AGENCY OF TRANSPORTATION **OFFICE MEMORANDUM**

To: Mahendra Thilliyar, P.E., Structures Project Manager

END CEE

From: Eric Denardo, P.E., Geotechnical Engineer and Callie Ewald, P.E., Senior Geotechnical Engineer

Date: October 16th, 2025

Subject: Londonderry ER P23-1(228) – Geotechnical Report

1.0 INTRODUCTION

As requested, we have completed an additional subsurface investigation for the proposed replacement of the culvert located at Mile Marker 3.17 on VT Route 100 over an unnamed tributary of the West River in Londonderry, Vermont. Additional borings and geophsyical testing were completed to better profile the depth to bedrock to aid in design of a replacement structure. Contained herein are the results of our field sampling and testing, laboratory analyses of rock samples, as well as geotechnical recommendations for the proposed wing walls.

2.0 FIELD INVESTIGATION

An initial field investigation for Borings B-101 and B-102 was conducted between December 2nd and December 4th, 2024. The results from this investigation can be found in a report submitted March 11th, 2025 and attached to this report. An additional geophysical investigation, to better profile the surface of bedrock was conducted by WSP and is summarized in a report dated September 2025, which can also be found attached to this report.

Based on the depth of bedrock encountered in the initial borings and the proposed bottom of footing locations, four additional borings were conducted between April 15th and April 23rd, 2025. The locations of the additional borings were provided by Amy Spera of Gill Engineering in an email dated March 20th, 2025, and laid out in the field during a site visit conducted April 2nd, 2025 by members of the Geotechnical Section. The as-drilled borings were located using the Geotechnical Section's handheld Trimble TDC600 and Trimble DA2 GNSS GPS receiver with submeter accuracy. A summary of the final location of each boring and corresponding approximate ground surface elevation can be found in Table 2.1 as well as the attached Boring Location Plan. The values for the Northings and Eastings are based on the Vermont State Plane Grid Coordinate System NAD 83. The elevations for the borings, based on the North American Vertical Datum, NAVD 88, were estimated using the design file z23b831sv.dgn, dated November 2024. The locations and elevations for the borings should be considered accurate only to the degree implied by the method used to determine them.

Table 2.1: Boring Locations

Boring	Station	Offset (ft)	Northing (ft)	Easting (ft)	Elevation (ft)	Approx. Bedrock Elevation (ft)
B-103	105+42	4.6 RT	253378.1	1556101.5	1052.3	1030.3
B-104	105+39	28.2 RT	253373.0	1556127.5	1053.1	1038.9
B-105	105+56	16.3 LT	253393.0	1556091.2	1051.4	1029.4
B-106	105+61	5.3 RT	253396.0	1556113.0	1052.8	1041.8

The borings were advanced to bedrock without sampling. When bedrock was encountered, 5-foot (ft) NX rock core runs were taken to confirm the presence of bedrock. In B-104, no bedrock was recovered in the first foot of core due to an equipment malfunction. No rock was recovered after approximately 4 feet of core; likely this was also due to an equipment malfunction and not a void in the rock.

Details of the bedrock coring were recorded on the boring logs when applicable. Cores were then placed in core boxes and returned to the VTrans Construction and Materials Bureau Laboratory for further evaluation and testing, where applicable. The boring logs were revised to reflect the classification and description of the bedrock cores and any pertinent observations made by the drilling crew were included.

3.0 ROCK CORE RESULTS

A summary of the rock core findings are provided attached in Figure 1 as well as available in the attached boring logs. Information from the cores indicate the bedrock present at the project site is moderately hard to hard, black to gray, Sulfidic Biotite-Muscovite-Quartz-Plagioclase-GNEISS. The bedrock had an average rock quality designation (RQD) of 24 and an average rock mass rating (RMR) of 48, indicating fair rock.

4.0 SHALLOW FOUNDATION ANALYSIS

Based on the subsurface conditions on site and the proposed culvert inlet and outlet elevations, it appears that the inlet and wing wall 3 (WW3) and WW4 will bear directly on bedrock and the outlet and WW1 and WW2 will bear on soil.

AASHTO's LRFD Bridge Design Specifications Manual (2024) was used as the reference for settlement and bearing resistance equations. Section 10.6.3.1.2 contains the equation used for bearing resistance. Neither depth factors nor load inclination factors were used in the analysis as they were not considered pertinent due to the designed embedment of the structure, per Section C.10.6.3.1.2a. Hough's Method, used to calculate settlement in normally consolidated cohesionless soils, can be found in Section 10.6.2.4.2.

It is recommended that the bottom of the wingwall footings in soil be at least 4 ft below the ground surface based on frost susceptibility and bearing stratum at the site. An embedment value of 4 ft was used for the strength limit state analysis and an embedment value of 0 ft was used for the service limit state analysis, which tends to control the design, to account for potential scour conditions at the design flood elevation per Section 2.6.4.4.2. A conservative groundwater elevation of the footing elevation was used in design at the outlet.

As per section 10.5.5.1 of the 2024 AASHTO LRFD Bridge Design Specifications, a resistance factor of 1.0 should be applied to the unfactored bearing resistance for use in service limit state design. Service limit state design includes, but is not limited to, settlement and scour. Section 10.5.5.2.2 specifies that a resistance factor of 0.45 should be applied to the unfactored bearing resistance for use in strength limit state design for spread footings on rock and soil. Strength limit state design includes, but is not limited to, checks for bearing resistance, sliding, and constructability. Potential for overturning is limited by controlling the location of the resultant of the reaction forces (eccentricity). Eccentricity, e, shall be limited as follows:

Foundations on soil:	$\|e\| < b/3$
Foundations on rock:	$\|e\| < 0.45b$

Eccentricity should be considered for settlement and bearing resistance design of spread footings by using effective footing widths based on AASHTO Section 10.6.1.3. All footing widths presented in this report are *effective* footing widths.

4.1 Bearing Resistance (Outlet Bearing Stratum, B-101/B-105)

The maximum length of wingwalls used in the analysis was 8 ft, based on final plans dated June 2025. A bottom of footing elevation for both proposed WW1 and WW2 was listed as 1035.24 feet. Based on the geometry and elevation it appears as though the footings will bear on a medium dense SAND layer, which based on the boring information and subsequent calculations was assigned a friction angle, $\phi = 33^{o}$ and density, $\gamma = 130$ lb/ft^3.

For effective footing widths of 4 ft through 8 ft, the maximum factored bearing resistances for the strength and service limit states are given in Table 4.1.1. Considering the granular nature of the foundation soils and thickness of overburden material, any settlement is expected to be negligible and occur during or immediately after construction.

Table 4.1.1 Factored Bearing Resistances at Various Effective Footing Widths at the Outlet

Maximum Wingwall Length (ft)	Effective Footing Width (ft)	Factored Bearing Resistance, Strength Limit State (ksf)	Factored Bearing Resistance, Service Limit State (ksf)
8.0	4	5.7	3.7
	5	6.2	4.3
	6	6.7	4.8
	7	7.1	5.2
	8	7.5	5.5

4.2 Bearing Resistance (Inlet Bearing Stratum, B-104)

The maximum length of wingwalls used in the analysis was 12 ft, based on final plans dated June 2025. A bottom of footing elevation for both proposed WW3 and WW4 was listed as 1040.37 feet. Based on the geometry and elevation it appears as though the footings will bear on bedrock, however bedrock may be variable across the footprint of the wing walls as information is limited in this area.

The bedrock at the footing locations has a fair rock quality designation. Classified as moderately hard to hard, slightly weathered Gneiss, AASHTO recommends a presumptive bearing resistance of 70 ksf per Table C10.6.2.6.1-1 for “foliated metamorphic rock”. Taken as the nominal bearing resistance, in combination with a resistance factor of 0.45 for spread footings on rock, per AASHTO 10.5.5.2.2-1, this yields a factored bearing resistance of 31.5 ksf.

Settlement of the footings, with maximum allowable bearing pressures indicated and footing founded on bedrock, is anticipated to be negligible.

5.0 RECOMMENDATIONS

Shallow foundations appear to be feasible for the proposed wingwalls as outlined above in Section 4. Factored bearing resistances for various footing widths were calculated for the wingwalls and can be found in Sections 4.1 and 4.2. The bearing resistances presented in this report at the service limit state were calculated assuming a conservative scour condition (0 ft embedment). Sections 10.5.2 and 10.5.3 of AASHTO outline all design states relevant to spread footing design and their respective resistance factors. Eccentricity should be considered for settlement and bearing resistance design of spread footings by using effective footing widths based on AASHTO Section 10.6.1.3. Table 6.1 shows the appropriate resistance factors for various design states.

Table 5.1: Summary of Resistance Factors

Design State	Resistance Factor, φ
Settlement	1.0
Scour	1.0
Bearing Resistance	0.45
Sliding*	0.90

*Assumes precast concrete placed on sand

5.1 Plan Notes & Details

Based on the subsurface investigation and subsequent analyses, we recommend including the following information on the plans for wing wall design:

- For strength limit state, using a resistance factor of 0.45, the factored bearing resistance for soil is 5.7 ksf
- For service limit state, using a resistance factor of 1.0, the factored bearing resistance for soil is 3.7 ksf
- For strength limit state, using a resistance factor of 0.45, the factored bearing resistance for rock is 31.5 ksf

Based on the condition of the rock described in the cores, we anticipate the rock at the inlet and box location to be rippable with difficulty. Depending on the competency of the intact rock it may be problematic to excavate with conventional equipment in a timely manner. Blasting will likely be the method chosen by the contractor to remove bedrock to the proposed elevations. Due to the proximity of rock excavation and potentially blasting to existing structures, Section 250 of VTrans' *2024 Standard Specifications for Construction* should be used to appropriately manage any risk during construction.

It is recommended that any incompetent, weathered, and fractured bedrock encountered during construction of the spread footing be removed until competent bedrock is encountered. During excavation, the Agency Geologist should inspect the bedrock to determine the amount and extent of excavation needed. If uneven bedrock contours are encountered, the concrete subfooting should be stepped along the existing bedrock in order to transfer the footing pressure directly to the bedrock.

5.2 Design Parameters

Table 5.2.1 highlights engineering properties assigned to the in-situ soils as well as the engineering properties of common construction materials. These values should be used when

designing any substructure units. It is recommended that values of K_o be used for calculating earth pressures where the structure is not allowed to deflect longitudinally, away from or into the retained soil mass. Values for K_a should be utilized for an active earth pressure condition where the structure is moving away from the soil mass and K_p where the structure is moving toward the soil mass. The design earth pressure coefficients are based on horizontal surfaces (non-sloping backfill) and a vertical wall face.

Table 5.2.1: Engineering Properties of In-Situ and Construction Materials

	703.04 – Granular Borrow	**704.08 – Granular Backfill for Structures**	**Medium Dense SAND (Outlet Bearing Stratum)**
Unit Weight, γ (lbs/ft^3):	130	140	130
Internal Friction Angle, φ (degrees):	32	34	33
Coefficient of Friction, f			
- mass concrete cast against soil:	0.45	0.55	0.50
- soil against precast/formed concrete:	0.40	0.54	0.35
Active Earth Pressure Coef., K_a:	0.31	0.28	0.30
Passive Earth Pressure Coef., K_p:	3.26	3.57	3.39
At-Rest Earth Pressure Coefficient, K_o:	0.47	0.44	0.46

5.3 Construction Considerations

5.3.1 Cofferdams/Temporary Earthwork Support

The Contractor should be reminded that Section 208.06 of VTrans' *2024 Standard Specifications for Construction* indicates that "The Contractor shall prepare detailed plans and a schedule of operations for each cofferdam specified in the Contract. Construction drawings shall be submitted in accordance with Subsection 105.06."

5.3.2 Construction Dewatering

A stabilized groundwater table was not measured during the investigation; therefore, temporary construction dewatering may be required to construct the foundations. Temporary dewatering will also be necessary to limit disturbance to and maintain the integrity of the bearing surface.

Temporary dewatering can likely be accomplished by open pumping from shallow sumps, temporary ditches, and trenches within and around the excavation limits. Sumps should be provided with filters suitable to prevent pumping of fine-grained soil particles. The water trapped by the temporary dewatering controls should be discharged to settling basins or an

approved filter "sock" so that the fine particles suspended in the discharge have adequate time to "settle out" prior to discharge. All effluent water, or discharge, should comply with all applicable permits and regulations.

Sumps and trenches should lie outside a 1V:1H line extending downward and outward from the edge of footing. Installation and operation of the Contractor's dewatering system should be integrated with other earthwork operations and sequence of cutting, filling, foundation construction, and backfilling.

5.3.3 Placement and Compaction of Soils

Fills should be placed systematically in horizontal layers not more than 12 inches in thickness, prior to compaction. Cobbles larger than 8 inches should be removed from the fill prior to placement. Compaction equipment should preferably consist of large, self-propelled vibratory rollers. Where hand-guided equipment is used, such as a small vibratory plate compactor, the loose lift thickness shall not exceed 6 inches. Cobbles larger than 4 inches should be removed from the fill prior to placement.

