



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17 EMBANKMENT INSTABILITIES AND UNNAMED
CULVERT REPLACEMENT
HIGHWAY 17, DISTRICT OF THUNDER BAY, ONTARIO
TOWNSHIP OF TUURI
AGREEMENT NO. 6019-E-0021, ASSIGNMENT NO. 008
GWP 6137-20-00**

GEOCRES NO.: 42D-65

Report

to

Hatch

Latitude: 48.793406
Longitude: -86.811617

Date: March 18, 2022

File: 31981



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PART 1. FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual data obtained from foundation investigations carried out by Thurber Engineering Ltd. (Thurber) for the assessment of embankment instabilities on Highway 17 and the replacement of an existing unnamed timber culvert at the same location. The site is located on Highway 17, approximately 33 km east of the Town of Terrace Bay, Ontario within the Township of Turri, Thunder Bay District, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the site and based on the data obtained, to provide a borehole location plan, stratigraphic profiles, records of boreholes, laboratory test results, and a written description of the subsurface conditions. A model of the subsurface conditions was developed in the course of the current investigation.

Thurber was retained by Hatch to carry out this foundation investigation under the Ministry of Transportation (MTO) Northwest Region Agreement Number 6019-E-0021, Assignment #8.

2. SITE DESCRIPTION

2.1 Project Site

The existing culvert conveys an unnamed watercourse under Highway 17 with the watercourse flow from north to south and the Highway 17 alignment is generally in a west-east direction at the site. The Terms of Reference prepared by MTO indicates that the existing structure is a 33.8 m long, 1.2 m wide by 1.3 m rise open bottom creosote timber culvert, built in 1950. Based on existing survey data for the site, the pavement elevation of Highway 17 is sloped from approximately elevation 215 to 213.5 m from west to east. The estimated culvert invert is at



approximate Elevation 207.2 m. The existing timber culvert is embedded below approximately 5.1 m of fill.

Highway 17 is three lanes wide at the site, with a westbound passing lane. An approximately 30 to 40 m length of longitudinal cracking and 150 mm of settlement was previously identified by MTO in the outer wheel path of the north (westbound) lane from approximate Sta. 16+925 to 16+965. Large erosion gullies were also identified along the north gravel shoulder and embankment in this area. At the time of Thurber's site investigation, the lane had been patched with asphalt (see Photos in Appendix D). The existing north slope is approximately 5.2 m in height, sloped at 1.5H:1V and mainly consists of unvegetated granular fill in proximity to the culvert. The north slope is also exhibiting signs of erosion / gullyng and settlement. The existing south slope is approximately 5.4 m in height, sloped at 1.5H:1V and is mainly vegetated along the entire slope with no visible signs of distress.

The lands surrounding the culvert site are predominantly heavily forested, with bedrock outcrops observed near the highway to the east and west of the creek valley. Photographs of the culvert, instability area, and surrounding area taken at the time of the field investigation are presented in Appendix D.

2.2 Site Geology

Based on published geological information, the culvert and embankment lie within an area where the quaternary geology mainly consists of exposed bedrock covered by a discontinuous, thin layer of drift. The bedrock in the area is identified as metasedimentary.

3. INVESTIGATION PROCEDURES

It is understood that the existing culvert is proposed to be replaced along with measures to remediate the existing north embankment slope. The field investigation was planned based on the understanding that any culvert replacement would be within the same alignment as the existing structure.

The field investigation was carried out in two phases between June 17 to 19 and August 18 to 19, 2021 and consisted of drilling and sampling six (6) boreholes. Two (2) boreholes, labeled 21-01 and 21-04, were located near the ends of the existing culvert, and four (4) boreholes, labelled 21-02, 21-03, 21-05 and 21-06, were located along Highway 17 in the vicinity of the embankment instabilities, culvert alignment and potential temporary roadway protection system locations. The boreholes were drilled to depths ranging from approximately 5.6 to 11.5 m (Elevation 207.8 to 199.6 m) below the existing grades.



Utility clearances were obtained prior to the start of drilling. The ground surface elevations for the boreholes were estimated with field measurements and the topographic drawings provided to Thurber by Hatch. The coordinate system MTM NAD 83, Zone 14 was used for the boreholes.

A rubber tracked CME 55 drill rig was used to advance the boreholes through the road (21-02, 21-03, 21-05 and 21-06) using solid stem augers and NW casing. The off-road boreholes (21-01 and 21-04) were advanced using a portable Hilti drill and tripod equipment using wash boring techniques. In all boreholes, soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in general accordance with ASTM D 1586. NQ coring methods were used to advance all boreholes 1.0 to 3.4 m into bedrock. The obtained rock cores were logged, and the Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were measured.

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil and rock samples for transport to Thurber's laboratory for further examination and testing.

Standpipe piezometers were installed in Boreholes 21-01 and 21-04 to permit measurement of the groundwater level. The piezometers were decommissioned at the end of the field investigation in general accordance with Ontario Regulation 903 as amended.

Completion details of the boreholes are summarized in Table 3.1.

Table 3.1 Borehole Completion Details

Borehole	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
21-01 (culvert inlet)	8.4 / 199.6	4.9 / 203.1	Borehole caved to 4.9 m. Filter sand from 4.9 to 3.0 m, bentonite to surface.
21-02 (culvert / embankment)	10.7 / 202.6	-	Borehole caved to 1.9 m. Backfilled with bentonite from 1.9 to 0.2 m, gravel to 0.1 m, then asphalt to surface.
21-03 (culvert / embankment)	11.5 / 202.1	-	Borehole caved to 2.4 m. Backfilled with bentonite from 2.4 to 1.1 m, gravel to 0.1 m, then asphalt to surface.
21-04 (culvert outlet)	6.5 / 201.7	3.1 / 205.1	Backfilled with bentonite from 6.5 to 3.3 m, filter sand to 1.2 m, then bentonite to surface.
21-05 (TPS / embankment)	7.1 / 206.8	-	Borehole caved to 3.8 m. Backfilled with sand and gravel from 3.8 m to 1.3 m, bentonite to 0.1 m, then asphalt to surface.
21-06 (TPS / embankment)	5.6 / 207.8	-	Borehole caved to 2.5 m. Backfilled with bentonite from 2.5 to 0.5 m, gravel to 0.1 m, then asphalt to surface.

4. LABORATORY TESTING

All recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (hydrometer and/or sieve) for 25% of the collected samples. Point load tests were conducted on the bedrock cores, and an Unconfined Compressive Strength (UCS) test was conducted on one rock sample from Borehole 21-02. The results of this laboratory testing program are shown on the Record of Borehole sheets included in Appendix B and on the figures included in Appendix C.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the buried elements of the structure, samples of the native soil from the boreholes near the proposed foundation elements were collected, as well as a surface water sample from the watercourse. The samples were submitted to SGS, a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity



parameters and sulphate content. In order to assess the quality of the groundwater for disposal purposes, a water sample was collected from the well installed in Borehole 21-04. The results of the analytical testing are summarized in this report and are presented in Appendix C.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix B and the encountered soil stratigraphy is presented on the Borehole Locations and Soil Strata Drawings included in Appendix A. A general description of the stratigraphy based on the conditions encountered in the boreholes is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and must be used for interpretation of the site conditions. It must be recognized and expected that soil and groundwater conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions encountered at the boreholes consisted of asphalt underlain by gravelly sand to sandy gravel fill, which is further underlain by rock fill and sandy coarse gravel fill with cobbles. Native deposits of silt and silty sand were also encountered at the inlet and outlet of the culvert respectively. The overburden soils are underlain by metasedimentary bedrock. Descriptions of the individual strata are presented below.

5.1 Asphalt

A 150 mm thick layer of asphalt was encountered at the ground surface in Boreholes 21-02, 21-03, 21-05 and 21-06.

5.2 Peat

A fibrous peat deposit with a thickness of 1.1 m was encountered at the ground surface at Borehole 21-04, extending to a base Elevation of 207.1 m. An SPT N-value of 4 blows per 0.4 m penetration was recorded in the peat, indicating a soft consistency. The layer contained trace rootlets and had measured moisture contents of 39 to 232%.

5.3 Sandy Gravel to Gravelly Sand Fill

Sandy gravel to gravelly sand fill was encountered at the ground surface in Borehole 21-01 and below the asphalt in Boreholes 21-02, 21-03, 21-05 and 21-06. The fill also contained trace to some silt, as well as cobbles or rock fill in Boreholes 21-01 and 21-02. The sandy gravel to gravelly sand fill extended to underside depths ranging from 0.9 to 4.1 m (Elev. 212.0 to 207.1 m).

The sandy gravel to gravelly sand fill typically ranged from dense to very dense, with SPT N-values typically ranging from 33 to 72 blows per 0.3 m penetration. One SPT N-value of 146 blows per 0.3 m penetration was measured in Borehole 21-01, indicating a localized zone with higher blows, possibly due to the presence of rock fill pieces. A localized compact to loose layer was also encountered in Borehole 21-02, based on SPT N-values ranging from 13 to 4 blows per 0.3 m penetration. The measured moisture content in the cohesionless fill ranged from 1 to 8%.

The results of grain size analyses conducted on four (4) samples of the sandy gravel to gravelly sand fill are summarized on the Record of Boreholes in Appendix B, illustrated on Figure C1 of Appendix C, and are summarized as follows:

Soil Particle	Percentage (%)
Gravel	29 to 39
Sand	49 to 64
Silt & Clay	7 to 16

5.4 Sandy Coarse Gravel with Cobbles (Possible Rock Fill)

Sandy coarse gravel with cobbles (possible rock fill) was encountered in all boreholes and was noted to contain cobbles up to 200 mm diameter. The sandy coarse gravel with cobbles ranged in thickness from 0.9 to 3.8 m and extended to underside depths ranging from 2.0 to 7.9 m (Elev. 209.5 to 204.6 m). Rock coring methods were required to advance the boreholes through the cobbles and rock fill.

The sandy coarse gravel with cobbles typically ranged from compact to very dense, with SPT N-values typically ranging from 15 to greater than 50 blows per 0.3 m penetration. A very loose to loose layer, based on SPT N-values of 3 to 7 blows, was encountered in Borehole 21-02. The measured moisture content in the cohesionless fill ranged from 2 to 7%.

The results of grain size analysis conducted on one (1) sample of the sandy coarse gravel with cobbles is summarized on the Record of Boreholes in Appendix B, illustrated on Figure C2 of Appendix C, and is summarized as follows:

Soil Particle	Percentage (%)
Gravel	74
Sand	23
Silt & Clay	3

5.5 Silt

A layer of silt was encountered below the fill in Borehole 21-01, which was 2.0 m thick with an underside depth of 5.4 m (Elev. 202.6 m).

The SPT N-values recorded in the silt deposit ranged from 17 to 19 blows per 0.3 m penetration indicating that the deposit was compact. The measured moisture content ranged from 26 to 30%.

The results of a grain size analysis conducted on a sample of the silt deposit is summarized on the Record of Boreholes in Appendix B, illustrated on Figure C3 of Appendix C, and summarized as follows:

Soil Particle	Percentage (%)
Gravel	0
Sand	6
Silt	85
Clay	9

5.6 Silty Sand

A deposit of silty sand was encountered below the fill in Borehole 21-04, which was 1.4 m thick with an underside depth of 3.4 m (Elev. 204.7 m)

The SPT N-values recorded in the silty sand deposit ranged from 33 to 37 blows per 0.3 m penetration, indicating that the deposit was dense. The measured moisture contents were 26%.

The results of a grain size analysis conducted on a sample of the silty sand deposit is summarized on the Record of Boreholes in Appendix B, illustrated on Figure C4 of Appendix C, and summarized as follows:

Soil Particle	Percentage (%)
Gravel	10
Sand	54
Silt	31
Clay	5

5.7 Bedrock

The overburden soils are underlain by metasedimentary bedrock, which was cored in all of the boreholes. The bedrock was grey in colour and is generally described as slightly weathered to fresh. In Borehole 21-01, the upper approximately 1.5 m of the bedrock was moderately weathered. Table 5.1 summarizes the depths and elevations to the top of the bedrock at the borehole locations. It should be noted that the bedrock elevation varied from 209.6 to 202.6 m and indicates that sloping bedrock conditions exist at this site. The bedrock appears to slope towards the alignment of the watercourse.

Table 5.1 Depths and Elevations of Top of Bedrock

Borehole	Top of Bedrock	
	Depth Below Existing Grade Level (m)	Elevation (m)
21-01	5.4	202.6
21-02	7.3	206.1
21-03	7.9	205.7
21-04	3.4	204.7
21-05	4.3	209.6
21-06	4.6	208.8

Total Core Recovery (TCR) in the bedrock ranged from 97 to 100%, and Solid Core Recovery (SCR) ranged between 49 and 100%. The Rock Quality Designation (RQD) determined from the recovered cores ranged between 25 and 100%, typically exceeding 50% which indicates fair to excellent rock quality (CFEM 2006). The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, ranged from 0 to more than 10.

Average unconfined compressive strengths (UCS) of the rock, interpreted from point load tests, ranged between 58 and 197 MPa, indicating the rock is strong to very strong. One Unconfined Compressive Strength (UCS) test conducted on a sample from Borehole 21-02, Run 2 indicated a UCS value of 58 MPa. The point load and UCS test results as well as photographs of the rock cores are presented in Appendix C.

5.8 Groundwater Level

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the monitoring wells installed in Boreholes 21-01 and 21-04. It should be noted that water was introduced into the boreholes during coring activities and may not be representative of stabilized water level. A summary of the water level measurements from the field investigation is provided in Table 5.2 below.

Table 5.2 Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
21-01	August 19, 2021	0.9	207.1	Monitoring well
21-02	June 18, 2021	*	*	Open borehole
21-03	June 17, 2021	Dry	-	Open borehole
21-04	August 19, 2021	0.4	207.8	Monitoring Well
21-05	June 17, 2021	*	*	Open borehole
21-06	June 19, 2021	Dry	-	Open borehole

*No water level recorded due to residual drilling water in borehole

The groundwater level is likely to reflect the local watercourse water level. The surface water level is estimated to be at approximate Elevation 207.3 m, based on the approximate culvert invert level of 207.3 to 207.1 m. Groundwater levels are short-term observations and seasonal fluctuations of the groundwater levels are to be expected. In particular, the groundwater levels may be at a higher elevation during spring and after periods of significant or prolonged precipitation.

6. CORROSIVITY AND SULPHATE TEST RESULTS

Two (2) samples of the native soil, and a sample of the surface water from the watercourse were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1.1. The laboratory certificates of analysis are presented in Appendix C.

Table 6.1 Analytical Testing Results

Parameter	Units (soil)	Units (water)	Test Results		
			21-01 SS2, 3.3 to 4.0 m	21-04 SS4, 2.7 to 3.3 m	Unnamed Watercourse
			Native Silt	Native Silty Sand	Surface Water
Sulphide	%	µg /L	<0.04	0.06	6
Chloride	µg/g	mg/L	140	200	3.4
Sulphate	µg/g	mg/L	16	19	3.8
pH	no unit	no unit	8.56	8.23	8.09
Conductivity	uS/cm	uS/cm	330	492	232
Resistivity (calculated)	ohms.cm	ohms.cm	3030	2030	4310*
Redox Potential	mV	mV	63	130	14

* calculated by Thurber

7. WATER QUALITY

For assessment of the general water quality in the project area, a sample of the groundwater was collected from the monitoring well in Borehole 21-04 on August 19, 2021. The water sample was analyzed for selected inorganic parameters included in the Ontario Provincial Water Quality Objectives (PWQO) as well as Total Suspended Solids (TSS). An additional filtered sample was also tested for dissolved metal parameters for comparison purposes. The analytical test results are presented in Appendix C.

The analytical results of the water testing were compared to limits for the PWQO for surface water discharge. The concentrations of all parameters tested that did not meet the criteria established in the PWQO are listed below in Table 7.1. The TSS concentration was 148,000 mg/L (no assigned PWQO criteria).

Table 7.1 – Water Parameters Exceeding PWQO Criteria

Sample ID	Parameter	Criteria	Parameter Limit (µg/L)	Result (µg/L)
BH21-04	Total Aluminum	PWQO	15	133000
	Total Aluminum (0.2 µm)	PWQO	0.015 (mg/L)	0.081 (mg/L)
	Total Arsenic	PWQO	5	75.4
	Total Boron	PWQO	200	214

Sample ID	Parameter	Criteria	Parameter Limit (µg/L)	Result (µg/L)
	Total Cobalt	PWQO	0.9	2620
	Total Cadmium	PWQO	0.1	3.76
	Total Copper	PWQO	1	1150
	Total Chromium	PWQO	100	647
	Total Iron	PWQO	300	358000
	Total Nickel	PWQO	25	766
	Total Phosphorus	PWQO	0.01 (mg/L)	13.3 (mg/L)
	Total Lead	PWQO	11	243
	Total Silver	PWQO	0.1	13.7
	Total Thallium	PWQO	0.3	3.12
	Total Uranium	PWQO	5	34.6
	Total Vanadium	PWQO	6	344
	Total Zinc	PWQO	20	999
BH21-04 (Filtered Sample)	Dissolved Cobalt	PWQO	0.9	18.9
	Dissolved Copper	PWQO	1	<2*
	Dissolved Phosphorous	PWQO	0.01 (mg/L)	0.037 (mg/L)
	Dissolved Silver	PWQO	0.1	< 0.5*

*Note: The laboratory detection limit is higher than the PWQO criteria for this parameter and therefore this test result may not be indicative of an actual parameter exceeding the criteria.

8. SINGLE WELL RESPONSE TESTS

8.1 Test Procedure

Single well response tests (SWRTs), or “slug” tests, were carried out in the 50 mm diameter wells installed in Boreholes 21-01 and 21-04. The well installed in Borehole 21-01 was screened across silt and rock fill. The well installed in Borehole 21-04 was screened across silty sand and rock fill. The tests were completed using the following method:

- The static water level was measured and recorded, and a datalogger was inserted into the well below the water level. The datalogger was set to record water levels every 5 seconds, based on the anticipated rate of recovery of the wells.
- A slug of groundwater was removed from the well with a dedicated bailer to induce a change in hydraulic head (rising head test).
- Manual and electronic measurements were recorded until the water level in the well recovered sufficiently.



