To: Stephen Madden, Geotechnical Engineer, Lead Project Engineer

From: Matthew Riegel, Geotechnical Engineer, P. E., Geotechnical Task Lead

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Subject: Lyndon – IM 091-3(53) **FINAL** Geotechnical Data Report

1.0 INTRODUCTION

As requested by the Vermont Agency of Transportation (VTrans), HNTB has completed a geotechnical subsurface investigation for the Lyndon IM 091-3(53) project located on VT Interstate 91 Northbound (NB) and Southbound (SB), just north of exit 24 at mile marker (MM) 141.3, in Lyndon, VT. This project consists of replacing two existing corrugated galvanized metal plate pipe (CGMPP) culverts that cross underneath I-91 NB and SB, including an associated headwall at both the inlet and outlet orifice. Geotechnical borings and installation of groundwater monitoring wells were performed to provide a general geotechnical characterization of the project site and to inform a baseline geotechnical report. Results of the field and lab sampling, and all subsequent boring logs are contained herein.

2.0 SITE GEOLOGY

The project site, as shown in **Figure 1** is situated in the New England physiographic province between the Vermont Piedmont and the Northeast Highlands divisions. The surficial deposits along the site consists primarily of fill material that was placed during the construction of the roadway embankment. The natural soil consists of silt and clay as well as outwash sand and gravel deposited by glacial meltwater. Underlying the surficial deposits are largely described as metamorphic bedrock formations comprised of calcerous phyllite, limestone, quartzite, and dolomite. **Figures 2 and 3** provide a detailed depiction of the Lyndon geology.

3.0 FIELD INVESTIGATION

A subsurface exploration was performed as part of the assessment and includes (10) ten geotechnical borings, designated as B-1, B-3 through B-6, and B-8 through B-12, which were advanced from the existing ground surface to depths ranging from 11 feet to 96 feet below existing grade. Several borings were offset from the original location due to difficult drilling conditions encountered within the embankment fill. Borings B-1, B-3, B-6 & B-10 were advanced using a Mobile B-57 ATV drill rig with an automatic hammer. Borings B-4, B-4A, B-5, & B-5A were advanced using a Versadrill GT-8 truck rig with an automatic hammer. Borings B-5B, B-8, B-8C, B-9, B-11, B-11B, & B-12 were advanced using a Stratastar truck rig with an automatic hammer. Borings B-9A and B-12A were advanced using both the Stratastar and the Versadrill GT-8 truck rigs. For Boring B-9A, the Stratastar truck rig hammer was used between depths of 19 to 59ft (Samples S-1 to S-14), and then switched to the Versadrill GT-8 between depths of 59 to 81ft (Samples S-15 to S-21). For Boring B-12A, the Stratastar truck rig hammer was used between depths of 9 to 61ft (Samples S-1 to S-11), and then switched to the Versadrill GT-8 between depths of 64 to 89ft (Samples S-12 to S-17). All borings were advanced in general

accordance with VTrans MREI 11-01 and AASHTO T 206, Standard Method of Test for Penetration Test and Split-Barrel Sampling of Soils. The subsurface exploration program was performed by New England Boring Contractors (NEBC) of Derry, New Hampshire between August 29, 2022, and December 5, 2022. Oversight and quality control services for the field work were provided by HNTB. All borings located on the roadway embankment were advanced using a combination of percussive drilling and rotary drilling techniques. The percussive drilling technique was performed using a down the hole hammer, with air introduced during advancement of the borehole, due to large boulders encountered within the embankment fill causing difficult drilling conditions. The rotary drilling technique was performed in all borings, using a tricone drill bit with water continuously introduced into the drilling process. A mud tub was used during rotary drilling to prevent drilling fluid and cuttings from flowing onto the surrounding areas.

Northings and Eastings of the borings are based on the Vermont State Plane Grid Coordinate System NAD83. The borings, including the elevations, were field located and verified by VTrans survey forces. The boring locations were then translated onto a base map provided by VTrans. The locations and elevations of the borings should be considered accurate only to the degree implied by the method used to determine them. See **Table 1** for a summary of the as-drilled boring locations.

The as-drilled boring locations from the current exploration are shown on the As-Drilled Boring Location Plan provided in **Appendix I**, and noted in the boring logs provided in **Appendix II**. **Table 1** presents a summary of the boring locations.

