AGENCY OF TRANSPORTATION **OFFICE MEMORANDUM**

To: Sasa Dejan, Rail Project Manager

CEE

From: Callie Ewald, P.E., Senior Geotechnical Engineer

Date: June 21st, 2024

Subject: Barre City STP 6000(32) – Geotechnical Recommendations

1.0 INTRODUCTION

As requested, we have completed our subsurface investigation and geotechnical analyses of the proposed walls as part of the Barre City Hill Street Rail project. The project consists of minor realignment of the railroad tracks, reconstruction of the crossing, new signals, and installation of one retaining wall. The project is located approximately 350 feet north of the intersection with VT Route 14 in Barre City. Contained herein are the results of our subsurface investigation, field sampling, and geotechnical analyses for use in the design of the proposed retaining walls, as determined using the 2020 AASHTO LRFD Bridge Design Specifications.

2.0 FIELD INVESTIGATION

The field investigation was conducted on May 6th and 7th, 2024. Two standard penetration borings were advanced to evaluate the subsurface profile for design and construction of two retaining walls. Preliminary boring locations were provided by Scott Burbank, of Vanasse Hangen Brustlin (VHB) in a Geotechnical Request Form dated March 8th, 2024, and were located in the field by personnel from the Geotechnical Section and Drill Unit. The proposed retaining wall at Boring B-101 has since been removed from the project. A summary of the final location of each boring and corresponding ground surface elevation can be found in Table 2.1. 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 determined from the VHB survey file z21g340sv.dgn dated February 13, 2024 based on the Northings and Eastings gathered in the field using the handheld GPS. 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 and Elevations.

Boring No.	Purpose	Northing (ft)	Easting (ft)	Approximate Ground Surface Elevation (ft)
B-101	Eliminated Retaining Wall	616664.0	1640757.3	634.4
B-102	Proposed Retaining Wall	616702.1	1640707.0	636.3

The borings were performed in general accordance with AASHTO T206, *Standard Method of Test for Penetration Test and Split-Barrel Sampling of Soils.* During boring operations, split spoon

samples and standard penetration tests (SPT) were taken for each boring. Both borings were sampled continuously to 10 feet and then at 5-foot intervals until 27 and 25.5 feet bgs, for borings B-101 and B-102 respectively. Bedrock was not encountered in either boring.
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 Central Laboratory for further evaluation. The attached boring logs in Appendix A display the types of soil strata encountered and include the SPT data and any pertinent observations made by the field staff.

3.0 FIELD TESTING

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

The VT Agency of Transportation has determined a hammer correction value, C_E, to account for the efficiency of the SPT hammers on its drill rigs. An Acker Renegade was used for both borings. Due to this drill rig being new, an energy efficiency factor has not been calibrated for hammer correction, therefore a conservative value of 1.3 was used in all soil parameter calculations. This value should be used in calculations to estimate soil parameters.

4.0 SOIL PROFILE

The following soil strata have been identified based on our review of the boring logs. It should be noted that groundwater elevations are subject to change given the fact that boreholes were generally left open for a short period of time. Because groundwater elevations can fluctuate seasonally and are affected by temperature and precipitation, groundwater may be encountered during construction when not previously noted on the logs.

4.1 Boring B-101

The ground surface elevation at B-101 was approximately 634.4 ft. The hole collapsed after drilling and no water was measured to a depth of 10.8 feet. This boring was initially performed for a proposed retaining wall that has since been eliminated from the project.

Depth (Below Ground Surface Elevation)	Soil Profile
0 – 12 ft	Loose to Medium Dense SAND, little Silt
12 – 20 ft	Medium Dense SAND and SILT
20 – 27 ft	Medium Dense GRAVEL, some Silt

4.2 Boring B-102

The ground surface elevation at B-102 was approximately 636.3 ft. Groundwater was measured after drilling on May 7, 2024 at an approximate depth of 17.2 ft bgs corresponding to an elevation of 619.1 ft.

Depth (Below Ground Surface Elevation)	Soil Profile
0 – 8 feet	Loose SAND, little Gravel
8 – 12 feet	Med Dense to Dense SAND and SILT, trace Gravel
12 – 25.5 feet	Dense SAND and GRAVEL, trace Silt

5.0 SHALLOW FOUNDATION ANALYSIS

AASHTO's LRFD Bridge Design Specifications Manual (2020) 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 footings 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. The bearing stratum identified at this site is a sandy material with little fines. Some wall systems use a stone leveling pad for foundation support which should be sufficient given the soil conditions at the site.

As per section 10.5.5.1 of the 2020 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.