Embankment fills should be compacted to a dry density of no less than 95% of the maximum dry density determined in accordance with AASHTO T-99, Method C. Granular Backfill for Structures, or other select materials placed within the roadway base section shall be compacted to a dry density equal to 95% of the maximum dry density as determined in accordance with AASHTO T-99.

6.0 CONCLUSION

If you have any questions, or you would like to discuss this report, please contact us via email. Please let us know when more information is available and if you'd like assistance with foundation analyses and design. Typed boring logs are attached and are available in the CADD design files: M:\Projects\23b831MaterialsResearch

Attachments: Figure 1: Rock Core Sample Results
Boring Layout (1 Page)
Boring Logs (4 pages)
Subsurface Investigation Report by VTrans (8 Pages)
Geophsyical Report by WSP (10 Pages)

cc: Read File/MG
Project File/CEE

Figure 1: Rock Core Sample Results

Boring	Run No.	Core Size	Depth (ft)	Recovery (%)	RQD (%)	Dip (º)	Lithologic Description	RMR
B-103	1	NX	22.0-27.0	74	42	25-35	Gray to Black Sulfidic Biotite-Muscovite-Quartz-Plagioclase-GNEISS. Some rusty brown staining / brown discoloration along some joints. Joint surfaces moderately rough. Moderately hard and fresh to very slightly weathered. Fair Rock	53
B-104	2	NX	15.2-18.2	70	0	10	Gray to Black Sulfidic Biotite-Muscovite-Quartz-Plagioclase-GNEISS. Rust staining and brown discoloration along joints and core. Joint surfaces moderately rough. Hard to moderately hard and moderately weathered. Fair Rock	43
B-104	4	NX	19.0-19.5	100	0	10	Gray to Black Sulfidic Biotite-Muscovite-Quartz-Plagioclase-GNEISS. Joint surfaces moderately rough. Moderately hard and fresh to slightly weathered. Fair Rock	41
B-105	1	NX	22.0-25.0	57	0	6	Gray to Black Sulfidic Biotite-Muscovite-Quartz-Plagioclase-GNEISS. Rust staining and brown discoloration along joints and on core. Joint surfaces moderately rough. Hard to moderately hard and very slightly weathered to slightly weathered. Fair Rock	42
B-105	2	NX	25.0-29.0	98	88	30-35	Gray to Black Sulfidic Biotite-Muscovite-Quartz-Plagioclase-GNEISS. Some rusty brown staining / brown discoloration along some joints. Joint surfaces moderately rough. Moderately hard and fresh to very slightly weathered. Good Rock	62
B-106	1	NX	11.0-16.0	62	15	20	Gray to Black Sulfidic Biotite-Muscovite-Quartz-Plagioclase-GNEISS Some rusty orange staining along joints, tan and brown discoloration along some joints. Joint surfaces moderately rough. Moderately hard and fresh to moderately weathered. Fair Rock	44

SOIL CLASSIFICATION

AASHTO	
A1	Gravel and Sand
A3	Fine Sand
A2	Silty or Clayey Gravel and Sand
A4	Silty Soil - Low Compressibility
A5	Silty Soil - Highly Compressible
A6	Clayey Soil - Low Compressibility
A7	Clayey Soil - Highly Compressible

ROCK QUALITY DESIGNATION

R.Q.D. (%)	ROCK DESCRIPTION
<25	Very Poor
25 to 50	Poor
51 to 75	Fair
76 to 90	Good
>90	Excellent

SHEAR STRENGTH

UNDRAINED SHEAR STRENGTH IN P.S.F.	CONSISTENCY
<250	Very Soft
250-500	Soft
500-1000	Med. Stiff
1000-2000	Stiff
2000-4000	Very Stiff
>4000	Hard

CORRELATION GUIDE OF "N" TO DENSITY/CONSISTENCY

DENSITY (GRANULAR SOILS)		CONSISTENCY (COHESIVE SOILS)	
N	DESCRIPTIVE TERM	N	DESCRIPTIVE TERM
<5	Very Loose	<2	Very Soft
5-10	Loose	2-4	Soft
11-24	Med. Dense	5-8	Med. Stiff
25-50	Dense	9-15	Stiff
>50	Very Dense	16-30	Very Stiff
		31-60	Hard
		>60	Very Hard

COMMONLY USED SYMBOLS

▼	Water Elevation
⊗	Standard Penetration Boring
⊕	Auger Boring
⊙	Rod Sounding
S	Sample
N	Standard Penetration Test Blow Count Per Foot For: 2" O.D. Sampler 1 3/8" I.D. Sampler Hammer Weight Of 140 Lbs. Hammer Fall Of 30"
VS	Field Vane Shear Test
US	Undisturbed Soil Sample
B	Blast
DC	Diamond Core
MD	Mud Drill
WA	Wash Ahead
HSA	Hollow Stem Auger
AX	Core Size 1 1/8"
BX	Core Size 1 5/8"
NX	Core Size 2 1/8"
M	Double Tube Core Barrel Used
LL	Liquid Limit
PL	Plastic Limit
PI	Plasticity Index
NP	Non Plastic
w	Moisture Content (Dry Wgt. Basis)
D	Dry
M	Moist
MTW	Moist To Wet
W	Wet
Sat	Saturated
Bo	Boulder
Gr	Gravel
Sa	Sand
Si	Silt
Cl	Clay
HP	Hardpan
Le	Ledge
NLTD	No Ledge To Depth
CNPF	Can Not Penetrate Further
TLOB	Top of Ledge Or Boulder
NR	No Recovery
Rec.	Recovery
%Rec.	Percent Recovery
ROD	Rock Quality Designation
CBR	California Bearing Ratio
<	Less Than
>	Greater Than
R	Refusal (N > 100)
VTSPG	NAD83 - See Note 7

COLOR			
blk	Black	pnk	Pink
bl	Blue	pu	Purple
brn	Brown	rd	Red
dk	Dark	tn	Tan
gry	Gray	wh	White
gn	Green	yel	Yellow
lt	Light	mltc	Multicolored
or	Orange		

DEFINITIONS (AASHTO)

BEDROCK (LEDGE) - Rock in its native location of indefinite thickness.

BOULDER - A rock fragment with an average dimension > 12 inches.

COBBLE - Rock fragments with an average dimension between 3 and 12 inches.

GRAVEL - Rounded particles of rock < 3" and > 0.0787" (#10 sieve).

SAND - Particles of rock < 0.0787" (#10 sieve) and > 0.0029" (#200 sieve).

SILT - Soil < 0.0029" (#200 sieve), non or slightly plastic and exhibits no strength when air-dried.

CLAY - Fine grained soil, exhibits plasticity when moist and considerable strength when air-dried.

VARVED - Alternate layers of silt and clay.

HARDPAN - Extremely dense soil, cemented layer, not softened when wet.

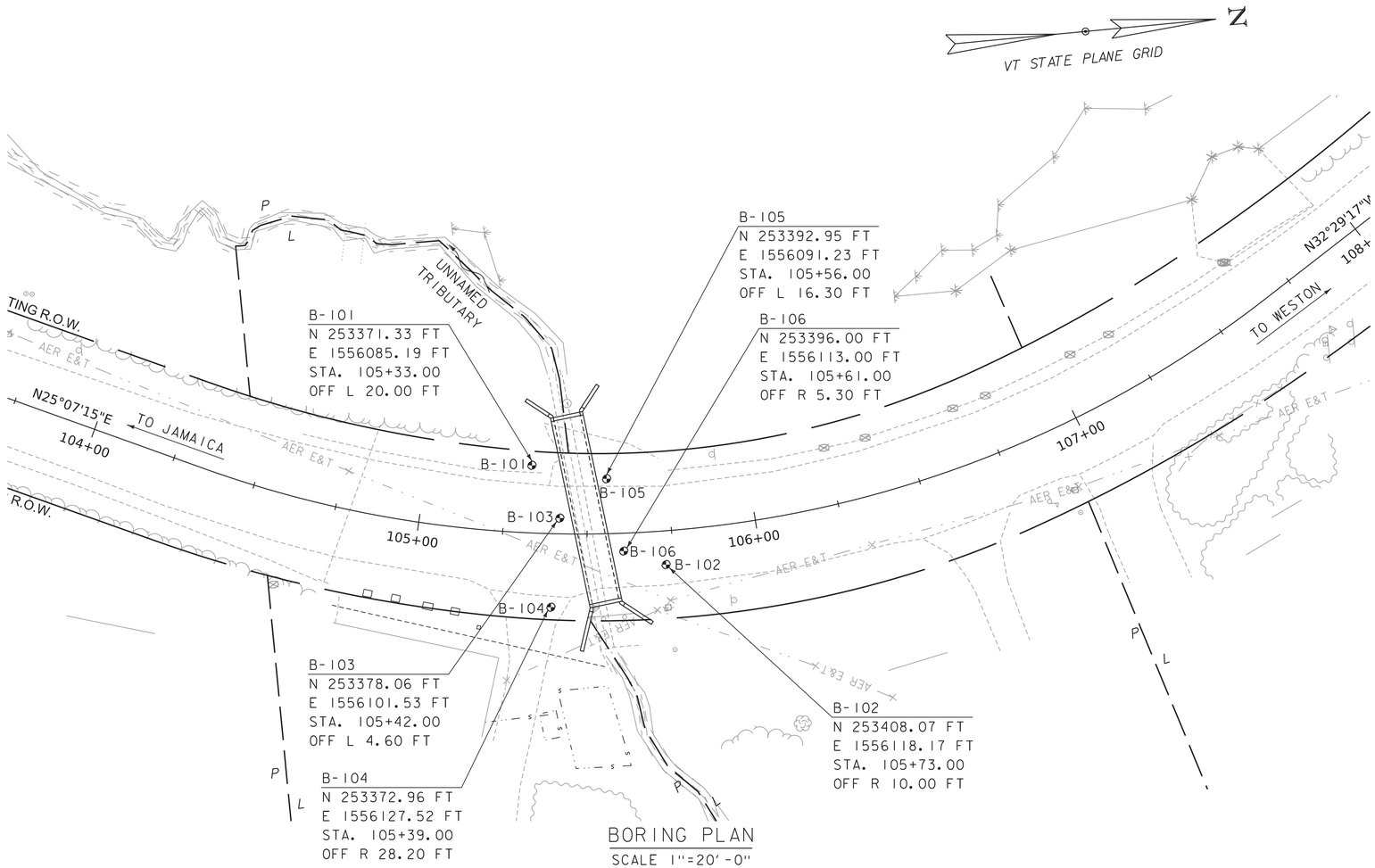
MUCK - Soft organic soil (containing > 10% organic material.

MOISTURE CONTENT - Weight of water divided by dry weight of soil.

FLOWING SAND - Granular soil so saturated (loose) that it flows into drill casing during extraction of wash rod.

STRIKE - Angle from magnetic north to line of intersection of bed with a horizontal plane.

DIP - Inclination of bed with a horizontal plane.



BORING PLAN

SCALE 1"=20'-0"

BORING LOCATIONS						
BORING	NORTHING	EASTING	STATION	OFFSET	GROUND ELEV.	BEDROCK ELEV.
B-101	253371.33	1556085.19	105+33.00	-20.00	1050.9	1021.4
B-102	253408.07	1556118.17	105+73.00	10.00	1053.2	1044.2
B-103	253378.06	1556101.53	105+42.00	-4.60	1052.3	1030.3

BORING LOCATIONS (CONT.)						
BORING	NORTHING	EASTING	STATION	OFFSET	GROUND ELEV.	BEDROCK ELEV.
B-104	253372.96	1556127.52	105+39.00	28.20	1053.1	1038.9
B-105	253392.95	1556091.23	105+56.00	-16.30	1051.4	1029.4
B-106	253396.00	1556113.00	105+61.00	5.30	1052.8	1041.8

GENERAL NOTES

1. The subsurface explorations shown herein were made between December 2, 2024 and April 23, 2025 by the Agency.
2. Soil and rock classifications, properties and descriptions are based on engineering interpretation from available subsurface information by the Agency and may not necessarily reflect actual variations in subsurface conditions that may be encountered between individual boring or sample locations.
3. Observed water levels and/or conditions indicated are as recorded at the time of exploration and may vary according to the prevailing rainfall, methods of exploration and other factors.
4. Engineering judgment was exercised in preparing the subsurface information presented herein. Analysis and interpretation of subsurface data was performed and interpreted for Agency design and estimating purposes. Presentation of the information in the Contract is intended to provide the Contractor access to the same data available to the Agency. The subsurface information is presented in good faith and is not intended as a substitute for personal investigation, independent interpretation, independent analysis or judgment by the Contractor.
5. Pictorial structure details shown on the boring plan layout or soils profile are for illustrative purposes only and may not accurately portray final contract details.
6. Terminology used on boring logs to describe the hardness, degree of weathering, and spacing of fractures, joints and other discontinuities in the bedrock is defined in the AASHTO Manual on Subsurface Investigations, 1988.
7. Northing and Easting coordinates are shown in Vermont State Plane Grid North American Datum 1983 in meters and survey feet.