Table 1: Boring Locations

Boring Number	Interstate	Station	Offset (ft)	Northing (ft)	Easting (ft)	Ground Elev. (ft)
B-1	NB	106+76	55 RT	755418	1760397	861.2
B-3	SB	102+47	32 RT	755039	1760272	834.1
B-4	NB	102+89	25 RT	755133	1760661	856.3
B-4A	NB	102+69	25 RT	755119	1760675	856.6
B-5	NB	103+24	16 LT	755128	1760607	858.0
B-5A	NB	103+29	16 LT	755131	1760604	858.1
B-5B	NB	103+11	18 LT	755117	1760615	857.5
B-6	NB	102+46	191 LT	754946	1760546	785.5
B-8	SB	98+30	19 RT	754734	1760556	825.8
B-8A	SB	98+22	19 RT	754729	1760562	825.8

Boring Number	Interstate	Station	Offset (ft)	Northing (ft)	Easting (ft)	Ground Elev. (ft)
B-8B	SB	98+17	19 RT	754725	1760565	825.8
B-8C	SB	98+50	18 RT	754748	1760541	825.8
B-9	SB	99+61	23 LT	754797	1760434	826.6
B-9A	SB	99+67	23 LT	754802	1760429	827.4
B-10	SB	97+89	183 LT	754563	1760441	760.5
B-11	NB	100+71	19 LT	754953	1760791	854.8
B-11A	NB	100+59	19 LT	754945	1760800	854.8
B-11B	NB	100+65	19 LT	754959	1760795	854.8
B-12	SB	96+97	24 LT	754610	1760619	823.1
B-12A	SB	96+91	24 LT	754605	1760624	823.1

1. Vertical Datum NAVD 88. Horizontal Datum VTSPG NAD83

Groundwater monitoring wells were installed in borings in general accordance with the project specific groundwater monitoring well schematic provided by VHB as shown in **Attachment I**. Field recorded groundwater monitoring well logs are provided in **Appendix III**. Each boring contained a temporary HOBO water level data logger (U20L-02), provided and calibrated by Onset Computer Corporation, to produce continuous water level monitoring. One temporary HOBO water level data logger was used as a barometric pressure reader (Serial # 21453176). See **Table 2** for the data logger information with the associated borings.

Table 2: HOBO (U20L-02) Data Logger Depth

Boring Number	Depth[1] (ft)	Elevation (ft)	Serial Number
B-1	30.4	830.8	21400074
B-3	61.1	773.0	21400070
B-4A	83.0	773.6	21400072
B-5B	75.0	782.5	21400069
B-6	19.6	765.9	21400085
B-8C	53.7	772.1	21400073
B-9A	69.0	758.4	21400071
B-10	11.0	749.5	21400076

Boring Number	Depth[1] (ft)	Elevation (ft)	Serial Number
B-11B	86.9	767.9	21400075
B-12A	69.0	754.1	21400084

1. Depth measurements referenced from ground surface.

Appendix IV provides the latest extraction of the automatic groundwater data collected from the HOBO data loggers at the completion of the boring investigation. A water level station, providing cloud-based monitoring and data access through HOBOlink, will be installed and distributed to the design build team. Manual groundwater readings were performed periodically during the subsurface investigation. See **Table 3** for a summary of the groundwater readings.

Table 3: Manual Ground Water Readings

Boring Number	Boring Completion Date	GW Reading Date	Time	Depth[1] (ft)	Approximate GW Elev. (ft)
B-1	9/28/22	9/29/22	10:30 AM	24.2	837.0
B-1	9/28/22	9/30/22	11:53 AM	24.1	837.1
B-1	9/28/22	10/4/22	3:40 PM	24.0	837.2
B-1	9/28/22	10/5/22	3:28 PM	24.1	837.1
B-1	9/28/22	10/19/22	8:26 AM	23.7	837.5
B-1	9/28/22	11/29/22	11:06 AM	23.2	838.0
B-1	9/28/22	1/23/23	1:02 PM	17.3	843.9
B-3	10/4/22	10/5/22	3:37 PM	43.4	790.7
B-3	10/4/22	11/29/22	10:20 AM	43.6	790.5
B-3	10/4/22	1/23/23	11:54 AM	43.4	790.7
B-4A	10/17/22	10/20/22	7:50 AM	72.5	784.1
B-4A	10/17/22	11/29/22	11:50 AM	72.2	784.4
B-4A	10/17/22	1/23/23	1:28 PM	71.3	785.3
B-5B	10/3/22	10/3/22	3:17 PM	49.5	808.0
B-5B	10/3/22	10/4/22	1:36 PM	49.5	808.0
B-5B	10/3/22	10/5/22	3:13 PM	49.6	807.9
B-5B	10/3/22	10/19/22	10:39 AM	49.7	807.8
B-5B	10/3/22	11/29/22	11:34 AM	49.7	807.8

