MAINE DEPARTMENT OF TRANSPORTATION
HIGHWAY PROGRAM
GEOTECHNICAL SECTION
AUGUSTA, MAINE

GEOTECHNICAL DESIGN REPORT

For the Construction of

MUDDY BROOK BRIDGE
ROUTE 43
INDUSTRY, MAINE

Prepared by:
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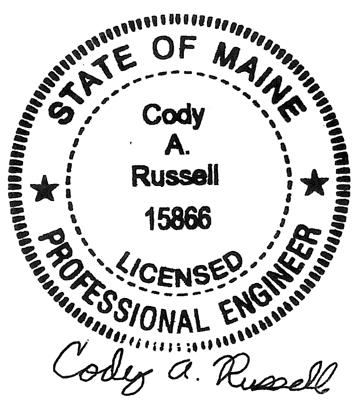
Assistant Geotechnical Engineer



Reviewed by:
Cody Russell, P.E.
Senior Geotechnical Engineer

Franklin County
WIN 27224.00

Soils Report 2026-09
Bridge No. 6737

February 2, 2026

Table of Contents

1.0 INTRODUCTION

The purpose of this Geotechnical Design Report is to present subsurface information and make geotechnical recommendations for the replacement of an existing large culvert (#1068804) on Route 43 in Industry. A subsurface investigation has been completed at the site to evaluate subsurface conditions and to develop geotechnical design and construction recommendations for the replacement structure. This report presents the subsurface information obtained during the subsurface investigation and soil laboratory testing programs and provides design and construction recommendations and geotechnical design parameters for the culvert replacement.

The existing structure consists of an approximately 60-inch diameter, 80-foot long corrugated metal pipe (CMP). The CMP is in poor condition and needs replacement both from an infrastructure and environmental standpoint. Route 43 is a Highway Corridor Priority 4 road.

The proposed replacement structure will be an approximately 18-foot span by 10-foot rise by 92-foot-long precast concrete box culvert. The invert of the proposed culvert is approximately 17.1 feet below the existing road grade at the roadway centerline. The roadway embankment slopes at the proposed culvert inlet and outlet shall be no steeper than 1.75H:1V to protect against erosion.

2.0 GEOLOGIC SETTING

The existing culvert carries an unnamed stream under Route 43 in Industry and is located approximately 0.23 of a mile northeast of Farmington town line as shown on Sheet 1 – Location Map.

According to the Maine Geological Survey (MGS) map titled Surficial Geology of the Farmington Quadrangle, Maine, Open File 86-29 (1986) the surficial soils at the site consist of Till. Till consists of sand, silt, and clay.

According to the map titled Bedrock Geologic Map of Maine (1985) published by the MGS, the bedrock in the vicinity of the site consists of sulfidic or carbonaceous pelite of the Towow Formation.

3.0 SUBSURFACE INVESTIGATION

Two (2) borings (HB-IND-101 and HB-IND-101A) and three (3) probes (HB-IND-102, HB-IND-102A, and HB-IND-102B) were drilled for this project on September 5, 2023 by the MaineDOT drill crew using a trailer-mounted drill rig. Exploration locations are shown on Sheet 2 – Boring Location Plan & Interpretive Subsurface Profile. Details and sampling methods used, field data obtained, and soil and groundwater conditions encountered are presented on the Boring Logs in Appendix A.

Borings HB-IND-101 and HB-IND-101A were drilled using solid stem auger, cased wash boring, open hole, roller cone, and rock core drilling techniques. Soil samples were obtained at 5-foot intervals using Standard Penetration Test (SPT) methods. The MaineDOT drill rig is equipped with an automatic hammer to drive the split spoon. The MaineDOT calibrated automatic hammer delivers approximately 51 percent more energy during driving than the standard rope and cathead system. All N-values discussed in this report are corrected values (N_{60}) computed by applying an average energy transfer factor of 0.906 to the raw field N-values. Probes HB-IND-102, HB-IND-102A, and HB-IND-102B were drilled using solid stem auger techniques. No soil samples were obtained in the probes.

The MaineDOT Geotechnical Team member selected the boring and probe locations, drilling methods, designated type and depth of sampling, reviewed field logs for accuracy and identified field and laboratory testing requirements. A NorthEast Transportation Training and Certification (NETTCP) certified Subsurface Investigator logged the subsurface conditions encountered. The boring and probe were located in the field by taping to surveyed site features after completion of the drilling program.

4.0 LABORATORY TESTING

A laboratory testing program was conducted to assist in soil classification, evaluation of engineering properties of the soils and geologic assessment of the project site. Laboratory testing consisted of four (4) standard grain size analyses with natural water content. The results of the laboratory testing program are discussed in the following section and are included in Appendix B – Laboratory Test Results. Laboratory test information is also shown on the Boring Logs in Appendix A.

5.0 SUBSURFACE CONDITIONS

Subsurface conditions encountered in the test borings and probes generally consisted of sand fill underlain by native silty sand underlain by bedrock. An interpretive subsurface profile depicting the generalized soil stratigraphy at the boring location is shown on Sheet 2 – Boring Location Plan & Interpretive Subsurface Profile.

5.1 Fill Materials

The borings encountered fill soils at the ground surface consisting of:

- Reddish brown, dark brown, and brown, damp to moist, fine to coarse sand, little to some gravel, little to some silt, cobbles.

The thickness of the fill was approximately 15.0 feet. Three (3) N_{60}-values obtained in the fill ranged from 11 to 42 blows per foot (bpf) indicating that the fill is medium dense to dense in consistency.

Water contents from three (3) samples obtained within the fill ranged from approximately 4.6% to 10.3%. Grain size analyses conducted on three (3) samples of the fill resulted in the soil being classified as an A-1-b or A-2-4 under the AASHTO Soils Classification System and a SW-SM or SM under the Unified Soil Classification System.

