O'Reilly, Talbot & Okun
ENGINEERING ASSOCIATES

J2950-22-01
February 28, 2023

# Preliminary Geotechnical Engineering Recommendations
# Pearl Street Culvert Replacement
# South Hadley, Massachusetts, 01075

**PREPARED FOR:**
Fuss & O'Neill, Inc.
1550 Main Street, Suite 400
Springfield, Massachusetts, 01103

Attention: Ms. Lara Sup, PE

**PREPARED BY:**
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Springfield, MA 01103

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Ms. Lara Sup, P.E.
Fuss & O'Neill, Inc.
1550 Main Street, Suite 400
Springfield, Massachusetts, 01103

Re: Preliminary Geotechnical Engineering Recommendations
Pearl Street Culvert Replacement Project
South Hadley, Massachusetts

Dear Ms. Sup:

O'Reilly, Talbot & Okun Associates, Inc. (OTO) is pleased to provide these geotechnical findings and recommendations for the culvert replacement project referenced above. The subject culvert spans Elmer Brook and is located on Pearl Street, approximately 1,550 feet east of the intersection with Hadley Street (Route 47) in South Hadley, Massachusetts. A Site Locus and Boring Location Plan are attached.

Our geotechnical recommendations are based upon published information and subsurface conditions observed in seven borings (two deep borings). Our services consisted of a review of published geologic information, the full-time observation of the borings, review of the logs and soil samples, laboratory analysis, engineering analyses, and preparation of this report. This report is subject to the limitations attached in Appendix A.

The recommendations in this report should be reviewed during final design and updated as appropriate.

If you have any questions, please do not hesitate to contact the undersigned.

Sincerely yours,
O'Reilly, Talbot & Okun Associates, Inc.

Ashley L Sullivan

Dustin A. Humphrey, P.E.
Project Engineer

Ashley Sullivan, P.E.
Principal

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## 1.0 EXECUTIVE SUMMARY

This report provides our geotechnical findings and recommendations for the design of foundations for the proposed Pearl Street replacement culvert over Elmer Brook in South Hadley, Massachusetts.

**Summary of Existing and Proposed Replacement Structure**

<table>
<tr><th colspan="4">Existing Structure</th></tr>
<tr><th><em>Type</em></th><th><em>Size, Type</em></th><th><em>Inlet Invert (elevation)</em></th><th><em>Outlet Invert (elevation)</em></th></tr>
<tr><td>Corrugated steel</td><td>6 foot diameter</td><td>118.55</td><td>118.03</td></tr>
<tr><th colspan="4">Proposed Replacement Structure</th></tr>
<tr><td>Metal Pipe Arch</td><td>16 foot span x 6 foot height</td><td>118.27</td><td>118.00</td></tr>
</table>

We understand that the existing pipe culvert will be completely removed, and a new culvert will be constructed in its place. The type of structure has not been chosen, but it will likely consist of a corrugated metal pipe arch culvert with a clear span of 16 feet. A three-sided concrete box culvert may be proposed as an alternative. Based upon the proposed type of structure, existing data and estimated scour depth of 5.5 feet (corresponding to an elevation near 112.5 feet), we anticipate that the new culvert will be founded on shallow foundations bearing in the varved silt and sand layer near an elevation 110 to 112 feet. At this time, it appears that the scour depth will govern the bearing depth of foundations. To provide a firm bearing surface of the new culvert, we recommend that footings bear on a minimum one-foot layer of imported Crushed Stone over the varved silt and clay present at footing levels.

An organic layer, consisting primarily of a silty sand mixed with organics and wood fragments, was encountered in the two deep borings. The bottom of this organic layer was observed between an elevation of 114 and 117 feet (approximate). These elevations are above anticipated culvert bottom of footing elevation; and therefore, this layer will be removed as part of footing construction. If this material extends below anticipated culvert and wingwall foundations (which may be higher), it should be removed in its entirety. Resulting excavations may be backfilled with Crushed Stone to proposed footing grade.

A sheet pile cofferdam will likely be necessary for temporary earth support and to prevent groundwater flow into the construction work area. Basal heave of the open excavation is a significant safety concern during construction. The contractor should evaluate the potential for basal heave when designing earth support and dewatering systems and include provisions to prevent this condition from occurring.

### 1.1 Subsurface Conditions

Seven soil borings were performed in the roadway or off the shoulder of the road. Four of the soil borings encountered shallow refusal in the upper gravelly sand layer and one encountered a geotextile fabric at a depth of 6 feet. These drilling locations were offset. Two deep borings (PS-2C and PS-3C) were completed approximately 25 to 40 feet from the existing culvert. The deep borings were terminated at depth of 43.3 to 50.5 feet (approximate elevation 84.2 to 77 feet) after obtaining rock core samples. Boring locations are shown on the attached Boring Location Plan. Boring logs are attached.

Subsurface conditions at the Site generally consist of a surface layer of gravely sand underlain by (in order of increasing depth): organics, varved clay, and bedrock. Little to no glacial till was observed above the bedrock, which was encountered at a depth of 33 to 40 feet, corresponding to approximate elevations 94.5 and 87.5 feet. The upper one to three feet of the bedrock was fractured. Bedrock cores were collected below the fractured zone. A summary of conditions encountered in the soil borings is provided as Table 1. A summary of bedrock conditions, based on the cores collected, is presented in Table 2.

**Table 1**
**Summary of Soil Boring Information**

| Boring | Ground Surface Elevation[1] (ft) | Depth (ft) / Elevation (ft) to: | | |
|---|---|---|---|---|
| | | Ground Water | Bottom of Organics | Bedrock or Refusal[2] |
| PS-1 | 127.0 | N/A | N/A | N/A |
| PS-2A | 127.5 | N/A | N/A | 6.0 / 121.5 (R) |
| PS-2B | 127.5 | N/A | N/A | 4.5 / 123.0 (R) |
| PS-2C | 127.5 | 8.3 / 119.2 | 13.0 / 114.5 | 33.0 / 94.5 (B) |
| PS-3A | 127.5 | N/A | N/A | 2.0 / 125.5 (R) |
| PS-3B | 127.5 | N/A | N/A | 3.0 / 124.5 (R) |
| PS-3C | 127.5 | 8.5 / 119.0 | 10.5 / 117.0 | 40.0 / 87.5 (B) |

Notes:

1. Ground surface elevations were estimated by referring to the Boring Location Plan. Data presented in this table are based upon conditions encountered in the soil borings. Data shown in this table should be considered accurate only to the degree implied by the methods used.
2. "B" indicates the depth/elevation bedrock was encountered. "R" indicates drilling refusal.

**Table 2**
**Summary of Bedrock Conditions**

| Boring | Core | Depth / Elev. (ft) | Recovery (%) | RQD (%) | RMQ | Description |
|---|---|---|---|---|---|---|
| PS-2C | C-1 | 34.0-39.0 / 93.5-88.5 | 53 | 48 | Poor | Slightly fractured basaltic lahar |
| | C-2 | 39.0-43.3 / 88.5-84.2 | 100 | 65 | Fair | Intensely to moderately fractured lahar to basalt |
| PS-3C | C-1 | 43.0-48.0 / 84.5-79.5 | 27 | 7 | Poor | Moderately to intensely fractured basaltic lahar |
| | C-2 | 48.0-50.5 / 79.5-77.0 | 78 | 13 | Poor | Slightly fractured basaltic lahar |

Groundwater was encountered at a depth of 8.3 to 8.5 feet below ground surface, corresponding to an approximate elevation of 119 feet, which is near the water elevation in Elmer Brook. We anticipate that groundwater levels will fluctuate with changes in the brook level.

The seismic Site Class was determined according to the AASHTO LRFD Culvert Design Specifications, Article 3.10.3.1. Using the SPT N-value, the Site was determined to be Site

Class D. Based upon conditions encountered in the soil borings and the observed density of saturated Site soils, it is unlikely that liquefaction would occur under the design earthquake.

### 1.2 Recommended Foundation System

We recommend that the new culvert and associated wingwalls be supported on traditional spread footings bearing on at least one foot of Crushed Stone. The minimum embedment depth of foundations should be 48 inches below surrounding grade for frost, or below the maximum scour depth, whichever is greater. For this project, it appears that the scour depth will govern embedment depth.

The base of the Crushed Stone layer should be below the organic layer observed in borings PS-2C and PS-3C, which extends to approximate elevation 114.5 feet and below the scour depth (elevation 110.5 feet). The Crushed Stone layer will provide a firm bearing surface and protect the subgrade from disturbance during construction. A geosynthetic separation fabric should be installed between the bottom of the Crushed Stone layer and the varved silt and clay. Foundation recommendations are presented in Table 3. Soil conditions and design parameters for use in the preliminary design of wingwalls are presented in Table 4.

### 1.3 Construction Considerations

The proposed culvert foundations will be installed below the base of Elmer Brook and below the maximum scour depth. We recommend that the designer consider requiring a sheet pile wall/cofferdam for temporary earth support and to allow for the construction of footings in the dry. The wall/cofferdam should also be designed to protect the work during periods of high water levels in Elmer Brook. Dewatering may also be required to install other culvert elements, such as wingwalls. The sheet piles should be embedded a sufficient depth for lateral support and to limit the infiltration of water from the brook into the construction excavations. The contractor should evaluate the potential for basal heave when designing earth support and dewatering systems and include provisions to prevent this condition from occurring.

## Table 3
## Properties and Design Parameters for Shallow Foundations Bearing on 1-foot Crushed Stone over Varved Clay

| Property/Design Parameter | Recommended Value |
|---|---|
| Angle of Internal Friction | 22 Degrees |
| Soil Unit Weight | 110 pcf |
| Interface Friction Angle[1] | 18 degrees (Cast in Place)<br>14 degrees (Precast) |
| Friction Factor[1] | 0.33 (Cast in Place)<br>0.31 (Precast) |
| Strength Limit State – Nominal Bearing Resistance[4] | 3.3 ksf |
| Strength Limit State – Factored Bearing Resistance[4] | 1.5 ksf |
| Service Limit State – Bearing Resistance for Settlement of 1 inch[4] | 1.0 ksf |
| Bearing Resistance Factor[2], $\varphi_b$ | 0.45 |
| Sliding Resistance Factor[2,3], $\varphi_\tau$ | 0.85 |
| Passive Earth Pressure Component of Sliding Resistance[2,3], $\varphi_{ep}$ | 0.50 |

Notes:

1. Interface friction and friction factor for Crushed Stone in contact with concrete from AASHTO Table 3.11.5.3-1.2.
2. Bearing and sliding resistance factors from AASHTO Table 10.5.5.2.2-1.
3. Sliding resistance factors for footings placed on Crushed Stone leveling pad.
4. Bearing resistance values for foundations immediately underlain by a minimum 12-inch layer of Crushed Stone. Bearing pressures should be evaluated on the basis of the “effective footing width” in accordance with Article 10.6.1.3 of the AASHTO LRFD.
5. Minimum embedment depth will be the greater either frost depth (48 inches below finished grade) or scour depth. For this project, it appears scour depth will govern footing embedment.

## Table 4
## Soil Properties and Design Parameters for Headwalls, Wingwalls[1,2]

| Soil Property/ Design Parameter | M1.03.0 Type B Gravel Borrow | Native Soils and Fill |
|---|---|---|
| Angle of Internal Friction | 36 degrees | 22 degrees |
| Soil Unit Weight | 125 pcf | 110 pcf |
| Equivalent Fluid Pressure (Active)[3] | 35 pcf | 35 pcf |
| Interface Friction Angle[4] | 22 degrees | 15 degrees |
| **Earth Pressure Coefficients** | | |
| Active, $K_a$ | 0.26 | N/A[5] |
| At-Rest, $K_0$ | 0.41 | N/A |
| Passive, $K_p$[6] | 3.00 | N/A |
| Dynamic, $K_{ae}$ | 0.34 | N/A |

Notes:

1. Values presented in this table assume drained soil conditions.
2. Appropriate Resistance Factors from AASHTO LRFD Bridge Manual Table 11.5.7.1 should be applied.
3. Equivalent fluid pressure assumes that retaining walls will be unbraced and free to deflect (cantilevered).
4. Interface friction assumes soil in contact with formed/precast concrete.
5. N/A indicates that the material is Not Applicable for use below footings or behind retaining walls and should be removed.
6. We recommend passive resistance be neglected for soils subject to frost and/or scour.

## 2.0 INTRODUCTION

### 2.1 Scope of Report

This report provides preliminary geotechnical engineering recommendations for foundation design of the proposed replacement culvert to carry Elmer Brook beneath Pearl Street in South Hadley, Massachusetts. The location of the Site is shown on Figure 1. This report also addresses earthwork considerations associated with the proposed construction.

### 2.2 Subject Background, Proposed Construction, and History

### *2.2.1 Existing Conditions*

The existing corrugated metal pipe culvert carries Elmer Brook, which flows from north to south within the Site area, beneath Pearl Street. The existing culvert and brook alignment are shown on the attached Boring Location Plan. The existing culvert has a diameter of 6 feet and length of approximately 47 feet. The inlet and outfall invert elevations of the existing culvert are shown on a 2022 survey by Guntlow and Associates to be at 118.55 and 118.03 feet, respectively.

The roadway surface in the subject area is approximately 8.5 feet above the brook (or near elevation 127.5 feet). The soils in the streambed consist of medium sand.

Buried water lines are located in the southern (eastbound) travel lane and off the shoulder of the road. These utilities appear to cross the location of the existing pipe culvert. In addition, overhead electric power and communication lines are located along the northern shoulder of the road.

### *2.2.2 Proposed Construction*

The alternative selected for this project calls for the removal of the existing pipe culvert, and its replacement with an open-bottom culvert. The structure type has not been selected; however, we understand that a corrugated metal pipe arch type culvert with a span of 16 feet is currently being considered. The invert elevations for the replacement culvert will be 118.27 and 118.0 at the inlet and outlet, respectively. We understand that the foundation system and other elements of the replacement culvert will be chosen based, in part, upon the conditions described and recommendations provided in this report. We anticipate that the replacement culvert will be founded upon traditional concrete spread footings bearing below the design scour depth.

