

PRELIMINARY DESIGN REPORT

17-0683

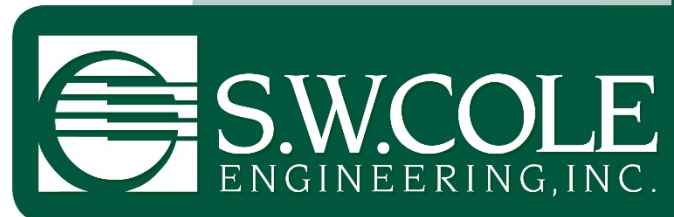
January 2, 2018

Explorations and Geotechnical Engineering Services

Kimball Brook Bridge #5573 Replacement
Route 113 over Kimball Brook
Fryeburg, Maine
WIN 021691

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

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

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Attention: Laura Krusinski, P.E.
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Subject: Preliminary Geotechnical Design Report
Explorations and Geotechnical Engineering Services
Kimball Brook Bridge #5573 Replacement
Route 113 over Kimball Brook
Fryeburg, Maine
WIN 21691.00

Dear Laura:

In accordance with our Proposal dated June 28, 2017 and project specific Assignment Letter #16 dated July 10, 2017, we have made the requested subsurface explorations for the subject project. The purpose of our services was to obtain subsurface information in order to provide geotechnical parameters and recommendations for foundations and earthwork associated with the proposed construction. 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. 2015072000000000085, dated July 20, 2015. The contents of this report are subject to the limitations in Appendix A.

1.0 INTRODUCTION

1.1 Site Conditions

The site is located on Route 113 at the crossing of Kimball Brook in Fryeburg, Maine. The site location is shown on the "Site Location Map" attached in Appendix B.

Based on our review of the historic plans provided by MaineDOT, we understand the existing crossing was constructed in 1954 and consists of twin structural plate pipe arch culverts each with a 10'-11" span and 7'-1" rise.

1.2 Proposed Construction

Based on discussions with MaineDOT, we understand the existing structure will be replaced. Replacement alternatives under consideration include:

- Single precast concrete box culvert; and
- Twin precast concrete box culverts.

We understand current planning is considering a clear span/opening of about 24 to 29 feet with a 0 degree skew. We understand the structure will be replaced on the existing horizontal and vertical alignment.

2.0 EXPLORATIONS AND TESTING

2.1 Explorations

Four test borings (BB-FKB-101, -102, -103 and -104) were made at the site on July 24, 25 and 26, 2017 by S. W. Cole Explorations, LLC. The as-drilled exploration locations were selected and established in the field by S.W.COLE using taped measurements from existing site features. The ground surface elevations of the test borings were provided by MaineDOT. The approximate exploration locations are shown on the "Boring Location Plan" 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 as Appendix C.

2.2 Testing

The test borings were drilled using a combination of solid-stem auger, cased wash boring and rock core drilling techniques. The soils were sampled at 2 to 5-foot intervals using a split-spoon sampler and Standard Penetration Testing (SPT) techniques using a calibrated automatic hammer. Upon encountering refusal on bedrock, borings BB-FKB-101, BB-FKB-102 and BB-FKB-104 were advanced about 10 feet into bedrock using a NQ2 wireline rock coring. The hammer efficiency factor (0.813), raw field N-value, corrected N-value (N_{60}) and rock core intervals are shown on the logs in Appendix C. Corrected N-values in this report were computed by applying an average energy transfer of 0.813 for the calibrated automatic hammer to the raw field N-values.

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

performed on disturbed SPT samples obtained during the explorations. Laboratory testing was performed by the MaineDOT Materials Testing and Exploration Central Laboratory in Bangor, Maine in accordance with applicable American Association of State Highway and Transportation Officials (AASHTO) testing procedures. Laboratory testing included thirteen (13) natural water content tests, nine (9) grain size analyses, two (2) Atterberg Limits and three (3) organic content tests. Results of the laboratory testing are noted on the logs and provided in Appendix D.

3.0 SUBSURFACE CONDITIONS

3.1 Surficial and Bedrock Geology

According to the Maine Geological Survey's (MGS's) mapping of the Fryeburg Quadrangle, Maine (Open-File No. 14-29, MGS 2014), surficial geologic units within the site vicinity consists of stream alluvium consisting of sand, silt, gravel and organic material. The subsurface conditions encountered were consistent with the mapped surficial geology; however, the explorations also encountered a surface deposit of fill soils from previous site development and a layer of silty clay was encountered in borings BB-FKB-101 and BB-FKB-103 made for the west abutment.

Bedrock in the site vicinity is mapped as Carboniferous age muscovite granite (Bedrock Geologic Map of Maine, MGS 1985). The bedrock is generally composed of medium- to coarse-grained, hard, slightly weathered, muscovite granite. The bedrock cores recovered from the test borings are generally consistent with the mapped bedrock geology.

3.2 Subsurface Conditions

The test borings encountered a soils profile generally consisting of a surface layer of pavement overlying fill overlying alluvium overlying bedrock. The principal strata encountered in the explorations are summarized below. An "Interpretive Subsurface Profile" is attached in Appendix B. Refer to the attached logs for more detailed information of the subsurface findings at the exploration locations.

Fill: Below an approximate 5 to 8 inch layer of pavement, the borings encountered fill extending to depths of about 5 to 8.5 feet below ground surface (bgs), corresponding to Elevation (El.) 379.4 to 376 feet. The fill generally consisted of:

- Brown, SAND, trace gravel, trace silt;
- Brown, SAND, some gravel, little silt; and
- Brown, Silty SAND.

The fill was generally medium dense to dense with SPT N_{60} values ranging from 19 to 37 blows per foot (bpf).

Alluvium: Below the fill, the borings generally encountered stream alluvium to depths of about 23 to 27 feet bgs, corresponding to El. 361.3 to 357.6 feet. The alluvium generally consisted of:

- Brown, SAND, trace silt;
- Brown, SAND, trace silt, trace gravel;
- Dark brown to brown, SAND, some silt, little gravel; and
- Dark brown, Silty SAND; and

The upper 5 to 10 feet of the alluvium deposit contained wood fibers and wood fragments. Laboratory testing indicated organic contents varying from about 1 to 5 percent within this zone.

The alluvium was generally very loose to medium dense with SPT N_{60} values ranging from 3 to 35 bpf.

Borings BB-FKB-101 and BB-FKB-103 encountered an approximately 4-foot thick layer of grey, low plasticity, silty clay, trace sand at a depth of about 15 to 16 feet. The clay layer was generally stiff with SPT N_{60} values of 11 and 14 bpf.

Bedrock: Bedrock was encountered in each boring and sampled in borings BB-FKB-101, BB-FKB-102 and BB-FKB-104. The top of bedrock was about 23 to 27 feet bgs, corresponding to El. 361.3 to 357.6 feet. The bedrock consisted of light grey, hard, slightly weathered, granite. Joints were generally horizontal to moderately dipping, tight and very close to close.

The following table summarizes the approximate depths to bedrock, corresponding top of bedrock elevations and Rock Quality Designation (RQD) where encountered.

Boring Number (Substructure)	Approximate Depth to Bedrock (feet)	Approximate Bedrock Elevation (feet)	RQD (RMQ)
BB-FKB-101 (West Abutment)	24.8	359.5	93 to 95% (Excellent)
BB-FKB-102 (East Abutment)	26.8	357.6	80 to 82% (Good)
BB-FKB-104 (East Abutment)	25.2	358.8	10 to 55% (Poor to Fair)

RQD values for the bedrock generally ranged from 10 to 95 percent correlating to a Rock Mass Quality (RMQ) of poor to excellent.

3.3 Groundwater Conditions

The soils encountered at the test borings were damp to moist from the ground surface. The measured water levels during drilling ranged from about 5 to 6 feet below ground surface. 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, as well as changes in site use and the water level of Kimball Brook.

4.0 PRELIMINARY GEOTECHNICAL EVALUATION

S.W.COLE conducted geotechnical engineering evaluations in accordance with 2014 AASHTO LRFD Bridge Design Specifications, 7th Edition with 2016 interim revisions (AASHTO) and the MaineDOT Bridge Design Guide, 2003 Edition with revisions through August 2014 (MaineDOT BDG) and offers the following:

4.1 Foundation Options

The site is generally underlain by alluvium consisting of very loose to medium dense sand with varying amounts of silt and little to trace gravel to a depth of about 23 to 27 feet overlying bedrock. The upper 5 to 10 feet of the alluvium contained wood fibers and wood fragments. Below the alluvium, a 4 foot layer of stiff, silty clay, trace sand was encountered beneath the west abutment.

We understand the proposed replacement structure alternatives include:

- Single precast concrete box culvert; and
- Twin precast concrete box culverts.

We understand the proposed total span will be about 24 to 29 feet and the horizontal alignment and vertical profile will not change. We understand the final span will be at least 1.2 times the bank-full width.

Additionally, based on the subsurface conditions encountered during the investigation, we anticipate that a single-span, pile supported integral abutment bridge (IAB) would be a viable replacement structure alternative. We understand an Single Span IAB is currently not being considered by the team.

4.2 Precast Concrete Box Culvert

The precast box culvert options would consist of single or twin precast concrete box culverts with a 0 degree skew. We understand the replacement structure will have an overall span of 24 to 29 feet. The slopes on the inlet and outlet ends of the culvert shall have 1.75:1(H:V) or flatter riprap slopes. The invert of the box culverts will be recessed approximately 3 feet into the stream bed and about 2 feet of "special fill" will be placed inside the bottom of the culvert to create a natural streambed.

Based on the MaineDOT BDG Section 8.3.1, the precast box culvert shall include toe walls at the inlet and outlet ends to prevent undermining. The toe walls should extend at least 1 foot below the maximum scour depth.

We recommend the box culvert be founded on a minimum 1-foot thick mat of MaineDOT Standard Specification 703.19 Granular Borrow for Underwater Backfill. The culvert backfill shall consist of MaineDOT Standard Specification 703.19 Granular Borrow for Underwater Backfill modified with a maximum particle size of 3 inches.

Based on the subsurface conditions and subgrade preparation described herein, the factored bearing resistance for a precast box culvert strength and service limit states based on LRFD Section 10.6.3.2.2a shall not exceed the factored bearing resistances shown in the following table.

Overall Foundation Width (feet)	Factored Bearing Resistance (ksf)	
	Strength Limit State	Service Limit State
26	3.6	2.0
27	3.7	2.0
28	3.8	2.0
29	3.9	2.0
30	4.0	2.0
31	4.1	2.0

The service limit state may govern the design. The bearing stress shall not exceed the nominal structural resistance of the structural concrete of $0.3 \times f'_c$.