- Manual measurements were compared to electronic measurements for quality control of the data.

8.2 Hydraulic Conductivity

The slug tests were completed and analyzed using the Hvorslev method. The plots of the slug test results are included in Appendix C. The hydraulic conductivity values calculated from the in-situ slug tests are summarized in the following table.

Table 8.1 Single Well Response Test Results

Monitoring Well	Hydraulic Conductivity (m/s)	Screened Formation
21-01	5.4×10^{-6}	silt
21-04	4.8×10^{-6}	silty sand

9. MISCELLANEOUS

Thurber obtained subsurface utility clearances prior to drilling. Borehole locations were selected relative to existing site features. The northing and easting coordinates and ground surface elevations were estimated based on field measurements relative to the topographic plans provided by MTO and Hatch.

RPM Drilling of Thunder Bay, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full-time basis by Mr. Greg Stanhope and Mr. Amir Fereidouni of Thurber. The overall supervision of the field program was conducted by Mr. Joshua Alexander, EIT and Mr. Mark Farrant, P.Eng. of Thurber.

Routine geotechnical laboratory testing was carried out by Thurber's geotechnical laboratory in Oakville, Ontario. Analytical testing was carried out by SGS Canada Inc. in Lakefield, Ontario. Interpretation of the field data and preparation of this report was carried out by Mr. Joshua Alexander, EIT and Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

10. GENERAL

This section of the report provides an interpretation of the factual data from Part 1 of the report and presents foundation recommendations to assist the project team in the design of slope improvements to preserve the existing highway embankment, as well as the potential replacement of the existing unnamed culvert on Highway 17 in the Township of Turri. The discussion and recommendations presented in this report are based on the information provided by Hatch and on the factual data obtained during the course of the field investigation.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation and Hatch and shall not be used or relied upon for any other purposes or by any other parties including the construction or a design-build contractor. The construction or design-build contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

This report refers to the following applicable codes:

- Canadian Highway Bridge Design Code (CHBDC), 2019
- National Building Code of Canada (NBCC), 2015

10.1 Proposed Structure and Slope Improvements

At the time of the preparation of this report, the existing embankment slope on the north side of the highway was sloped at 1.5H:1V and exhibited signs of erosion and settlement in the outer



westbound (north lane of traffic). An approximately 30 to 40 m long section of longitudinal cracking and 150 mm of settlement was previously identified by MTO in the outer wheel path of the north (westbound) lane, from approximately Sta. 16+925 to 16+965. Large erosion gullies were also identified along the north gravel shoulder and embankment in this area. At the time of Thurber's site investigation, the lane settlement had been patched with asphalt (see Photo 3 in Appendix D). The purpose of this investigation is to assess the stability of the existing highway slopes and to provide foundation recommendations for slope improvement in order to avoid further settlement or material loss.

It is also understood that the existing timber culvert on Highway 17 may be replaced during the construction of the slope improvement measures. General Arrangement (GA) drawings for the culvert were not available at the time this report was prepared, but it is assumed that the proposed culvert would be replaced with a similar alignment, length and elevation as the existing structure. The existing open bottom creosote timber culvert is 33.8 m long, 1.2 m wide by 1.3 m rise. The estimated culvert invert is at approximate Elevation 207.3 to 207.1 m. The existing timber culvert is embedded below approximately 5.1 m of fill.

Along with foundation recommendations for slope improvement and culvert replacement, this report also provides recommendations for excavations and groundwater control (including a preliminary dewatering assessment), stream diversion, cofferdams and temporary roadway protection systems.

11. CULVERT DESIGN

11.1 Culvert Alternatives

This section presents discussions on various types of replacement culverts and foundation alternatives and provides recommendations on preferred culvert types and foundation options.

Several common culvert types that may be considered for the culvert replacement at this site are listed below:

- Corrugated steel pipe (CSP) or twin CSPs
- Concrete box (closed) culvert composed of pre-cast segments
- Concrete box, open footing culvert

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix E. From a foundations and constructability perspective, use of the CSP or pre-cast concrete closed box culverts are preferred over the open footing culvert option, based on the following considerations:



- Pre-cast closed box or pipe culverts would require shallower depth of excavation compared with the open footing culvert;
- Pre-cast concrete box or pipe segments can often be installed more expeditiously than cast in place open footing culverts, resulting in shorter durations for dewatering and construction;
- A segmental box or pipe structure can accommodate some potential differential settlement along the culvert axis.

The open footing culvert is not recommended at this site since it would involve deeper excavation in cohesionless soils, potential localized excavation of hard bedrock, and more dewatering effort to provide adequate frost protection.

Recommendations for the design and installation of pipe and concrete box culverts are presented below.

11.2 Summary of Subsurface Conditions

In general, the subsurface conditions encountered at the boreholes consisted of asphalt underlain by gravelly sand to sandy gravel fill, and rock fill with sandy coarse gravel with cobbles. The fill layers are underlain by native deposits of silt and silty sand and an uneven bedrock surface. The bedrock surface varies from approximate Elevation 209.6 to 202.6 m.

The groundwater level in the open boreholes and monitoring wells was typically measured at an approximate Elevation of 207.1 to 207.8 m. The surface water level is estimated to be at approximate Elevation 207.3 m, based on the approximate culvert invert level.

11.3 Foundation Design for Culverts

The invert level of the existing culvert is at approximate Elevation 207.3 to 207.1 m. It is assumed that the replacement culvert would be installed at a similar invert level.

Foundation design aspects for the replacement culvert include subgrade conditions and preparation, geotechnical capacities, settlement of foundation soils, lateral earth pressures, roadway protection system design, groundwater control, staged construction, and restoration of the roadway embankment.



11.3.1 Corrugated Steel Pipe (CSP) or Multiple CSP Culverts

Replacement of the culvert with a single or multiple CSPs along the same alignment may be considered for this site. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the culvert replacement, except where the culvert may be lengthened beyond the existing culvert, such as to accommodate flatter embankment slopes.

If this alternative is selected, the CSPs should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.010. Any peat encountered at and below the culvert subgrade must be removed and replaced by compacted granular fill or rock fill up to the underside of the bedding material, as described in Section 11.3.4. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation should be carried out in the dry. However, as it may not be feasible to fully dewater the cohesionless soils below the existing water table, consideration may be given to conducting the subexcavation of cohesionless fill soils and preparation of the subgrade in the wet, as described in Section 11.3.5. The granular fill or rock fill below the culvert must be placed on the dense to very dense rock fill and sandy coarse gravel with cobbles, compact to dense native silt to silty sand, or bedrock. Adequate preparation of the subgrade will be essential for performance of the culvert. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction. A separation layer consisting of a non-woven geotextile should be placed between the subgrade soils and the bedding material. The geotextile should meet the specifications for the OPSS Class II (OPSS.PROV 1860) and have a fabric opening size (FOS) not greater than 212 µm.

The underside of the bedding layer should be placed at or below Elevation 207 m or lower, on the prepared subgrade. Any other buried topsoil, excessively soft soil, large cobbles and boulders, and any soft, very loose organic or other deleterious material encountered during subgrade preparation should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition. Based on the variable bedrock elevation, observed as high as Elevation 206.1 m near the culvert in Borehole 21-02 and higher beyond the culvert, there is a potential that some bedrock excavation may be encountered during subgrade preparation.

11.3.2 Concrete Box Culvert

Replacement of the culvert with a concrete box culvert on the same alignment is also considered a viable alternative for this site. It is anticipated that the subgrade soils within the culvert footprint



will not be subjected to any significant additional loading due to the culvert replacement, except where the culvert may be lengthened beyond the existing culvert, such as to accommodate flatter embankment slopes.

In order to provide a uniform foundation subgrade, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the box culvert, similar to as shown on OPSD 803.010. Any peat encountered at and below the culvert subgrade, including where the culvert may be lengthened, must be removed and replaced by compacted granular fill or rock fill up to the underside of the bedding material, as described in Section 11.3.4. The bedding material should be placed on the prepared subgrade as soon as practicable following its inspection and approval. The subgrade preparation and placement and compaction of the bedding material should be carried out in the dry. However, as it may not be feasible to fully dewater the cohesionless soils, consideration may be given to conducting the subexcavation and preparation of the subgrade in the wet, as described in Section 11.3.5. The granular fill or rock fill below the culvert must be placed on the dense to very dense rock fill and sandy coarse gravel with cobbles, compact to dense native silt to silty sand, or bedrock. Adequate preparation of the subgrade will be essential for performance of the culvert. A separation layer consisting of a non-woven geotextile should be placed between the subgrade soils and the bedding material. The geotextile should meet the specifications for the OPSS Class II, and have a fabric opening size (FOS) not greater than 212 μm . The subgrade surface prepared to support the box units should have a 75 mm minimum thick top levelling course consisting of uncompacted Granular A as per OPSS 422. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

The underside of the bedding layer should be placed at or below Elevation 206.9 m, on the prepared subgrade. Any other buried topsoil, excessively soft soil, large cobbles and boulders, and any soft, very loose organic or other deleterious material encountered during subgrade preparation should be sub-excavated and replaced with compacted granular material to provide a uniformly competent subgrade condition. Based on the variable bedrock elevation, observed as high as Elevation 206.1 m near the culvert in Borehole 21-02 and higher beyond the culvert, there is a potential that some bedrock excavation may be encountered during subgrade preparation.

The following geotechnical resistances are recommended for the preliminary design of a box culvert with a 4 to 5 m bearing width founded at or below Elevation 206.9 m on the dense to very dense rock fill and sandy coarse gravel with cobbles, compact to dense native silt to silty sand, or bedrock:

Geotechnical Resistance	4 to 5 m wide Culvert
Factored Geotechnical Resistance at ULS	300 kPa
Geotechnical Resistance at SLS (for up to 25 mm settlement)	200 kPa

A consequence factor of 1.0 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per Canadian Highway Bridge Design Code (CHBDC) 2019, Section 6.9.

The factored ultimate resistance and settlement are dependent on the culvert size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the culvert width or founding/invert elevation differs significantly from that given above.

The above geotechnical resistances are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance values used in design must be adjusted in accordance with CHBDC 2019, Clause 6.10.2. Foundation settlement, based on the recommended SLS resistance is expected to be up to 25 mm.

Resistance to sliding between the concrete and the underlying Granular A or B Type II bedding material should be calculated assuming an unfactored coefficient of friction of 0.45.

The culvert should be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

11.3.3 Frost Cover

The depth of frost penetration at this site is approximately 2.3 m based on OPSD 3090.100. The base of any concrete footings if employed should be provided with a minimum of 2.3 m of earth cover as protection against frost action. The frost cover requirement does not apply to the pipe and box culvert options.



11.3.4 Subgrade Preparation

Performance of the replacement culvert will depend on the preparation of the subgrade. After the excavation reaches the design subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any topsoil, peat or loose materials within the replacement culvert footprint must be removed. Care must be exercised not to destabilize the existing highway embankment if excavating near the toe of the embankment.

The sub-excavated area should then be backfilled with granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements and be compacted as per OPSS.PROV 501, provided that the sub-excavation and compaction and placement of the replacement granular fill is carried out in the dry as per OPSS 902 and SP 109S12. If full dewatering is not possible, the sub-excavation should be backfilled with rock fill as described in Section 11.3.5.

Construction equipment should not be allowed to travel on the prepared subgrade, which must be protected from disturbance during construction.

11.3.5 Construction in Wet Conditions

If excavation below the water table is required, it is anticipated that seepage of groundwater through the embankment fill will occur, and it may not be practical to dewater the subgrade. Therefore backfilling in the wet conditions (below water level) may be considered. This approach will still require diversion of the stream flow and surface water so that the excavations can be done within stagnant water. When backfilling is conducted in the wet, select rock fill should be used below the water table after removal of organics or loose material. The recommended gradation of the rock fill is as follows:

Sieve Size	Percent Passing (%)
150 mm	100
106 mm	50 – 100
75 mm	15 – 80
26.5 mm	0 – 15
0.075 mm	0 – 2

Care must be exercised not to destabilize the existing highway embankment while excavating near the toe of the embankment.



Following subexcavation, a separation layer consisting of a non-woven geotextile should be placed between the native soil and rock fill. The geotextile should meet the specifications for OPSS.PROV 1860 Class II, and have a fabric opening size (FOS) not greater than 212 micro millimetres. The rock fill should be completely wrapped with the geotextile to minimize migration of fines into the rock fill.

Rock fill used to backfill sub-excavated areas below the water table may be placed by end dumping. Granular fill must not be used to backfill excavations below the water table. The rock fill placement below the water level should follow OPSS.PROV 209 (Embankments over Swamps and Compressible Soils).

Rock fill placed above the water level should be placed in a controlled manner (not end dumped) including blading, dozing and chinking of the rock to minimize voids and bridging. Rock fill above the water level must be compacted as per OPSS.PROV 206. Where granular fill or bedding material is to be placed over rock fill, the rock fill subgrade must be blinded with spall material and rock fill chinking shall be in accordance with OPSS.PROV 206. All granular fill must be compacted as per OPSS.PROV 501.

Other options would be to use a coarse 53 mm clear stone, fully wrapped in geotextile, for backfilling in the wet below the culvert. Once the clear stone backfill is above the water level, granular bedding for the culvert may be placed in the dry. The granular bedding may consist of OPSS.PROV 1010 Granular A, Granular B Type II or 19 mm clear stone. The bedding should be placed in the dry so that it can be compacted.

Please note that this option will still require dewatering in order to lower the groundwater level to a sufficient depth to allow for placement of the culvert bedding in the dry.

11.3.6 Settlement

The replacement culvert will be constructed approximately on the same alignment and with a similar or larger opening size as the existing culvert with no grade raise on the overlying embankment. As discussed in Section 20, placement of additional fill may be proposed to flatten the existing embankment side slopes. The foundation soils in the fill areas generally consist of compact to dense sand to silty sand below the existing fill. Provided that all surface vegetation, peat, topsoil, disturbed material or otherwise loose/soft soils are stripped from the culvert subgrade areas within the culvert footprint, then the post-construction settlement induced by the additional fill to flatten the embankment side slopes is expected to be less than 25 mm. The post-construction settlement will essentially be complete at the end of construction.



If the final design involves any additional embankment widening or a grade raise, foundation soil settlement due to the additional fill must be assessed to determine the impact of such settlement on the performance of the replacement culvert.

12. EXCAVATION AND GROUNDWATER CONTROL

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill, native silt and silty sand deposits at this site are classified as a Type 3 soil above the water table. Below the water table (i.e., if the groundwater flow is not controlled), the soils would be classified as Type 4 soils. The native peat and other surficial alluvial deposits that are anticipated at the inlet and outlet areas should be classified as Type 4 soils.

Excavation and backfilling for culvert construction should be carried out in accordance with OPSS 902 and SP 109S12.

It is anticipated that excavation for culvert replacement will be carried out below the creek water level, and diversion of the creek flow will be required. Furthermore, groundwater and surface runoff will tend to seep into and accumulate in the excavations. Due to the presence of cohesionless embankment fill, full dewatering to the base of the temporary excavations is likely to be difficult at this site. It is anticipated that watertight sheet pile cofferdam enclosures driven into the underlying very dense rock fill or native soils will not be effective to cut-off groundwater flow, since it may be difficult to drive the sheet piles to sufficient depth within the rock fill. Therefore, it may be necessary to construct the culvert in the wet, as described in Section 11.3.5. Further discussion on dewatering is provided in Section 14. Please note that this option of constructing in the wet will still require some dewatering in order to lower the groundwater level to a sufficient depth to allow for placement of the culvert bedding in the dry.

The design of any dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP FOUN0003 which amends OPSS 902.

In accordance with SP FOUN0003, the dewatering system is to be designed in accordance with OPSS.PROV 517. A preconstruction survey is not required at this site, thus Designer Fill-In ** in SP FOUN0003 should be "N/A". An NSSP in this regard is included in Appendix G.

The groundwater level will fluctuate and the minimum groundwater elevation at the time of the proposed work should be taken as the creek water level of the design storm return period defined by the contract documents for the temporary dewatering system.

13. STREAM DIVERSION PIPE

A temporary stream diversion pipe may be required to accommodate creek water flow during culvert replacement. It is anticipated that the invert level of the diversion pipe will be similar to the invert level of the existing culvert at approximate Elevation of 207 m, which corresponds to rock fill and sandy coarse gravel with cobbles, native silt to silty sand, or bedrock.

Due to the variability of the bedrock elevation at the site, excavation of bedrock may be necessary depending on the final design grades of the diversion pipe. Consideration should be given to raising the invert level of the diversion pipe to avoid rock excavation.

The temporary diversion pipe should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation should be carried out in the dry unless measures are taken to work in the wet as described in Section 11.3.5. The prepared subgrade should be protected from disturbance during construction.

The stream diversion pipe could be installed within the temporary open cut excavations, or within a shored excavation using a trench box.

14. DEWATERING ASSESSMENT

Groundwater taking for construction dewatering is governed by the Ontario Water Resources Act (OWRA), Environmental Protection Act (EPA) and the Water Taking and Transfer Regulation 387/04, a regulation under the OWRA.

If the water taking rate will be greater than 50,000 L/day and less than 400,000 L/day then registration on the Environmental Activity and Sector Registry (EASR) will be required. If the water taking rate will be greater than 400,000 L/day, then a Category 3 Permit To Take Water (PTTW) will be required. On July 1, 2021, changes to EASR registrations came into effect, and storm water values no longer contribute to EASR maximum water taking rates. They are still, however, applicable to maximum water taking rates for PTTWs. A preliminary assessment of the need for water taking permitting is provided herein; however, additional analysis will be required to confirm this.