5.1 Bearing Resistance

Initially, two retaining walls were proposed as part of the project, however the proposed wall on the Northeast side of the crossing adjacent to the driveway and house has been eliminated.

Boring B-102 was performed in the vicinity of the short retaining wall on the Northwest corner of the crossing to facilitate the installation of a junction box. Geotechnical recommendations for that wall are included herein.

Based on the soil profile for B-102, an assumed bottom of footing elevation located in the medium dense sandy silt stratum and using established empirical relationships, it was determined the soil has a friction angle, $\varphi = 31°$ and density, $\gamma = 120$ lbs/ft^3. Figure 5.1 below displays the minimum effective footing width per maximum bearing resistance, factored due to LRFD strength limit. For footing widths of 3, 4, 5 and 6 feet, the maximum factored bearing resistance is 3.4, 3.8, 4.1, 4.5 kips/ft^2 (ksf), respectively.

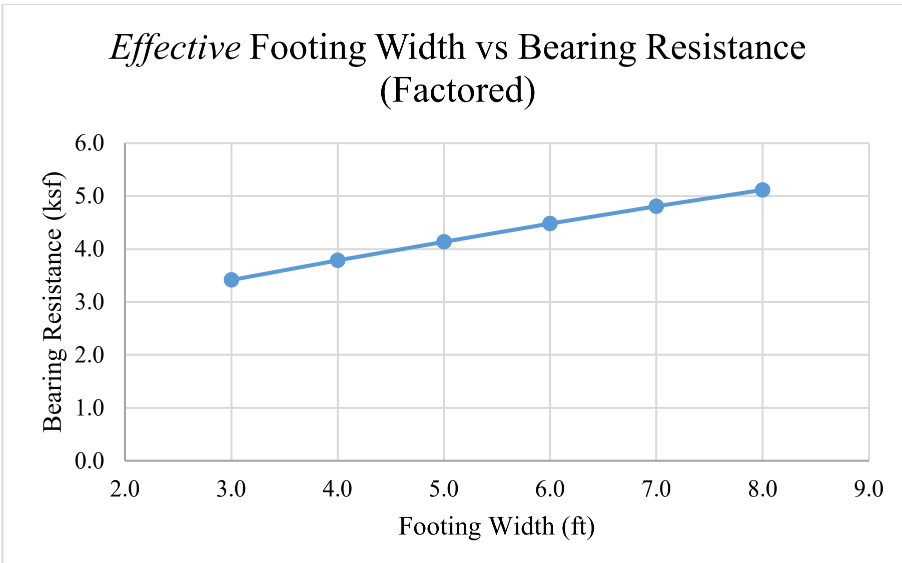

Figure 5.1 Factored bearing resistance. Load resistance factor, Φ=0.45

Settlement analyses were performed to calculate bearing pressures resulting in 1 inch of settlement for various footing widths. For the Service Limit State, we recommend that the footings be designed such that the footing contact pressures do not exceed 8 ksf. Due to the more granular nature of the soils at the footing elevation, any settlement is expected to occur during or immediately after construction.

5.3 Global Stability Analysis

A global stability analysis was conducted to evaluate the overall stability of the soil slope and proposed retaining wall. Using Slide version 6.0 developed by Rocscience, a slope stability analysis was performed which evaluated both compound and deep-seated failures for a 5-foot-tall exposed section of wall with a conservative groundwater table at the bottom of footing. According to the VTrans GEI 14-01, *Slope Stability Investigation and Evaluation*, the Spencer Method is recommended to be used for slope stability analyses of failure surfaces of any shape and a minimum factor of safety of 1.3 shall be used for slopes adjacent to but not directly supporting structures. As a result, the Spencer Method produced a factor of safety against slope failure well above 1.3.

6.0 RECOMMENDATIONS

A shallow foundation appears to be feasible for the proposed retaining wall. Factored bearing resistances for various footing widths were calculated and can be found above in Figure 5.1. These calculations are based on the geometric and geotechnical assumptions outlined in Section 5.0 of this report. 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 6.1: Summary of Resistance Factors

Design State	Resistance Factor, φ
Settlement	1.0
Scour	1.0
Bearing Resistance	0.45
Sliding	0.80

6.1 Plan Notes

Based on our analyses, we recommend including the following information on the plans:

- For strength limit state, using a resistance factor of 0.45, the factored bearing resistance to use in design is 3.4 ksf
- For service limit state, factored bearing pressures should be limited to 8 ksf

6.2 Retaining Wall Selection

A conceptual plan (end result) approach to retaining wall solicitation is recommended for all wall systems except conventional cast-in-place reinforced concrete walls and bin walls in which case detailed plans should be included in the bidding documents.