We recommend the following coefficients of subgrade reaction (k_v) for preliminary analysis for the box culvert bearing on 1 foot mat of Granular Borrow for Underwater Backfill overlying undisturbed native alluvial sands.

Location	Coefficient of Subgrade Reaction (k_v)
Corner of Box Culvert	11 pci
Center of Box Culvert	10 pci

We recommend the bearing resistance and coefficient of subgrade reaction be re-evaluated during the final design.

4.3 Single-Span Bridge

The single-span bridge option would have a span greater than 24 to 29 feet with a 0 degree skew. This bridge alternative would be supported on pile-supported integral abutments. We anticipate the soils on the inlet and outlet ends of the bridge structure would be retained with short wing walls and 1.75:1(H:V) or flatter riprap slopes in accordance with Standard Detail 610(03).

We anticipate a pile supported IAB structure is viable and feasible from a geotechnical perspective. Detailed design recommendations are not provided herein and can be provided if an IAB bridge is selected for final design.

4.4 Frost Considerations

Based on the Maine Design Freezing Index Map¹, the design freezing index for the Fryeburg, Maine area is approximately 1,400 freezing degree-days. Based on Section

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

5.2.1 of the MaineDOT BDG and subsurface soils encountered, the maximum seasonal frost penetration is estimated to be on the order of about 6.6 feet. Considering this, we recommend foundations should have at least 6.6 feet of soil cover to provide frost protection.

4.5 Seismic Design Considerations

Seismic site class was evaluated in accordance with AASHTO Section 3.10.3.1 Method B (average N-value method). Based on the subsurface information, the average N-value was between 15 and 50 bpf corresponding to an AASHTO Site Class D as defined in AASHTO Table 3.10.3.1-1.

The USGS on-line Seismic Design Maps Tool was used to obtain the seismic design parameters for the site. Based on the assigned Site Class (AASHTO Site Class D) and site coordinates, the USGS resource provides the recommended AASHTO Response Spectrum for a 7 percent probability of exceedance in 75 years. The results for the project site are summarized below:

RECOMMENDED SEISMIC DESIGN PARAMETERS²	
Site Class	D
PGA	0.099 g
S _s	0.194 g
S ₁	0.050 g
F _{pga}	1.6
F _a	1.6
F _v	2.4
A _s	0.158 g
S _{DS}	0.311 g
S _{D1}	0.119 g
Seismic Zone (based on S _{D1} < 0.15)	Zone 1

NOTE: Site Coordinates: N44.12124722, W70.97792222

Based on LRFD Section 3.10.1, seismic analysis is not required for buried structures except when they cross active faults. There are no known active faults at the site, therefore no seismic analysis is required for the buried structure alternatives.

² U.S. Geological Survey, Seismic Design Map, , accessed September 15, 2017
<http://earthquake.usgs.gov/designmaps/us/application.php>

4.6 Recommendations for Scour Evaluation

Based on the laboratory grain size analyses test results, we estimated the average grain diameter corresponding to 50 percent passing by weight (D_{50}) for use in scour evaluations ranges from 0.4 to 0.7 mm. Results of the grain size analyses tests are included in Appendix B and the estimated D_{50} for samples near the channel elevation are summarized in the following table:

Boring No.	Sample No.	Approximate Depth (ft)	Approximate Sample Elevation (ft)	Estimated D_{50}
BB-FKB-101	5D	10	374.3	0.64 mm
BB-FKB-102	5D(B)	11	373.4	0.43 mm
BB-FKB-104	4D	10	374.5	0.40 mm

MaineDOT BDG Sections 2.3.11 and 5.3.4.4 requires that footings for bridges on soil be founded at least 2 feet below the scour elevation as determined from the check flood (Q500) event. Furthermore, spread footings supported on soil shall be located a minimum of 6 feet below the thalweg of the waterway.

5.0 CLOSURE

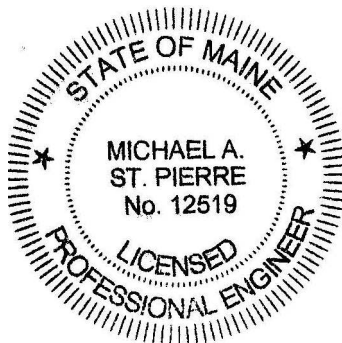
We trust this information meets your present needs. Please contact us if you have any questions or need further assistance.

Sincerely,

S. W. Cole Engineering, Inc.

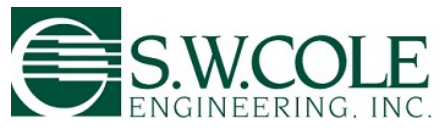


Michael A. St. Pierre, P.E.
Geotechnical Engineer



Timothy J. Boyce, P.E.
Senior Geotechnical Engineer

MAS/ejb-tjb



APPENDIX A

Limitations



This report has been prepared for the exclusive use of the Maine Department of Transportation for specific application to the Kimball Brook Bridge #5573 Replacement carrying Route 113 over Kimball Brook (MaineDOT WIN 021691.00) in Fryeburg, 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.

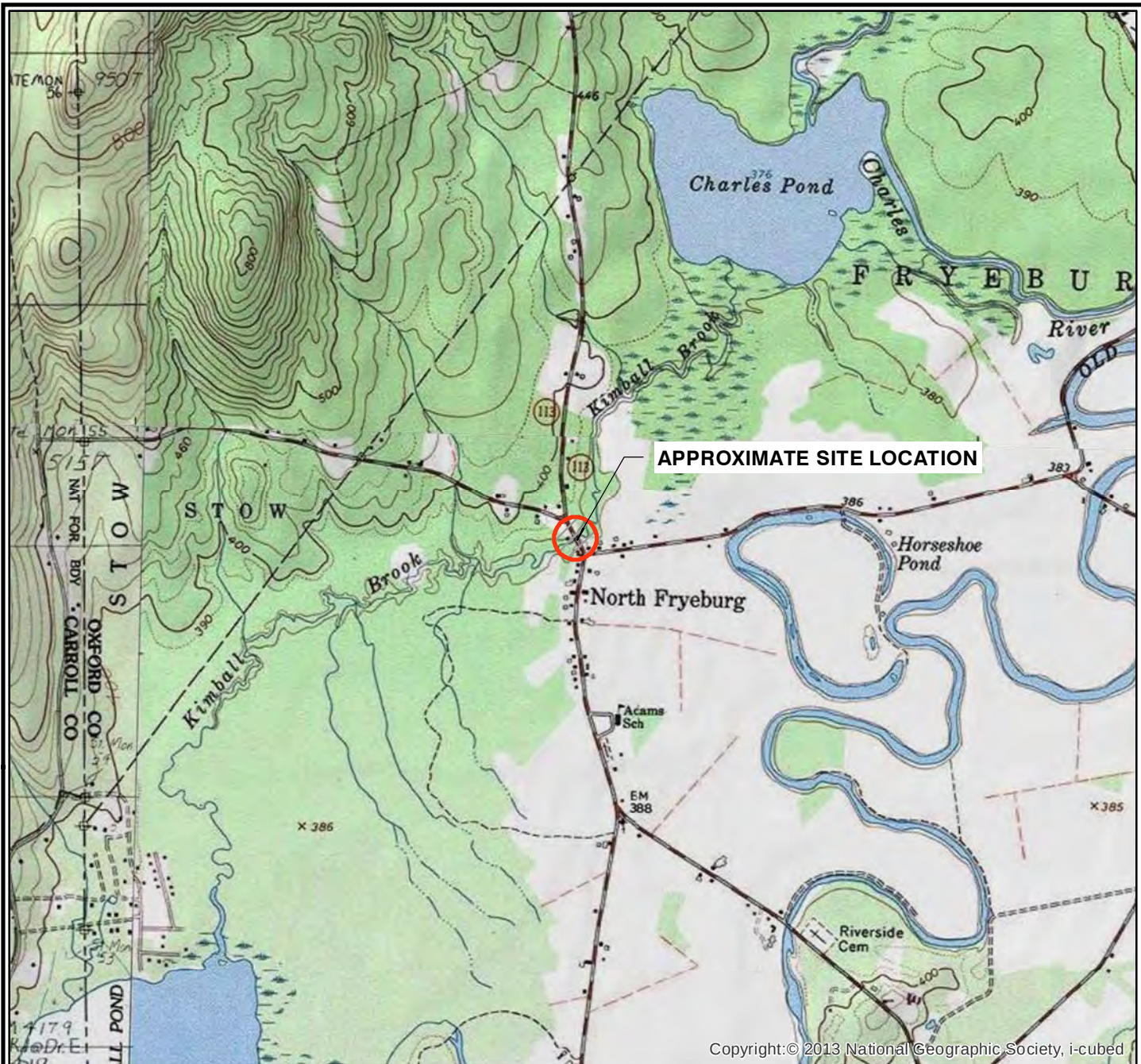
The analyses performed during this investigation and recommendations presented in this report are based in part upon the data obtained from subsurface explorations made at the site. Variations in subsurface conditions may occur between explorations and may not become evident until construction. If variations 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.