Based on the plan and profile drawings of the pre-existing culvert, the dimensions and conditions that were assumed for the preliminary dewatering assessment are provided in Table 14.1 below. For full dewatering to 1 m below the base of the temporary excavation, the geologic units that would need to be dewatered are rock fill, sandy coarse gravel fill, peat, and silt to silty sand.

Table 14.1: Assumed Excavation Dimensions and Ground Conditions

Structure	Assumed Excavation Footprint (m)	Lowest Assumed Elevation of Excavation (m)	Assumed Groundwater Elevation (m)	Geologic Units to Dewater
One Half of Highway 17 Culvert	20 long x 10 wide	206.8	207.8	rock and granular fill, peat, and silt to silty sand

The water taking will be temporary in nature for the purpose of construction dewatering for installation of the infrastructure. Dewatering rates were estimated using the Dupuit analytical solution. The radius of influence was calculated using the Sichardt equation. It is assumed the water level will be required to be lowered to about 1 m below the proposed excavation, or to elevation 205.8 m, in order to facilitate a dry, stable work area.

Provided no methods are used to cut off groundwater present in the fill, and assuming that the fill is hydraulically connected to the excavation on all sides and that dewatering of the highly permeable rock fill is required, the preliminary peak water taking rate was estimated to be significantly greater than 400,000 litres per day including a safety factor and rainfall allowance. The preliminary radius of influence was estimated to be approximately 330 m from the edge of the excavation.

Considering the estimated peak water taking rate is greater than 400,000 L/day, a Category 3 Permit to Take Water will be required. A Hydrogeological Study would be required to provide the necessary data and analysis for application to the Ministry of the Environment, Conservation and Parks (MECP). The Hydrogeological Study will need to include an impact assessment as well as mitigation measures, a monitoring plan, and a contingency plan. An assessment of the potential need for additional field work will need to be assessed. The duration required to receive the permit from MECP once it has been received in good order is typically 3 to 5 months, assuming no further field work or significant revisions are required.

Based on the above factors, it is recommended that consideration be given to constructing the replacement culvert in the wet, as described in Section 11.3.5.

15. WATER QUALITY

For assessment of the general groundwater quality in the project area for potential discharge purposes, a sample of the groundwater from the monitoring well at Borehole 21-04 was collected. As noted in Section 7, the water sample was tested and the results were compared to the Provincial Water Quality Objectives (PWQO) criteria. A filtered sample was also tested for

dissolved metal parameters for comparison purposes. The water sample test results are summarized in Table 7.1.

The test results indicate that seventeen (17) of the metals parameters tested exceeded the PWQO criteria for total concentrations. However, testing of a filtered sample to remove the high Total Suspended Solids, indicated considerably reduced metals concentrations, with only two (2) parameters exceeding the PWQO criteria. If dewatering is used at this site, it is likely that treatment of the discharge water through the use of filtering, settling tanks or other methods may be required to reduce the amount of suspended solids and the metals concentrations prior to discharge into local surface water bodies such as creeks. It is recommended that additional water samples be collected and tested during construction to confirm the groundwater quality and monitor the quality of discharge water, if necessary to meet PTTW requirements.

16. CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.010 or 803.010, as appropriate. Backfilling for the culvert should be in accordance with OPSS PROV 401 for a CSP and OPSS 902 for a box culvert. All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS PROV 501.

Lateral earth pressures acting on the culvert walls may be assumed to be a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2019, but are generally given by the expression:

$$p_h = K (\gamma h + q)$$

where	p_h	=	horizontal pressure on the wall at depth h (kPa)
	K	=	earth pressure coefficient (see table below)
	γ	=	bulk unit weight of retained soil (see table below)
	h	=	depth below top of fill where pressure is computed (m)
	q	=	value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert walls are dependent on the material used as backfill. Recommended unfactored values are shown in Table 16.1 below.

Table 16.1 – Lateral Earth Pressure Coefficients (K)

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ$; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) or Type III $\phi = 32^\circ$; $\gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At-rest (Restrained Wall)	0.43	0.62	0.47	0.70
Passive	3.7	-	3.2	-

Note: Submerged unit weight should be used below the groundwater level/high surface water level.

For rigid structures such as concrete box culverts, at-rest horizontal earth pressures should be used for design. Active earth pressures should be used for any unrestrained wall.

The use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) is preferred as it results in lower earth pressures acting on the culvert.

In accordance with Clause 6.12.3 of the CHBDC 2019, a compaction surcharge should be added.

17. SEISMIC CONSIDERATIONS

In accordance with the CHBDC 2019, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. Based on the presence of compact to very dense granular fill, rock fill and silt to silty sand, underlain by relatively shallow bedrock, the site is classified as Seismic Site Class C in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50-year probability of exceedance at this site is 0.033 g as per the National Building Code of Canada (NBCC).

In accordance with Section 6.14.7 of the CHBDC 2019, the culvert walls should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 17.1 may be used:



Table 17.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I (modified) or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
Active (K_{AE}) ¹	0.28	0.32
Passive (K_{PE}) ²	3.6	3.2
At Rest (K_{OE}) ³	0.47	0.51

Note 1: Mononobe and Okabe, 1929, World Engineering Congress 9: 179-187

Note 2: Passive case assumes a horizontal surface in front of the wall.

Note 3: Wood, J. H. 1973, earthquake induced soil pressures on structures, PhD Thesis, California Institute of Technology, Pasadena, CA.

In view of the low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

18. COFFERDAMS

Construction of cofferdams will be required for stream diversion and constructing the culvert replacement in the dry. Options for cofferdams include interlocking sheet piles or sandbags. However due to the presence of rock fill and shallow and sloping bedrock, it will be difficult to drive sheet piles, which therefore may not achieve sufficient embedment at all locations along the culvert. Therefore, the use of sandbag cofferdam enclosures and pumping from within these enclosures is anticipated.

19. TEMPORARY PROTECTION SYSTEM

A temporary roadway protection system, if utilized, should be implemented in accordance with OPSS PROV 539 and designed for Performance Level 2.

Options for roadway protection are a soldier pile and lagging system or interlocking sheet piles. However due to the presence of shallow and sloping bedrock and possible obstructions in the fill, including rock fill, it will be difficult to drive interlocking sheet piles at this site. Suggested wording for an NSSP on Obstructions is provided in Appendix G. For the soldier pile and lagging system, if sufficient embedment cannot be achieved by driving, the soldier piles may need to be drilled in and socketed into bedrock. Tiebacks may be required in light of the shallow bedrock.

The soil parameters in Table 19.1 may apply for the design of the temporary roadway protection system with horizontal backfill.

Table 19.1 – Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Gravelly Sand to Sandy Gravel Fill	Existing Rockfill and Sandy Coarse Gravel with Cobbles	Native Silt	Native Silty Sand
Φ (angle of internal friction)	32°	42°	29°	30°
γ (total unit weight)	21 kN/m ³	19 kN/m ³	19 kN/m ³	20 kN/m ³
γ_w (submerged unit weight)	11 kN/m ³	9 kN/m ³	9 kN/m ³	10 kN/m ³
K_a	0.31	0.20	0.35	0.33
K_p	3.3	5.04	2.9	3.0

Full hydrostatic pressure should be considered assuming a water level at least equal to the design watercourse level.

The temporary protection system may be removed or partially removed upon completion of the work. Care must be taken when removing the soldier piles as to not incur damage to the subgrade of the newly installed culvert. If the soldier piles are drilled into bedrock, it will not be possible to remove them, and the piles should be left in place with the top portion removed as per the guidelines in OPSS PROV 539.

The design of the temporary protection system is the responsibility of the Contractor. The actual pressure distribution acting on the protection/shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors have to be considered when designing the shoring system. All protection systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

20. SLOPE STABILITY AND IMPROVEMENTS

This section addresses the stability assessment of the existing highway slopes and provides foundation recommendations for slope improvements to maintain stable slopes. This includes assessment of new slopes that would be constructed if the culvert is replaced concurrently with the slope repair work.



The existing Highway 17 embankment side slopes above the culvert are inclined at approximately 1.5H:1V. In the area of instability on the north slope, the embankment surface is mainly unvegetated granular fill in proximity to the culvert. The north slope also exhibits signs of erosion and settlement, with settlement having occurred in the westbound (north) lane of traffic. The existing south slope is mainly vegetated along the entire slope with no visible signs of distress.

Slope stability analyses were conducted to assess the existing north Highway 17 embankment slopes, based on Sta. 16+940. Figure 1 in Appendix F shows that the existing 1.5H:1V north slope conditions provided a Factor of Safety against slope failure of 1.2, which is below the accepted value of 1.5. This indicates that the slope is too steep, which has likely contributed to the erosion and settlement issues that have occurred at the site.

Several improvement options were assessed to improve and maintain stability of the embankment, based on whether the existing culvert will be replaced concurrently or not. These options include:

- Flatten existing north slope to 2H:1V with granular fill (no culvert replacement)
- 3 m thick rock fill north slope treatment to maintain existing 1.5H:1V slope or flatten to 1.75H:1V slope (no culvert replacement)
- Replace culvert and rebuild embankment with granular fill at 2H:1V slopes for full length of instability section
- Replace culvert and rebuild embankment with rock fill at 1.25H:1V slopes for full length of instability section

Please note that slope flattening / granular fill options will require benching of the existing earth slopes as per OPSD 208.010, and may also require lengthening or replacement of the existing culvert with a longer culvert. Alternatively, headwalls may be considered if lengthening of the existing culvert cannot be accommodated. The granular or rock fill slope treatments should be placed from the bottom of the embankment up, and not by end-dumping. All options will require removal of any existing peat, topsoil or other loose / soft soils for a distance of 1.5 m beyond the toe of the final embankment and replacement with well-compacted granular fill, rock fill or clear stone.

For the culvert replacement options, the existing embankment fill must be replaced with the new granular or rock fill culvert backfill for at least the entire length of the approximately 30 to 40 m long instability section previously identified.

The results of the stability analyses for these options are summarized in Table 20.1 below and shown on Figures 2 to 5 in Appendix F. The analyses show that each of these options is acceptable, with a Factor of Safety against slope failure of 1.5, except for the rock fill slope treatment (Figure 3), which has a Factor of Safety of 1.4. Figure 3a indicates that this option is acceptable if the rock fill slope is constructed at 1.75H:1V instead of 1.5H:1V.

Table 20.1 – Summary of Slope Improvement Options

Case	Slope	Factor of Safety	Figure
Existing Condition	1.5H:1V	1.2	1
Slope Flattening with Granular Fill (No culvert replacement)	2H:1V	1.5	2
3.0 m thick Rock Fill Slope Treatment (No culvert replacement)	1.5H:1V	1.4	3
3.0 m to 4.25 m thick Rock Fill Slope Treatment (No culvert replacement)	1.75H:1V	1.6	3a
Replace Culvert and Backfilling with New Granular Fill	2H:1V	1.5	4
Replace Culvert and Backfilling with New Rock Fill	1.25H:1V	1.5	5

21. EMBANKMENT RESTORATION

Any modifications to the embankment for slope improvement measures or restoration of the embankment after completion of the culvert replacement should be carried out in accordance with OPSS PROV 206. The embankment reconstruction material should consist of imported Granular A, Granular B Type II, Granular B Type III or Rock Fill material. The restored embankment beyond the culvert replacement should be reinstated at the existing slope inclination, but no steeper than 2H:1V. Soils generated from the culvert excavation should not be used for reinstatement of the embankment.

In general, surface vegetation, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlets and outlets, and within the embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel should be conducted.

22. SCOUR AND EROSION PROTECTION

Erosion protection should be provided at the culvert inlet and outlet. Design of the erosion protection measures should consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field in accordance with OPSD 810.010, OPSS 511 and OPSS PROV 1004.

Typically, rock protection should be provided over all surfaces with which surface water is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS PROV 804.

Surficial erosion gullies in the embankment material were observed within the area of instability during the field investigation. The eroded portion will likely be removed during excavation of the existing embankment to replace the culvert or improve the slope; however it is recommended that additional erosion protection should be added to the embankment slopes to prevent future loss of material. To channelize surface water flow to the erosion protection measures, an asphalt barrier curb in general accordance with OPSD 601.010 with a rock-lined ditch or other measures may be considered.

A concrete cut-off wall and a clay seal (only at the inlet) should be used to minimize the potential for erosion or piping around the culvert. The clay seal should extend to approximately 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS PROV 1205. A geosynthetic clay liner may be used in place of a compacted clay seal.

Liaison between the Foundations Consultant, Structural Engineer and Hydraulic / Drainage Engineer will be required in design to ensure that scour protection is adequately addressed.

23. CORROSION AND SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate content analytical tests conducted on the soil and surface water samples indicate the following conditions at the locations tested:

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding soil and surface water is considered to be negligible due to the low concentration of sulphate and chloride in the samples tested. The effect of road deicing salt should be considering while selecting the class of concrete.
- The potential for soil corrosion on metal is considered to be mild to moderate.



- Appropriate protection measures are recommended for metal or concrete structural elements. The effect of road deicing salt should be considered while selecting the corrosion protection measures.

24. CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to:

- Temporary roadway protection / shoring for culvert excavation with approximately 5 m high embankment fill will be difficult.
- Full dewatering to below the base of the culvert excavation may not be practical at this site and would also require a Category 3 PTTW. Accordingly, appropriate methods for constructing in the wet should be developed.
- The water level in the watercourse may fluctuate and be at a higher elevation at the time of construction than indicated in the report.
- Due to the presence of shallow and sloping bedrock and the existing rock fill in the embankment, it is like not possible to drive sheet piles at this site.
- There is a potential that rock excavation may be required if the culvert is installed at a lower invert level or different alignment than the existing culvert.

25. CLOSURE

Engineering analysis and preparation of the design report was carried out by Mr. Joshua Alexander, E.I.T. and Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



THURBER ENGINEERING LTD.

Josh Alexander

Joshua Alexander, E.I.T.
Geotechnical Engineering Intern



Mark Farrant, P.Eng.
Associate, Senior Geotechnical Engineer

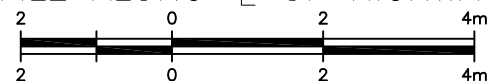
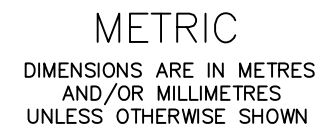


Dr. P.K. Chatterji, P.Eng.
Designated MTO Principal Contact



Appendix A

Borehole Locations and Soil Strata Drawing



H 1:100

V 1:100








HATCH



KEYPLAN

LEGEND

	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

[illegible]

-NOTES-

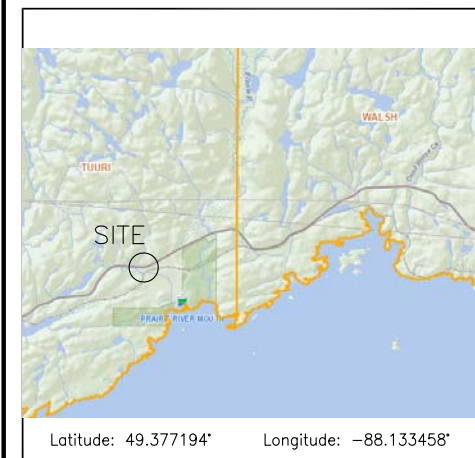
- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 14.

GEOCRES No. 42D-65

REVISIONS									
	DATE	BY	DESCRIPTION						
DESIGN	JA	CHK MEF			LOAD		DATE	MAR 2022	
DRAWN	AN	CHK JA	SITE		STRUCT		DWG 1		






SHEET

HATCH



KEYPLAN

LEGEND

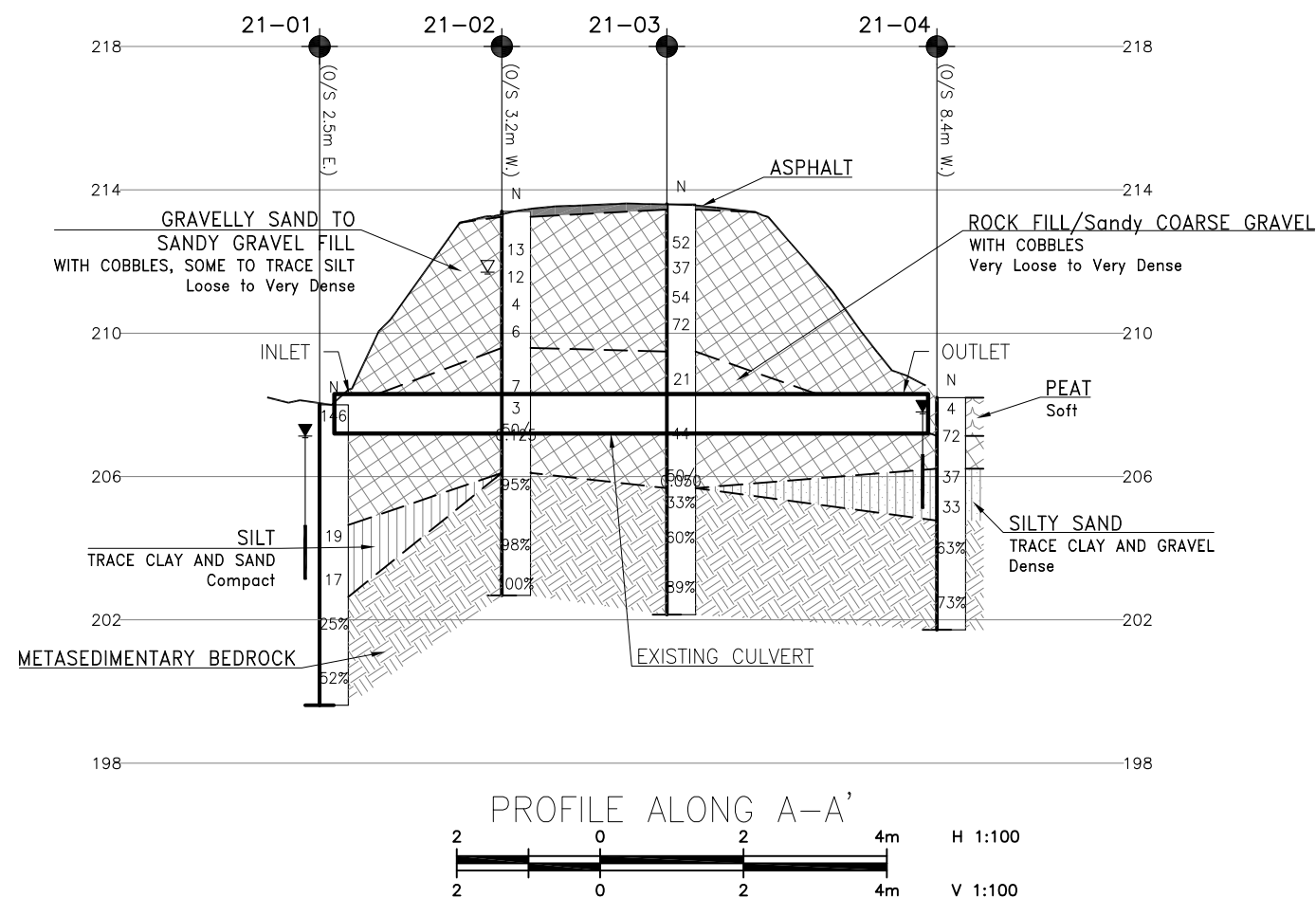
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
21-01	208.0	5 406 142.9	318 652.1
21-02	213.4	5 406 133.1	318 646.1
21-03	213.6	5 406 123.7	318 649.9
21-04	208.2	5 406 109.1	318 639.9
21-05	213.9	5 406 125.9	318 631.1
21-06	213.4	5 406 127.4	318 664.4

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 14.