GILL ENGINEERING

PROJECT NAME: LONDONDERRY

PROJECT NUMBER: ER P23-1(228)

FILE NAME: z23b83lbor.dgn
PROJECT LEADER: A.SPERA
DESIGNED BY: C.BURNER
BORING LAYOUT SHEET

PLOT DATE: 6-JUN-2025
DRAWN BY: C.BURNER
CHECKED BY: A.SPERA
SHEET 18 OF 35

STATE OF VERMONT
AGENCY OF TRANSPORTATION
CONSTRUCTION AND
MATERIALS BUREAU
CENTRAL LABORATORY

BORING LOG

Londonderry
ER P23-1(228)
VT 100

Boring No.: **B-103**
Page No.: 1 of 1
Pin No.: 23b831
Checked By: END

Boring Crew: McGinley, Thurston, Degener
Date Started: 4/22/25 Date Finished: 4/23/25
VTSPG NAD83: N 253378.06 ft E 1556101.53 ft
Station: 105+42 Offset: 4.6 LT
Ground Elevation: 1052.3 ft

	Casing	Sampler
Type:	WB	SS
I.D.:	4 in	1.5 in
Hammer Wt:	N.A.	140 lb.
Hammer Fall:	N.A.	30 in.
Hammer/Rod Type:		Auto/AWJ
Rig:	Diedrich 25	C_E = 1.45

Groundwater Observations

Date	Depth (ft)	Notes
04/23/25	2.8	WT After Drilling

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Run (Dip deg.)	Core Rec. % (RQD %)	Drill Rate minutes/ft	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %
		Asphalt 0 ft-0.8 ft, 0.0 ft - 0.8 ft								
5										
		Cleanout barrel, 8.0 ft - 10.0 ft								
10										
		Cleanout barrel, 11.5 ft - 13.5 ft								
15										
20		Cleanout barrel, 20.0 ft - 22.0 ft, Casing would not advance beyond 22 ft								
		22.0 ft - 27.0 ft, Gray to black, Biotite-muscovite-quartz-plagioclase-GNEISS, Some rusty brown staining / brown discoloration along some joints. Joint surfaces moderately rough. Moderately hard, Fresh to very slightly weathered, Fair rock, NX, RMR = 53	R1 (25-35)	74 (42)	2 3.25 3.5 1.5 3.3	Top of Bedrock @ 22.0 ft				
25										
		Hole stopped @ 27.0 ft								
30		Remarks: Hole collapsed at 18.6 ft.								
35										

Notes:
1. Stratification lines represent approximate boundary between material types. Transition may be gradual.
2. N Values have not been corrected for hammer energy. C_E is the hammer energy correction factor.
3. Water level readings have been made at times and under conditions stated. Fluctuations may occur due to other factors than those present at the time measurements were made.

BORING LOG LONDONDERRY ER P23-1(228).GPJ VERMONT AOT.GDT 5/2/25

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CONSTRUCTION AND
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BORING LOG

Londonderry
ER P23-1(228)
VT 100

Boring No.: **B-104**
Page No.: 1 of 1
Pin No.: 23b831
Checked By: END

Boring Crew: Thurston, Lubas, Degener
Date Started: 4/15/25 Date Finished: 4/16/25
VTSPG NAD83: N 253372.96 ft E 1556127.52 ft
Station: 105+39 Offset: 28.2 RT
Ground Elevation: 1053.1 ft

	Casing	Sampler
Type:	WB	SS
I.D.:	4 in	1.5 in
Hammer Wt:	N.A.	140 lb.
Hammer Fall:	N.A.	30 in.
Hammer/Rod Type:		Auto/AWJ
Rig:	Diedrich 25	C_E = 1.45

Groundwater Observations

Date	Depth (ft)	Notes
04/16/25	8.2	WT After Drilling

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Run (Dip deg.)	Core Rec. % (RQD %)	Drill Rate minutes/ft	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %
5		Cleanout barrel, 6.0 ft - 8.0 ft								
10										
15		14.2 ft - 15.2 ft, No recovery. Suspected core stuck in core barrel. NX	R1	0	8.5	Top of Bedrock @ 14.2 ft				
		15.2 ft - 18.2 ft, Gray to black, Sulfidic biotite-muscovite-quartz-plagioclase- GNEISS, Rust staining and brown discoloration along joints and core. Joint surfaces moderately rough. Moderately hard to hard, Moderately weathered, Fair rock, NX, RMR = 43	R2 (10)	70 (0)	11 5 13.3					
			R3	0	30.5					
20		18.2 ft - 19.2 ft, No recovery. Core barrel malfunction. NX	R4 (10)	100 (0)						
		19.2 ft - 19.6 ft, Gray to black, Sulfidic biotite-muscovite-quartz-plagioclase- GNEISS, Joint surfaces moderately rough. Moderately hard, Fresh to very slightly weathered, Fair rock, NX, RMR = 41								
		Hole stopped @ 19.6 ft								
25		Remarks: Hole collapsed at 9.8 ft.								
30										
35										

Notes:
1. Stratification lines represent approximate boundary between material types. Transition may be gradual.
2. N Values have not been corrected for hammer energy. C_E is the hammer energy correction factor.
3. Water level readings have been made at times and under conditions stated. Fluctuations may occur due to other factors than those present at the time measurements were made.

BORING LOG LONDONDERRY ER P23-1(228).GPJ VERMONT AOT.GDT 5/2/25

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BORING LOG

Londonderry
ER P23-1(228)
VT 100

Boring No.: **B-105**
Page No.: 1 of 1
Pin No.: 23b831
Checked By: END

Boring Crew: Thurston, McGinley, Lubas, Degener
Date Started: 4/17/25 Date Finished: 4/22/25
VTSPG NAD83: N 253392.95 ft E 1556091.23 ft
Station: 105+56 Offset: 16.3 LT
Ground Elevation: 1051.4 ft

	Casing	Sampler
Type:	WB	SS
I.D.:	4 in	1.5 in
Hammer Wt:	N.A.	140 lb.
Hammer Fall:	N.A.	30 in.
Hammer/Rod Type:	Auto/AWJ	
Rig:	Diedrich 25	C_F = 1.45

Groundwater Observations

Date	Depth (ft)	Notes
04/22/25	12.1	WT After Drilling

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Run (Dip deg.)	Core Rec. % (RQD %)	Drill Rate minutes/ft	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %
		Roller cone, 3.0 ft - 5.0 ft								
5		Cleanout barrel, 5.0 ft - 7.0 ft								
		Roller cone, 8.0 ft - 10.0 ft								
10										
		Cleanout barrel, 12.0 ft - 14.0 ft								
15										
		Cleanout barrel, 16.0 ft - 18.0 ft								
20										
		22.0 ft - 25.0 ft, Gray to black, Sulfidic biotite-muscovite-quartz-plagioclase- GNEISS, Rust staining and brown discoloration along joints and on core. Joint surfaces moderately rough. Moderately hard to hard, Slightly weathered, Fair rock, NX, RMR = 42	R1 (6)	57 (0)	1.3 9.75 3	Top of Bedrock @ 22.0 ft				
25		25.0 ft - 29.0 ft, Gray to black, Sulfidic biotite-muscovite-quartz-plagioclase- GNEISS, Some rusty brown staining / brown discoloration along some joints. Joint surfaces moderately rough. Moderately hard, Fresh to very slightly weathered, Good rock, NX, RMR = 62	R2 (30-35)	98 (88)	3.5 3.25 4 3.75					
		Hole stopped @ 29.0 ft								
30		Remarks: Hole collapsed at 19.2 ft.								
35										

Notes:
1. Stratification lines represent approximate boundary between material types. Transition may be gradual.
2. N Values have not been corrected for hammer energy. C_E is the hammer energy correction factor.
3. Water level readings have been made at times and under conditions stated. Fluctuations may occur due to other factors than those present at the time measurements were made.

BORING LOG LONDONDERRY ER P23-1(228).GPJ VERMONT AOT.GDT 5/2/25

STATE OF VERMONT
AGENCY OF TRANSPORTATION
CONSTRUCTION AND
MATERIALS BUREAU
CENTRAL LABORATORY

BORING LOG

Londonderry
ER P23-1(228)
VT 100

Boring No.: **B-106**
Page No.: 1 of 1
Pin No.: 23b831
Checked By: END

Boring Crew: Thurston, Lubas, McGinley, Degener
Date Started: 4/17/25 Date Finished: 4/17/25
VTSPG NAD83: N 253396.00 ft E 1556113.00 ft
Station: 105+61 Offset: 5.3 RT
Ground Elevation: 1052.8 ft

	Casing	Sampler
Type:	WB	SS
I.D.:	4 in	1.5 in
Hammer Wt:	N.A.	140 lb.
Hammer Fall:	N.A.	30 in.
Hammer/Rod Type:		Auto/AWJ
Rig:	Diedrich 25	C_F = 1.45

Groundwater Observations

Date	Depth (ft)	Notes

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Run (Dip deg.)	Core Rec. % (RQD %)	Drill Rate minutes/ft	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %
5										
		Cleanout barrel, 6.0 ft - 8.0 ft								
		Roller cone, 8.0 ft - 10.0 ft								
10										
		11.0 ft - 16.0 ft, Gray to black, Sulfidic biotite-muscovite-quartz-plagioclase- GNEISS, Some rusty orange staining along joints, tan and brown discoloration along some joints. Joint surfaces moderately rough. Moderately hard, Fresh to moderately weathered, Fair rock, NX, RMR = 44	R1 (20)	62 (15)	1.6 2.5 3.9 6.3 8.5	Top of Bedrock @ 11.0 ft				
15		Hole stopped @ 16.0 ft								
20										
25										
30										
35										

Notes:
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BORING LOG LONDONDERRY ER P23-1(228).GPJ VERMONT AOT.GDT 5/2/25

AGENCY OF TRANSPORTATION **OFFICE MEMORANDUM**

To: Mahendra Thilliyar, P.E., Structures Project Manager

END

From: Eric Denardo, P.E., Geotechnical Engineer

Date: March 11, 2025

Subject: Londonderry ER P23-1(228) – Geotechnical Data Report

1.0 INTRODUCTION

As requested, we have completed our geotechnical and geological subsurface investigation for the proposed replacement of the culvert located at Mile Marker 3.17 on VT Route 100 over an unnamed tributary of the West River in Londonderry, Vermont. The culvert is located approximately 470 feet north of the intersection of VT 100 and TH-55(Cresent St.). The borings were completed to determine the soil strata and depth to bedrock to aid in design of a replacement structure. Contained herein are the results of our field sampling and testing, laboratory analyses of soil and rock samples, as well as attached boring logs.

2.0 FIELD INVESTIGATION

The field investigation was conducted between December 2, and December 4, 2024. Two standard penetration borings were drilled to evaluate the subsurface profile to aid in the design and construction of the replacement structure. Boring locations were provided by Mahendra Thilliyar as part of the Geotechnical Request Form dated June 20, 2024, and the locations were identified at the site by members of the VTrans Drill Unit and Geotechnical Engineering Section using the Geotechnical Section's handheld TrimbleTDC600 and Trimble Da2 receiver with submeter accuracy. A summary of the boring locations can be found in Table 2.1 as well as on the attached Boring Location Plan.

The values for the Northings and Eastings are based on the Vermont State Plane Grid Coordinate System NAD 83. The elevations for the borings, based on the North American Vertical Datum, NAVD 88, were estimated using the design file 'z23b831sv.dgn', dated July 2024. The locations of the borings should be considered accurate only to the degree implied by the method used to determine them.

Table 2.1: Boring Locations and Elevations

Boring	Station	Offset (ft)	Northing (ft)	Easting (ft)	Elevation (ft)	Approximate Bedrock Elevation (ft)
B-101	105+33	-20.0	253371.3	1556085.2	1050.9	1021.4
B-102	105+73	10.0	253408.1	1556118.2	1053.2	1044.2

The borings were performed in general accordance with AASHTO T206, *Standard Method of Test for Penetration Test and Split-Barrel Sampling of Soils.* During drilling operations for boring B-101 split spoon samples and standard penetration tests (SPT) were taken at 5-foot(ft) intervals to a depth of 10 ft below ground surface (bgs), then continuously until bedrock was encountered at a

depth of 29.5 ft bgs. For B-102, split spoon samples and SPTs were taken at 5 ft intervals until bedrock was encountered at a depth of 9 ft bgs. When refusal was encountered during drilling operations for B-102, 5 ft core runs were taken to recover 10 ft of NX rock cores to confirm the presence of bedrock. Due to the similarity of the rock recovered, only 5 ft of core was drilled in B-101.