APPENDIX B

Figures



2,000 0 2,000 4,000
Scale in Feet



MAINEDOT

SITE LOCATION MAP

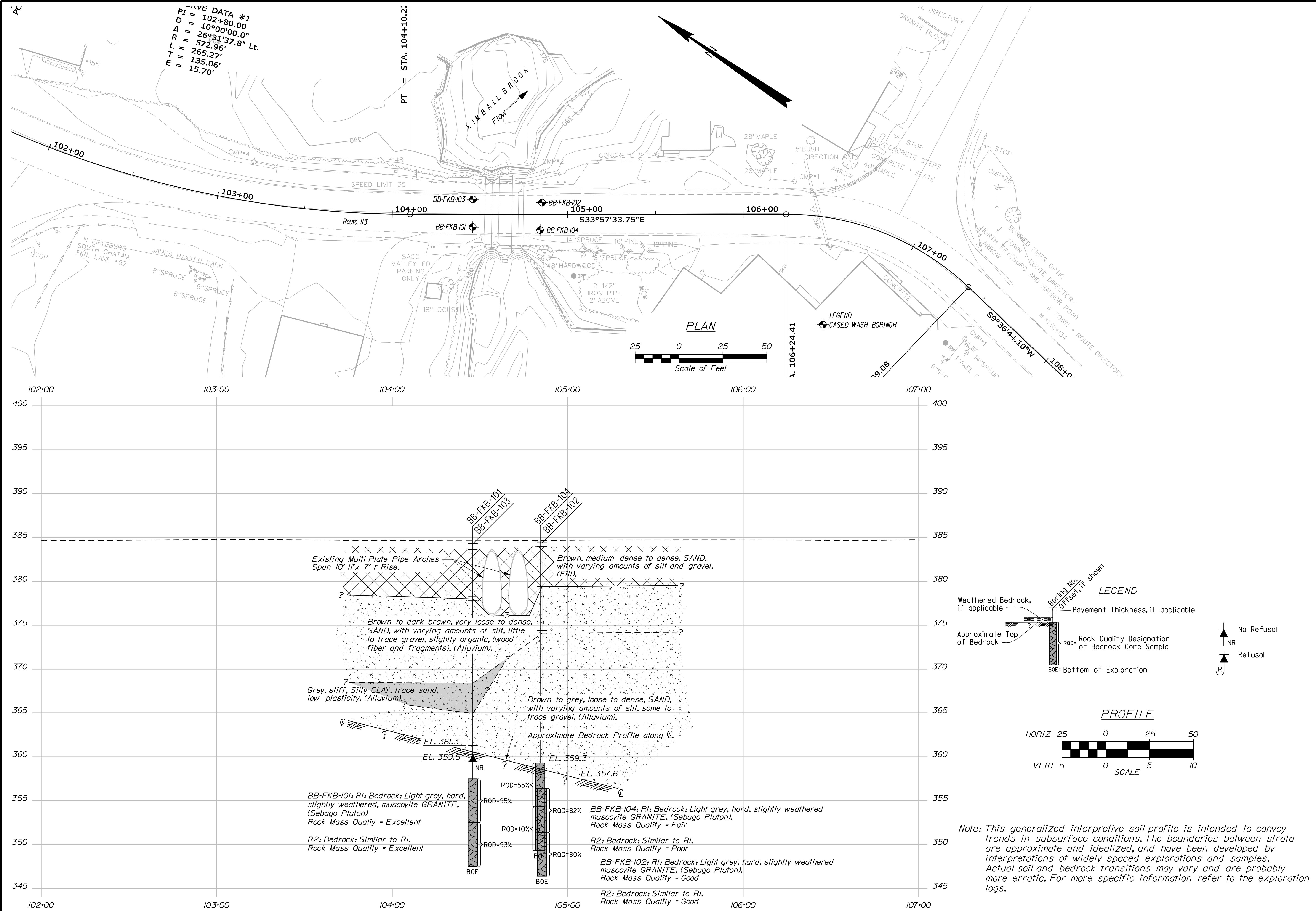
KIMBALL BROOK BRIDGE #5573 REPLACEMENT
ROUTE 113 OVER KIMBALL BROOK
FREYBURG, MAINE
WIN 21691.00

NOTE:

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

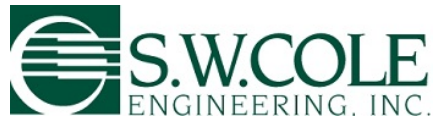
Job No. 17-0683
Date: 09/12/2017

Scale 1:24000
Sheet 1



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

STATE OF MAINE		DEPARTMENT OF TRANSPORTATION		STP-2169(100)		BRIDGE PLANS	
KIMBALL BROOK BRIDGE		KIMBALL BROOK		OXFORD COUNTY		FRYEBURG	
BORING LOCATION PLAN & INTERPRETIVE SUBSURFACE PROFILE		SHEET NUMBER		6		OF 1	
PROJ. MANAGER		BY		SIGNATURE		P.E. NUMBER	
DESIGN-DETAILED		DATE		AUG 2017		DATE	
CHECKED-REVIEWED		DESIGN-DETAILED		REVISIONS 1		REVISIONS 2	
DESIGN-DETAILED		REVISIONS 3		REVISIONS 4		FIELD CHANGES	



APPENDIX C

Boring Logs & Key to Soil and Rock Descriptions and Terms

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Kimball Brook Bridge #5573 carries Route 113 over Kimball Brook Location: Fryeburg, Maine				Boring No.: BB-FKB-101 WIN: 21691					
Driller: S. W. Cole Explorations, LLC				Elevation (ft.): 384.3				Auger ID/OD: 5" Solid Stem					
Operator: J. Lee				Datum: NAVD88				Sampler: Standard Split Spoon					
Logged By: E. Walker				Rig Type: CME 850				Hammer Wt./Fall: 140#/30"					
Date Start/Finish: 07-24-17				Drilling Method: Cased Wash				Core Barrel: NQ2					
Boring Location: Sta. 104+45.9, 7.2 Rt.				Casing ID/OD: HW 4"/4.5"				Water Level*: 5.5' (after drilling)					
Hammer Efficiency Factor: 0.813				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 Information								Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.	
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows						
0	1D	24/16	0.90 - 2.90	7/12/11/12	23	31	SSA	383.63		8" of Pavement	G#243337 A-1-b, SP WC=24.2% #243338 A-6, CL WC=39.0% LL=36 PL=24 PI=12		
										Brown, damp, dense, Gravelly SAND, little silt, (Fill).			
	2D	24/18	2.90 - 4.90	10/7/13/12	20	27				Dark brown, moist, medium dense, SAND, some gravel, little silt, (Fill). Red brick at 3.5 ft bgs.			
5	3D	24/18	5.00 - 7.00	2/11/3/2	14	19		378.30		3D(A): Dark brown, moist, medium dense, Silty SAND, little gravel, (Fill).			
	4D	24/18	7.00 - 9.00	6/5/11/30	16	22				3D(B): Dark brown, moist, medium dense, SAND, little gravel, little silt, slightly organic (wood fiber), (Alluvium). 3D(C): Grey-brown, wet, medium dense, SAND, some gravel, trace silt, (Alluvium). Dark brown, wet, medium dense, SAND, some silt, little gravel, slightly organic (wood fiber/fragments), (Alluvium).			
10	5D	24/18	10.00 - 12.00	3/4/16/14	20	27	85			Grey-brown, wet, medium dense, SAND, trace gravel, trace silt, slightly organic (wood fiber/fragments), (Alluvium).			
							64			Similar to above.			
	6D	24/15	12.00 - 14.00	5/5/3/3	8	11	79						
							49						
							56						
15	7D	24/17	15.00 - 17.00	13/5/3/4	8	11	50	368.30		7D(A): Grey-brown, wet, medium dense, SAND, little gravel, trace silt, (Alluvium).			
							61			7D(B): Grey, wet, stiff, stiff, Silty CLAY, trace sand, low plasticity, (Alluvium).			
							64						
							55						
							56						
20	8D	24/15	20.00 - 22.00	4/3/3/4	6	8	36	364.30		Grey, loose, Silty SAND, (Alluvium).			
							34						
							75						
							64						
25							74	359.50					
								24.80					
Remarks: -bgs = below ground surface. -PP = Pocket Penetrometer Test No water circulation/return below 31.7 ft bgs.													
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.										Page 1 of 2 Boring No.: BB-FKB-101			

[illegible]

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Kimball Brook Bridge #5573 carries Route 113 over Kimball Brook Location: Fryeburg, Maine				Boring No.: BB-FKB-102 WIN: 21691				
Driller: S. W. Cole Explorations, LLC				Elevation (ft.): 384.4				Auger ID/OD: 5" Solid Stem				
Operator: J. Lee				Datum: NAVD88				Sampler: Standard Split Spoon				
Logged By: E. Walker				Rig Type: CME 850				Hammer Wt./Fall: 140#/30"				
Date Start/Finish: 07-25-17				Drilling Method: Cased Wash				Core Barrel: NQ2				
Boring Location: Sta. 104+85.4, 6.6 Lt.				Casing ID/OD: HW 4"/4.5"				Water Level*: 5.3' (after drilling)				
Hammer Efficiency Factor: 0.813				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 $N_{60} = (\text{Hammer Efficiency Factor}/60\%) * N\text{-uncorrected}$ 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							Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.	
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows					
0	1D	24/19	0.50 - 2.50	5/7/9/6	16	22	SSA	383.98		5" of Pavement	G#243339 A-1-b, SM WC=11.7%	
										0.42		
	2D	24/12	2.50 - 4.50	2/7/20/12	27	37						
5	3D	24/24	5.00 - 7.00	2/1/1-12"	2	3		379.40		Dark brown, moist, very loose, SAND, trace silt, slightly organic (wood fiber), (Alluvium).	#243340 WC=58.2% Loss on Ignition 4.9%	
	4D	24/15	7.00 - 9.00	1/1/1/1	2	3						
10	5D	24/20	10.00 - 12.00	1/3/4/5	7	9	22	373.40		5D(A): Dark brown, wet, loose, SAND, some silt, slightly organic (wood fiber), (Alluvium).	G#243341 A-1-b, SP WC=24.4%	
							34					
							47					
							46					
15	6D	24/6	15.00 - 17.00	2/1/4/3	5	7	14			6D(A): Brown, wet, loose, SAND, trace silt, trace gravel, (Alluvium).	G#270349 A-1-b, SP WC=22.0%	
							13					
							22					
							35					
20	7D	24/15	20.00 - 22.00	6/5/4/3	9	12	28			Grey, wet, medium dense, SAND, some silt, little gravel, (Alluvium).	G#270350 A-2-4, SM WC=10.6%	
							34					
							52					
							47					
25							48					
Remarks: -bgs = below ground surface. No water circulation/return below 32.2 ft bgs.												
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.										Page 1 of 2 Boring No.: BB-FKB-102		

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS						Project: Kimball Brook Bridge #5573 carries Route 113 over Kimball Brook Location: Fryeburg, Maine							Boring No.: BB-FKB-102																																																																																																																																																																																																																																																																																																												
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R1:Bedrock: Light grey, medium-grained, muscovite GRANITE, hard, slightly weathered, joints are low angle (5-35 degrees), moderately close and tight, (Sebago Pluton). Rock Mass Quality = Good. R1:Core Times (min:sec) 28.0-29.0 ft (2:58) 29.0-30.0 ft (3:10) 30.0-31.0 ft (2:57) 31.0-32.0 ft (3:04) 32.0-33.0 ft (2:38) 90% Recovery. R2:Bedrock: Similar to R1 except medium to coarse-grained, slightly to moderately weathered, with low angle (5-35 degrees) to moderately dipping (35-55 degrees) joints. Rock Mass Quality = Good. R1:Core Times (min:sec) 33.0-34.0 ft (1:57) 34.0-35.0 ft (2:14) 35.0-36.0 ft (1:34) 36.0-37.0 ft (1:38) 37.0-38.0 ft (1:53) 92% Recovery.</td><td rowspan="5"></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>R2</td><td>60/55</td><td>33.00 - 38.00</td><td>RQD = 80%</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td rowspan="5">35</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="5"></td><td rowspan="5"></td><td>Bottom of Exploration at 38.00 feet below ground surface.</td><td rowspan="5"></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td rowspan="5">40</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="5"></td><td rowspan="5"></td><td></td><td rowspan="5"></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td rowspan="5">45</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="5"></td><td rowspan="5"></td><td></td><td rowspan="5"></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td rowspan="5">50</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="5"></td><td rowspan="5"></td><td></td><td rowspan="5"></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table>																		25	8D	21/18	25.00 - 26.75	10/9/17/50-3"	26	35	46	357.60		Grey, wet, dense, SAND, some silt, some gravel, (Alluvium).																						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Boring No.: BB-FKB-102																																																																																																																																																																																																																																																																																																																									