A boulder was encountered from 12.8 feet to 14.9 feet bgs in boring HB-IND-101.

5.2 Native Silty Sand

The fill soils were underlain by silty sand consisting of:

- Brown, moist, silty fine to coarse sand, trace gravel.

The thickness of the silty sand layer was approximately 0.2 feet.

Water contents from one (1) sample obtained within the silty sand was approximately 11.4%. Grain size analyses conducted on one (1) sample of the silty sand resulted in the soil being classified as an A-4 under the AASHTO Soils Classification System and a SM under the Unified Soil Classification System.

5.3 Bedrock / Refusal Surfaces

Bedrock or a refusal surface was encountered at elevations ranging from approximately 10.3 feet to 15.2 feet in the vicinity of the proposed culvert. The table below summarizes the refusal surfaces encountered.

Boring No.	Station	Offset (feet)	Approximate Depth to Top of Refusal Surface (feet)	Approximate Elevation of Top of Refusal Surface (feet)	RQD (%)[1]
HB-IND-101	22+57	12.4 Right	15.2	545.7	NA
HB-IND-101A	22+51	11.9 Right	14.9	546.2	32.5
HB-IND-102	22+80	9.3 Left	10.3	551.1	NA
HB-IND-102A	22+82	10.3 Left	12.9	548.5	NA

[1] RQD = Rock Quality Designation

Bedrock was encountered in borings HB-IND-101 and HB-IND-101A. A 5-foot bedrock core was drilled in boring HB-IND-101A. The exact nature of the refusal surface was not determined in the remaining explorations.

The bedrock consists of sulfidic or carbonaceous pelite of the Towow Formation. The Rock Quality Designation (RQD) of the bedrock was determined to be 32.5%, correlating to a Rock Quality of Poor. The approximate elevations of the top of bedrock or the refusal surface encountered at the boring and probe locations are presented in Appendix A – Boring Logs.

5.4 Groundwater

Groundwater was recorded at depths ranging from approximately 3.5 feet to 4.5 feet bgs in borings HB-IND-101 and HB-IND-101A. Groundwater levels can be expected to fluctuate subject to seasonal variations, local soil conditions, topography, precipitation, and construction activity.

6.0 Geotechnical Design and Construction Recommendations

The following sections discuss geotechnical recommendations for the design and construction of the proposed culvert.

6.1 Precast Concrete Box Culvert Design and Construction

The proposed replacement structure will consist of a 18-foot span by 10-foot rise by 92-foot-long precast concrete box culvert. The proposed box culvert shall be designed and constructed in accordance with MaineDOT Standard Specification 534.

The approximate invert of the proposed culvert ranges from an elevation of 546.4 feet at the inlet to 543.4 feet at the outlet with a 3.3% slope. To facilitate fish passage, Habitat Connectivity Design elements will be used inside the precast concrete box culvert as shown on the Streambed Details Sheet in the Plans.

The full nature of the culvert bearing surface will not become evident until the culvert excavation is made. Any cobbles or boulders in excess of 6 inches encountered at the bedding elevation shall be removed and replaced with compacted Granular Borrow Material for Underwater Backfill or Crushed Stone ¾-Inch. Any disturbed soils at the bedding elevation resulting from excavation activities should be removed by hand prior to placement of the bedding material. The prepared subgrade shall be proof rolled using a static roller to visually confirm the prepared subgrade is firm and stable. The exposed subgrade shall be free of ponded water so that bedding material placement and compaction can be completed in the dry.

The proposed structure shall be bedded on a 1-foot-thick layer of Granular Borrow, Material for Underwater Backfill meeting the requirements of MaineDOT Standard Specification 703.19. The soil envelope and backfill shall consist of Standard Specification 703.19 - Granular Borrow with a maximum particle size of 4 inches. The Granular Borrow bedding and backfill material shall be placed in lifts of 6 to 8 inches loose measure and compacted to the manufacturer’s specifications or, in the absence of manufacturer’s specifications, the bedding and backfill soil shall be compacted to at least 92 percent of the AASHTO T-180 maximum dry density.

6.2 Bedrock Removal and Subgrade Preparation

The approximate invert of the proposed culvert ranges from an elevation of 546.4 feet at the inlet to 543.4 feet at the outlet. Constructing the culvert at this elevation may require removal of bedrock. The need for and depth of weathered bedrock removal will vary over the length of the precast concrete box culvert. The bottom elevation of the excavation shall take into account the wall thickness of the culvert bottom and the required 1-foot layer of bedding material. The boring indicates that the Rock Quality of the bedrock is Poor with an RQD of approximately 32.5 percent.

The bedrock surface shall be prepared in accordance with MaineDOT standard practices. The nature, slope, and degree of fracturing in the bedrock bearing surfaces will not be evident until the excavation from the precast concrete box culvert is made. Construction activities should not be permitted to create any open fissures in the bedrock to remain. Any irregularities in the existing bedrock surface or irregularities created during the excavation process should be backfilled with crushed stone to the bottom of the required bedding material.

The Contractor shall remove any overburden soil and bedrock that can be removed using ordinary excavation equipment to expose the proposed bearing surface at the required elevation. The cleanliness and condition of the bedrock surface should be confirmed and accepted by the Resident prior to placing the structural bedding material. If soil is encountered at bedding material subgrade it shall be proof-rolled using multiple passes of a static roller to achieve a firm and stable surface for construction. Any cobbles, boulders, or loose bedrock encountered in excess of 6 inches shall be removed and replaced with compacted Granular Borrow Material for Underwater Backfill or Crushed Stone ¾-Inch.

Blasting shall be conducted in accordance with MaineDOT Standard Specifications Sections 105.2.7 and 203. The Contractor is required to conduct pre- and post-blast surveys, as well as blast vibrations monitoring at nearby structures in accordance with industry standards at the time of the blast.