During drilling operations, soil samples were visually identified in the field and SPT blow counts were recorded on the boring logs when applicable. Soil samples were preserved and returned to the VTrans Construction and Materials Bureau Laboratory for testing and further evaluation. Upon completion of the laboratory testing, the borings logs were revised to reflect the results of the laboratory classification analysis. The attached boring logs display the types of soil strata encountered and include the laboratory test data, SPT data, and any pertinent observations made by the Drilling Crew.

Details of the bedrock coring were recorded on the boring logs. Cores were then placed in core boxes and returned to the VTrans Construction and Materials Bureau Laboratory for further evaluation and testing, where applicable. The boring logs were revised to reflect the classification and description of the bedrock.

3.0 FIELD AND LABORATORY TESTS

The standard penetration resistance of the in-situ soil is calculated as the number of blows required to drive a 2-inch (in) outside diameter (OD) split-barrel sampler 24 inches into the soil by a 140-pound hammer dropped from a height of 30 in, in accordance with procedures specified in AASHTO T206. The number of blows required to drive the sampler each 6 in increment is recorded and the Standard Penetration Resistance (N-Value) is calculated as the sum of the blows over the second and third 6-in intervals.

The SPT N-value is commonly used with established correlations to estimate several soil parameters, particularly the shear strength and density of cohesionless soils. The N-values provided on the boring logs are raw values and have not been corrected for energy, borehole diameter, rod length, or overburden pressure. VTrans has determined a hammer correction value, C_E, to account for the efficiency of the SPT hammers on its drill rigs. For the borings, a trailer mounted CME 45 skid rig was used with a C_E value of 1.56. This value, included on the boring logs, should be used in calculations to estimate soil parameters.

Geotechnical laboratory tests were performed to assist with soil classification and evaluate engineering properties of the soil. Grain size analyses were performed on select representative soil samples in accordance with AASHTO T 88, *Standard Method of Test for Particle Size Analysis of Soils*.

A detailed description of the rock cores is presented on the boring logs including run length, drill times, recovery, and Rock Quality Designation (RQD). Recovery is defined as the length of core obtained expressed as a percentage of the total length cored. In accordance with ASTM D6032, *Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core*, RQD is the total length of core pieces, 4 inches or greater in length, expressed as a percentage of the total length cored. RQD provides an indication of the integrity of the rock mass and relative extent of seams, jointing and bending planes. The Rock Mass Rating (RMR) is also included on the logs.

RMR is AASHTO's (LRFD Bridge Design Specification) recommended method of classifying rock and is based on five different parameters that all have relative ratings which combine to form the RMR. These parameters include rock strength, RQD, joint spacing, joint condition, and groundwater (AASHTO Section 10.4.6.4).

4.0 SOIL PROFILE

Review of the laboratory data, field testing, and boring logs revealed the following information pertaining to the soil strata. It should be noted that groundwater elevations are subject to change. Because groundwater elevations can fluctuate seasonally and are affected by temperature and precipitation, groundwater may be encountered during construction when not previously noted in the logs.

B-101: The ground surface elevation at B-101 is approximately 1050.9 ft. Groundwater was not measured during drilling operations on December 2 nor December 3, 2024.

Table 4.1: B-101 Soil Strata

Depth (Below Ground Surface Elevation)	Soil Profile
0 – 18 ft	Dense SAND and Gravel, some to little Silt
18 – 29.5 ft	Very Dense GRAVEL and Sand, some Silt*
>29.5 ft	Bedrock (GNEISS)

**Cobbles noted at depths from 9.5-14.5 ft bgs*

B-102: The ground surface elevation at B-102 is approximately 1053.2 ft. Groundwater was not measured during drilling operations on December 2, 2024.

Table 4.2: B-102 Soil Strata

Depth (Below Ground Surface Elevation)	Soil Profile
0 – 0.8 ft	Asphalt Pavement
0.8 – 9 ft	Medium Dense SAND, trace Gravel, trace Silt
>9 ft	Bedrock (GNEISS)

4.1 Rock Parameters

A summary of the rock core findings are listed in Table 4.3 as well as available in the attached boring logs. Information from the cores indicated moderately hard to hard Gneiss to be present at the boring locations. The bedrock had an average rock mass rating (RMR) of 59, indicating good rock.

Table 4.3: Rock Core Sample Results

Run Number	Core Size	Depth (ft)	Recovery (%)	RQD (%)	Dip (deg)	Lithologic Description	RMR
B-101, C-1	NX	29.5-34.5	98	51	50	Gray to Black Sulfidic Biotite-Muscovite-Quartz-Plagioclase-GNEISS Gneissic layering / foliatation, joint surfaces rough. Moderately hard and slightly weathered.	61
B-102, C-1	NX	9-14	96	36	60	Gray to Black Sulfidic Biotite-Muscovite-Quartz-Plagioclase-GNEISS. Gneissic layering / foliatation, joint surfaces rough. Hard and slightly weathered.	57
B-102, C-2	NX	14-19	94	39	60	Gray to Black Sulfidic Biotite-Muscovite-Quartz-Plagioclase-GNEISS. Gneissic layering / foliatation, joint surfaces rough. Moderately hard and slightly weathered.	61

5.0 CONCLUSION

If you have any questions, or you would like to discuss this report, please contact us via email. Please let us know when more information is available for assistance with foundation analyses and design. Typed boring logs are attached and are available in the CADD design files: M:\Projects\23b831\MaterialsResearch

Attachments: Boring Layout
Boring Logs (3 pages)

Reviewed by: August Arles, Geotechnical Engineer AJA

cc: Read File/MG
Project File/CEE
END

Z:\Highways\CMB\GeotechEngineering\Projects\Londonderry ER P23-1(228)\REPORTS\Londonderry ER P23-1(228) Geotechnical Data Report.docx

SOIL CLASSIFICATION

AASHTO	
A1	Gravel and Sand
A3	Fine Sand
A2	Silty or Clayey Gravel and Sand
A4	Silty Soil - Low Compressibility
A5	Silty Soil - Highly Compressible
A6	Clayey Soil - Low Compressibility
A7	Clayey Soil - Highly Compressible

ROCK QUALITY DESIGNATION

R.Q.D. (%)	ROCK DESCRIPTION
<25	Very Poor
25 to 50	Poor
51 to 75	Fair
76 to 90	Good
>90	Excellent

SHEAR STRENGTH

UNDRAINED SHEAR STRENGTH IN P.S.F.	CONSISTENCY
<250	Very Soft
250-500	Soft
500-1000	Med. Stiff
1000-2000	Stiff
2000-4000	Very Stiff
>4000	Hard

CORRELATION GUIDE OF "N" TO DENSITY/CONSISTENCY

DENSITY (GRANULAR SOILS)		CONSISTENCY (COHESIVE SOILS)	
N	DESCRIPTIVE TERM	N	DESCRIPTIVE TERM
<5	Very Loose	<2	Very Soft
5-10	Loose	2-4	Soft
11-24	Med. Dense	5-8	Med. Stiff
25-50	Dense	9-15	Stiff
>50	Very Dense	16-30	Very Stiff
		31-60	Hard
		>60	Very Hard

COMMONLY USED SYMBOLS

▼	Water Elevation
⊗	Standard Penetration Boring
⊕	Auger Boring
⊙	Rod Sounding
S	Sample
N	Standard Penetration Test Blow Count Per Foot For: 2" O.D. Sampler 1 3/8" I.D. Sampler Hammer Weight Of 140 Lbs. Hammer Fall Of 30"
VS	Field Vane Shear Test
US	Undisturbed Soil Sample
B	Blast
DC	Diamond Core
MD	Mud Drill
WA	Wash Ahead
HSA	Hollow Stem Auger
AX	Core Size 1 1/8"
BX	Core Size 1 5/8"
NX	Core Size 2 1/8"
M	Double Tube Core Barrel Used
LL	Liquid Limit
PL	Plastic Limit
PI	Plasticity Index
NP	Non Plastic
w	Moisture Content (Dry Wgt. Basis)
D	Dry
M	Moist
MTW	Moist To Wet
W	Wet
Sat	Saturated
Bo	Boulder
Gr	Gravel
Sa	Sand
Si	Silt
Cl	Clay
HP	Hardpan
Le	Ledge
NLTD	No Ledge To Depth
CNPF	Can Not Penetrate Further
TLOB	Top of Ledge Or Boulder
NR	No Recovery
Rec.	Recovery
%Rec.	Percent Recovery
ROD	Rock Quality Designation
CBR	California Bearing Ratio
<	Less Than
>	Greater Than
R	Refusal (N > 100)
VTSPG	NAD83 - See Note 7

COLOR

blk	Black	pnk	Pink
bl	Blue	pu	Purple
brn	Brown	rd	Red
dk	Dark	tn	Tan
gry	Gray	wh	White
gn	Green	yel	Yellow
lt	Light	mltc	Multicolored
or	Orange		

DEFINITIONS (AASHTO)

BEDROCK (LEDGE) - Rock in its native location of indefinite thickness.

BOULDER - A rock fragment with an average dimension > 12 inches.

COBBLE - Rock fragments with an average dimension between 3 and 12 inches.

GRAVEL - Rounded particles of rock < 3" and > 0.0787" ("10 sieve).

SAND - Particles of rock < 0.0787" ("10 sieve) and > 0.0029" ("200 sieve).

SILT - Soil < 0.0029" ("200 sieve), non or slightly plastic and exhibits no strength when air-dried.

CLAY - Fine grained soil, exhibits plasticity when moist and considerable strength when air-dried.

VARVED - Alternate layers of silt and clay.

HARDPAN - Extremely dense soil, cemented layer, not softened when wet.

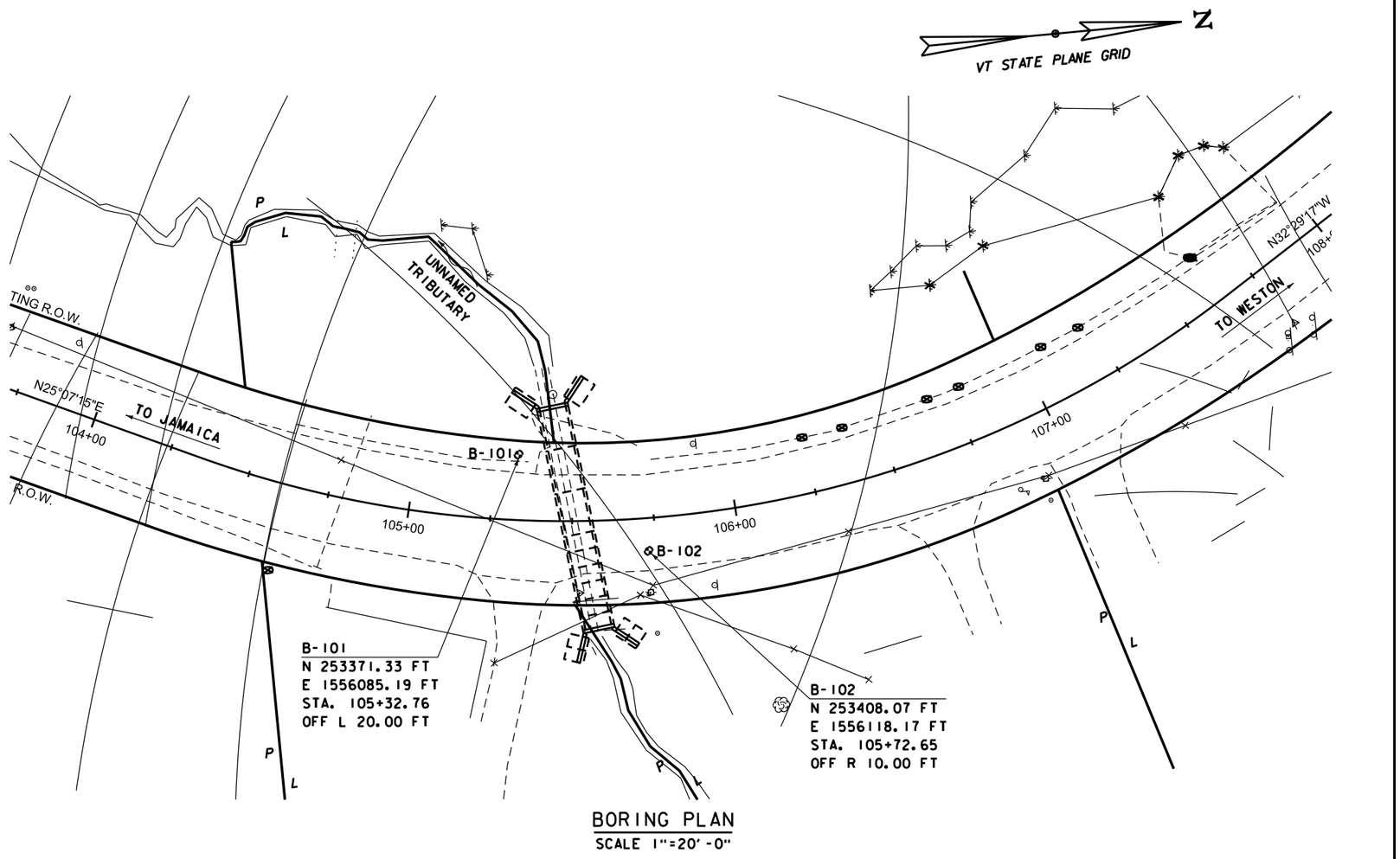
MUCK - Soft organic soil (containing > 10% organic material.