### 2.3 Site Reconnaissance and Overall Description

The Site is located on Pearl Street, approximately 1,550 feet to the east of the intersection with Hadley Street (Route 47) in South Hadley, Massachusetts. The state (MassDOT) and federal classification for Pearl Street is ‘other principal arterial’ (Code 3). An existing conditions survey plan has been completed for this location, which was used to generate the attached Boring Location Plan. Topography along the roadway near the proposed culvert is generally flat (at approximate elevation 127.5 feet), but the roadway slopes gently upwards toward the east and west approaches. The roadway embankment slopes downwards towards the north and south, towards Elmer Brook and the associated waterfront areas. The existing culvert at this location consists of a 6-foot diameter corrugated metal pipe, with an inlet invert of 118.55 to the north of Pearl Street and an outfall invert of 118.03 to the south. Therefore, the base of the existing culvert is approximately 9 to 9.5 feet below the roadway surface. The top of the existing culvert is approximately three feet below the pavement surface. The location of the existing culvert is shown on the attached Boring Location Plan.

The streambank of the brook is shown near elevation 119.5 feet to the north of Pearl Street and approximately 118 feet to the south. At the time of the 2022 survey, the brook was relatively shallow at the culvert location, with a maximum depth on the order of two to three feet (we anticipate that the depth of the stream will vary based upon rainfall and snow melt). The subject area is located within National Flood Insurance Program (NFIP) identified 100-year (Zone A) and 500-year (Zone B) flood boundaries[1]. The base flood elevation (100-year event) is approximately 121 feet (NGVD 29) and has a regulatory floodway width of approximately 55 feet adjacent to Pearl Street. Therefore, the 100-year flood elevation is approximately six feet below the roadway level and up to ten feet above the likely foundation level for the new crossing. The 500-year flood is shown to have an approximately 215-foot regulatory floodway width immediately adjacent to Pearl Street.

## 3.0 SUBSURFACE CONDITIONS

### 3.1 Local Geology

We reviewed the surficial geologic map for the Mount Holyoke Quadrangle[2] to evaluate likely geologic conditions at the Site. This map indicates Elmer Brook flows through flood plain alluvium underlain by fine grained post-glacial lake deposits at this crossing. The glacial lake deposits include alternating layers of clay and sandy silt, commonly known as varved silt and clay. A Surficial Geologic Map of the Site area is provided as Figure 3. We note that Pearl Street appears to have been constructed on an earth embankment spanning a low-lying area.

### 3.2 Subsurface Exploration Program and Testing

Subsurface investigations consisted of seven soil borings performed on November 10 and 11, 2022, by Seaboard Drilling of Chicopee, Massachusetts. The borings were performed using a Mobile B-53 truck mounted drill rig and were advanced using drive and wash drilling techniques.

Each boring was performed within the roadway or along the shoulder of Pearl Street (at the top of the roadway embankment), approximately 15 to 50 feet (horizontally) from the existing pipe culvert and 18 to 30 feet from the water edge. The boring locations were

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[1] U.S. Department of Housing and Urban Development (1979). “Flood Insurance Rate Map: Town of South Hadley, Massachusetts, Hampshire County”, *National Flood Insurance Program*, Community Panel Number 250170 0005 A, Panel 5 of 10.

[2] Stone, Janet R. & DiGiacomo-Cohen, Mary (2018). “Surficial Materials Map of the Springfield North Quadrangle, Massachusetts” *US Geological Survey*, Scientific Investigations Map 3402, Quadrangle 45 – Springfield North.

selected based upon rig access and proximity to overhead and buried utilities. Four of the borings (PS-2A, PS-2B, PS-3A and PS-3B) encountered drilling refusal on an unknown obstruction approximately 15 to 20 feet from the edge of the existing culvert. Boring PS-1 was terminated when a geosynthetic fabric was encountered at a depth of six feet. We recommend that the nature of these obstructions be investigated further, prior to the start of construction. No obstructions were encountered at boring locations PS-2C and PS-3C (which were located approximately 35 to 45 feet from the edge of the existing culvert). Boring locations are shown on the attached Boring Location Plan. Boring logs are provided in Appendix B.

Soil samples were collected continuously from the ground surface, until native soils were encountered, and at five-foot intervals thereafter. Soil samples were collected using a two-inch diameter split spoon sampler, driven 24 inches with a 140-pound automatic hammer falling 30 inches (American Society for Testing and Materials Test Method D1586 “Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils”). The number of blows required to drive the sampler each six inches was recorded. The standard penetration resistance, or N-value, is the number of blows required to drive the sampler the middle 12 inches. Soil properties, such as strength and density, are related to the N-value. The field N-values are corrected to a standard 60% hammer efficiency, known as $N_{60}$, to account for differing depth, sampler type, borehole diameter, and hammer efficiencies for each hammer type and drill rig. The N-values presented on the boring logs are field values, which are not adjusted for hammer efficiency. However, the adjusted $N_{60}$ values were used in our engineering calculations and analysis.

An O’Reilly, Talbot & Okun Associates, Inc. (OTO) engineer observed and logged the borings. Samples were classified according to a modified version of the Burmister Soil Classification System. Borings performed in the roadway were finished with a surface layer of cold patch asphalt.

### *3.2.1 Grain Size Analysis*

Two composite soil samples were analyzed for grain size distribution (sieve only) by Allied Testing Laboratories of Springfield, Massachusetts. These tests were performed to evaluate the suitability of on-Site soils for use as engineered fill. Results are discussed below.

### *3.2.2 Field Strength Testing*

Field strength testing was performed on selected samples of the silt and clay using pocket torvane (E-285 Pocket Vane Shear Tester) and pocket penetrometer devices. These field measurements are intended to provide a rough measure of the strength of fine-grained soils. The pocket penetrometer provides a measure of the unconfined compressive strength of soil by failing the clay by “punching”. The torvane device provides an estimate of the undrained shear strength of fine-grained soils by failing the silt and/or clay in a rotational shearing mode. Theoretically, the unconfined compressive strength is twice the undrained shear strength. A total of six pocket penetrometer and torvane tests (each) were completed in the field. Pocket torvane and pocket penetrometer results are presented on the attached boring logs and are discussed below.

#### *3.2.3 In-Situ Moisture Content*

Selected samples collected from the varved silt and clay layer were analyzed for moisture content determination. Published correlations between moisture content and engineering properties of the varved silt and clay were used to determine the design parameters recommended in this report.

#### *3.2.4 Rock Cores*

Bedrock cores were collected from borings PS-2C and PS-3C. The rock cores were obtained using a two-inch diameter, double core barrel with diamond bit. No down pressure was applied during the core runs. Rock drilling times (minutes per foot) were recorded. In addition, the Rock Quality Designation (RQD) and Rock Mass Quality (RMQ) were determined based upon the samples collected from each rock core. An OTO geologist classified each core. Rock core information is presented on the boring logs, provided in Appendix B. Photographs of the rock cores are provided in Appendix C.

### 3.3 Verification of Sample Descriptions on Boring Logs

I, Dustin A. Humphrey, a Massachusetts registered professional engineer, attest that I visually and manually examined all soil and rock samples as part of the preparation of this geotechnical report. Samples collected from the subsurface investigations were reviewed at the O'Reilly, Talbot, & Okun Associates, Inc. office, located in Springfield, Massachusetts on December 6, 2022. The soil and rock descriptions presented on the boring logs are consistent with the soil samples and rock cores collected during the Site explorations.

### 3.4 Subsurface Profile

Subsurface conditions were interpreted based upon information collected in the soil borings and upon our review of published geologic maps. In general, subsurface conditions at the boring locations consisted of the following, in order of increasing depth: a surface layer of asphalt or topsoil; organics and non-engineered fill; native fine-grained soils; and bedrock. We note that the borings were performed at the top of bank, approximately 20 feet (horizontally) from the bank of Elmer Brook. The ground surface elevation at each boring location is approximately 11 to 12 feet above the level of the brook channel bottom.

Soil conditions are generally favorable for the proposed construction, and it appears that the foundation for the new culvert will bear in the upper, medium stiff varved clayey silt layer present below elevation 114 feet. Since the new culvert foundations will be near or below the brook level, the control of water will be a significant construction consideration.

We note that the descriptions of. Cross Section A-A', which is provided as Figure 4, is based upon subsurface conditions that have been inferred from the soil borings. We note that actual conditions may vary and include localized variations. A summary of the conditions encountered in each of the soil borings is provided in Table 1.

### 3.4.1 Soil Conditions

*Asphalt and Topsoil*: Three inches of topsoil was present at the ground surface in boring PS-1. The topsoil generally consisted of medium sand with trace silt and organics (roots). The remaining borings were performed in the existing roadway. The pavement generally consisted of 6.5 inches of asphalt, underlain by two inches of granular base consisting of medium sand and gravel.

*Non-Engineered Fill*: Non-engineered fill was encountered in each of the borings. The fill soils generally consist of a loose to very loose gravelly sand or medium sand. These soils were likely placed to achieve final grades for the existing roadway. Therefore, the deepest fill likely coincides with the location of the existing pipe culvert. We note that four of the borings encountered drilling refusal at a depth of two to six feet below the roadway surface and one of the borings encountered a geosynthetic fabric at a depth of six feet. It is unknown if the refusals or fabric are related to the existing culvert, embankment fill material, a previous structure at this location, or an unknown buried utility. We recommend that this be investigated further.

*Organics and Silty Sand*: An organic soil layer consisting of a silty sand with organics and wood fragments was observed between a depth of 10 and 13 feet. The organic layer was observed in boring PS-3C, near the center of a silty sand layer that extended from approximately 6 to 13.5 feet below ground surface (elevation 121.5 to 114 feet). The organic material is an unsuitable bearing material and should be completely removed from beneath footings for the culvert and wingwalls. We note that the depth of the organic layer may vary based upon proximity to the current alignment of and historic meanders of Elmer Brook.

*Varved Clay*: Fine grained soils were encountered beneath the surficial fill at a depth of 13 to 13.5 feet, corresponding to elevations 114 to 114.5 feet. This soil generally consisted of very soft to medium stiff varved clayey silt and fine sand. The proposed culvert will likely bear near the top of this layer. The upper five feet of this layer was medium stiff, below which the varved silt and clay became soft. The bottom of varved silt and clay was present at a depth of between 33 and 40 feet.

*Fractured Bedrock*: Bedrock was encountered at a depth of 33 to 40 feet below ground surface, corresponding to approximate elevations 87.5 to 94.5 feet. Little or no glacial till was observed over the bedrock surface. The upper one foot of rock at boring location PS-2C and the upper three feet of rock at boring location PS-3C were fractured and were penetrated with little to moderate difficulty using the drill bit. Bedrock cores, described below, were collected from the underlying competent bedrock after bit refusal was encountered.

### 3.4.2 Results of Field Testing and Laboratory Analysis

Two composite samples were analyzed for grain size distribution (sieve only). The samples consisted of soil from the upper 0.5 to 3 feet in borings PS-2A and PS-3B. Both samples are classified (based on lab results) as fine to medium sand with some fine gravel, little coarse sand, and trace amounts of fines (silt and clay). The laboratory results indicate that the on-Site soils do not meet criteria for reuse as engineered fill. We note that the is close to meeting requirements for use as Gravel Borrow or Special Borrow. It may be possible to amend the existing on-Site soils by adding coarser material, such as Crushed Stone, to meet the requirements for these engineered fill types.

The unconfined compressive strength of the clay stratum was estimated in the field using a pocket penetrometer and the undrained shear strength was estimated using an E-285 Pocket Vane Shear Tester. These field measurements are intended to provide a rough measure of the engineering properties of the fine-grained soils. Vane Shear measurements of shear strength ranged from approximately 200 to 1,200 pounds per square foot (psf). Pocket penetrometer measurements of unconfined compression strength ranged from approximately 500 to 2,000 psf. Pocket vane shear and penetrometer test results are presented in the boring logs, attached as Appendix B.

Nine samples collected from the varved silt and clay layer were analyzed for in-situ moisture content. The moisture content of the fine-grained stratum ranged from 32 to 56 percent. Individual moisture content values are presented on the attached boring logs.

#### *3.4.1 Bedrock Conditions*

Rock cores were obtained from the competent rock encountered at the bottom of borings PS-2C and PS-3C. The locations of the borings are shown on the attached boring location plan. The elevation, run times, recovery, rock quality designation (RQD), and rock mass quality (RMQ) are presented on the boring logs, provided in Appendix B. A summary of rock conditions, based upon the cores collected is provided in Table 2. Rock core photographs are provided in Appendix C.

A total of 20-feet of rock core was attempted. At both locations PS-2C and PS-3C, the upper five-foot core run was completed successfully, but the barrel jammed during the second run. A total of 9.3 and 7.5 feet of rock core was completed at locations PS-2C and PS-3C, respectively.

Core recovery is the ratio of the length of core recovered to the length drilled and ranges from 0 percent for no core recovery to 100 percent for total recovery. Total core recovery ranged from 27 to 100 percent. Drilling times ranged from approximately 2.5 to 11 minutes per foot.

The rock recovered generally consisted of a dark gray basaltic lahar, which has significant voids in the rock mass, that transitioned to diorite and basalt with depth. The rock is consistent with the Granby Basaltic Tuff formation described on bedrock geology maps for the area[3], which is igneous rock of the Lower Jurassic epoch. We note that the Site is located near the foot of the Holyoke Range and rock formations are closely banded in this region. Therefore, the rock types present may change quickly over short lateral and vertical distances.

The upper portion (core C-1) of rock recovered from both locations is slightly fractured with slight weathering at the edge of open fractures. Fractures were typically straight and

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[3] Zen, E. et al. (1983). “Bedrock Geologic Map of Massachusetts” *US Geological Survey*.

dipped approximately 20 to 30 degrees from horizontal. The lower portion (core C-2) was generally intensely to slightly fractured with slight weathering at the edge of open fractures. Fractures in the lower portions dipped approximately 20 to 45 degrees from horizontal.

Rock mass properties can be described using the rock quality designation (RQD)[4], which is a modification of core recovery: the intact pieces of core longer than four inches are added together, the sum is divided by the total run length (typically 60 inches for a standard core run); and the resultant is multiplied by 100 to obtain percent RQD. Table 2 presents a summary of RQD values, which ranged from 7 to 65%. Both the recovery and RQD of rock increased with depth. The rock mass quality (RMQ) ratings were ‘poor’ to ‘fair’.