It is anticipated that there will be seepage of water from fractures and joints exposed in the bedrock surface. Water should be controlled by pumping from sumps. The Contractor should maintain the excavation so that all work is completed in the dry.

6.3 Settlement

No settlement issues are anticipated at the site. The proposed precast concrete box culvert is larger than the existing culvert and will result in a net unloading of the site soils at the proposed structure location. Placement of fill soils at the location of the existing structure is not anticipated to exceed the past loading condition of the site soils. Any settlement due to elastic compression of the bedding material will be immediate and negligible.

6.4 Bearing Resistance

The factored bearing resistances for the precast concrete box culvert bearing on compacted granular bedding material placed on native soils and/or bedrock at the service and strength limit states are presented in the table below. Supporting calculations in accordance with AASHTO LRFD Bridge Design Specifications 10th Edition 2024 (LRFD) are provided in Appendix C – Calculations.

Limit State	Resistance Factor φ_b	AASHTO LRFD Reference	Factored Bearing Resistance (ksf)
Service	1.0	Article 10.5.5.1	5.0
Strength	0.45	Table 10.5.5.2.2-1	17.0

6.5 Modulus of Subgrade Reaction

A modulus of subgrade reaction (k_s) equal to 20 pounds per cubic inch shall be used for the structural design of the box culvert's base slab. Calculations are included in Appendix C – Calculations.

6.6 Scour and Riprap

Both the inlet and outlet of the precast concrete box culvert shall be protected against scour with riprap conforming to MaineDOT Standard Specification Section 703.26 Plain and Hand Laid Riprap. Slopes shall be no steeper than 1.75H:1V on the inlet and outlet end. No specific scour protection recommendations are needed other than armoring with riprap. The riprap on the slopes shall be underlain by a 1-foot layer of protective aggregate cushion consisting of Granular Borrow Material for Underwater Backfill (703.19) that is underlain by a non-woven, Class 1 Erosion Control Geotextile meeting the requirements of MaineDOT Standard Specification 722.03. The toe of the riprap sections shall be keyed into the existing soils 1 foot below the streambed elevation.

6.7 Seismic Design Considerations

In conformance with LRFD Article 3.10.1, seismic analysis is not required for buried structures, except where they cross active faults. There are no known active faults in Maine; therefore, seismic analysis is not required.

6.8 Construction Considerations

Construction activities may include construction of cofferdams and earth support systems to control stream flow during construction. Construction activities will also include common earth excavation. Construction of the proposed precast concrete box culvert will require deep soil excavation. Earth support systems shall be implemented if laying back slopes is not feasible. It is likely that the use of complex (four-sided) braced excavations with dewatering will be necessary due to the depth of the excavation. If this is the case, adequate embedment into sand or bedrock will be necessary to allow for the excavation and maintenance of a stable excavation bottom. All earth support systems shall be designed by a Professional Engineer licensed in the State of Maine. Regardless of the method of excavation, all excavations and earth support systems shall meet all applicable OSHA regulations.

The Contractor shall control groundwater and surface water infiltration using temporary ditches, sumps, granular drainage blankets, stone ditch protection or hand-laid riprap with geotextile underlayment to divert groundwater and surface water as needed to maintain a stable excavation and allow work in the dry.

Using the excavated native soils as backfill around the culvert shall not be permitted. The native soils may only be used as common borrow in accordance with MaineDOT Standard Specifications 203 and 703.

The Contractor will have to excavate the existing subbase and subgrade fill soils in the vicinity of the culvert. These materials should not be used to re-base the roadway. Excavated subbase sand and gravel may be used as fill below roadway subgrade level in fill areas provided all other requirements of MaineDOT Standard Specifications 203 and 703 are met.

7.0 CLOSURE

This report has been prepared for the use of the MaineDOT Highway Program for specific application to the proposed replacement of an existing large culvert (#1068804) under Route 43 in Industry, Maine in accordance with generally accepted geotechnical and foundation engineering practices. No other intended use or warranty is expressed or implied.

In the event that any changes in the nature, design, or location of the proposed project are planned, this report should be reviewed by a geotechnical engineer to assess the appropriateness of the conclusions and recommendations and to modify the recommendations as appropriate to reflect the changes in design. These analyses and recommendations are based in part upon a limited subsurface investigation at discrete exploratory location completed at the site. If variations from the conditions encountered during the investigation appear evident during construction, it may also become necessary to re-evaluate the recommendations made in this report.

It is recommended that a geotechnical engineer be provided the opportunity for a review of the design and specifications in order that the earthwork and foundation recommendations and construction considerations presented in this report are properly interpreted and implemented in the design and specifications.