GEOCRES No. 42D-65



REVISIONS									
	DATE	BY					DESCRIPTION		
DESIGN	JA	CHK	MEF	CODE			LOAD	DATE	MAR 2024
DRAWN	AN	CHK	JA	SITE			STRUCT	DWG	2



Appendix B

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer


4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$


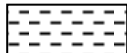



 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
Fresh (FR)	No visible signs of weathering.		
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				
<u>TERMS</u>		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.				
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 21-02

1 OF 2

METRIC

GWP# 6137-20-00 LOCATION MTM NAD83-14; N 5 406 133.1 E 318 646.3 ORIGINATED BY GS
DIST Thunder Bay HWY 17 BOREHOLE TYPE Solid Stem Auger/Wash Boring/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2021.06.18 - 2021.06.18 LATITUDE 48.793440 LONGITUDE -86.811530 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	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						w _P w w _L				
213.4	GROUND SURFACE						20	40	60	80	100	20	40	60	GR	SA	SI	CL
0.0	ASPHALT: (150mm)																	
0.2	Gravelly SAND to Sandy GRAVEL , trace silt, trace cobbles Brown Moist (FILL) Compact to Loose		1	GS								○						
			2	SS	13							○						
			3	SS	12							○						
			4	SS	4													
			5	SS	6													
209.5																		
3.8	Sandy COARSE GRAVEL with COBBLES (POSSIBLE ROCK FILL) up to 100mm diameter Very Loose to Very Dense Brown Wet (FILL) Cored through 175mm diameter cobble			RUN														
				RUN														
			6	SS	7													
			7	SS	3							○						
			8	SS	50/ 0.125							○						
206.1				RUN														
7.3	BEDROCK slightly weathered to fresh, strong, grey: (METASEDIMENTARY)		1	RUN														
			2	RUN														

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No 21-02

2 OF 2

METRIC

GWP# 6137-20-00 LOCATION MTM NAD83-14; N 5 406 133.1 E 318 646.3 ORIGINATED BY GS
DIST Thunder Bay HWY 17 BOREHOLE TYPE Solid Stem Auger/Wash Boring/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2021.06.18 - 2021.06.18 LATITUDE 48.793440 LONGITUDE -86.811530 CHECKED BY MEF

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 γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	Continued From Previous Page		3	RUN		203											
202.6 10.7	END OF BOREHOLE AT 10.7m. BOREHOLE CAVED TO 1.9m AND NO WATER LEVEL RECORDED DUE TO RESIDUAL DRILLING WATER IN BOREHOLE. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.2m, GRAVEL TO 0.1m, THEN ASPHALT COLD PATCH TO SURFACE.																

METRIC

SOIL PROFILE					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT
			NUMBER	TYPE	"N" VALUES
213.6	GROUND SURFACE				
0.0	ASPHALT: (150mm)				
0.2	Gravelly SAND to Sandy GRAVEL trace to some silt Dense to Very Dense Brown Moist (FILL)		1	GS	
			2	SS	52
			3	SS	37
			4	SS	54
			5	SS	72
209.5	Sandy COARSE GRAVEL with COBBLES trace silt, (POSSIBLE ROCK FILL) up to 100mm diameter Compact to Dense Brown to Grey Wet (FILL)		6	SS	21
4.1			7	SS	44
			8	SS	50 / 0.050
205.7	BEDROCK slightly weathered to fresh, very strong to strong, greenish grey: (METASEDIMENTARY) Vertical fracture from 8.2m to 8.2m Sub-vertical fracture from 8.6m to 8.7m Sub-vertical fractures from 9.5m to 9.6m and 10.5m to 10.6m		1	RUN	
7.9			2	RUN	

+³, ×³: Numbers refer to Sensitivity

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RECORD OF BOREHOLE No 21-03

2 OF 2

METRIC

GWP# 6137-20-00 LOCATION MTM NAD83-14; N 5 406 123.7 E 318 649.2 ORIGINATED BY GS
DIST Thunder Bay HWY 17 BOREHOLE TYPE Solid Stem Auger/Wash Boring/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2021.06.17 - 2021.06.17 LATITUDE 48.793356 LONGITUDE -86.811490 CHECKED BY MEF

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 γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	Continued From Previous Page Vertical fracture from 9.9m to 10.1m		3	RUN												2 1 0 0 0	RUN #3 TCR=100% SCR=100% RQD=89% UCS=110MPa (average UCS from PLT's)
202.1 11.5	END OF BOREHOLE AT 11.5m. BOREHOLE CAVED TO 2.4m AND DRY. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.1m, GRAVEL TO 0.1m, THEN ASPHALT COLD PATCH TO SURFACE.																

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RECORD OF BOREHOLE No 21-04

1 OF 1

METRIC

GWP# 6137-20-00 LOCATION MTM NAD83-14; N 5 406 109.1 E 318 639.9 ORIGINATED BY AF
DIST Thunder Bay HWY 17 BOREHOLE TYPE Tripod/Wash Boring/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2021.08.18 - 2021.08.18 LATITUDE 48.793225 LONGITUDE -86.811617 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								○ UNCONFINED + FIELD VANE							
								● QUICK TRIAXIAL × LAB VANE							
						20	40	60	80	100	PLASTIC LIMIT w _P	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	WATER CONTENT (%)	
208.2	GROUND SURFACE														
0.0	PEAT (Fibrous) Very Soft to Very Stiff Dark Brown Wet		1	SS	4										232
	Trace rootlets														
207.1			2	SS	72										
1.1	Sandy COARSE GRAVEL with COBBLES (POSSIBLE ROCK FILL) up to 150 to 200mm diameter														
206.2															
2.0	Silty SAND , trace clay, trace gravel Dense Grey Wet		3	SS	37										
			4	SS	33										
204.7															
3.4	BEDROCK slightly weathered to fresh, very strong, grey: (METASEDIMENTARY) Subvertical fracture (100mm) at 3.5m and (75mm) at 3.7m		1	RUN											
	Highly fractured zone (75mm) at 4.9m														
	Sub horizontal fracture (75mm) at 5.4m														
	Highly broken zone (300mm) at 5.7m		2	RUN											
201.7															
6.5	END OF BOREHOLE AT 6.5m. Monitoring Well installation consists of 50mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.														
	WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2021.08.19 0.4 207.8														

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RECORD OF BOREHOLE No 21-05

1 OF 1

METRIC

GWP# 6137-20-00 LOCATION MTM NAD83-14; N 5 406 125.9 E 318 631.4 ORIGINATED BY GS
DIST Thunder Bay HWY 17 BOREHOLE TYPE Solid Stem Auger/Wash Boring/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2021.06.17 - 2021.06.17 LATITUDE 48.793376 LONGITUDE -86.811733 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa												
213.9	GROUND SURFACE							20	40	60	80	100								
0.0	ASPHALT: (150mm)							20	40	60	80	100								
0.2	Gravelly SAND to Sandy GRAVEL some to trace silt Dense Brown Moist (FILL)		1	GS			213													
			2	SS	36															
			3	SS	33		212													
211.7																				
2.2	Sandy COARSE GRAVEL with COBBLES (POSSIBLE ROCK FILL) Up to 100mm diameter Very Dense Brown Wet (FILL) Borehole 21-05 was continued 2m to the west due to refusal		4	SS	50/ 0.100		211													
			5	SS	50/ 0.125															
							210													
209.6			6	SS	50/0.025															
4.3	BEDROCK slightly weathered to fresh, strong, grey: (METASEDIMENTARY) Sub-vertical fractures at 4.5m and 4.9m to 5.1m		1	RUN			209													
							208													
			2	RUN																
206.8							207													
7.1	END OF BOREHOLE AT 7.1m. BOREHOLE CAVED TO 3.8m AND NO WATER LEVEL RECORDED DUE TO RESIDUAL DRILLING WATER IN BOREHOLE. BOREHOLE BACKFILLED WITH SAND AND GRAVEL TO 1.3m, BENTONITE HOLEPLUG TO 0.1m, THEN ASPHALT COLD PATCH TO SURFACE.																			

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 21-06

1 OF 1

METRIC

GWP# 6137-20-00 LOCATION MTM NAD83-14; N 5 406 127.4 E 318 664.1 ORIGINATED BY GS
DIST Thunder Bay HWY 17 BOREHOLE TYPE Solid Stem Auger/Wash Boring/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2021.06.19 - 2021.06.19 LATITUDE 48.793389 LONGITUDE -86.811287 CHECKED BY MEF

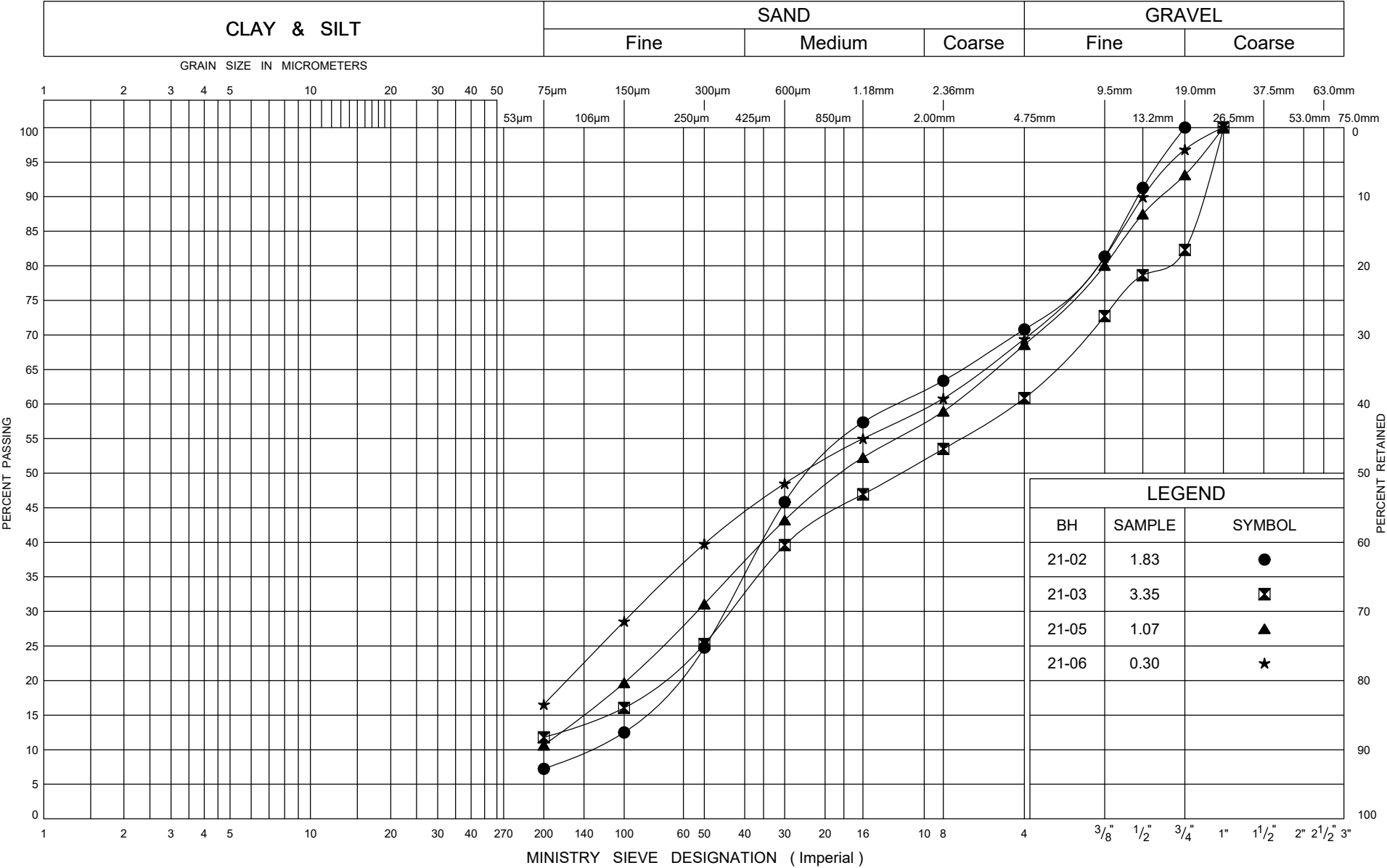
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					W _P	W		W _L			
213.4	GROUND SURFACE						20	40	60	80	100								
0.0	ASPHALT: (150mm)						20	40	60	80	100								
0.2	Gravelly SAND , some silt Very Dense Brown Moist (FILL)		1	GS								○					31	53 16 (SI+CL)	
			2	SS	57							○							
212.0																			
1.4	Sandy COARSE GRAVEL with COBBLES (POSSIBLE ROCK FILL) Up to 100mm diameter Very Dense to Compact Brown Wet (FILL)		3	SS	50/ 0.125														
			4	SS	31														
			5	SS	15														
			6	SS	33														
208.8			7	SS	60/ 0.075														
4.6	BEDROCK slightly weathered to fresh, grey (METASEDIMENTARY)		1	RUN														RUN #1 TCR=100% SCR=100% RQD=83%	
207.8																			
5.6	END OF BOREHOLE AT 5.6m. BOREHOLE CAVED TO 2.5m AND DRY. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.5m, GRAVEL TO 0.1m, THEN ASPHALT COLD PATCH TO SURFACE.																		

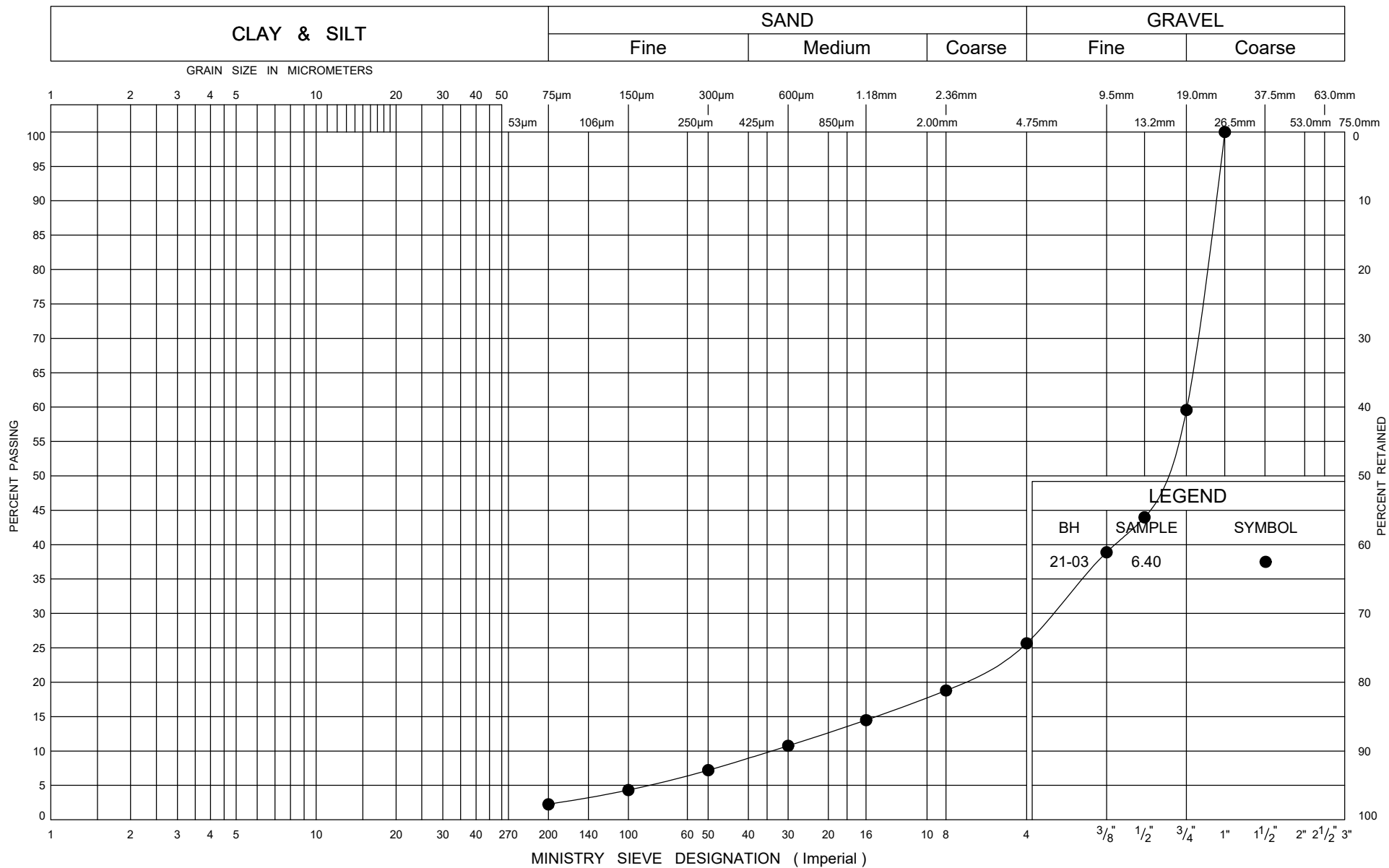
ONTMT4S2 2020LIBRARY(MTO) - COPY.GLB MTO-31981.GPJ 1/21/22