### *3.4.2 Groundwater Conditions*

Groundwater was encountered in borings PS-2C and PS-3C at a depth of 8 to 8.5 feet below ground surface, corresponding to approximate elevation 119 feet. This groundwater elevation was near the water level in the brook at the time of our explorations. We note that groundwater will vary with changing water levels in Elmer Brook.

## 3.5 Seismic Design Category Evaluation

Earthquake loadings must be considered under requirements of the 2021 MassDOT *Bridge Manual* (MassDOT) and the most recent version of AASHTO *LRFD Bridge Design Specifications* (AASHTO).

Section 3.4 of MassDOT covers seismic analysis and design. Lateral forces generated during a seismic event are dependent on the type and properties of soils present beneath the Site as well as geographic location. The *USGS Seismic Design Maps* web service was used to determine seismic parameters for the Site. The peak ground acceleration (PGA), as well as the maximum considered earthquake spectral response accelerations for short periods ($S_s$) and for one-second ($S_1$) were determined to be 0.058, 0.13, and 0.039, respectively, for South Hadley, Massachusetts. These values are for a non-critical/non-essential bridge and based upon a seven percent probability of exceedance in 75 years for a 1,000-year event.

Soil properties are represented through Site Classification. Procedures for the Site-specific determination of Site Classification are provided in Article 3.10.3.1 of AASHTO. At this Site, we evaluated Site Classification using Standard Penetration Resistance (SPT N-value). Using the SPT N-value, the Site was determined to be Site Class D. Furthermore, the Site coefficients $F_{pga}$, $F_a$, and $F_v$ are determined using the PGA, $S_s$, and $S_1$ values and the Site Class. For Site Class D, $F_{pga}$, $F_a$, and $F_v$ were determined to be 1.6, 1.6, and 2.4, respectively.

---

[4] Deere, D.U. (1968). “Technical Descriptions of Rock Cores for Engineering Purposes”, *Rock Mechanics and Engineering Geology* Vol. I/1, pp. 16-22.

### 3.6 Liquefaction Potential

The potential for liquefaction of the saturated Site soils was evaluated. Based upon the fine-grained nature of the varved silt and clay soils, it is unlikely that liquefaction would occur under the design earthquake.

Seismic design and analysis of the proposed culvert should be performed in accordance with the specifications provided in the 2021 MassDOT *Bridge Manual* and the most recent AASHTO *LRFD Bridge Design Specifications*.

## 4.0 RECOMMENDED FOUNDATION SYSTEM

The following recommendations are provided for preliminary design of culvert and wingwall foundations. Foundations will be designed to resist lateral and vertical loads. Vertical loads consist of downward pressures due to the dead weight of the culvert, the weight of soils on the culvert roof, and live traffic loads, as well as uplift pressures due to overturning loads (such as buoyant and seismic forces). All foundations should be designed according to requirements provided in the 2021 MassDOT *Bridge Manual* (MassDOT) and the most recent AASHTO *LRFD Bridge Design Specifications* (AASHTO). We anticipate that the most appropriate foundation system will be spread footings bearing on a one-foot-thick (minimum) layer of Crushed Stone, over the medium stiff varved clay.

### 4.1 Existing Foundation

Construction drawings were not available at the time of this report. However, we anticipate that the existing pipe culvert was bedded on an imported crushed stone layer over the natural medium stiff varved silt and clay layer present below elevation 114 feet. Therefore, we do not anticipate the presence of any associated substructures, such as abutments or foundations. We note that obstructions were encountered in four borings and a geosynthetic fabric was encountered in another. These should be evaluated during final design.

### 4.2 Embankment Considerations

We anticipate that the proposed culvert will penetrate the existing embankment along Pearl Street. Therefore, the fills anticipated as part of this project will include:

- Placement of Crushed Stone beneath footings
- Backfill around and over the new culvert
- Replacement of soils disturbed during construction
- Backfill against wingwalls
- Placement of Processed Gravel for Subbase (M1.03.1) beneath final pavements after the culvert is constructed

Since the installation of the new culvert will involve the removal of soil, which will reduce the stress on the underlying varved silt and clay, post-construction settlement should be small. Therefore, geotechnical concerns associated with the settlement or global stability of embankment soils are not significant. Earthwork recommendations provided in Section 5.0 should be followed.

## 4.3 Deep Foundations

At this time, we do not anticipate that deep foundations will be used to support the proposed replacement culvert.

## 4.1 Spread Footing Foundations for Culverts and Wingwalls

The proposed culvert and associated wingwalls may be founded upon shallow spread footings bearing on a one-foot-thick (minimum) layer of Crushed Stone over native Site soils. Table 3 provides soil properties and design parameters for use in design of spread footings. Spread footings should bear a minimum of four feet below adjacent ground surface for frost protection. Footings should also extend below the design scour depth and below organic soils layers, whichever is greater. Therefore, we anticipate that footings for the new culvert and wingwalls will bear in the varved clay. Additional recommendations for design of footings can be provided after foundation systems for the culvert and associated wingwalls have been selected.

We recommend that a geosynthetic separation fabric be placed beneath and around the Crushed Stone layer beneath footings to prevent the migration of stone into the underlying clay.

### *4.1.1 Lateral Earth Pressures*

Static lateral earth pressures will be imposed against the proposed culvert, wingwalls, and any other earth retaining structures (such as earth support systems used during construction). In addition, dynamic lateral earth pressures under the design earthquake must be considered. These structures should be backfilled with MassDOT Gravel Borrow (M1.03.0 Type B). A drainage system should be provided as required by MassDOT specifications. Soil properties and design parameters for the determination of lateral loading under drained conditions are provided in Table 4.

### *4.1.2 Scour Protection*

We understand that a scour analysis for the 100 year design storm has been performed by others, and the modeled scour depth is on the order of 5.5 feet below the stream bed elevation at the culvert (or elevation 112.5 feet based upon a stream bed elevation of 118.0 feet). We recommend that scour-reduction features be incorporated into final design of the replacement culvert to reduce scour and minimize the modeled scour depth.

## 5.0 CONSTRUCTION CONSIDERATIONS

### 5.1 Groundwater Considerations and Recommended Method for Water Control

Groundwater was encountered at a depth of approximately 8.5 feet below ground surface, corresponding to approximate elevation of 119 feet. We note that the groundwater levels will likely be higher in the future, due to fluctuations in the water level of Elmer Brook. We note that the 100-year flood elevation is approximately 121 feet in the Site vicinity.

Based upon the observed groundwater levels and potential water levels in Elmer Brook, it is likely that groundwater will be present in excavations for foundations and the installation of the new culvert. During periods of relatively low water levels, it should be possible to dewater small, short duration excavations extending only a couple feet into the water table using sump pits and submersible pumps or well points. However, for work during high water periods, the contractor will either need to stop work or install a more robust system (such as sheet pile cutoff walls) around excavations to cut off groundwater flow. The contractor should review the results of the design phase hydraulic analysis (and supplement with their own analyses as appropriate) to evaluate potential water, which will need to be considered for construction.

### 5.2 Engineered Fill Recommendations

Four types of engineered fill are recommended:

- Gravel Borrow (MassDOT designation M1.03.0, Type B) for use immediately behind culvert walls and wingwalls
- Processed Gravel for Subbase (M1.03.1) for use immediately below pavements
- Special Borrow (M1.02.0) for use as miscellaneous fill
- Crushed Stone (M2.01.4) for use immediately below footings, in drainage structures, and in place of Gravel Borrow

Grain size distribution requirements are presented in Table 5. The existing Site soils do not meet requirements for reuse as engineered fill.

#### *5.2.1 Compaction Recommendations*

We recommend that final footing subgrade excavations be completed with a smooth-bladed excavator bucket to prevent disturbance to the varved silt and clay subgrade. As discussed above, footings should be underlain by a minimum one-foot-thick layer of Crushed Stone to protect the subgrade from disturbance and provide a firm bearing surface. The Crushed Stone layer should be surrounded by a geosynthetic separation fabric to prevent the migration of the Crushed Stone into the underlying clay.

Compacted fill should be placed in lifts ranging in thickness between 6 and 12 inches depending on the size and type of equipment. Recommended degrees of compaction and compaction means and methods are presented on Sheet 1. Compaction within five feet of the culvert or wingwalls should be performed using a hand-operated roller or vibratory plate compactor weighing 250 pounds or less.

**Table 5**
**Grain Size Distribution Requirements**

| **Fill Type/Use** | Gravel Borrow | Processed Gravel for Subbase | Special Borrow | Crushed Stone |
|---|---|---|---|---|
| **MassDOT Designation** | M1.03.0, Type B | M1.03.1 | M1.02.0 | M2.01.4 |
| **Sieve Size** | **Percent Finer by Weight** | | | |
| 3 inch | 100 | 100 | 100 (6" max) | --- |
| 2 inch | --- | --- | 90 – 100 | --- |
| 1 ½ inch | --- | 70 – 100 | --- | --- |
| 1 inch | --- | --- | --- | 100 |
| ¾ inch | --- | 50 – 85 | --- | 90 – 100 |
| ½ inch | 50 – 85 | --- | --- | 10 – 50 |
| ⅜ inch | --- | --- | --- | 0 – 20 |
| No. 4 | 40 – 75 | 30 – 60 | 20 – 65 | 0 – 5 |
| No. 50 | 8 – 28 | --- | --- | --- |
| No. 200 | 0 – 10 | 0 – 10 | 0 – 12 | --- |

## 5.3 Excavations

The need for temporary earth support should be evaluated by the contractor. Sloping and earth support may be needed if the excavation cannot be safely sloped to remove debris fill soils, install utilities, and construct the new culvert and its associated foundations. As discussed above, sheet pile cutoff walls may be needed to limit water infiltration into excavations. The contractor should evaluate the potential for basal heave when designing earth support and dewatering systems and include provisions to prevent this condition from occurring.

### *5.3.1 Removal of Existing Culvert and Obstructions*

The existing culvert will be removed as part of this project. The excavation should be backfilled with Special Borrow compacted to a minimum of 95% of the maximum dry density (as determined by ASTM D1557). If the excavation extends below the groundwater table, it may be appropriate to backfill portions of the excavation below the groundwater table with Crushed Stone. The obstructions encountered in four of the borings may also have to be removed prior to the installation of the new culvert.

Abandoned buried utilities containing asbestos (such as electrical conduit insulation or transite pipe) are commonly found during construction excavations. Furthermore, former structures (pipes, conduits, foundations walls) may contain or be covered with materials containing asbestos. Such materials should be handled in accordance with MassDEP's asbestos regulations (310 CMR 7.15). We recommend that suspect materials be managed appropriately and tested by a Department of Labor Standards (DLS) certified asbestos inspector prior to disturbances.

### *5.3.2 Sloping and Earth Support*

Soil may become unstable when excavations extend deeper than four feet or beneath the groundwater table. The upper non-engineered fill and native silty sand encountered in the upper 20 feet are estimated to be Type C soils for slope stability purposes. The maximum allowable slope for excavations of Class C soils is 1.5H:1V (34°). All excavations should conform to current OSHA requirements. These conditions apply only to excavations above the groundwater table. We note that protective systems for any excavation exceeding 20 feet in depth must be designed by a registered professional engineer. All excavations should conform to current OSHA requirements. The contractor should also follow requirements in 29 CFR 1926.651(H)(3) for excavations that interrupt the natural drainage of surface water.

In areas where sloping is not feasible, a temporary earth support system will be required during construction. The design and engineering of the temporary earth support systems should be the responsibility of the contractor. Prior to construction, we recommend that the contractor evaluate the need for a temporary earth support system to protect the existing roadway and personnel during construction.

### 5.4 Obstructions

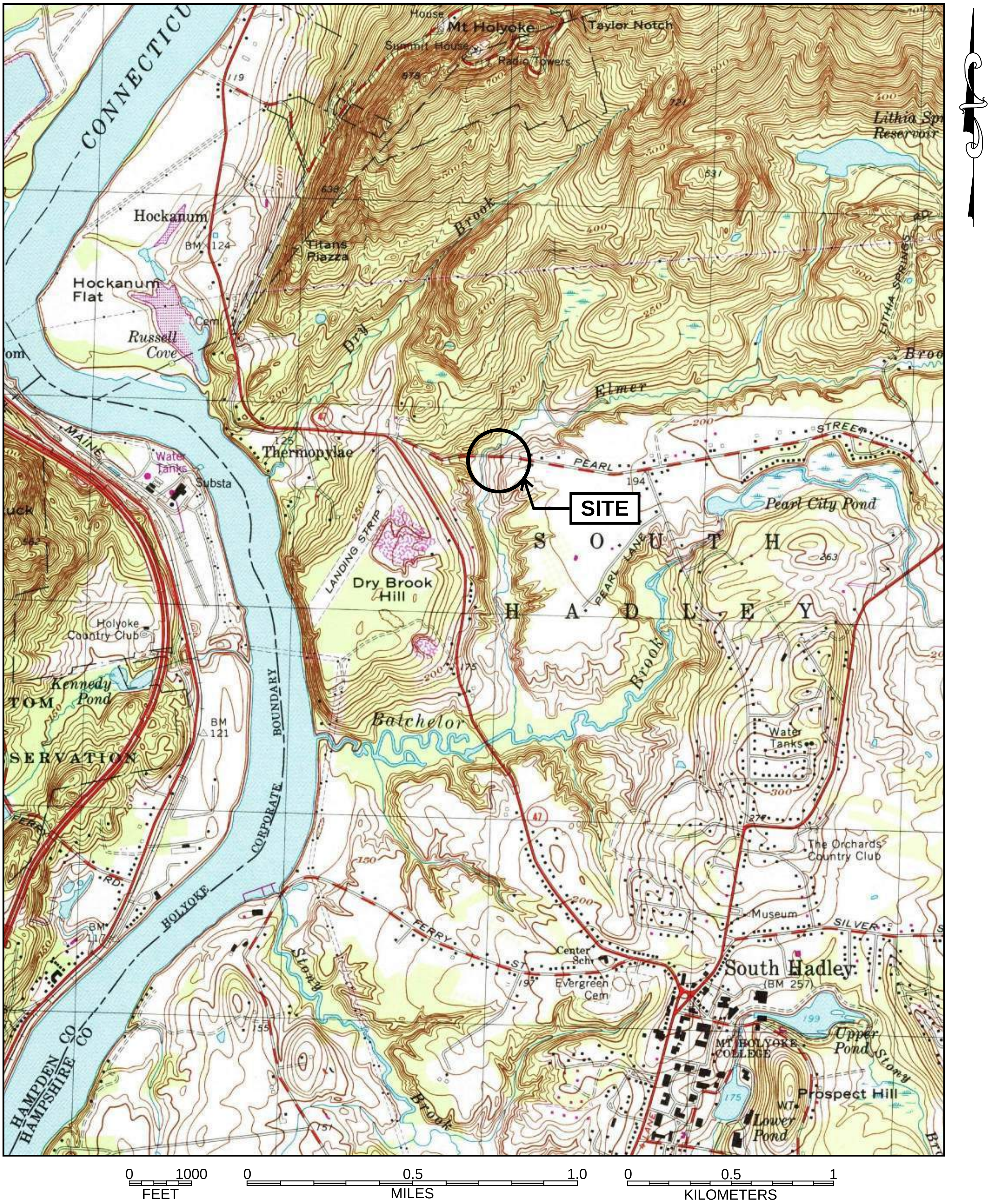
Large boulders, cobbles, or other obstructions may be encountered in the non-engineered fill. We recommend that provisions be made to remove obstructions, if encountered.