Sheets

Date:1/20/2026

Division: GEOTECH

Username: Terry.White

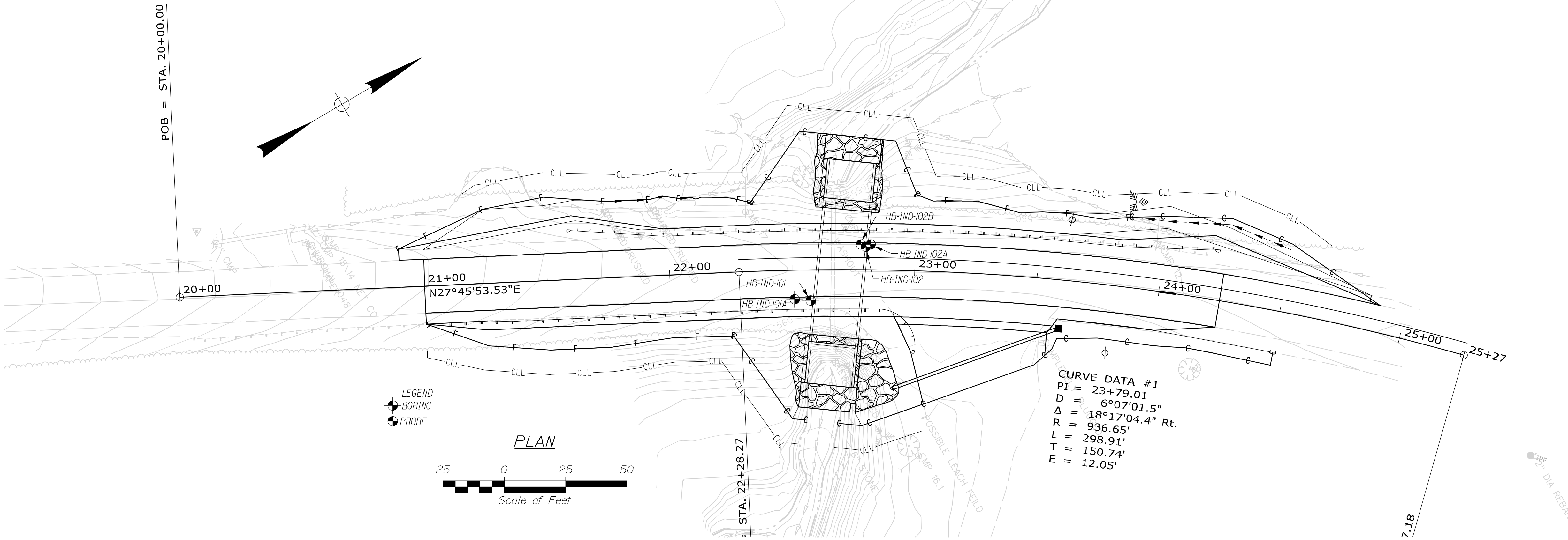
INDUSTRY, MAINE

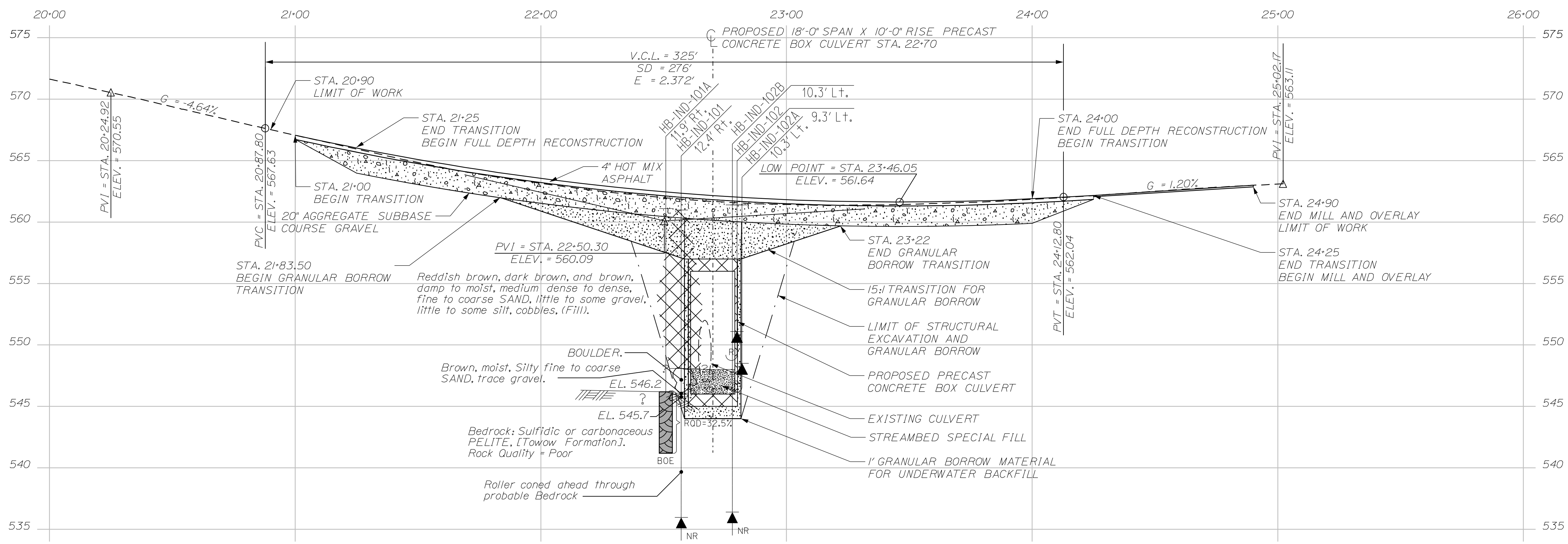
0.25 Miles

1 inch =0.28 miles

Date: 1/20/2026
Time: 7:52:39 AM

SHEET NUMBER	INDUSTRY ROUTE 43	STATE OF MAINE DEPARTMENT OF TRANSPORTATION
1		2722400
OF 2	LOCATION MAP	WIN 27224.00 HIGHWAY PLANS





LEGEND

- Weathered Bedrock, if applicable
- Approximate Top of Bedrock
- Boring No., Offset, if shown
- Pavement Thickness, if applicable
- RQD= Rock Quality Designation of Bedrock Core Sample
- BOE= Bottom of Exploration
- NR No Refusal
- R Refusal

PROFILE

HORIZ 25 0 25 50
VERT 5 0 5 10
SCALE

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.

