49) 8.3-9.3 ft (4:10) 9.3-10.2 ft (4:04) 91% Recovery.	
10	R2	8/6	10.22 - 10.89	RQD = 0%				49.1		R2:Bedrock: Similar to R1. Rock Mass Quality = Very Poor. R2:Core Times (min:sec) 10.2-10.9 ft (4:04) 75% Recovery.	
										10.9 **Bottom of Exploration at 10.9 feet below ground surface.**	
15											
20											
25											

Remarks:

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Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Intersection Improvements and Signalization of Cumberland Mills Rotary
Location: Westbrook, Maine

Boring No.: HB-WBR-112
WIN: 018637.00

Driller:	S. W. Cole Explorations, LLC	**Elevation (ft.)**	64.6	**Auger ID/OD:**	5" Solid-Stem
Operator:	M. Leonard	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	J. DuBois	**Rig Type:**	Diedrich D-50	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	09-09-2018	**Drilling Method:**	Cased Wash	**Core Barrel:**	N/A
Boring Location:	Sta. 86+46.6, 31.1' R CS to HA	**Casing ID/OD:**	HW 4"/4.5"	**Water Level*:**	±4 ft (after drilling)
Hammer Efficiency Factor: 0.918		**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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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
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WC = Water Content, percent
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
G = Grain Size Analysis
C = Consolidation Test

Sample Information

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	64.0		7.5" of Pavement.	
										0.6	
	1D	24/8	1.20 - 3.20	4/4/3/3	7	11				Brown, damp, medium dense, Gravelly SAND, trace silt, (Fill).	
								61.4		3.2	
	2D	24/24	3.20 - 5.20	4/5/5/6	10	15				Grey-brown, damp, stiff, Silty CLAY, (Presumpscot Formation). PP=4.0-5.5 ksf	
5	3D	24/24	5.20 - 7.20	4/4/6/7	10	15				Similar to above, except wet. PP=5.5-6.5 ksf	
							62				
							77				
							69				
							64				
10	4D	24/24	10.00 - 12.00	2/2/3/3	5	8	81			Grey, wet, medium stiff, Silty CLAY, (Presumpscot Formation). PP=2.0-4.0 ksf	
							72				
							74				
							71				
							80				
15	5D	19/12	15.00 - 16.58	2/1/57/50-1"	58	89	93	49.6		15.0	
							59			Grey, wet, very dense, Gravelly SAND, little silt, (Glacial Till).	
								47.7		Casing Refusal.	
										16.9	
										Bottom of Exploration at 16.9 feet below ground surface. Refusal.	
20											
25											

Remarks:

Autohammer SN 367
bgs = below ground surface

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.

S.W.COLE ENGINEERING, INC.