### 5.5 Protection of Adjacent Structures and Utilities

The nearest residences are located at 344 and 349 Pearl Street and are approximately 700 and 775 feet from the existing culvert, respectively. We anticipate vibrations associated with construction will be negligible at these residences. Nearby utilities include water and sewer that cross the existing culvert. Therefore, vibration monitoring is recommended during the installation of sheet piles. The contractor should evaluate the need for support and/or geotechnical monitoring of adjacent utilities.

# FIGURES

O'Reilly, Talbot & Okun
ENGINEERING ASSOCIATES



1:25,000 SCALE NATIONAL GEODETIC VERTICAL DATUM 1929 10 FOOT CONTOUR INTERVAL

O:\J2900\2950 Fuss & O'Neill\22-01 Pearl Street, Elmer Brook, South Hadley, MA - Geotech\Figures

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PEARL STREET
CULVERT REPLACEMENT
SOUTH HADLEY, MASSACHUSETTS

SITE LOCUS

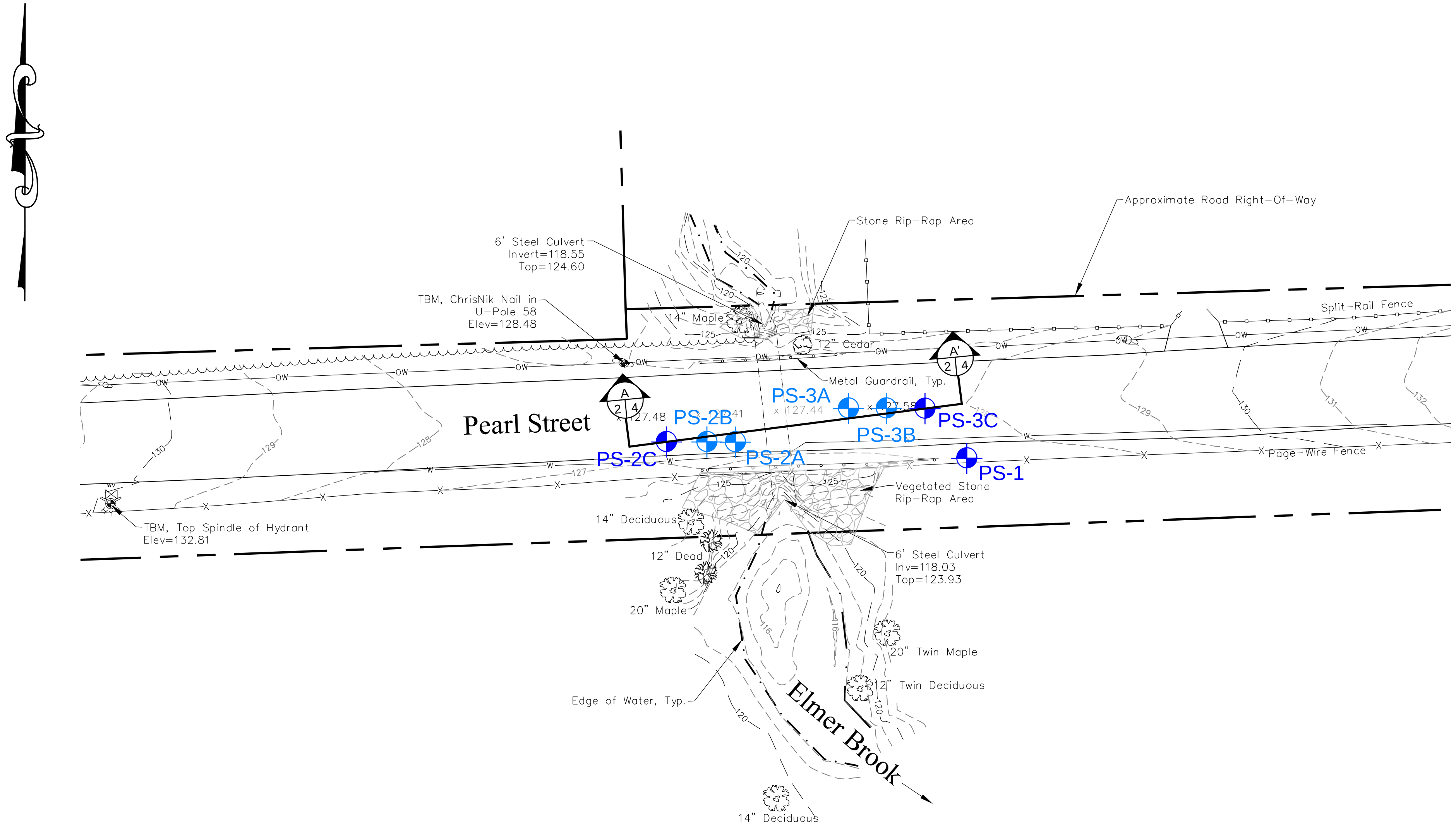
Topographic Map Quadrant: MOUNT HOLYOKE, MA

Map Version: 1964

Current As Of: 1979

Date: DECEMBER 2022

| | |
|---|---|
| PROJECT No. | J2950-22-01 |
| FIGURE No. | 1 |



## LEGEND

⊕ DEEP SOIL BORING LOCATIONS PERFORMED BY SEABOARD DRILLING FROM 11/10/2022 TO 11/11/2022, OBSERVED BY OTO

⊕ SHALLOW SOIL BORING LOCATIONS PERFORMED BYSEABOARD DRILLING FROM 11/10/2022 TO 11/11/2022, OBSERVED BY OTO

A 2|3 — A' 2|4
CROSS SECTION LABEL
FIGURE SHOWING CROSS SECTION
FIGURE CROSS SECTION IS CUT FROM

## NOTES

1. NORTHING AND EASTING IN US FEET, IN REFERENCE TO STATE PLANE ZONE MA M-2001
2. BASE MAP PROVIDED TO OTO IN ELECTRONIC FORMAT. ORIGINAL DRAWING TITLED "EXISTING CONDITIONS" (SHEET C1) BY GUNTLOW & ASSOCIATES, DATED 9/22/2022
3. SAMPLE LOCATIONS ARE SHOWN ACCORDING TO TAPED MEASUREMENTS TAKEN FROM EXISTING SITE FEATURES
4. ALL DATA IS TO BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHODS USED IN THE DEVELOPMENT OF THIS PLAN

SCALE IN FEET
1" = 40'
0' 20' 40' 100'

| BORING LOCATIONS (FEET) | | | | | |
|---|---|---|---|---|---|
| BORING | NORTHING | EASTING | STATION | OFFSET | SURFACE ELEV. |
| PS-1 | 2,929,907 | 362,051 | - | - | 127 |
| PS-2A | 2,929,910 | 361,988 | - | - | 127.5 |
| PS-2B | 2,929,909 | 361,981 | - | - | 127.5 |
| PS-2C | 2,929,912 | 361,973 | - | - | 127.5 |
| PS-3A | 2,929,919 | 362,018 | - | - | 127.5 |
| PS-3B | 2,929,920 | 362,029 | - | - | 127.5 |
| PS-3C | 2,929,921 | 362,039 | - | - | 127.5 |

PROJECT FILE NO. 2950-22-01

massDOT
Massachusetts Department of Transportation
Highway Division

# BORING PLAN OF
# PROPOSED BRIDGE IN
# SOUTH HADLEY

## PEARL STREET OVER
## ELMER BROOK

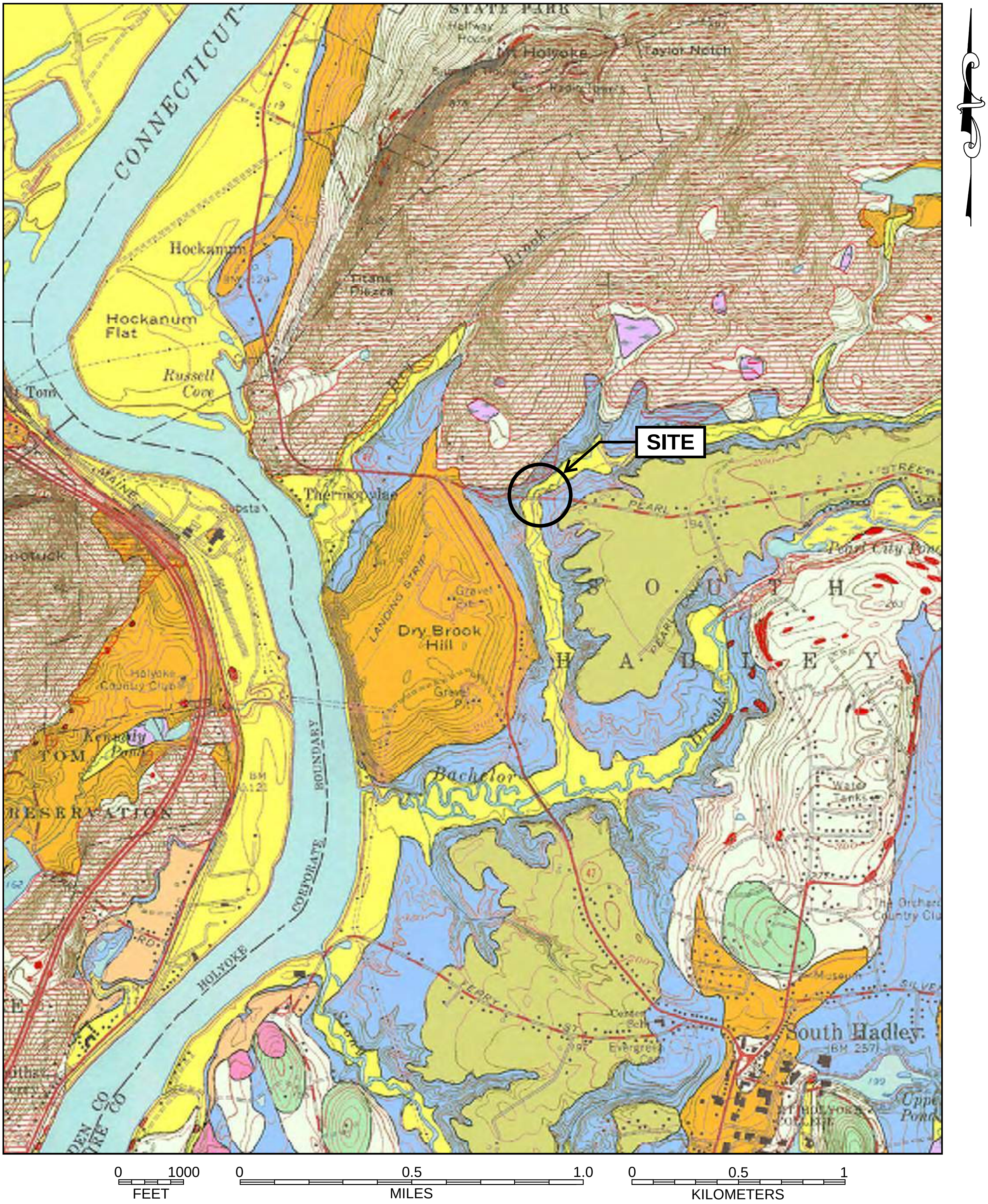
MASSACHUSETTS DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION

SCALE: 1" = 40'-0" JANUARY, 2023

BRIDGE NO. NOT YET DESIGNATED

O:\2900\2950 Fuss & O'Neill\22-01 Pearl Street, Elmer Brook, South Hadley, MA - Geotech\Fig 2 Boring Location Plan 2950-22-01.pdf

O:\J2900\2950 Fuss & O'Neill\22-01 Pearl Street, Elmer Brook, South Hadley, MA - Geotech\Figures & Lab Data\2950-22-01 Figure 3 Surficial Geologic Map 2022.9.21.pdf