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Kimball Brook Bridge #5573 carries Route 113 over Kimball Brook Location: Fryeburg, Maine				Boring No.: BB-FKB-103 WIN: 21691																																							
Driller: S. W. Cole Explorations, LLC				Elevation (ft.): 384.3				Auger ID/OD: 5" Solid Stem																																							
Operator: J. Lee				Datum: NAVD88				Sampler: Standard Split Spoon																																							
Logged By: E. Walker				Rig Type: CME 850				Hammer Wt./Fall: 140#/30"																																							
Date Start/Finish: 07-25-17				Drilling Method: Cased Wash				Core Barrel: NQ2																																							
Boring Location: Sta. 104+46.0, 8.5 Lt.				Casing ID/OD: HW 4"/4.5"				Water Level*: 5.8' (after drilling)																																							
Hammer Efficiency Factor: 0.813				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 Information								Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.																																			
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows																																								
0	1D	24/15	0.70 - 2.70	11/9/10/8	19	26	SSA	383.80		6" of Pavement	G#243342 A-1-b, SM WC=6.0%																																				
										0.50		Brown, damp, medium dense, SAND, some gravel, little silt, (Fill).																																			
5	2D	24/16	5.00 - 7.00	1/1/8/7	9	12		379.30			Dark brown, wet, medium dense, SAND, some silt, trace gravel, slightly organic (wood fiber/fragments), (Alluvium).																																				
											Cobbles.																																				
											Cobbles.																																				
10	3D	24/18	10.00 - 12.00	14/13/10/5	23	31	142				3D(A): Dark brown, wet, dense, SAND, some silt, slightly organic (wood fiber), (Alluvium).	#243343 WC=22.1% Loss on Ignition 1.2%																																			
							154				3D(B): Brown, wet, dense, SAND, some silt, trace gravel, slightly organic, (wood fiber), (Alluvium).																																				
							97																																								
							108																																								
15	4D	24/6	15.00 - 17.00	18/7/3/3	10	14	51	369.10			4D(A): Dark brown, wet, medium dense, Silty SAND, little gravel, slightly organic (wood fiber), (Alluvium).	#243344 A-4, CL WC=26.7% LL=34 PL=24 PI=10																																			
							51				4D(B): Grey, wet, stiff, Silty CLAY, little sand, low plasticity, (Alluvium).																																				
							47																																								
							58																																								
20	5D	24/15	20.00 - 22.00	3/2/4/5	6	8	74	365.30			Grey, wet, loose, SAND, some silt, some gravel, (Alluvium).																																				
							60																																								
							75																																								
							100	361.30			Top of Bedrock at Elev. 361.3 ft.																																				
25								360.30		Advanced by rollercone from 23.0 to 24.0 ft bgs.																																					
										Bottom of Exploration at 24.00 feet below ground surface.																																					

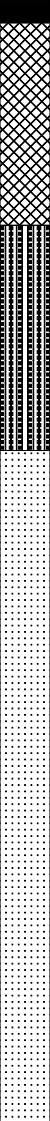
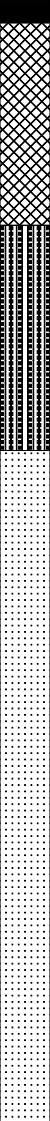
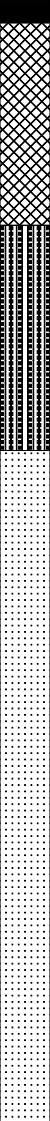
Remarks:
 -bgs = below ground surface.

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.

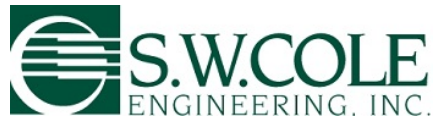
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Boring No.: BB-FKB-103

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Kimball Brook Bridge #5573 carries Route 113 over Kimball Brook Location: Fryeburg, Maine				Boring No.: BB-FKB-104 WIN: 21691																																																																																																																																																																																																																																																							
Driller: S. W. Cole Explorations, LLC				Elevation (ft.) 384.5				Auger ID/OD: 5" Solid Stem																																																																																																																																																																																																																																																							
Operator: J. Lee				Datum: NAVD88				Sampler: Standard Split Spoon																																																																																																																																																																																																																																																							
Logged By: E. Walker				Rig Type: CME 850				Hammer Wt./Fall: 140#/30"																																																																																																																																																																																																																																																							
Date Start/Finish: 07-26-17				Drilling Method: Cased Wash				Core Barrel: NQ2																																																																																																																																																																																																																																																							
Boring Location: Sta. 104+84.3, 9.0 Rt.				Casing ID/OD: HW 4"/4.5"				Water Level*: 5.6' (after drilling)																																																																																																																																																																																																																																																							
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Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Kimball Brook Bridge #5573 carries Route 113 over Kimball Brook Location: Fryeburg, Maine				Boring No.: BB-FKB-104 WIN: 21691																																																																																																																																																																		
Driller: S. W. Cole Explorations, LLC		Elevation (ft.) 384.5		Auger ID/OD: 5" Solid Stem																																																																																																																																																																						
Operator: J. Lee		Datum: NAVD88		Sampler: Standard Split Spoon																																																																																																																																																																						
Logged By: E. Walker		Rig Type: CME 850		Hammer Wt./Fall: 140#/30"																																																																																																																																																																						
Date Start/Finish: 07-26-17		Drilling Method: Cased Wash		Core Barrel: NQ2																																																																																																																																																																						
Boring Location: Sta. 104+84.3, 9.0 Rt.		Casing ID/OD: HW 4"/4.5"		Water Level*: 5.6' (after drilling)																																																																																																																																																																						
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UNIFIED SOIL CLASSIFICATION SYSTEM					MODIFIED BURMISTER SYSTEM					
MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES						
COARSE-GRAINED SOILS (more than half of material is larger than No. 200 sieve size)	GRAVELS (more than half of coarse fraction is larger than No. 4 sieve size)	CLEAN GRAVELS	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Descriptive Term		Portion of Total (%)			
		(little or no fines)	GP	Poorly-graded gravels, gravel sand mixtures, little or no fines.	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 (%) = $\frac{\text{sum of the lengths of intact pieces of core} * > 4 \text{ inches}}{\text{length of core advance}}$					
					*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))					
					Sample Container Labeling Requirements:					
					WIN		Blow Counts			
					Bridge Name / Town		Sample Recovery			
					Boring Number		Date			
					Sample Number		Personnel Initials			
					Sample Depth					
Maine Department of Transportation Geotechnical Section Key to Soil and Rock Descriptions and Terms Field Identification Information										

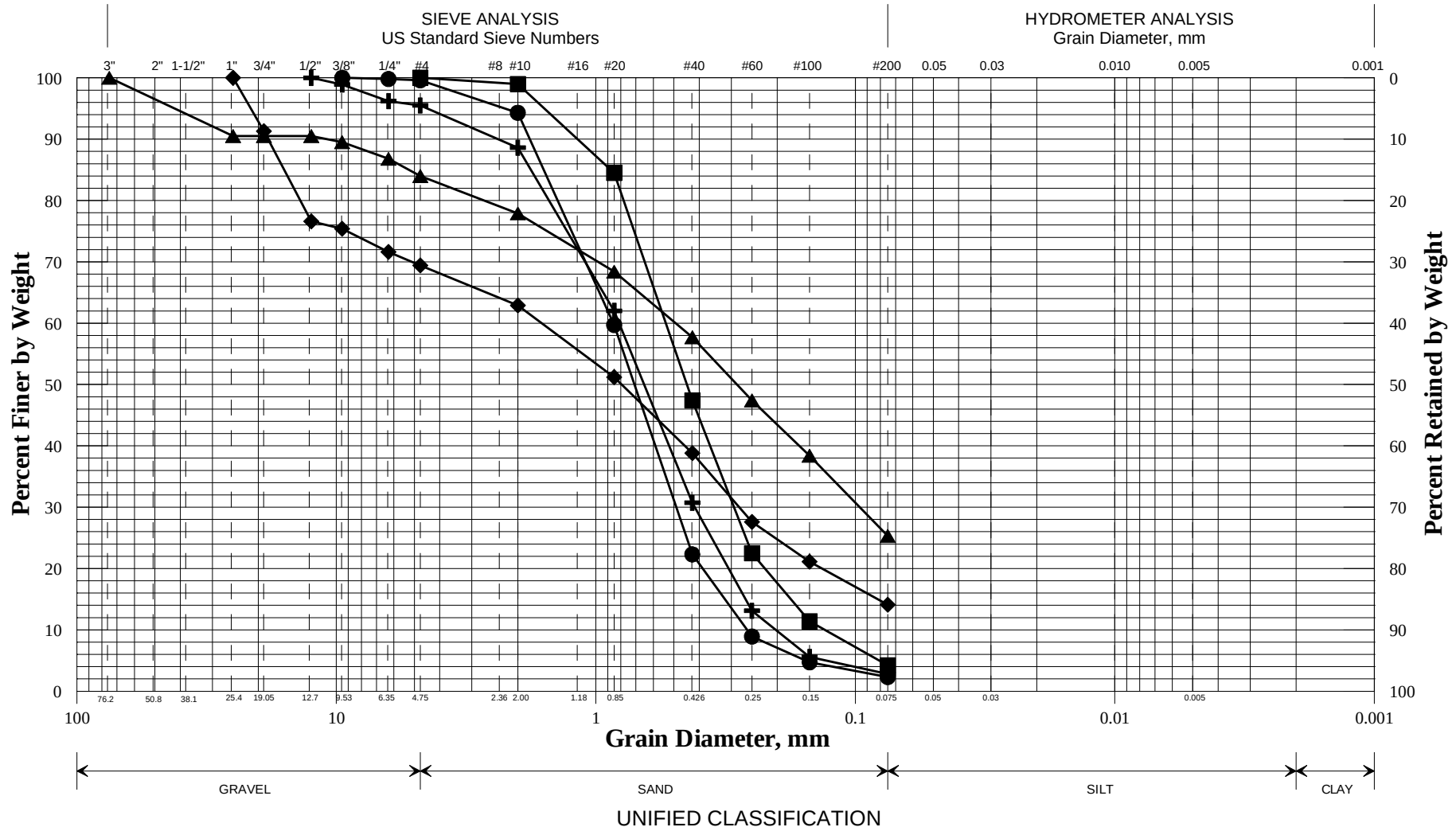


APPENDIX D
Laboratory Test Results

Work Number: 21691.00

GSDC = Grain Size Distribution Curve as determined by AASHTO T 88-93 (1996) and/or ASTM D 422-63 (Reapproved 1998)
 WC = water content as determined by AASHTO T 265-93 and/or ASTM D 2216-98
 LL = Liquid limit as determined by AASHTO T 89-96 and/or ASTM D 4318-98 NP = Non Plastic
 PI = Plasticity Index as determined by AASHTO 90-96 and/or ASTM D4318-98