APPENDIX D

Evaluations

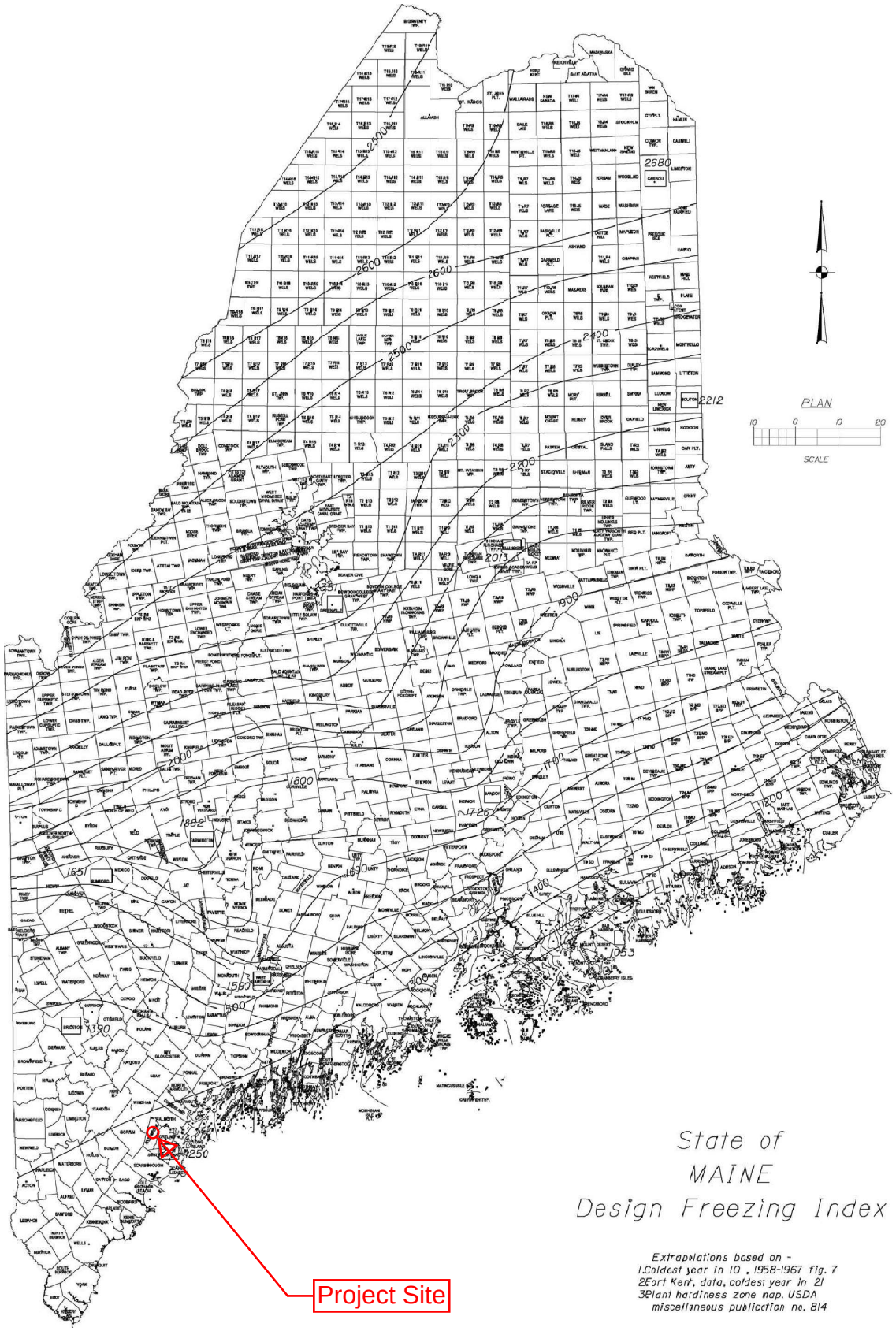

Figure 5-1 Maine Design Freezing Index Map

5.2 General

5.2.1 Frost

Any foundation placed on seasonally frozen soils must be embedded below the depth of frost penetration to provide adequate frost protection and to minimize the potential for freeze/thaw movements. Fine-grained soils with low cohesion tend to be most frost susceptible. Soils containing a high percentage of particles smaller than the No. 200 sieve also tend to promote frost penetration.

In order to estimate the depth of frost penetration at a site, Table 5-1 has been developed using the Modified Berggren equation and Figure 5-1 Maine Design Freezing Index Map. The use of Table 5-1 assumes site specific, uniform soil conditions where the Geotechnical Designer has evaluated subsurface conditions. Coarse-grained soils are defined as soils with sand as the major constituent. Fine-grained soils are those having silt and/or clay as the major constituent. If the make-up of the soil is not easily discerned, consult the Geotechnical Designer for assistance. In the event that specific site soil conditions vary, the depth of frost penetration should be calculated by the Geotechnical Designer.

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	58.2	52.5
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

S.W.COLE ENGINEERING, INC.

SPT BLOW COUNT CONVERSION AND FRICTION ANGLE CORRELATION FOR GRANULAR SOILS

Project Name: Mast Arm Structures / Cumberland Mills Rotary
Project No.: WIN 18637 (S.W.COLE #18-0952)
Evaluated By/Date: MAS / October 2018
Reviewed By/Date: TJM / October 2018

91.8 Hammer Efficiency
u = 8 Depth to Water

		BORING		HB-WBR-108			Correction Factors							
Soil Layer	Stratum	Sample No.	Top of Sample Depth (ft)	Field N-Value N_m	Total Stress at Sample Depth (psf)	Effective Stress at Sample Depth (psf)	Overburden Stress[1] C_N	Hammer Efficiency C_E	Borehole Diameter[2] C_B	Rod Length[2] C_R	Sampler[2] C_S	N_{60}	$(N1)_{60}$	Friction Angle[3] (degrees)
1	Fill	1D	1	3	130	130	1.92	1.53	1.0	0.75	1.0	4	8	28
1	Fill	2D	3	6	390	390	1.55	1.53	1.0	0.75	1.0	7	11	29
1	Fill	3D	5	8	650	650	1.38	1.53	1.0	0.75	1.0	10	14	30
1	Fill	4D	10	2	1300	1175	1.18	1.53	1.0	0.75	1.0	3	4	28
2	Presumpscot	5D	15	10	1940	1503	1.10	1.53	1.0	0.85	1.0	14	16	31
2	Presumpscot	6D	20	1	2540	1791	1.04	1.53	1.0	0.95	1.0	2	3	28