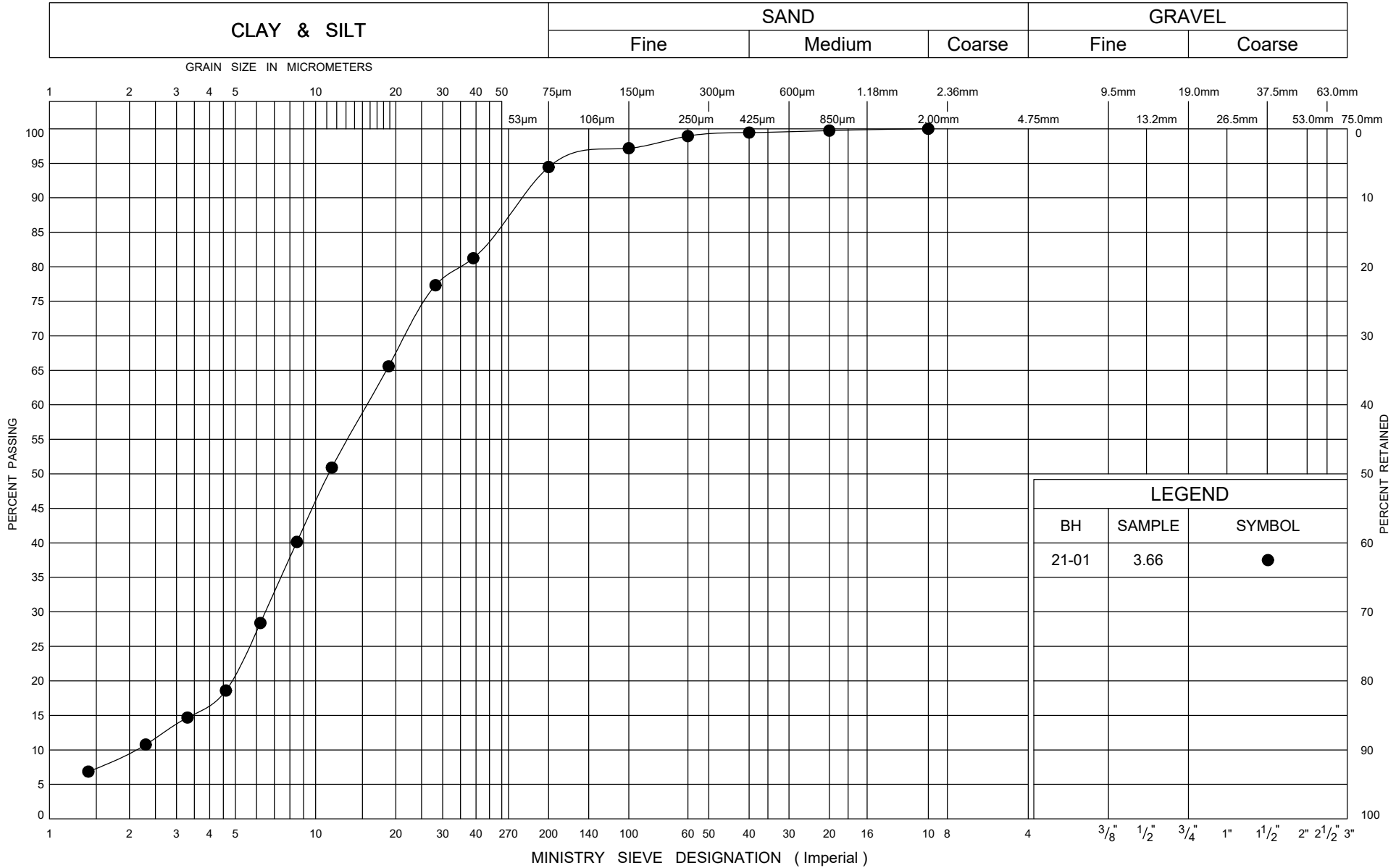


Appendix C

Laboratory and Slug Test Results





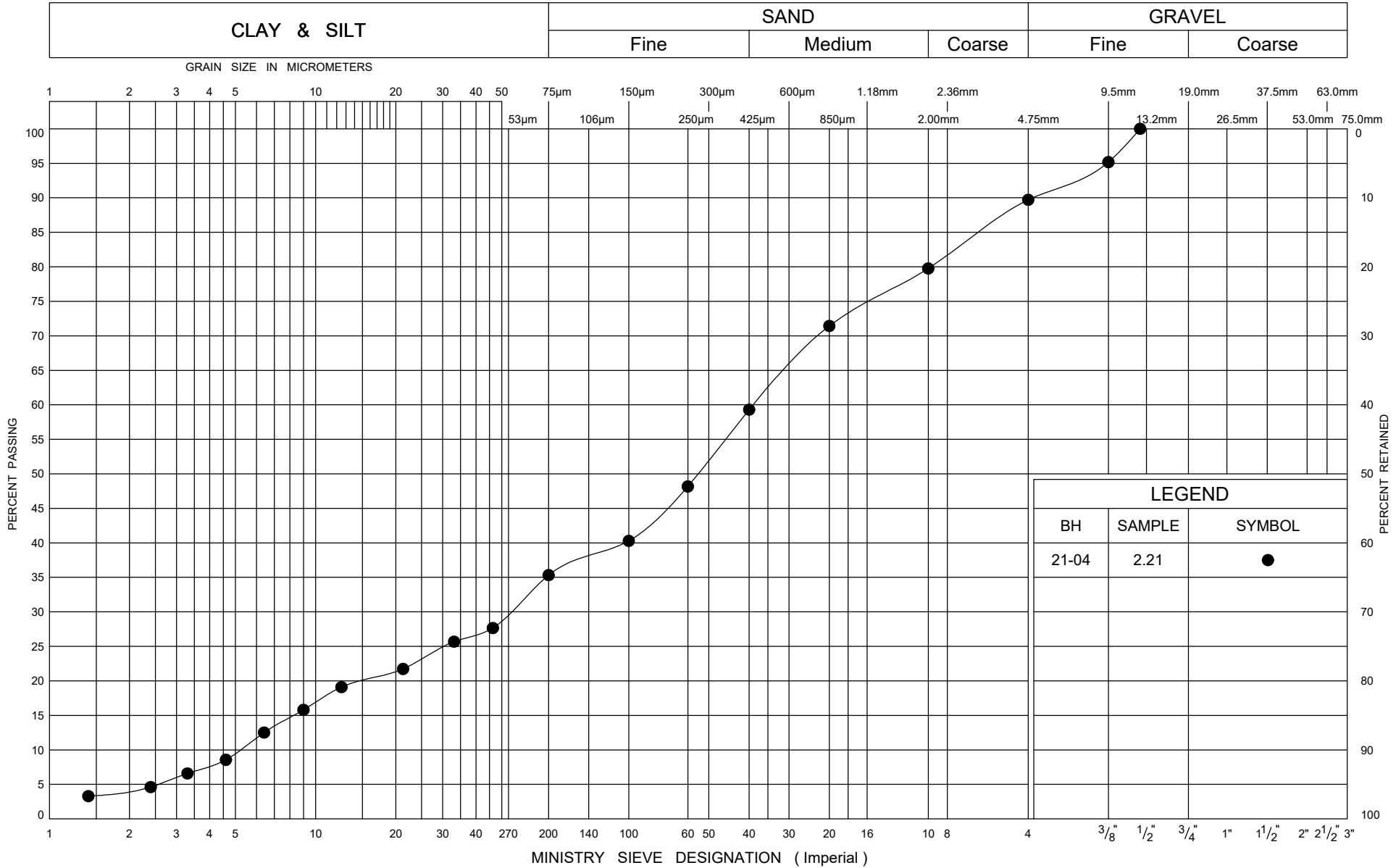


ONTARIO MOT GRAIN SIZE 2 MTO-31981.GPJ ONTARIO MOT.GDT 11/15/21



GRAIN SIZE DISTRIBUTION
SILT

FIG No C3
W P 6137-20-00



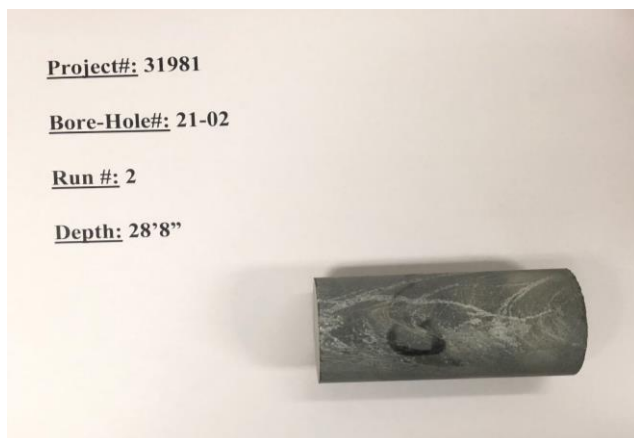
UNCONFINED COMPRESSION TEST REPORT

ASTM D7012-14

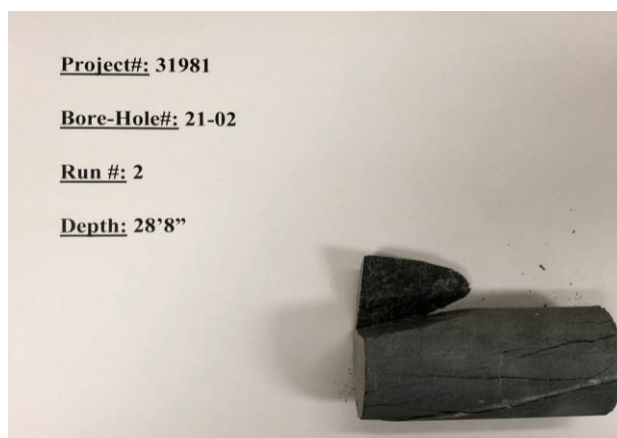
CLIENT:	Hatch Corporation	FILE NUMBER:	31981
PROJECT NAME:	Highway 17 Embankment Instabilities	REPORT DATE:	26-Aug-21
BOREHOLE No.:	21-02	TEST DATE:	30-Jul-21
SAMPLE No.:	NQ RUN 2		
SAMPLE DEPTH:	28'8"		
DESCRIPTION:	Metasedimentary		

Avg. Height (cm):	10.2	Weight (g):	494.9
Avg. Diameter (cm):	4.7	Wet Density (kg/m ³):	2,750
H. to Dia. Ratio**:	2.2:1	Dry Density (kg/m ³):	2,750
Cross Sectional Area (cm ²):	17.65	Moisture Content* (%):	N/A
Sample Volume (cm ³):	179.99		

ORIGINAL SPECIMEN



FRACTURED SPECIMEN



AVG. RATE OF STRAIN TO FAILURE:	0.250 MPa/sec
MAXIMUM COMPRESSIVE LOAD:	103.1 kN
UNCONFINED COMPRESSIVE STRENGTH:	58.4 MPa

Note: * The moisture content was obtained after the test.
 ** Dimensions of Specimen conform to ASTM D 4543-04.

TEST DONE BY: HH
 REVIEWED BY: WM

21-02 Run 2 - UCS



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

Job No : 31981

Client : Hatch

Project Name : HWY 17 Embankment Instabilities

Date Drilled : 23-Aug-21

Core Size : NQ BH No : BH21-01

Date Tested : 27-Aug-21

Tester : GF

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Notes
1	1	6.5	D	5.28	49.48	69.79	2.0	48.8	Siltstone	Medium Strong
2	1	6.6	D	13.78	49.69	71.77	5.3	126.6	Siltstone	Very Strong
3	2	7.4	D	8.62	49.96	69.38	3.3	78.5	Siltstone	Strong
4	2	8.1	D	23.90	49.27	68.93	9.3	222.5	Siltstone	Very Strong
5										
6										
7					Average RUN #1 (MPa) =			87.7		Strong
8					Average RUN #2 (MPa) =			150.5		Very Strong
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30										

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

Last Modified: August 15, 2013



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 31981
 Client: Hatch
 Project Name: Highway 17 Embankment Instabilities
 Core Size: NQ BH No : 21-02

Date Drilled: June 18, 2021
 Date Tested: July 28, 2021
 Tester: HH
 Reviewed by: WM

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	7.5	A	10.66	47.40	58.40	3.1	74.3	Metasedimentary	Strong
2	2	8.6	A	11.52	48.34	66.43	3.0	71.6	Metasedimentary	Strong
3										
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34										

- * It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
 Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- * Diametral Test should have $0.7 \times D$ on either side of test point.
- * Correlation factor to obtain UCS values is 24.



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 31981
 Client: Hatch
 Project Name: Highway 17 Embankment Instabilities
 Core Size: NQ BH No : 21-03

Date Drilled: June 17, 2021
 Date Tested: July 24, 2021
 Tester: HH
 Reviewed by: WM

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	I _{s(50)} (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	8.1	D	11.62	47.05	58.20	4.8	116.2	Metasedimentary	Very Strong
2	2	9.1	D	9.76	46.82	57.10	4.1	98.3	Metasedimentary	Strong
3	3	10.2	A	14.42	47.33	52.30	4.6	109.7	Metasedimentary	Very Strong
4										
5										
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- * It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
 Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- * Diametral Test should have $0.7 \times D$ on either side of test point.
- * Correlation factor to obtain UCS values is 24.



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

Job No : 31981

Client : Hatch

Project Name : HWY 17 Embankment Instabilities

Date Drilled 23-Aug-21

Core Size : NQ BH No : BH21-04

Date Tested 27-Aug-21

Tester : GF

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	I _{s(50)} (MPa)	UCS (MPa)	Rock Type	Notes
1	1	3.8	D	18.16	49.03	70.31	7.1	170.4	Metasedimentary	Very Strong
2	1	4.6	D	23.88	49.07	70.81	9.3	223.7	Metasedimentary	Very Strong
3	2	5.3	D	5.86	49.12	70.08	2.3	54.8	Metasedimentary	Strong
4	2	6.1	D	20.68	49.48	69.47	8.0	191.3	Metasedimentary	Very Strong
5										
6										
7					Average RUN #1 (MPa):			197.1		Very Strong
8					Average RUN #2 (MPa):			123.0		Very Strong
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* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

Last Modified: August 15, 2013

**THURBER ENGINEERING LTD.****POINT LOAD TEST SHEET****ASTM D5731-08**

Job No: 31981
Client: Hatch
Project Name: Highway 17 Embankment Instabilities
Core Size: NQ **BH No :** 21-05B

Date Drilled: June 17, 2021
Date Tested: July 28, 2021
Tester: IA
Reviewed by: WM

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	4.6	A	7.90	47.05	55.19	2.4	57.9	Metasedimentary	Strong
2	2	6.5	A	9.66	47.16	51.22	3.1	74.9	Metasedimentary	Strong
3										
4										
5										
6										
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- * It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- * Diametral Test should have $0.7 \times D$ on either side of test point.
- * Correlation factor to obtain UCS values is 24.

BOREHOLE: 21-01
CORE RUN #1: 17'7" - 22'6"
CORE RUN #2: 22'6" - 27'6"

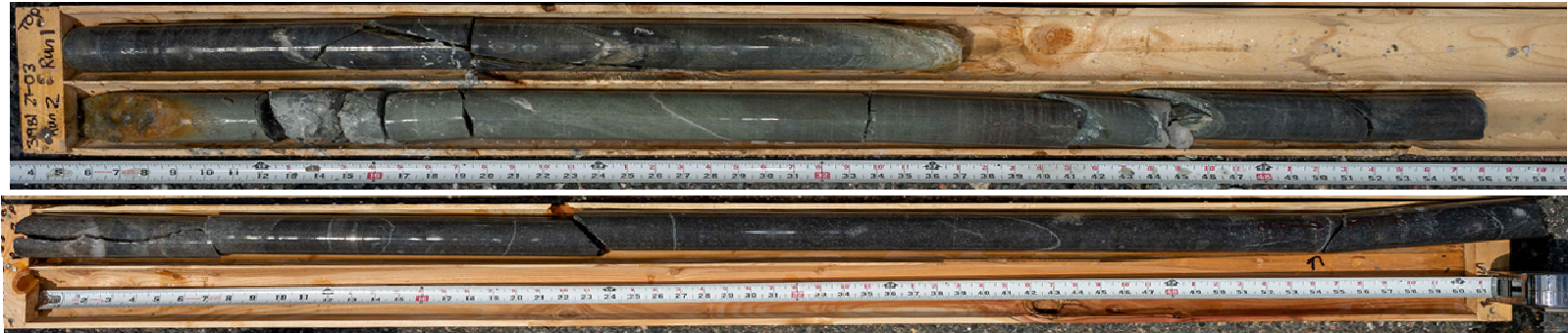


BOREHOLE: 21-02
CORE RUN #1: 24'1" - 28'0" (Bedrock Core Only)
CORE RUN #2: 28'0" - 33'0"
CORE RUN #3: 33'0" - 35'2"



BOREHOLE: 21-03
CORE RUN #1: 26'0" - 28'6"
CORE RUN #2: 28'6" - 32'6"

CORE RUN #3: 32'6" - 37'7"



BOREHOLE: 21-04
CORE RUN #1: 11'3" - 16'3"
CORE RUN #2: 16'3" - 21'3"



BOREHOLE: 21-05B (21-05)
CORE RUN #1: 14'1" - 18'5"
CORE RUN #2: 18'5" - 23'3"



BOREHOLE: 21-06
CORE RUN #1: 15'7" - 18'4"





THURBER ENGINEERING LTD.