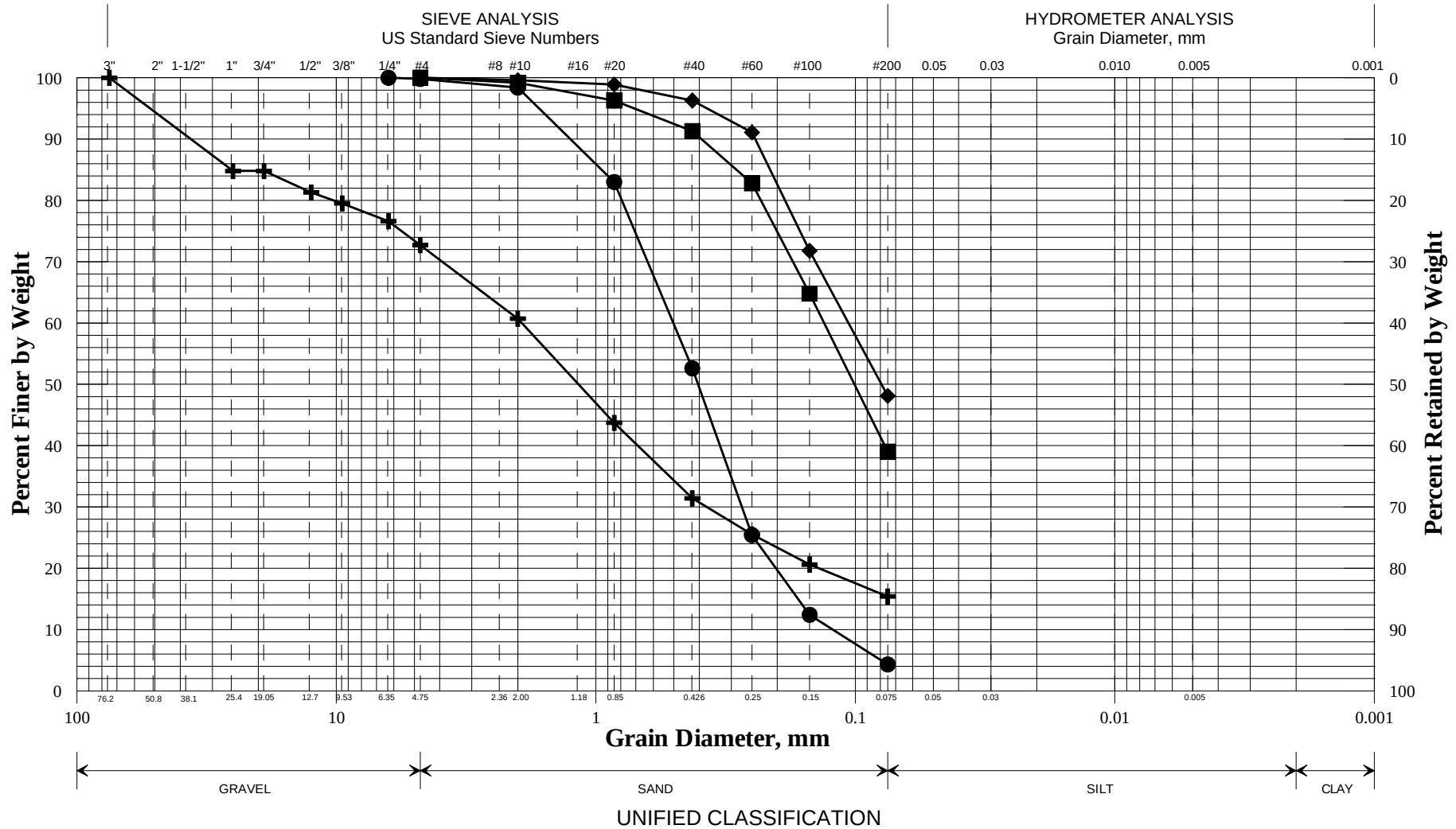
State of Maine Department of Transportation
GRAIN SIZE DISTRIBUTION CURVE



	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
+	BB-FKB-101/5D	104+45.9	9.2 RT	10.0-12.0	SAND, trace gravel, trace silt.	24.2			
◆	BB-FKB-102/2D	104+85.4	6.6 LT	2.5-4.5	SAND, some gravel, little silt.	11.7			
■	BB-FKB-102/5D(B)	104+85.4	6.6 LT	11.0-12.0	SAND, trace silt.	24.4			
●	BB-FKB-102/6D(A)	104+85.4	6.6 LT	15.0-16.0	SAND, trace silt, trace gravel.	22.0			
▲	BB-FKB-102/7D	104+85.4	6.6 LT	20.0-22.0	SAND, some silt, little gravel.	10.6			
×									

WIN	
021691.00	
Town	
Fryeburg	
Reported by/Date	
WHITE, TERRY A	8/30/2017

State of Maine Department of Transportation
GRAIN SIZE DISTRIBUTION CURVE



	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
+	BB-FKB-103/1D	104+46	8.5 LT	0.7-2.7	SAND, some gravel, little silt.	6.0			
◆	BB-FKB-104/1D	104+84.3	9.0 RT	0.6-2.6	Silty SAND.	6.2			
■	BB-FKB-104/3D	104+84.3	9.0 RT	7.0-9.0	Silty SAND.	56.2			
●	BB-FKB-104/4D	104+84.3	9.0 RT	10.0-12.0	SAND, trace silt, trace gravel.	23.1			
▲									
×									

WIN	
021691.00	
Town	
Fryeburg	
Reported by/Date	
WHITE, TERRY A	8/30/2017



GEOTECHNICAL TEST REPORT

Central Laboratory

SAMPLE INFORMATION

Reference No. **243338** Boring No./Sample No. **BB-FKB-101/7D(B)** Sample Description **GEOTECHNICAL (DISTURBED)** Sampled **7/24/2017** Received **8/16/2017**

Sample Type: **GEOTECHNICAL** Location: Station: **104+45.9** Offset, ft: **9.2** RT Dbfg, ft: **16.0-17.0**

WIN/Town **021691.00 - FRYEBURG** Sampler: **CONSULTANT SW COLE**

TEST RESULTS

Sieve Analysis (T 27)

Wash Method

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	
¾ in. [19.0 mm]	
½ in. [12.5 mm]	
⅜ in. [9.5 mm]	
¼ in. [6.3 mm]	
No. 4 [4.75 mm]	
No. 10 [2.00 mm]	
No. 20 [0.850 mm]	
No. 40 [0.425 mm]	
No. 60 [0.250 mm]	
No. 100 [0.150 mm]	
No. 200 [0.075 mm]	

Miscellaneous Tests

Liquid Limit @ 25 blows (T 89), %	36
Plastic Limit (T 90), %	24
Plasticity Index (T 90), %	12
Specific Gravity, Corrected to 20°C (T 100)	
Loss on Ignition, % (T 267)	
Water Content (T 265), %	39.0

Consolidation (T 216)

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

Vane Shear Test on Shelby Tubes (Maine DOT)

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

Comments:

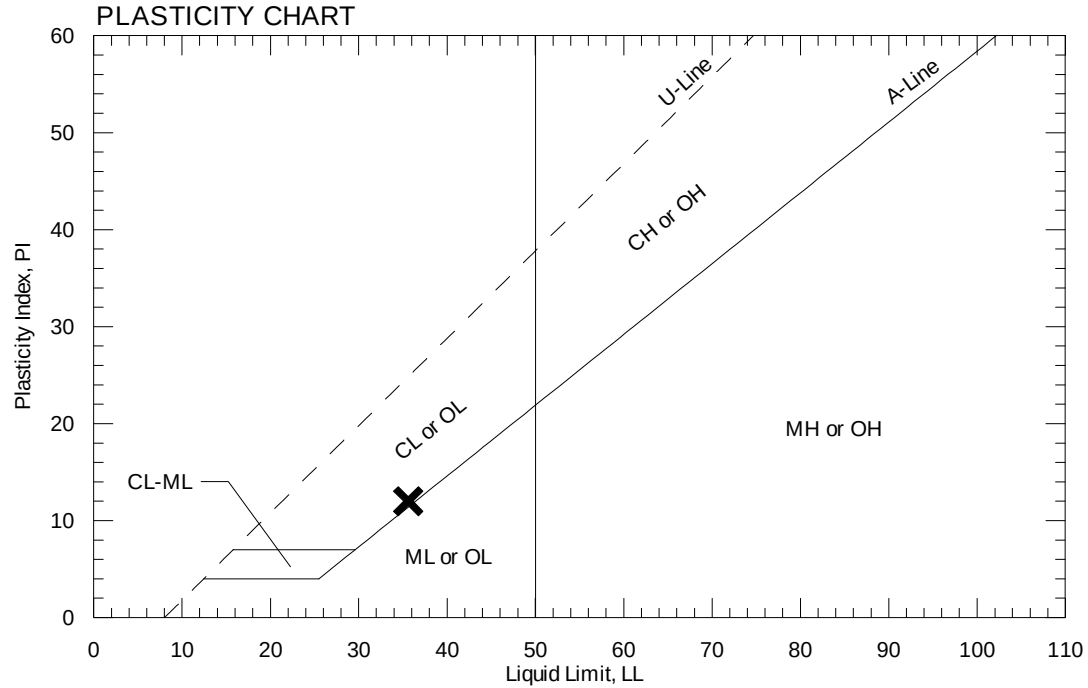
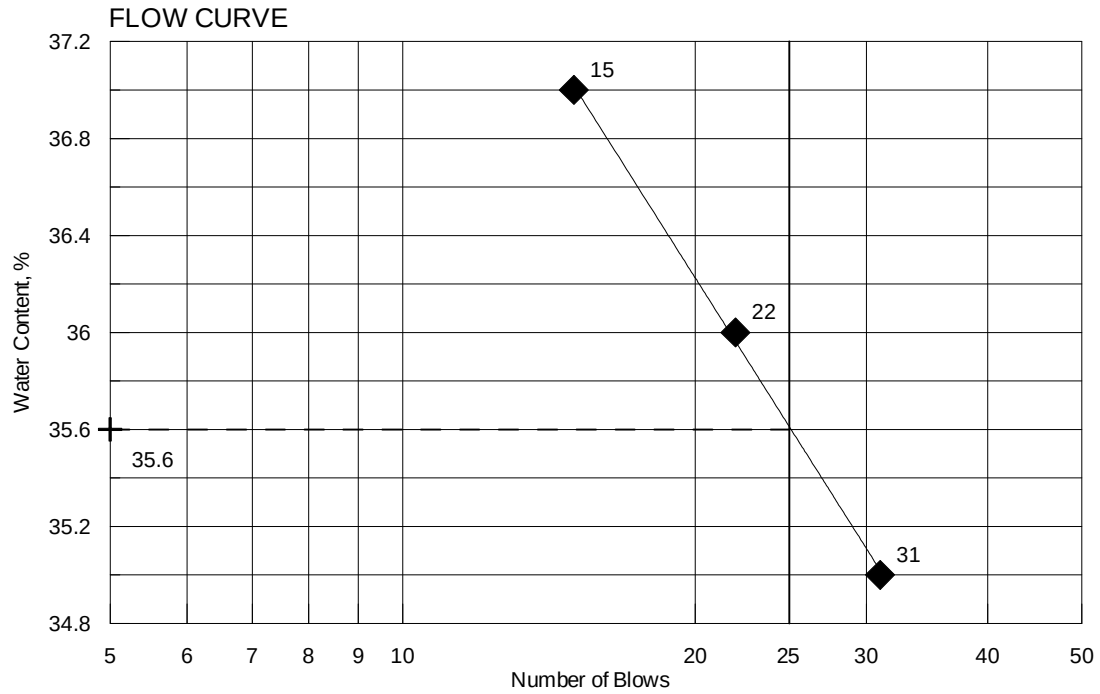
AUTHORIZATION AND DISTRIBUTION

