



## Foundation Investigation and Design Report

*Ontario Ministry of Transportation*

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Replacement of the Everett Lake Tributary Culvert (#38S-0402/C0)

Highway 17, Township of Thompson, Ontario

Sault Ste. Marie Area, Northeast Region

(Lat: 46.257° Long: -83.195°)

Geocres No. 41J00-151

**Project Number:**

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# 1. Foundation Investigation Report

## 1.1 Introduction

EXP Services Inc. (EXP) was retained by the Ontario Ministry of Transportation (MTO) to provide foundation engineering services for the proposed replacement of the Everett Lake Tributary Culvert on Highway 17. The culvert is located 3.3 km southeast of the junction of Highway 546 in the Township of Thompson, Sault Ste. Marie Area (Lat: 46.257° Long: -83.195°). The work was undertaken under Assignment No. 5022-E-0007. The Terms of Reference (TOR) for this project were provided by the MTO within the Request for Quotation dated May 2022.

The purpose of this investigation was to evaluate the subsurface conditions along the existing culvert to permit detailed design for its replacement. The site-specific geotechnical investigation consisted of a field investigation including visual inspections, drilling, soil sampling, and laboratory testing.

This Foundation Investigation Report has been prepared specifically and solely for the project described herein. It contains the factual results of the investigation and the laboratory testing completed for this project.

## 1.2 Site Description and Geological Setting

### 1.2.1 Site Description

The Everett Lake Tributary Culvert (Site 38S-402/C0) is located along Highway 17 approximately 3.3 km southeast of the junction with Highway 546. The culvert is located in the geographic township of Thompson, Ontario. At the site, Highway 17 is classified as a Rural Arterial and is a three-lane roadway (two lanes plus a passing lane) with a posted speed limit of 90 km/h. The pavement is roughly 11.1 m wide from edge of pavement to edge of pavement, with 1.7 to 2.0 m wide paved and 1.2 to 1.8 m wide granular shoulders. A steel cable guardrail is present along the south side of the highway with a steel beam guardrail present along the north side. The elevation at the pavement centreline is 186.5 m. The roadway embankment above the existing ground is roughly 4.2 to 4.6 m high. Rip-rap is present along the southern embankment (outlet), with gabion walls present near the toe of the southern embankment, adjacent to the culvert.

Based on the information in the TOR, the existing culvert is a reinforced, cast-in-place, concrete box culvert having a skew angle of approximately 16° with a length of 31.8 m, a span of 3.1 m, and a height of 1.8 m. The top of culvert elevation at the inlet (north side) is 183.06 m and at the outlet (south side) is 182.70 m.

The general site conditions were assessed by EXP during our site reconnaissance on August 30, 2022, and during the field investigation between October 17 and 18, 2022. Photographs of the culvert site from the investigation are included in Appendix A. At the culvert, Highway 17 follows a generally northwest to southeast direction, however, overall, the highway runs in a general east-west direction. For purposes of this report, eastbound and westbound directions will be referenced. One lane travels in the westbound direction, with two lanes (one travelled lane and one passing lane) in the eastbound direction. The flow direction within the culvert runs from north to south. The approximate top of water elevation within the creek at the time of the field investigation was 181.3 m at the inlet and 180.6 m at the outlet.

No existing geotechnical information is available within the MTO Foundation Library for the existing culvert.

### 1.2.2 Geological Setting

In accordance with Ontario Geological Survey, Northern Ontario Engineering Geology Terrain Study 97, the local geology at the site consists of sandy gravelly alluvial plain. Relief is low (< 15 m) with planar and channeled surfaces and drainage is dry with a suspected high water table. In accordance with MNDMNRF Bedrock Geology of Ontario Map 2544, southern sheet, bedrock in the area consists of conglomerate, sandstone, siltstone, and argillite of the Cobalt Group of the Huronian Supergroup.

## 1.3 Investigation Procedures

### 1.3.1 Field Investigation

The field investigation for this project was performed between October 17 and 18, 2022. The field program consisted of four (4) sampled boreholes. Two boreholes, BH-D1 and BH-D2, were advanced at accessible locations near the culvert outlet and inlet, respectively. The remaining two boreholes, BH-R1 and BH-R2, were located on the roadway to provide subsurface information for the culvert replacement and the temporary roadway protection system, if required. Borehole BH-R1 was advanced as close as possible to the existing culvert, and BH-R2 was advanced approximately 16 m east of the culvert. The borehole locations are shown on Dwg. No. B-1, included in Appendix B. A summary of the advanced borehole details is included on Table 1-1 below.

The roadway boreholes (BH-R1 and BH-R2) were advanced using a CME 55 truck mounted drill rig, while the outlet and inlet boreholes (BH-D1 and BH-D2) were advanced using a portable tripod drill. Both drills were equipped with hollow stem augers and standard soil sampling equipment. All drilling equipment was operated by Landcore Drilling. Traffic control was provided throughout the investigation by Beacon Lite Limited.

For the drilling program, soil samples were obtained directly from the augers within the existing pavement structure and using a 51 mm outside diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586) at intervals ranging from 0.75 m to 1.5 m in depth as shown on the attached borehole logs (Appendix C). The original field (uncorrected) SPT “N” values were recorded on the borehole logs as recommended in the Canadian Foundation Engineering Manual (CFEM, pg. 40) and used to provide an assessment of in-situ relative density of non-cohesive soils.

The borehole elevations and locations were surveyed by EXP personnel using a Trimble Catalyst DA2 Global Navigation Satellite System (GNSS) receiver. The borehole locations are referenced to both NAD83 Lat/Long, as well as NAD83 MTM Zone 13 coordinates.

Groundwater level measurements were completed within the boreholes upon completion. At the culvert inlet, Borehole BH-D2 was completed with a 50 mm diameter standpipe piezometer. EXP returned to the site on November 4, 2022 to measure groundwater within the piezometer. The boreholes were decommissioned by bentonite/cement mixtures in accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the *Ontario Water Resources Act*).

The fieldwork was supervised by an EXP geotechnical representative who directed the drilling and sampling operation, logged borehole data in accordance with MTO and/or ASTM Standards for Soils Classification and retrieved samples for subsequent laboratory testing and identification.

All recovered soil samples were placed in labelled moisture-proof bags and returned to EXP’s Sudbury laboratory for additional visual, textual, olfactory examination and selective testing.

**Table 1-1: Summary of Boreholes**

Location	Borehole No.	Location (NAD83 MTM 13)		Ground Surface Elevation (m)	Borehole Depth (m)
		Northing	Easting		
Roadway, Adjacent to Culvert	BH-R1	5124466.1	366818.0	182.2	10.0
Roadway, 16 m East of Culvert	BH-R2	5124492.4	366846.9	182.1	10.0
Culvert Outlet	BH-D1	5124479.0	366822.8	186.8	14.5
Culvert Inlet	BH-D2	5124461.1	366852.5	186.8	14.5

### 1.3.2 Laboratory Testing

All soil samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program included the determination of natural moisture content on all soil samples and grain/particle size distribution and Atterberg Limits (as appropriate) for approximately 25% of the collected soil samples. All of the laboratory tests were carried out according to MTO and/or ASTM Standards as appropriate.

In addition to the geotechnical laboratory testing, one (1) representative sample was submitted to a CALA Certified Laboratory for chemical corrosivity analysis including pH, resistivity, redox potential, chloride, sulphate, and sulphide contents.

The results of the geotechnical laboratory testing are included in Appendix D and the corrosivity test results are included in Appendix E.

## 1.4 Subsurface Conditions

The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the borehole log sheets in Appendix C. Laboratory test results are provided in Appendix D. The “Explanation of Terms Used in Report” preceding the borehole logs in Appendix C forms an integral part of and should be read in conjunction with this report.

A borehole location plan and cross section subsurface profiles are provided in Appendix B. It should be noted that the stratigraphic boundaries indicated on the borehole log and cross section stratigraphic profiles are inferred from semi-continuous sampling, observations of drilling progress, and results of Standard Penetration Tests. These boundaries typically represent transitions from one soil type to another and should not be regarded as exact planes of geological change. Furthermore, subsurface conditions may vary between and beyond the borehole locations.

A detailed description of the subsurface conditions encountered is discussed further in subsequent sections.

### 1.4.1 Asphalt

Asphalt was encountered at the surface of Boreholes BH-R1 and BH-R2, and was 360 mm and 300 mm thick, respectively. Asphalt thicknesses may further vary beyond the borehole locations.

### 1.4.2 Topsoil

Topsoil was encountered at the surface of Boreholes BH-D1 and BH-D2, and was 100 mm and 150 mm thick, respectively. Topsoil thicknesses may further vary beyond the borehole locations.

### 1.4.3 Fill Materials

Fill materials were encountered below the asphalt at Boreholes BH-R1 and BH-R2. At BH-R1, the fill materials extended to 6.9 m depth. At BH-R2, the fill materials extended to the base of the pavement structure at 1.5 m depth.

#### 1.4.3.1 Sand and Gravel Fill

A 150 to 160 mm thick base layer was encountered below the asphalt at Boreholes BH-R1 and BH-R2. The base fill consisted of sand and gravel with trace silt. The base fill materials were brown in colour and dry. Moisture content tests and one (1) grain size analysis were performed on representative samples of the base fill materials with the results summarized as follows:

##### Moisture Content:

- 1.3 to 2.1%

##### Grain Size Distribution:

- 38% Gravel
- 55% Sand
- 8% Fines

The results of the moisture content and grain size distribution tests are included on the borehole logs in Appendix C. The results of the grain size distribution test are also provided on Figure 1 in Appendix D.

#### 1.4.3.2 Sand Fill

A subbase layer was encountered below the base fill materials at Boreholes BH-R1 and BH-R2, and extended to 2.3 and 1.5 m depth, respectively. The subbase fill consisted of sand with some gravel and trace silt. The subbase fill was brown in colour and dry to moist. Uncorrected SPT “N” values within the subbase fill ranged from 12 to 44 blows per 300 mm, classifying the fill as compact to dense in compactness condition. Moisture content tests were performed on representative samples of the subbase fill materials with the results summarized as follows:

##### Moisture Content:

- 1.8 to 9.5%

The results of the moisture content tests are included on the borehole logs in Appendix C.

#### 1.4.3.3 Sandy Silt Fill

Sandy silt fill was encountered below the subbase fill materials at Borehole BH-R1 and extended to 6.9 m depth. The sandy silt fill contained trace gravel in the upper portion changing to no gravel with some organics and some clay below approximately 3.8 m depth. The sandy silt fill was grey, brown, and dark brown in colour, and moist becoming wet with depth. Uncorrected SPT “N” values within the sandy silt fill ranged from 2 to 6 blows per 300 mm, classifying the fill as very loose to loose in compactness condition. Moisture content tests and one (1) particle size analysis were performed on representative samples of the sandy silt fill materials with the results summarized as follows:

##### Moisture Content:

- 1.3 to 2.1%

**Grain Size Distribution:**

- 0% Gravel
- 20% Sand
- 68% Silt
- 11% Clay

The results of the moisture content and particle size distribution tests are included on the borehole logs in Appendix C. The results of the particle size distribution test are also provided on Figure 2 in Appendix D.

**1.4.4 Sandy Silt**

A thin layer of native sandy silt was encountered below the fill material at Borehole BH-R2, from 1.5 to 2.3 m depth. The sandy silt is considered possible fill, however, could not be confirmed based on observations of the soil. The sandy silt contained some organics and was dark brown to brown in colour and wet. One SPT performed within the sandy silt resulted in an uncorrected "N" value of 20 blows per 300 mm, classifying the sandy silt as compact in compactness condition. A moisture content test was performed on a representative sample of the sandy silt with the results summarized as follows:

**Moisture Content:**

- 25.8%.

The result of the moisture content test is included on the borehole log in Appendix C.

**1.4.5 Organic Silt**

Native organic silt with intermediate plasticity was encountered below the topsoil at Boreholes BH-D1 and BH-D2 and extended to 1.5 m depth. The organic silt contained some clay, and trace to some sand. The organic silt was dark brown to brown in colour and wet. Uncorrected SPT "N" values within the organic silt were 1 blow per 300 mm, classifying the soil as very soft in consistency. Moisture content tests, one (1) particle size analysis, and one (1) Atterberg Limits test were performed on a representative sample of the organic silt with the results summarized as follows:

**Moisture Content:**

- 44.9 to 54.0%

**Grain Size Distribution:**

- 0% Gravel
- 6% Sand
- 79% Silt
- 15% Clay

**Atterberg Limits:**

- Liquid Limit: 41%
- Plastic Limit: 32%
- Plasticity Index: 9%

The results of the various tests are included on the borehole logs. The result of the particle size distribution test is also provided on Figure 3 in Appendix D, with the Atterberg Limits test results also provided on Figure 8 in Appendix D.

### 1.4.6 Clayey Silt

Native clayey silt with trace sand was encountered at 1.5 m depth at Boreholes BH-D1 and BH-D2 and extended to 4.6 m and 3.1 m depth, respectively. Clayey silt was also encountered below the fill materials at BH-R1 and extended to 9.1 m depth. The clayey silt was dark grey in colour and wet. Uncorrected SPT “N” values within the clayey silt ranged from 0 to 4 blows per 300 mm, classifying soil as very soft to firm in consistency. Moisture content tests, three (3) particle size analyses, and three (3) Atterberg Limits tests were performed on representative samples of the clayey silt with the results summarized as follows:

#### Moisture Content:

- 52.0 to 70.9%, one sample at 18.0%.

#### Grain Size Distribution:

- 0% Gravel
- 1 to 2% Sand
- 70 to 74% Silt
- 25 to 29% Clay

#### Atterberg Limits:

- Liquid Limit: 50 to 58%
- Plastic Limit: 33 to 41%
- Plasticity Index: 11 to 17%

The results of the various tests are included on the borehole logs. The results of the particle size distribution tests are also provided on Figure 4 in Appendix D, with the Atterberg Limits test results also provided on Figure 8 in Appendix D.

### 1.4.7 Silty Sand

A layer of native silty sand was encountered below the clayey silt at Borehole BH-D1, extending from 4.6 to 6.1 m depth. The silty sand contained trace gravel and trace clay and was grey in colour and wet. One SPT performed within the silty sand resulted in an uncorrected “N” value of 6 blows per 300 mm, classifying the silty sand as loose in compactness condition. A moisture content test and one (1) particle size analysis test were performed on a representative sample of the silty sand with the results summarized as follows:

#### Moisture Content:

- 34.7%.

#### Grain Size Distribution:

- 5% Gravel
- 66% Sand
- 23% Silt
- 6% Clay

The results of the moisture content and particle size distribution tests are included on the borehole log in Appendix C. The results of the particle size distribution test are also provided on Figure 5 in Appendix D.

### 1.4.8 Sand

Native sand layers were found in each borehole as follows:

- At BH-R1 below the clayey silt from 9.1 m depth to the borehole termination depth of 14.5 m;
- At BH-R2 below the sandy silt from 2.3 to 4.6 m depth (possible fill), and at 12.2 m depth to the borehole termination depth of 14.5 m;
- At BH-D1 below the silty sand from 6.1 m depth to the borehole termination depth of 10.0 m; and,
- At BH-D2 below the clayey silt from 3.1 m depth to the borehole termination depth of 10.0 m.

At Borehole BH-R2, the upper layer of sand is considered possible fill, however, could not be confirmed based on observations of the soil.

The sand contained trace silt, trace gravel, trace clay, and was brown to grey in colour, and moist to wet. Uncorrected SPT “N” values within the sand ranged from 1 to 13 blows per 300 mm, classifying the soil as very loose to compact in compactness condition. Moisture contents tests and five (5) particle size analyses were performed on representative samples of the sand with the results summarized as follows:

#### Moisture Content:

- 4.5 to 31.3%

#### Grain Size Distribution:

- 0% Gravel
- 82 to 97% Sand
- 3 to 16% Silt
- 1 to 2% Clay

The results of the moisture content and particle size distribution tests are included on the borehole logs. The results of the particle size distribution tests are also provided on Figure 6 in Appendix D.

### 1.4.9 Silt and Sand

Native silt and sand was encountered below the upper sand layer at Borehole BH-R2, extending from 4.6 to 12.2 m depth. The silt and sand contained trace clay and was brown in colour and wet. Uncorrected SPT “N” values within the silt and sand ranged from 1 to 3 blows per 300 mm, classifying the silt and sand as very loose in compactness condition. Moisture contents tests and two (2) particle size analyses were performed on representative samples of the silt and sand with the results summarized as follows:

#### Moisture Content:

- 4.5 to 31.3%

#### Grain Size Distribution:

- 0% Gravel
- 32 to 35% Sand
- 60% Silt
- 5 to 8% Clay

The results of the moisture content and particle size distribution tests are included on the borehole logs. The results of the particle size distribution tests are also provided on Figure 6 in Appendix D.

#### 1.4.10 DCPT

Dynamic Cone Penetration Tests were advanced from approximately 1.5 m depth immediately adjacent to Boreholes BH-R1 and BH-R2. In general, the DCPT values were generally higher than the corresponding SPT “N” values, suggesting the in-situ soils are more compact than indicated by the SPT results.

#### 1.4.11 Groundwater and Surface Water

Boreholes BH-R1, BH-R2, and BH-D1 were dry upon completion. However, the boreholes were not left open for any significant amount of time upon completion, and as such, groundwater levels may not have fully recharged within the boreholes. As noted previously, a piezometer was installed at Borehole BH-D2 (culvert inlet). Groundwater was encountered within the piezometer at 0.45 m depth (Elev. 181.65) upon completion. EXP returned to the site on November 4, 2022 and April 26, 2023 to again measure the groundwater level within the installed piezometer. A summary of the measured groundwater levels is noted on Table 1-2.

**Table 1-2:** Summary of Groundwater Level Measurements

Measurement Date	Borehole BH-D2	
	Groundwater Depth (m)	Elevation (m)
<b>October 18, 2022 (upon BH completion)</b>	0.45	181.65
<b>November 4, 2022</b>	3.5	178.60
<b>April 26, 2023</b>	1.9	180.20

The approximate top of water elevation within the creek at the time of the field investigation was 181.3 m at the inlet and 180.6 m at the outlet.

Seasonal variations in the water table should be anticipated, with higher levels occurring during wet weather conditions (spring thaw and late fall) and lower levels occurring during dry weather conditions.



## 1.5 Corrosivity Testing

One (1) representative soil sample was submitted to a CALA certified laboratory for chemical corrosivity testing. The results of the chemical testing are summarized below, with detailed results included in Appendix E.

**Table 1-3:** Summary of Corrosivity Test Results

Parameter	Borehole, Sample No., Depth
	BH-R1, SS8, 4.6 to 5.2 m
Chloride (µg/g)	870
Sulphate (µg/g)	420
Sulfide (%)	< 0.04
pH	5.89
Electrical Conductivity (mS/cm)	1,440
Resistivity (ohm.cm)	696
Redox Potential (mV)	342
Corrosivity Index	11

## 2. Foundation Design Report

### 2.1 General

This section of the report provides geotechnical design recommendations for the proposed replacement of the Everett Lake Tributary Culvert located along Highway 17. The culvert is located 3.3 km southeast of the junction of Highway 546 in the Township of Thompson, Sault Ste. Marie Area (Lat: 46.257° Long: -83.195°). The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation at the site by EXP in October 2022. The compiled factual data is presented in **Section 1. Foundation Investigation Report** of this report. The interpretation and recommendations provided are intended solely to permit designers to assess foundation alternatives and design the new replacement culvert. Comments on construction are only provided to highlight issues that could affect the design. Contractors bidding on the works should make their own assessments of the factual data and how it might affect construction means and methods, scheduling, and the like.

The existing culvert which conveys water below Highway 17 is a reinforced, cast-in-place, concrete box culvert having a skew angle of approximately 16° with a length of 31.8 m, a span of 3.1 m, and a height of 1.8 m. A Structure Inspection Report provided by the MTO from 2021 indicates the existing culvert is in overall fair to poor condition with scaling and cracking of the concrete and some areas of spalling with exposed corroded rebar. The embankment on the inlet (north) side has an approximate side slope of 1.5H:1V, flattening to 3H:1V near the toe, and has displayed moderate erosion. The embankment on the outlet (south) side has an approximate side slope of 2H:1V. Movement of the rock slope protection on the south embankment was observed, with rocks found in the watercourse. The southwest gabion basket at the toe of the slope has failed, with the southeast gabion basket showing tears, corrosion, and movement.

The water level in the water course was measured at Elev. 180.6 to 181.3 m at the time of the investigation, with groundwater measured at Elev. 178.6 to 180.2 m in November 2022 and April 2023. Seasonal variations in the water levels should be expected, with higher levels occurring during wetter periods of the year and lower levels during drier periods.

The type of culvert and method of replacement is not known at the time of writing this report. However, it is assumed that the new culvert will be installed at the same location of the existing culvert having the same or similar elevation of the invert at the inlet and outlet sides. It is also assumed that the new embankment will be constructed with no grade change at the culvert location. Furthermore, it has been assumed that the Gabion Wall currently located adjacent to the outlet of the culvert will be replaced as part of the new construction.

This report addresses the geotechnical design of the foundation for the proposed culvert and Gabion Wall by providing geotechnical design parameters at the Ultimate Limit State (ULS) and Serviceability Limit States (SLS) as well as other geotechnical parameters that may be required in accordance with the latest edition of the Canadian Highway Bridge Design Code (CHBDC) (CAN/CSA-S6-19), the Guideline for Professional Engineers Providing Geotechnical Engineering Service (1992), the Canadian Foundation Engineering Manual (CFEM) (2006), the Ontario Ministry of Transportation (MTO) Guideline for Foundation Engineering Services, Version 3.0 (2022) and good practice. The proposed structure and its foundation system are interpreted to be classified as having a “typical” consequence level associated with exceeding limits states design. Given the level of foundation investigation completed, the level of confidence for design is interpreted to be “typical” degree of site and prediction model understanding. Table 6.1 and 6.2 of the CHBDC, CAN/CSA-S6-19 have been used in the design to establish the appropriate consequence factor and geotechnical resistance factors.

Pertinent construction issues from a geotechnical standpoint are examined in general accordance with the Terms of Reference provided to us in the RFP for this project dated May 2022. The assessment involved review of options for replacement of the existing culvert along the proposed alignment using different replacement methods, as well as replacement of the Gabion Wall.

## 2.2 Expected Ground Conditions

The following ground conditions along the proposed culvert alignment are evident from the current investigation:

- At the site, Highway 17 is a three-lane roadway (two lanes plus a passing lane). The pavement is roughly 11.1 m wide, with 1.7 to 2.0 m wide paved and 1.2 to 1.8 m wide granular shoulders. A steel cable guardrail is present along the south side of the highway with a steel beam guardrail present along the north side. The elevation at the pavement centreline is 186.5 m. The roadway embankment above the existing ground is roughly 4.2 to 4.6 m high. Rip-rap is present along the southern embankment (outlet), with gabion basket walls present near the toe of the southern embankment, adjacent to the culvert. Embankment side slopes are roughly 1.4H:1V.
- The existing culvert is a reinforced, cast-in-place, concrete box culvert having a skew angle of approximately 16° with a length of 31.8 m, a span of 3.1 m, and a height of 1.8 m. The top of culvert elevation at the inlet (north side) is 183.06 m and at the outlet (south side) is 182.70 m.
- Per Borehole BH-R1, below the asphalt, the pavement structure of the highway consists of 0.15 m of sand and gravel fill granular base material overlying 1.8 m of sand fill subbase material. Below the pavement structure, the embankment fill consisted of 4.6 m of loose to very loose sandy silt fill. The embankment fill was underlain by 2.2 m of soft to firm native clayey silt followed by very loose to compact native sand that extended to the borehole termination depth or 14.5 m.
- Per Borehole BH-R2, east of the culvert, below the asphalt the pavement structure of the highway consists of 0.15 m of sand and gravel fill base material overlying 1.0 m of sand fill subbase material. Below the pavement structure was 0.8 m of compact sandy silt overlying 2.3 m of compact sand. It is unclear from observations during the investigation whether these materials were native soils or possible fill. Below the sand was 7.6 m of very loose silt and sand overlying a lower very loose sand layer that extended to the borehole termination depth of 14.5 m.
- At the outlet, Borehole BH-D1 encountered 0.1 m of topsoil overlying 1.4 m of very soft native organic silt followed by 3.1 m of very soft clayey silt, 1.5 m of loose silty sand, and finally loose to compact sand that extended to the borehole termination depth of 10 m. At the inlet, Borehole BH-D2 encountered 0.15 m of topsoil overlying 1.35 m of very soft native silt followed by 1.6 m of very soft to soft clayey silt, and loose to compact sand that extended to the borehole termination depth of 10 m.
- It is assumed the invert of the new culvert will be at roughly Elev. 181.0 m +/- . The foundation soil below the culvert is anticipated to be very soft to firm clayey silt.
- Groundwater was measured within the installed piezometer at Elev. 178.6 and 180.2 m in November 2022 and April 2023, respectively. The approximate top of water elevation within the creek at the time of the field investigation was 181.3 m at the inlet and 180.6 m at the outlet. Seasonal variations in the water table should be anticipated, with higher levels occurring during wet weather conditions (spring thaw and late fall) and lower levels occurring during dry weather conditions.

## 2.3 Culvert Foundation Options

It is understood that type and size of the new culvert has not been determined yet. The choice of culvert type and size depends on hydraulic performance, staging requirements, geotechnical resistance available in the foundation soils, initial cost, maintenance costs, ease of construction, soil corrosiveness, salvageability and local availability of material and equipment. However, from a geotechnical perspective, the following options were considered at this site:

- Precast rigid frame concrete box culvert,
- Cast-in-place rigid frame concrete box culvert, and
- Cast-in-place rigid frame open footing concrete culvert supported on shallow foundations.

Based on the subsurface information obtained from the site investigations, the native very soft to firm silt/clayey silt is not considered suitable for supporting the culvert; therefore, it is recommended that the new culvert be founded on 0.3 m thick granular engineered fill over the native soil.

It is noted that regardless of the option selected, the existing culvert is to be removed. This will require excavation down to the existing founding elevation for all options (Approx. Elev. 181.0 m). This suggests the need for surface/groundwater control as discussed in Section 2.19 below.