Slug Test Analysis Report

Project: Highway 17 Embankment Instabilities

Number: 31981

Client: Hatch

Location: District of Thunder Bay

Slug Test: 21-01

Test Well: 21-01

Test Conducted by: AF

Test Date: 2021-08-19

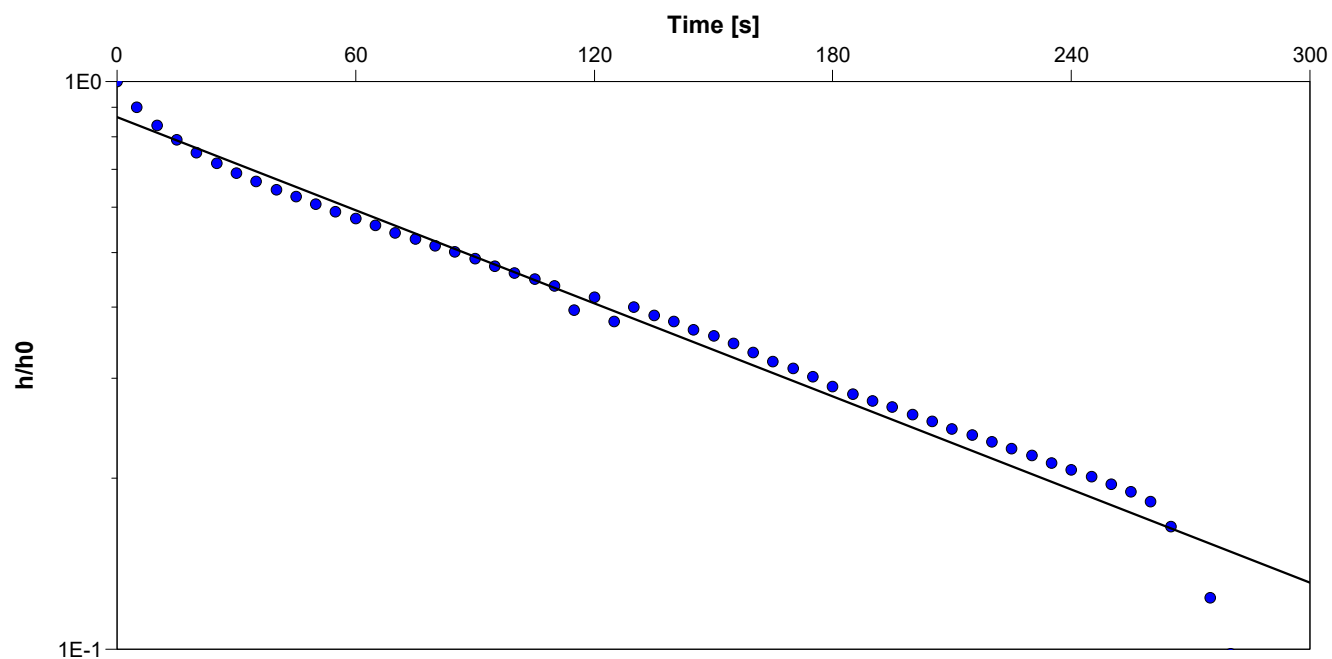
Analysis Performed by: PC

21-01 SWRT Analysis

Analysis Date: 2021-11-11

Aquifer Thickness:

Checked by: DH



Calculation using Hvorslev

Observation Well

Hydraulic
Conductivity
[m/s]

21-01

5.4×10^{-6}



THURBER ENGINEERING LTD.

Slug Test Analysis Report

Project: Highway 17 Embankment Instabilities

Number: 31981

Client: Hatch

Location: District of Thunder Bay

Slug Test: 21-04

Test Well: 21-04

Test Conducted by: AF

Test Date: 2021-08-19

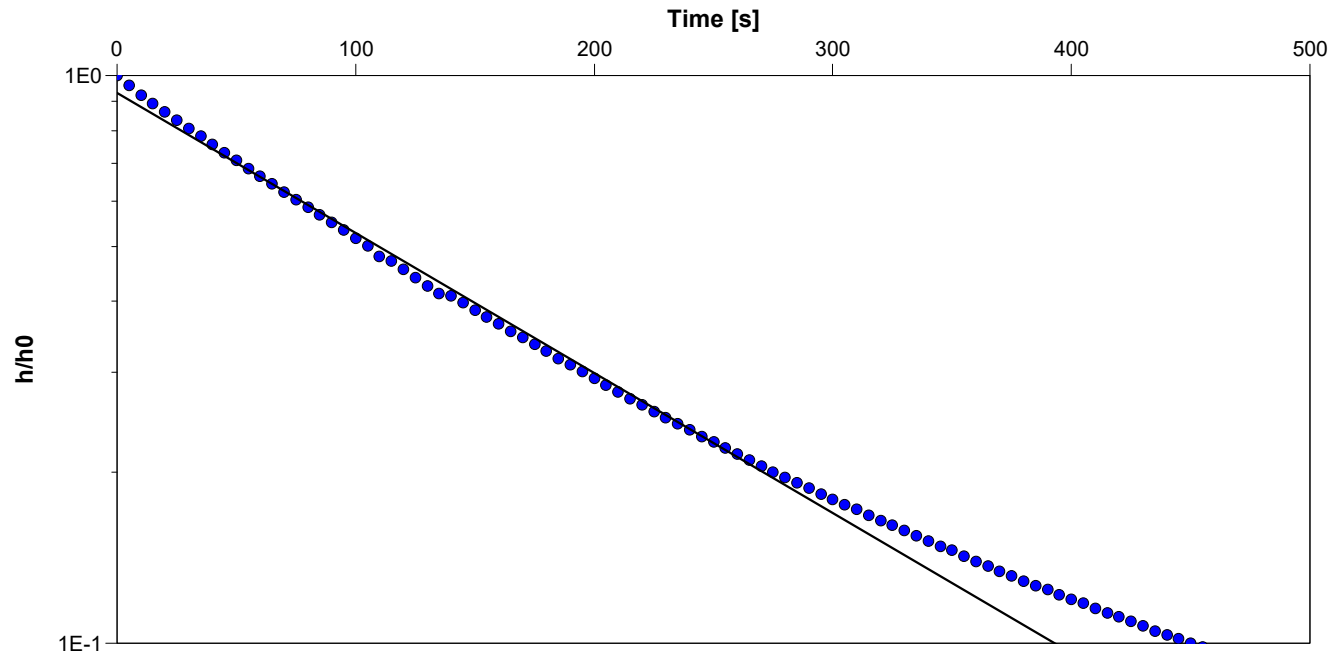
Analysis Performed by: PC

21-04 SWRT Analysis

Analysis Date: 2021-11-11

Aquifer Thickness:

Checked by: DH



Calculation using Hvorslev

Observation Well

Hydraulic
Conductivity
[m/s]

21-04

4.8×10^{-6}



FINAL REPORT

CA14474-AUG21 R1

31981, Hwy 17 Embankment Instabilities

Prepared for

Thurber Engineering Ltd.

First Page

CLIENT DETAILS		LABORATORY DETAILS	
Client	Thurber Engineering Ltd.	Project Specialist	Brad Moore Hon. B.Sc
Address	103, 2010 Winston Park Drive Oakville, ON L6H 5R7, Canada	Laboratory	SGS Canada Inc.
Contact	Joshua Alexander	Address	185 Concession St., Lakefield ON, K0L 2H0
Telephone	613-606-7303	Telephone	705-652-2143
Facsimile		Facsimile	705-652-6365
Email	jalexander@thurber.ca	Email	brad.moore@sgs.com
Project	31981, Hwy 17 Embankment Instabilities	SGS Reference	CA14474-AUG21
Order Number		Received	08/27/2021
Samples	Soil (2)	Approved	09/02/2021
		Report Number	CA14474-AUG21 R1
		Date Reported	09/02/2021

COMMENTS

Temperature of Sample upon Receipt: 7 degrees C

Cooling Agent Present: Yes

Custody Seal Present: Yes

Chain of Custody Number: 022134

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

Brad Moore Hon. B.Sc

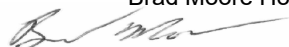




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FINAL REPORT

CA14474-AUG21 R1

Client: Thurber Engineering Ltd.

Project: 31981, Hwy 17 Embankment Instabilities

Project Manager: Joshua Alexander

Samplers: Joshua Alexander

PACKAGE: - Corrosivity Index (SOIL)

Sample Number	5	6
Sample Name	BH21-01, SS2	BH21-04, SS4
Sample Matrix	Soil	Soil
Sample Date	19/08/2021	18/08/2021

Parameter	Units	RL		Result	Result
Corrosivity Index					
Corrosivity Index	none	1		6	10
Soil Redox Potential	mV	-		63	130
Sulphide (Na ₂ CO ₃)	%	0.04		< 0.04	0.06
pH	pH Units	0.05		8.56	8.23
Resistivity (calculated)	ohms.cm	-9999		3030	2030

PACKAGE: - General Chemistry (SOIL)

Sample Number	5	6
Sample Name	BH21-01, SS2	BH21-04, SS4
Sample Matrix	Soil	Soil
Sample Date	19/08/2021	18/08/2021

Parameter	Units	RL		Result	Result
General Chemistry					
Conductivity	uS/cm	2		330	492

PACKAGE: - Metals and Inorganics (SOIL)

Sample Number	5	6
Sample Name	BH21-01, SS2	BH21-04, SS4
Sample Matrix	Soil	Soil
Sample Date	19/08/2021	18/08/2021

Parameter	Units	RL		Result	Result
Metals and Inorganics					
Moisture Content	%	0.1		17.4	15.8
Sulphate	µg/g	0.4		16	19



FINAL REPORT

CA14474-AUG21 R1

Client: Thurber Engineering Ltd.

Project: 31981, Hwy 17 Embankment Instabilities

Project Manager: Joshua Alexander

Samplers: Joshua Alexander

PACKAGE: - Other (ORP) (SOIL)

Sample Number	5	6
Sample Name	BH21-01, SS2	BH21-04, SS4
Sample Matrix	Soil	Soil
Sample Date	19/08/2021	18/08/2021

Parameter	Units	RL		Result	Result
Other (ORP)					
Chloride	µg/g	0.4		140	200



FINAL REPORT

CA14474-AUG21 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	DIO0502-AUG21	µg/g	0.4	<0.4	6	35	100	80	120	105	75	125
Sulphate	DIO0502-AUG21	µg/g	0.4	<0.4	15	35	93	80	120	93	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)	ECS0064-AUG21	%	0.04	< 0.04	ND	20	112	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	EWL0512-AUG21	uS/cm	2	< 2	0	20	99	90	110	NA		



QC SUMMARY

pH
Method: SM 4500 | Internal ref.: ME-CA-IENVIEWL-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	EWL0512-AUG21	pH Units	0.05	NA	0		100			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

Samples analysed as received. 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" 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. 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. 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.

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-- End of Analytical Report --



FINAL REPORT

CA14395-AUG21 R1

31981, Hwy 17 Embankment Instabilities

Prepared for

Thurber Engineering Ltd.



FINAL REPORT

CA14395-AUG21 R1

First Page

CLIENT DETAILS

Client Thurber Engineering Ltd.

Address 103, 2010 Winston Park Drive
Oakville, ON
L6H 5R7, Canada

Contact Joshua Alexander

Telephone 613-606-7303

Facsimile

Email jalexander@thurber.ca

Project 31981, Hwy 17 Embankment Instabilities

Order Number

Samples Surface Water (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 CA14395-AUG21

Received 08/23/2021

Approved 08/25/2021

Report Number CA14395-AUG21 R1

Date Reported 11/30/2021

COMMENTS

Temperature of Sample upon Receipt: 4 degrees C

Cooling Agent Present:Yes

Custody Seal Present:Yes

SIGNATORIES

Jill Campbell, B.Sc.,GISAS



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FINAL REPORT

CA14395-AUG21 R1

Client: Thurber Engineering Ltd.

Project: 31981, Hwy 17 Embankment Instabilities

Project Manager: Joshua Alexander

Samplers: N/A

PACKAGE: - **General Chemistry** (WATER)

Sample Number 6
Sample Name Hwy 17
Embankment
Instabilities
Sample Matrix Surface Water
Sample Date 19/08/2021

Parameter	Units	RL	Result
General Chemistry			
Conductivity	uS/cm	2	232
Redox Potential	mV	-	14
Sulphide	µg/L	6	6

PACKAGE: - **Metals and Inorganics** (WATER)

Sample Number 6
Sample Name Hwy 17
Embankment
Instabilities
Sample Matrix Surface Water
Sample Date 19/08/2021

Parameter	Units	RL	Result
Metals and Inorganics			
Sulphate	mg/L	0.04	3.8

PACKAGE: - **Other (ORP)** (WATER)

Sample Number 6
Sample Name Hwy 17
Embankment
Instabilities
Sample Matrix Surface Water
Sample Date 19/08/2021

Parameter	Units	RL	Result
Other (ORP)			
pH	No unit	0.05	8.09



FINAL REPORT

CA14395-AUG21 R1

Client: Thurber Engineering Ltd.

Project: 31981, Hwy 17 Embankment Instabilities

Project Manager: Joshua Alexander

Samplers: N/A

PACKAGE: - Other (ORP) (WATER)

Sample Number 6
Sample Name Hwy 17
Embankment
Instabilities
Sample Matrix Surface Water
Sample Date 19/08/2021

Parameter	Units	RL	Result
Other (ORP) (continued)			
Chloride	mg/L	0.04	3.4



FINAL REPORT

CA14395-AUG21 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	DIO0411-AUG21	mg/L	0.04	<0.04	1	20	98	90	110	90	75	125
Sulphate	DIO0411-AUG21	mg/L	0.04	<0.04	3	20	99	90	110	101	75	125

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	EWL0418-AUG21	uS/cm	2	< 2	0	20	99	90	110	NA		

pH
Method: SM 4500 | 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
pH	EWL0418-AUG21	No unit	0.05	NA	0		100			NA		



FINAL REPORT

CA14395-AUG21 R1

QC SUMMARY

Redox Potential
Method: SM 2580 I

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
Redox Potential	EWL0391-AUG21	mV	no	NA	1	20	103	80	120	NA		

Sulphide by SFA
Method: SM 4500 I Internal ref.: ME-CA-IENVISFA-LAK-AN-008

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	SKA0224-AUG21	ug/L	6	<0.006	ND	20	85	80	120	NA	75	125

QC SUMMARY

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

Samples analysed as received. 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" 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. 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. 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.

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-- End of Analytical Report --



Environment, Health & Safety - Lakefield: 185 Concession St., Lakefield, ON K0L 2H0 Phone: 705-652-2000 Fax: 705-652-6365 Web: www.sgs.com/environment
 - London: 657 Consortium Court, London, ON, N6E 2S8 Phone: 519-672-4500 Toll Free: 877-848-8060 Fax: 519-672-0361

Request for Laboratory Services and CHAIN OF CUSTODY

No: 026095

Page 1 of 1

Laboratory Information Section - Lab use only

Received By: Scott
 Received Date: 08/23/2011 (mm/dd/yy)
 Received Time: 08:00 (hr:min)

Received By (signature): _____
 Custody Seal Present: Yes ☒ No ☐ Cooling Agent Present: Yes ☐ No ☐ Type: Ice
 Custody Seal Intact: Yes ☒ No ☐ Temperature Upon Receipt (°C): 4.4, 4.4, 4.4

LAB LIMS #: CA1439596-AUGA

REPORT INFORMATION Company: <u>Thurber</u> Contact: <u>Joshua Alexander</u> Address: <u>2010-25103 Windsor Park Dr</u> Phone: <u>613 606 7303</u> Fax: <u>jalexander@thurber.ca</u> Email: <u>M.Torant@thurber.ca</u>		INVOICE INFORMATION <input type="checkbox"/> (same as Report Information) Company: _____ Contact: _____ Address: _____ Phone: _____ Email: _____		Quotation #: _____ P.O. #: _____ Project #: <u>31981</u> Site Location/ID: <u>780Y17 Embankment</u> TURNAROUND TIME (TAT) REQUIRED <input checked="" type="checkbox"/> Regular TAT (5-7 days) TAT's are quoted in business days (exclude statutory holidays & weekends). Samples received after 6pm or on weekends: TAT begins next business day RUSH TAT (Additional Charges May Apply): <input type="checkbox"/> 1 Day <input type="checkbox"/> 2 Days <input type="checkbox"/> 3 Days <input type="checkbox"/> 4 Days PLEASE CONFIRM RUSH FEASIBILITY WITH SGS REPRESENTATIVE PRIOR TO SUBMISSION Specify Due Date: _____ *NOTE: DRINKING (POTABLE) WATER SAMPLES FOR HUMAN CONSUMPTION MUST BE SUBMITTED WITH SGS DRINKING WATER CHAIN OF CUSTODY	
--	--	---	--	--	--