Reported by: **GREGORY LIDSTONE**

Date Reported: **8/28/2017**

Paper Copy: Lab File; Project File; Geotech File

TOWN	Fryeburg	Reference No.	243338
WIN	021691.00	Water Content, %	39
Sampled	7/24/2017	Liquid Limit @ 25 blows (T 89), %	36
Boring No./Sample No.	BB-FKB-101/7D(B)	Plastic Limit (T 90), %	24
Station	104+45.9	Plasticity Index (T 90), %	12
Depth	16.0-17.0	Tested By	BBURR





GEOTECHNICAL TEST REPORT

Central Laboratory

SAMPLE INFORMATION

Reference No. **243344** Boring No./Sample No. **BB-FKB-103/4D(B)** Sample Description **GEOTECHNICAL (DISTURBED)** Sampled **7/25/2017** Received **8/16/2017**

Sample Type: **GEOTECHNICAL** Location: Station: **104+46** Offset, ft: **8.5** LT Dbfg, ft: **15.2-17.0**

WIN/Town **021691.00 - FRYEBURG** Sampler: **CONSULTANT SW COLE**

TEST RESULTS

Sieve Analysis (T 27)

Wash Method

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	
¾ in. [19.0 mm]	
½ in. [12.5 mm]	
⅜ in. [9.5 mm]	
¼ in. [6.3 mm]	
No. 4 [4.75 mm]	
No. 10 [2.00 mm]	
No. 20 [0.850 mm]	
No. 40 [0.425 mm]	
No. 60 [0.250 mm]	
No. 100 [0.150 mm]	
No. 200 [0.075 mm]	

Miscellaneous Tests

Liquid Limit @ 25 blows (T 89), %	34
Plastic Limit (T 90), %	24
Plasticity Index (T 90), %	10
Specific Gravity, Corrected to 20°C (T 100)	
Loss on Ignition, % (T 267)	
Water Content (T 265), %	26.7

Consolidation (T 216)

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

Vane Shear Test on Shelby Tubes (Maine DOT)

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

Comments:

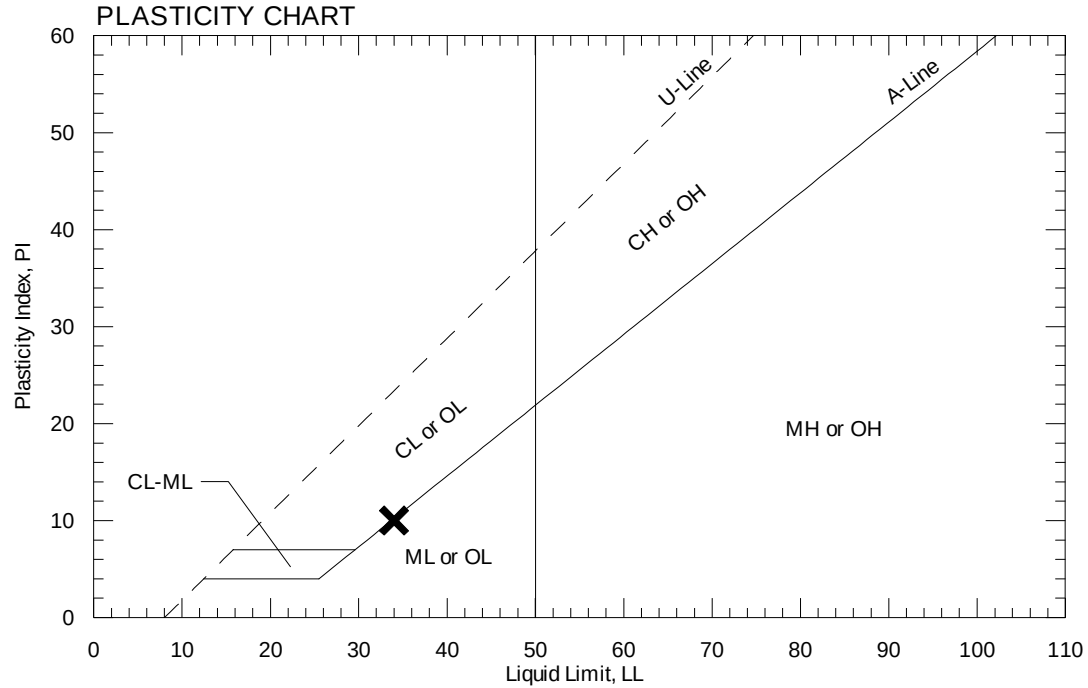
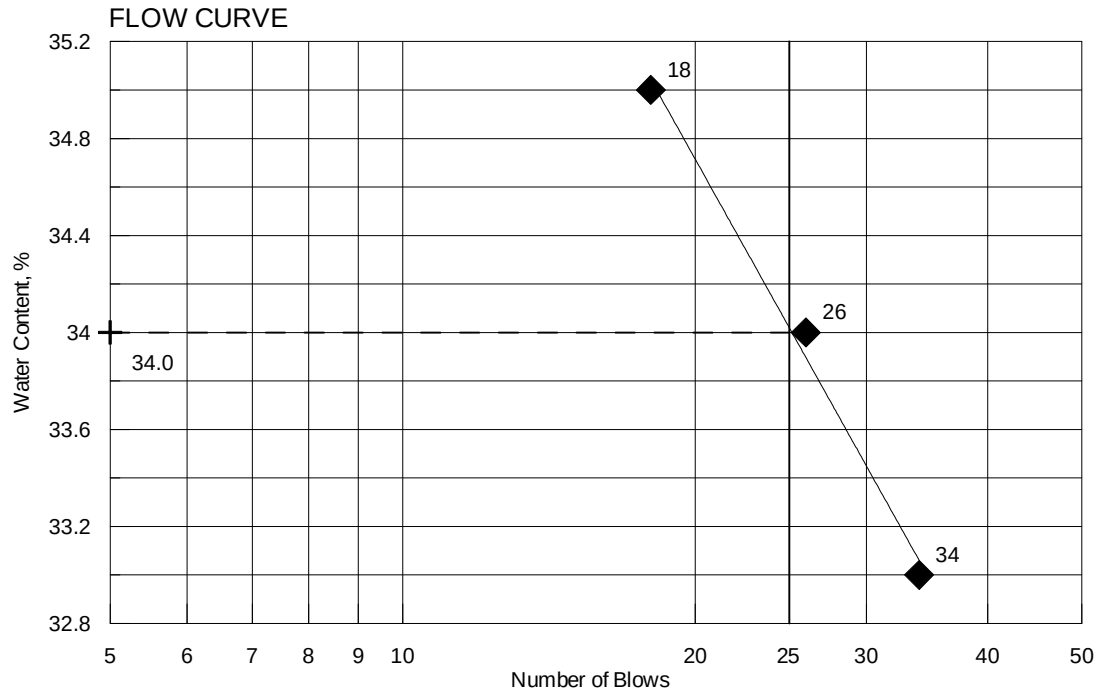
AUTHORIZATION AND DISTRIBUTION

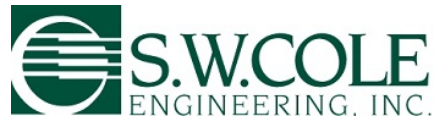
Reported by: **GREGORY LIDSTONE**

Date Reported: **8/28/2017**

Paper Copy: Lab File; Project File; Geotech File

TOWN	Fryeburg	Reference No.	243344
WIN	021691.00	Water Content, %	26.7
Sampled	7/25/2017	Liquid Limit @ 25 blows (T 89), %	34
Boring No./Sample No.	BB-FKB-103/4D(B)	Plastic Limit (T 90), %	24
Station	104+46	Plasticity Index (T 90), %	10
Depth	15.2-17.0	Tested By	BBURR





APPENDIX E

Calculations

Bearing Resistance of Precast Box Culvert

Foundation Soil Parameters: v. loose to loose, SAND, some to trace silt, little to trace gravel

$\gamma_{sat} := 120$ <i>pcf</i>	Saturated Unit Weight
$\gamma_{moist} := 118$ <i>pcf</i>	Moist Unit Weight
$\phi := 28$ <i>deg</i>	Undrained Friction Angle
$c_s := 0$ <i>psf</i>	Undrained Shear Strength
$\gamma_w := 62.4$ <i>pcf</i>	Unit Weight of Water

Foundation Parameters:

$$B := \begin{bmatrix} 26 \\ 27 \\ 28 \\ 29 \\ 30 \\ 31 \end{bmatrix} \text{ ft} \quad \text{Overall Foundation Width}$$

$D_f := 2$ *ft* Embedment Depth 2 ft below streambed or design scour elevation

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

Nominal 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 to medium sand, silty or clayey medium to coarse sand (SW, SM, SC)

Consistency in Place: very loose to loose

Bearing Resistance Range: 2 to 4 ksf

Recommended Bear Resistance: 2 ksf

**For very loose to loose, SAND, some to trace silt, little to trace gravel
Recommend Bearing Resistance of 2 ksf to limit settlement for Service Limit**

Nominal 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

$$N_c := 25.8$$

$$N_q := 14.7$$

$$N_\gamma := 16.7$$

From Table 10.6.3.1.8a-2, for Dw = Df

$$C_{wq} := 1$$

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

LRFD Eqn 10.6.3.1.2a-1

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

$$q_n = \begin{bmatrix} 7.9 \\ 8.2 \\ 8.4 \\ 8.7 \\ 8.9 \\ 9.1 \end{bmatrix} \text{ ksf} \quad \text{for} \quad B = \begin{bmatrix} 26 \\ 27 \\ 28 \\ 29 \\ 30 \\ 31 \end{bmatrix} \text{ ft} \quad \text{Nominal Bearing Resistance}$$

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

$$\varphi_b := 0.45$$

$$q_r := \varphi_b \cdot q_n = \begin{bmatrix} 3.6 \\ 3.7 \\ 3.8 \\ 3.9 \\ 4 \\ 4.1 \end{bmatrix} \text{ ksf} \quad \text{for} \quad B = \begin{bmatrix} 26 \\ 27 \\ 28 \\ 29 \\ 30 \\ 31 \end{bmatrix} \text{ ft} \quad \text{Strength Limit Factored Bearing Resistance}$$

Modulus of Subgrade Reaction

Reference: Bowles (1996) Foundaton Analysis and Design, 5th Ed.