The in-situ silt/clayey silt founding soils will be easily disturbed by construction traffic or inclement weather. As such, exposed subgrade soils should be immediately protected following excavation to prevent disturbance and provide a stable working surface. In general, any loose and/or soft soils encountered below the existing embankment should be excavated and replaced with engineered fill. If the depth of excavation to remove unstable soils is excessive, using a geotextile fabric in accordance with OPSS.PROV 1860, Class II Non-Woven (OPSS 1860 II-N), in conjunction with engineered fill can be considered to assist in providing a stable base for the new culvert. Based on previous experience, typically it should consist of Granular A or Granular B Type II (OPSS.PROV 1010) with a minimum thickness of 300 mm beneath the culvert and extend a minimum of 500 mm horizontally on either side of the foundation/culvert edges. The fabric should be installed in a manner to mitigate the migration of fines from adjacent material. Alternatively, a thin layer of lean mix concrete (10 MPa) can be placed over the exposed subgrade to provide protection. The lean mix concrete should extend a minimum of 500 mm horizontally on either side of the foundation/culvert edges.

An evaluation of culvert/foundation alternatives including advantages, disadvantages, risk/consequences and relative cost from a foundation perspective is provided in Table 2-1. The key findings and conclusions of the assessment are summarized as follows:

Closed box culverts, either precast or cast-in-place, installed with appropriate granular bedding over the subgrade were determined to be feasible. Among these three options, the use of a box culvert is ranked highest for the criteria evaluated. It should be noted that the proposed culvert must meet the required flow capacity and hydraulic requirements.

Open footed concrete culvert on spread footings is feasible at this site however likely more expensive than other options due to deeper excavations required for casting the footings.

**Table 2-1: Evaluation of Foundation Alternatives**

Option	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
<b>Precast rigid frame concrete box culvert</b>	1	<ul style="list-style-type: none"> <li>• Straightforward construction</li> <li>• Reduced construction period; consequently, traffic management and water control period</li> <li>• Reduced excavation depth</li> <li>• Can be more readily installed during cold weather conditions</li> </ul>	<ul style="list-style-type: none"> <li>• If floor is thin and poorly reinforced, it may heave and cracks</li> <li>• During high flows, the concrete floor can be undermined</li> <li>• Susceptible to defects/leakage at joints</li> <li>• Requires bedding material</li> <li>• Disturbance of natural streambed</li> <li>• Possible sediments accumulation in the upstream of the culvert</li> </ul>	<ul style="list-style-type: none"> <li>• Low to medium</li> </ul>	<ul style="list-style-type: none"> <li>• Risk of unacceptable differential settlements if the entire foundation is not supported on competent soil</li> <li>• Risk of leaking from joints if not properly installed</li> </ul>
<b>Cast-in-place rigid frame concrete box culvert</b>	2	<ul style="list-style-type: none"> <li>• Suitable if site is not appropriate to heavy equipment for installation of precast sections</li> <li>• Reduced excavation depth</li> <li>• Culvert design can be customized in the field for high stress or load conditions or other site-specific requirements</li> </ul>	<ul style="list-style-type: none"> <li>• Slower construction process</li> <li>• If floor is thin and poorly reinforced, it may heave and crack</li> <li>• During high flows, the concrete floor can be undermined</li> <li>• Requires concrete curing</li> <li>• Disturbance of natural streambed</li> <li>• Possible sediments accumulation in the upstream of the culvert</li> <li>• Extensive dewatering is required</li> </ul>	<ul style="list-style-type: none"> <li>• Likely more expensive than precast option due to need for extensive dewatering and slower construction process</li> </ul>	<ul style="list-style-type: none"> <li>• Risk of unacceptable differential settlements if the entire foundation is not supported on competent soil</li> <li>• Risk of disturbance of base during construction</li> </ul>

Option	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
<b>Cast-in-place rigid frame open footing concrete culvert</b>	3	<ul style="list-style-type: none"> <li>Wider span may be considered to maintain existing channel and to allow for natural streambed to remain intact</li> <li>Less accumulation of sediments in the upstream of culvert</li> </ul>	<ul style="list-style-type: none"> <li>Deeper excavation or below water excavation required</li> <li>Dewatering system required</li> <li>Requires concrete curing</li> </ul>	<ul style="list-style-type: none"> <li>Likely more expensive than other options due to need for extensive dewatering and deeper excavations</li> </ul>	<ul style="list-style-type: none"> <li>Risk of unacceptable differential settlements if the entire footing is not supported on competent soil</li> <li>Risk of delay in construction due to deeper excavation below water if proper dewatering is not maintained</li> <li>Higher scour risk</li> </ul>

## 2.4 Culvert Shallow Foundations

### 2.4.1 Geotechnical Resistance

Based on the subsurface stratigraphy encountered at this site and the proposed invert elevation of the new culvert, the following Table 2-2 summarizes the recommended resistances at the founding elevations for different types of culverts. The geotechnical resistances provided are for vertical loading condition only; load eccentricity and load inclination effects should be addressed in accordance with the CHBDC and its commentary. The geotechnical resistances provided in sections below were factored with a typical consequence factor of 1.0 at ULS and SLS; and typical degree of understanding (factor of 0.5 at ULS and factor of 0.8 at SLS) in accordance with Table 6.1 and 6.2 of the CHBDC S6-19.

**Table 2-2:** Recommended Resistances and Founding Elevations

Culvert Type	Founding Elevation (m)	Footing Size (m)	Founding Soil Type	Factored Geotechnical Resistance at ULS (kPa)	Factored Geotechnical Resistance at SLS <sup>(2)</sup> (kPa)
<b>Precast or cast-in-place rigid frame concrete box culvert</b>	~181.0	3.1	~ 0.6 m thick Gran. A or B Type II <sup>(3)</sup> Pad underlain by very loose clayey silt to silt	225	120
<b>Cast-in-place rigid frame open footing concrete culvert</b>	~179.2 <sup>(1)</sup>	1.0	~ 0.6 m thick Gran. A or B Type II <sup>(3)</sup> Pad underlain by very loose clayey silt	225	120

Notes:

- Below the frost line. Requires deeper groundwater control
- For maximum settlement of 25 mm
- The granular material used for the granular pad shall be Granular 'A' or Granular B Type II conforming to OPSS.PROV 1010 and compacted according to OPSS.PROV 501 (for Granular A) and OPSS.PROV 314 (for Granular B Type II).

It is assumed that, if any, underlying organic soils and any other soft or very loose materials are to be replaced with clean and compactable soil such as Granular A or Granular B Type II. Given that no grade raise, nor widening is planned, the anticipated maximum total settlements for the new proposed culvert are not expected to exceed 25 mm for construction done in accordance with these design parameters and assuming good construction practice including sound base preparation.

## 2.4.2 Resistance to Lateral Loads

Resistance to lateral forces/sliding should be calculated in accordance with Section 6.10.4 of the CHBDC. The coefficient of friction,  $\tan \delta$ , may be taken as 0.55 between the base of pre-cast concrete and Granular "A", and 0.6 between cast-in-place concrete and Granular "A". These values represent unfactored values; in accordance with the CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistance.

## 2.5 Culvert Bedding

OPSD 803.010 provides the bedding, embedment, cover and backfill standards for the concrete culverts. Culvert bedding should consist of Granular A or Granular B Type II (OPSS.PROV 1010) with a minimum thickness of 300 mm beneath the culvert and extend a minimum of 500 mm horizontally on either side of the culvert edge. The bedding material should be placed in layers not exceeding 200 mm in thickness, loose measurement, and compacted in accordance with OPSS.PROV 501, or according to OPSS.PROV 314 if Granular B Type II is used, before a subsequent layer is placed in accordance with OPSS.PROV 401. Based on the existing conditions at the site, Granular B Type II is the preferred material for culvert bedding below the water table.

Prior to placing any fill material, the exposed native subgrade should be inspected by a qualified geotechnical engineer. A non-woven geotextile separator is to be placed between the approved subgrade and the compacted fill to assist in material placement and maintain the integrity of the founding soil along the entire length of the culvert. The geotextile separator is to be a Class II non-woven material with an equivalent opening size of 75-150  $\mu\text{m}$ .

For the site area, a frost penetration depth of approximately 1.8 m can occur in open, unheated areas without snow cover. At the culvert inlet and outlet, and beneath the proposed culvert, the soils are comprised of mostly sandy silt fill and native clayey silt soils. This material has moderate to high frost susceptibility based upon the MTO Frost Classification guideline of percent particles between 5 to 75  $\mu\text{m}$ . Therefore, non-frost susceptible materials such as sand and gravel might be considered to be provided to the limit of frost penetration beneath the inlet and outlet of the culvert. However, considering that cold air blowing through the culvert during the winter season will freeze soil next to the culvert, a minimum 300 mm thick layer of non-susceptible material should be considered to be placed as bedding along the entire culvert length.

## 2.6 Culvert Backfill

The selection and placing of the backfill and cover should be in accordance with OPSS.PROV 902, OPSS.PROV 421, OPSS 422 and OPSD 803.010 for concrete culverts. The backfill should consist of free-draining, non-frost susceptible granular materials conforming to OPSS.PROV 1010 (i.e. Granular A/Granular B Type I or II).

All granular backfill materials should be placed in thin lifts (i.e., not exceeding 300 mm before compaction) and each lift should be compacted in accordance with OPSS. PROV 501, or according to OPSS.PROV 314 if Granular B Type II is used.

The use of heavy compaction equipment should be avoided immediately adjacent and above the culvert, as per MTO practice. The minimum height of fill cover above the crown of the culvert before power operated tractors or rolling equipment shall be 900 mm, unless otherwise noted by the Structural Engineer. During backfill placement, the height of the backfill should be maintained at approximately the same level on both sides of the structure, to avoid lateral displacement of the structure.

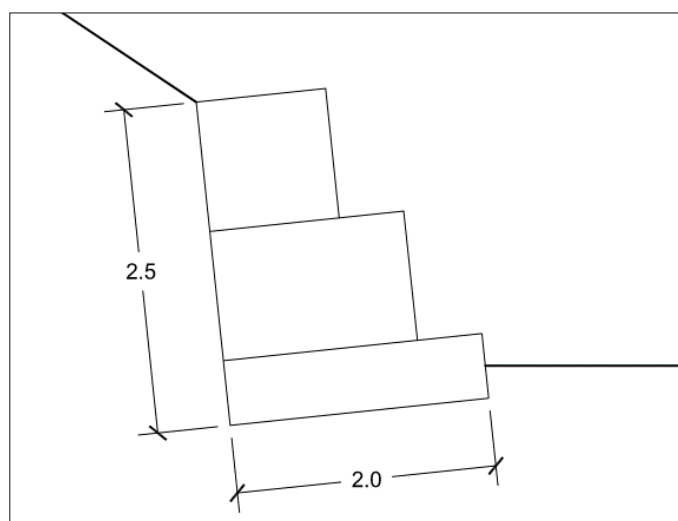
Although not anticipated, where less than 1.8 m (the frost depth) of earth cover is provided above the top of the culvert, a frost taper should be included as per OPSD 803.031.

## 2.7 Gabion Wall

The base of the Gabion wall at the outlet is assumed to be located at a similar level as the culvert outlet, embedded to a certain depth to avoid disturbance from erosion. An approximate Elevation of 180.5 m is anticipated. As such, the base of the retaining wall will likely be located in the encountered silt/clayey silt native soils.

The current Gabion wall is roughly 0.5 m taller in height than the culvert. Assuming a similar height of the new wall (approx. 2.5 m), conservatively a 2 m width base has been assumed. A cross-section of the anticipated wall section is shown on Fig. 2-1 below.

**Figure 2-1:** Anticipated Gabion Wall Section



The assumed 2 m wide footing, can be designed with a factored geotechnical resistance at Ultimate Limit States (ULS) of 190 kPa, calculated using a geotechnical resistance factor of 0.5. A geotechnical resistance at Serviceability Limit States (SLS) of 100 kPa may be used. The SLS value assumes a maximum settlement of 25 mm. A Gabion wall is typically considered a flexible structure, which can sustain some settlement.

A base layer of Granular A or Granular B Type II (OPSS.PROV 1010) with a minimum thickness of 300 mm should be placed beneath the wall and extend a minimum of 500 mm horizontally beyond the foundation edges. The base material should be placed in layers not exceeding 200 mm in thickness, loose measurement, and compacted in accordance with OPSS.PROV 501, or according to OPSS.PROV 314 if Granular B Type II is used, before a subsequent layer is placed in accordance with OPSS.PROV 401. Based on the existing conditions at the site, Granular B Type II is the preferred material for the base below the water table.

Prior to placing any fill material, the exposed native subgrade should be inspected according to OPSS.PROV 902. A non-woven geotextile separator is to be placed between the approved subgrade and the compacted fill to assist in material placement and maintain the integrity of the founding soil.

Backfill for the Gabion wall will be consistent with the embankment/culvert backfill noted in Section 2.5, consisting of free-draining, non-frost susceptible granular materials conforming to OPSS.PROV 1010. A geotextile separator should be placed between the Gabion wall and the backfill to prevent loss of retained soil during drainage.



Geotextile where required is to be a Class II non-woven material with an equivalent opening size of 75-150 µm.

## 2.8 Frost Protection

The frost depth in the area of the culvert is estimated to be approximately 1.8 m in accordance with OPSD 3090.100. A minimum 1.8 m of soil cover or equivalent frost protection should be provided using thermal insulation only to the rigid frame open footing culvert option. For the box culvert options, frost protection is not required. The Gabion wall is flexible, allowing for frost movement without fractures.

## 2.9 Lateral Earth Pressures

Culvert walls, retaining walls, and temporary shoring should be designed to resist lateral earth pressure. The expression for calculating lateral earth pressure is given by:

$$P = K(\gamma h + q) \text{ for non-braced cut, or } K(0.65\gamma h + q) \text{ for braced cut}$$

where,

P = earth pressure intensity at depth h, kPa

K = earth pressure coefficient

$\gamma$  = unit weight of retained soil, kN/m<sup>3</sup>

q = surcharge near wall, kPa

h = depth to point of interest, m

The above expression does not take into account hydrostatic pressure, which must be included for the groundwater levels measured on the site. Table 2-3 lists earth pressure parameters for given materials. These recommendations assume level backfill and ground surface behind the walls.

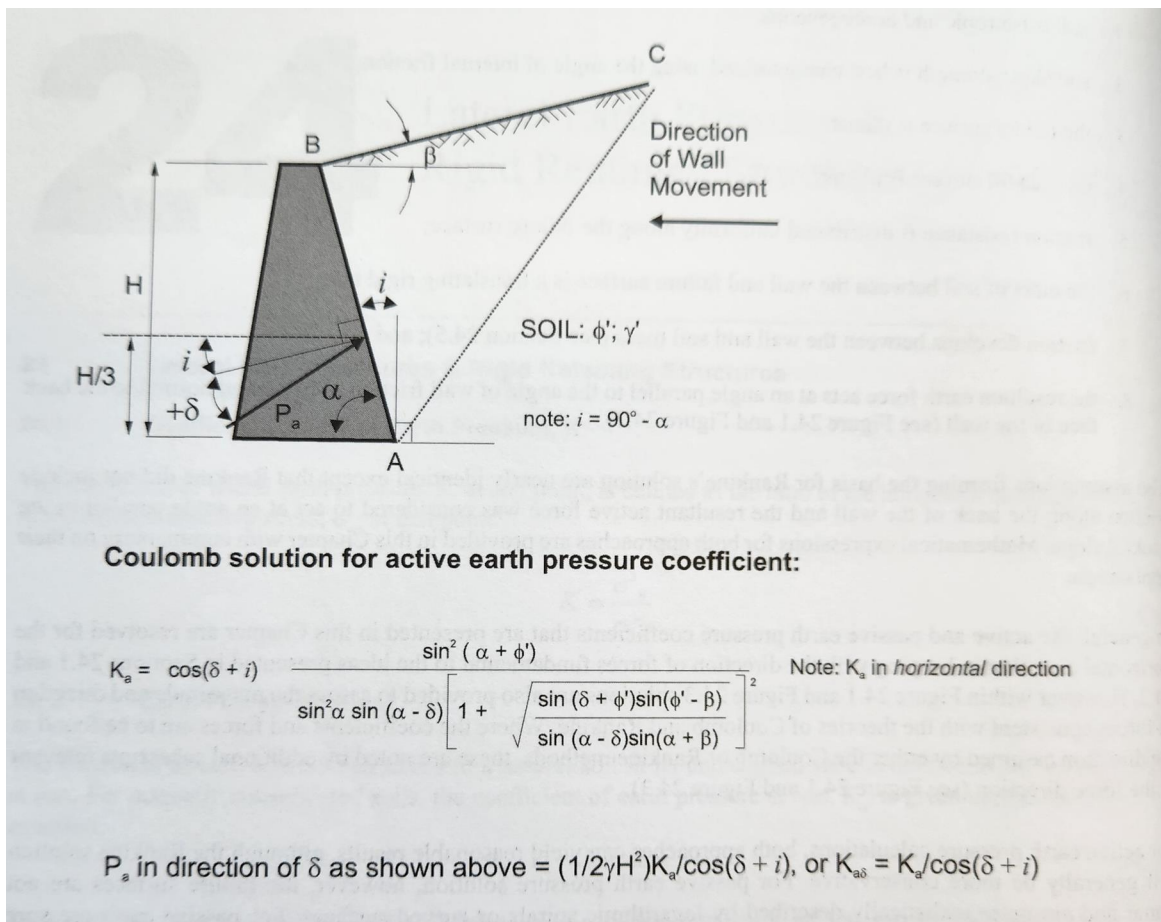
**Table 2-3: Earth Pressure Properties**

Material	Friction Angle $\phi'$ (unfactored)	Coefficient of Active Earth Pressure ( $k_a$ )	Coefficient of Passive Earth Pressure ( $k_p$ )	Coefficient of Earth Pressure at Rest ( $k_o$ )	Unit Weight $\gamma$ (kN/m <sup>3</sup> )
Granular "A"	35°	0.27	3.7	0.43	22
Granular "B" Type II	35°	0.27	3.7	0.43	21
Existing Sand Fill (compact to dense)	35°	0.27	3.7	0.43	20
Existing Sandy Silt Fill (very loose to compact)	29°	0.35	2.88	0.52	18
Native Sandy Silt (compact)	29°	0.35	2.88	0.52	18
Native Organic Silt to Clayey Silt (very soft to firm)	26°	0.39	2.56	0.56	14
Native Silty Sand to Sand (very loose to compact)	30°	0.33	3.00	0.50	19
Native Silt and Sand (very loose)	29°	0.35	2.88	0.52	18

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation. Therefore, unless the structural element can tolerate these deflections, the at-rest earth pressure should be used in design. This would normally be the case for concrete box culverts. For the Gabion wall, where it is assumed that some movement would be permissible, the active earth pressure would apply.

For sloping backfill, which is assumed behind the Gabion wall, the Coulomb solution for active earth pressure can be utilized from Fig. 24.1 of the CFEM 4<sup>th</sup> Edition as follows as shown on Fig. 2-2 below:

**Figure 2-2:** Coulomb Solution for Active Earth Pressure Coefficient (Fig. 24.1, CFEM 4<sup>th</sup> Edition)



For Fig. 2-2,  $\delta$  is the friction angle between the Gabion Basket retaining wall and backfill soil, which can be taken as 10°.

The effect of compaction surcharge should be taken into account in the calculations of active and at-rest earth pressures. The lateral pressure due to compaction should be taken as at least 12 kPa at the surface, and its magnitude should be assumed to diminish linearly with depth to zero at the depth where the active (or at-rest) pressure is equal to 12 kPa. This pressure distribution should be added to the calculated active (or at-rest) pressure. Notwithstanding, lighter compaction equipment and smaller lifts should be used adjacent to walls to prevent overstressing.

## 2.10 Seismic Considerations

Seismic characterization of the site should be compliant with the Canadian Highway Bridge Design Code (CHBDC, CAN/CSA-S6-19). Table 4.1 in CHBDC (see Clause 4.4.3.2) shows site classification for seismic site response based on average soil properties in the top 30 m. The borehole information shows the presence of native very loose to compact cohesionless soil and very soft to firm cohesive soils with no bedrock was encountered at the investigated depth. Based on these soil characteristics, the site class for this site is estimated to be Class “E” according to Table 4.1.

From the Natural Resources Canada website, 2020 NBCC seismic hazard values obtained using the site location coordinates and Site Class “E”, are shown in Table 2-4 below, with detailed results attached in Appendix G:

**Table 2-4:** Seismic design values for footings (Lat: 46.257° Long: -83.195°)

Probability of Exceedance in 50 Years (Return Period)	S <sub>a</sub> (0.2)	S <sub>a</sub> (0.5)	S <sub>a</sub> (1.0)	S <sub>a</sub> (2.0)	PGA (g)
2%	0.162	0.191	0.12	0.0579	0.0906
5%	0.0932	0.112	0.0682	0.0315	0.0506
10%	0.0581	0.0694	0.0409	0.018	0.0308

These values are associated with an earthquake having a 2 percent, 5 percent, and 10 percent probability of exceedance in a 50-year period.

Based on soil and groundwater conditions encountered at the site, no liquefaction is expected due to the ground motion from an earthquake having 10% probability of exceedance in a 50-year period.

## 2.11 Corrosivity Analysis

One (1) soil sample from Borehole BH-R1 was selected for chemical analysis to determine the potential degradation of the concrete in the presence of soluble sulphates and potential of corrosion of exposed steel used in foundations and buried infrastructure. The analysis results are summarized on Table 1-3 with detailed results attached in Appendix E.

The pH, resistivity, and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH level was measured at 5.89 and is indicative of a moderately acidic soil which is below the normal range of soil pH of 7.5 to 8.5. Resistivity was measured at 696 ohm.cm which suggests a very high potential for corrosion of buried metallic elements in accordance with MTO Gravity Pipe Design Guidelines, April 2014. Chloride concentrations greater than 500 µg/g (ppm) are generally considered corrosive. Chloride was measured at 870 µg/g and as such, is considered corrosive.

Based on the chemical results, corrosion protection for buried metallic elements will be required. It is up to the designer to determine the requirements of appropriate protective coating measures to ensure that all aspects of CHBDC 2019, Section 2 “Durability” requirements are followed. The test results provided in Table 1-2 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. Based on the results of the tested sample and given that the structure is located adjacent to the roadway and will be exposed to de-icing salt, consideration should be given to designing concrete for a “C” type exposure class as defined by Table 1 of CAN/CSA A23.1.

The maximum water-soluble sulphate content of the tested sample was 420 µg/g (ppm), i.e. 0.042%. As such, there is negligible potential for sulphate attack from the encountered soils on concrete based on Table 3 of CAN/CSA A23.1 and sulphate resistant concrete is not required.

## 2.12 Construction Alternatives

The following construction alternatives for the culvert replacement at this site were considered:

- (i) open-cut unsupported excavation and replacement under a full highway closure;
- (ii) Staged replacement with temporary roadway protection system (i.e. half-and-half construction with roadway protection to allow excavation while maintaining traffic on the existing embankment during construction) with unsupported cut side; and,
- (iii) Staged replacement with temporary roadway protection system (i.e. half-and-half construction with roadway protection to allow excavation while maintaining traffic on the existing embankment during construction) with braced cut sides.

All methods considered utilize a cut and cover approach for the culvert replacement which allows complete removal of the existing culvert, but it requires disruption of traffic.

Additional construction alternatives are available such as “Staged Construction using a Temporary Modular Bridge” or “Staged Construction with Temporary Widening of Highway 17 to Construct Local Detour”, however, these options have not been considered herein as additional geotechnical investigation would be required (i.e. at proposed bridge abutments or along detour alignment) to provide recommendations.

Table 2-5 summarize advantages and disadvantages of the considered construction alternatives from a geotechnical perspective. The table also shows assessed risk/consequences and relative costs of the considered methods. Schematic diagrams of the half-and half construction alternatives are attached in Appendix H.

**Table 2-5: Geotechnical Evaluation of Construction Alternatives for Culvert Replacement**

Installation Method		Rank	Advantages	Disadvantages	Relative Costs
<b>Open Cut Unsupported Excavation under a Full Highway Closure</b>		1	<ul style="list-style-type: none"> <li>Allows for assessment of the foundation soil</li> <li>Removal of existing culvert</li> <li>Existing sandy silt embankment fill can be removed and replaced with free draining granular material</li> <li>Adaptable to changing ground conditions</li> <li>Straight forward construction and construction procedures</li> <li>No excavation support/roadway protection required</li> <li>Short construction period</li> </ul>	<ul style="list-style-type: none"> <li>Large amount of soil to be excavated</li> <li>Need to temporarily control existing creek water and groundwater</li> </ul>	<ul style="list-style-type: none"> <li>Less expensive than other cut and cover methods with shoring systems</li> <li>Low risk of cost overrun and inability to finish job</li> </ul>
<b>Half and Half Construction</b>	<b>Shoring System with Sloping Cuts</b>	2	<ul style="list-style-type: none"> <li>Allows for assessment of the foundation soil</li> <li>Removal of existing culvert</li> <li>Existing sandy silt embankment fill can be removed and replaced with free draining granular material</li> <li>Short mobilization time</li> <li>Straight forward construction and construction procedures</li> <li>Min. 1 lane of traffic maintained during construction. As existing Hwy. is 3 lanes wide, may be possible to maintain 2 lanes of traffic during construction</li> </ul>	<ul style="list-style-type: none"> <li>Roadway protection required for up to 6 m +/- deep excavation</li> <li>High cost of shoring system (i.e. roadway protection)</li> <li>Large amount of soil to be excavated</li> <li>Need to temporarily control existing creek water and groundwater</li> </ul>	<ul style="list-style-type: none"> <li>Higher costs due to roadway protection system</li> <li>Moderate risk of cost overrun and instability to finish job due to roadway protection system</li> </ul>

Installation Method		Rank	Advantages	Disadvantages	Relative Costs
Half and Half Construction	Shoring System with Braced Cuts	3	<ul style="list-style-type: none"> <li>One or possibly two lanes (e.g. steel decking, but costly) of traffic flow maintained on existing road</li> <li>Allows for assessment of the foundation soil</li> <li>Global stability of excavation enhanced by narrow geometry</li> <li>Removal of existing culvert</li> <li>Less traffic interruption than shoring system with sloping cuts approach</li> <li>Less roadway protection required due to smaller culvert excavation</li> <li>Min. 1 lane of traffic maintained during construction. As existing Hwy. is 3 lanes wide, may be possible to maintain 2 lanes of traffic during construction</li> </ul>	<ul style="list-style-type: none"> <li>Roadway protection required for up to 6 m +/- deep excavation</li> <li>Bracing (e.g. struts) may interfere with excavation</li> <li>Excavation material and placement of bracing required in limited space</li> <li>Limited removal of existing sandy silt embankment fill</li> <li>More expensive due to cost of shoring</li> <li>Shoring for braced excavation will need to be decommissioned</li> <li>Need to temporarily control existing creek water and groundwater</li> </ul>	<ul style="list-style-type: none"> <li>Higher costs due to roadway protection system and additional shoring for braced excavation</li> <li>Moderate risk of cost overrun and instability to finish job due to roadway protection/shoring system</li> </ul>

Based on the above list of advantages and disadvantages of possible construction methods, we recommend the following ranking of the considered options:

Cut and cover method:

- 1) open-cut replacement under a full highway closure
- 2) open-cut staged replacement with temporary protection system with sloping cuts;
- 3) open-cut staged replacement with temporary protection system with braced cuts;

The following sections discuss these options in more detail.