In accordance with the Agency standard practice, projects containing earth retaining structures (except conventionally reinforced concrete and bin walls) shall use a concept drawing approach. The design shall meet the requirements of the latest LRFD Bridge Design Specifications. The concept drawing, furnished in the bidding documents will contain the following geometric and design project specific information:

<u>Geometric:</u>

1. Beginning and end of wall stations.
2. Elevations on top of wall at beginning and end of wall station as well as all profile break points.
3. Original and proposed ground line profiles in front of and behind the retaining wall.
4. Cross sections at the retaining wall location at 25foot intervals.
5. Horizontal wall alignment.
6. Details of wall appurtenances such as traffic barriers, coping, fencing, drainage, location and configurations of signs and lighting including conduit locations.

Design:

1. Soil parameters of foundation soils, retained soil, and select backfill.
2. Nominal bearing resistance for the foundation soil and minimum footing embedment depth.
3. Maximum tolerable total and differential settlement.
4. Limits and requirements for drainage features beneath, behind, or through the retaining structure.
5. Backfill requirements for both within and behind the retaining structure. (Both material and placement requirements should be specified, i.e., gradation, plasticity index, electrochemical, soundness, maximum loose lift thickness, minimum density and allowable moisture content).
6. Special facing panel and module finishes or colors.

Geometric, geotechnical and structural considerations must be complementary for the conceptual plan to convey the desired end product to the bidders. The recently updated 2024 Standard Specifications for Construction material specification 760.06 states that Precast Concrete Retaining Wall Systems shall be listed on the Approved Products List.

6.3 Design Parameters

Based on the soil profiles above and attached boring logs, the in-situ soil properties as well as engineering values for common construction materials can be found in Table 6.1.

The table below highlights the geotechnical design parameters of the in-situ soils as well as regularly specified aggregates. These values should be used when designing any substructure units. It is recommended that values of K_0 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. K_a and K_p values are based on a vertical back of wall and a horizontal ground surface behind the wall or structure.

	Loose SAND, little Gravel (bearing stratum)	**703.04 – Granular Borrow**	**704.08 – Granular Backfill for Structures**
Unit Weight, γ (lbs/ft^3):	120	130	140
Internal Friction Angle, φ (degrees):	31	32	34
Coefficient of Friction, f			
- mass concrete cast against soil:	0.45	0.45	0.55
- soil against precast/formed concrete:	0.40	0.40	0.48

Active Earth Pressure Coef., K_a:	0.32	0.31	0.28
Passive Earth Pressure Coef., K_p:	3.12	3.26	3.57
At-Rest Earth Pressure Coefficient, K_o:	0.49	0.47	0.44

Figure 6.1 Engineering Properties for Construction and In-Situ Materials

6.4 Construction Considerations

6.4.1 Construction Dewatering

Temporary construction dewatering may be required to install the retaining wall, which 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, 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 the 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.

6.4.2 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, such as a small vibratory plate compactor, is used 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 at least 95% of the maximum dry density determined in accordance with AASHTO T-99. Granular Backfill for Structures, or other select materials placed within the roadway base section shall be compacted to a dry density of 95% of the maximum dry density determined in accordance with AASHTO T-99.

7.0 CONCLUSION

If you have any questions or would like to discuss this report, please call me at (802) 595-4589 and by email at callie.ewald@vermont.gov. Computer generated boring logs are attached and available in the *M:\Projects\21g340\MaterialsResearch* folder.

Reviewed by: Eric Denardo,P.E., Geotechnical Engineer END

Attachments: Boring Logs (2 Pages)

Cc: Project File

Z:\Highways\CMB\GeotechEngineering\Projects\Barre City STP 6000(32)\REPORTS\Barre City STP 6000(32) Geotechnical Data Report.docx

VTrans Working to Get You There	STATE OF VERMONT AGENCY OF TRANSPORTATION CONSTRUCTION AND MATERIALS BUREAU CENTRAL LABORATORY	BORING LOG **Barre City** **STP 6000(32)** **WCRR MP 8.28**

Boring No.: **B-101**
Page No.: 1 of 1
Pin No.: 21G340
Checked By: CEE

Boring Crew: McGinley, Thurston, Arles
Date Started: 5/06/24 Date Finished: 5/06/24
VTSPG NAD83: N 616664.00 ft E 1640757.30 ft
Station: 403+10.00 Offset: 25.00
Ground Elevation: 634.1 ft