1:24,000 SCALE NATIONAL GEODETIC VERTICAL DATUM 1929 10 FOOT CONTOUR INTERVAL

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PEARL STREET
CULVERT REPLACEMENT
SOUTH HADLEY, MASSACHUSETTS

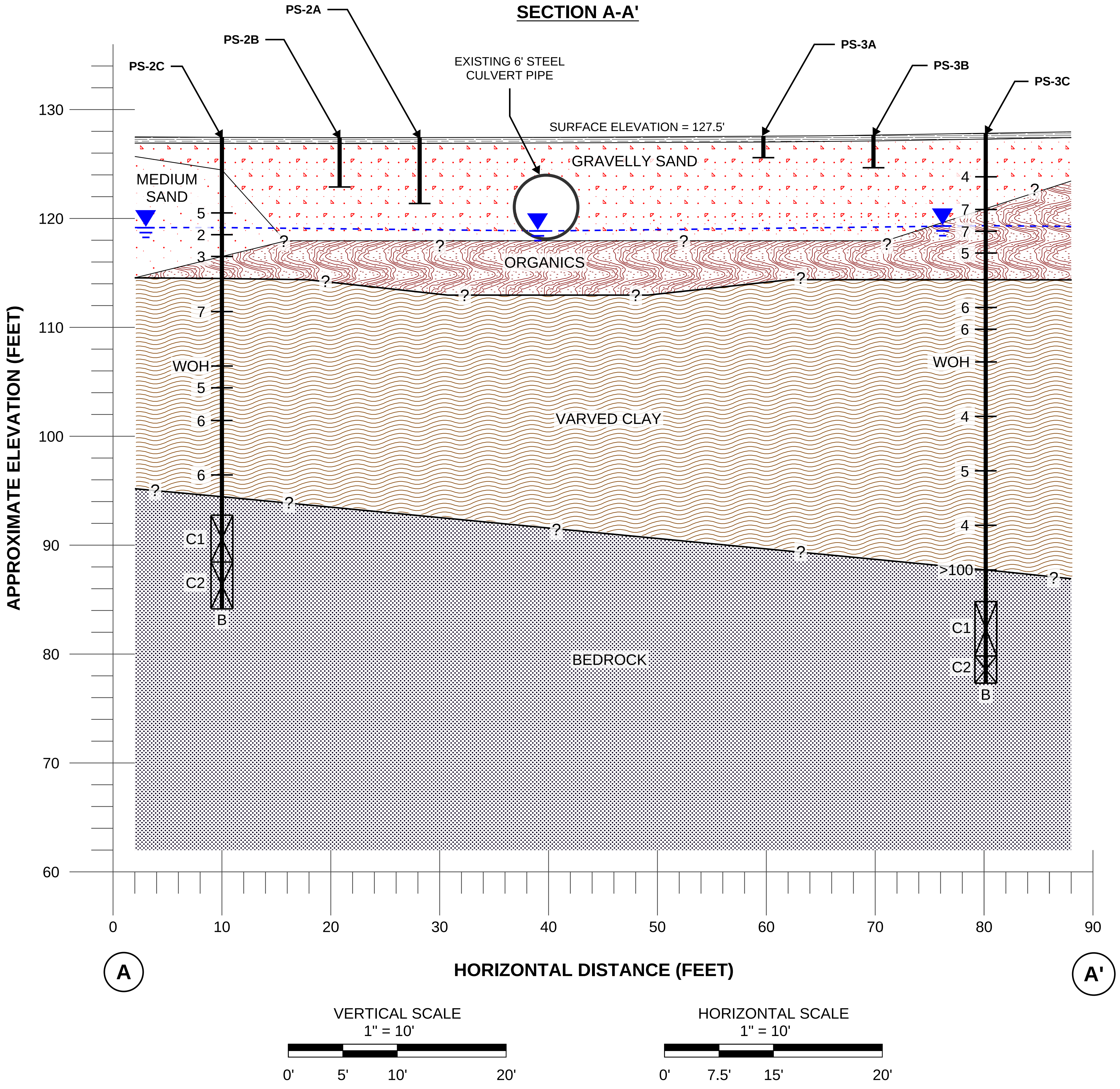
SURFICIAL GEOLOGIC MAP

Source:
"Surficial Materials Map of the Mount Holyoke Quadrangle, Massachusetts" US Geological Survey, Scientific Investigations Map 3402, Quadrangle 44 – Mount Holyoke, 2018

PROJECT No.
J2950-22-01

FIGURE No.
3

## SECTION A-A'



## LEGEND

▤ - ASPHALT: APPROXIMATELY 6.5 INCHES ASPHALT AND 2" AND GRANULAR BASE

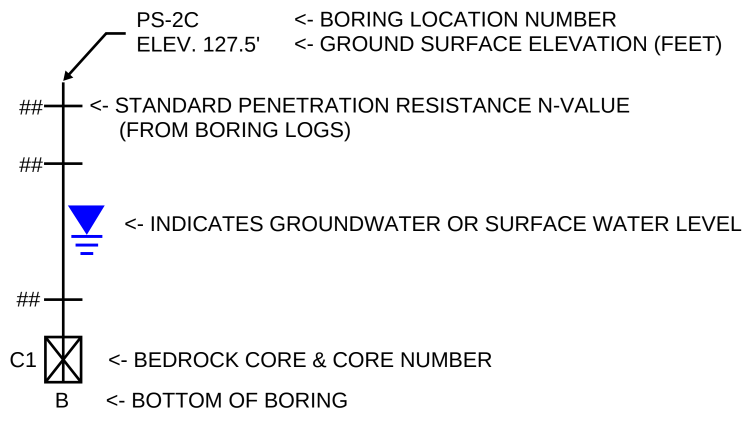
▨ - GRAVELLY SAND: MEDIUM DENSE TO VERY DENSE, MEDIUM SAND, SOME GRAVEL, LITTLE TO SOME COARSE SAND, AND LITTLE TO TRACE SILT. LIKELY LARGE COBBLES AND BOULDERS.

☐ - MEDIUM SAND: VERY LOOSE TO LOOSE, MEDIUM SAND WITH LITTLE COARSE SAND, LITTLE GRAVEL AND TRACE SILT

▨ - ORGANICS AND SILTY SAND: LOOSE, FINE TO MEDIUM SILTY SAND WITH WOOD FRAGMENTS

▤ - VARVED CLAY: LOOSE, VARVED FINE SAND AND CLAYEY SILT OR SOFT TO MEDIUM STIFF, VARVED CLAYEY SILT AND FINE SAND

▩ - BEDROCK: POOR TO FAIR, MODERATELY FRACTURED TO SLIGHTLY FRACTURED, SLIGHTLY WEATHERED



## NOTES

1. STRATIFICATION LINES ARE BASED UPON DATA OBTAINED IN WIDELY SPACED BORINGS AND THUS REPRESENT APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES. ACTUAL TRANSITIONS MAY VARY FROM THOSE SHOWN. INTERPRETATIONS OF THE INFORMATION HAVE BEEN MADE IN THE TEXT OF THIS REPORT.
2. WE NOTE THAT THE THICKNESS OF NON-ENGINEERED FILL MAY VARY SIGNIFICANTLY ACROSS THE SITE. LOCALIZED AREAS OF DEEP FILL ARE LIKELY PRESENT ADJACENT TO EXISTING ABUTMENT WALLS.
3. WATER LEVEL READINGS WERE OBTAINED FROM BORE HOLES AT THE TIMES AND UNDER THE CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THESE WATER LEVELS MAY OCCUR DUE TO VARIATIONS IN PRECIPITATION, RUNOFF, AND OTHER FACTORS.

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Designed By: CYI
Drawn By: CYI
Checked By: DAH
Date: 12/14/2022
Revised Date:

PEARL STREET
CULVERT REPLACEMENT
SOUTH HADLEY, MA

CROSS SECTION A-A'

PROJECT NO.
J2950-22-01

FIGURE NO.
4

O:\J2900\2950 Fuss & O'Neill\22-01 Pearl Street, Elmer Brook, South Hadley, MA - Geotech

# SHEETS

## Table 1-1
## Degree of Compaction Recommendations

| Location | Minimum Compaction |
|---|---|
| Below Structures (Foundations and Slabs) | 95% |
| Below Pavements/Sidewalks/Exterior Slabs | 95% |
| Against Basement Walls/Retaining Walls | 92% |
| Utility Trenches | 95% |
| General Landscaped Areas | 90% |

Notes.

1. Percentage of the maximum dry density as determined by Modified Proctor ASTM D1557, Method C.
2. When location falls into two or more categories, the engineer should be notified to determine appropriate compaction efforts and/or methods.
3. Crushed stone should be compacted in lifts of 12 inches to form a dense matrix using either traditional compaction methods (vibratory plate and/or roller) or tamping with an excavator bucket in deep excavations. It is generally not necessary to perform laboratory or field density testing on crushed stone.

## Table 1-2
## General Guidelines for Compaction Means and Methods

| Compaction Method | Maximum Stone Size (Inches Diameter) | Maximum Lift Thickness (Inches) | | Minimum Number of Passes | |
|---|---|---|---|---|---|
| | | Below Structures & Pavement | Non-Critical Areas | Below Structures & Pavement | Non-Critical Areas |
| Hand-operated Vibratory Plate and confined spaces | 3 | 6 | 8 | 6 | 4 |
| Hand-operated vibratory drum roller (less than 1000 pounds) | 3 | 6 | 8 | 6 | 4 |
| Hand-operated vibratory drum roller (at least 1,000 pounds) | 6 | 8 | 10 | 6 | 4 |
| Light vibratory drum roller (minimum 3000 pounds) | 6 | 10 | 14 | 6 | 4 |
| Heavy vibratory drum roller (minimum 6000 pounds) | 6 | 12 | 18 | 6 | 4 |

Note: The contractor should reduce or stop drum vibration if pumping of the subgrade is observed.

O:\J2900\2950 Fuss & O'Neill\22-01 Pearl Street, Elmer Brook, South Hadley, MA - Geotech\Figures & Lab Data\2950-22-01 Sheet 1 - Compaction 2022.10.17.pdf

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PEARL STREET
CULVERT REPLACEMENT
SOUTH HADLEY, MASSACHUSETTS

GENERAL COMPACTION GUIDELINES

DESIGNED BY: ALS
DRAWN BY: DAH
CHECKED BY: MJT
DATE: 11/15/2022
REV. DATE:

PROJECT No.
J2950-22-01

SHEET No.
1

APPENDIX A

# Limitations

# LIMITATIONS

1. The observations presented in this report were made under the conditions described herein. The conclusions presented in this report were based solely upon the services described in the report and not on scientific tasks or procedures beyond the scope of the project or the time and budgetary constraints imposed by the client. The work described in this report was carried out in accordance with the Statement of Terms and Conditions attached to our proposal.

2. The analysis and recommendations submitted in this report are based in part upon the data obtained from widely spaced subsurface explorations. The nature and extent of variations between these explorations may not become evident until construction. If variations then appear evident, it may be necessary to reevaluate the recommendations of this report.

3. The generalized soil profile described in the text is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized and have been developed by interpretations of widely spaced explorations and samples; actual soil transitions are probably more erratic. For specific information, refer to the boring logs.

4. In the event that any changes in the nature, design or location of the proposed structures are planned, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and conclusions of this report modified or verified in writing by O'Reilly, Talbot & Okun Associates Inc. It is recommended that we be retained to provide a general review of final plans and specifications.

5. Our report was prepared for the exclusive benefit of our client. Reliance upon the report and its conclusions is not made to third parties or future property owners.

# BORING LOGS

O'Reilly, Talbot & Okun
ENGINEERING ASSOCIATES

# BORING LOGS

## SUMMARY OF THE BURMISTER SOIL CLASSIFICATION SYSTEM (MODIFIED)

***RELATIVE DENSITY (of non-plastic soils) OR CONSISTENCY (of plastic soils)***

| STANDARD PENETRATION TEST (SPT) |
|---|
| Method: Samples were collected in accordance with ASTM D1586, using a 2" diameter split spoon sampler driven 24 inches. If samples were collected using direct push methodology (Geoprobe), SPTs were not performed and relative density/consistency were not reported.<br>N-Value: The number of blows with a 140 lb. hammer required to drive the sampler the middle 12 inches.<br>WOR: Weight Of Rod (depth dependent)<br>WOH: Weight Of Hammer (140 lbs.) |

| COHESIONLESS SOILS | | COHESIVE SOILS | |
|---|---|---|---|
| BLOWS/FOOT (SPT N-Value) | RELATIVE DENSITY | BLOWS/FOOT (SPT N-Value) | CONSISTENCY |
| 0-4 | Very loose | <2 | Very soft |
| 4-10 | Loose | 2-4 | Soft |
| 10-30 | Medium dense | 4-8 | Medium Stiff |
| 30-50 | Dense | 8-15 | Stiff |
| >50 | Very dense | 15-30 | Very stiff |
| *Based upon uncorrected field N-values | | >30 | Hard |

***MATERIAL: (major constituent identified in CAPITAL letters)***

| COHESIONLESS SOILS | | |
|---|---|---|
| MATERIAL | FRACTION | GRAIN SIZE RANGE |
| **GRAVEL** | Coarse | 3/4" to 3" |
| | Fine | 1/4" to 3/4" |
| **SAND** | Coarse | 1/16" to 1/4" |
| | Medium | 1/64" to 1/16" |
| | Fine | Finest visible & distinguishable particles |
| **SILT/CLAY** | see adjacent table | Cannot distinguish individual particles |
| **COBBLES** | 3" to 6" in diameter | |
| **BOULDERS** | > 6" in diameter | |
| Note: Boulders and cobbles are observed in test pits and/or auger cuttings. | | |

| COHESIVE SOILS | | |
|---|---|---|
| SMALLEST DIAMETER | PLASTICITY | IDENTITY |
| None | Non-plastic | **SILT** |
| 1/4" (pencil) | Slight | **Clayey SILT** |
| 1/8" | Low | **SILT & CLAY** |
| 1/16" | Medium | **CLAY & SILT** |
| 1/32" | High | **Silty CLAY** |
| 1/64" | Very High | **CLAY** |
| Wetted sample is rolled in hands to smallest possible diameter before breaking. | | |

**ORGANIC SILT: Typically gray to dark gray, often has strong H2S odor. May contain shells or shell fragments. Light weight.**

Fibrous PEAT: Light weight, spongy, mostly visible organic matter, water squeezed readily from sample. Typically near top of layer.

Fine grained PEAT: Light weight, spongy, little visible organic matter, water squeezed from sample. Typically below fibrous peat.

**DEBRIS: Detailed contents described in parentheses (wood, glass, ash, crushed brick, metal, etc.)**

BEDROCK: Underlying rock beneath loose soil, can be weathered (easily crushed) or competent (difficult to crush).

***ADDITIONAL CONSTITUENTS***

| TERM | % OF TOTAL |
|---|---|
| and | 35-50% |
| some | 20-35% |
| little | 10-20% |
| trace | 1-10% |

***COMMON TERMS***

Glacial till: Very dense/hard, heterogeneous mixture of sand, silt, clay, sub-angular gravel. Deposited at base of glaciers, which covered all of New England.

Varved clay: Fine-grained, post-glacial lake sediments characterized by alternating layers (or varves) of silt, sand and clay.

Fill: Material used to raise ground, can be engineered or non-engineered.

***COMMON FIELD MEASUREMENTS***

Torvane: Undrained shear strength is estimated using an E285 Pocket Torvane (TV). Values in tons/ft2.

Penetrometer: Unconfined compressive strength is estimated using a Pocket Penetrometer (PP). Values in tons/ft2.