1. Determination of overburden stress correction factor (CN) based on Peck, Hanson and Thornburn (1974) and guidance from AASHTO LRFD Section 10.4.6.2.4 (AASHTO LRFD 8th Ed., 2017).
2. Determination of correction factors (CB, CR, CS) based on guidance from Seed et al. (1985) and Skempton (1986) as presented in Das (2014) Principles of Foundation Engineering, 8th Ed. Table 3.5.
3. Estimated friction angle based on guidance from Peck, Hanson and Thornburn (1974)

Bearing Resistance of Mast Arm Foundations

Foundation Soil Parameters: silty CLAY (ML-CL)

$\gamma_{sat} := 118\ pcf$ Saturated Unit Weight

$\gamma_{moist} := 115\ pcf$ Moist Unit Weight

$\phi := 0\ deg$ Undrained Friction Angle

$c_s := \begin{bmatrix} 400 \\ 600 \\ 800 \\ 1200 \end{bmatrix}\ psf$ Undrained Shear Strenght

$\gamma_w := 62.4\ pcf$ Unit Weight of Water

Foundation Patameters:

$B := 3\ ft$ Foundation Width

$L := B$ Circular Foundation

$D_f := 10\ ft$ Minimum Embedment Depth

$D_w := 0\ ft$ Depth of Foundation Below Water

Bearing Resistance - Service Limit State

From AASHTO LRFD Table 10.6.2.6.1-1, Presumptive Bearing Resistance for Spread Footing Foundations at the Service Limit State Modified after U.S. Department of the Navy (1982)

Bearing Material: homogeneous inorganic clay, sandy or silty clay (CL, CH)

Consistency in Place: soft to medium stiff

Bearing Resistance Range: 1 to 2 ksf (soft) / 2 to 6 ksf (medium stiff to stiff)

Recommended Bearing Resistance: 1 ksf (soft) / 3 ksf (medium stiff to stiff)

Recommend Factored Bearing Resistance to limit settlement for Service Limit State

1 ksf in soft silty CLAY
2 ksf in medium stiff silty CLAY
3 ksf in stiff silty CLAY

Bearing Resistance - Strength Limit State

From AASHTO LRFD Section 10.6.3.1.2a

$$q_n = c_s \cdot N_{cm} + (\gamma_{sat} - \gamma_w) \cdot D_f \cdot N_{qm} \cdot C_{wq} + 0.5 \cdot (\gamma_{sat} - \gamma_w) \cdot B \cdot N_{\gamma m} \cdot C_{w\gamma}$$

From Table 10.6.3.1.8a-1

$N_c := 5.14$ $N_q := 1$ $N_\gamma := 0$

$s_c := 1$ $s_q := 1$ $s_\gamma := 1$

$i_c := 1$ $i_q := 1$ $i_\gamma := 1$

$N_{cm} := N_c \cdot s_c \cdot i_c = 5.14$ $N_{qm} := N_q \cdot s_q \cdot i_q = 1$ $N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma = 0$

From Table 10.6.3.1.8a-2, for Dw = 0.0

$C_{wq} := 0.5$ $C_{w\gamma} := 0.5$

Nominal Bearing Resistance

LRFD Eqn 10.6.3.1.2a-1

$$q_n := c_s \cdot N_{cm} + (\gamma_{sat} - \gamma_w) \cdot D_f \cdot N_{qm} \cdot C_{wq} + 0.5 \cdot (\gamma_{sat} - \gamma_w) \cdot B \cdot N_{\gamma m} \cdot C_{w\gamma}$$

$$q_n = \begin{bmatrix} 2.3 \\ 3.4 \\ 4.4 \\ 6.4 \end{bmatrix} \textit{ksf} \quad \text{for} \quad c_s = \begin{bmatrix} 400 \\ 600 \\ 800 \\ 1200 \end{bmatrix} \textit{psf}$$