Boring Number	Boring Completion Date	GW Reading Date	Time	Depth[1] (ft)	Approximate GW Elev. (ft)
B-5B	10/3/22	1/23/23	1:50 PM	49.0	808.5
B-6	9/29/22	9/30/22	12:03 PM	12.1	773.4
B-6	9/29/22	10/4/22	4:00 PM	12.1	773.4
B-6	9/29/22	10/5/22	3:47 PM	11.9	773.6
B-6	9/29/22	11/29/22	10:38 AM	10.5	775.0
B-6	9/29/22	1/23/23	12:22 PM	9.7	775.8
B-8C	11/14/22	11/15/22	9:00 AM	49.0	776.8
B-8C	11/14/22	11/29/22	8:30 AM	48.7	777.1
B-8C	11/14/22	12/6/22	12:20 PM	48.9	776.9
B-8C	11/14/22	1/23/23	4:26 PM	49.2	776.6
B-9A	12/01/22	12/2/22	7:33 AM	53.3	774.1
B-9A	12/01/22	12/7/22	9:05 AM	52.8	774.6
B-9A	12/01/22	1/23/23	3:38 PM	53.2	774.2
B-10	10/06/22	10/7/22	7:55 AM	7.0	753.5
B-10	10/06/22	11/29/22	9:44 AM	5.5	755.0
B-10	10/06/22	1/24/23	11:03 AM	4.0	756.5
B-11B	9/28/22	9/29/22	9:31 AM	57.1	797.7
B-11B	9/28/22	9/30/22	10:00 AM	57.2	797.6
B-11B	9/28/22	10/3/22	11:43 AM	57.1	797.7
B-11B	9/28/22	10/5/22	3:07 PM	57.0	797.8
B-11B	9/28/22	1/23/22	2:20 PM	55.3	799.5
B-12A	12/02/22	12/6/22	3:00 PM	55.9	767.2
B-12A	12/02/22	1/24/23	10:36 AM	53.5	769.6

1. Manual reading depths referenced from ground surface.

Slug testing was performed by HNTB, with assistance from VHB, in all borings in general accordance with the *VHB Standard Operating Procedure: Slug Testing* provided by VHB via email 06/24/2022. A 1.5 inch diameter, 4 feet in length, PVC solid slug was used for initial displacement during the slug testing. Data loggers remained in the borehole during the

performance of each manual slug test to remove field errors. Data loggers were calibrated to read every second during the manual readings. See **Appendix V** for the Manual Slug testing readings, and **Appendix VI** for the Raw Data Logger Slug Testing Readings.

Manual water level readings at the inverts of the culverts were measured on 11-15-22.

- I-91 NB – INLET: Depth of water is 8 inches above the culvert invert.
- I-91 NB – OUTLET: Depth of water is 10 inches above the culvert invert.
- I-91 SB – INLET: Depth of water is 6 inches above the culvert invert.
- I-91 SB – OUTLET: Depth of water is 9 inches above culvert invert.

See **Table 4** for a summary of the manual water readings above the culverts inverts.

Table 4: Manual Water Readings at Culvert Inverts

Culvert	Culvert Invert Elevations		Stream Elevations	
	Inlet	Outlet	Inlet	Outlet
NB	790.0	769.6	791.6	770.4
SB	766.6	747.7	767.1	748.4

4.0 FIELD AND LABORATORY TESTS

Borings B-1, B-3, B-6, and B-10 were performed adjacent to I-91 NB and SB lanes, within the grass areas of the project zone. Borings B-1 and B-3 were continuously sampled below ground surface to a depth of 12 feet, then every 5 feet thereafter until reaching refusal material on the split spoon and tri-cone rollerbit. Borings B-6 and B-10 were continuously sampled below ground surface. Rock coring was performed for borings B-1 and B-6.