Determine Fouldation and Soil Properties

Foundation Soil: v. loose to loose, SAND, some to trace silt, little to trace gravel

$$\mu_s := 0.3$$

Poisson's Ratio (Bowles Table 2-7, pg 123)
typical value 0.3-0.4 - sand, gravelly sand

$$N_{60} := 9$$

N60 values near $\pm$ El 375 ft (anticipated subgrade elevation)
range from 3, 5, 7, 9, 22, 27, 31

$$N_{55} := N_{60} \cdot \frac{60}{55} = 10$$

Use 9

Young's Modulus (from Bowles Table 5-6, pg 316)

$$E_s := 500 \cdot kPa \cdot (N_{55} + 15) \quad \text{for Sand (norm. consolidated)}$$

$$E_s = 259.2 \text{ } ksf$$

$$\text{USE } E_s := 250 \text{ } ksf$$

Foundation Patameters:

$$B := \begin{bmatrix} 26 \\ 27 \\ 28 \\ 29 \\ 30 \\ 31 \end{bmatrix} \text{ } ft$$

Foundation Width

$$L_f := 52 \text{ } ft$$

Assumed Length of Box Culvert

$$D_f := 2 \text{ } ft$$

Base Embedment Depth

$$B' := 0.5 \cdot B$$

$$L'_f := 0.5 \cdot L_f$$

Determine Steinbrenner Influence Factors

$$H_s := 17 \text{ } ft \quad \text{Approximate thickness of soil stratum}$$

$$\frac{D_f}{B} = \begin{bmatrix} 0.08 \\ 0.07 \\ 0.07 \\ 0.07 \\ 0.07 \\ 0.06 \end{bmatrix}$$

Depth Ratio

$$M_{corner} := \frac{L_f}{B} = \begin{bmatrix} 2 \\ 1.9 \\ 1.9 \\ 1.8 \\ 1.7 \\ 1.7 \end{bmatrix} \quad M_{center} := \frac{L'_f}{B'} = \begin{bmatrix} 2 \\ 1.9 \\ 1.9 \\ 1.8 \\ 1.7 \\ 1.7 \end{bmatrix}$$

$$N_{corner} := \frac{H_s}{B} = \begin{bmatrix} 0.7 \\ 0.6 \\ 0.6 \\ 0.6 \\ 0.6 \\ 0.5 \end{bmatrix} \quad N_{center} := \frac{H_s}{B'} = \begin{bmatrix} 1.3 \\ 1.3 \\ 1.2 \\ 1.2 \\ 1.1 \\ 1.1 \end{bmatrix}$$

From Bowles Table 5-2 (pg 304 and 305) using interpolation

$$I_{1_corner} := \begin{bmatrix} 0.072 \\ 0.056 \\ 0.056 \\ 0.056 \\ 0.057 \\ 0.042 \end{bmatrix} \quad I_{1_center} := \begin{bmatrix} 0.178 \\ 0.178 \\ 0.161 \\ 0.163 \\ 0.148 \\ 0.148 \end{bmatrix}$$

$$I_{2_corner} := \begin{bmatrix} 0.098 \\ 0.091 \\ 0.091 \\ 0.091 \\ 0.090 \\ 0.081 \end{bmatrix} \quad I_{2_center} := \begin{bmatrix} 0.110 \\ 0.108 \\ 0.108 \\ 0.106 \\ 0.104 \\ 0.104 \end{bmatrix}$$

$$I_{s_corner} := I_{1_corner} + \frac{1 - 2 \mu_s}{1 - \mu_s} \cdot I_{2_corner} = \begin{bmatrix} 0.128 \\ 0.108 \\ 0.108 \\ 0.108 \\ 0.108 \\ 0.088 \end{bmatrix}$$

$$I_{s_center} := I_{1_center} + \frac{1 - 2 \mu_s}{1 - \mu_s} \cdot I_{2_center} = \begin{bmatrix} 0.241 \\ 0.24 \\ 0.223 \\ 0.224 \\ 0.207 \\ 0.207 \end{bmatrix}$$

From Bowles Figure 5-7 (pg 303)

$$I_{F_corner} := 0.76$$

$$I_{F_center} := 0.67$$

$$E'_s := \frac{(1 - \mu_s^2)}{E_s}$$

$$k_{1_center} := \frac{1}{B' \cdot E'_s \cdot I_{s_center} \cdot I_{F_center}} = 12 \text{ pci}$$

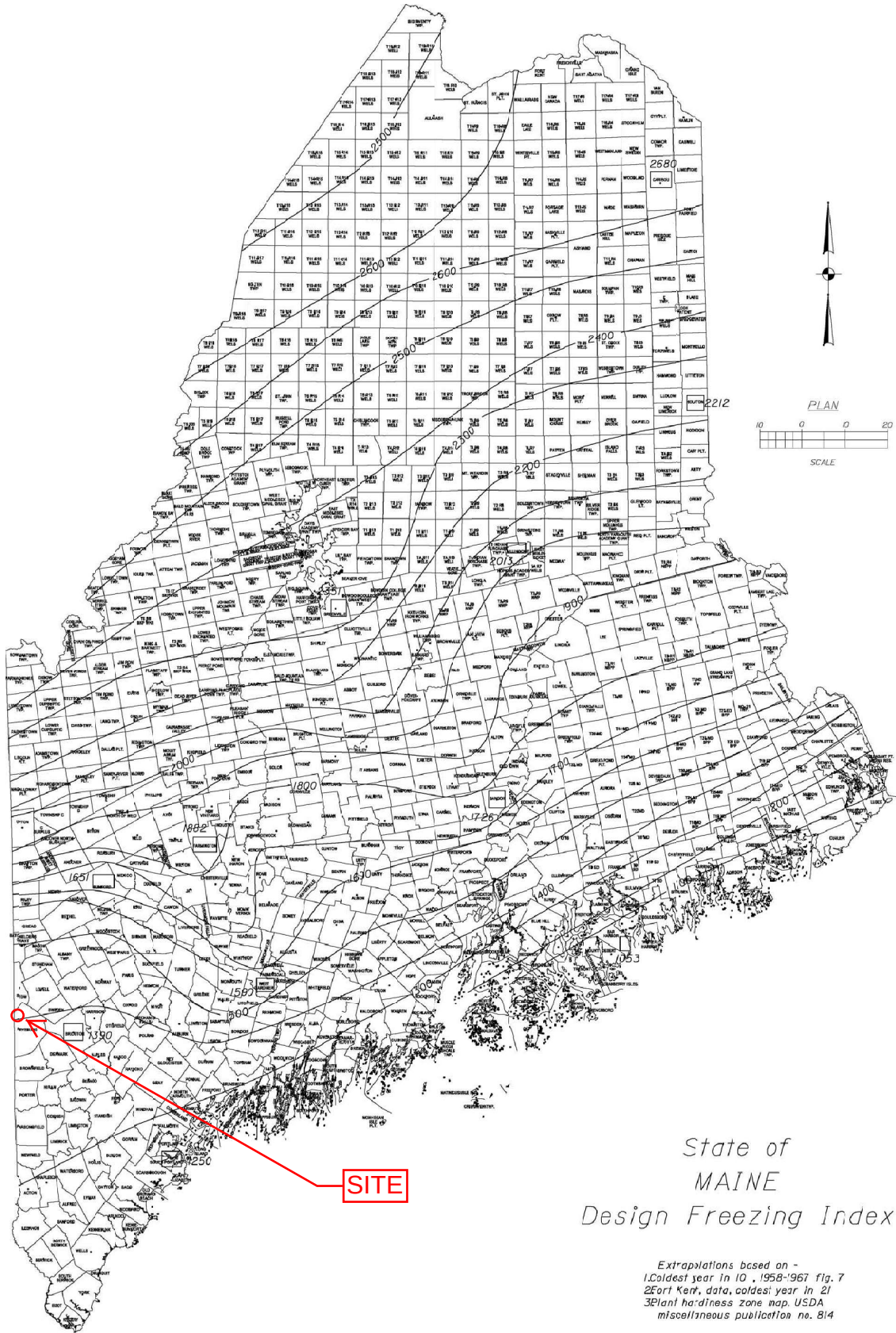
$$k_{1_corner} := \frac{1}{B \cdot E'_s \cdot I_{s_corner} \cdot I_{F_corner}} = 11 \text{ pci}$$

From Das Principles of Foundation Engineering, 7th Ed. Eqn. 6.44

$$k_{s_center} := \frac{k_{1_center} \cdot \left(1 + 0.5 \frac{B'}{L'_f}\right)}{1.5} = \begin{bmatrix} 10 \\ 10 \\ 11 \\ 11 \\ 11 \\ 11 \end{bmatrix} \text{ pci}$$

$$k_{s_corner} := \frac{k_{1_corner} \cdot \left(1 + 0.5 \frac{B}{L_f}\right)}{1.5} = \begin{bmatrix} 9 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 \end{bmatrix} \text{ pci}$$

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

Determine Seismic Site Classification per AASHTO LRFD Table C3.10.3.1-1 - Method B