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STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

2722400

WIN 27224.00 HIGHWAY PLANS

	BY	DATE
PROJ. MANAGER	M. ROONEY	
DESIGN-DETAILED		
CHECKED-REVIEWED		
DESIGN2-DETAILED2	YT LEE	JAN 2026
DESIGN3-DETAILED3	T. WHITE	MAR 2026
REVISIONS 1	UPDATED ISP	
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE
P.E. NUMBER
DATE

INDUSTRY
ROUTE 43

BORING LOCATION PLAN & INTERPRETIVE SUBSURFACE PROFILE

SHEET NUMBER
2
OF 2

Appendix A

Boring Logs

UNIFIED SOIL CLASSIFICATION SYSTEM

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

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

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

MODIFIED BURMISTER SYSTEM

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

TERMS DESCRIBING DENSITY/CONSISTENCY

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

Density of Cohesionless Soils	Standard Penetration Resistance N-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):

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

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

Rock Quality Based on RQD

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

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

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

Sample Container Labeling Requirements:

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

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Large Culvert Replacement on Route 43
Location: Industry, Maine

Boring No.: HB-IND-101
WIN: 27224.00

Driller:	MaineDOT	**Elevation (ft.)**	560.9	**Auger ID/OD:**	5" Solid Stem
Operator:	Daggett/Andrle	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	C. Russell	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	9/5/2023; 09:40-13:00	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	N/A
Boring Location:	22+57.2, 12.4 ft Rt.	**Casing ID/OD:**	NW-3"	**Water Level*:**	4.5 ft bgs.
Hammer Efficiency Factor:	0.906	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0	1D	24/13	0.00 - 2.00	6/8/6/5	14	21	SSA			Reddish-brown to dark brown, damp, medium dense, fine to coarse SAND, some gravel, little silt, (Fill).	G#379650 A-1-b, SW-SM WC=4.6%
5	2D	24/6	5.00 - 7.00	8/17/11/6	28	42				Brown, damp, dense, fine to coarse SAND, some silt, some gravel, cobbles, (Fill).	G#379651 A-2-4, SM WC=8.2%
10	3D	24/3	10.00 - 12.00	6/3/4/9	7	11	14			Brown, moist, medium dense, fine to coarse SAND, some silt, little gravel, cobbles in tip of spoon, (Fill).	G#379652 A-2-4, SM WC=10.3%
							45				
							a112			a112 blows for 0.8 ft.	
							OPEN HOLE			Roller Coned through Boulder from 12.8- 14.9 ft bgs.	
15								545.9		15.0	
	4D	2.4/2.4	15.00 - 15.20	40(2.4")	---		RC	545.7		Brown, moist, Silty fine to coarse SAND, trace gravel. 15.2	G#379653 A-4, SM WC=11.4%
										Roller Coned ahead from 15.2-25.0 ft bgs., (Probable Bedrock).	
20											
25											

Remarks:

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

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

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project:	Large Culvert Replacement on Route 43	**Boring No.:**	HB-IND-101		
Location:	Industry, Maine	**WIN:**	27224.00		
Driller:	MaineDOT	**Elevation (ft.)**	560.9	**Auger ID/OD:**	5" Solid Stem
Operator:	Daggett/Andrle	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	C. Russell	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	9/5/2023; 09:40-13:00	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	N/A
Boring Location:	22+57.2, 12.4 ft Rt.	**Casing ID/OD:**	NW-3"	**Water Level*:**	4.5 ft bgs.
Hammer Efficiency Factor:	0.906	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
25								535.9		25.0 **Bottom of Exploration at 25.0 feet below ground surface.** Moved to HB-IND-101A.	
30											
35											
40											
45											
50											

Remarks:

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

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

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Large Culvert Replacement on Route 43
Location: Industry, Maine
Boring No.: HB-IND-101A
WIN: 27224.00

Driller:	MaineDOT	**Elevation (ft.)**	561.1	**Auger ID/OD:**	5" Solid Stem
Operator:	Daggett/Andrle	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	C. Russell	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	9/5/2023; 13:00-14:15	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	N/A
Boring Location:	22+50.9, 11.9 ft Rt.	**Casing ID/OD:**	NW-3"	**Water Level*:**	3.5 ft bgs.
Hammer Efficiency Factor:	0.906	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0							SSA			Similar soils as HB-IND-101.	
										Boulder from 13.7-14.7 ft bgs.	
	R1	60/60	14.90 - 19.90	RQD = 32.5%			NQ-2	546.2		14.9 Top of Bedrock at Elev. 546.2 ft. Auger REFUSAL at 14.9 ft bgs. R1: Bedrock: Sulfidic or Carbonaceous PELITE, [Towow Formation]. Rock Quality = Poor R1: Core Times (min:sec) 14.9-15.9 ft (2:15) 15.9-16.9 ft (1:51) 16.9-17.9 ft (2:13) 17.9-18.9 ft (2:25) 18.9-19.9 ft (3:08) 100% Recovery	
20								541.2		19.9 **Bottom of Exploration at 19.9 feet below ground surface.**	
25											

Remarks:

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

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

Boring No.: HB-IND-101A

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Large Culvert Replacement on Route 43		**Boring No.:**	HB-IND-102
Location: Industry, Maine		**WIN:**	27224.00

Drilling Contractor:	MaineDOT	**Elevation (ft.)**	561.4	**Auger ID/OD:**	5" Dia.
Operator:	Daggett/Andrle	**Datum:**	NAVD88	**Sampler:**	N/A
Logged By:	C. Russell	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	N/A
Date Start/Finish:	9/5/2023; 08:30-08:45	**Drilling Method:**	Soild Stem Auger	**Core Barrel:**	N/A
Boring Location:	22+79.9, 9.3 ft Lt.	**Casing ID/OD:**	N/A	**Water Level*:**	None Observed

Definitions: D = Spilt Spoon Sample
S = Sample off Auger Flights
B = Bucket Sample off Auger Flights
MD = Unsuccessful Split Spoon Sample Attempt
U = Thin Wall Tube Sample
MV = Unsuccessful Field Vane Shear Test Attempt
V = Field Vane Shear Test, PP= Pocket Penetrometer
MU = Unsuccessful Thin Wall Tube Sample 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 1 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-value = Raw Field SPT N-value
T_v = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent ≅ = Similar or Equal too
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-value	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks		Laboratory Testing Results/ AASHTO and Unified Class.
0						SSA			Probe, no material samples take.		
5											
10							551.1			10.3	
									Bottom of Exploration at 10.3 feet below ground surface. Auger REFUSAL		
15											
20											
25											