MOISTURE CONTENT - Weight of water divided by dry weight of soil.

FLOWING SAND - Granular soil so saturated (loose) that it flows into drill casing during extraction of wash rod.

STRIKE - Angle from magnetic north to line of intersection of bed with a horizontal plane.

DIP - Inclination of bed with a horizontal plane.



BORING PLAN

SCALE 1"=20'-0"

BORING LOCATIONS

BORING	NORTHING	EASTING	STATION	OFFSET	GROUND ELEV.	BEDROCK ELEV.
B-101	253371.3	1556085.2	105+33	-20.0	1050.9	1021.4
B-102	253408.1	1556118.2	105+73	10.0	1053.2	1044.2

GENERAL NOTES

1. The subsurface explorations shown herein were made between 12/02/2024 and 12/04/2024 by the Agency.
2. Soil and rock classifications, properties and descriptions are based on engineering interpretation from available subsurface information by the Agency and may not necessarily reflect actual variations in subsurface conditions that may be encountered between individual boring or sample locations.
3. Observed water levels and/or conditions indicated are as recorded at the time of exploration and may vary according to the prevailing rainfall, methods of exploration and other factors.
4. Engineering judgment was exercised in preparing the subsurface information presented herein. Analysis and interpretation of subsurface data was performed and interpreted for Agency design and estimating purposes. Presentation of the information in the Contract is intended to provide the Contractor access to the same data available to the Agency. The subsurface information is presented in good faith and is not intended as a substitute for personal investigation, independent interpretation, independent analysis or judgment by the Contractor.
5. Pictorial structure details shown on the boring plan layout or soils profile are for illustrative purposes only and may not accurately portray final contract details.
6. Terminology used on boring logs to describe the hardness, degree of weathering, and spacing of fractures, joints and other discontinuities in the bedrock is defined in the AASHTO Manual on Subsurface Investigations, 1988.
7. Northing and Easting coordinates are shown in Vermont State Plane Grid North American Datum 1983 in meters and survey feet.

PROJECT NAME: LONDONDERRY
PROJECT NUMBER: ER P23-1(228)

FILE NAME: $FILES$ | PLOT DATE: $$$$DATE$$$
PROJECT LEADER: LEAD | DRAWN BY: C.BURNER
DESIGNED BY: C.BURNER | CHECKED BY: BR CHECK
BORING LAYOUT SHEET | SHEET $S"$ OF $T"$

STATE OF VERMONT
AGENCY OF TRANSPORTATION
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BORING LOG

Londonderry
ER P23-1(228)
VT 100

Boring No.: **B-101**
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Pin No.: 23b831
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VTSPG NAD83: N 253371.33 ft E 1556085.19 ft
Station: 105+32.76 Offset: L 20.00 FT
Ground Elevation: 1050.9 ft

	Casing	Sampler
Type:	WB	SS
I.D.:	4 in	1.5 in
Hammer Wt:	N.A.	140 lb.
Hammer Fall:	N.A.	30 in.
Hammer/Rod Type:		Auto/AWJ
Rig:	CME 45C SKID	C_F = 1.56

Groundwater Observations

Date	Depth (ft)	Notes

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Run (Dip deg.)	Core Rec. % (RQD %)	Drill Rate minutes/ft	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %
		Field Description, Top soil into SAND and Gravel, brn, Wet, Rec. = 0.65 ft, Frozen				2-4-10-5 (14)				
2.5										
5.0		A-1-b, Lab Clssification: GRAVEL and SAND, little Silt, brn, Wet, Rec. = 0.85 ft				13-14-13-15 (27)	9.8	45.4	40.2	14.4
7.5										
10.0		Field Description, Refusal @ 9.5' w/ Roller Rock. Cored 9.5'-14.5'. Nested Cobbles. No Recovery								
12.5										
15.0		A-1-b, Lab Classification: SAND some Gravel, little Silt, brn, Wet, Rec. = 1.0 ft				3-3-6-8 (9)	14.7	30.8	57.1	12.1
		A-2-4, Lab Classification: SAND, little Silt, little Gravel, brn, Wet, Rec. = 0.4 ft				6-6-5-8 (11)	16.0	17.9	61.8	20.3
17.5										

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Groundwater Observations

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20.0		A-1-b, Lab Classification: GRAVEL and SAND, some Silt, brn, Wet, Rec. = 1.0 ft				15-19-35-26 (54)	20.1	42.1	35.8	22.1
22.5		A-1-b, Lab Classiification: GRAVEL and SAND, little Silt, brn, Wet, Rec. = 1.1 ft				13-16-18-18 (34)	9.8	43.7	36.9	19.4
		A-2-4, Lab Classification: SAND some Gravel, little Silt, brn, Wet, Rec. = 0.85 ft				9-14-16-14 (30)	12.7	31.4	41.2	27.4
25.0		A-2-4, Lab Classification: GRAVEL and SAND, some Silt Refusal @ 25.9', brn, Wet				12-R@5" (R)	12.0	37.7	36.0	26.3
		Field Description, Auger to 28'								
27.5		A-1-a, Lab Classification: GRAVEL trace SAND, trace Silt Refusal @ 28.4', brn, Wet, Rec. = 0.2 ft				R@5" (R)	1.5	83.2	8.7	8.1
30.0		29.5 ft - 34.5 ft, Gray to black, Sulfidic biotite-muscovite-quartz-plagioclase GNEISS, Gneissic layering / foliatation, joint surfaces rough. Moderately hard, Slightly weathered, Good rock, NX, RMR = 61	C1 (50-70)	98 (51)	1.2 1.5 1.25 1.2 4.75					
32.5										
		Hole stopped @ 34.5 ft								
35.0										
37.5										

Notes:
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BORING LOG

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VT 100

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Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Run (Dip deg.)	Core Rec. % (RQD %)	Drill Rate minutes/ft	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %
		Field Description, Asphalt 0.0 ft - 0.8 ft								
		Pounded Casing to 5', 0.8 ft - 5.0 ft, Wash out barrel used inside casing								
2.5										
5.0		A-1-b, Lab Classification: SAND, trace Gravel, trace Silt, brn, Wet, Rec. = 0.6 ft				5-9-8-6 (17)	18.4	7.5	88.0	4.5
		Roller Rock unitl Refusal @ 9', 7.0 ft - 9.0 ft								
7.5										
		9.0 ft - 14.0 ft, Gray to black, Sulfidic biotite-muscovite-quartz-plagioclase GNEISS, Gneissic layering / foliation, joint surfaces rough with signs of oxidation. Band of coarse, predominately K-Feldspar Gneiss from 9ft to 10.8ft.. Hard, Slightly weathered, Fair rock, NX, Magnetic, RMR = 57	C1 (60-70)	96 (36)	4.5 2 2 2 2.3					
10.0										
12.5										
		14.0 ft - 19.0 ft, Gray to black, Sulfidic biotite-muscovite-quartz-plagioclase GNEISS, Gneissic layering / foliatation, joint surfaces rough.. Moderately hard, Slightly weathered, Good rock, NX, RMR = 61	C2 (60-70)	94 (39)	1.5 1.25 1.25 1.5 2					
15.0										
17.5										
		Hole stopped @ 19.0 ft								
20.0										

Notes:
1. Stratification lines represent approximate boundary between material types. Transition may be gradual.
2. N Values have not been corrected for hammer energy. C_E is the hammer energy correction factor.
3. Water level readings have been made at times and under conditions stated. Fluctuations may occur due to other factors than those present at the time measurements were made.

BORING LOG LONDONDERRY ER P23-1(228).GPJ VERMONT AOT.GDT 3/10/25

TECHNICAL MEMORANDUM

DATE September 9, 2025 **Project No.** 31405712.6625

TO Callie Ewald, PE
Vermont Agency of Transportation

CC

FROM Melissa E. Landon, PhD, PE **EMAIL melissa.landon@wsp.com**

SUMMARY OF GEOPHYSICAL BEDROCK SURFACE INVESTIGATION
CULVERT REPLACEMENT ON VT 100 AT MM 3.17, LONDONDERRY, VT
LONDONDERRY ER P23-1(228)

INTRODUCTION

WSP USA, Inc., (WSP) is pleased to submit this Technical Memorandum to the Vermont Agency of Transportation (VTrans) to summarize the geophysical investigation performed to identifying bedrock variability at the proposed culvert for replacement of a culvert carrying an unnamed tributary of the West River under Vermont Route (RT) 100 at Mile Marker (MM) 3.17 in Londonderry, Vermont. This memorandum summarizes the results of the geotechnical investigation of the bedrock surface from the Geotechnical Data Report[1] and Supplemental Subsurface Investigation Memorandum[2] provided to us by VTrans and the scope of work we developed following review of the Work Order Request[3]. This memorandum constitutes the completion of our proposed scope of work from our proposal submitted[4] to VTrans on May 21, 2025, and subsequent work authorization #WA00037 budget adjustment dated May 27, 2025, under our On-Call Geotechnical Services Agreement with VTrans (Contract No. PS0836) dated November 1, 2020.

BEDROCK ELEVATIONS FROM GEOTECHNICAL BORINGS

The Report[1] and Memo[2] provide bedrock depths at six (6) locations. The borings indicate that bedrock is located at 34.5 feet bgs (EL. 1021.4 feet), 22.0 feet bgs (EL. 1030.3 feet), and 22.0 feet bgs (EL. 1029.4 feet) at B-101, B-103, and B-105, respectively on the RT 100 southbound side of the project and 9 feet bgs (EL. 1044.2 feet), 14.2 feet bgs (EL. 1038.9 feet), and 11.0 feet bgs (EL. 1041.8 feet) at B-102, B-104, and B-106, respectively on the RT 100 northbound side of the project. The soils encountered in B-101 and B-102 consist of gravel and sand and sand with little to some gravel and silt. Cobbles were also identified and the SPT sampler was met with refusal several times. Figure 1 (attached) illustrates the locations of the borings at the site.

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[1] Denardo, Eric. to Thilliyar, M, Memorandum, March 11, 2025, "Londonderry ER P23-1(228) – Geotechnical Data Report", 8 pp.

[2] Denardo, Eric. to Thilliyar, M, Memorandum, May 7, 2025, "Londonderry ER P23-1(228) – Supplemental Subsurface Investigation", 8 pp.

[3] Work Order Request (WOR) for Geotechnical Engineering Services, Londonderry ER P23-1(228), Dated 5/7/2025, from Callie Ewald, Geotechnical PM.

[4] WSP USA, Inc. Proposal for Geotechnical and Geophysical Services, Culvert Replacement on VT 100 at MM 3.17, Londonderry, VT, Londonderry ER P23-1(228), submitted May 21, 2025.

GEOLOGIC SETTING

Regional Surficial Geology

Overburden geology[5] of the Londonderry area consists of glacial and glaciolacustrine deposits. These deposits are comprised of glacial till, glacial outwash, and areas of alluvium and colluvium. These conditions were observed in the exposed overburden deposits in and along the West River and unnamed tributary at the time of data collection. These surficial deposits overlie the metamorphic bedrock comprised primarily of individual gneissic units. The thickness of the overburden can vary significantly, with deeper deposits found in valleys and thinner layers or exposed bedrock at higher elevations, both found in the area surveyed as part of this investigation.

Regional Bedrock Geology

The bedrock geology[6] of the South Londonderry, Vermont area consists of multiple Middle Proterozoic gneissic units that have undergone some degree of faulting and fracturing. The work area contains more than one of these units with the primary being the Rawsonville trondhjemite of the Mount Holly Complex. Of note is the location of the work area immediately adjacent to a fault zone that has resulted in the degree of bedrock offset observed in the completed borings. These faults act as structural boundaries and influence the localized geologic structure present within the work area. In addition to the offset in bedrock, the faulting will result in areas subjected to fracturing and subsequent weathering of the bedrock.

GEOPHYSICAL INVESTIGATION

Ground-penetrating radar (GPR) was used in an effort to identify the bedrock surface at the proposed abutment locations and evaluate the existing limits of rock excavation. GPR is often used to detect a variety of metallic, non-metallic, natural and manmade targets to include underground utilities, burial plots, disturbed soils, sinkholes, and voids. GPR emits a series of high-frequency, high amplitude EM pulses (radio waves) from a transmitting antenna into the ground. When the EM pulses encounter materials that differ in electrical properties, a portion of the energy is reflected back to a receiving element (antenna) at the surface. These reflections are collected as digital images and fed to a portable computer, which then displays a real-time continuous "picture" or profile of the subsurface that can be used to help pinpoint the location of the subsurface feature.