REGULATIONS <input type="checkbox"/> O.Reg 153/04 <input type="checkbox"/> O.Reg 406/19 <input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Soil Texture: <input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Com <input type="checkbox"/> Coarse <input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/Other <input type="checkbox"/> Medium/Fine <input type="checkbox"/> Table _____ Appx. _____ Soil Volume <input type="checkbox"/> <350m3 <input type="checkbox"/> >350m3				Other Regulations: <input type="checkbox"/> Reg 347/558 (3 Day min TAT) <input checked="" type="checkbox"/> PWQO <input type="checkbox"/> MMR <input type="checkbox"/> CCME <input type="checkbox"/> Other: <input type="checkbox"/> MISA <input type="checkbox"/> ODWS Not Reportable *See note				Sewer By-Law: <input type="checkbox"/> Sanitary <input type="checkbox"/> Storm Municipality: _____				ANALYSIS REQUESTED <table border="1" style="width:100%"> <tr> <th>M & I</th> <th>SVOC</th> <th>PCB</th> <th>PHC</th> <th>VOC</th> <th>Pest</th> <th>Other (please specify)</th> <th>SPLP</th> <th>TCLP</th> <th rowspan="4">COMMENTS:</th> </tr> <tr> <td>Field Filtered (Y/N)</td> <td>PAHs only</td> <td>SVOCs all incl PAHs, ABNs, CPs</td> <td>PCBs Total <input type="checkbox"/> Aroclor <input type="checkbox"/></td> <td>F1-F4 + BTEX</td> <td>F1-F4 only no BTEX</td> <td>VOCs all incl BTEX</td> <td>Pesticides Organochlorine or specify other</td> <td>Cr6+ and Hg+ TSS</td> <td>Metals (Total)</td> <td>Water Characterization Pkg</td> <td>Sewer Use: <input checked="" type="checkbox"/> Lab Filtered (Residuals)</td> <td>Specify tests</td> <td>Specify tests</td> </tr> <tr> <td>Metals & Inorganics (ICP CVI, CN, Hg, Pb, B(HWS), EC, SAR-soil, Cu, Ni, Water)</td> <td>Full Metals Suite (ICP metals plus B(HWS-soil only) Hg, CVI)</td> <td>ICP Metals only (Sb, As, Ba, Be, B, Cd, Cr, Co, Cu, Pb, Mo, Ni)</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td><input type="checkbox"/> Metals</td> <td><input type="checkbox"/> M&I</td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td><input type="checkbox"/> VOC</td> <td><input type="checkbox"/> VOC</td> </tr> </table>												M & I	SVOC	PCB	PHC	VOC	Pest	Other (please specify)	SPLP	TCLP	COMMENTS:	Field Filtered (Y/N)	PAHs only	SVOCs all incl PAHs, ABNs, CPs	PCBs Total <input type="checkbox"/> Aroclor <input type="checkbox"/>	F1-F4 + BTEX	F1-F4 only no BTEX	VOCs all incl BTEX	Pesticides Organochlorine or specify other	Cr6+ and Hg+ TSS	Metals (Total)	Water Characterization Pkg	Sewer Use: <input checked="" type="checkbox"/> Lab Filtered (Residuals)	Specify tests	Specify tests	Metals & Inorganics (ICP CVI, CN, Hg, Pb, B(HWS), EC, SAR-soil, Cu, Ni, Water)	Full Metals Suite (ICP metals plus B(HWS-soil only) Hg, CVI)	ICP Metals only (Sb, As, Ba, Be, B, Cd, Cr, Co, Cu, Pb, Mo, Ni)										<input type="checkbox"/> Metals	<input type="checkbox"/> M&I													<input type="checkbox"/> VOC	<input type="checkbox"/> VOC
M & I	SVOC	PCB	PHC	VOC	Pest	Other (please specify)	SPLP	TCLP	COMMENTS:																																																																		
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													<input type="checkbox"/> VOC	<input type="checkbox"/> VOC																																																													
RECORD OF SITE CONDITION (RSC) <input type="checkbox"/> YES <input type="checkbox"/> NO																																																																											
SAMPLE IDENTIFICATION		DATE SAMPLED	TIME SAMPLED	# OF BOTTLES	MATRIX																																																																						
1 <u>Hwy 17 Embankment</u>		<u>Aug 19/21</u>	<u>-</u>	<u>3</u>	<u>Water</u>																																																																						
2 <u>BH21-04</u>		<u>"</u>	<u>-</u>	<u>15</u>	<u>Water</u>																																																																						
3 <u>BH21</u>		<u>"</u>	<u>-</u>	<u>1</u>	<u>Soil</u>																																																																						
4 <u>BH21</u>		<u>"</u>	<u>-</u>	<u>1</u>	<u>Soil</u>																																																																						
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12																																																																											

Observations/Comments/Special Instructions

Sampled By (NAME): _____	Signature: _____	Date: ____/____/____ (mm/dd/yy)	Pink Copy - Client
Relinquished by (NAME): <u>Josh Alexander</u>	Signature: _____	Date: ____/____/____ (mm/dd/yy)	Yellow & White Copy - SGS

Revision #: 1.5
 Date of Issue: 11 June 2021
 Note: Submission of samples to SGS is acknowledgement that you have been provided direction on sample collection/handling and transportation of samples. (2) Submission of samples to SGS is considered authorization for completion of work. Signatures may appear on this form or be retained on file in the contract, or in an alternative format (e.g. shipping documents). (3) Results may be sent by email to an unlimited number of addresses for no additional cost. Fax is available upon request. This document is issued by the Company under its General Conditions of Service accessible at http://www.sgs.com/terms_and_conditions.htm. (Printed copies are available upon request.) Attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.



FINAL REPORT

CA14396-AUG21 R1

31981, Hwy 17 Embankment Instabilites

Prepared for

Thurber Engineering Ltd.

First Page

CLIENT DETAILS		LABORATORY DETAILS	
Client	Thurber Engineering Ltd.	Project Specialist	Brad Moore Hon. B.Sc
Address	103, 2010 Winston Park Drive, Oakville Canada, L6H 5R7 Phone: 613-606-7303. Fax:	Laboratory	SGS Canada Inc.
Contact	Joshua Alexander	Address	185 Concession St., Lakefield ON, K0L 2H0
Telephone	613-606-7303	Telephone	705-652-2143
Facsimile		Facsimile	705-652-6365
Email	jalexander@thurber.ca	Email	brad.moore@sgs.com
Project	31981, Hwy 17 Embankment Instabilities	SGS Reference	CA14396-AUG21
Order Number		Received	08/23/2021
Samples	Ground Water (2)	Approved	09/07/2021
		Report Number	CA14396-AUG21 R1
		Date Reported	09/07/2021

COMMENTS

MAC - Maximum Acceptable Concentration

AO/OG - Aesthetic Objective / Operational Guideline

NR - Not reportable under applicable Provincial drinking water regulations as per client.

Temperature of Sample upon Receipt: 4 degrees C

Cooling Agent Present: Yes

Custody Seal Present: Yes

Chain of Custody Number: 02609

metals limits raised 10x due to Sample Matrix

Large volume of Solids in samples causing high Ion balance and Ion ratio

SIGNATORIES

Brad Moore Hon. B.Sc

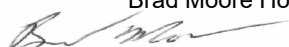




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FINAL REPORT

CA14396-AUG21 R1

Client: Thurber Engineering Ltd.

Project: 31981, Hwy 17 Embankment Instabilities

Project Manager: Joshua Alexander

Samplers: N/A

PACKAGE: **General Chemistry** (WATER)

Sample Number 7
Sample Name BH21-04
Sample Matrix Ground Water
Sample Date 19/08/2021

L1 = PWQO_L / WATER / - - Table 2 - General - July 1999 PIBS 3303E

Parameter	Units	RL	L1	Result
General Chemistry				
UV Transmittance	%T			0.5
Alkalinity	mg/L as CaCO ₃	2		300
Bicarbonate	mg/L as CaCO ₃	2		300
Carbonate	mg/L as CaCO ₃	2		< 2
OH	mg/L as CaCO ₃	2		< 2
Colour	TCU	3		11
Conductivity	uS/cm	2		1510
Total Suspended Solids	mg/L	2		148000
Organic Nitrogen	mg/L	0.05		0.16
Total Kjeldahl Nitrogen (N)	as N mg/L	0.05		1.54
Ammonia+Ammonium (N)	as N mg/L	0.04		1.38
Dissolved Organic Carbon	mg/L	1		30
Total Organic Carbon	mg/L	1		34
Sulphide	µg/L	6		7
Ion Ratio	none	-9999		23.1
Total Dissolved Solids (calculated)	mg/L	-9999		6488
Conductivity (calculated)	uS/cm	-9999		18310
Langeliers Index 4° C	@ 4° C	-9999		2.07
Saturation pH 4°C	pHs @ 4°C	-9999		5.93



FINAL REPORT

CA14396-AUG21 R1

Client: Thurber Engineering Ltd.

Project: 31981, Hwy 17 Embankment Instabilities

Project Manager: Joshua Alexander

Samplers: N/A

PACKAGE: **Metals and Inorganics (WATER)**

Sample Number	7	8
Sample Name	BH21-04	BH21-04 Dissolved
Sample Matrix	Ground Water	Ground Water
Sample Date	19/08/2021	19/08/2021

L1 = PWQQ_L / WATER / - - Table 2 - General - July 1999 PIBS 3303E

Parameter	Units	RL	L1	Result	Result
Metals and Inorganics					
Fluoride	mg/L	0.06		0.16	
Bromide	mg/L	0.05		0.14	
Nitrite (as N)	as N mg/L	0.003		0.008	
Nitrate (as N)	as N mg/L	0.006		0.007	
Sulphate	mg/L	0.04		7.7	
Hardness	mg/L as CaCO3	0.05		16200	506
Aluminum	µg/L	1	15	133000	12
Aluminum (0.2µm)	mg/L	0.01	0.015	0.081	
Arsenic	µg/L	2	5	75.4	< 2
Boron	µg/L	20	200	214	32
Barium	µg/L	0.2		4750	426
Beryllium	µg/L	0.07	11	5.25	< 0.07
Bismuth	µg/L	0.1		1.62	< 0.1
Cobalt	µg/L	0.04	0.9	2620	18.9
Calcium	mg/L	0.1		4750	153
Cadmium	µg/L	0.03	0.1	3.76	< 0.03
Copper	µg/L	2	1	1150	< 2
Chromium	µg/L	0.8	100	647	< 0.8
Iron	ug/L	70	300	358000	< 70
Potassium	mg/L	0.09		37.3	8.41
Magnesium	mg/L	0.01		1040	30.0
Manganese	µg/L	0.1		16400	267



FINAL REPORT

CA14396-AUG21 R1

Client: Thurber Engineering Ltd.

Project: 31981, Hwy 17 Embankment Instabilities

Project Manager: Joshua Alexander

Samplers: N/A

PACKAGE: **Metals and Inorganics (WATER)**

Sample Number	7	8
Sample Name	BH21-04	BH21-04 Dissolved
Sample Matrix	Ground Water	Ground Water
Sample Date	19/08/2021	19/08/2021

L1 = PWQQ_L / WATER / - - Table 2 - General - July 1999 PIBS 3303E

Parameter	Units	RL	L1	Result	Result
Metals and Inorganics (continued)					
Molybdenum	µg/L	0.4	40	3.25	7.18
Nickel	µg/L	1	25	766	4.0
Sodium	mg/L	0.1		153	161
Phosphorus	mg/L	0.03	0.01	13.3	0.037
Lead	µg/L	0.1	11	243	< 0.1
Silicon	ug/L	200		127000	4730
Silver	µg/L	0.5	0.1	13.7	< 0.5
Strontium	µg/L	0.2		9230	2100
Thallium	µg/L	0.05	0.3	3.12	< 0.05
Tin	µg/L	0.6		1.03	< 0.6
Titanium	ug/L	0.5		2120	< 0.5
Antimony	µg/L	9	20	< 9	< 9
Selenium	µg/L	0.4	100	2.63	< 0.4
Uranium	µg/L	0.02	5	34.6	3.21
Vanadium	µg/L	0.1	6	344	1.43
Zinc	µg/L	20	20	999	< 20
Cation sum	meq/L	-9999		351	
Anion Sum	meq/L	-9999		15.2	
Anion-Cation Balance	% difference	-9999		91.7	



FINAL REPORT

CA14396-AUG21 R1

Client: Thurber Engineering Ltd.

Project: 31981, Hwy 17 Embankment Instabilities

Project Manager: Joshua Alexander

Samplers: N/A

PACKAGE: Other (ORP) (WATER)

Sample Number 7
Sample Name BH21-04
Sample Matrix Ground Water
Sample Date 19/08/2021

L1 = PWQO_L / WATER / - - Table 2 - General - July 1999 PIBS 3303E

Parameter	Units	RL	L1	Result
Other (ORP)				
pH	No unit	5	0.1	8.00
Chloride	mg/L	0.04		320
Chromium VI	µg/L	0.2	1	< 0.2
Mercury (dissolved)	mg/L	0.00001		0.00020
Phenols				
4AAP-Phenolics	mg/L	0.002	0.001	< 0.002

EXCEEDANCE SUMMARY

				PWQO_L / WATER / - - Table 2 - General - July 1999 PIBS 3303E L1
Parameter	Method	Units	Result	

BH21-04

Aluminum	SM 3030/EPA 200.8	µg/L	133000	15
Aluminum (dissolved)	SM 3030/EPA 200.8	mg/L	0.081	0.015
Arsenic	SM 3030/EPA 200.8	µg/L	75.4	5
Boron	SM 3030/EPA 200.8	µg/L	214	200
Cadmium	SM 3030/EPA 200.8	µg/L	3.76	0.1
Chromium	SM 3030/EPA 200.8	µg/L	647	100
Cobalt	SM 3030/EPA 200.8	µg/L	2620	0.9
Copper	SM 3030/EPA 200.8	µg/L	1150	1
Iron	SM 3030/EPA 200.8	ug/L	358000	300
Lead	SM 3030/EPA 200.8	µg/L	243	11
Nickel	SM 3030/EPA 200.8	µg/L	766	25
Phosphorus	SM 3030/EPA 200.8	mg/L	13.3	0.01
Silver	SM 3030/EPA 200.8	µg/L	13.7	0.1
Thallium	SM 3030/EPA 200.8	µg/L	3.12	0.3
Uranium	SM 3030/EPA 200.8	µg/L	34.6	5
Vanadium	SM 3030/EPA 200.8	µg/L	344	6
Zinc	SM 3030/EPA 200.8	µg/L	999	20
pH	SM 4500	No unit	8.00	0.1
4AAP-Phenolics	SM 5530B-D	mg/L	< 0.002	0.001

BH21-04 Dissolved

Cobalt	SM 3030/EPA 200.8	µg/L	18.9	0.9
Copper	SM 3030/EPA 200.8	µg/L	< 2	1
Phosphorus	SM 3030/EPA 200.8	mg/L	0.037	0.01
Silver	SM 3030/EPA 200.8	µg/L	< 0.5	0.1



FINAL REPORT

CA14396-AUG21 R1

QC SUMMARY

Alkalinity

Method: SM 2320 | Internal ref.: ME-CA-1ENVIEWL-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
Alkalinity	EWL0402-AUG21	mg/L as CaCO3	2	< 2	0	20	104	80	120	NA		

Ammonia by SFA

Method: SM 4500 | Internal ref.: ME-CA-1ENVISFA-LAK-AN-007

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
Ammonia+Ammonium (N)	SKA0265-AUG21	mg/L	0.04	<0.04	4	10	102	90	110	96	75	125



FINAL REPORT

CA14396-AUG21 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
Bromide	DIO0409-AUG21	mg/L	0.05	<0.05	ND	20	97	90	110	99	75	125
Nitrite (as N)	DIO0409-AUG21	mg/L	0.003	<0.003	ND	20	94	90	110	90	75	125
Nitrate (as N)	DIO0409-AUG21	mg/L	0.006	<0.006	0	20	99	90	110	96	75	125
Chloride	DIO0411-AUG21	mg/L	0.04	<0.04	1	20	98	90	110	90	75	125
Sulphate	DIO0411-AUG21	mg/L	0.04	<0.04	3	20	99	90	110	101	75	125

Carbon by SFA
Method: SM 5310 | Internal ref.: ME-CA-IENVISFA-LAK-AN-009

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
Dissolved Organic Carbon	SKA0250-AUG21	mg/L	1	<1	2	10	93	90	110	NV	75	125
Total Organic Carbon	SKA0250-AUG21	mg/L	1	<1	2	10	93	90	110	NV	75	125



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QC SUMMARY

Carbonate/Bicarbonate

Method: SM 2320 | Internal ref.: ME-CA-ENVIEWL-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
Carbonate	EWL0402-AUG21	mg/L as CaCO3	2	< 2	ND	10	NA	90	110	NA		
Bicarbonate	EWL0402-AUG21	mg/L as CaCO3	2	< 2	0	10	NA	90	110	NA		
OH	EWL0402-AUG21	mg/L as CaCO3	2	< 2	ND	10	NA	90	110	NA		

Colour

Method: SM 2120 | Internal ref.: ME-CA-ENVIEWL-LAK-AN-002

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
Colour	EWL0410-AUG21	TCU	3	< 3	2	10	95	80	120	NA		



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QC SUMMARY

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	EWL0402-AUG21	uS/cm	2	4	1	20	99	90	110	NA		

Fluoride by Specific Ion Electrode
Method: SM 4500 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-014

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
Fluoride	EWL0403-AUG21	mg/L	0.06	<0.06	ND	10	104	90	110	100	75	125

Hexavalent Chromium by SFA
Method: EPA218.6/EPA3060A | Internal ref.: ME-CA-IENVISKA-LAK-AN-012

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
Chromium VI	SKA0235-AUG21	ug/L	0.2	<0.2	ND	20	101	80	120	99	75	125



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QC SUMMARY

Mercury by CVAAS
Method: EPA 7471A/SM 3112B | Internal ref.: ME-CA-IENVISPE-LAK-AN-004

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
Mercury (dissolved)	EHG0031-AUG21	mg/L	0.00001	< 0.00001	5	20	96	80	120	77	70	130