RQD: Rock Quality Designation is determined by measuring total length of pieces of core 4" or greater and dividing by the total length of the run, expressed as %. 100-90% excellent; 90-75% good; 75-50% fair; 50-25% poor; 25-0% very poor.

PID: Soil screened for volatile organic compounds (VOCs) using a photoionization detector (PID) referenced to benzene in air. Readings in parts per million by volume.

# LOG OF BORING PS-1

Page 1 of 1

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PROJECT | Pearl Street Culvert Replacement | | | CONTRACTOR | Seaboard Environmental Drilling | | |
| JOB NUMBER | 2950-22-01 | FINAL DEPTH (ft) | 6.0 | DRILLING EQUIPMENT | B-53 Truck Mounted Rig | | |
| LOCATION | South Hadley, MA | SURFACE ELEV (ft) | 127 | FOREMAN | Jeff N. | CASING | |
| START DATE | 11/10/2022 | DISTURBED SAMPLES | 3 | HELPER | Joe N. | CASE DIAMETER | N/A |
| FINISH DATE | 11/10/2022 | UNDISTURBED SAMPLES | 0 | BIT TYPE | Hollow Stem Auger | HAMMER WGT | N/A |
| ENGINEER/SCIENTIST | Caren Irgang | WATER LEVEL | | ROD TYPE | N (2 3/8" O.D.) | HAMMER DROP | N/A |
| BORING LOCATION | East of culvert, southern shoulder of road | FIRST (ft) | N/A | SAMPLER | 2" O.D. Split Spoon | ROCK CORING INFORMATION | |
| | | LAST (ft) | N/E | HAMMER TYPE | Automatic | TYPE | N/A |
| | | TIME (hr) | N/E | HAMMER WGT/DROP | 140 lb / 30" | SIZE | N/A |

| DEPTH (ft)/ SAMPLES | SAMPLES | | | | SAMPLE DESCRIPTION (MODIFIED BURMISTER) | PROFILE DEPTH (ft) ELEV. | REMARKS/ WELL CONSTRUCTION |
|---|---|---|---|---|---|---|---|
| | PENETR. RESIST. (bl / 6 in) | REC. (in) | TYPE/ NO. | FIELD TEST DATA | | | |
| | 6/6/6/4 | 14/24 | S-1<br>(0-2') | -- | Top 3": Medium dense, dark brown to brown, medium SAND, little fine sand, trace silt, trace organics (roots), damp (TOPSOIL)<br>Next 6": Medium dense, very dark brown, medium SAND, some gravel, little fine sand, little coarse sand, little silt, damp<br>Bottom 5": Medium dense, light brown, medium SAND, little coarse sand, little gravel, trace fine sand, trace silt, damp | TOPSOIL<br>GRAVELLY SAND<br>1.3 125.7<br>MEDIUM SAND | |
| | 1/4/2/3 | 7/24 | S-2<br>(2-4') | -- | Loose, light brown, medium SAND, little coarse sand, little gravel, trace fine sand, trace silt, damp | | |
| 5' | 2/4/1/2 | 11/24 | S-3<br>(4-6') | -- | Top 2": Loose, light brown, medium SAND, little coarse sand, little gravel, trace fine sand, trace silt, damp<br>Bottom 9": Medium stiff, brown, SILT and CLAY, trace medium sand, damp (fabrid at bottom) | 5.5 121.5<br>SILT AND CLAY<br>6.0 121.0 | 1. |
| | | | | | End of exploration at 6' | | |
| 10' | | | | | | | |
| 15' | | | | | | | |
| 20' | | | | | | | |
| 25' | | | | | | | |

Remarks:
1. Geosynthetic fabric layer encountered at depth of 6 feet. Boring location terminated.

**PROJECT NO.**
**2950-22-01**

**LOG OF BORING**
**PS-1**

O'Reilly, Talbot & Okun
ENGINEERING ASSOCIATES

# LOG OF BORING PS-2A

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PROJECT | Pearl Street Culvert Replacement | | | CONTRACTOR | Seaboard Environmental Drilling | | |
| JOB NUMBER | 2950-22-01 | FINAL DEPTH (ft) | 6.0 | DRILLING EQUIPMENT | B-53 Truck Mounted Rig | | |
| LOCATION | South Hadley, MA | SURFACE ELEV (ft) | 127.5 | FOREMAN | Jeff N. | CASING | |
| START DATE | 11/10/2022 | DISTURBED SAMPLES | 3 | HELPER | Joe N. | CASE DIAMETER | N/A |
| FINISH DATE | 11/10/2022 | UNDISTURBED SAMPLES | 0 | BIT TYPE | Hollow Stem Auger | HAMMER WGT | N/A |
| ENGINEER/SCIENTIST | Caren Irgang | WATER LEVEL | | ROD TYPE | N (2 3/8" O.D.) | HAMMER DROP | N/A |
| BORING LOCATION | West of culvert | FIRST (ft) | N/A | SAMPLER | 2" O.D. Split Spoon | ROCK CORING INFORMATION | |
| | | LAST (ft) | N/E | HAMMER TYPE | Automatic | TYPE | N/A |
| | | TIME (hr) | N/E | HAMMER WGT/DROP | 140 lb / 30" | SIZE | N/A |

| DEPTH (ft)/ SAMPLES | SAMPLES | | | | SAMPLE DESCRIPTION (MODIFIED BURMISTER) | PROFILE | | | REMARKS/ WELL CONSTRUCTION |
|---|---|---|---|---|---|---|---|---|---|
| | PENETR. RESIST. (bl / 6 in) | REC. (in) | TYPE/ NO. | FIELD TEST DATA | | DEPTH (ft) | | ELEV. | |
| | 15/11/10/6 | 14/24 | S-1 (0-2') | -- | 6.5" ASPHALT<br>Top 2": Medium dense, black, medium to coarse SAND and GRAVEL, damp (BASE COARSE; fabric at bottom)<br>Bottom 12": Medium dense, light brown, medium SAND, some gravel, little coarse sand, little fine sand, trace silt, damp | ASPHALT/BASE<br>GRAVELLY SAND | | | |
| | 5/8/9/14 | 10/24 | S-2 (2-4') | -- | Top 6": Medium dense, light brown, medium SAND, some gravel, little coarse sand, little fine sand, trace silt, damp<br>Bottom 4": Medium dense, light red brown, medium SAND, some gravel, little coarse sand, trace fine sand, trace silt, damp | | | | 1 |
| 5' | 15/8/6/6 | 7/24 | S-3 (4-6') | -- | Medium dense, light red brown, medium SAND, some gravel, little coarse sand, trace fine sand, trace silt, damp (0.25" black seam) | 6.0 | | 121.5 | 2 |
| | | | | | Auger refusal at 6' | | | | |
| 10' | | | | | | | | | |
| 15' | | | | | | | | | |
| 20' | | | | | | | | | |
| 25' | | | | | | | | | |

Remarks:
1. Auger grinding from 3.5 to 4.5 feet.
2. Offset boring approximately 7 feet west.

**PROJECT NO.**
**2950-22-01**

**LOG OF BORING**
**PS-2A**

O'Reilly, Talbot & Okun
ENGINEERING ASSOCIATES

# LOG OF BORING PS-2B

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| | | | |
|---|---|---|---|
| PROJECT | Pearl Street Culvert Replacement | | |
| JOB NUMBER | 2950-22-01 | FINAL DEPTH (ft) | 4.5 |
| LOCATION | South Hadley, MA | SURFACE ELEV (ft) | 127.5 |
| START DATE | 11/10/2022 | DISTURBED SAMPLES | 0 |
| FINISH DATE | 11/10/2022 | UNDISTURBED SAMPLES | 0 |
| ENGINEER/SCIENTIST | Caren Irgang | WATER LEVEL | |
| BORING LOCATION | West of culvert | FIRST (ft) | N/A |
| | | LAST (ft) | N/E |
| | | TIME (hr) | N/E |

| | |
|---|---|
| CONTRACTOR | Seaboard Environmental Drilling |
| DRILLING EQUIPMENT | B-53 Truck Mounted Rig |
| FOREMAN | Jeff N. |
| HELPER | Joe N. |
| BIT TYPE | Hollow Stem Auger |
| ROD TYPE | N (2 3/8" O.D.) |
| SAMPLER | 2" O.D. Split Spoon |
| HAMMER TYPE | Automatic |
| HAMMER WGT/DROP | 140 lb / 30" |

| CASING | |
|---|---|
| CASE DIAMETER | N/A |
| HAMMER WGT | N/A |
| HAMMER DROP | N/A |
| ROCK CORING INFORMATION | |
| TYPE | N/A |
| SIZE | N/A |

| DEPTH (ft)/ SAMPLES | SAMPLES | | | | SAMPLE DESCRIPTION (MODIFIED BURMISTER) | PROFILE | | | REMARKS/ WELL CONSTRUCTION |
|---|---|---|---|---|---|---|---|---|---|
| | PENETR. RESIST. (bl / 6 in) | REC. (in) | TYPE/ NO. | FIELD TEST DATA | | DEPTH | (ft) | ELEV. | |
| | | | | | 6.5" ASPHALT (fabric at bottom) | | ASPHALT | | |
| | | | | | From cuttings: Light brown, medium to coarse SAND, some gravel, trace silt, damp | | GRAVELLY SAND | | |
| | | | | | From cuttings (3-4.5'): Light red brown, medium SAND, some gravel, little fine sand, little coarse sand, trace silt, damp | | | | 1 |
| | | | | | | 4.5 | | 123.0 | 2 |
| 5' | | | | | Auger refusal at 4.5' | | | | |
| 10' | | | | | | | | | |
| 15' | | | | | | | | | |
| 20' | | | | | | | | | |
| 25' | | | | | | | | | |

Remarks:
1. Auger grinding from 2.5 to 4.5 feet.
2. Offset boring approximately 11 feet west.

**PROJECT NO.**
**2950-22-01**

**LOG OF BORING**
**PS-2B**

O'Reilly, Talbot & Okun
ENGINEERING ASSOCIATES

## LOG OF BORING PS-2C

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PROJECT | Pearl Street Culvert Replacement | | | CONTRACTOR | Seaboard Environmental Drilling | | |
| JOB NUMBER | 2950-22-01 | FINAL DEPTH (ft) | 43.3 | DRILLING EQUIPMENT | B-53 Truck Mounted Rig | | |
| LOCATION | South Hadley, MA | SURFACE ELEV (ft) | 127.5 | FOREMAN | Jeff N. | CASING | |
| START DATE | 11/10/2022 | DISTURBED SAMPLES | 8 | HELPER | Joe N. | CASE DIAMETER | 4" |
| FINISH DATE | 11/10/2022 | UNDISTURBED SAMPLES | 0 | BIT TYPE | H.S.A. & Roller Bit with Wash | HAMMER WGT | 300 lb |
| ENGINEER/SCIENTIST | Caren Irgang | WATER LEVEL | | ROD TYPE | N (2 3/8" O.D.) | HAMMER DROP | 30" |
| BORING LOCATION | West of culvert | FIRST (ft) | 8.3 | SAMPLER | 2" O.D. Split Spoon | ROCK CORING INFORMATION | |
| | | LAST (ft) | N/E | HAMMER TYPE | Automatic | TYPE | Diamond Bit |
| | | TIME (hr) | N/E | HAMMER WGT/DROP | 140 lb / 30" | SIZE | 2" |

| DEPTH (ft)/ SAMPLES | SAMPLES PENETR. RESIST. (bl / 6 in) | REC. (in) | TYPE/ NO. | FIELD TEST DATA | SAMPLE DESCRIPTION (MODIFIED BURMISTER) | PROFILE DEPTH (ft) ELEV. | REMARKS/ WELL CONSTRUCTION |
|---|---|---|---|---|---|---|---|
| | | | | | 6.5" ASPHALT<br>From cuttings: Red brown, medium to coarse SAND and GRAVEL, trace silt | ASPHALT<br>SAND & GRAVEL | 1 |
| | | | | | From cuttings (3-5'): Red brown, medium SAND, little coarse sand, little fine gravel, little fine sand, trace silt, damp | 3.0 124.5<br>MEDIUM SAND | |
| 5' | | | | | | | |
| | 3/3/2/2 | 0/24 | S-1<br>(6-8') | -- | (NO RECOVERY; likely pushing gravel) | | |
| | 1/1/1/1 | 14/24 | S-2<br>(8-10') | -- | Very loose, red brown, medium SAND, little coarse sand, little fine sand, trace silt, trace fine gravel, wet (top 3" damp to moist) | ▽ 119.2 | 1 |
| 10' | 2/1/2/2 | 9/24 | S-3<br>(10-12') | -- | Very loose, brown, medium SAND, little coarse sand, little fine sand, little silt, trace gravel (bottom 5" light orange to dark orange with rust staining) | | 2 |
| | | | | | | 12.0 115.5<br>LIKELY ORGANICS<br>13.0 114.5<br>VARVED CLAY | 3 |
| 15' | 4/3/4/4 | 15/24 | S-4<br>(15-17') | w = 36% | Medium stiff, red brown and gray, varved fine SAND and SILT, trace fine sand (4-5" sand, 1" clayey silt) | | 4 |
| 20' | WOH for 12" | 24/24 | S-5<br>(20-22') | TV = 0.10<br>PP = 0.75<br>w = 45% | Very soft, gray, varved SILT and CLAY, trace fine sand (1/2" clay, 1" silt) | | 5, 6, 7<br>8 |
| | 1/2/3/4 | 14/24 | S-6<br>(22-24') | TV = 0.50<br>PP = 0.25<br>w = 46% | Medium stiff, gray, varved clayey SILT, trace fine sand (1/8" clay, 1/2" silt) | | |
| 25' | 2/3/3/4 | 20/24 | S-7<br>(25-27') | w = 56% | Medium stiff, red gray, varved fine SAND and SILT, little silty clay (few 1/2 to 1" silty clay layers) | | |

Remarks:

1. Auger/bit grinding from 2 to 4.5 feet and at 8 feet.
2. Drive casing and begin drilling with wash after sampling S-2.
3. Silt pieces and wood fragments in wash water at 13'.
4. In-situ moisture content (w) determined according to ASTM D2216.
5. Begin open-hole drilling at 20 feet.
6. WOH = Weight of rods and 140 lb. hammer.
7. Undrained shear strength estimated in field using E285 Pocket Torvane (TV). Values in tons/ft$^2$.
8. Unconfined compressive strength estimated in field using Pocket Penetrometer (PP). Values in tons/ft$^2$.
9. Bit grinding at 33'. Dark gray angular sand in wash water.
10. See report for definitions of Rock Quality Designation (RQD) and Rock Mass Quality (RMQ).
11. Core barrel jammed.