For greater vertical and lateral resolution, the frequency of the emitted radar wave can be increased. However, greater accuracy and resolution is achieved at the expense of depth of penetration. Depth of penetration is also dependent upon the geologic conditions of the soils in which the investigation is being conducted. The radar waves may be absorbed or scattered depending on the properties of the soil, particularly electrical conductivity. This scattering may also be the result of sharp bedrock boundaries as may be present near faulted or sheared zones. Electrically resistive material such as unsaturated, coarse-grained sediments optimize GPR signal penetration, whereas exploration depths are limited by relatively conductive material such as saturated or fine-grained sediments, clay-rich soils, ash, or reinforced concrete. Based on boring log information provided by VTrans in preparation of the scope of work, it was determined that the overburden materials encountered during drilling would facilitate the use of GPR to further evaluate subsurface bedrock conditions in the work area.

[5] DeSimone, D.J. and Gale, M., 2009, The Surficial Geology and Hydrogeology of Londonderry, Vermont. Vermont Geological Survey.

[6] Ratcliffe, N.M., Stanley, R.S., Gale, M.H., Thompson, P.J., and Walsh, G.J., 2011, Bedrock geologic map of Vermont: U.S. Geological Survey Scientific Investigations Map 3184, 3 sheets, scale 1:100,000.

WSP employed a Geophysical Survey Systems, Inc. (GSSI) 200 MHz HyperStacking (HS) antenna. GPR profiles were positioned along RT 100 (Figure 2, attached) to facilitate the desired depth of investigation and resolution and located based on previously completed borings. GPR depth of signal penetration varied due to subsurface soil conditions, with the average depth being approximately 25 feet with some areas estimated up to 30 feet.

RESULTS

In general, the GPR profiles collected within the survey area were able to further define some of the subsurface bedrock conditions present. As illustrated in Figure 3a (attached), there is discernable topography along the interpreted bedrock surface with only minor variations between the interpreted surface and the depth to bedrock as encountered in the borings. The offset distance of completed borings from the GPR transects as illustrated on Figure 2 and highlighted in Figure 3a and Figure 3b (attached) results in an interpreted bedrock surface that does not match entirely with the depth to bedrock interpreted from the GPR. It is important to note that the correlation of the bedrock surface as encountered in borings and that interpreted from the GPR data will vary based on the distance of the boring from the GPR transect.

Of note is the area located at B-101 along Line 17 (Figure 3a) where a deeper refusal was encountered in the boring at 29.5 feet below ground surface (bgs). We surmise that this boring is located at the edge of a bedrock shelf that has offset to the north adjacent to the culvert and west along the roadway. This information suggests that bedrock has undergone some level of deformation/offset due to the local faults noted on the regional geologic map for the Londonderry area (see inset for Londonderry in Figure 4 below). Due to the location of Line 17 along the western edge of the roadway (Figure 2), the interpreted depth to bedrock is based on the depth to bedrock as encountered in B-101 (located directly on Line 17). The depth to bedrock encountered at B-101 (29.5 feet bgs) is at the estimated limits of the effective depth of GPR signal penetration along this profile. An interpreted depth to bedrock at the intersection of Line 17 with Lines 8, 10, 13, and 16 has been terminated to the eastern half of these transects (Figure 3b) as it is the interpreted edge of the bedrock ledge as discussed above.

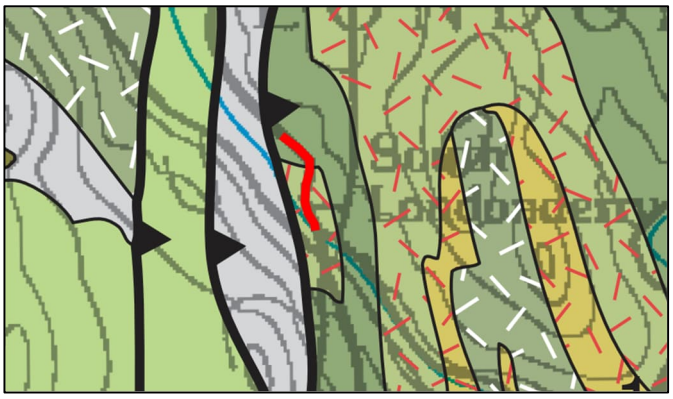


Figure 4. Inset of the bedrock geologic map[6] of the Londonderry area with the work location highlighted in red. Thin black lines indicate geologic contacts with the triangle hachured lined indicating a mapped thrust fault trace.

Bedrock encountered along Line 6 and Line 7 in borings B-102, B-106, and B-104 (Figure 3a) was consistent with the depths interpreted from the GPR data with the bedrock surface having some offset between the north and south sides of the culvert. The offset in bedrock between the north and south sides of the culvert is likely associated with the structural geologic conditions of the area as it is generally parallel to the fault traces present. The interpreted limits of existing excavation and backfill around the culvert is based on a discontinuity in subsurface GPR reflectors (strata) and was in an area of limited signal resulting from the presence of the existing infrastructure (i.e., reinforced concrete and backfill). The vertical accuracy of the GPR data varies with increased depth of the target (i.e., bedrock). It is estimated that the accuracy may be a foot or less where shallower bedrock was encountered (B-102, B-104, and B-106) up to an estimated 3 feet where deeper bedrock/refusal was recorded (B-101, B-103, and B-105).

GPR transects collected west to east across the roadway (Figure 3b) indicate a sharp drop in the bedrock surface based on the interpreted diffraction of the GPR signal. The bedrock surface is interpreted to be generally flat under the roadway in this direction with the western edge of the bedrock surface being sharper and discontinuous. This would be consistent with the path of the river, locations of the faulted areas in the geologic map, and information obtained from the borings (i.e., B-101). These profiles are generally consistent with one another with the area along the east end of each profile (Figure 3b) more indicative of a more laterally continuous bedrock surface.

SUMMARY

The collected and interpreted GPR data were generally consistent with information encountered during drilling; however, some variations in the interpreted bedrock surface exist. This includes the interpreted offset in the bedrock surface north and south of the current culvert and the depth to refusal encountered in B-101. The overburden lithology encountered during drilling is interpreted to be generally consistent with the observed GPR signal with signal penetration consistent with coarser-grained material (i.e., sand); however, several borings are located near the culvert and may be more representative of backfill used in the work area during culvert installation. In addition, overburden lithology is only available for B-101 and B-102 based on the provided exploration reports provided by VTrans. The interpreted bedrock surface was based on the interpreted GPR profile data, boring logs, and observations made in the field at the time of data collection (i.e., bedrock outcrops).

CLOSING AND LIMITATIONS

WSP prepared this Technical Memorandum for the exclusive use of VTrans for specific application to the replacement of a culvert carrying an unnamed tributary of the West River under Vermont Route (RT) 100 at Mile Marker (MM) 3.17 in Londonderry, Vermont. We performed the geophysical site investigation and compiled our interpretations in accordance with generally accepted geology and geophysics practices in this geographical area and under similar time and financial constraints. Our interpretations are based, in part, on information obtained from the referenced field explorations completed at the discrete locations described in the memorandum. Variations in the nature and extent of field conditions between explorations should be expected. WSP makes no other warranty, either express or implied.

WSP appreciates the opportunity to provide our geotechnical services to VTrans for this project. Please contact us if you have any questions.

Sincerely,
WSP USA, Inc.

Christopher F. Buckman, PG, LG
Assistant Vice President Geologist

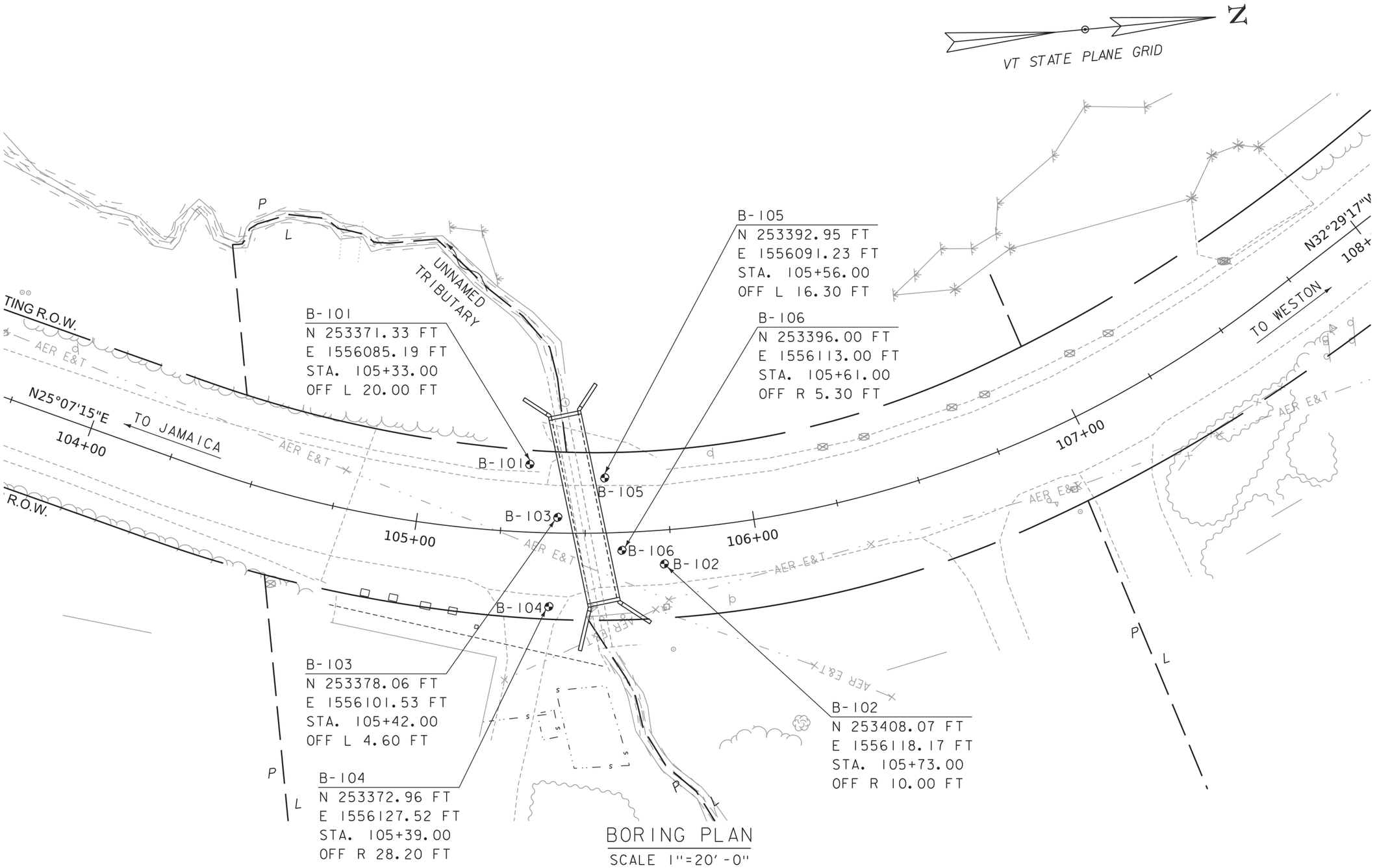
Melissa E. Landon, PhD, PE
Assistant Vice President Geotechnical Engineer

MEL/CFB/JDL

Attachments: Figure 1: Boring Location Plan
Figure 2: Ground Penetrating Radar Survey Lines
Figure 3a: Interpreted GPR Profiles – Selected Examples: North-South Oriented Transects
Figure 3b: Interpreted GPR Profiles – Selected Examples: West-East Oriented Transects

https://wsponlinenam.sharepoint.com/sites/us-vtrans-londonderr/shared documents/600 deliverables/londonderry er p23-1(228) geophysics investigation wsp final memo.docx

Attachments



BORING PLAN

SCALE 1"=20'-0"

BORING LOCATIONS						
BORING	NORTHING	EASTING	STATION	OFFSET	GROUND ELEV.	BEDROCK ELEV.
B-101	253371.33	1556085.19	105+33.00	-20.00	1050.9	1021.4
B-102	253408.07	1556118.17	105+73.00	10.00	1053.2	1044.2
B-103	253378.06	1556101.53	105+42.00	-4.60	1052.3	1030.3

BORING LOCATIONS (CONT.)						
BORING	NORTHING	EASTING	STATION	OFFSET	GROUND ELEV.	BEDROCK ELEV.
B-104	253372.96	1556127.52	105+39.00	28.20	1053.1	1038.9
B-105	253392.95	1556091.23	105+56.00	-16.30	1051.4	1029.4
B-106	253396.00	1556113.00	105+61.00	5.30	1052.8	1041.8

NOTES:

Ground penetrating radar profiles were collected using a GSSI 200HS 200 MHz antenna.