Remarks:

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

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

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project:	Large Culvert Replacement on Route 43	**Boring No.:**	HB-IND-102A		
Location:	Industry, Maine	**WIN:**	27224.00		
Drilling Contractor:	MaineDOT	**Elevation (ft.)**	561.4	**Auger ID/OD:**	5" Dia.
Operator:	Daggett/Andrle	**Datum:**	NAVD88	**Sampler:**	N/A
Logged By:	C. Russell	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	N/A
Date Start/Finish:	9/5/2023; 08:50-09:00	**Drilling Method:**	Soild Stem Auger	**Core Barrel:**	N/A
Boring Location:	22+81.9, 10.3 ft Lt.	**Casing ID/OD:**	N/A	**Water Level*:**	None Observed

Definitions: D = Spilt Spoon Sample
S = Sample off Auger Flights
B = Bucket Sample off Auger Flights
MD = Unsuccessful Split Spoon Sample Attempt
U = Thin Wall Tube Sample
MV = Unsuccessful Field Vane Shear Test Attempt
V = Field Vane Shear Test, PP= Pocket Penetrometer
MU = Unsuccessful Thin Wall Tube Sample 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 1 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-value = Raw Field SPT N-value
T_v = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent ≅ = Similar or Equal too
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-value	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0						SSA			Probe, no material samples take.	
12.9							548.5		**Bottom of Exploration at 12.9 feet below ground surface.** Auger REFUSAL	

Remarks:

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

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

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Large Culvert Replacement on Route 43
Location: Industry, Maine

Boring No.: HB-IND-102B
WIN: 27224.00

Drilling Contractor:	MaineDOT	**Elevation (ft.)**	561.4	**Auger ID/OD:**	5" Dia.
Operator:	Daggett/Andrle	**Datum:**	NAVD88	**Sampler:**	N/A
Logged By:	C. Russell	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	N/A
Date Start/Finish:	9/5/2023; 09:05-09:25	**Drilling Method:**	Soild Stem Auger	**Core Barrel:**	N/A
Boring Location:	22+78, 10.3 ft Lt.	**Casing ID/OD:**	N/A	**Water Level*:**	None Observed

Definitions: D = Spilt Spoon Sample
S = Sample off Auger Flights
B = Bucket Sample off Auger Flights
MD = Unsuccessful Split Spoon Sample Attempt
U = Thin Wall Tube Sample
MV = Unsuccessful Field Vane Shear Test Attempt
V = Field Vane Shear Test, PP= Pocket Penetrometer
MU = Unsuccessful Thin Wall Tube Sample 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 1 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-value = Raw Field SPT N-value
T_v = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent ≅ = Similar or Equal too
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-value	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0						SSA			Probe, no material samples take.	
5										
10										
15										
20										
25										

Remarks:

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

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

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS	Project: Large Culvert Replacement on Route 43 Location: Industry, Maine	Boring No.: HB-IND-102B WIN: 27224.00

Drilling Contractor:	MaineDOT	Elevation (ft.)	561.4	Auger ID/OD:	5" Dia.
Operator:	Daggett/Andrle	Datum:	NAVD88	Sampler:	N/A
Logged By:	C. Russell	Rig Type:	CME 45C	Hammer Wt./Fall:	N/A
Date Start/Finish:	9/5/2023; 09:05-09:25	Drilling Method:	Soild Stem Auger	Core Barrel:	N/A
Boring Location:	22+78, 10.3 ft Lt.	Casing ID/OD:	N/A	Water Level*:	None Observed

Definitions: D = Spilt Spoon Sample
S = Sample off Auger Flights
B = Bucket Sample off Auger Flights
MD = Unsuccessful Split Spoon Sample Attempt
U = Thin Wall Tube Sample
MV = Unsuccessful Field Vane Shear Test Attempt
V = Field Vane Shear Test, PP= Pocket Penetrometer
MU = Unsuccessful Thin Wall Tube Sample 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 1 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-value = Raw Field SPT N-value
T_v = Pocket Torvane Shear Strength (psf)
WC = Water Content, percent ≅ = Similar or Equal too
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-value	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
25							536.4		Bottom of Exploration at 25.0 feet below ground surface. 25.0 NO REFUSAL	
30										
35										
40										
45										
50										

Remarks:

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

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

Boring No.: HB-IND-102B

Appendix B

Laboratory Test Results

State of Maine - Department of Transportation

Laboratory Testing Summary Sheet

Town(s): Industry Work Number: 27224.00

Boring & Sample Identification Number	Station (Feet)	Offset (Feet)	Depth (Feet)	Reference Number	G.S.D.C. Sheet	W.C. %	L.L.	P.I.	Classification		
									Unified	AASHTO	Frost
HB-IND-101, 1D	22+57.2	12.4 Rt.	0.0-2.0	379650	1	4.6			SW-SM	A-1-b	0
HB-IND-101, 2D	22+57.2	12.4 Rt.	5.0-7.0	379651	1	8.2			SM	A-2-4	II
HB-IND-101, 3D	22+57.2	12.4 Rt.	10.0-12.0	379652	1	10.3			SM	A-2-4	II
HB-IND-101, 4D	22+57.2	12.4 Rt.	15.0-15.2	379653	1	11.4			SM	A-4	III