**PROJECT NO.**
**2950-22-01**

**LOG OF BORING**
**PS-2C**

O'Reilly, Talbot & Okun
ENGINEERING ASSOCIATES

Job No. 2950-22-01

## LOG OF BORING PS-2C

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| DEPTH (ft)/ SAMPLES | SAMPLES |  |  |  | SAMPLE DESCRIPTION (MODIFIED BURMISTER) | PROFILE DEPTH (ft) ELEV. | REMARKS/ WELL CONSTRUCTION |
|---|---|---|---|---|---|---|---|
|  | PENETR. RESIST. (bl / 6 in) | REC. (in) | TYPE/ NO. | FIELD TEST DATA |  |  |  |
|  |  |  |  |  |  | VARVED CLAY<br>(Continued) |  |
| 30' | 3/3/3/4 | 19/24 | S-8<br>(30-32') | TV = 0.10<br>PP = 0.75<br>w = 45% | Top 12": Medium stiff, brown gray, SILT, some fine sand (1/8" clay seam near center)<br>Bottom 7": Medium stiff, brown gray, varved clayey SILT, trace fine sand<br>(1/8 to 1/4" clay, 1/2 to 1" silt) |  |  |
|  |  |  |  |  |  | 33.0 94.5 |  |
|  | Core Rate (min/ft) |  |  |  |  | FRACTURED BEDROCK | 9 |
| 35' | 4.45<br>5.73<br>3.23<br>3.22<br>5.07 | 32/60 | C-1<br>(34-39') | -- | Slightly weathered, slightly fractured, dark purple gray, BASALTIC LAHAR<br>Recovery = 53%<br>RQD = 48%<br>RMQ = Poor<br>Total Run Time = 21.7 minutes | BEDROCK | 10 |
| 40' | 5.43<br>9.23<br>7.72<br>10.68<br>6.13 | 51/51 | C-2<br>(39-43.3') | -- | Top 13": Slightly weathered, intensely fractured, dark purple gray, BASALTIC LAHAR<br>Next 18": Slightly weathered, slightly fractured, dark green gray, DIORITE<br>Bottom 20": Slightly weathered, moderately fractured, very dark gray, BASALT<br>Recovery = 100%<br>RQD = 65%<br>RMQ = Fair<br>Total Run Time = 39.2 minutes |  |  |
|  |  |  |  |  |  | 43.3 84.2 | 11 |
|  |  |  |  |  | End of Exploration at 43.3' |  |  |
| 45' |  |  |  |  |  |  |  |
| 50' |  |  |  |  |  |  |  |
| 55' |  |  |  |  |  |  |  |
| 60' |  |  |  |  |  |  |  |

O'Reilly, Talbot & Okun
ENGINEERING ASSOCIATES

# LOG OF BORING PS-3A

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PROJECT | Pearl Street Culvert Replacement | | | CONTRACTOR | Seaboard Environmental Drilling | | |
| JOB NUMBER | 2950-22-01 | FINAL DEPTH (ft) | 2.0 | DRILLING EQUIPMENT | B-53 Truck Mounted Rig | | |
| LOCATION | South Hadley, MA | SURFACE ELEV (ft) | 127.5 | FOREMAN | Jeff N. | CASING | |
| START DATE | 11/11/2022 | DISTURBED SAMPLES | 1 | HELPER | Joe N. | CASE DIAMETER | N/A |
| FINISH DATE | 11/11/2022 | UNDISTURBED SAMPLES | 0 | BIT TYPE | Hollow Stem Auger | HAMMER WGT | N/A |
| ENGINEER/SCIENTIST | Caren Irgang | WATER LEVEL | | ROD TYPE | N (2 3/8" O.D.) | HAMMER DROP | N/A |
| BORING LOCATION | East of culvert | FIRST (ft) | N/A | SAMPLER | 2" O.D. Split Spoon | ROCK CORING INFORMATION | |
| | | LAST (ft) | N/E | HAMMER TYPE | Automatic | TYPE | N/A |
| | | TIME (hr) | N/E | HAMMER WGT/DROP | 140 lb / 30" | SIZE | N/A |

| DEPTH (ft)/ SAMPLES | SAMPLES<br>PENETR. RESIST. (bl / 6 in) | REC. (in) | TYPE/ NO. | FIELD TEST DATA | SAMPLE DESCRIPTION (MODIFIED BURMISTER) | PROFILE<br>DEPTH (ft) ELEV. | REMARKS/ WELL CONSTRUCTION |
|---|---|---|---|---|---|---|---|
| | 18/19/39/21 | 12/24 | S-1<br>(0-2') | -- | 6.5" ASPHALT<br>Top 2": Very dense, black, fine to medium SAND, some gravel, little silt, little coarse sand, dry (BASE COARSE)<br>Bottom 10": Very dense, red brown, medium SAND, some gravel, some coarse sand, little fine sand, trace silt, damp (2" rock pieces at bottom) | ASPHALT/BASE<br>GRAVELLY SAND<br>2.0 125.5 | 1, 2 |
| | | | | | Auger refusal at 2' | | |
| 5' | | | | | | | |
| 10' | | | | | | | |
| 15' | | | | | | | |
| 20' | | | | | | | |
| 25' | | | | | | | |

Remarks:
1. Auger grinding at 2 feet.
2. Offset approximately 10 feet east.

**PROJECT NO.**
**2950-22-01**

**LOG OF BORING**
**PS-3A**

O'Reilly, Talbot & Okun
ENGINEERING ASSOCIATES

# LOG OF BORING PS-3B

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PROJECT | Pearl Street Culvert Replacement | | | CONTRACTOR | Seaboard Environmental Drilling | | |
| JOB NUMBER | 2950-22-01 | FINAL DEPTH (ft) | 4.0 | DRILLING EQUIPMENT | B-53 Truck Mounted Rig | | |
| LOCATION | South Hadley, MA | SURFACE ELEV (ft) | 127.5 | FOREMAN | Jeff N. | CASING | |
| START DATE | 11/11/2022 | DISTURBED SAMPLES | 2 | HELPER | Joe N. | CASE DIAMETER | N/A |
| FINISH DATE | 11/11/2022 | UNDISTURBED SAMPLES | 0 | BIT TYPE | Hollow Stem Auger | HAMMER WGT | N/A |
| ENGINEER/SCIENTIST | Caren Irgang | WATER LEVEL | | ROD TYPE | N (2 3/8" O.D.) | HAMMER DROP | N/A |
| BORING LOCATION | East of culvert | FIRST (ft) | N/A | SAMPLER | 2" O.D. Split Spoon | ROCK CORING INFORMATION | |
| | | LAST (ft) | N/E | HAMMER TYPE | Automatic | TYPE | N/A |
| | | TIME (hr) | N/E | HAMMER WGT/DROP | 140 lb / 30" | SIZE | N/A |

| DEPTH (ft)/ SAMPLES | SAMPLES: PENETR. RESIST. (bl / 6 in) | REC. (in) | TYPE/ NO. | FIELD TEST DATA | SAMPLE DESCRIPTION (MODIFIED BURMISTER) | PROFILE DEPTH (ft) ELEV. | REMARKS/ WELL CONSTRUCTION |
|---|---|---|---|---|---|---|---|
| | 14/18/18/12 | 16/24 | S-1<br>(0-2') | -- | 6.5" ASPHALT<br>Top 2": Dense, black, fine to medium SAND, some gravel, little silt, little coarse sand, dry (BASE COARSE)<br>Bottom 14": Dense, red brown, medium SAND, some gravel, some coarse sand, little fine sand, trace silt, damp | ASPHALT/BASE<br>GRAVELLY SAND | |
| | 1/4/4/2 | 0/24 | S-2<br>(2-4') | -- | NO RECOVERY (likely pushing gravel) | 3.0 ▼ 124.5 | 1<br>2 |
| 5' | | | | | Auger refusal at 3' | | |
| 10' | | | | | | | |
| 15' | | | | | | | |
| 20' | | | | | | | |
| 25' | | | | | | | |

Remarks:
1. Auger griding at 2.5 feet.
2. Offset approximately 11 feet east.

**PROJECT NO.**
**2950-22-01**

**LOG OF BORING**
**PS-3B**

O'Reilly, Talbot & Okun
ENGINEERING ASSOCIATES

# LOG OF BORING PS-3C

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PROJECT | Pearl Street Culvert Replacement | | | CONTRACTOR | Seaboard Environmental Drilling | | |
| JOB NUMBER | 2950-22-01 | FINAL DEPTH (ft) | 42.5 | DRILLING EQUIPMENT | B-53 Truck Mounted Rig | | |
| LOCATION | South Hadley, MA | SURFACE ELEV (ft) | 127.5 | FOREMAN | Jeff N. | CASING | |
| START DATE | 11/11/2022 | DISTURBED SAMPLES | 8 | HELPER | Joe N. | CASE DIAMETER | 4" |
| FINISH DATE | 11/11/2022 | UNDISTURBED SAMPLES | 0 | BIT TYPE | H.S.A. & Roller Bit with Wash | HAMMER WGT | 300 lb |
| ENGINEER/SCIENTIST | Caren Irgang | WATER LEVEL | | ROD TYPE | N (2 3/8" O.D.) | HAMMER DROP | 30" |
| BORING LOCATION | East of culvert | FIRST (ft) | 8.5 | SAMPLER | 2" O.D. Split Spoon | ROCK CORING INFORMATION | |
| | | LAST (ft) | N/E | HAMMER TYPE | Automatic | TYPE | Diamond Bit |
| | | TIME (hr) | N/E | HAMMER WGT/DROP | 140 lb / 30" | SIZE | 2" |

| DEPTH (ft)/ SAMPLES | SAMPLES | | | | SAMPLE DESCRIPTION (MODIFIED BURMISTER) | PROFILE DEPTH (ft) ELEV. | REMARKS/ WELL CONSTRUCTION |
|---|---|---|---|---|---|---|---|
| | PENETR. RESIST. (bl / 6 in) | REC. (in) | TYPE/ NO. | FIELD TEST DATA | | | |
| | | | | | 6.5" ASPHALT<br>From cuttings: Red brown, medium SAND, some gravel, some coarse sand, little fine sand, trace silt, damp | ASPHALT<br>GRAVELLY SAND | 1 |
| 5' | 4/2/2/2 | 10/24 | S-1<br>(3-5') | -- | Top 3": Loose, red brown, medium SAND, some gravel, some coarse sand, little fine sand, trace silt, damp (0.25" diagonal black seam 1/2" from top)<br>Bottom 7": Loose, dark brown, medium SAND, little silt, little coarse sand, trace fine sand, damp | 6.0 121.5 | 2 |
| | 2/3/4/3 | 22/24 | S-2<br>(6-8') | -- | Top 13": Medium stiff, brown, SILT, trace fine sand, trace fine gravel, trace organics (tree seeds near top; trace rust staining in bottom half), moist<br>Next 4": Loose, brown, fine SAND, little to some silt, moist<br>Bottom 5": Loose, brown, fine to medium SAND, some silt, moist | SILTY SAND | |
| | 4/4/3/2 | 10/24 | S-3<br>(8-10') | -- | Loose, brown, fine to medium SAND, some coarse sand in bttom half, little silt, moist (bottom 5" wet) | ▽ 119.0 | 3 |
| 10' | 1/2/3/6 | 8/24 | S-4<br>(10-12') | -- | Top 1": Loose, gray brown, medium SAND, little fine sand, little silt, little coarse sand, trace organics (wood fragments)<br>Next 6": Loose, orange, ORGANICS (wood) (1-2" pieces, spongey)<br>Bottom 1": Loose, gray brown, medium SAND, little fine sand, little silt, little coarse sand, trace organics (wood fragments) | 10.3 117.2<br>ORGANICS<br>MEDIUM SAND | 4 |
| | | | | | | 13.5 114.0<br>VARVED CLAY | 5 |
| 15' | 4/3/3/2 | 0/24 | S-5<br>(15-17') | -- | NO RECOVERY(likely pushing gravel) | | |
| | 1/3/3/3 | 21/24 | S-6<br>(17-19') | TV = 0.60<br>PP = 0.40<br>w = 41% | Top 7": Medium stiff, red brown and gray, varved fine SAND and SILT (1-2" diagonal to horizontal layers)<br>Next 8": Medium stiff, brown gray, varved clayey SILT, trace fine sand, trace coarse sand (1/4" clay layers)<br>Bottom 6": Medium stiff, red gray, varved SILT, some fine sand | | 6<br>7<br>8 |
| 20' | WOH for 12" | 15/24 | S-7<br>(20-22') | TV = 0.10<br>PP = 0.75<br>w = 37% | Soft, gray, varved clayey SILT, little fine sand (1/4" clay, 1/2 to 1" silt) | | 9, 10 |
| 25' | 2/2/2/3 | 8/24 | S-8<br>(25-27') | TV = 0.15<br>PP = 1.00<br>w = 32% | Medium stiff, gray, varved clayey SILT and fine SAND (1" silt and clay layers) | | |

Remarks:
1. Auger grinding at 1 foot.
2. Rod sank from 5 to 6 feet.
3. Drove casing and began drilling with wash after sampling S-3.
4. Silt and clay pieces in wash water at 10 feet.
5. Wash water color changed to gray at 13.5'.
6. Undrained shear strength estimated in field using E285 Pocket Torvane (TV). Values in tons/ft$^2$.
7. Unconfined compressive strength estimated in field using Pocket Penetrometer (PP). Values in tons/ft$^2$.
8. In-situ moisture content (w) determined according to ASTM D2216.
9. Begin open-hole drilling at 20'.
10. WOH = Weight of rods and 140 lb. hammer.