### 2.12.1 Open Cut Replacement with a Full Highway Closure

From geotechnical and economical perspectives, an open cut unsupported excavation appears to be one of the most viable culvert replacement methods if a local detour is available and a full highway closure is possible. With this approach, the existing culvert will be removed, and the existing foundation soil conditions will be assessed. Stability analyses show that the existing embankment fill could be excavated in an open cut (Figures F-7 to F-10, Appendix F). The existing sandy silt embankment fill will be replaced with free draining granular material.

### 2.12.2 Half-and-Half Construction

The half-and-half construction method could be utilized to maintain the flow of the traffic on Highway 17 (see Figures H1.A and H1.B, Appendix H). In this method, one lane of the existing highway will be used to maintain the highway traffic while the other half of the existing highway will be excavated, and half of the existing culvert will be exposed. Then the excavated portion of the existing culvert will be removed and replaced with a new culvert, followed by the rebuilding of that half of the embankment to grade. Upon completion of the new embankment, the traffic will be moved onto the new fill and the process will be repeated to complete the construction and culvert replacement. The temporary excavation at the site required to remove half of the existing embankment would be up to 6.0 m +/- deep. Therefore, temporary shoring such as sheet piles or soldier pile and lagging systems will be required as a roadway protection system to allow staging excavation/construction. It will be the Contractor's responsibility to design a suitable temporary support system for the MTO review prior to installation. The Contractor is to follow OPSS.PROV 902, regarding excavations for structures, and OPSS.PROV 539, regarding temporary protection systems. Recommendations for a temporary roadway protection are given in Section 2.13.

For the half-and-half construction approach, the temporary shoring scheme can likely include two main forms:

1. *Half-and-Half Construction Using Shoring System and Unsupported Cut Sides:* This method provides roadway protection parallel to the highway to divert traffic to one side of the highway, while an open cut with sloping sides is performed on the opposite side of the highway. The roadway protection can take the form of reversible shoring such as a sheet piling or soldier pile and lagging with rakers for horizontal support. Where the cut extends below prevailing groundwater, a suitable control/system is required. Once one lane is completed, the supports can be reversed and the other lane constructed in similar fashion. The shoring system would likely be decommissioned in place. Stability analyses show that the existing embankment fill could be excavated in an open cut (Figures F7 to F-10, Appendix F). Temporary surface water flow diversion (e.g. through the temporary pipe) and/or control (e.g. pumping) must be developed by the Contractor.

2. *Half-and-Half Construction Using Shoring System and Braced Cut Sides:* This method provides roadway protection parallel to the highway to divert traffic to one side of the highway, while a braced cut shoring system perpendicular to the highway (or angled for the new alignment) is installed to allow culvert construction. Excavation in this case would have to accommodate the necessary cross-bracing, such as struts. With this option, consideration would have been given to how the new culvert sections will be installed given the relatively narrow work area and potential for obstructions from the lateral bracing (e.g. struts). Temporary decking could possibly be used over the braced cut to allow for excavation of both halves prior to diverting the stream and backfilling. However, decking would be costly. Like Option 1, temporary surface water flow diversion (e.g. through the temporary pipe) and/or control (e.g. pumping) must be developed by the Contractor.

Option 1 could be more economical due to possible cost savings for a reversible wall configuration, but it will be more disruptive to the highway embankment. Option 2 will disrupt less of the embankment but would cost more, i.e. about 1.8 times more than Option 1. Excavation and backfilling operations will also be more challenging with Option 2.

### 2.13 Temporary Roadway Protection

Temporary roadway protection is anticipated to be a part of the half-and-half construction approach that will be required to maintain on-site traffic during the construction. Roadway protection systems shall be designed and installed in accordance with OPSS.PROV 539. The complete design, construction, monitoring and removal of the installed protection system should be the responsibility of the Contractor. The protection system should be designed to provide protection for excavations as required by the OHSA, at locations specified in the contract, and at any locations where the stability, safety or function of an existing structure and/or utility may be impaired by construction work.

Based on the geotechnical conditions at the site, a shoring system such as steel sheet piling can be considered for design. It should be designed based on the earth pressures coefficients and soil parameters provided in Section 2.9 (Table 2-3). If a cantilever system is used, an embedded depth of sheet piles should be determined by balancing moments about the pile tip and it could be approximately 2.0 to 2.5 times its exposed height and would exceed the depth of boreholes completed for this project. Alternatively, a system of rakers can be used for support.

Cobbles and/or boulders were not noted to be contained within the existing embankment fill or native soil deposits at the site during site investigation.

The protection system shall be designed for Performance Level 2 (for small, less important sections). The minimum requirements for monitoring should include the survey measurements of 6 m apart scaled targets attached to the shoring wall at the elevations specified. If movement approaches the allowable limit of 25 mm (Performance level 2), suitable measures should be taken to ensure stability of the protection system and to ensure that the movement does not exceed the performance level specified.

After construction of the new culvert, the protection system could be removed. In that case the details of the procedures associated with the removal of the protection system indicating: method, sequence of work, and removal limits are required from the Contractor as per OPSS.PROV 539. However, if the protection system is decided to be left in place the top should be removed to at least 1.2 m below the finished grade or ground level. Decommissioning must be consistent with good practice to avoid interference with highway systems and utilities, if any. All disturbed areas should be restored to an equivalent or better condition than what existed prior to the commencement of construction.



## 2.14 Stability Analyses

### 2.14.1 Local Stability Analysis (Gabion Wall)

Local stability analysis has been completed for the Gabion Wall to check a) Factor of Safety (FOS) to overturning stability; b) FOS to sliding; c) the eccentricity of resultant force on the wall base; and, d) bearing capacity. Tabulated below in Table 2-6 are the estimated parameters used in the analysis for the Gabion wall.

**Table 2-6:** Gabion Wall Parameters Used in Slope Stability Analyses

Description	Parameter
Backfill Slope Angle Above the Wall	26.6°
Angle of Internal Friction	35°
Angle of Wall Friction	10°
Wall Inclination Angle	6°
Soil Density	20.4 kN/m <sup>3</sup>
Gabion Density	18.8 kN/m <sup>3</sup>
Wall Height	2.5 m
Wall Base	2.0 m

A summary of the results of the analysis is included on Table 2-7 below. As shown, the wall configuration noted in Section 2.6 satisfied the various criteria analyzed.

**Table 2-7:** Summary of Local Stability Analyses (Gabion Wall)

Criteria	Analysis Results
Overturning Stability	FOS = 3.7 ( $\geq 2.0$ )
Sliding	FOS = 1.6 ( $\geq 1.5$ )
Eccentricity of Resultant Force (resultant is in the middle third)	Satisfied
Bearing Capacity	Satisfied

### 2.14.2 Global Stability Analysis (Embankment)

Preliminary slope stability analyses were performed to assess the global stability of the final embankment configuration at the culvert location in order to check if a minimum Factor of Safety (FOS) of 1.5 for static and 1.1 for seismic conditions is achieved. Further temporary open cut excavation side slopes along the highway centreline profile were checked for a minimum FOS of 1.3 for temporary conditions. The static and seismic slope stability analyses were performed using the Morgenstern-Price method developed on the basis of limit equilibrium. The SLOPE/W computer program developed by GeoSlope International was employed for computation.

The stratigraphy and groundwater condition at the site were developed based on the results of the geotechnical investigation presented in Part I - Foundation Investigation Report. Water levels on site were modelled based on the water level observed within the creek at the time of the investigation (Elev. 181.3 m). The seismic properties were obtained as described previously in Section 2.10.

Based on the borehole information, the subsoils encountered at the work area consist of sand/silt fills and native soils. Therefore, effective stress analyses (drained/long-term conditions) of the slopes were performed taking into consideration the subsoil conditions encountered at the site. The analyses assume that all organic material, if any, will be removed prior to construction. A traffic surcharge of 16 kPa was adopted in the assessments. The SLOPE/W graphical printouts, for analyses performed, are included in Appendix F.

It is anticipated that the reconstructed embankment will have side slopes similar to existing and not steeper than 1.5H:1V at the location of the culvert. A Gabion Wall adjacent to the outlet is also anticipated as per existing conditions.

Tabulated below in Table 2-8 are the soil parameters used for the slope stability analyses. The soil parameters were generally estimated based on the results of the field and laboratory investigation.

**Table 2-8:** Soil Properties Used in Slope Stability Analyses

Material	Friction Angle $\phi'$ (unfactored)	Unit Weight $\gamma$ (kN/m <sup>3</sup> )	Cohesion $c'$ (kPa)
Engineered Fill (Granular "A" or "B")	35°	21	0
Engineered Fill (Select Subgrade Material)	32°	21	0
Existing Sand Fill (compact to dense)	35°	20	0
Existing Sandy Silt Fill (very loose to compact)	29°	18	0
Native Sandy Silt (compact)	29°	18	0
Native Organic Silt to Clayey Silt (very soft to firm)	26°	14	8
Native Silty Sand to Sand (very loose to compact)	30°	19	0
Native Silt and Sand (very loose)	29°	18	0
Gabion Basket	40°	19	12.5

The results of the analyses for the new embankment slopes are shown in Figures F-1 to F-6 in Appendix F. These results suggest that the new reconstructed embankment constructed with Granular "A" or "B", having the side slopes of 1.5H:1V, is stable for the static and seismic conditions (i.e. calculated FOS > 1.5 for static and FOS > 1.1 for seismic). As noted on Figures F-3 and F-4, the new embankment constructed with SSM does not achieve the minimum FOS for static conditions.

The results of the analyses for temporary open cut slopes east and west of the culvert are shown in Figures F-7 to F-10 in Appendix F. These results suggest that temporary excavation sides slopes of either 2.5H:1V or 2H:1V with a 2 m wide bench at 3 m above the base of the excavation, would be stable for temporary conditions (i.e. calculated FOS > 1.3). Steeper slopes than noted did not meet the minimum FOS of 1.3 for temporary conditions.

## 2.15 Embankment Reconstruction

It is anticipated that the reconstructed embankment will have side slopes not steeper than 1.5H:1V at the location of the culvert. The roadway embankment above the culvert should be reconstructed using free-draining, non-frost susceptible granular materials conforming to OPSS.PROV 1010 (i.e. Granular A/Granular B Type I or Type II). Based on stability analyses noted in Section 2.14.2, the use of Select Subgrade Material (SSM) as an embankment fill will not provide a sufficient FOS for static conditions based on the anticipated side slopes, and as such, is not recommended. The existing embankment fill and the new fill along the existing roadway embankment slopes should be integrated in accordance with OPSD 208.010. The final embankment side slopes should be protected against erosion by surface water runoff as soon as practical after completion of slope grading using a combination of materials in accordance with OPSS.PROV 802, OPSS.PROV 803 and/or OPSS.PROV 804. Rip rap protection (OPSS.PROV 511) may also be required to provide long term surface protection for the 1.5H:1V side slopes. Rockfill should not be used as a culvert backfill material.

### 2.15.1 Embankment Settlement

It is not planned to change the existing embankment grade nor widening at the culvert location. Therefore, there should be negligible additional settlements under the existing embankment. However, a settlement of about 25 mm should be allowed for due to rebound during the construction.

## 2.16 Scour/Erosion Protection

Foundation systems supporting culverts in flood plains, close to creeks, channel or rivers are very likely to be exposed to potentially harmful effects of stream flow, with particular concern during more significant storm events and where the river bed/valley is set in erodible soils. The need for and nature of scour and erosion protection systems must be assessed and where required, must be designed, implemented and remain effective over the design life of the culvert.

Scour/erosion protection should be provided at the culvert inlet and outlet (including the side slopes). The erosion/scour protection should be designed by a specialist Hydraulic Engineer (as erosion and scour largely depend on the velocity of water in the watercourse and its regime) who is familiar with the findings of this report. However, scour design is a multi-disciplinary exercise that involves the structural and hydraulic engineer as well as the geotechnical engineer working as a team. The following are some general suggestions, considering that the boreholes indicate that the main soil type consists of organic silt/clayey silt near the culvert.

Rip-rap protection should be provided where the culvert discharges into the open creek and where the open creek enters the culvert. The design should be finalized by the Hydraulics Engineer. For preliminary guidance, the rip-rap should extend approximately 5 m beyond the ends of the culvert and line the embankment slope to the spring line of the culvert. Such protection may involve 0.3 m thick rock (OPSS.PROV 511) extending from 1 m above the high-water level to the toe of the slope and into the stream bed within the plan limits of the culvert. The rip-rap configuration at the creek bed should generally follow OPSD 810.010. The slope of the riprap shall follow the embankment fill slope.

The erosion protection should consider the possible installation of seepage protection measures at both upstream and downstream ends. For culverts, the following are typical options for seepage cutoff approaches: a typical clay seal, steel or wooden sheet pile cutoff at the upstream end of culvert, a cutoff wall incorporated in the apron slab (if one is used) of the culvert, or a cut-off trench constructed with geotextile and rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert. The seepage protection is addressed in the following Section 2.17.

A clay seal should be placed at the inlet of the proposed culvert, to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment. The installation procedures and the material used for the clay seal should conform to all the requirements stipulated in OPSS 1205, as detailed in Section 2.17.1.

The scour design, nature and extent of the required protection is the responsibility of a qualified Hydraulic Design Engineer experienced in this field. Geotechnical soil parameters necessary for the scour analyses are: SPT N-value, in-situ moisture content, percent passing the No. 200 sieve (%200), mean grain size diameter (D50), liquid limit (LL), plastic limit (PL), and plasticity index (PI). These parameters can be determined based on the soils encountered at the site during the investigation.

EXP will review the scour analysis from the hydraulic engineer to check that the interpretation of the geotechnical soil types and thickness are in good agreement with the borehole information provided in this report to ensure that the material is considered appropriate for the analyses undertaken for the scour assessment of the culvert.

## 2.17 Seepage Cut-off Requirements

For the culvert replacement and new culvert installation, it is prudent to examine possible methods to avoid piping of the material resulting from seepage along the culvert. For culverts the following are typical methods: (i) clay seal, (ii) steel or wooden sheet pile cutoff at the upstream end of culvert, (iii) cut-off wall incorporated in the apron slab (if one is used) of the culvert, (iv) cut-off trench constructed with geotextile, and (v) rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert. Only the clay seal and cut-off trench will be addressed since the sheet pile cut-off will require the understanding of the hydraulics of the stream.

### 2.17.1 Clay Seal

Where readily available a clay seal should be placed at the inlet of the proposed culvert to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment. OPSS. PROV 1205 specifies that material used for clay seals shall be natural clay, clay mixture (1 part Bentonite powder and 3.5 parts Granular "A") or a Geosynthetic Clay Liner (GCL). The coefficient of permeability shall not exceed  $1 \times 10^{-6}$  cm/s.

The following outlines the installation procedures and minimum material requirements of the clay seal:

- The clay seal should be placed along the sides and top of the culvert a minimum of 1.0 m along the side of the culvert and extending out laterally 1.0 m from the culvert. The thickness of the clay seal should be a minimum of 500 mm. However, it is the responsibility of the designer to select the dimensions of the clay seal.
- The clay seal should be placed from the top of the culvert footings and extend along the side and the top of the culvert. The clay must not be placed below the culvert.
- The clay should have a Liquid Limit greater than 40% and a Plasticity Index greater than  $0.73 \times (\text{Liquid Limit} - 20\%)$ .
- The clay seal is to be placed in maximum 150 mm thick lifts and compacted to 95% SPMDD within 2% of the optimum moisture content.

If a GCL is used as a clay seal, its material specifications containing the physical, mechanical and hydraulic properties shall be obtained from the manufacturer. It is estimated that an approximately 12 mm thick GCL should be installed a minimum of 1.0 m along the side of the culvert.

### 2.17.2 Cut-Off Trench/Wall

A cut-off trench/wall can be used at both the upstream and downstream ends of the culvert and can be incorporated when the rip-rap aprons at both ends of the culvert are being installed. In general, a trench is dug across the stream alignment to well beyond the walls of the culvert and a geomembrane liner is laid on the side of the trench keyed into the culvert at the top and on the base of the trench. The trench is then backfilled with graded rip-rap.

## 2.18 Excavations

All excavations at this site must be conducted in accordance with the Occupational Health and Safety Act (OHSA) and Regulations for Construction (O. Reg. 213/91). The existing fill materials and native soils may be classified as a Type 3 soil above the groundwater table in conformance with the OHSA. The soils below the groundwater table may be classified as a Type 4 soil. It is expected that most of excavations will be above the groundwater levels except those at the invert level. To avoid disturbance of the founding subgrade and to allow placement of backfill in dry conditions, groundwater must be controlled to below the proposed invert excavation levels prior to digging to final levels. The ingress of surface water must be controlled using a suitable system as well, as described in Section 2.19.

Temporary excavation side slopes for Type 3 soils should not exceed 1H:1V in accordance with OHSA, while temporary excavation side slopes for Type 4 soils should not exceed 3H:1V where applicable. Slope stability analyses were performed considering the site-specific conditions encountered during the field investigation and suggest that excavations of 1H:1V are not feasible to achieve a FOS of 1.3 for temporary conditions. Temporary excavation sides slopes of either 3H:1V, or 2H:1V with a 2 m wide bench at 3 m above the base of the excavation, would be stable for temporary conditions. Further details of these analyses are outlined in Section 2.15.2.

The need to excavate flatter side slopes if excessively wet or soft/loose materials, or concentrated seepage zone are encountered, should not be overlooked. There is a potential for sloughing to occur if the trench remains open for an extended period of time (i.e. > 24 hours) or during a rainfall event. In addition, some localized surficial sloughing may be experienced in areas of perched groundwater seepage (i.e. within the embankment fill). Water (i.e. surface water runoff) should not be permitted to enter and/or pond within the construction area.

Preliminary analyses suggest a low to moderate risk of base heave for braced excavations extending in the encountered clayey silt subgrade soils. The effects of base heave must be considered in the design and construction of the proposed culvert. Further analysis will be required by the excavation contractor based on the proposed final geometry of the shoring system. If the factor of safety with respect to base heave is low (i.e. Below 1.5), the depth of penetration of the support system must extend below the base of the excavation.

To avoid potential base stability issues when excavating into the anticipated very soft to firm clayey silt foundation soils below the proposed culvert, it is recommended that excavations and the engineered fill placement be completed simultaneously in small sections. Excavations sections should be no longer than 3 m along the culvert alignment and are to be immediately backfilled with the compacted engineered fill pad prior to proceeding to the subsequent section. A NSSP has been included in Appendix I to notify the Contractor of this requirement.

All excavations must be completed in accordance with the most recent regulations in the Ontario Occupational Health and Safety Act. The contractor should be aware that slope height, slope inclination, or excavation depths, should in no case, exceed those specified in local, provincial or federal safety regulations. Such regulations are strictly enforced and, if not followed, the owner, the contractor or earthwork or utility subcontractor could be liable for substantial penalties.

### 2.18.1 Obstructions

Cobbles and/or boulders were not noted to be contained within the existing embankment fill or native soil deposits at the site during site investigation. Cobble and boulder sized rip-rap however is present along the surface of the southern embankment at the site.

## 2.19 Dewatering

### 2.19.1 Cofferdam

Temporary cofferdams will be required at both the upstream and downstream ends of the culvert to envelop the construction site and keep it free of water during culvert replacement. Based on the observed water levels/flow within the creek at the time of the investigation, a rockfill/earth dam can be considered. Design and construction specifications for the chosen temporary cofferdam system should be prepared in accordance with OPSS.PROV 539 (Construction Specification for Temporary Protection Systems) by the Contractor.

The rockfill/earth cofferdam will have to be constructed to accommodate all topographic constraints. The size of material suitable for use depends on the erosion potential, stream flow velocity, etc. The rockfill/earth cofferdam should be designed with a more impervious water barrier at the outside face to create a more watertight enclosure. Schemes involving 2-inch minus crusher run with finer facing material upstream have been successfully used in similar settings. Any required permitting must be determined. The proposed rockfill/earth cofferdam should be at least one meter above the designed high-water level (HWL) defined by the Hydraulic Engineer.

In addition to design and construction of the temporary cofferdam system, the Contractor is also responsible for its materials, maintenance, monitoring and removal. The temporary cofferdam shall be fully removed, unless it is specified in the Contract Documents that the cofferdam system may be partially left in place. The method and sequence of removal shall be so that there shall be no damage to the new work, existing work, and facility being protected.

### 2.19.2 Groundwater Control

The approximate top of water elevation within the creek at the time of the field investigation was 181.3 m at the inlet and 180.6 m at the outlet. Within the piezometer installed at Borehole BH-D2, groundwater levels were measured at depths ranging from 0.45 to 3.5 m (Elev. 178.60 to 181.65 m) from October 2022 to April 2023.

Proposed culverts are anticipated to be founded at approximate Elev. 181.0 m +/- for box culverts and at approximate Elev. 179.2 m for an open bottom culvert. As such, excavations for box culverts are anticipated to extend up to approximately 1.0 m below the water level. Considering that the surface water will be controlled by cofferdams it is expected that groundwater inflow through the native soils can be handled by pumping from filtered sumps located behind the cofferdams at the inlet and outlet. Excavations for an open footing concrete culvert supported on shallow foundations will extend approximately 2.1 m below the groundwater level. For this case, more extensive dewatering will likely be required.

The groundwater level needs to be controlled to 0.5 m below the excavation level to avoid disturbance, and any surface or groundwater seepage should be removed from the excavation prior to the placement of granular backfill in the dry. Granular B Type II or clear stone with geotextile wrapping can be used in the wet condition.

The estimated hydraulic conductivity (K) of the in-situ fill and soils is shown on Table 2-9:

**Table 2-9:** Hydraulic Conductivity of Encountered Soils

Soil Material	K (cm/sec)
Sand Fill, Sand	$10^{-1}$ to $10^{-4}$
Sandy Silt Fill, Silt, Silty Sand, Sandy Silt, Silt and Sand	$10^{-5}$ and less
Clayey Silt	$10^{-6}$ and less

Dewatering requirements behind the cofferdams to keep the construction site dry will be impacted by water levels in the creek at the time of construction activities. Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year and lower levels during drier periods. It is the responsibility of the Contractor to propose a suitable dewatering system based on the time of construction, water levels and flow conditions in the creek. The method used should not undermine the existing highway embankment or adjacent side slopes.

With the anticipated construction alternatives noted previously, a Permit to Take Water (PTTW) is not likely required. Based on the hydraulic conductivity of the founding clayey silt soils and the groundwater levels observed, water taking is not anticipated to exceed 50,000 L/day. If at the time of construction, groundwater levels are found to be high and water taking will exceed 50,000 L/day, an Environmental Activity and Sector Registry (EASR) for Construction Site Dewatering would likely be required (pumping less than 400,000 L/day).

Erosion and sediment control during culvert construction should be as per the MTO Drainage Manual, Volume 2. Silt fences and other sediment control measures should be included to protect the downstream environment from the construction activities.

### 3. Closure

The recommendations made in this report are in accordance with our present understanding of the project and are provided solely for the team responsible for the design of the works described herein.

We recommend that we be retained to review our recommendations as the design nears completion to ensure that the final design is in agreement with the assumptions on which our recommendations are based and that our recommendations have been interpreted as intended. If not accorded this review, EXP will assume no responsibility for the interpretation and use of the recommendations in this report.


A subsurface investigation is a limited sampling of a site; the subsurface conditions have been established only at the test hole locations. Should conditions at the site be encountered which differ from those reported at the test locations, we require that we be notified immediately in order to assess this additional information and our recommendations, as appropriate. It may then be necessary to perform additional investigation and analysis.

Contractors bidding on or undertaking any proposed work at this site should, relative to the subsurface conditions, decide on their own investigations, if deemed necessary, as well as their own interpretations of the factual results provided herein, so they may draw their own conclusions as to how the subsurface conditions may affect them.

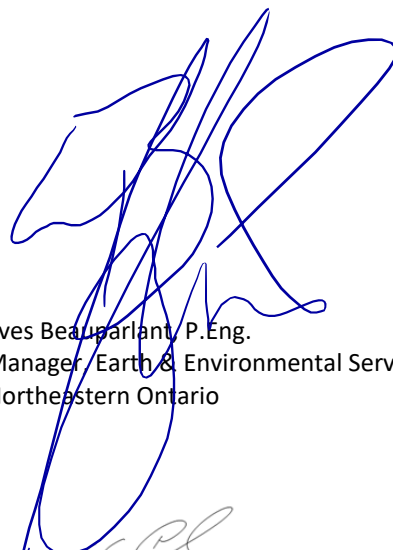
This Foundation Investigation and Design Report has been prepared by Ian MacMillan, P.Eng. It was reviewed by Yves Beauparlant, P.Eng., Tae Chul Kim, M.E.Sc., P.Eng. and Stan E. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact. The field investigation was supervised by Shane Tobias.


Yours truly,


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Canadian Standards Association (CSA), 2019. Canadian Highway Bridge Design Code and Commentary on CAN/CSA-S6-19. CSA Special Publication.