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

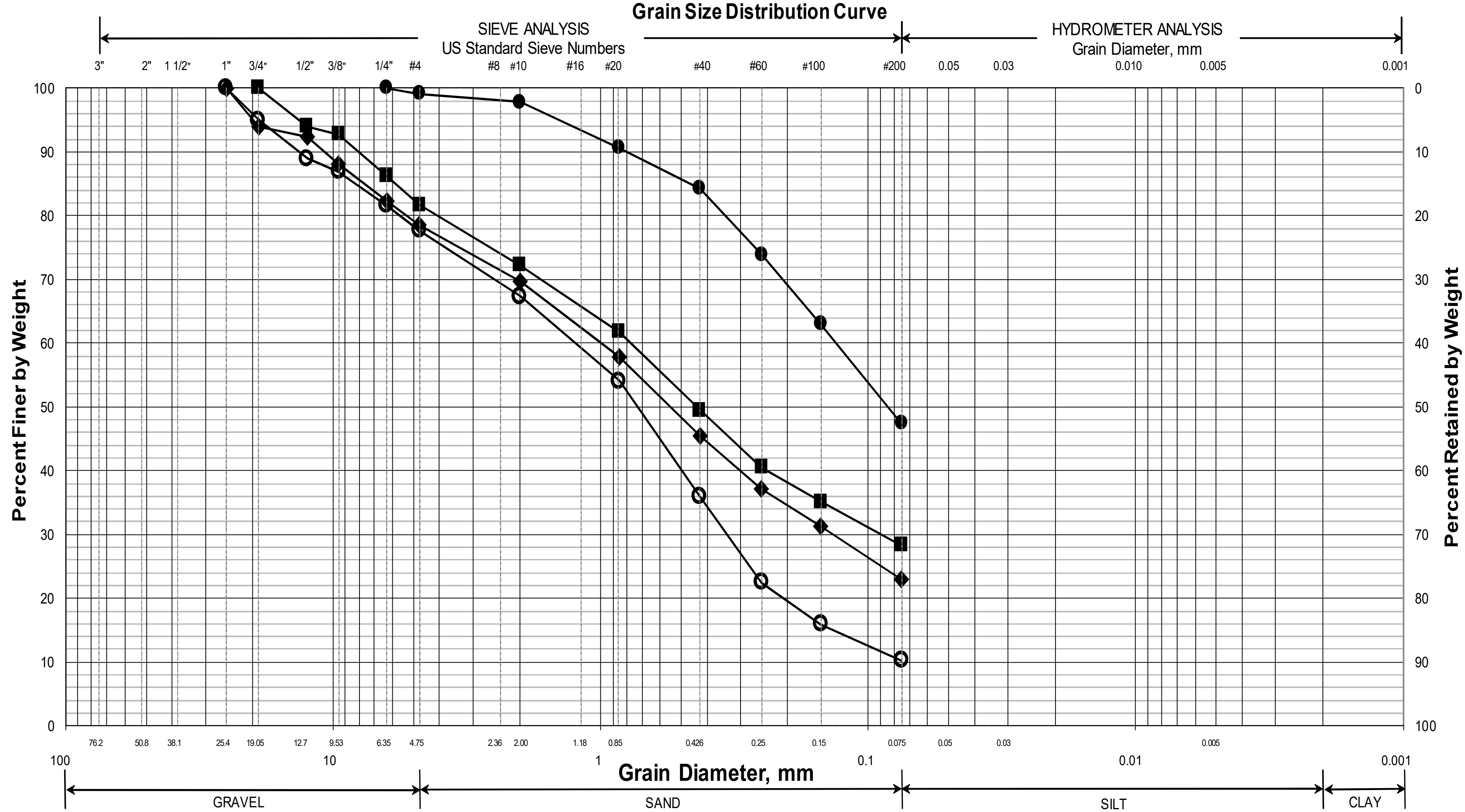
GSDC = Grain Size Distribution Curve as determined by AASHTO T 88-93 (1996) and/or ASTM D 422-63 (Reapproved 1998)

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

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

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

Maine Department of Transportation
Grain Size Distribution Curve



UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
○	HB-IND-101/1D	22+57.2	12.4 RT	0.0-2.0	SAND, some gravel, little silt.	4.6			
◆	HB-IND-101/2D	22+57.2	12.4 RT	5.0-7.0	SAND, some silt, some gravel.	8.2			
■	HB-IND-101/3D	22+57.2	12.4 RT	10.0-12.0	SAND, some silt, little gravel.	10.3			
●	HB-IND-101/4D	22+57.2	12.4 RT	15.0-15.2	Silty SAND, trace gravel.	11.4			
▲									
×									

WIN	
027224.00	
Town	
Industry	
Reported by/Date	
WHITE, TERRY A	1/19/2026

SHEET 1

Appendix C

Calculations

Bearing Resistance - Existing Soils:

Part 1 - Service Limit State

Nominal and factored Bearing Resistance - Box Culvert on Silty Sand

Presumptive Bearing Resistance for Service Limit State ONLY

Reference: AASHTO LRFD Bridge Design Specifications 10th Edition 2024
Table C10.6.2.5.1-1 Presumptive Bearing Resistances for Spread Footings at the Service Limit State Modified after US Department of Navy (1982)

Type of Bearing Material: Silty Sand (SM)

Based on N-values, soils are medium dense near the bearing elevation

Density In Place: medium dense to dense

Bearing Resistance: Ordinary Range (ksf) 4 to 8

Recommended Value of Use: $q_{nom} := 5 \cdot ksf$

Resistance factor at the **service limit state** = 1.0 (LRFD Article 10.5.5.1) $\phi_{service\_bc} := 1.0$

$q_{factored\_service\_bc} := q_{nom} \cdot \phi_{service\_bc}$ $q_{factored\_service\_bc} = 5 \cdot ksf$

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

Part 2 - Strength Limit State

Nominal and factored Bearing Resistance - Box Culvert on Silty Sand

Reference: AASHTO LRFD Bridge Design Specifications 10th Edition 2024 - Article 10.6.3.1

Assumptions:

1. The box will be founded at ~ Elev 546.4 feet

   Bottom of Construction will be 2 feet below box invert $D_{footing} := 2.0 \cdot ft$

2. Assumed parameters for fill soils:

   Saturated unit weight: $\gamma_s := 125 \cdot pcf$

   Internal friction angle: $\phi_{ns} := 32 \cdot deg$

   Undrained shear strength: $c_{ns} := 0 \cdot psf$

3. Box Culvert parameters

   Width of box culvert, B $B_{box} := 18 \cdot ft$

   Length of box culvert, L $L_{box} := 92 \cdot ft$

Nominal Bearing Resistance per LRFD Equation 10.6.3.1.2a-1

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

Bearing Capacity Factors - LRFD Table 10.6.3.1.2a-1

For ϕ=32 deg $N_c := 35.5$ $N_q := 23.2$ $N_\gamma := 30.2$

Shape Correction Factors LRFD Table 10.6.3.1.2a.-3

for ϕ=32 degrees

$$s_c := 1 + \left(\frac{B_{box}}{L_{box}}\right)\left(\frac{N_q}{N_c}\right) \qquad s_c = 1.13$$

$$s_\gamma := 1 - 0.4\left(\frac{B_{box}}{L_{box}}\right) \qquad s_\gamma = 0.9217$$

$$s_q := 1 + \left(\frac{B_{box}}{L_{box}} \cdot \tan(\phi_{ns})\right) \qquad s_q = 1.12$$

Load Inclination Factors:
Assume all are 1.0 (LRFD Article C10.6.3.1.2a)

$i_c := 1.0$ $i_q := 1.0$ $i_\gamma := 1.0$

Depth Correction Factor

$$d_q := 1 + 2 \cdot \tan(\phi_{ns}) \cdot (1 - \sin(\phi_{ns}))^2 \cdot \tan\left(\frac{D_{footing}}{B_{box}}\right)^{-1} \qquad d_q = 3.4752$$

LRFD Eq. 10.6.3.1.2a-10

$N_{cm} := N_c \cdot s_c \cdot i_c$ $N_{cm} = 40.0391$ LRFD Eq. 10.6.3.1.2a-2

$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q$ $N_{qm} = 90.48$ LRFD Eq. 10.6.3.1.2a-3

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $N_{\gamma m} = 27.84$ LRFD Eq. 10.6.3.1.2a-4

Coefficients for Groundwater Depths LRFD Table 10.6.3.1.2a-2

Depth the water table: $D_w := 4.5 \cdot ft$ $C_{wq} := 1.0$ $C_{w\gamma} := 0.5$

$$q_{nominal} := c_{ns} \cdot N_{cm} + \gamma_s \cdot D_{footing} \cdot N_{qm} \cdot C_{wq} + 0.5(\gamma_s)B_{box} \cdot N_{\gamma m} \cdot C_{w\gamma}$$

$$q_{nominal} = 38.3 \cdot ksf$$

Factored Bearing Resistance for Strength Limit State

Resistance Factor: $\phi_b := 0.45$ LRFD Table 10.5.5.2.2-1

$$q_{factored} := q_{nominal} \cdot \phi_b$$

$$q_{factored} = 17.2 \cdot ksf$$

Recommend a limiting factored bearing resistance of 17.0 ksf for the Strength Limit State.

Modulus of Subgrade Reaction:

Reference: Foundation Analysis and Design 5th Edition JE Bowles Section 9-6

Width of box culvert, B $B_{box} = 18\,ft$

Length of box culvert, L $L_{box} = 92\,ft$

Thickness of box culvert, t $t_{box} := 12 \cdot in$ assumed

Depth of box, D $D_{box} := 17.1 \cdot ft$

Bearing Resistance: $q_{factored\_service\_bc} = 5 \cdot ksf$ Calculated above

Modulus of Elasticity: Site soils at bearing elevation are Silty Sand. Use values for Silty Sand (medium dense)
From Bowles Table 2-8 Modulus Es for Silty Sand, ranges from 104 - 418 ksf

Use : Modulus of Elasticity, Es $E_s := 265 \cdot ksf$

Poisson's Ratio: Site conditions at bearing elevation are Silty Sand. Use values for Silty Sand (medium dense)
From Bowles Table 2-7 Poisson's Ration μ for Sand ranges from 0.3 - 0.4

Use : Possion's Ratio, μ $\mu := 0.3$

$$E_{prime\_s} := \frac{1 - \mu^2}{E_s} \qquad E_{prime\_s} = 0.003434 \cdot \frac{ft^2}{kip}$$

Analyze corner:

Take H as 5*B as recommended in Bowles Chapter 5

$$H_{inf} := \frac{5 \cdot B_{box}}{B_{box}} \qquad H_{inf} = 5$$ N in Table 5-2

$$\frac{L_{box}}{B_{box}} = 5.1111$$ M in Table 5-2

From Table 5-2 for N=5 and M=5.11

$I_1 := 0.552$

$I_2 := 0.112$

by interpolation

Determine Steinbrenner influence factor - Bowles Section 5-6:

$$I_s := I_1 + \left[\frac{1 - (2 \cdot \mu)}{1 - \mu}\right] \cdot I_2 \qquad I_s = 0.616$$

Determine Influence factor for footing depth - Bowles Figure 5-7

Depth ratio: $\frac{D_{box}}{B_{box}} = 0.95$ $\frac{L_{box}}{B_{box}} = 5.1111$ $\mu = 0.3$ $I_F := 0.79$

Calculate modulus of subgrade reaction - Bowles Eq. 9-7

$$k_s := \frac{1}{B_{box} \cdot E_{prime\_s} \cdot I_s \cdot I_F}$$ Bowles Eq. 9-7

$$k_s = 19 \cdot pci$$

Recommend Modulus of Subgrade Reaction of 20 pci