Borings B-4/4-A, B-5/5-A/5-B, B-8/8-A/8-B/8-C, B-9/B-9A, B-11/11-A/11-B, and B-12/12-A were performed behind the guardrails, off of pavement, adjacent to the I-91 NB and SB lanes. Borings B-5, B-8, B-11, and B-12, including their subsequent offset borings, were continuously sampled to a depth of 12 feet below ground surface, then every 5 feet thereafter. Borings B-4 and B-9, including their subsequent borings, were sampled continuously to a depth of 12 feet and again from 40 feet to refusal material. Rock coring was performed in boring B-9A. During split spoon advancement of boring B-4, the existing culvert was struck, but not penetrated, at a depth of 64.5 feet bgs. Boring B-4 was terminated, then offset 18-ft south to boring B-4A.

Due to difficult drilling conditions encountered in borings B-8, B-8C and B-9A, steel casing fractured and was abandoned at various depths after multiple attempts to retrieve the casing. The following summarizes the locations of the known obstructions within each boring.

- B-8: A 6 inch diameter casing 10 feet in length, from an approximate depth of 35 ft to 45 ft bgs, was abandoned in boring B-8 after lead casing fractured at the joint. The approximate location of the abandoned steel casing is estimated between elevations 790.8 to 780.8.
- B-8C: A 3 inch diameter casing 10 feet in length, from an approximate depth of 55 ft to 65 ft bgs, was abandoned in boring B-8C after lead casing fractured at the joint. The

approximate location of the abandoned steel casing is estimated between elevations 770.8 to 760.8.

- B-9A: A 4 inch diameter casing 45 feet in length, from an approximate depth of 25 ft to 70 ft bgs, was abandoned in boring B-9A. The approximate location of the abandoned steel casing is estimated between elevations 802.4 to 757.4.

The abandoned steel casing are known obstructions noted in the boring logs, and should be considered during proposed alignment shifts and construction considerations.

Standard Penetration Testing (SPT) was performed at each boring location. Soil samples were retrieved by driving a 24-inch split-spoon sampler (2-inch O.D., 1⅜ inch I.D.) using a 140-lb hammer free falling 30 inches, in accordance with procedures specified in VTrans MREI 11-01 and AASHTO T206. An automatic hammer was utilized for sampling purposes as noted on each boring log.

The standard penetration test energy measurement calibration was submitted by NEBC for the three drill rigs onsite during the investigation. The results indicate that the hammer transfer efficiency for the Mobile B-57 ATV rig varies from 79.7 to 91.4 percent with an average efficiency of 85 percent. The hammer transfer efficiency for the Versadrill GT-8 truck rig varies from 80.1 to 92.5 percent with an average efficiency of 87 percent. The hammer transfer efficiency for the Mobile Stratastar truck rig varies from 55 percent to 61 percent with an average efficiency of 58 percent. See **Attachment II** for the energy measurement calibration sheets provided by NEBC. The number of blows required to drive the sampler each 6-inch increment was recorded, and the Standard Penetration Resistance (N-Value) was calculated as the sum of the blows over the second and third 6-inch interval. 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. Each sample was photographed, removed from the sampler in the field, and classified using the Burmister and AASHTO Soil Classification Systems. Representative portions of each sample were collected and shipped to Geotesting Express in Acton, Massachusetts for additional testing.

Geotechnical laboratory tests were performed on select representative samples to assist with soil classification and for others to evaluate engineering properties of the soil. The following tests were performed:

Natural Moisture Content	ASTM D2216
Atterberg Limits	ASTM D4318
Sieve Analysis	ASTM D6913
Grain Size Analysis & Hydrometer	ASTMD6913 / D7928
Percent Passing No. 200 Sieve	ASTM D1140
Elastic Moduli of Rock in Uniaxial Compression	ASTM D7012
pH	AASHTO T289
Resistivity	ASTM G57
Sulfate	AASHTO T290
Chloride	ASTM T290 / T291

The laboratory test results are included in **Appendix VII**.

Enclosures: Figures - Project Location, Surficial Geology, and Bedrock Geology Maps
Appendix I – As-Drilled Boring Location Plan
Appendix II – Boring Logs
Appendix III – Field Recorded Groundwater Monitoring Well Logs
Appendix IV – Automatic HOBO data logger readings
Appendix V – Field Recorded Slug Test Results
Appendix VI – Automatic Slug Test Results from Data Loggers
Appendix VII – Laboratory Test Results
Attachment I – VHB Well Schematic
Attachment II – Energy Measurement Drill Rig Calibration Sheets