Ministry of Northern Development and Mines Map 2544. Bedrock Geology of Ontario, Southern Sheet, 1991

Ministry of Transportation, April 2022. Guideline for MTO Foundation Engineering Services, Version 03

Ontario Geological Survey, Northern Ontario Engineering Geology Terrain Study 97, Thessalon Area (NTS 41L/SW), 1980

### **ASTM International:**

ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

### **Ontario Provincial Standard Specifications (OPSS):**

OPSS.PROV 314 Construction Specification for Untreated Subbase, Base, Surface, Shoulder, Selected Subgrade, and Stockpiling

OPSS.PROV 401 Construction Specification for Trenching, Backfilling and Compacting

OPSS.PROV 421 Construction Specification for Pipe Culvert Installation in Open Cut

OPSS.MUNI 422 Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut

OPSS.PROV 501 Construction Specification for Compacting

OPSS.PROV 511 Rip Rap, Rock Protection and Granular Sheeting

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

OPSS.MUNI 802 Construction Specification for Topsoil

OPSS.PROV 803 Construction Specification for Vegetative Cover

OPSS.PROV 804 Temporary Erosion Control

OPSS.PROV 1010 Material Specification for Aggregates - Base, Subbase, Select Subgrade, And Backfill Material

OPSS.PROV 1205 Material Specification for Clay Seal

OPSS.PROV 1860 Material Specification for Geotextiles

### **Ontario Provincial Standard Drawings (OPSD):**

OPSD 208.010 Benching of Earth Slopes

OPSD 803.010 Backfill and Cover for Concrete Culverts with Span Less Than or Equal to 3.0 m

OPSD 803.031 Frost Treatment – Pipe Culverts Frost Penetration Line Between Top of Pipe and Bedding Grade

OPSD 810.010 Rip-Rap Treatment for Sewer and Culvert Outlets

OPSD 3090.100 Foundation Frost Penetration Depths for Northern Ontario

### **Ontario Water Resources Act:**

R.R.O 1990, Regulation 903 Wells, under Ontario Water Resources Act, R.S.O. 1990, c. O.40

### **Ontario Occupational Health and Safety Act (OHSA):**

Ontario Regulation 213/91 Construction Projects

## 5. Limitations and Use of Report

### **BASIS OF REPORT**

This report ("Report") is based on site conditions known or inferred by the geotechnical investigation undertaken as of the date of the Report. Should changes occur which potentially impact the geotechnical condition of the site, or if construction is implemented more than one year following the date of the Report, the recommendations of EXP may require re-evaluation.

The Report is provided solely for the guidance of design engineers and on the assumption that the design will be in accordance with applicable codes and standards. Any changes in the design features which potentially impact the geotechnical analyses or issues concerning the geotechnical aspects of applicable codes and standards will necessitate a review of the design by EXP. Additional field work and reporting may also be required.

Where applicable, recommended field services are the minimum necessary to ascertain that construction is being carried out in general conformity with building code guidelines, generally accepted practices and EXP's recommendations. Any reduction in the level of services recommended will result in EXP providing qualified opinions regarding the adequacy of the work. EXP can assist design professionals or contractors retained by the Client to review applicable plans, drawings, and specifications as they relate to the Report or to conduct field reviews during construction.

Contractors contemplating work on the site are responsible for conducting an independent investigation and interpretation of the borehole results contained in the Report. The number of boreholes necessary to determine the localized underground conditions as they impact construction costs, techniques, sequencing, equipment and scheduling may be greater than those carried out for the purpose of the Report.

Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates are based on investigations performed in accordance with the standard of care set out below and require the exercise of judgment. As a result, even comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations or building envelope descriptions involve an inherent risk that some conditions will not be detected. All documents or records summarizing investigations are based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated. Some conditions are subject to change over time. The Report presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, these should be disclosed to EXP to allow for additional or special investigations to be undertaken not otherwise within the scope of investigation conducted for the purpose of the Report.

### **RELIANCE ON INFORMATION PROVIDED**

The evaluation and conclusions contained in the Report are based on conditions in evidence at the time of site inspections and information provided to EXP by the Client and others. The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose as communicated by the Client. EXP has relied in good faith upon such representations, information and instructions and accepts no responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of any misstatements, omissions, misrepresentation or fraudulent acts of persons providing information. Unless specifically stated otherwise, the applicability and reliability of the findings, recommendations, suggestions or opinions expressed in the Report are only valid to the extent that there has been no material alteration to or variation from any of the information provided to EXP.

**STANDARD OF CARE**

The Report has been prepared in a manner consistent with the degree of care and skill exercised by engineering consultants currently practicing under similar circumstances and locale. No other warranty, expressed or implied, is made. Unless specifically stated otherwise, the Report does not contain environmental consulting advice.

**COMPLETE REPORT**

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## Appendix A – Site Photographs



Photograph 1: Highway 17 WBL, Facing East



Photograph 2: Culvert Inlet, Facing North





Photograph 3: North Embankment (Inlet), Facing East



Photograph 4: Culvert Inlet





Photograph 5: Existing Culvert, Facing South from Inlet



Photograph 6: Highway 17 EBL, Facing East





Photograph 7: Culvert Outlet, Facing South



Photograph 8: South Embankment (Outlet), Facing East





Photograph 9: Culvert Outlet



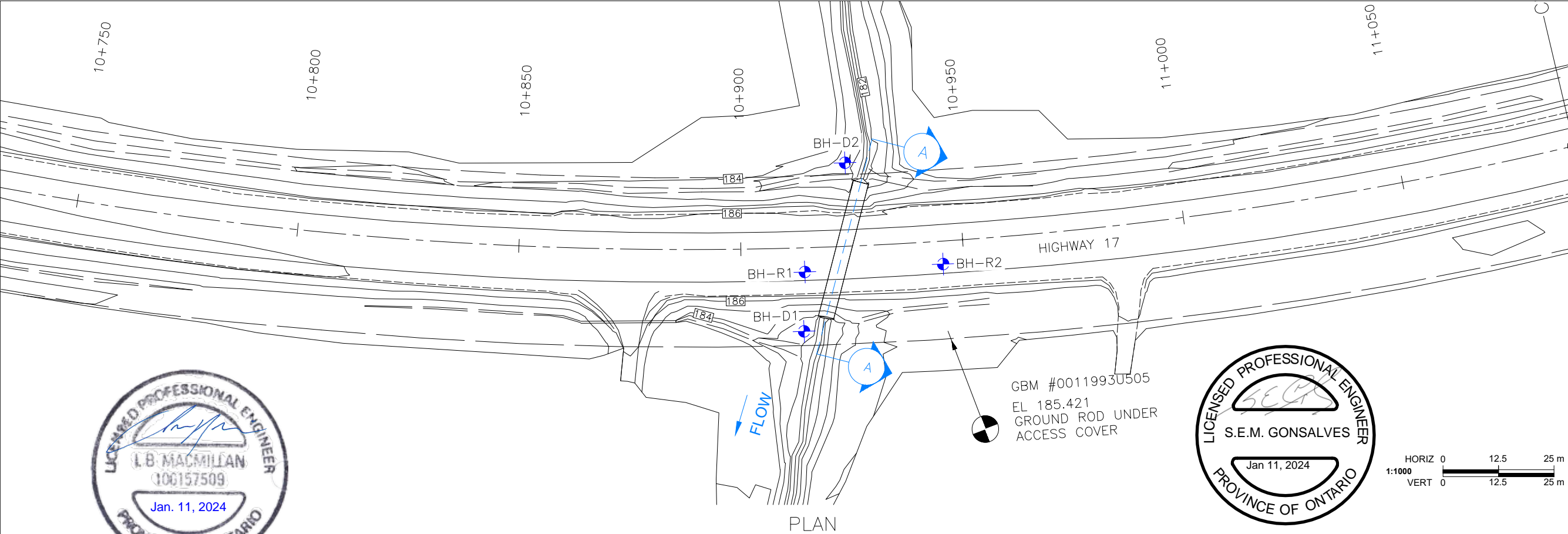
Photograph 10: Existing Culvert, Facing North from Outlet



Photograph 11: Damaged Gabion Basket Wall at Outlet

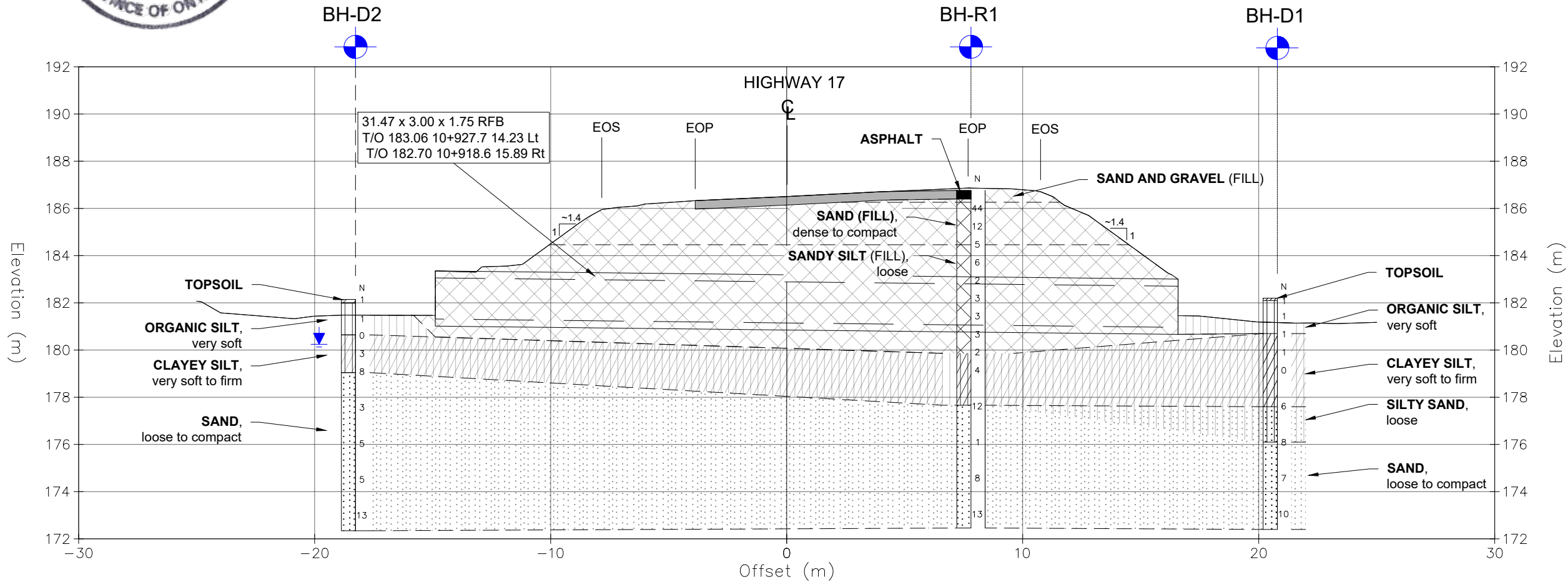
## Appendix B – Drawings



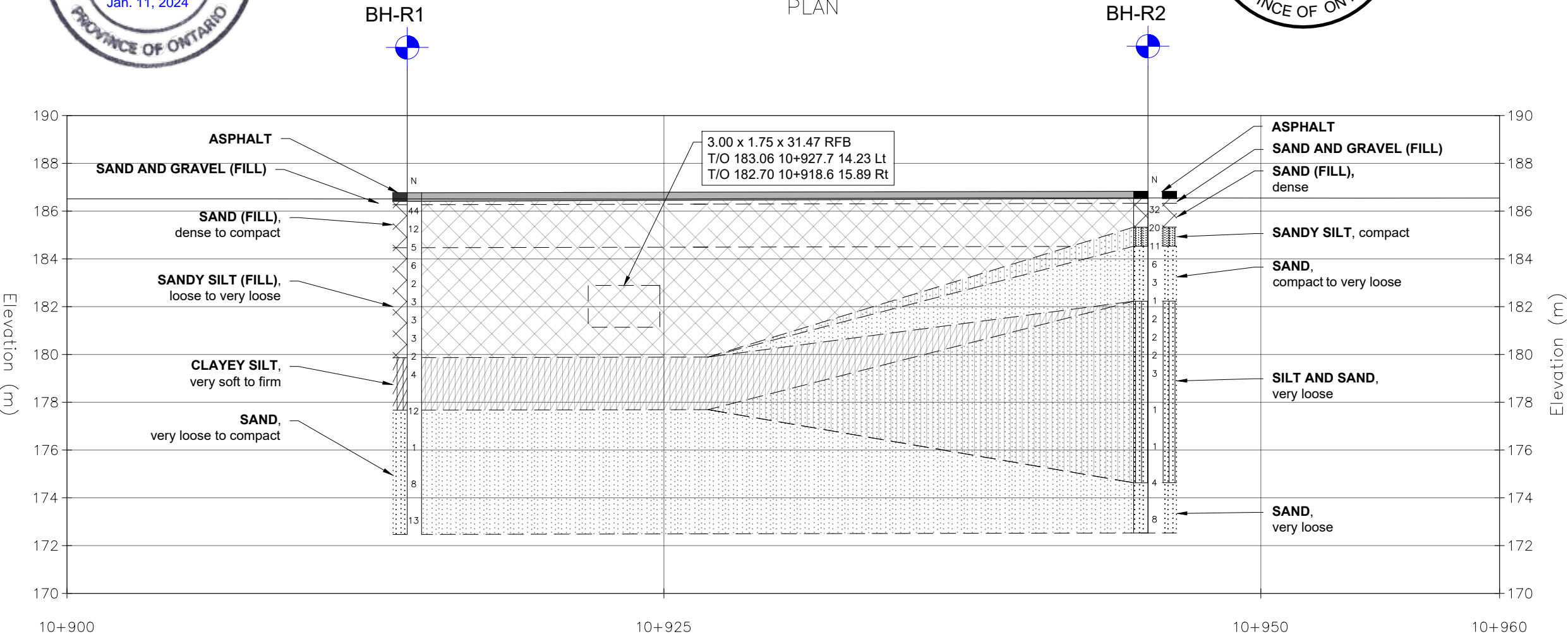
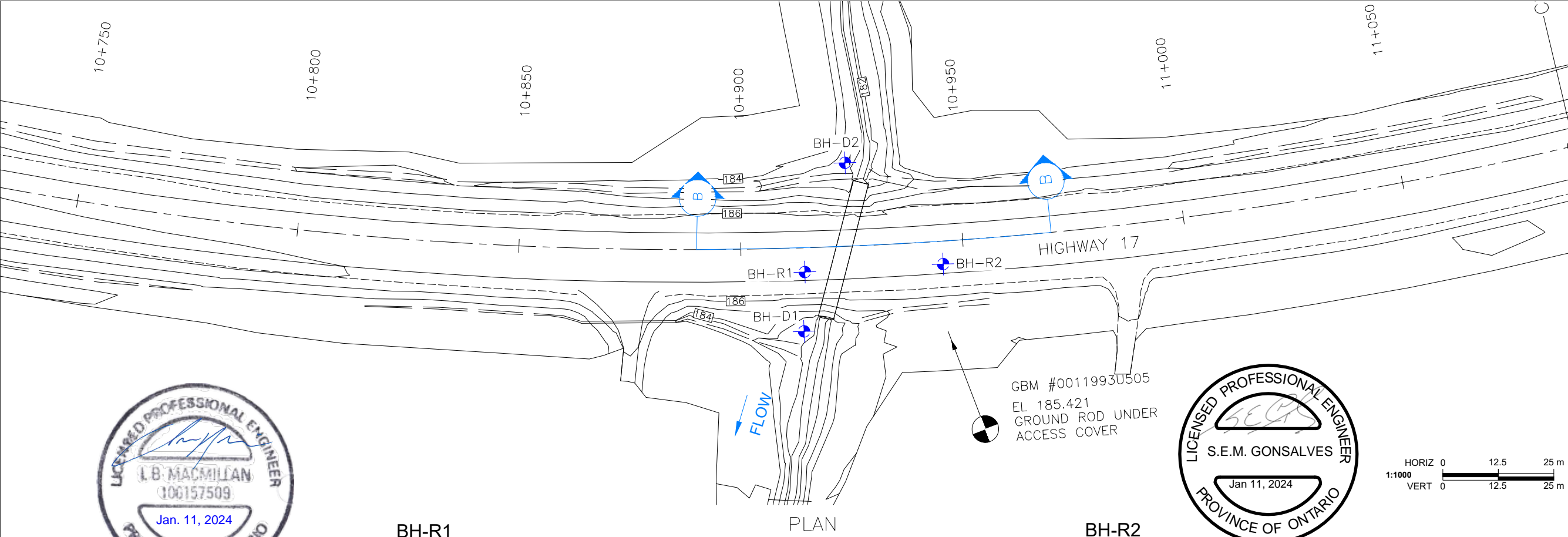


Agreement No. -	
GWP No. -	
Assignment No. 5022-E-0007	
Replacement of the Everett Lake Tributary Culvert at STA. 10+923, Highway 17 Township of Thompson, Ontario (Latitude: 46.2576° N ; Longitude: -83.1957° W)	
BOREHOLE LOCATION PLAN & SOIL STRATA	
exp	
EXP Services Inc.	
KEY PLAN	
LEGEND	
Borehole Location	
Blows/0.3m (Std. Pen. Test, 475 J/blow)	
Water Level in Piezometer	
SOIL STRATA SYMBOLS	
ASPHALT, FILL, TOPSOIL, SILTY SAND, CLAYEY SILT, SAND, ORGANIC SILT	
MTM COORDINATES NAD 83 (ZONE 13)	
BH No., ELEV. (m), NORTHING, EASTING	
BH-R1, 186.8, 5124477.1, 366825.7	
BH-R2, 186.8, 5124461.1, 366852.5	
BH-D1, 182.2, 5124466.1, 366818.0	
BH-D2, 182.1, 5124492.4, 366846.9	
NOTES	
1- This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents	
2- The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.	
PROJECT NO. MRK-22015604-A0	
SUBM'D KCV, CHECKED IM, DATE, 2023-07-13	
DRAWN KCV, CHECKED IM, APPROVED, DWG. B-1	

EXP		EXP Services Inc.	
KEY PLAN			
LEGEND		Borehole Location	
		Blows/0.3m (Std. Pen. Test, 475 J/blow)	
		Water Level in Piezometer	
SOIL STRATA SYMBOLS		ASPHALT, FILL, TOPSOIL, SILTY SAND, CLAYEY SILT, SAND, ORGANIC SILT	
MTM COORDINATES NAD 83 (ZONE 13)		BH No., ELEV. (m), NORTHING, EASTING	
		BH-R1, 186.8, 5124477.1, 366825.7	
		BH-R2, 186.8, 5124461.1, 366852.5	
		BH-D1, 182.2, 5124466.1, 366818.0	
		BH-D2, 182.1, 5124492.4, 366846.9	
NOTES		1- This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents	
		2- The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.	
PROJECT NO. MRK-22015604-A0			
SUBM'D KCV, CHECKED IM, DATE, 2023-07-13			
DRAWN KCV, CHECKED IM, APPROVED, DWG. B-1			



SECTION A-A'



PROFILE **B-B'** ALONG  $\text{CL}$  HIGHWAY 17 ALIGNMENT

Agreement No. -  
GWP No. -  
Assignment No. 5022-E-0007

Replacement of the Everett Lake Tributary Culvert  
at STA. 10+923, Highway 17  
Township of Thompson, Ontario  
(Latitude: 46.2576° N ; Longitude: -83.1957° W)

SHEET  
1

BOREHOLE LOCATION PLAN & SOIL STRATA

EXP Services Inc.

KEY PLAN

SAULT STE MARIE  
SITE

LEGEND

Borehole Location  
N Blows/0.3m (Std. Pen. Test, 475 J/blow)

SOIL STRATA SYMBOLS

	ASPHALT		FILL		SILT AND SAND
	SANDY SILT		CLAYEY SILT		SAND

BH No.	ELEV. (m)	MTM COORDINATES NAD 83 (ZONE 13)	
		NORTHING	EASTING
BH-R1	186.8	5124477.1	366825.7
BH-R2	186.8	5124461.1	366852.5
BH-D1	182.2	5124466.1	366818.0
BH-D2	182.1	5124492.4	366846.9

NOTES

1- This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents

2- The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

SUBM'D KCV		CHECKED IM		DATE		2023-07-13	
DRAWN KCV		CHECKED IM		APPROVED		DWG. B-2	

PROJECT NO. MRK-22015604-A0

## Appendix C – Borehole Logs

# Explanation of Terms Used on Borehole Records

## SOIL DESCRIPTION

Terminology describing common soil genesis:

*Topsoil:* mixture of soil and humus capable of supporting good vegetative growth.

*Peat:* fibrous fragments of visible and invisible decayed organic matter.

*Fill:* where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc.; none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

*Till:* the term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Terminology describing soil structure:

*Desiccated:* having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.

*Stratified:* alternating layers of varying material or color with the layers greater than 6 mm thick.

*Laminated:* alternating layers of varying material or color with the layers less than 6 mm thick.

*Fissured:* material breaks along plane of fracture.

*Varved:* composed of regular alternating layers of silt and clay.

*Slickensided:* fracture planes appear polished or glossy, sometimes striated.

*Blocky:* cohesive soil that can be broken down into small angular lumps which resist further breakdown.



*Lensed:* inclusion of small pockets of different soil, such as small lenses of sand scattered through a mass of clay; not thickness.

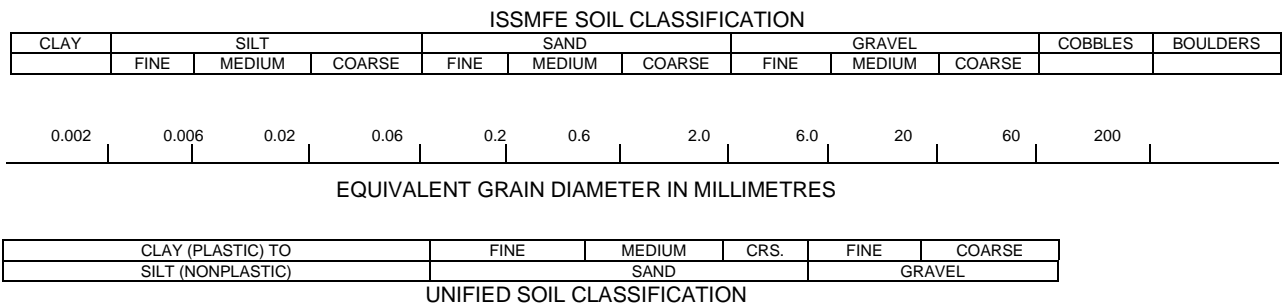
*Seam:* a thin, confined layer of soil having different particle size, texture, or color from materials above and below.

*Homogeneous:* same color and appearance throughout.

*Well Graded:* having wide range in grain sized and substantial amounts of all predominantly on grain size.

*Uniformly Graded:* predominantly on grain size.

All soil sample descriptions included in this report follow generally the ASTM D2487-11 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) with some modification to reflect current MTO practices. The system divides soils into three major categories: (1) coarse grained, (2) fine-grained, and (3) highly organic. The soil is then subdivided based on either gradation or plasticity characteristics. The system provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification. The classification excludes particles larger than 76 mm. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually in accordance with ASTM D2488-09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems. Others may use different classification systems; one such system is the ISSMFE Soil Classification.



Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present and as described below in accordance with Canadian Foundation Engineering Manual (CFEM):

Table a: Percent or Proportion of Soil

Term	Description	Criteria
"trace"	trace gravel, trace sand, etc.	1% - 10%
"some"	some gravel, some sand, etc.	10% - 20%
Adjective	gravelly, sandy, silty and clayey	20% - 35%
"and"	and gravel, and sand, etc.	>35%
Noun	gravel, sand, silt, clay	>35% and main fraction

The standard terminology to describe cohesionless soils includes the compactness as determined by the Standard Penetration Test 'N' value:

Table b: Apparent Density of Cohesionless Soil

	'N' Value (blows/0.3 m)
Very Loose	N<5
Loose	5≤N<10
Compact	10≤N<30
Dense	30≤N<50
Very Dense	50≤N



The standard terminology to describe cohesive soils includes consistency, which is based on undrained shear strength as measured by insitu vane tests, penetrometer tests, unconfined compression tests or similar field and laboratory analysis, Standard Penetration Test 'N' values can also be used to provide an approximate indication of the consistency and shear strength of fine grained, cohesive soils:

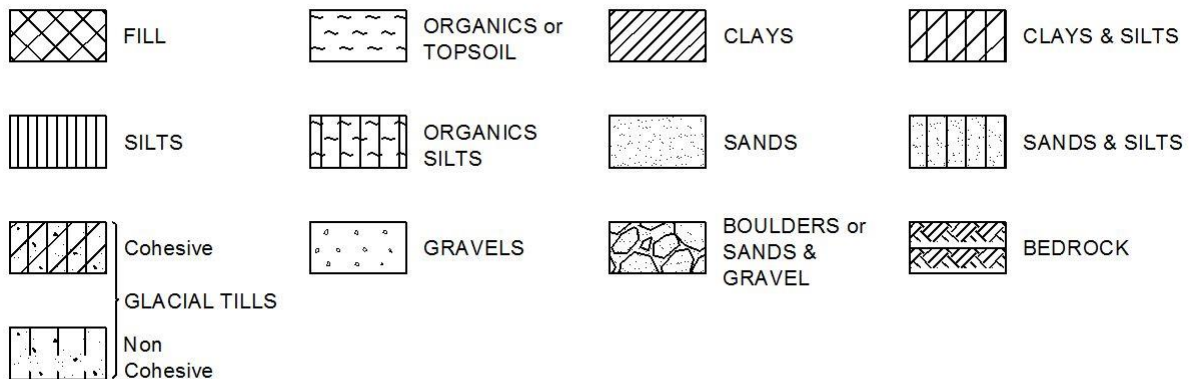
Table c: Consistency of Cohesive Soil

Consistency	Vane Shear Measurement (kPa)	'N' Value
Very Soft	<12.5	<2
Soft	12.5-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very Stiff	100-200	15-30
Hard	>200	>30

Note: 'N' Value - The Standard Penetration Test records the number of blows of a 140 pound (64kg) hammer falling 30 inches (760mm), required to drive a 2 inch (50.8mm) O.D. split spoon sampler 1 foot (305mm). For split spoon samples where full penetration is not achieved, the number of blows is reported over the sampler penetration in meters (e.g. 50/0.15).

## STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols:



## WATER LEVEL MEASUREMENT



Open Borehole or Test Pit



Monitoring Well, Piezometer or Standpipe

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

SS	Split spoon sample (obtained from the Standard Penetration Test)
WS	Wash sample
BS	Bulk sample
TW	Thin wall sample or Shelby tube
PS	Piston sample
AS	Auger sample
VT	Vane test
GS	Grab sample
HQ, NQ, etc.	Rock core samples obtained with the use of standard size diamond drilling bits

### STRESS AND STRAIN

$u_w$	kPa	Pore water pressure
$r_u$	1	Pore pressure ratio
$\sigma$	kPa	Total normal stress
$\sigma'$	kPa	Effective normal stress
$\tau$	kPa	Shear stress
$\sigma_1, \sigma_2, \sigma_3$	kPa	Principal stresses
$\varepsilon$	%	Linear strain
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	Principal strains
E	kPa	Modulus of linear deformation
G	kPa	Modulus of shear deformation
$\mu$	1	Coefficient of friction

### MECHANICAL PROPERTIES OF SOIL

$m_v$	kPa <sup>-1</sup>	Coefficient of volume change
$c_c$	1	Compression index
$c_s$	1	Swelling index
$c_r$	1	Recompression index
$c_v$	m <sup>2</sup> /s	Coefficient of consolidation
H	m	Drainage path
$T_v$	1	Time factor
U	%	Degree of consolidation
$\sigma'_{v0}$	kPa	Effective overburden pressure
$\sigma'_p$	kPa	Preconsolidation pressure
$\tau_f$	kPa	Shear strength
$c'$	kPa	Effective cohesion intercept
$\phi'$	—°	Effective angle of internal friction
$c_u$	kPa	Apparent cohesion intercept
$\phi_u$	—°	Apparent angle of internal friction
$\tau_R$	kPa	Residual shear strength
$\tau_r$	kPa	Remoulded shear strength
$S_t$	1	Sensitivity = $c_u/\tau_r$

### PHYSICAL PROPERTIES OF SOIL

$P_s$	kg/m <sup>3</sup>	Density of solid particles
$\gamma_s$	kN/m <sup>3</sup>	Unit weight of solid particles
$\rho_w$	kg/m <sup>3</sup>	Density of water
$\gamma_w$	kN/m <sup>3</sup>	Unit weight of water
$\rho$	kg/m <sup>3</sup>	Density of soil
$\gamma$	kN/m <sup>3</sup>	Unit weight of soil
$\rho_d$	kg/m <sup>3</sup>	Density of dry soil
$\gamma_d$	kN/m <sup>3</sup>	Unit weight of dry soil
$\rho_{sat}$	kg/m <sup>3</sup>	Density of saturated soil
$\gamma_{sat}$	kN/m <sup>3</sup>	Unit weight of saturated soil
$\rho'$	kg/m <sup>3</sup>	Density of submerged soil
$\gamma'$	kN/m <sup>3</sup>	Unit weight of submerged soil
$e$	1, %	Void ratio
$n$	1, %	Porosity
$w$	1, %	Water content
$S_r$	%	Degree of saturation
$W_L$	%	Liquid limit
$W_P$	%	Plastic limit
$W_s$	%	Shrinkage limit
$I_p$	%	Plasticity index = $(W_L - W_P)$
$I_L$	%	Liquidity index = $(W - W_P)/I_p$
$I_C$	%	Consistency index = $(W_L - W)/I_p$
$e_{max}$	1, %	Void ratio in loosest state
$e_{min}$	1, %	Void ratio in densest state
$I_D$	1	Density index = $(e_{max} - e)/(e_{max} - e_{min})$
D	mm	Grain diameter
$D_n$	mm	N percent - diameter
$C_u$	1	Uniformity coefficient
h	m	Hydraulic head or potential
q	m <sup>3</sup> /s	Rate of discharge
v	m/s	Discharge velocity
i	1	Hydraulic gradient
k	m/s	Hydraulic conductivity
j	kN/m <sup>3</sup>	Seepage force

**RECORD OF BOREHOLE No BH-D1**

1 OF 1

**METRIC**

PROJECT Everett Lake Tributary Culvert LOCATION Culvert Outlet, N5124466.1, E366818.0, NAD83 MTM Zone 13 ORIGINATED BY ST  
DIST SSM HWY Hwy 17 BOREHOLE TYPE Portable Tripod 70lb Full Stroke Hammer COMPILED BY KR  
DATUM Geodetic DATE 2022.10.17 LATITUDE 46.257104 LONGITUDE 83.195573 CHECKED BY IM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)				
								20 40 60 80 100											
182.2 0.1	TOPSOIL, ~ 100 mm thick ORGANIC SILT, some sand, dark brown, wet, intermediate plasticity, very soft		SS1	SPT	1														
			SS2	SPT	1														
180.7 1.5			CLAYEY SILT, trace sand, dark grey, wet, high plasticity, very soft	SS3	SPT	1													
	SS4	SPT		1															
	SS5	SPT		0															
177.6 4.6	SILTY SAND, trace gravel, trace clay, grey, wet, loose	SS6		SPT	6														
176.1 6.1	SAND, trace silt, trace clay, grey, wet, loose  compact below ~9.1 m depth.		SS7	SPT	8														
			SS8	SPT	7														
				SS9	SPT	10													
172.2 10.0	BOREHOLE TERMINATED AT ~ 10.0 m DEPTH  Borehole was Dry upon completion.																		

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

EXP MTO IMPK-22015604-A0 - EVERETT LAKE TRIBUTARY CULVERT.GPJ ONTARIO MTO.GDT 7/13/23

## RECORD OF BOREHOLE No BH-D2

1 OF 1

METRIC

PROJECT Everett Lake Tributary Culvert LOCATION Culvert Inlet, N5124492.4, E366846.9, NAD83 MTM Zone 13 ORIGINATED BY ST  
 DIST SSM HWY Hwy 17 BOREHOLE TYPE Portable Tripod 70lb Full Stroke Hammer COMPILED BY KR  
 DATUM Geodetic DATE 2022.10.18 LATITUDE 46.257338 LONGITUDE 83.195195 CHECKED BY IM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE									
182.1																				
182.0	TOPSOIL, ~ 150 mm thick		SS1	SPT	1															
0.2	ORGANIC SILT, some clay, trace sand, dark brown to brown, wet, intermediate plasticity, very soft																			
			SS2	SPT	1												0 6 79 15			
180.6	CLAYEY SILT, trace sand, dark grey, wet, high plasticity, very soft to soft		SS3	SPT	0												0 1 74 25			
1.5			SS4	SPT	3															
179.1	SAND, trace gravel, trace silt, trace clay, grey, wet, loose		SS5	SPT	8															
3.1																				
			SS6	SPT	3															
			SS7	SPT	5															
	no gravel below ~7.6 m depth.		SS8	SPT	5												0 96 3 1			
	compact below ~9.1 m depth.		SS9	SPT	13															
172.1	BOREHOLE TERMINATED AT ~ 10.0 m DEPTH																			
10.0	50 mm Diameter Monitoring Well Installed.  Groundwater Levels: Upon Completion: 0.45 m Depth November 3, 2022: 3.5 m Depth April 26, 2023: 1.9 m Depth																			

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

## RECORD OF BOREHOLE No BH-R1

1 OF 2

METRIC

PROJECT Everett Lake Tributary Culvert LOCATION EBL at Culvert, N5124479.0, E366822.8, NAD83 MTM Zone 13 ORIGINATED BY ST  
 DIST SSM HWY Hwy 17 BOREHOLE TYPE Continuous Flight HSA, CME 75 Truck Mount COMPILED BY KR  
 DATUM Geodetic DATE 2022.10.17 LATITUDE 46.25722 LONGITUDE 83.19551 CHECKED BY IM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE									
186.8 0.0	ASPHALT, ~ 360 mm thick																	
186.4 0.5	FILL, sand and gravel, trace silt, brown, dry		AG1	AUGER											38 55 (8)			
	FILL, sand, some gravel, trace silt, brown, dry		AG2	AUGER														
	FILL, sand, some gravel, trace silt, brown, dry dense to compact below ~ 0.8 m depth		SS3	SPT	44													
			SS4	SPT	12													
184.5 2.3	FILL, sandy silt, trace gravel, brown, moist, loose		SS5	SPT	5													
			SS6	SPT	6													
	some organics, some clay, no gravel, grey to dark brown, moist to wet, very loose below ~ 3.8 m depth		SS7	SPT	2										0 20 68 11			
			SS8	SPT	3													
	dark brown below ~ 5.33 m depth		SS9	SPT	3													
			SS10	SPT	3													
179.9 6.9	CLAYEY SILT, trace sand, dark grey, moist, high plasticity, soft to firm		SS11	SPT	2										0 2 71 27			
			SS12	SPT	4													
177.7 9.1	SAND, trace to some silt, trace clay, grey, wet, compact		SS13	SPT	12													
	very loose below ~ 10.7 m depth		SS14	SPT	1													

Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

EXP MTO IMPK-22015604-A0 - EVERETT LAKE TRIBUTARY CULVERT.GPJ ONTARIO MTO.GDT 7/13/23

**RECORD OF BOREHOLE No BH-R1**

2 OF 2

**METRIC**

PROJECT Everett Lake Tributary Culvert LOCATION EBL at Culvert, N5124479.0, E366822.8, NAD83 MTM Zone 13 ORIGINATED BY ST  
DIST SSM HWY Hwy 17 BOREHOLE TYPE Continuous Flight HSA, CME 75 Truck Mount COMPILED BY KR  
DATUM Geodetic DATE 2022.10.17 LATITUDE 46.25722 LONGITUDE 83.19551 CHECKED BY IM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT  $w_p$	NATURAL MOISTURE CONTENT  $w$	LIQUID LIMIT  $w_L$	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)				GR	SA	SI	CL
								<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div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+ <sup>3</sup>, × <sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

**RECORD OF BOREHOLE No BH-R2**

1 OF 2

**METRIC**

PROJECT Everett Lake Tributary Culvert LOCATION EBL 20m E of Culvert, N5124461.1, E366852.5, NAD83 MTM Zone 13 ORIGINATED BY ST  
DIST SSM HWY Hwy 17 BOREHOLE TYPE Continuous Flight HSA, CME 75 Truck Mount COMPILED BY KR  
DATUM Geodetic DATE 2022.10.18 LATITUDE 46.257056 LONGITUDE 83.195127 CHECKED BY IM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE									
186.8 0.0	ASPHALT, ~ 300 mm thick																	
186.5 186.3	FILL, sand and gravel, trace silt, brown, dry FILL, sand, some gravel, trace silt, brown, dry to moist dense below ~ 0.8 m depth		AG1	AUGER														
186.3 0.5			AG2	AUGER														
			SS3	SPT	32													
185.3 1.5	SANDY SILT, some organics, dark brown to brown, wet, compact  (possible fill)		SS4	SPT	20													
184.5 2.3	SAND, trace silt, trace clay, brown, moist, compact  (possible fill)  wet, loose to very loose below ~ 3.05 m depth		SS5	SPT	11										0 88 9 2			
			SS6	SPT	6													
			SS7	SPT	3													
182.2 4.6	SILT AND SAND, trace clay, brown, wet, very loose		SS8	SPT	1													
			SS9	SPT	2										0 35 60 5			
			SS10	SPT	2													
			SS11	SPT	2													
		SS12	SPT	3														
		SS13	SPT	1											0 32 60 8			
						</												

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE


EXP MTO IMPK-22015604-A0 - EVERETT LAKE TRIBUTARY CULVERT.GPJ ONTARIO MTO.GDT 7/13/23

**RECORD OF BOREHOLE No BH-R2**

2 OF 2

**METRIC**

PROJECT Everett Lake Tributary Culvert LOCATION EBL 20m E of Culvert, N5124461.1, E366852.5, NAD83 MTM Zone 13 ORIGINATED BY ST  
DIST SSM HWY Hwy 17 BOREHOLE TYPE Continuous Flight HSA, CME 75 Truck Mount COMPILED BY KR  
DATUM Geodetic DATE 2022.10.18 LATITUDE 46.257056 LONGITUDE 83.195127 CHECKED BY IM

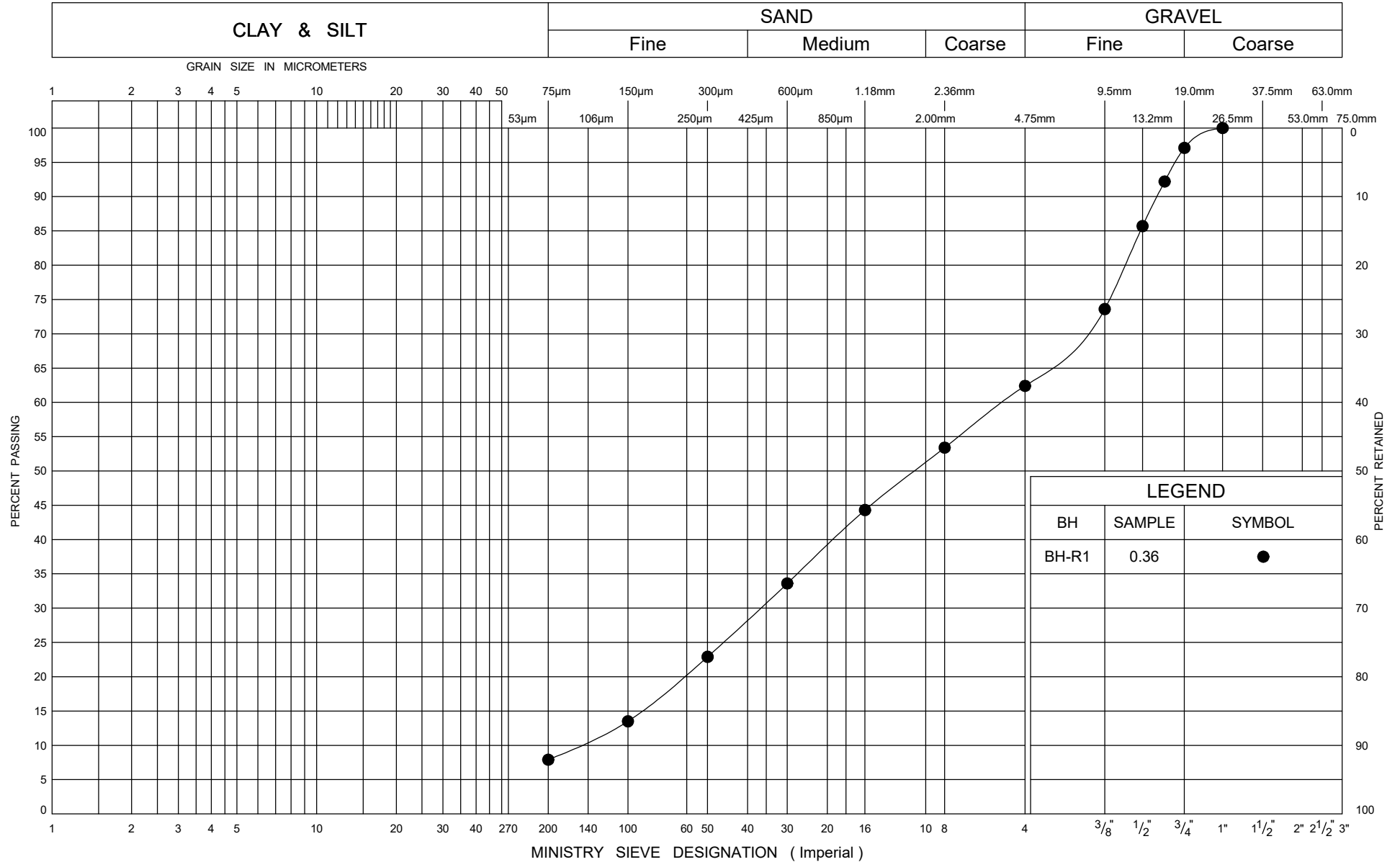
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	+	FIELD VANE	● QUICK TRIAXIAL	×						LAB VANE		
174.6																				
12.2	<b>SAND</b> , some silt, trace gravel, trace clay, brown, wet, very loose		SS15	SPT	4												4 82 12 2			
			SS16	SPT	8															
172.3																				
14.5	BOREHOLE TERMINATED AT 14.5 m DEPTH																			
	Borehole was Dry upon completion.																			