Factored Bearing Resistance

From AASHTO LRFD Table 10.5.5.2.2-1, Resistance Factor for Geotechnical Resistance of Shallow Foundations at the Strength Limit State

$\varphi_b := 0.45$

$q_r := \varphi_b \cdot q_n$

$$q_r = \begin{bmatrix} 1.1 \\ 1.5 \\ 2 \\ 2.9 \end{bmatrix} \textit{ksf} \quad \text{for} \quad c_s = \begin{bmatrix} 400 \\ 600 \\ 800 \\ 1200 \end{bmatrix} \textit{psf}$$

Strength Limit Factored Bearing Resistance

Bearing Resistance of Mast Arm Foundations

Foundation Soil Parameters: silty CLAY (ML-CL)

$\gamma_{sat} := 122\ pcf$ Saturated Unit Weight

$\gamma_{moist} := 120\ pcf$ Moist Unit Weight

$\phi := 28\ deg$ Undrained Friction Angle

$c_s := 0\ psf$ Undrained Shear Strenght

$\gamma_w := 62.4\ pcf$ Unit Weight of Water

Foundation Patameters:

$B := \begin{bmatrix} 2.5 \\ 3 \\ 3.5 \\ 4 \\ 4.5 \\ 5 \end{bmatrix} ft$ Foundation Width

$L := B$ Circular Foundation

$D_f := 10\ ft$ Minimum Embedment Depth

$D_w := 0\ ft$ Depth of Foundation Below Water

Bearing Resistance - Service Limit State

From AASHTO LRFD Table 10.6.2.6.1-1, Presumptive Bearing Resistance for Spread Footing Foundations at the Service Limit State Modified after U.S. Department of the Navy (1982)

Bearing Material: fine sand, silty or clayey medium to fine sand (SP, SM, SC)

Consistency in Place: loose

Bearing Resistance Range: 2 to 4 ksf (loose)

Recommended Bearing Resistance: 3 ksf (loose)

Recommend Factored Bearing Resistance to limit settlement for Service Limit State
3 ksf

Bearing Resistance - Strength Limit State

From AASHTO LRFD Section 10.6.3.1.2a

$$q_n = c_s \cdot N_{cm} + (\gamma_{sat} - \gamma_w) \cdot D_f \cdot N_{qm} \cdot C_{wq} + 0.5 \cdot (\gamma_{sat} - \gamma_w) \cdot B \cdot N_{\gamma m} \cdot C_{w\gamma}$$

From Table 10.6.3.1.8a-1

$N_c := 25.8$ $N_q := 14.7$ $N_\gamma := 16.7$

$s_c := 1$ $s_q := 1$ $s_\gamma := 1$

$i_c := 1$ $i_q := 1$ $i_\gamma := 1$

$N_{cm} := N_c \cdot s_c \cdot i_c = 25.8$ $N_{qm} := N_q \cdot s_q \cdot i_q = 14.7$ $N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma = 16.7$

From Table 10.6.3.1.8a-2, for Dw = 0.0

$C_{wq} := 0.5$ $C_{w\gamma} := 0.5$

Nominal Bearing Resistance

LRFD Eqn 10.6.3.1.2a-1

$$q_n := c_s \cdot N_{cm} + (\gamma_{sat} - \gamma_w) \cdot D_f \cdot N_{qm} \cdot C_{wq} + 0.5 \cdot (\gamma_{sat} - \gamma_w) \cdot B \cdot N_{\gamma m} \cdot C_{w\gamma}$$

$$q_n = \begin{bmatrix} 5 \\ 5.1 \\ 5.3 \\ 5.4 \\ 5.5 \\ 5.6 \end{bmatrix} \textit{ksf} \quad \text{for} \quad c_s = 0 \ \textit{psf}$$

Factored Bearing Resistance

From AASHTO LRFD Table 10.5.5.2.2-1, Resistance Factor for Geotechnical Resistance of Shallow Foundations at the Strength Limit State

$\varphi_b := 0.45$

$q_r := \varphi_b \cdot q_n$

$$q_r = \begin{bmatrix} 2.3 \\ 2.3 \\ 2.4 \\ 2.4 \\ 2.5 \\ 2.5 \end{bmatrix} \textit{ksf} \quad \text{for} \quad c_s = 0 \ \textit{psf}$$

Strength Limit Factored Bearing Resistance