	Casing	Sampler
Type:	H.S.A.	SS
I.D.:	3 in	1.5 in
Hammer Wt:	140 lb.	N.A.
Hammer Fall:	30 in.	N.A.
Hammer/Rod Type:	Auto/AWJ	
Rig:	Acker Renegade	C_E =

Groundwater Observations

Date	Depth (ft)	Notes
05/06/24		See Notes

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %
0		Visual Class:, Med Dense SAND, little Silt, trace Gravel, Lt brn, Moist, Rec. = 1.7 ft	4-6-6-5 (12)				
		Visual Class:, Loose Fine SAND, trace Silt, Lt brn, Moist, Rec. = 1.4 ft	5-4-4-4 (8)				
		Visual Class:, Loose Fine SAND, Lt brn, Moist, Rec. = 1.8 ft	2-2-3-4 (5)				
5		Visual Class:, Loose Coarse SAND, brn-gry, Moist					
		Visual Class:, Med Dense fine to Coarse SAND, brn, Moist, Rec. = 1.4 ft	6-7-7-9 (14)				
		Visual Class:, Med Dense fine to coarse SAND, brn-gry, Moist, Rec. = 1.8 ft	6-7-6-10 (13)				
10		Visual Class:, Med Dense Coarse SAND, brn-gry, Moist, Rec. = 1.6 ft	6-9-11-7 (20)				
15		Visual Class:, Med Dense fine SAND and SILT, brn, Wet, Rec. = 1.4 ft	5-5-7-8 (12)				
20		Visual Class:, Med Dense GRAVEL and coarse SAND, gry-brn, Wet, Rec. = 2.0 ft, Driller noted gravel at 18'	12-12-13-16 (25)				
25		Visual Class:, Med Dense GRAVEL, some Sand, brn, Wet, Rec. = 2.0 ft	12-14-12-13 (26)				

Hole stopped @ 27.0 ft

30

Remarks:
1. Hole Collapsed @ 10.8 ft. No WT after collapse.
2. Water encountered at 11.4 ft during auger removal.

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.

VTrans Working to Get You There — Vermont Agency of Transportation	STATE OF VERMONT AGENCY OF TRANSPORTATION CONSTRUCTION AND MATERIALS BUREAU CENTRAL LABORATORY	BORING LOG **Barre City** **STP 6000(32)** **WCRR MP 8.28**	Boring No.: **B-102** Page No.: 1 of 1 Pin No.: 21G340 Checked By: CEE

Boring Crew: McGinley, Thurston, Arles
Date Started: 5/07/24 Date Finished: 5/07/24
VTSPG NAD83: N 616702.10 ft E 1640707.00 ft
Station: 403+51.00 Offset: -25.00
Ground Elevation: 636.3 ft

	Casing	Sampler
Type:	H.S.A.	SS
I.D.:	3 in	1.5 in
Hammer Wt:	140 lb.	N.A.
Hammer Fall:	30 in.	N.A.
Hammer/Rod Type:	Auto/AWJ	
Rig:	Acker Renegade	C_E =

Groundwater Observations

Date	Depth (ft)	Notes
05/07/24	17.2	WT After Drilling

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %
		Visual Class:, Loose SAND, some Gravel, some broken rock, brn, MTD, Rec. = 1.0 ft	2-2-3-3 (5)				
		Visual Class:, Very Loose SAND, little Gravel, little Silt, brn, MTD, Rec. = 0.8 ft	2-1-1-1 (2)				
5		Visual Class:, Loose SAND, little Gravel, little Silt, brn, MTD, Rec. = 1.4 ft	1-2-2-4 (4)				
		Visual Class:, Loose fine to med Course SAND, brn, MTD, Rec. = 1.4 ft	3-5-4-4 (9)				
		Visual Class:, Loose fine SAND and SILT, brn-Lt/brn, Moist, Rec. = 1.6 ft	5-3-4-4 (7)				
10		Visual Class:, Med Dense fine, SAND, some Silt, trace Gravel, brn, Moist, Rec. = 1.8 ft	5-5-9-16 (14)				
15		Visual Class:, Dense coarse SAND, some Gravel, trace Silt, brn, Moist, Rec. = 1.2 ft, Light rig chatter augering to 18.5 ft	14-18-15-31 (33)				
20		Visual Class:, Dense coarse SAND and GRAVEL, trace Silt, brn-gry, MTW, Rec. = 1.2 ft, Rig chatter augering to 23.5 ft	11-10-14-14 (24)				
25		Visual Class:, Dense coarse SAND, trace Silt, brn, Moist, Rec. = 1.3 ft	10-9-15-13 (24)				
		Hole stopped @ 25.5 ft					
30							

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.