+ <sup>3</sup>, × <sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE



## Appendix D – Laboratory Testing Data

## UNIFIED SOIL CLASSIFICATION SYSTEM



## GRAIN SIZE DISTRIBUTION

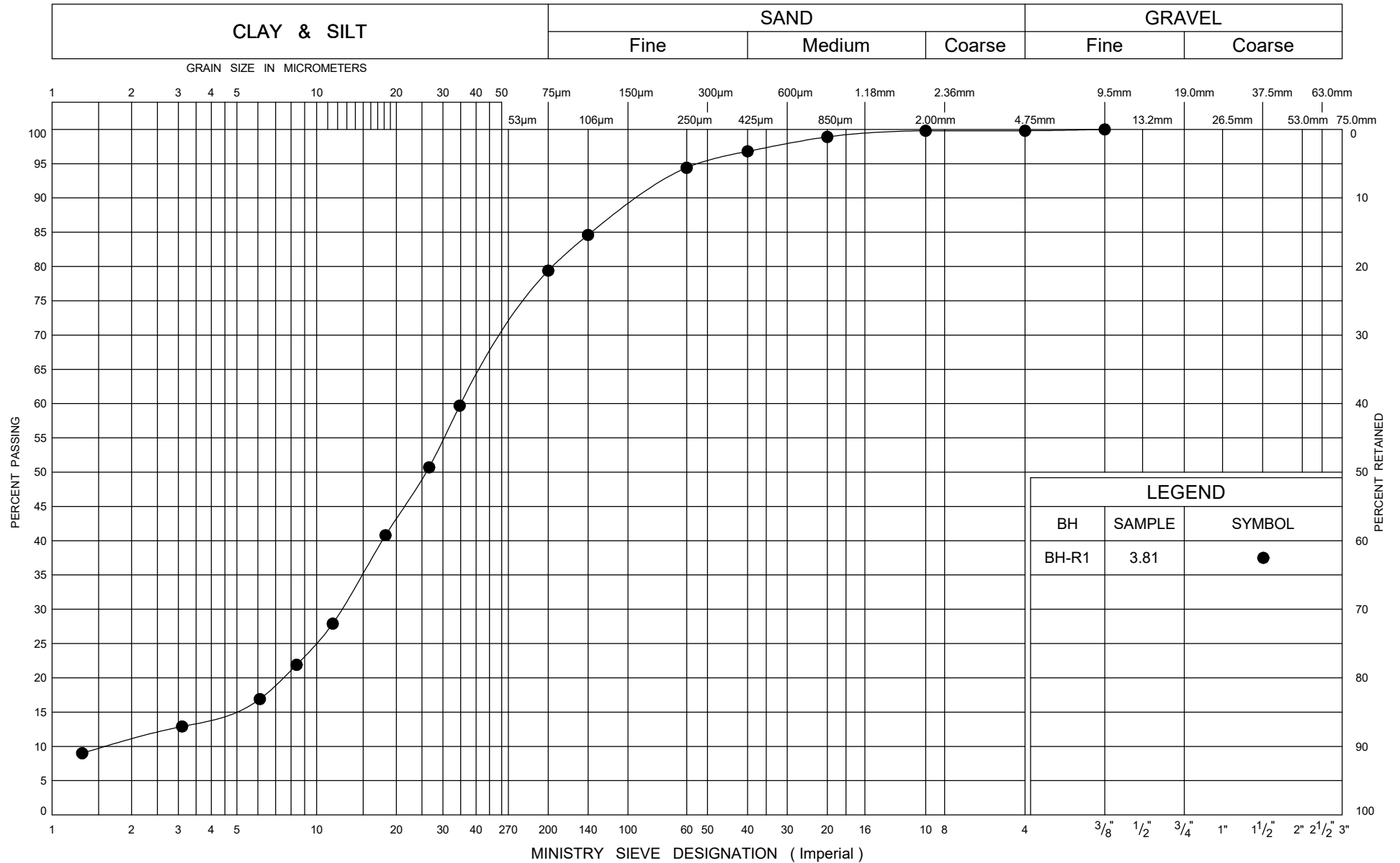
Sand and Gravel Fill

FIG No 1

5022-E-0007,GWP5115-20-00

Everett Lake Tributary Culvert

## UNIFIED SOIL CLASSIFICATION SYSTEM



## GRAIN SIZE DISTRIBUTION

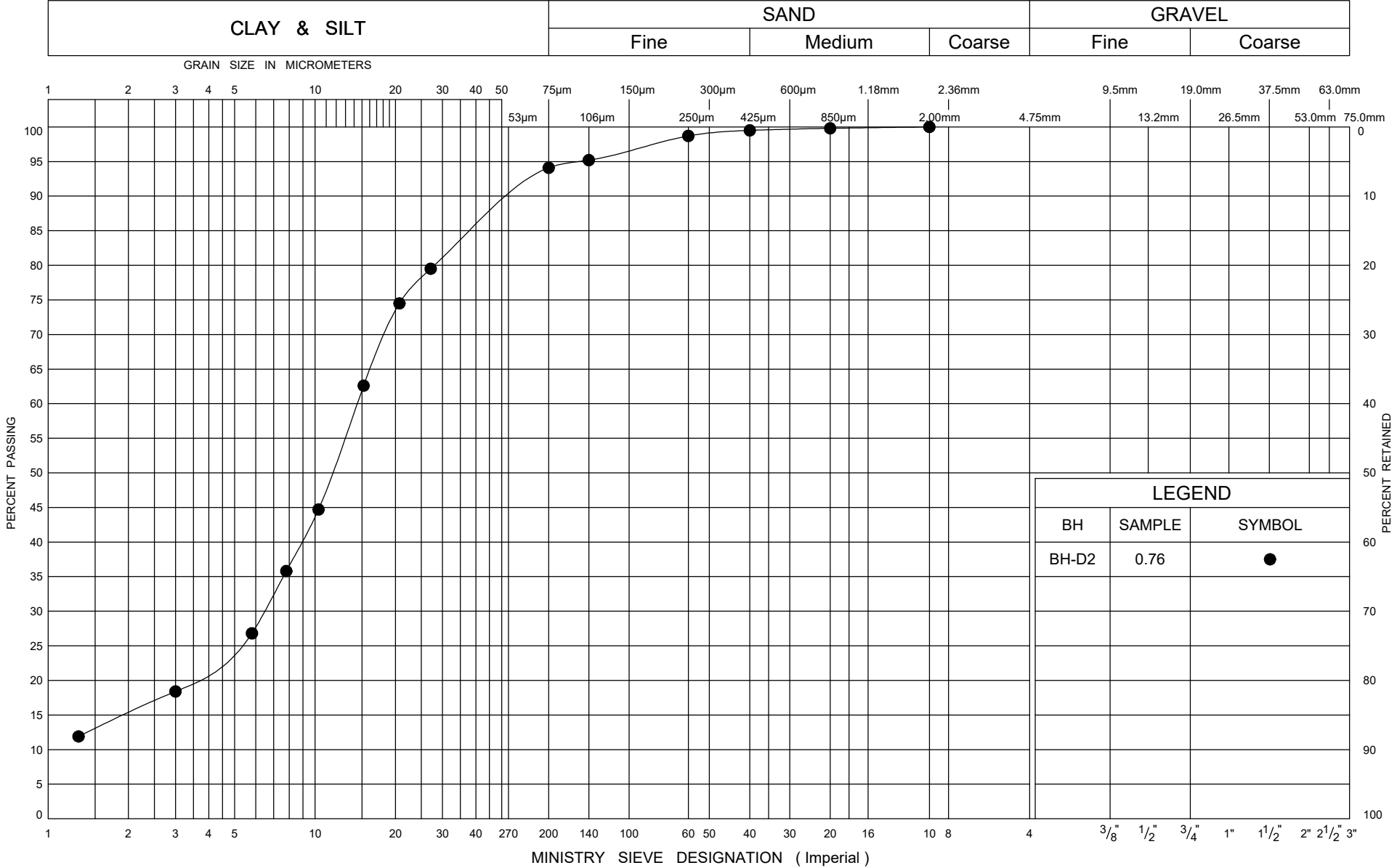
Sandy Silt Fill

FIG No 2

5022-E-0007,GWP5115-20-00

Everett Lake Tributary Culvert

UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION

Organic Silt

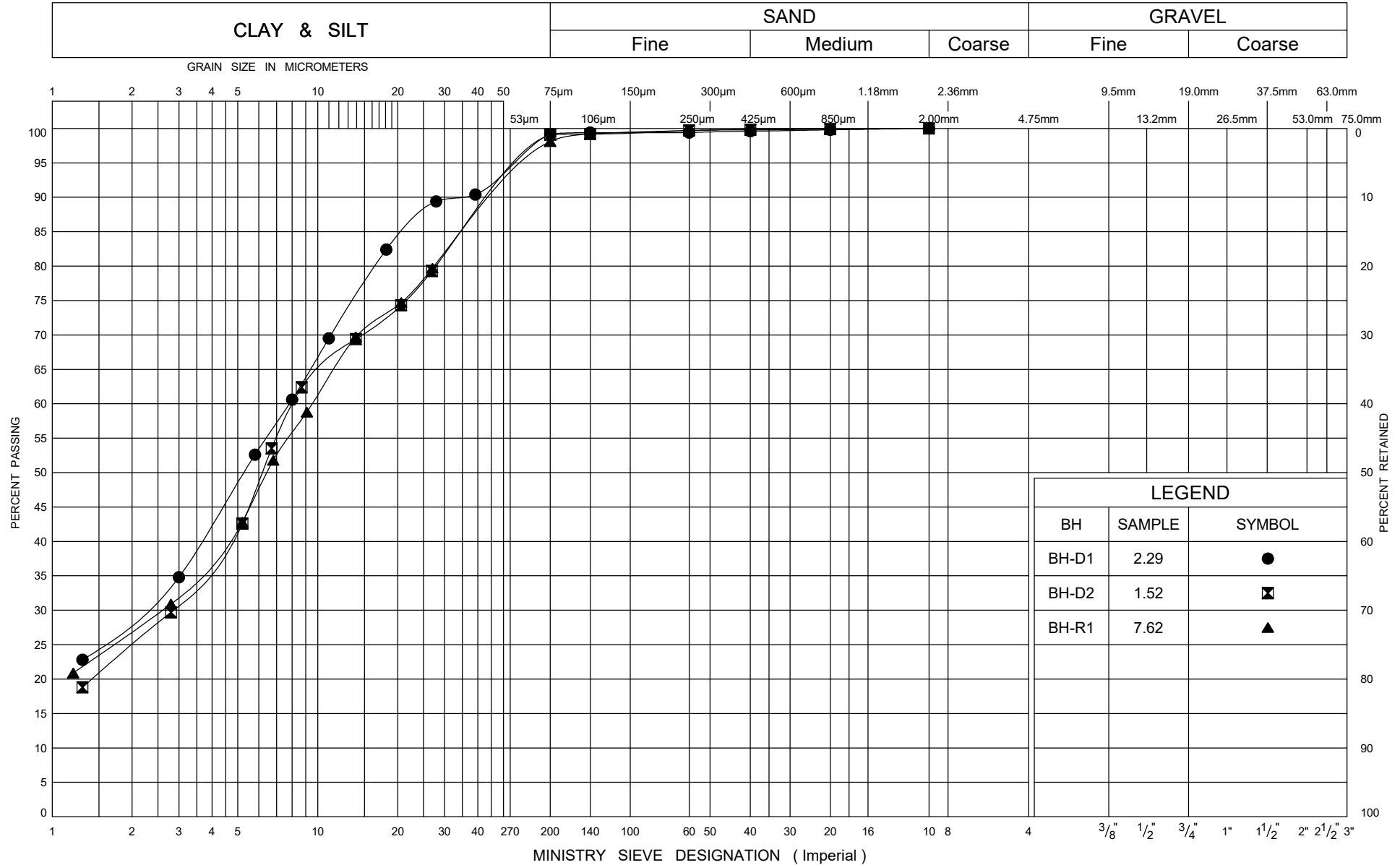
FIG No 3

5022-E-0007,GWP5115-20-00

Everett Lake Tributary Culvert



## UNIFIED SOIL CLASSIFICATION SYSTEM



## GRAIN SIZE DISTRIBUTION

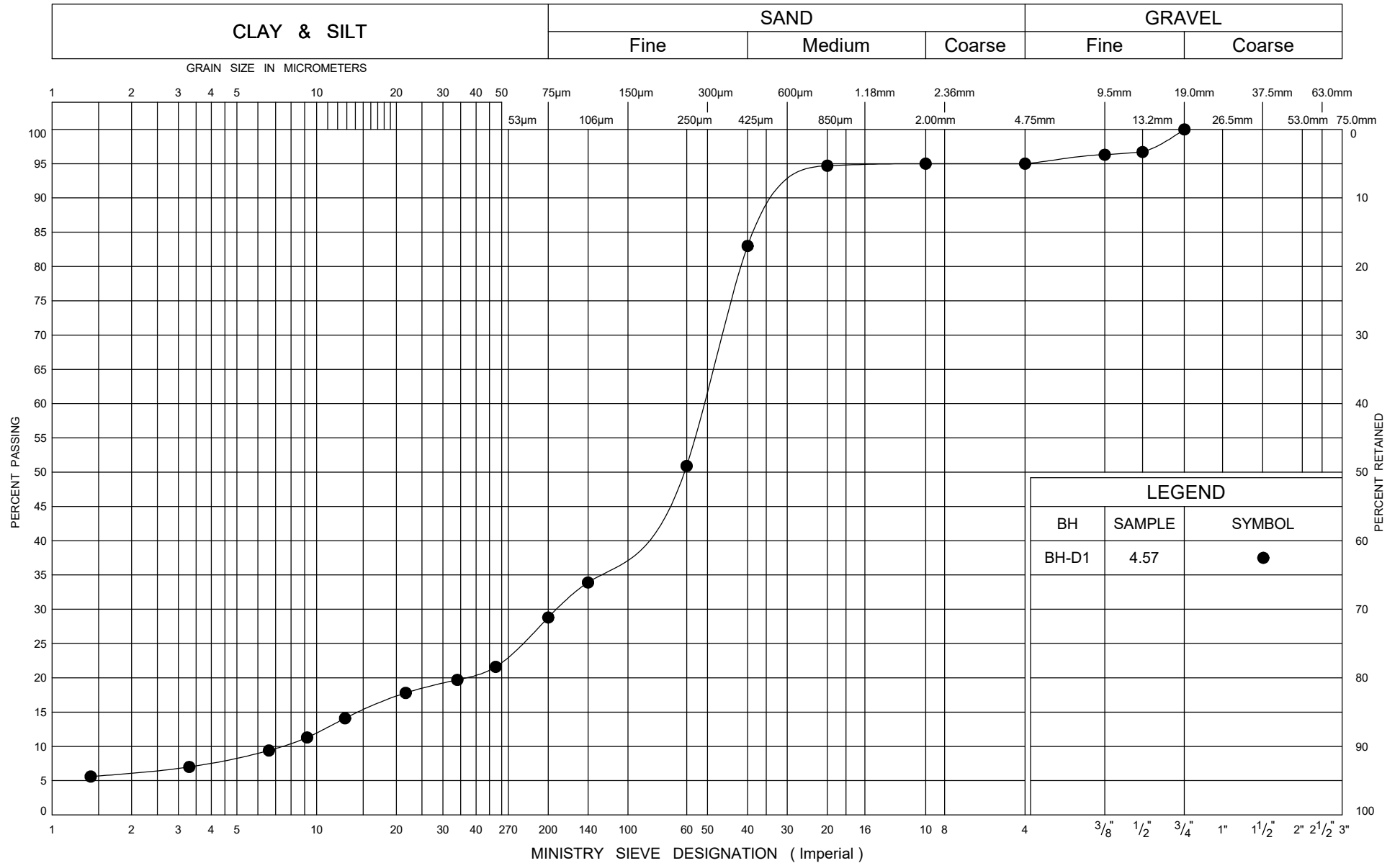
Clayey Silt

FIG No 4

5022-E-0007,GWP5115-20-00

Everett Lake Tributary Culvert

## UNIFIED SOIL CLASSIFICATION SYSTEM



## GRAIN SIZE DISTRIBUTION

Silty Sand

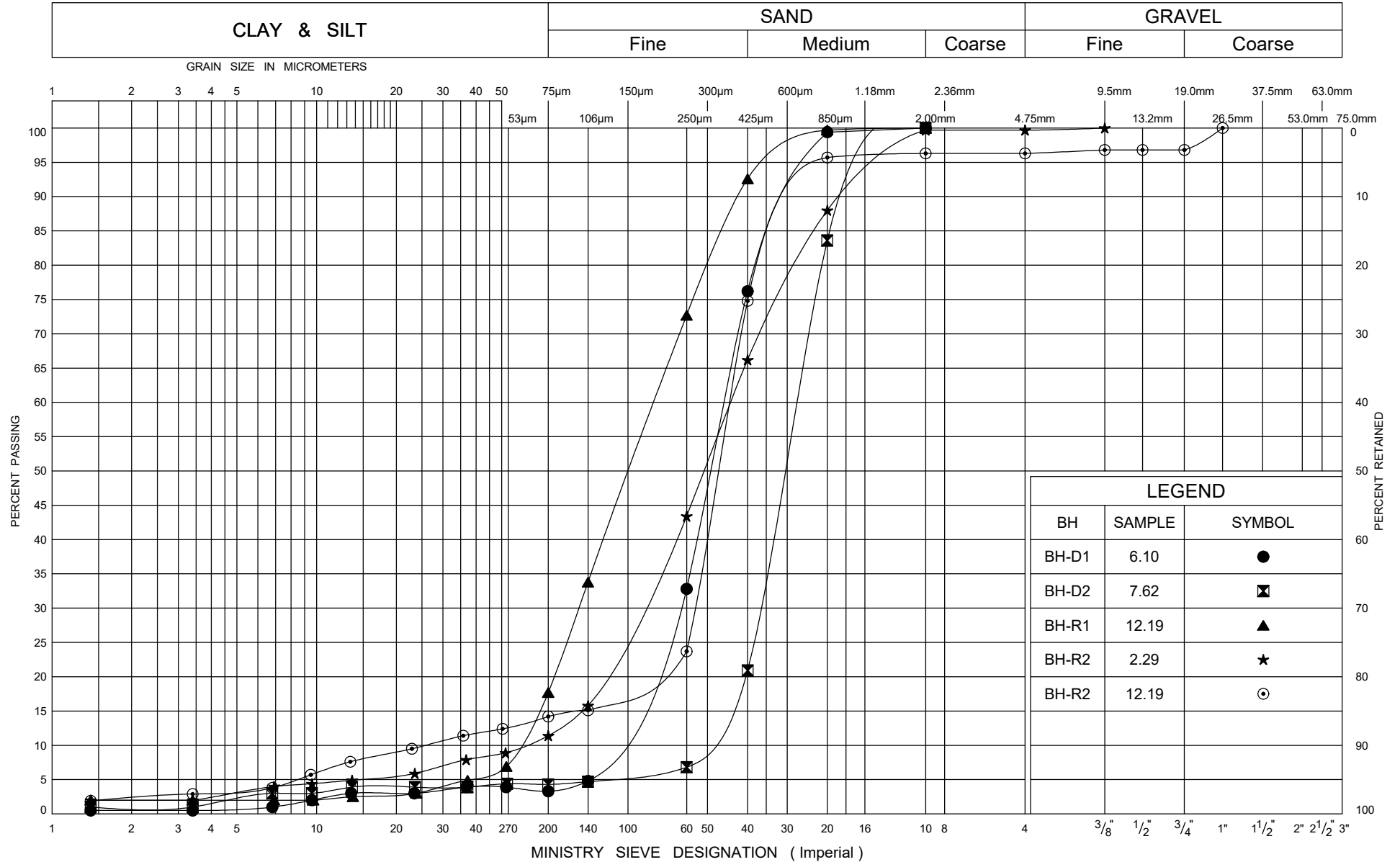
FIG No 5

5022-E-0007,GWP5115-20-00

Everett Lake Tributary Culvert



## UNIFIED SOIL CLASSIFICATION SYSTEM



## GRAIN SIZE DISTRIBUTION

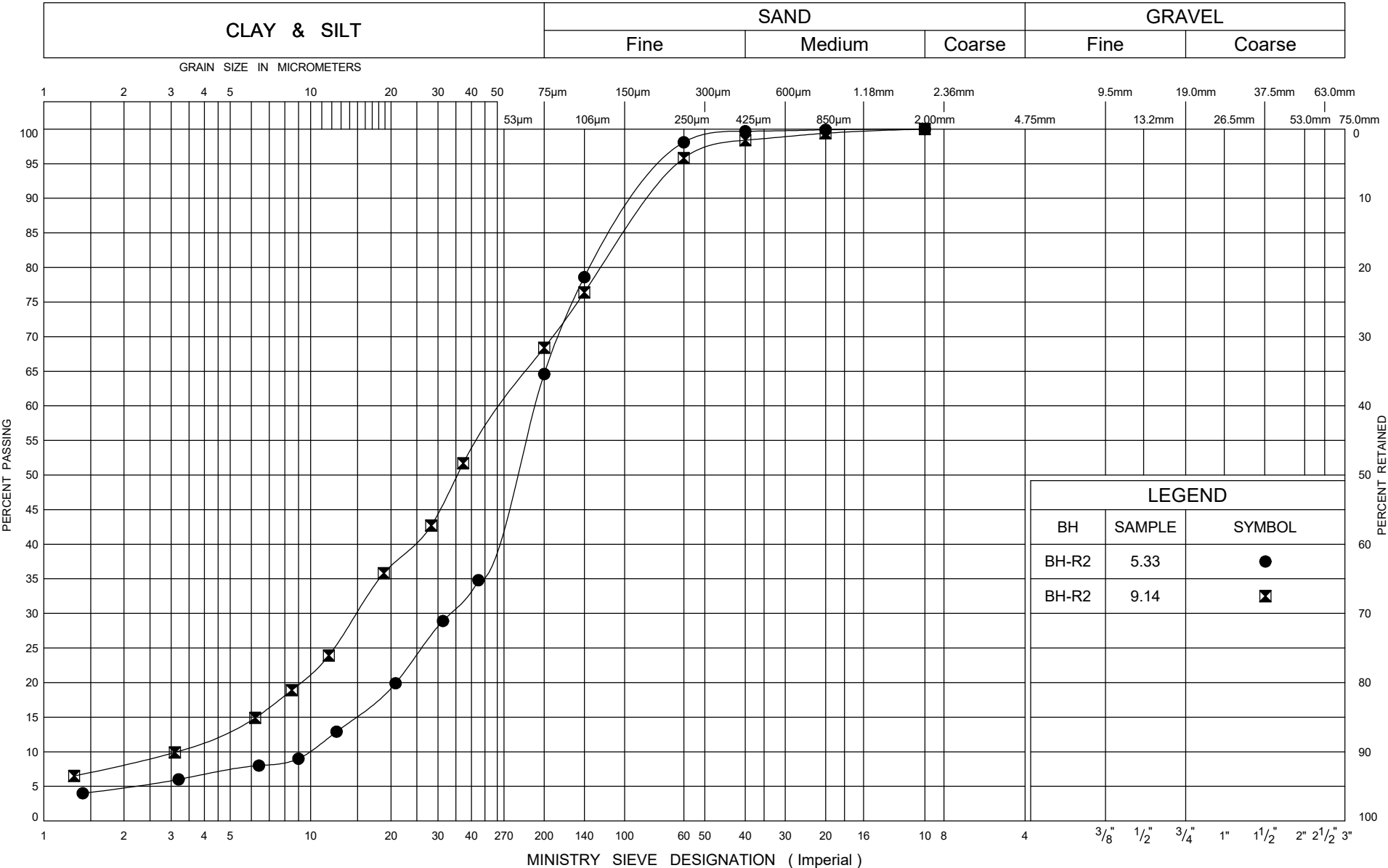
Sand

FIG No 6

5022-E-0007,GWP5115-20-00

Everett Lake Tributary Culvert

UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION

Silt and Sand

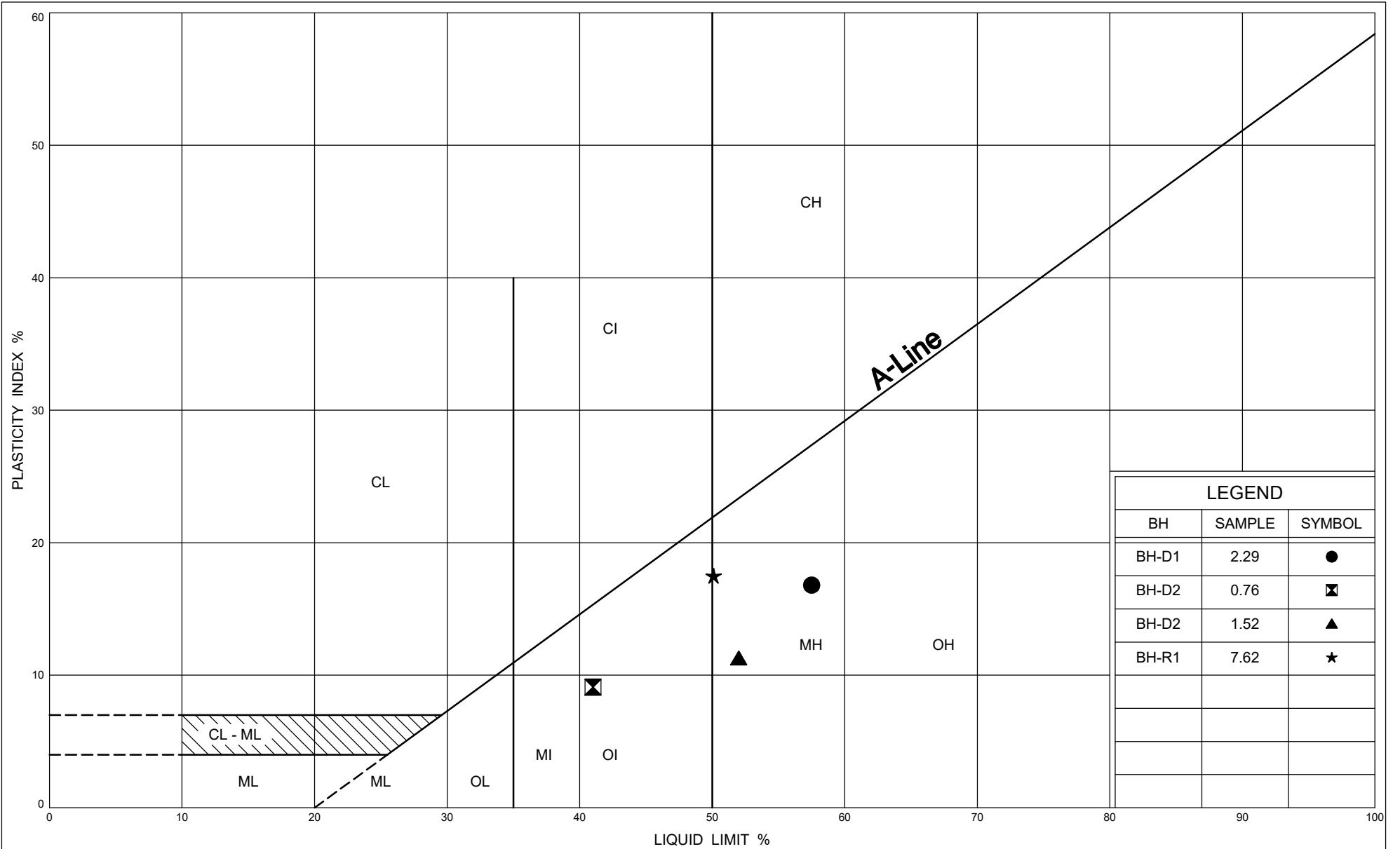
FIG No 7

5022-E-0007,GWP5115-20-00

Everett Lake Tributary Culvert







## PLASTICITY CHART

FIG No 8

5022-E-0007,GWP5115-20-00

Everett Lake Tributary Culvert

## Appendix E – Corrosivity Testing – Certificate of Analysis



## FINAL REPORT

CA15234-NOV22 R1

MRK-22015604 Ph.04

Prepared for

**EXP Services Inc.**

## First Page

### CLIENT DETAILS

Client EXP Services Inc.

Address 885 Reagent Street  
Sudbury, Ontario  
P3E 5M4, Canada

Contact Ian MacMillan

Telephone 705-674-9681

Facsimile 705-674-5583

Email ian.macmillan@exp.com

Project MRK-22015604 Ph.04

Order Number

Samples Soil (1)

### LABORATORY DETAILS

Project Specialist Jill Campbell, B.Sc.,GISAS

Laboratory SGS Canada Inc.

Address 185 Concession St., Lakefield ON, K0L 2H0

Telephone 2165

Facsimile 705-652-6365

Email jill.campbell@sgs.com

SGS Reference CA15234-NOV22

Received 11/11/2022

Approved 12/05/2022

Report Number CA15234-NOV22 R1

Date Reported 12/05/2022

### COMMENTS

Temperature of Sample upon Receipt: 5 degrees C

Cooling Agent Present: Yes

Custody Seal Present: Yes

Chain of Custody Number: 032909

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

### SIGNATORIES

Jill Campbell, B.Sc.,GISAS







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# FINAL REPORT

CA15234-NOV22 R1

**Client:** EXP Services Inc.

**Project:** MRK-22015604 Ph.04

**Project Manager:** Ian MacMillan

**Samplers:** Adriana Burgos

MATRIX: SOIL

**Sample Number** 5  
**Sample Name** BHR1-SS8,  
15-17'  
**Sample Matrix** Soil  
**Sample Date** 02/11/2022

Parameter	Units	RL	Result
<b>Corrosivity Index</b>			
Corrosivity Index	none	1	11
Soil Redox Potential	mV	no	342
Sulphide (Na <sub>2</sub> CO <sub>3</sub> )	%	0.04	< 0.04
pH	pH Units	0.05	5.89
Resistivity (calculated)	ohms.cm	-9999	696
<b>General Chemistry</b>			
Conductivity	uS/cm	2	1440
<b>Metals and Inorganics</b>			
Moisture Content	%	0.1	29.0
Sulphate	µg/g	0.4	420
<b>Other (ORP)</b>			
Chloride	µg/g	0.4	870



FINAL REPORT

CA15234-NOV22 R1

QC SUMMARY

Anions by IC  
Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-IENVIIC-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Chloride	DIO0438-NOV22	µg/g	0.4	<0.4	4	35	99	80	120	80	75	125
Sulphate	DIO0438-NOV22	µg/g	0.4	<0.4	0	35	96	80	120	107	75	125

Carbon/Sulphur  
Method: ASTM E1915-07A | Internal ref.: ME-CA-IENVIARD-LAK-AN-020

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Sulphide (Na2CO3)	ECS0065-NOV22	%	0.04	< 0.04	0	20	115	80	120			

Conductivity  
Method: SM 2510 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Conductivity	EWL0343-NOV22	uS/cm	2	< 2	3	20	101	90	110	NA		





FINAL REPORT

CA15234-NOV22 R1

QC SUMMARY

pH  
Method: SM 4500 | Internal ref.: ME-CA-1ENVIEWL-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
pH	EWL0343-NOV22	pH Units	0.05	NA	0		101			NA		

Method Blank: a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.

Duplicate: Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.

LCS/Spike Blank: Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate laboratory accuracy with sample matrix effects.

Reference Material: a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.

RL: Reporting limit

RPD: Relative percent difference

AC: Acceptance criteria

**Multielement Scan Qualifier:** as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.

**Duplicate Qualifier:** for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

**Matrix Spike Qualifier:** for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.

## LEGEND

### FOOTNOTES

**NSS** Insufficient sample for analysis.

**RL** Reporting Limit.

↑ Reporting limit raised.

↓ Reporting limit lowered.

**NA** The sample was not analysed for this analyte

**ND** Non Detect

Results relate only to the sample tested.

Data reported represent the sample as submitted to SGS. Solid samples expressed on a dry weight basis.

"Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

Analysis conducted on samples submitted pursuant to or as part of Reg. 153/04, are in accordance to the "Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act and Excess Soil Quality" published by the Ministry and dated March 9, 2004 as amended.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated.

SGS Canada Inc. statement of conformity decision rule does not consider uncertainty when analytical results are compared to a specified standard or regulation.

This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at [http://www.sgs.com/terms\\_and\\_conditions.htm](http://www.sgs.com/terms_and_conditions.htm).

The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents. Reproduction of this analytical report in full or in part is prohibited.

This report supersedes all previous versions.

-- End of Analytical Report --

## Request for Laboratory Services and CHAIN OF CUSTODY

Received By: CAYLUS GRATHAMReceived Date: 11/11/22 (mm/dd/yy)Received Time: 4:30 (hr : min)

Received By (signature):

Custody Seal Present: Yes ☒ No ☐  
Custody Seal Intact: Yes ☒ No ☐Cooling Agent Present: Yes ☒ No ☐ Type: ice  
Temperature Upon Receipt (°C): 4.55LAB LIMS #: CA15234-NOV22

## REPORT INFORMATION

Company: EXP ServicesContact: Ian MacmillanAddress: 885 Regent StPhone: 705 674 9681

Fax:

Email: Ian.Macmillan@exp.com

## INVOICE INFORMATION

☐ (same as Report Information)

Company:

Contact:

Address:

Phone:

## REGULATIONS

☐ O.Reg 153/04 ☐ O.Reg 406/19☐ Table 1 ☐ Res/Park ☐ Soil Texture:☐ Table 2 ☐ Ind/Com ☐ Coarse☐ Table 3 ☐ Agr/Other ☐ Medium/Fine☐ Table ☐ Appx. ☐ MISASoil Volume ☐ <350m3 ☐ >350m3☐ ODWS Not Reportable - See note

Other Regulations:

☐ Reg 347/558 (3 Day min TAT)☐ PW/OO ☐ MMER☐ CCME ☐ Other:☐ MISA

Sewer By-Law:

☐ Sanitary☐ Storm

Municipality:

## ANALYSIS REQUESTED

M &amp; I

SVOC

PCB

PHC

VOC

Pest

Other (please specify)

SPLP

TCLP

Field Filtered (Y/N)

Metals & Inorganics  
incl CrVI, CN, Hg pH, B(HWS), EC, SAR-soil  
(Cl, Na-water)Full Metals Suite  
ICP metals plus B(HWS-soil only) Hg, CrVIICP Metals only Sb, As, Ba, Be, B, Cd,  
Cr, Co, Cu, Pb, Mo, Ni, Se, Ag, Ti, U, V, Zn

PAHs only

SVOCs  
all incl PAHs, ABNs, CPsPCBs Total ☐ Aroclor ☐

F1-F4 + BTEX

F1-F4 only  
no BTEXVOCs  
all incl BTEX

BTEX only

Pesticides  
Organochlorine or specify other

X Corrosivity

Sewer Use:

Specify pkg:

Water Characterization Pkg

General ☐ Extended ☐☐ Metals☐ VOC☐ 1,4-  
Dioxin☐ PCB☐ BtAP☐ ABN☐ Ignit.