GPR records were processed using RADAN 7 Software.

Site feature locations were recorded using a Juniper Geode differential global positioning system (DGPS).

Map taken from Agency of Transportation Office Memorandum dated May 7, 2025 RE: Londonderry ER P23-1(228).

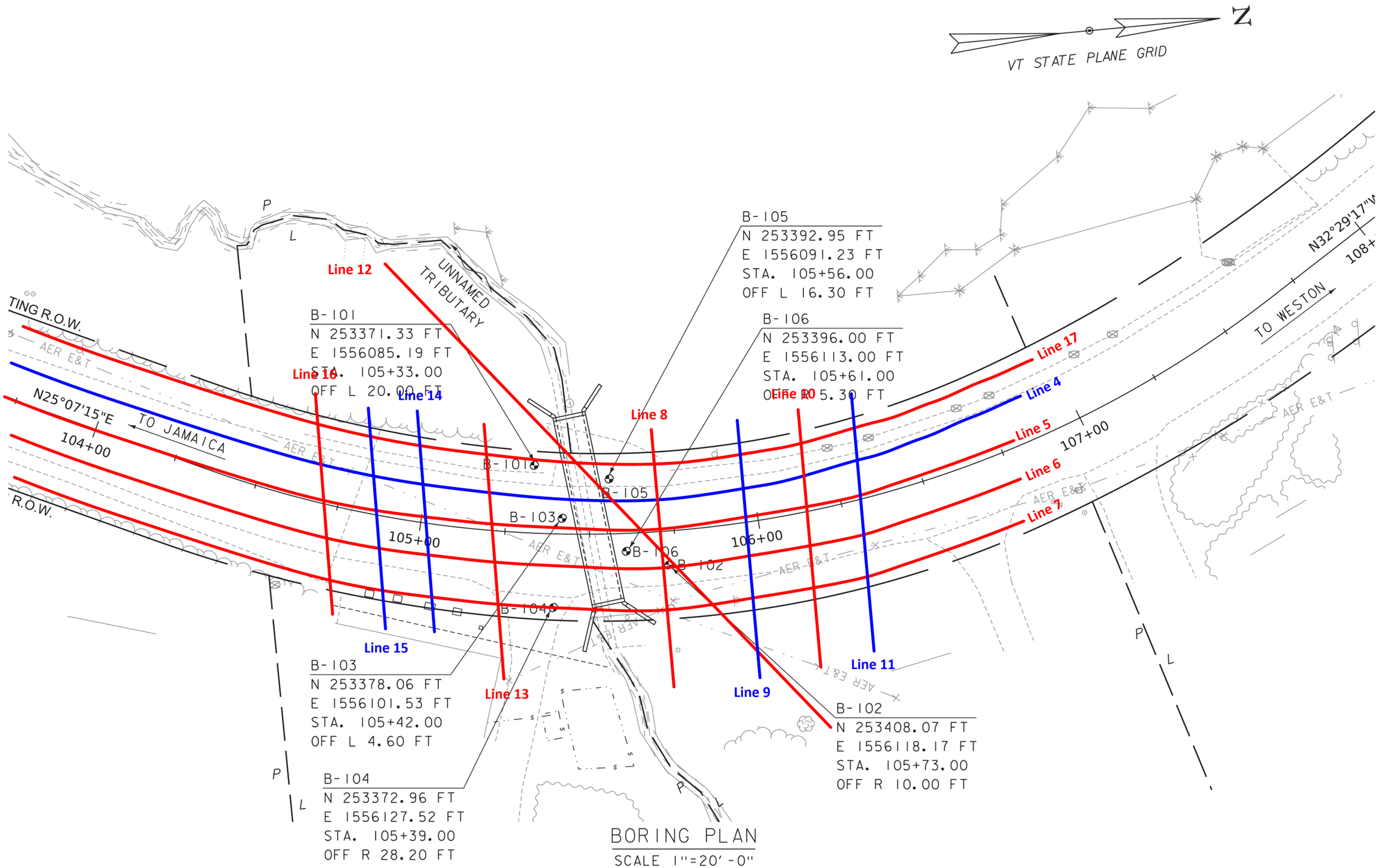
WSP USA Inc.
2 Gannett Drive, Suite 200
Portland, ME 04101

VTrans Working to Get You There
Vermont Agency of Transportation

Boring Layout Site Plan
Bridge VT 100 at Mile Marker 3.17
Londonderry, Vermont
July 2025

SCALE: AS SHOWN
DATE: 09/08/2025
PROJECT NUMBER: 31405712.6625

DRAWING NUMBER:
FIGURE 1
SHEET NUMBER:
1 OF 1



BORING PLAN
SCALE 1"=20'-0"

BORING LOCATIONS						
BORING	NORTHING	EASTING	STATION	OFFSET	GROUND ELEV.	BEDROCK ELEV.
B-101	253371.33	1556085.19	105+33.00	-20.00	1050.9	1021.4
B-102	253408.07	1556118.17	105+73.00	10.00	1053.2	1044.2
B-103	253378.06	1556101.53	105+42.00	-4.60	1052.3	1030.3

BORING LOCATIONS (CONT.)						
BORING	NORTHING	EASTING	STATION	OFFSET	GROUND ELEV.	BEDROCK ELEV.
B-104	253372.96	1556127.52	105+39.00	28.20	1053.1	1038.9
B-105	253392.95	1556091.23	105+56.00	-16.30	1051.4	1029.4
B-106	253396.00	1556113.00	105+61.00	5.30	1052.8	1041.8

/3b)

NOTES:

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Map taken from Agency of Transportation Office Memorandum dated May 7, 2025 RE: Londonderry ER P23-1(228).

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2 Gannett Drive, Square, Suite 200
Portland, ME 04101

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Vermont Agency of Transportation

GPR Profile Layout Plan
Bridge VT 100 at Mile Marker 3.17
Londonderry, Vermont
July 2025

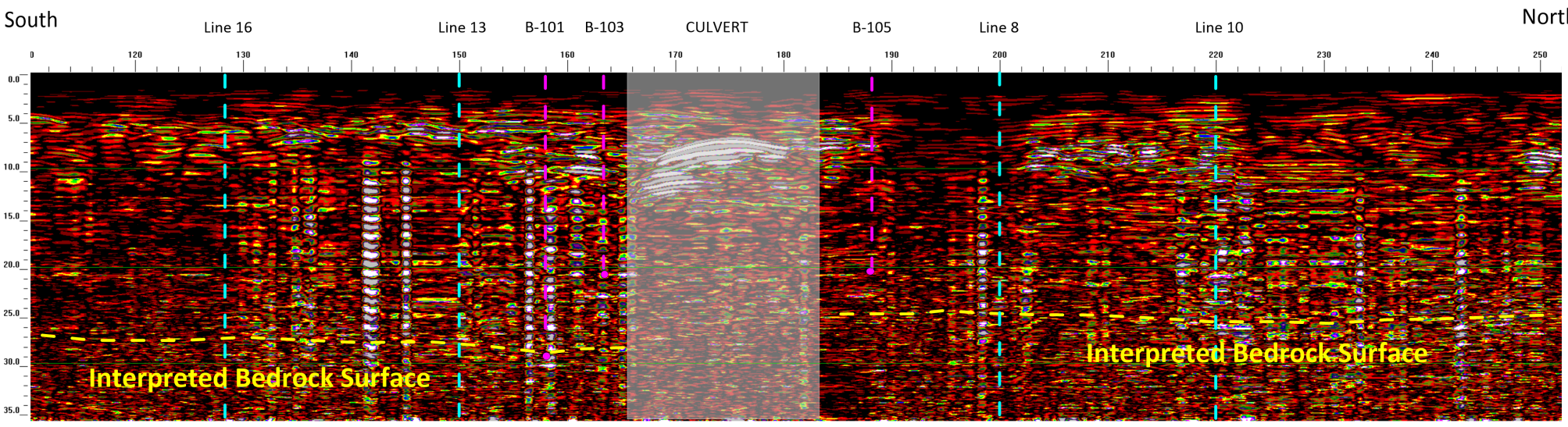
SCALE:	DATE:	PROJECT NUMBER:
AS SHOWN	09/08/2025	31405712.6625

DRAWING NUMBER:

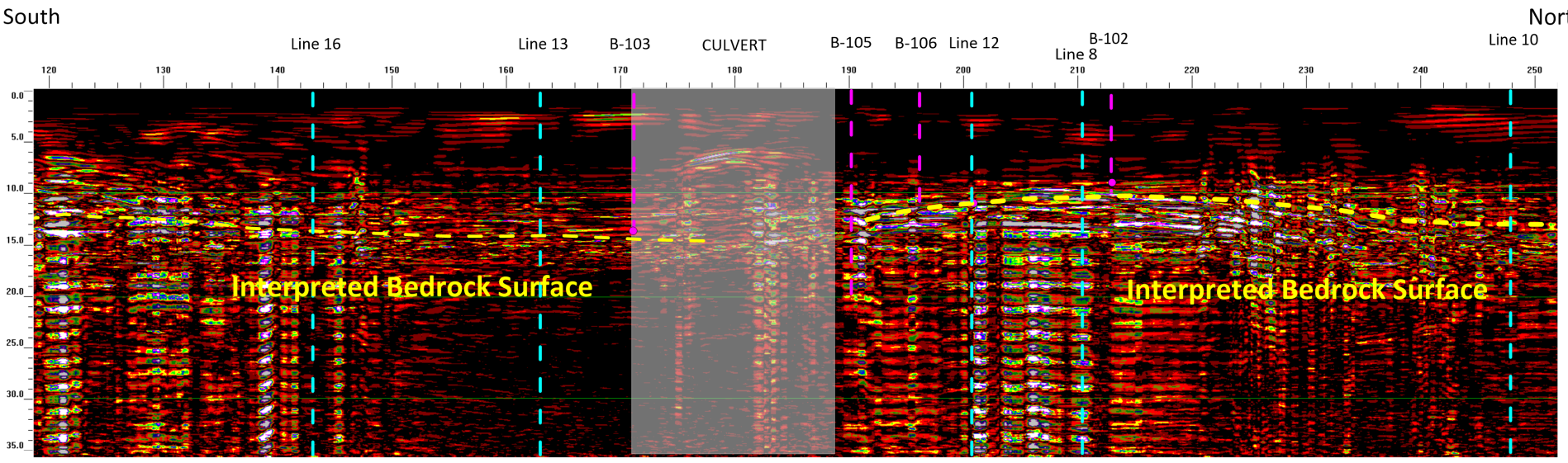
FIGURE 2

SHEET NUMBER:

1 OF 1



Line 17



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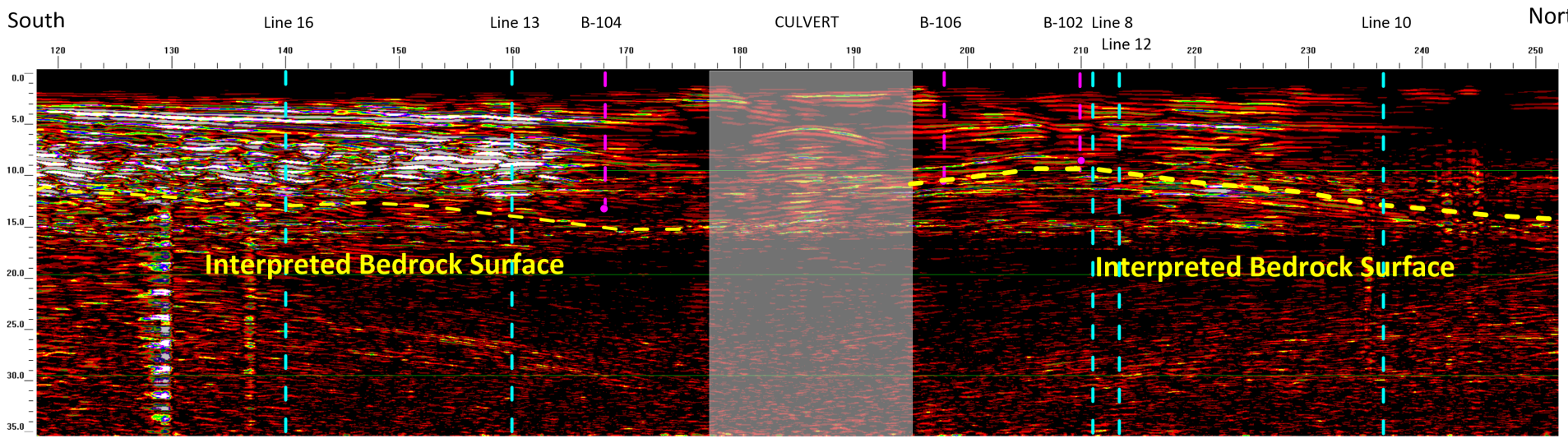
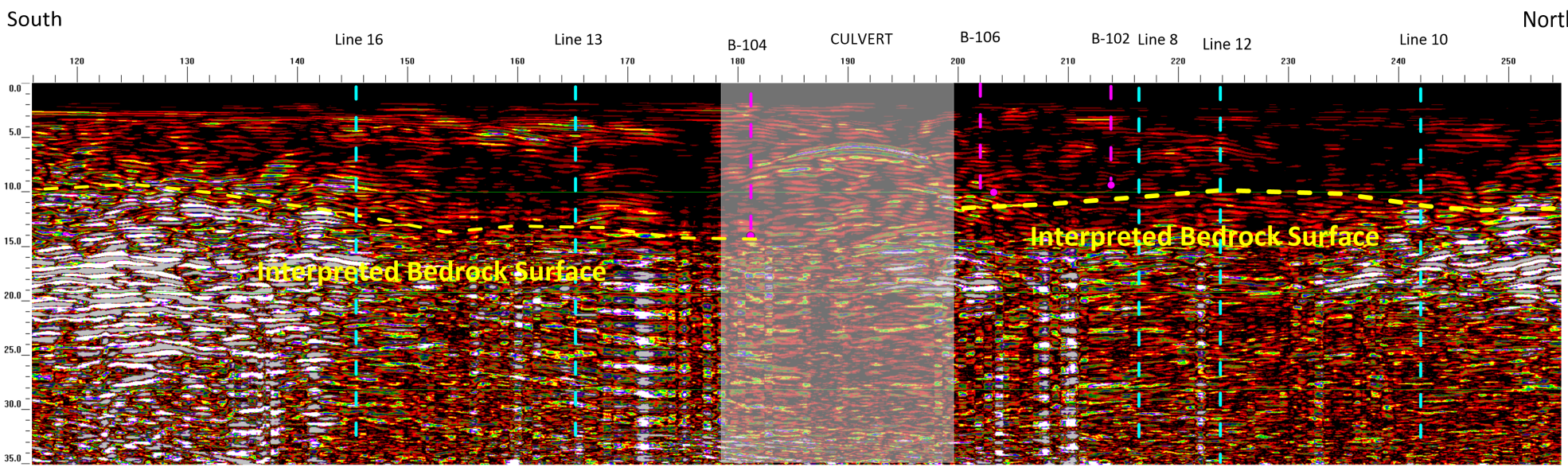