Data From Boring BB-FKB-101

Layer No.	Layer Description	Depth Range (ft)		N ₆₀ values recorded within layer								Average N ₆₀ value	Layer Thickness	d _i /N _i
		Top	End									N _i	d _i	
1	Fill	0	6	31	27	19						25.7	6	0.23
2	Alluvium	6	25	22	27	11	11	8				15.8	19	1.20
3	Bedrock	25	100	100								100.0	75	0.75

$$\Sigma = 100 \quad 2.19$$

$$N_bar = d_i/d_i/N_i = 45.7$$

Site Class **D**

Data From Boring BB-FKB-102

Layer No.	Layer Description	Depth Range (ft)		N ₆₀ values recorded within layer								Average N ₆₀ value	Layer Thickness	d _i /N _i
		Top	End									N _i	d _i	
1	Fill	0	5	22	37							29.5	5	0.17
2	Alluvium	5	27	3	3	9	7	12	35			11.5	22	1.91
4	Bedrock	27	100	100								100.0	73	0.73

$$\Sigma = 100 \quad 2.81$$

$$N_bar = d_i/d_i/N_i = 35.6$$

Site Class **D**

Data From Boring BB-FKB-103

Layer No.	Layer Description	Depth Range (ft)		N ₆₀ values recorded within layer								Average N ₆₀ value	Layer Thickness	d _i /N _i
		Top	End									N _i	d _i	
1	Fill	0	5	26								26.0	5	0.19
2	Alluvium	5	23	12	31	14	8					16.3	18	1.11
3	Bedrock	23	100	100								100.0	77	0.77

$$\Sigma = 100 \quad 2.07$$

$$N_bar = d_i/d_i/N_i = 48.3$$

Site Class **D**

Data From Boring BB-FKB-104

Layer No.	Layer Description	Depth Range (ft)		N ₆₀ values recorded within layer								Average N ₆₀ value	Layer Thickness	d _i /N _i
		Top	End									N _i	d _i	
1	Fill	0	5	30								30.0	5	0.17
2	Alluvium	5	25	4	5	7	8	18				8.4	20	2.38
4	Bedrock	25	100	100								100.0	75	0.75

$$\Sigma = 100 \quad 3.30$$

Notes: 1. N60 value for bedrock taken as N=100

$$N_bar = d_i/d_i/N_i = 30.3$$

Site Class **D**

USGS Design Maps Summary Report

User-Specified Input

Report Title 5573Fryeburg

Fri September 15, 2017 14:21:31 UTC

Building Code Reference Document 2009 AASHTO Guide Specifications for LRFD Seismic Bridge Design
(which utilizes USGS hazard data available in 2002)

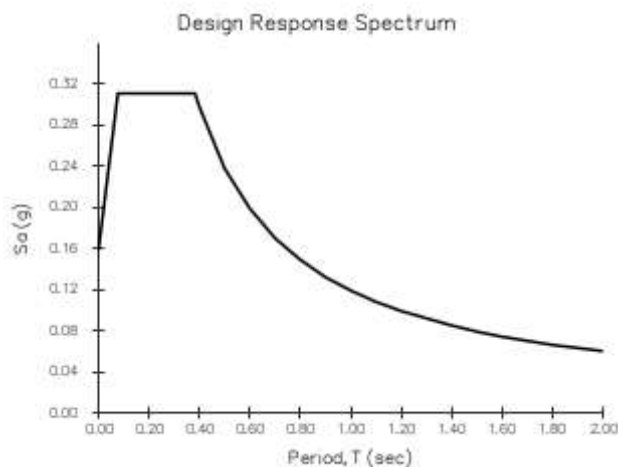
Site Coordinates 44.12125°N, 70.97792°W

Site Soil Classification Site Class D – “Stiff Soil”



USGS-Provided Output

PGA = 0.099 g	A_s = 0.158 g
S_s = 0.194 g	S_{DS} = 0.311 g
S₁ = 0.050 g	S_{D1} = 0.119 g



Although this information is a product of the U.S. Geological Survey, we provide no warranty, expressed or implied, as to the accuracy of the data contained therein. This tool is not a substitute for technical subject-matter knowledge.



Design Maps Detailed Report

2009 AASHTO Guide Specifications for LRFD Seismic Bridge Design (44.12125°N, 70.97792°W)

Site Class D – “Stiff Soil”

Article 3.4.1 — Design Spectra Based on General Procedure

Note: Maps in the 2009 AASHTO Specifications are provided by AASHTO for Site Class B. Adjustments for other Site Classes are made, as needed, in Article 3.4.2.3.

From [Figure 3.4.1-2](#) ^[1]

PGA = 0.099 g

From [Figure 3.4.1-3](#) ^[2]

S_s = 0.194 g

From [Figure 3.4.1-4](#) ^[3]

S_1 = 0.050 g

Article 3.4.2.1 — Site Class Definitions

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class D, based on the site soil properties in accordance with Article 3.4.2.

Table 3.4.2.1-1 Site Class Definitions

SITE CLASS	SOIL PROFILE NAME	Soil shear wave velocity, $\bar{v}_s$, (ft/s)	Standard penetration resistance, $\bar{N}$	Soil undrained shear strength, $\bar{s}_u$, (psf)
A	Hard rock	$\bar{v}_s > 5,000$	N/A	N/A
B	Rock	$2,500 < \bar{v}_s \leq 5,000$	N/A	N/A
C	Very dense soil and soft rock	$1,200 < \bar{v}_s \leq 2,500$	$\bar{N} > 50$	$> 2,000$ psf
D	Stiff soil profile	$600 \leq \bar{v}_s < 1,200$	$15 \leq \bar{N} \leq 50$	1,000 to 2,000 psf
E	Stiff soil profile	$\bar{v}_s < 600$	$\bar{N} < 15$	$< 1,000$ psf
E	—	Any profile with more than 10 ft of soil having the characteristics: 1. Plasticity index $PI > 20$, 2. Moisture content $w \geq 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H > 10$ feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H > 25$ feet with plasticity index $PI > 75$) 4. Very thick soft/medium stiff clays ($H > 120$ feet)		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Article 3.4.2.3 — Site Coefficients

Table 3.4.2.3-1 (for F_{pga})—Values of F_{pga} as a Function of Site Class and Mapped Peak Ground Acceleration Coefficient

Site Class	Mapped Peak Ground Acceleration				
	PGA ≤ 0.10	PGA = 0.20	PGA = 0.30	PGA = 0.40	PGA ≥ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See AASHTO Article 3.4.3				

Note: Use straight-line interpolation for intermediate values of PGA

For Site Class = D and PGA = 0.099 g, $F_{PGA} = 1.600$ Table 3.4.2.3-1 (for F_a)—Values of F_a as a Function of Site Class and Mapped Short-Period Spectral Acceleration Coefficient

Site Class	Spectral Response Acceleration Parameter at Short Periods				
	$S_s \leq 0.25$	$S_s = 0.50$	$S_s = 0.75$	$S_s = 1.00$	$S_s \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See AASHTO Article 3.4.3				

Note: Use straight-line interpolation for intermediate values of S_s **For Site Class = D and $S_s = 0.194$ g, $F_a = 1.600$**

Table 3.4.2.3-2—Values of F_v as a Function of Site Class and Mapped 1-sec Period Spectral Acceleration Coefficient

Site Class	Mapped Spectral Response Acceleration Coefficient at 1-sec Periods				
	$S_1 \leq 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \geq 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See AASHTO Article 3.4.3				

Note: Use straight-line interpolation for intermediate values of S_1

For Site Class = D and $S_1 = 0.050$ g, $F_v = 2.400$

Equation (3.4.1-1):

$$A_s = F_{PGA} \text{ PGA} = 1.600 \times 0.099 = 0.158 \text{ g}$$

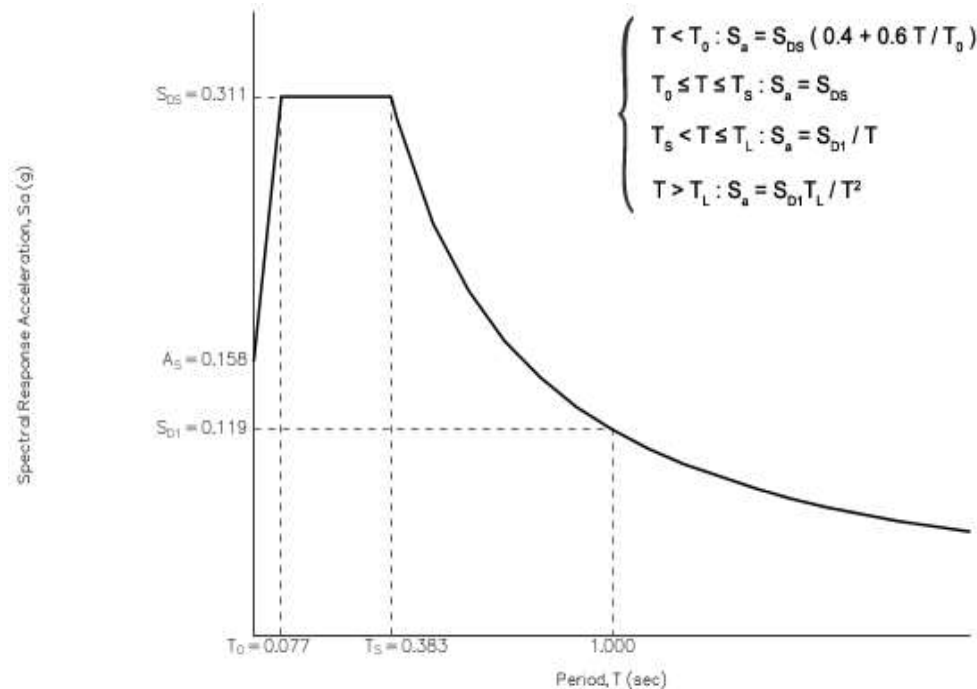
Equation (3.4.1-2):

$$S_{DS} = F_a S_s = 1.600 \times 0.194 = 0.311 \text{ g}$$

Equation (3.4.1-3):

$$S_{D1} = F_v S_1 = 2.400 \times 0.050 = 0.119 \text{ g}$$

Figure 3.4.1-1: Design Response Spectrum



Article 3.5 - Selection of Seismic Design Category (SDC)

Table 3.5-1—Partitions for Seismic Design Categories A, B, C, and D

VALUE OF S_{D1}	SDC
$S_{D1} < 0.15g$	A
$0.15g \leq S_{D1} < 0.30g$	B
$0.30g \leq S_{D1} < 0.50g$	C
$0.50g \leq S_{D1}$	D

For $S_{D1} = 0.119 g$, Seismic Design Category = A

Seismic Design Category $\equiv$ "the design category in accordance with Table 3.5-1" = A

References

1. *Figure 3.4.1-2*: <https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/AASHTO-2009-Figure-3.4.1-2.pdf>
2. *Figure 3.4.1-3*: <https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/AASHTO-2009-Figure-3.4.1-3.pdf>
3. *Figure 3.4.1-4*: <https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/AASHTO-2009-Figure-3.4.1-4.pdf>