COMMENTS:

MRK-22015604

Phase G4

## SAMPLE IDENTIFICATION

DATE  
SAMPLEDTIME  
SAMPLED# OF  
BOTTLES  
BAG

MATRIX

1 BHQ1-SS8, 15-17'

2

3

4

5

6

7

8

9

10

11

12

## Observations/Comments/Special Instructions

Sampled By (NAME):

Adriana Burgos

Signature:



Relinquished by (NAME):

Signature:

Date: NOV 10 22 (mm/dd/yy)Date: NOV 10 22 (mm/dd/yy)

Pink Copy - Client

Yellow &amp; White Copy - SGS

## Appendix F – Slope Stability Analyses

Assignment Number: 5022-E-0007  
Replacement of the Everett Lake Tributary Culvert (#38S-0402/C0)  
Highway 17, Township of Thompson, Ontario  
Sault Ste. Marie Area, Northeast Region

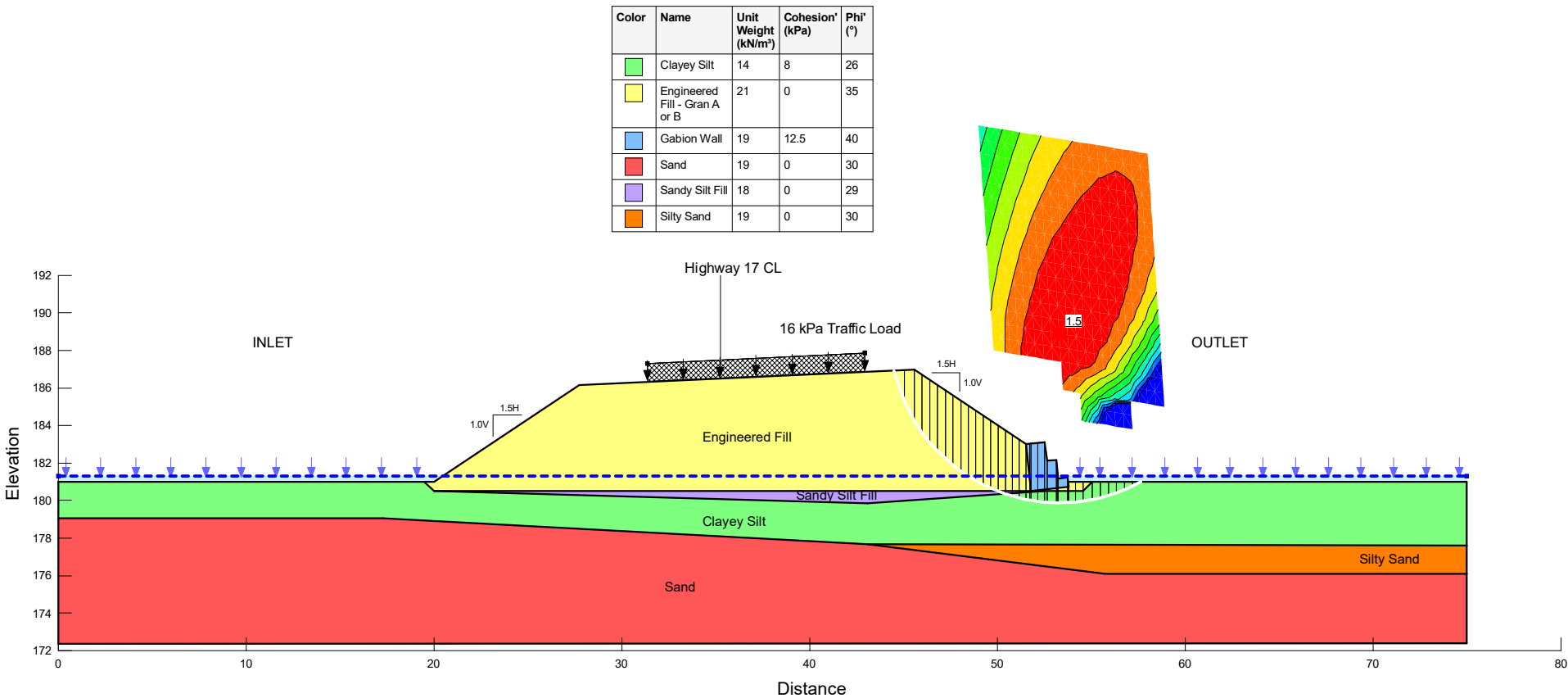


Figure F-1  
Outlet Embankment with Gran A or B  
1.5H:1V Side Slopes with Gabion Wall  
Drained, Static Condition

Assignment Number: 5022-E-0007  
 Replacement of the Everett Lake Tributary Culvert (#38S-0402/C0)  
 Highway 17, Township of Thompson, Ontario  
 Sault Ste. Marie Area, Northeast Region

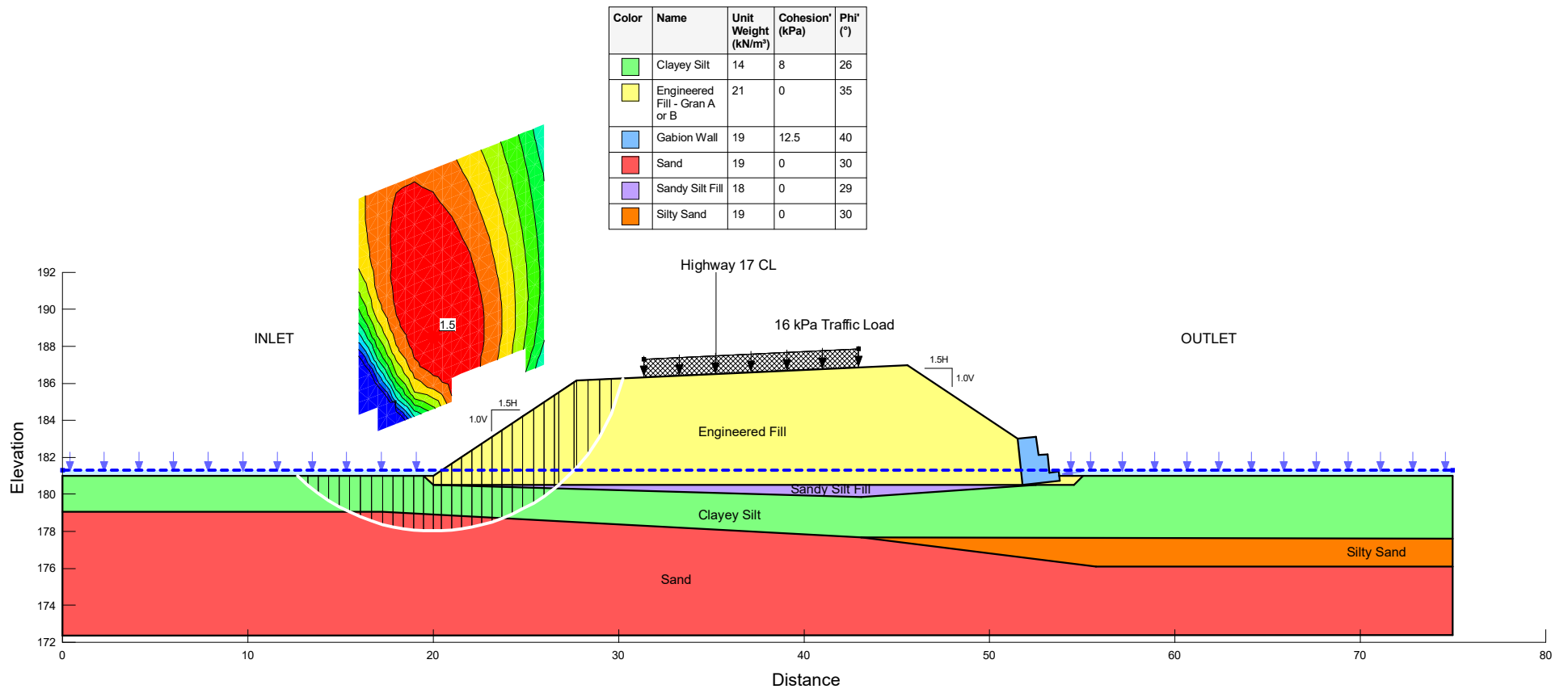


Figure F-2  
 Inlet Embankment with Gran. A or B  
 1.5H:1V Side Slopes with Gabion Wall  
 Drained, Static Condition

Assignment Number: 5022-E-0007  
 Replacement of the Everett Lake Tributary Culvert (#38S-0402/C0)  
 Highway 17, Township of Thompson, Ontario  
 Sault Ste. Marie Area, Northeast Region

Color	Name	Unit Weight (kN/m <sup>3</sup> )	Cohesion' (kPa)	Phi' (°)
Light Green	Clayey Silt	14	8	26
Light Blue	Engineered Fill - SSM	21	0	32
Blue	Gabion Wall	19	12.5	40
Red	Sand	19	0	30
Purple	Sandy Silt Fill	18	0	29
Orange	Silty Sand	19	0	30

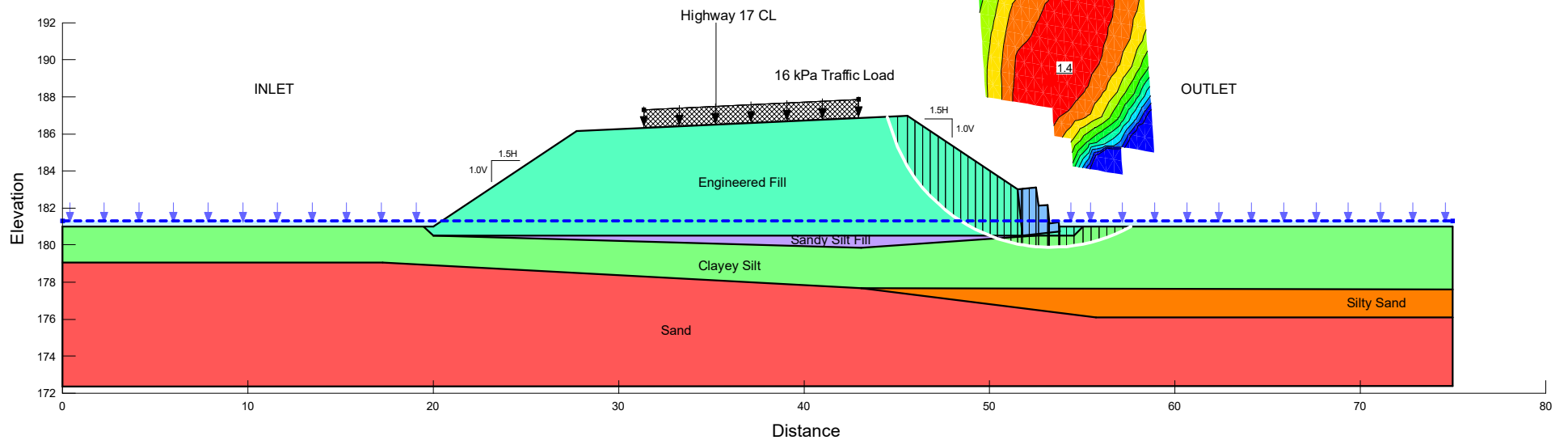


Figure F-3  
 Outlet Embankment with SSM  
 1.5H:1V Side Slopes with Gabion Wall  
 Drained, Static Condition



Assignment Number: 5022-E-0007  
 Replacement of the Everett Lake Tributary Culvert (#38S-0402/C0)  
 Highway 17, Township of Thompson, Ontario  
 Sault Ste. Marie Area, Northeast Region

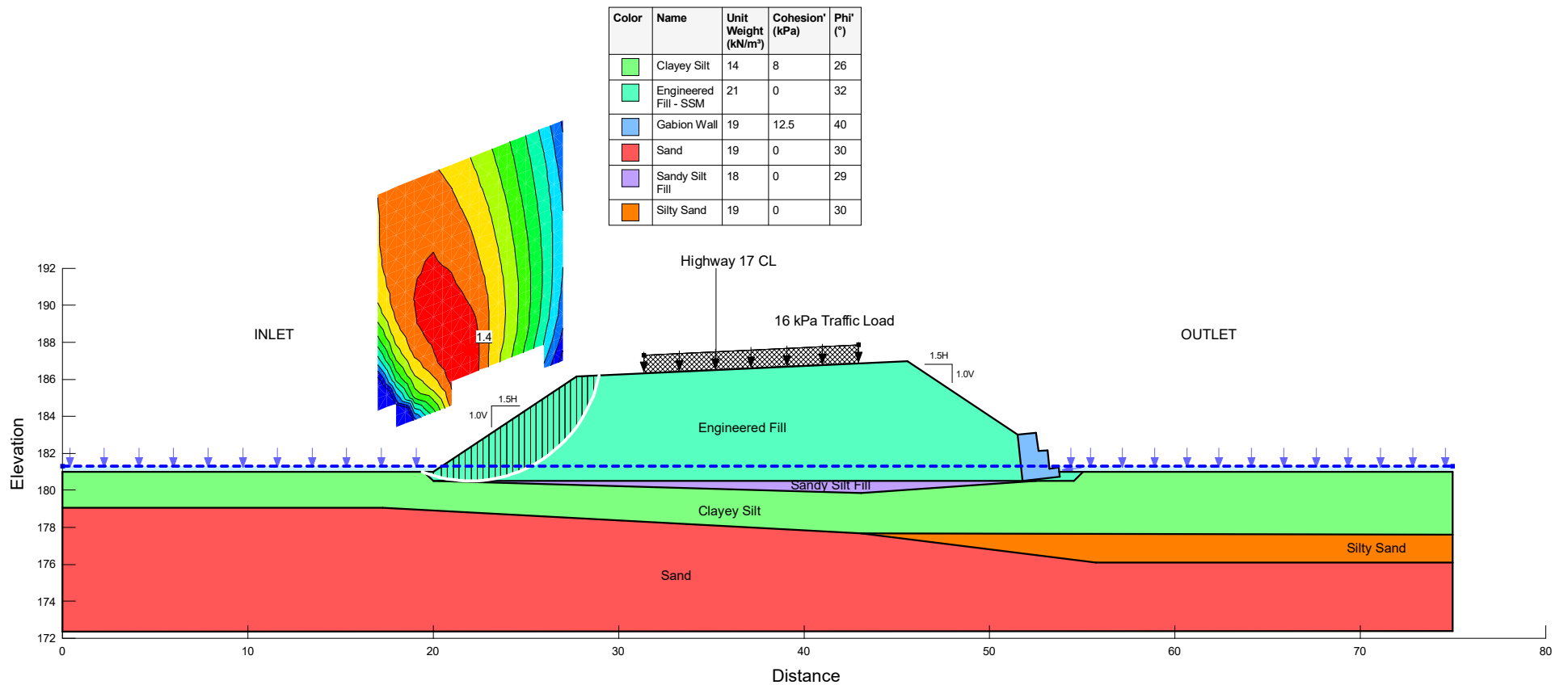


Figure F-4  
 Inlet Embankment with SSM  
 1.5H:1V Side Slopes with Gabion Wall  
 Drained, Static Condition

Assignment Number: 5022-E-0007  
 Replacement of the Everett Lake Tributary Culvert (#38S-0402/C0)  
 Highway 17, Township of Thompson, Ontario  
 Sault Ste. Marie Area, Northeast Region

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
Green	Clayey Silt	14	8	26
Yellow	Engineered Fill - Gran A or B	21	0	35
Blue	Gabion Wall	19	12.5	40
Red	Sand	19	0	30
Purple	Sandy Silt Fill	18	0	29
Orange	Silty Sand	19	0	30

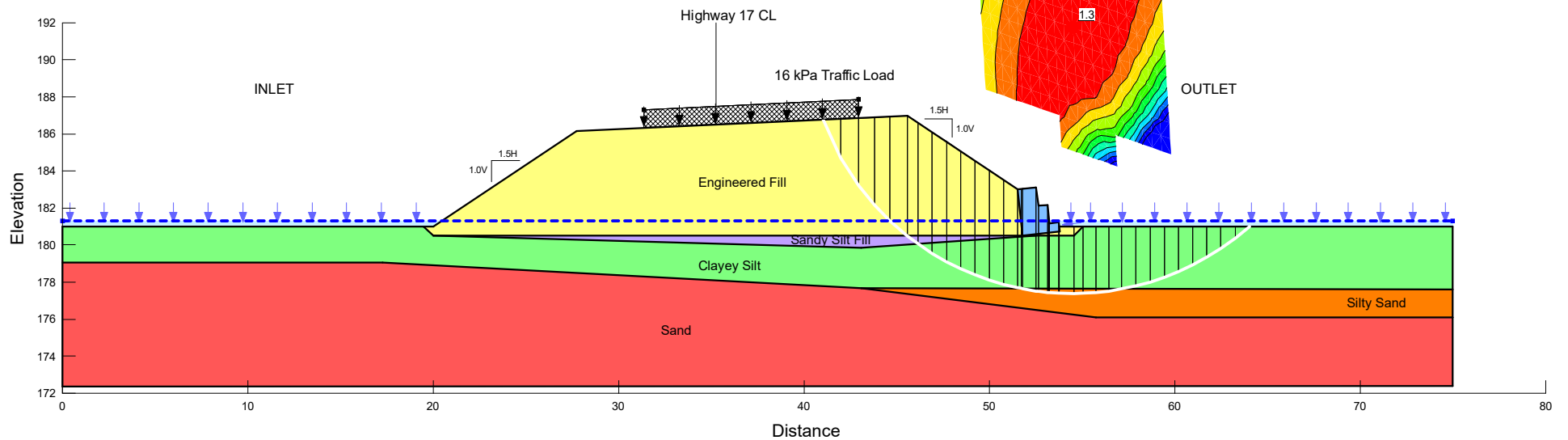


Figure F-5  
 Outlet Embankment with Gran A or B  
 1.5H:1V Side Slopes with Gabion Wall  
 Drained, Seismic Condition

Assignment Number: 5022-E-0007  
 Replacement of the Everett Lake Tributary Culvert (#38S-0402/C0)  
 Highway 17, Township of Thompson, Ontario  
 Sault Ste. Marie Area, Northeast Region

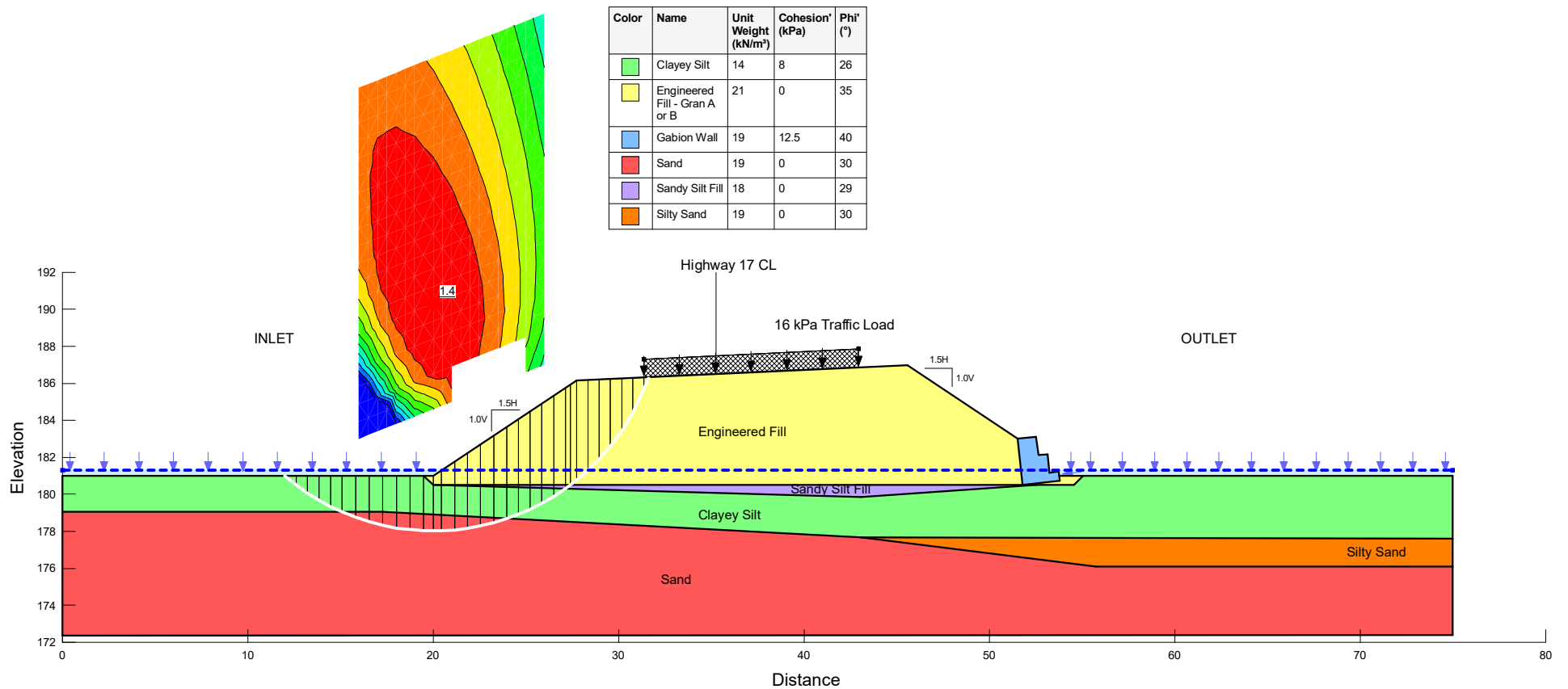


Figure F-6  
 Inlet Embankment with Gran A or B  
 1.5H:1V Side Slopes with Gabion Wall  
 Drained, Seismic Condition

Assignment Number: 5022-E-0007  
Replacement of the Everett Lake Tributary Culvert (#38S-0402/C0)  
Highway 17, Township of Thompson, Ontario  
Sault Ste. Marie Area, Northeast Region

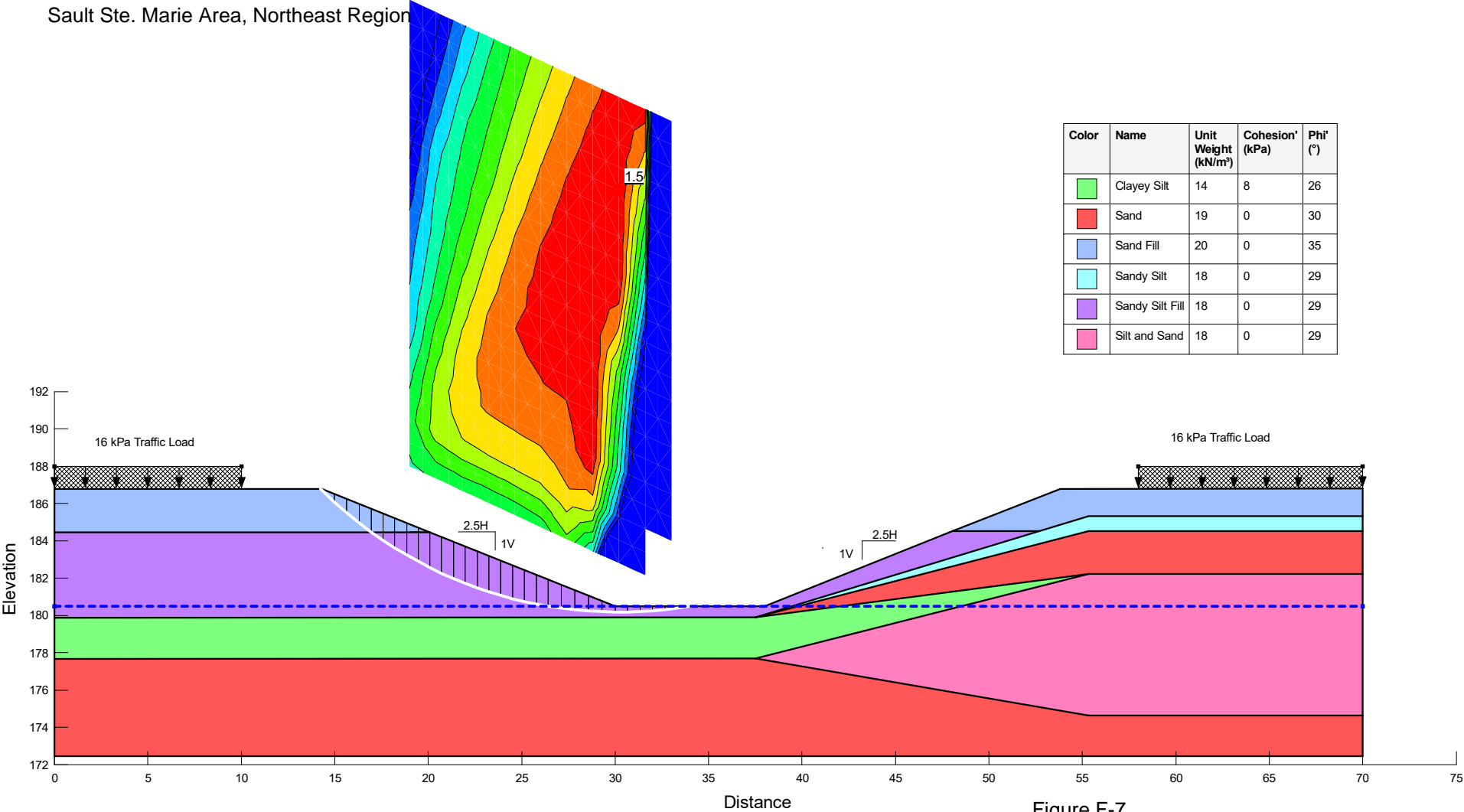
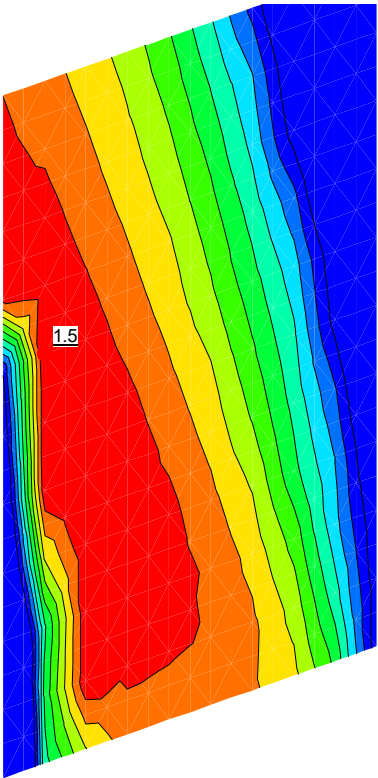


Figure F-7  
Temporary Embankment - West Side  
2.5H:1V Side Slopes  
Drained, Static Condition

Assignment Number: 5022-E-0007  
Replacement of the Everett Lake Tributary Culvert (#38S-0402/C0)  
Highway 17, Township of Thompson, Ontario  
Sault Ste. Marie Area, Northeast Region



Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
Green	Clayey Silt	14	8	26
Red	Sand	19	0	30
Blue	Sand Fill	20	0	35
Cyan	Sandy Silt	18	0	29
Purple	Sandy Silt Fill	18	0	29
Pink	Silt and Sand	18	0	29