Line 6



Line 7

LEGEND

- Depth to Bedrock/Refusal
- Interpreted Limits of Excavation

FIGURE 3a

SHEET NUMBER: 1 OF 1

DRAWING NUMBER:

Interpreted GPR Profiles: Selected Examples
North-South Oriented Transects
Bridge VT 100 at Mile Marker 3.17
Londonderry, Vermont

SCALE:	DATE:	PROJECT NUMBER:
AS SHOWN	09/08/2025	31405712.6625

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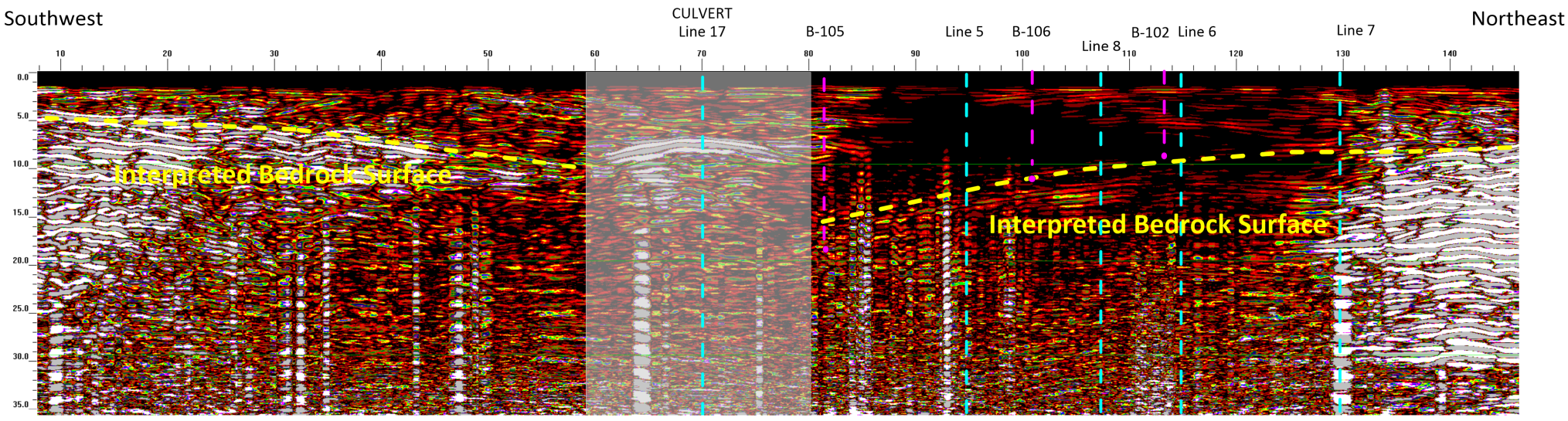
WSP USA Inc.
2 Monument Square, Suite 200
Portland, ME 04101

NOTES:

Ground penetrating radar profiles were collected using a GSSI 200HS 200 MHz antenna.

GPR records were processed using RADAN 7 Software.

Site feature locations were recorded using a Juniper Geode differential global positioning system (DGPS).



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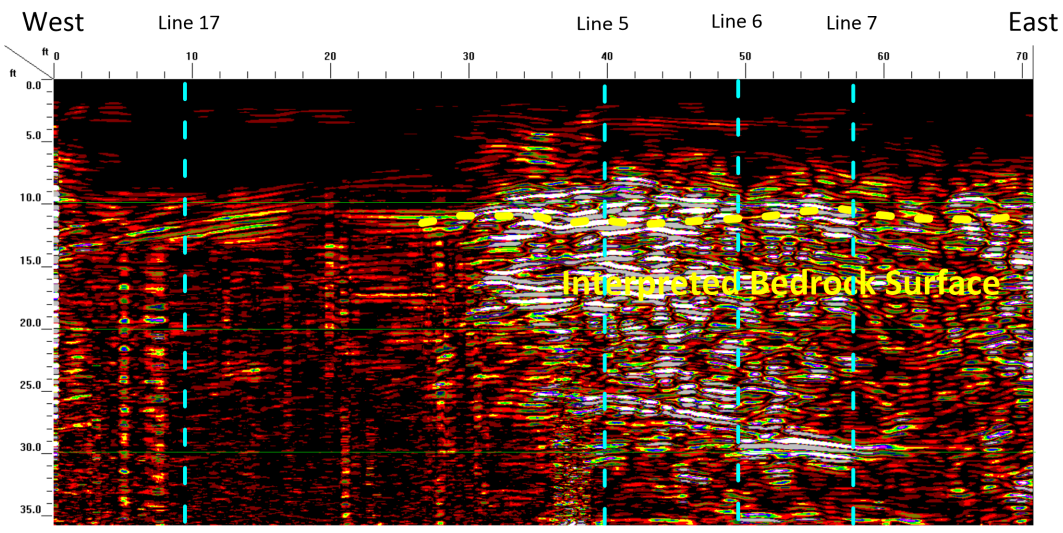

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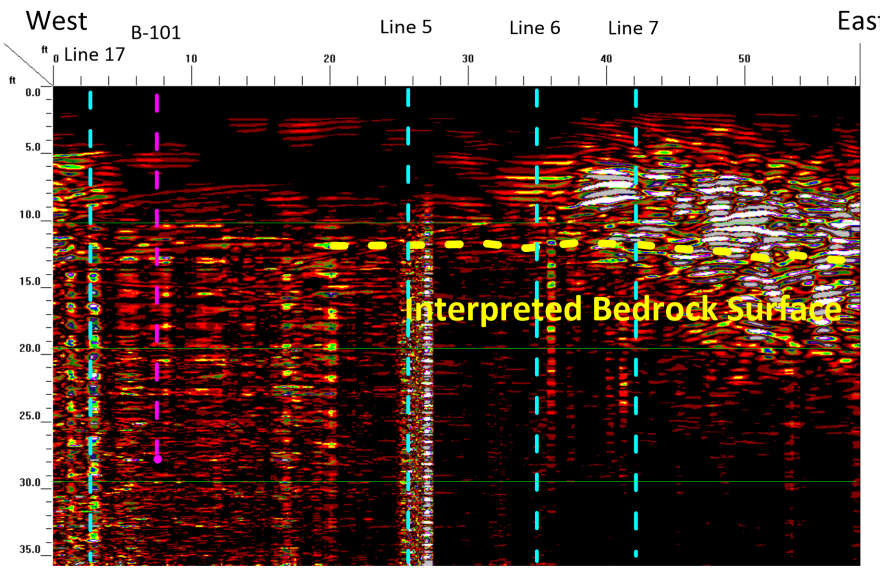

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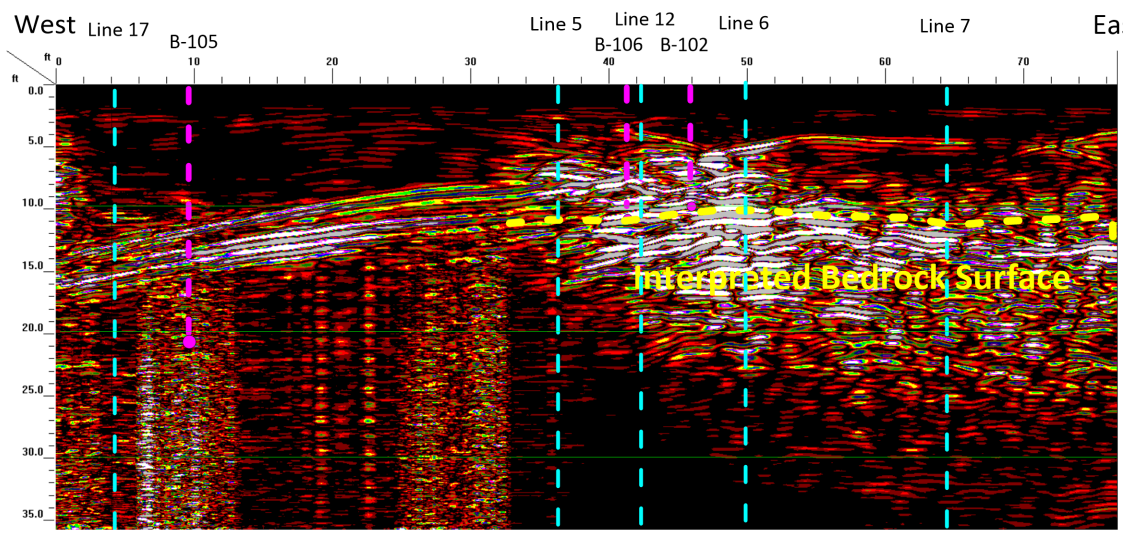

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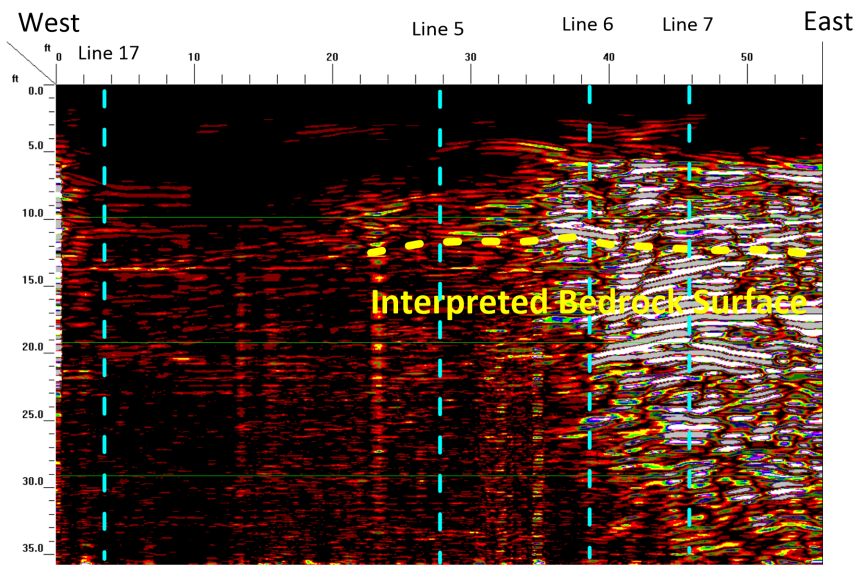

Line 16

LEGEND

- Depth to Bedrock/Refusal
- Interpreted Limits of Excavation

SHEET NUMBER: 1 OF 1	FIGURE 3b	DRAWING NUMBER:

Interpreted GPR Profiles: Selected Examples
West-East Oriented Transects
Bridge VT 100 at Mile Marker 3.17
Londonderry, Vermont

SCALE:	DATE:	PROJECT NUMBER:
AS SHOWN	09/08/2025	31405712.6625

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