**PROJECT NO.**
**2950-22-01**

**LOG OF BORING**
**PS-3C**

O'Reilly, Talbot & Okun
ENGINEERING ASSOCIATES

Job No. 2950-22-01

## LOG OF BORING PS-3C

| DEPTH (ft)/ SAMPLES | SAMPLES<br>PENETR. RESIST. (bl / 6 in) | <br>REC. (in) | <br>TYPE/ NO. | <br>FIELD TEST DATA | SAMPLE DESCRIPTION (MODIFIED BURMISTER) | PROFILE<br>DEPTH (ft) | <br>ELEV. | REMARKS/ WELL CONSTRUCTION |
|---|---|---|---|---|---|---|---|---|
| | | | | | | VARVED CLAY (Continued) | | |
| 30' | 2/3/2/2 | 14/24 | S-9<br>(30-32') | w = 39% | Medium stiff, red gray, SILT and fine SAND | | | |
| 35' | 2/2/2/2 | 20/24 | S-10<br>(35-37') | -- | Medium stiff, red gray, fine SAND and varved clayey SILT<br>(1" clayey silt, 7" fine sand) | | | |
| 40' | 49/50 for 2" | 6/8 | S-11<br>(40-40.2') | -- | Hard, very dark gray, ROCK (weathered) | 40.0<br>FRACTURED BEDROCK | 87.5 | 11 |
| | Core Rate (min/ft)<br>2.62<br>3.50<br>2.83<br>3.67<br>5.50 | 16/60 | C-1<br>(43-48') | | Slightly weathered, moderately to intensely fractured, dark purple gray, BASALTIC LAHAR<br>Recovery = 27%<br>RQD = 7%<br>RMQ = Poor<br>Total Run Time = 18.1 minutes | 43.0<br>BEDROCK | 84.5 | 12<br>13<br>14 |
| 45' | | | | | | | | |
| 50' | 3.78<br>3.40<br>6.65 | 23.5/30 | C-2<br>(48-50.5') | | Slightly weathered, moderately to intensely fractured, dark purple gray, BASALTIC LAHAR<br>Recovery = 78%<br>RQD = 13%<br>RMQ = Poor<br>Total Run Time = 13.8 minutes | 50.5 | 77.0 | 15 |
| | | | | | End of exploration at 50.5' | | | |
| 55' | | | | | | | | |

Remarks:

11. Roller bit "jumping" at 40'.
12. Lost approximately one tub volume of water while coring rock.
13. Rock Quality Designation (RQD) is determined by summing the length of all rock core pieces longer than 4", then dividing by the length of the coring run.
14. Rock Mass Quality (RMQ) is determined based upon the RQD %.
14. Core barrel jammed at 50.5 feet.

# APPENDIX C

# ROCK CORE PHOTOGRAPHS

## Boring PS-2C, Core C-1, 34-39 feet (Elev. 93.5-88.5 feet)

**Photo 1:** PS-2C, C-1 Overview

**Photo 2:** PS-2C, C-1 Top

**Photo 3:** PS-2C, C-1 Middle

**Photo 4:** PS-2C, C-1 Bottom

## Boring PS-2C, Core C-2, 39-43.3 feet (Elev. 88.5-84.2 feet)

**Photo 5:** PS-2C, C-2 Overview

**Photo 6:** PS-2C, C-2 Top

**Photo 7:** PS-2C, C-2 Upper portion

**Photo 8:** PS-2C, C-2 Center

**Photo 9:** PS-2C, C-2 Lower portion

**Photo 10:** PS-2C, C-2 Bottom

## Boring PS-3C, Core C-1, 43-48 feet (Elev. 84.5-79.5 feet)

**Photo 11:** PS-3C, C-1 Overview

**Photo 12:** PS-3C, C-1

## Boring PS-3C, Core C-2, 48-50.5 feet (Elev. 79.5-77 feet)

**Photo 13:** PS-3C, C-2 Overview

**Photo 14:** PS-3C, C-2 Top

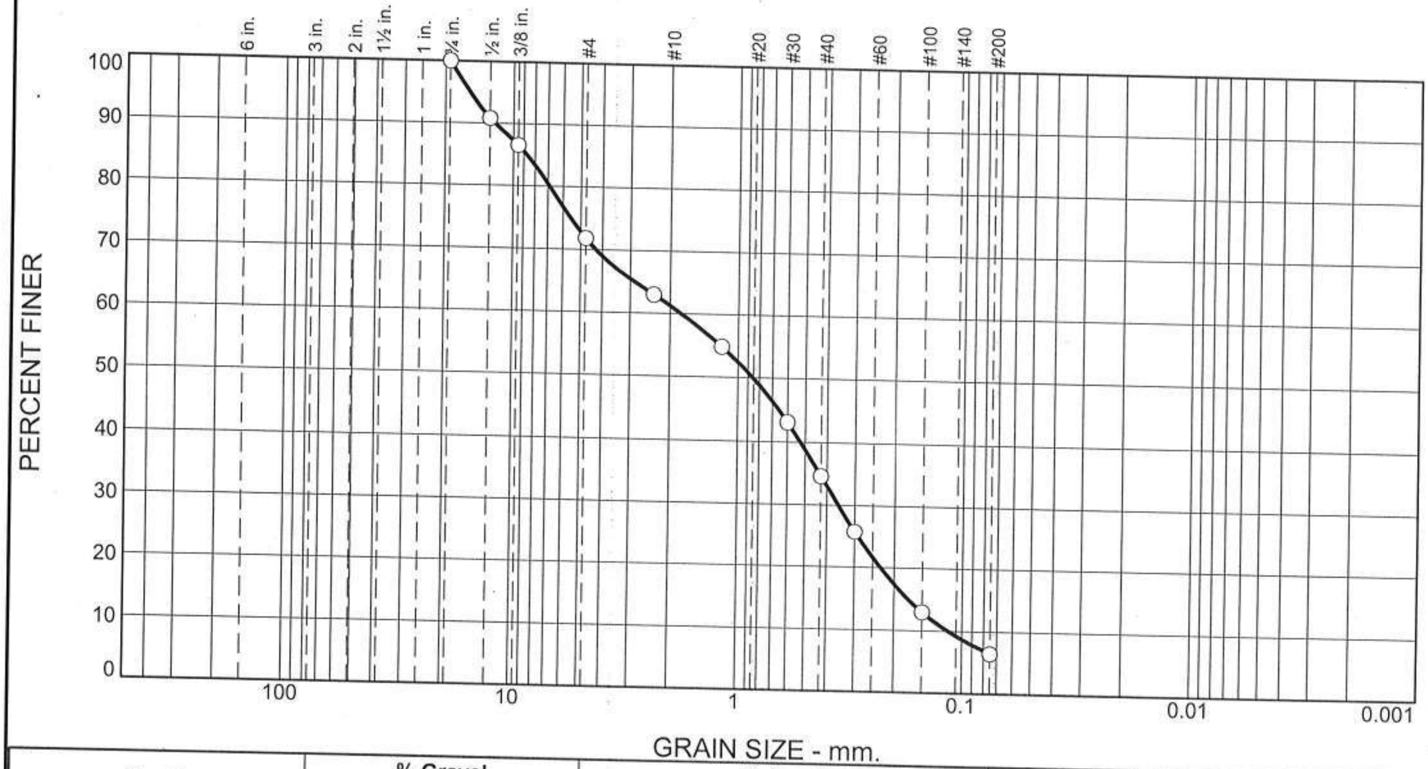
**Photo 15:** PS-3C, C-2 Middle portion

**Photo 16:** PS-3C, C-2 Bottom

# APPENDIX D

# LABORATORY DATA SHEETS

# Particle Size Distribution Report



| % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|
| | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| 0.0 | 0.0 | 28.2 | 10.6 | 26.6 | 28.2 | 6.4 | |

**Test Results (ASTM C 136 & ASTM C 117)**

| Opening Size | Percent Finer | Spec.* (Percent) | Pass? (X=Fail) |
|---|---|---|---|
| 3/4 | 100.0 | | |
| 1/2 | 90.8 | | |
| 3/8 | 86.6 | | |
| #4 | 71.8 | | |
| #8 | 63.0 | | |
| #16 | 54.8 | | |
| #30 | 43.1 | | |
| #40 | 34.6 | | |
| #50 | 25.8 | | |
| #100 | 13.0 | | |
| #200 | 6.4 | | |

* (no specification provided)

**Material Description**

PS-2A (0.5'-3')

**Atterberg Limits (ASTM D 4318)**

**PL=** **LL=** **PI=**

**Classification**

**USCS (D 2487)=** **AASHTO (M 145)=**

**Coefficients**

$D_{90}$= 12.0849 $D_{85}$= 8.7179 $D_{60}$= 1.7884

$D_{50}$= 0.8566 $D_{30}$= 0.3555 $D_{15}$= 0.1732

$D_{10}$= 0.1155 $C_u$= 15.49 $C_c$= 0.61

**Remarks**

This sample delivered to lab by client. This sample was washed.

**Date Received:** 11/17/22 **Date Tested:** 11/18/22

**Tested By:**

**Checked By:** John McGreevy

**Title:** Dir. of Testing Services

**Sample Number:** 3639

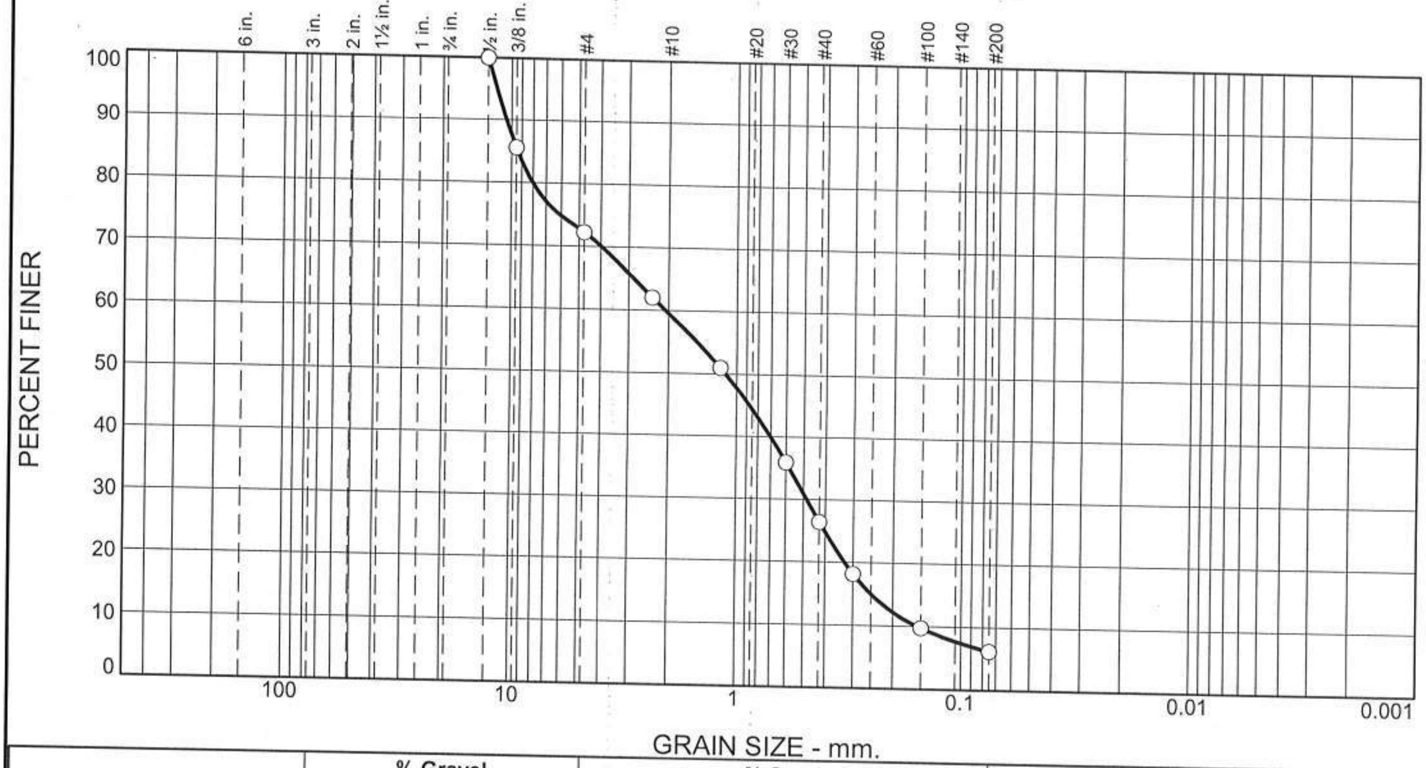
**Date Sampled:**

**ALLIED TESTING**
**LABORATORIES, INC.**
**Springfield, Massachusetts**

**Client:** OTO
**Project:** Pearl St South Hadley

**Project No:** 2950-22-01 **Figure**

# Particle Size Distribution Report



| % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|
| | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| 0.0 | 0.0 | 27.8 | 12.7 | 33.1 | 20.3 | 6.1 | |

**Test Results (ASTM C 136 & ASTM C 117)**

| Opening Size | Percent Finer | Spec.* (Percent) | Pass? (X=Fail) |
|---|---|---|---|
| 1/2 | 100.0 | | |
| 3/8 | 85.6 | | |
| #4 | 72.2 | | |
| #8 | 62.0 | | |
| #16 | 51.0 | | |
| #30 | 35.9 | | |
| #40 | 26.4 | | |
| #50 | 18.2 | | |
| #100 | 9.7 | | |
| #200 | 6.1 | | |

* (no specification provided)

**Material Description**

PS-3B (0.5'-2.5')

**Atterberg Limits (ASTM D 4318)**

**PL=** **LL=** **PI=**

**Classification**

**USCS (D 2487)=** **AASHTO (M 145)=**

**Coefficients**

| | | |
|---|---|---|
| $D_{90}$= 10.5151 | $D_{85}$= 9.3940 | $D_{60}$= 2.0686 |
| $D_{50}$= 1.1189 | $D_{30}$= 0.4842 | $D_{15}$= 0.2497 |
| $D_{10}$= 0.1563 | $C_u$= 13.23 | $C_c$= 0.73 |

**Remarks**

This sample delivered to lab by client. This sample was washed.

**Date Received:** 11/17/22 **Date Tested:** 11/18/22

**Tested By:**

**Checked By:** John McGreevy

**Title:** Dir. of Testing Services

**Sample Number:** 3640

**Date Sampled:**

**ALLIED TESTING**
**LABORATORIES, INC.**
**Springfield, Massachusetts**

**Client:** OTO

**Project:** Pearl St South Hadley

**Project No:** 2950-22-01

**Figure**