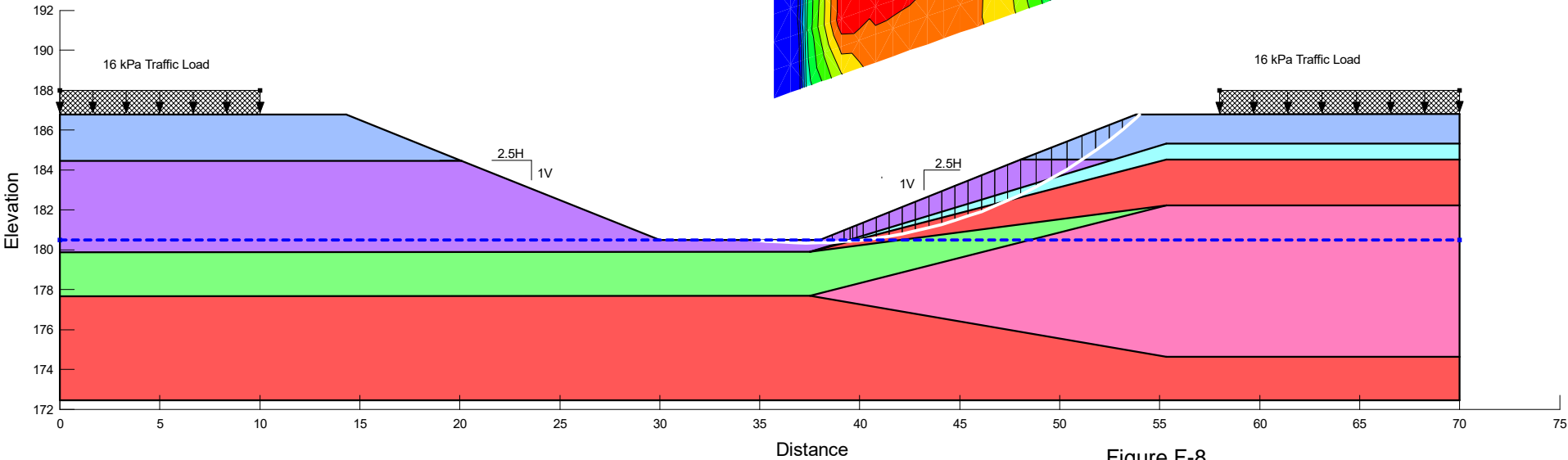
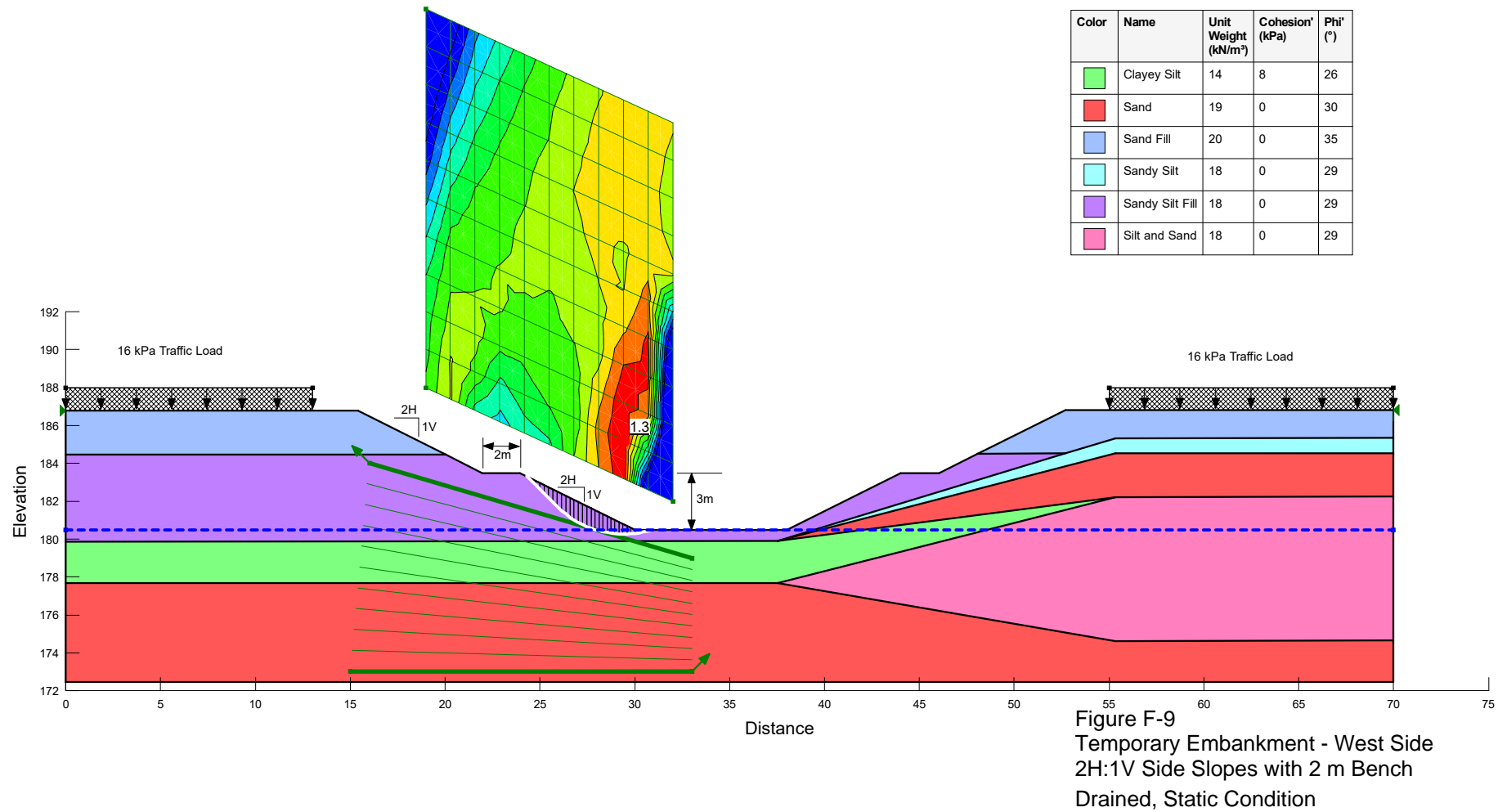


Figure F-8  
Temporary Embankment - East Side  
2.5H:1V Side Slopes  
Drained, Static Condition

Assignment Number: 5022-E-0007  
 Replacement of the Everett Lake Tributary Culvert (#38S-0402/C0)  
 Highway 17, Township of Thompson, Ontario  
 Sault Ste. Marie Area, Northeast Region





Assignment Number: 5022-E-0007  
 Replacement of the Everett Lake Tributary Culvert (#38S-0402/C0)  
 Highway 17, Township of Thompson, Ontario  
 Sault Ste. Marie Area, Northeast Region

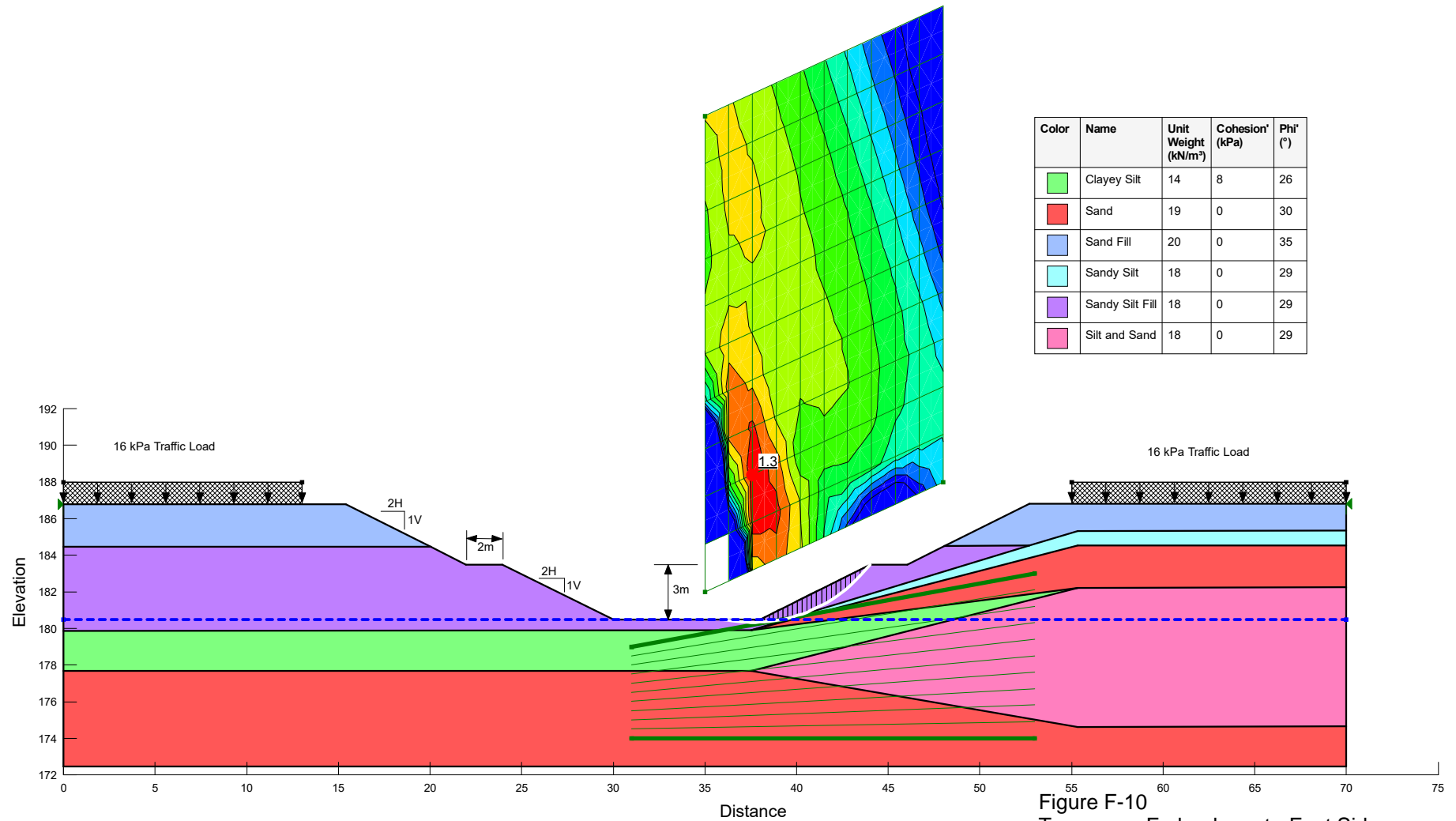


Figure F-10  
 Temporary Embankment - East Side  
 2H:1V Side Slopes with 2 m Bench  
 Drained, Static Condition

## Appendix G – Seismic Hazard Calculation

# 2020 National Building Code of Canada Seismic Hazard Tool

**i** This application provides seismic values for the design of buildings in Canada under Part 4 of the National Building Code of Canada (NBC) 2020 as prescribed in Article 1.1.3.1. of Division B of the NBC 2020.

## Seismic Hazard Values

User requested values	
Code edition	NBC 2020
Site designation $X_s$	$X_E$
Latitude (°)	46.257
Longitude (°)	-83.195

Please select one of the tabs below.

- NBC 2020
- Additional Values
- Plots
- API
- Background Information

The 5%-damped spectral acceleration ( $S_a(T,X)$ , where T is the period, in s, and X is the site designation) and peak ground acceleration ( $PGA(X)$ ) values are given in units of acceleration due to gravity ( $g$ ,  $9.81\text{ m/s}^2$ ). Peak ground velocity ( $PGV(X)$ ) values are given in m/s. Probability is expressed in terms of percent exceedance in 50 years. Further information on the calculation of seismic hazard is provided under the *Background Information* tab.

The 2%-in-50-year seismic hazard values are provided in accordance with Article 4.1.8.4. of the NBC 2020. The 5%- and 10%-in-50-year values are provided for additional performance checks in accordance with Article 4.1.8.23. of the NBC 2020.

See the *Additional Values* tab for additional seismic hazard values, including values for other site designations, periods, and probabilities not defined in the NBC 2020.

NBC 2020 - 2%/50 years (0.000404 per annum) probability							
$S_a(0.2, X_E)$	$S_a(0.5, X_E)$	$S_a(1.0, X_E)$	$S_a(2.0, X_E)$	$S_a(5.0, X_E)$	$S_a(10.0, X_E)$	$PGA(X_E)$	$PGV(X_E)$
0.162	0.191	0.12	0.0579	0.0148	0.00461	0.0906	0.115

The log-log interpolated 2%/50 year  $S_a(4.0, X_E)$  value is : **0.0206**

▼ Tables for 5% and 10% in 50 year values

NBC 2020 - 5%/50 years (0.001 per annum) probability							
$S_a(0.2, X_E)$	$S_a(0.5, X_E)$	$S_a(1.0, X_E)$	$S_a(2.0, X_E)$	$S_a(5.0, X_E)$	$S_a(10.0, X_E)$	$PGA(X_E)$	$PGV(X_E)$
0.0932	0.112	0.0682	0.0315	0.00742	0.00234	0.0506	0.062

The log-log interpolated 5%/50 year  $S_a(4.0, X_E)$  value is : **0.0106**

NBC 2020 - 10%/50 years (0.0021 per annum) probability							
$S_a(0.2, X_E)$	$S_a(0.5, X_E)$	$S_a(1.0, X_E)$	$S_a(2.0, X_E)$	$S_a(5.0, X_E)$	$S_a(10.0, X_E)$	$PGA(X_E)$	$PGV(X_E)$
0.0581	0.0694	0.0409	0.018	0.00388	0.00122	0.0308	0.0358

The log-log interpolated 10%/50 year  $S_a(4.0, X_E)$  value is : **0.0056**

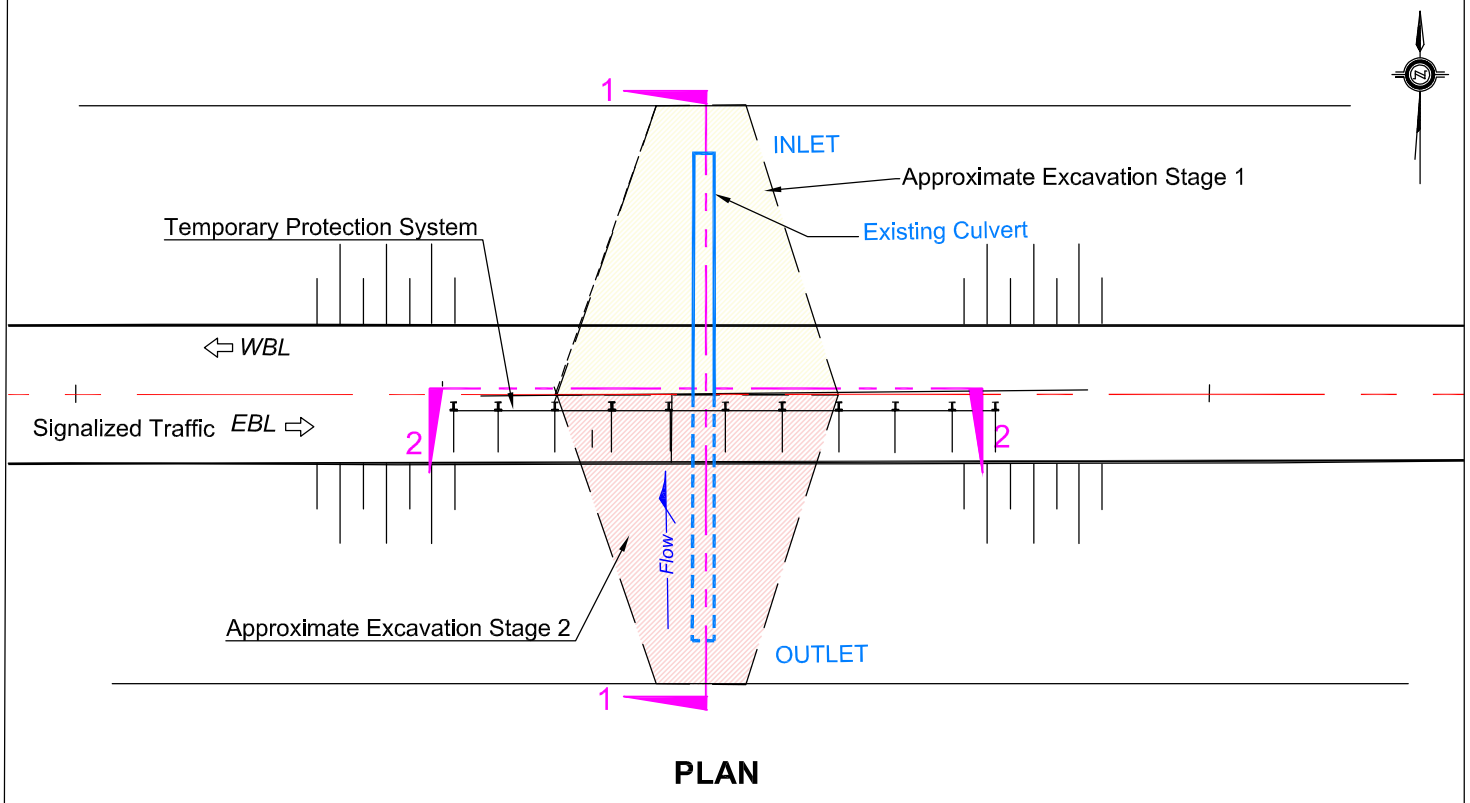
Download CSV

← Go back to the [seismic hazard calculator form](#)

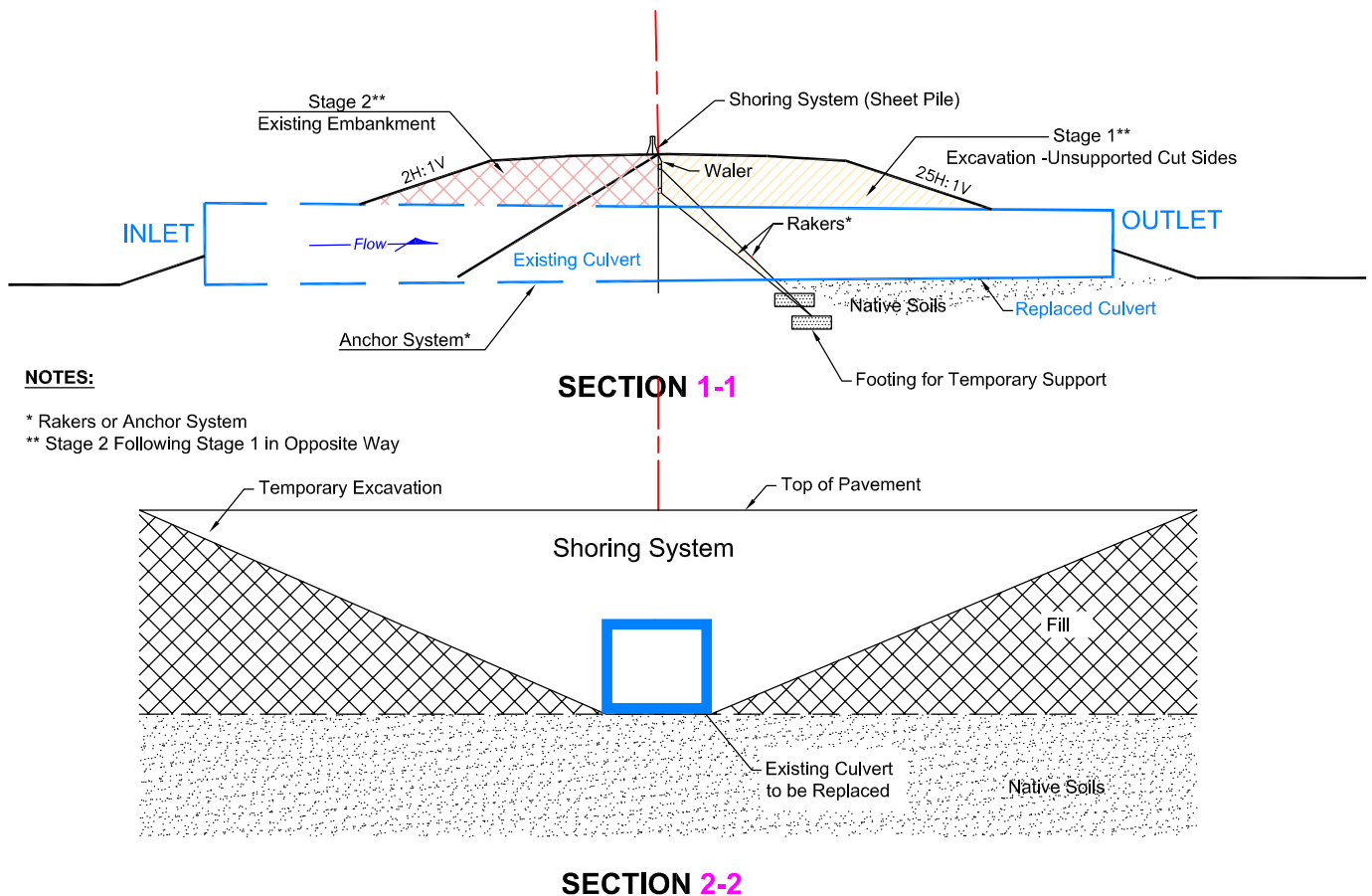
## Appendix H – Schematics

**FIGURE H1A: HALF AND HALF CONSTRUCTION WITH UNSUPPORTED CUT SIDES**

**SCHEMATIC DIAGRAMS (NST)**



**Half and Half Construction, Shoring System with either Cut or Anchor System - Unsupported Cut**



**NOTES:**

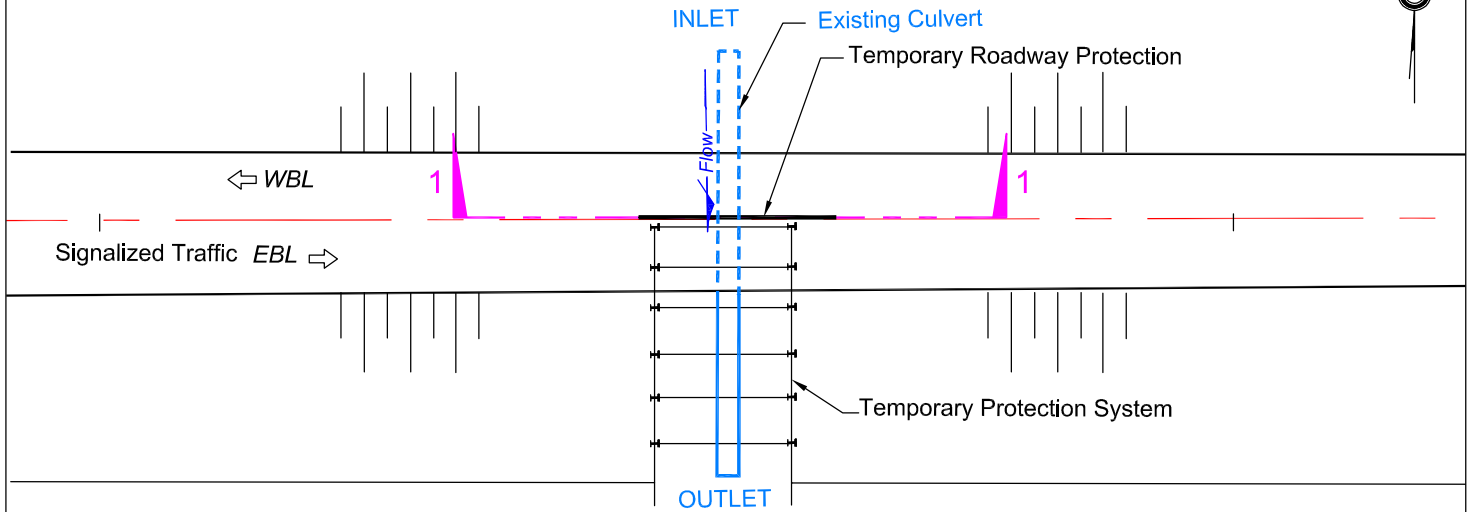
\* Rakers or Anchor System

\*\* Stage 2 Following Stage 1 in Opposite Way

**FIGURE H1B: HALF AND HALF CONSTRUCTION WITH BRACED CUT SIDES OR ANCHOR SYSTEM**  
**SCHEMATIC DIAGRAMS (NST)**

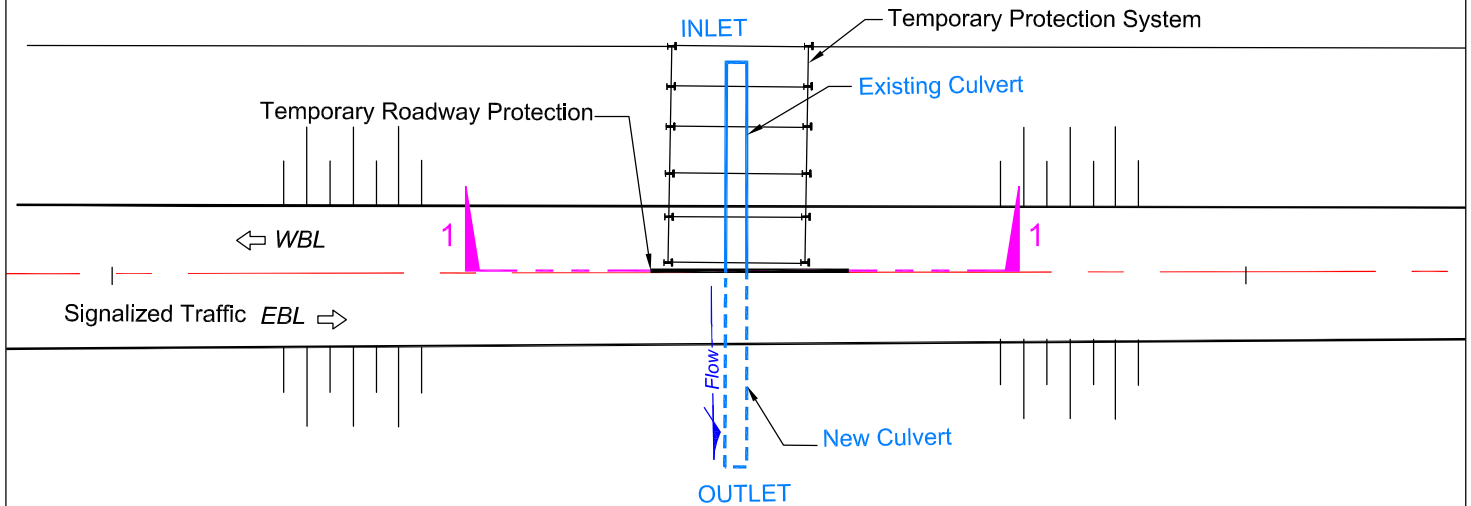


Stage 1



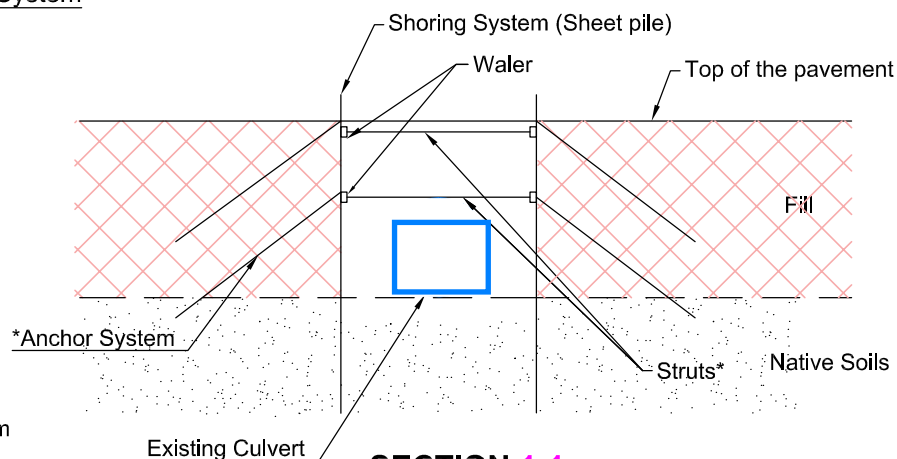
**PLAN**

Stage 2



**PLAN**

Half and half Construction, Shoring System- Braced Cut Struts or Anchor System



NOTE:

\* Struts or Anchor System

**SECTION 1-1**



## Appendix I – NSSP

## NSSP FOR EXCAVATIONS BELOW PROPOSED CULVERT

### Scope of Work

Excavation of very soft to firm clayey silt foundations soils below the proposed culvert foundation and immediate backfill with compacted engineered fill pad.

### Construction

Excavations below the proposed culvert foundation are to be completed in small sections not greater than 3.0 m in length along the culvert alignment. Once a 3.0 m section is excavated to the required depth, it is to be immediately backfilled with the compacted engineered fill pad prior to proceeding to the subsequent section.