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QC SUMMARY

Metals in aqueous samples - ICP-MS
Method: SM 3030/EPA 200.8 | Internal ref.: ME-CA-ENVISPE-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
Aluminum (0.2µm)	EMS0150-AUG21	mg/L	0.01	< 0.001	17	20	101	90	110	110	70	130
Silver	EMS0162-AUG21	ug/L	0.5	<0.00005	1	20	98	90	110	93	70	130
Aluminum	EMS0162-AUG21	ug/L	1	<0.001	4	20	93	90	110	100	70	130
Arsenic	EMS0162-AUG21	ug/L	2	<0.0002	8	20	96	90	110	101	70	130
Barium	EMS0162-AUG21	ug/L	0.2	<0.00002	4	20	96	90	110	102	70	130
Beryllium	EMS0162-AUG21	ug/L	0.07	<0.00007	ND	20	91	90	110	96	70	130
Boron	EMS0162-AUG21	ug/L	20	<0.002	1	20	106	90	110	105	70	130
Bismuth	EMS0162-AUG21	ug/L	0.1	< 0.007	1	20	95	90	110	93	70	130
Calcium	EMS0162-AUG21	mg/L	0.1	<0.01	4	20	100	90	110	106	70	130
Cadmium	EMS0162-AUG21	ug/L	0.03	< 0.003	3	20	97	90	110	100	70	130
Cobalt	EMS0162-AUG21	ug/L	0.04	< 0.004	4	20	95	90	110	97	70	130
Chromium	EMS0162-AUG21	ug/L	0.8	<0.00008	5	20	94	90	110	86	70	130
Copper	EMS0162-AUG21	ug/L	2	<0.0002	0	20	95	90	110	96	70	130
Iron	EMS0162-AUG21	ug/L	70	<0.007	1	20	101	90	110	125	70	130
Potassium	EMS0162-AUG21	mg/L	0.09	<0.009	5	20	98	90	110	104	70	130
Magnesium	EMS0162-AUG21	mg/L	0.01	<0.001	4	20	99	90	110	103	70	130
Manganese	EMS0162-AUG21	ug/L	0.1	<0.00001	5	20	96	90	110	95	70	130
Molybdenum	EMS0162-AUG21	ug/L	0.4	<0.00004	1	20	99	90	110	102	70	130
Sodium	EMS0162-AUG21	mg/L	0.1	<0.01	3	20	106	90	110	105	70	130
Nickel	EMS0162-AUG21	ug/L	1	<0.0001	ND	20	94	90	110	94	70	130



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CA14396-AUG21 R1

QC SUMMARY

Metals in aqueous samples - ICP-MS (continued)

Method: SM 3030/EPA 200.8 | Internal ref.: ME-CA-1ENVISPE-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
Lead	EMS0162-AUG21	ug/L	0.1	<0.00001	2	20	108	90	110	108	70	130
Phosphorus	EMS0162-AUG21	mg/L	0.03	<0.003	ND	20	97	90	110	NV	70	130
Antimony	EMS0162-AUG21	ug/L	9	<0.0009	ND	20	105	90	110	122	70	130
Selenium	EMS0162-AUG21	ug/L	0.4	<0.00004	1	20	98	90	110	107	70	130
Silicon	EMS0162-AUG21	ug/L	200	<0.02	5	20	96	90	110	NV	70	130
Tin	EMS0162-AUG21	ug/L	0.6	<0.00006	1	20	105	90	110	NV	70	130
Strontium	EMS0162-AUG21	ug/L	0.2	< 0.02	6	20	95	90	110	97	70	130
Titanium	EMS0162-AUG21	ug/L	0.5	<0.00005	2	20	94	90	110	NV	70	130
Thallium	EMS0162-AUG21	ug/L	0.05	< 0.005	0	20	98	90	110	103	70	130
Uranium	EMS0162-AUG21	ug/L	0.02	<0.000002	9	20	98	90	110	100	70	130
Vanadium	EMS0162-AUG21	ug/L	0.1	<0.00001	16	20	94	90	110	98	70	130
Zinc	EMS0162-AUG21	ug/L	20	<0.002	20	20	94	90	110	103	70	130



FINAL REPORT

CA14396-AUG21 R1

QC SUMMARY

pH
Method: SM 4500 | 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
pH	EWL0402-AUG21	No unit	5	NA	1		100			NA		

Phenols by SFA
Method: SM 5530B-D | Internal ref.: ME-CA-IENVISFA-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
4AAP-Phenolics	SKA0231-AUG21	mg/L	0.002	<0.002	ND	10	99	80	120	95	75	125

Sulphide by SFA
Method: SM 4500 | Internal ref.: ME-CA-IENVISFA-LAK-AN-008

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	SKA0224-AUG21	ug/L	6	<0.006	ND	20	85	80	120	NA	75	125



FINAL REPORT

CA14396-AUG21 R1

QC SUMMARY

Suspended Solids

Method: SM 2540D | Internal ref.: ME-CA-IENVIEWL-LAK-AN-004

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
Total Suspended Solids	EWL0478-AUG21	mg/L	2	< 2	2	10	97	90	110	NA		

Total Nitrogen

Method: SM 4500-N C/4500-NO3- F | Internal ref.: ME-CA-IENVISFA-LAK-AN-002

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
Total Kjeldahl Nitrogen (N)	SKA0238-AUG21	mg/L	0.05	<0.05	2	10	100	90	110	98	75	125

QC SUMMARY

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

Samples analysed as received. 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" 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. 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. 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.

This report must not be reproduced, except in full. This report supersedes all previous versions.

-- End of Analytical Report --



Appendix D

Site Photographs



Photograph 1: Area of instability. Outside westbound lane looking east [taken May 2021, Credit MTO]



Photograph 1: Area of instability. Outside westbound lane looking west [taken May 2021, Credit MTO]



Photograph 3: Borehole 21-02 looking east toward east approach [taken July 2021]



Photograph 4: Borehole 21-02, looking west toward west approach [taken July 2021]



Photograph 5: North embankment looking west toward culvert [taken July 2021]



Photograph 6: South embankment looking west toward culvert [taken July 2021]



Appendix E

Foundation Comparison



GEOTECHNICAL COMPARISON OF ALTERNATIVE FOUNDATION TYPES

Corrugated Steel Pipe (CSP) Culvert or Twin CSPs	Concrete Box Culvert	Concrete Open Footing Culvert
<u>Advantages:</u> i. Ease of construction. ii. Steel pipes may be more cost effective than concrete box or open footing culverts.	<u>Advantages:</u> i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used. ii. Segmental option can accommodate some potential differential settlement along culvert axis. iii. Able to be constructed in the wet.	<u>Advantages:</u> i. Conventional construction. ii. Possibly less disturbance of creek channel / less environmental issues such as those involving spawning fish species.
<u>Disadvantages:</u> i. Steel pipes may have shorter design life than concrete culverts. ii. Multiple pipes maybe needed to meet hydraulic requirements. iii. Not recommended to be placed in the wet.	<u>Disadvantages:</u> i. More expensive than a Concrete pipe or CSP culvert.	<u>Disadvantages:</u> i. Greater potential for differential settlement. ii. Deeper excavation and potentially longer dewatering requirements in cohesionless soils. iii. Potential need for localized bedrock excavation.
FEASIBLE	RECOMMENDED	NOT RECOMMENDED








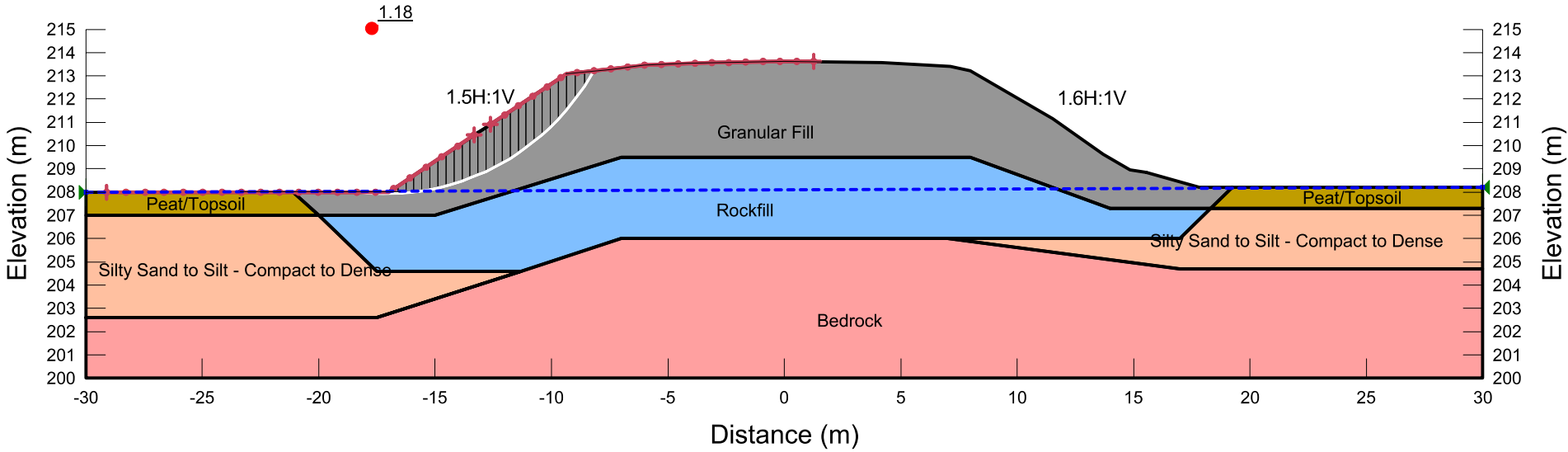
Appendix F

Slope Stability Analysis Figures

STABILITY ANALYSIS
HIGHWAY 17
EXISTING CONDITION

FIGURE 1

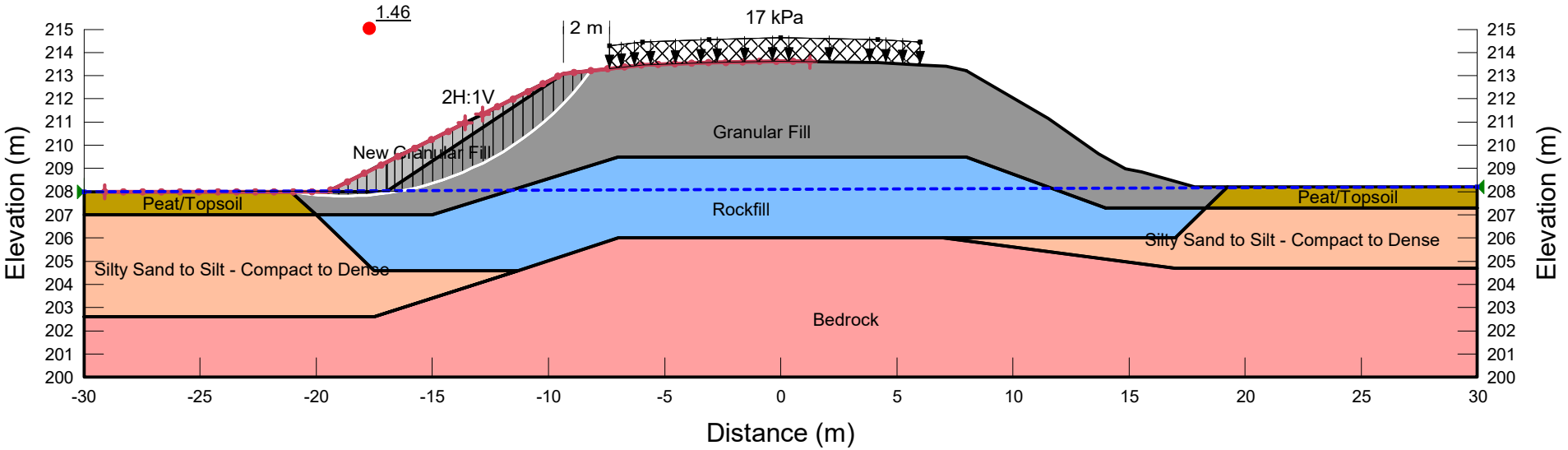
Color	Name	Model	Unit Weight	Effective Cohesion	Effective Friction Angle
	Bedrock	Bedrock (Impenetrable)			
	Granular Fill	Mohr-Coulomb	21	0	32
	Peat/Topsoil	Mohr-Coulomb	16	2	25
	Rockfill	Mohr-Coulomb	19	0	42
	Silty Sand to Silt - Compact to Dense	Mohr-Coulomb	20	0	30



STABILITY ANALYSIS
HIGHWAY 17
SLOPE FLATTENING WITH 2H:1V
GRANULAR FILL
(NO CULVERT REPLACEMENT)

FIGURE 2

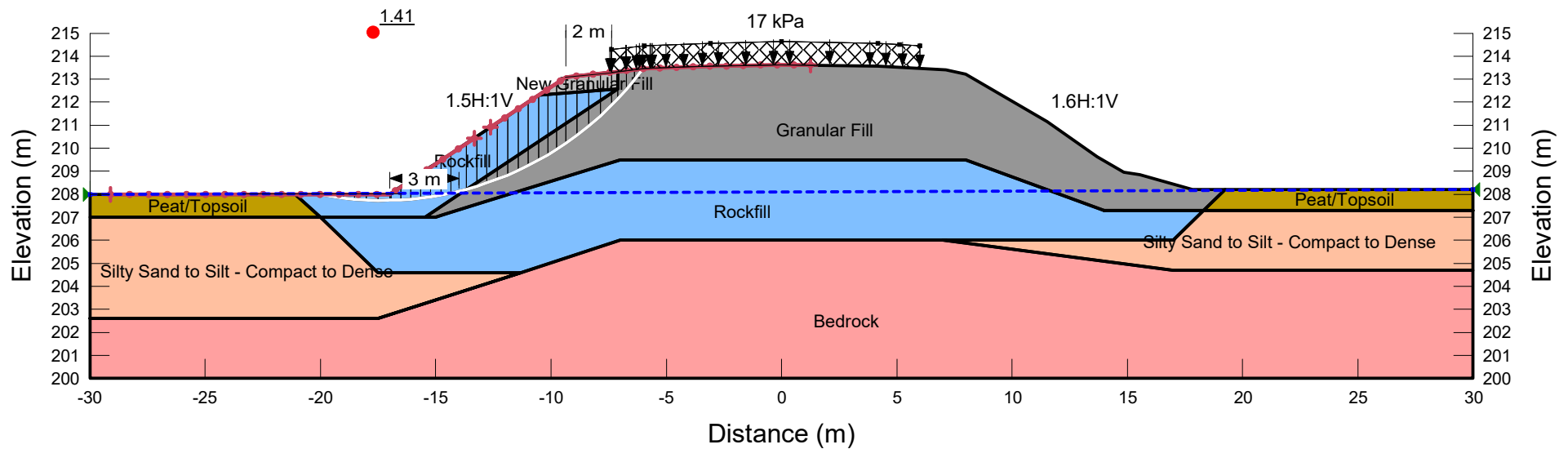
Color	Name	Slope Stability Material Model	Unit Weight	Effective Cohesion	Effective Friction Angle
<div></div>	Bedrock	Bedrock (Impenetrable)			
<div></div>	Granular Fill	Mohr-Coulomb	21	0	32
<div></div>	New Granular Fill	Mohr-Coulomb	21	0	32
<div></div>	Peat/Topsoil	Mohr-Coulomb	16	2	25
<div></div>	Rockfill	Mohr-Coulomb	19	0	42
<div></div>	Silty Sand to Silt - Compact to Dense	Mohr-Coulomb	20	0	30



**STABILITY ANALYSIS
HIGHWAY 17
SLOPE TREATMENT WITH 1.5H:1V
ROCK FILL
(NO CULVERT REPLACEMENT)**

FIGURE 3

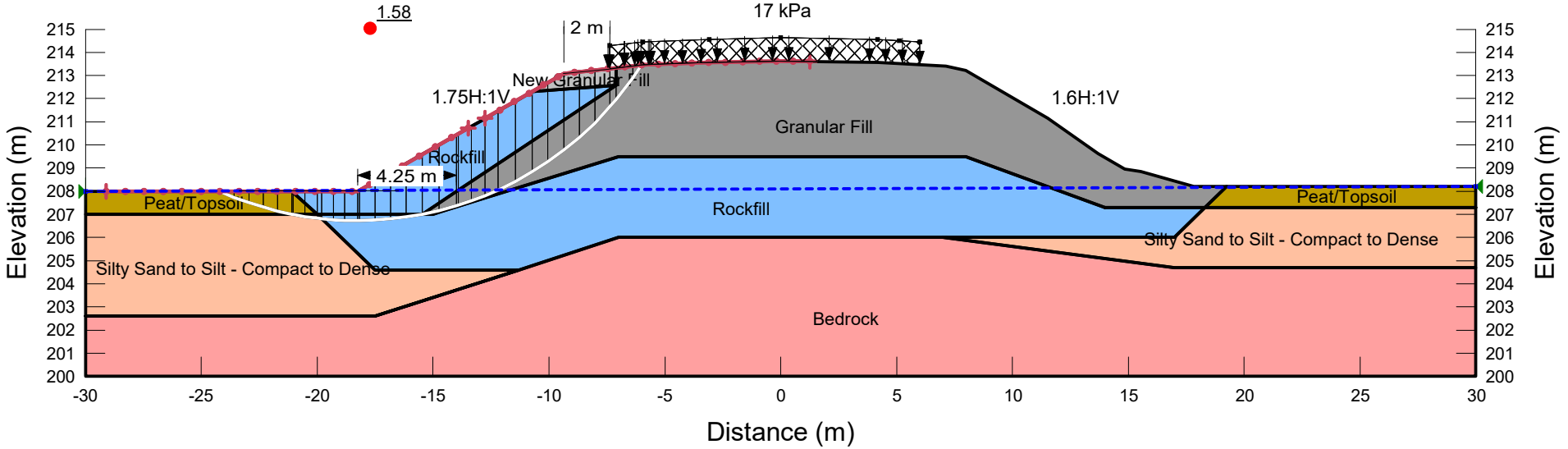
Color	Name	Slope Stability Material Model	Unit Weight	Effective Cohesion	Effective Friction Angle
	Bedrock	Bedrock (Impenetrable)			
	Granular Fill	Mohr-Coulomb	21	0	32
	New Granular Fill	Mohr-Coulomb	21	0	32
	Peat/Topsoil	Mohr-Coulomb	16	2	25
	Rockfill	Mohr-Coulomb	19	0	42
	Silty Sand to Silt - Compact to Dense	Mohr-Coulomb	20	0	30



**STABILITY ANALYSIS
HIGHWAY 17
SLOPE TREATMENT WITH 1.75H:1V
ROCK FILL
(NO CULVERT REPLACEMENT)**

FIGURE 3a

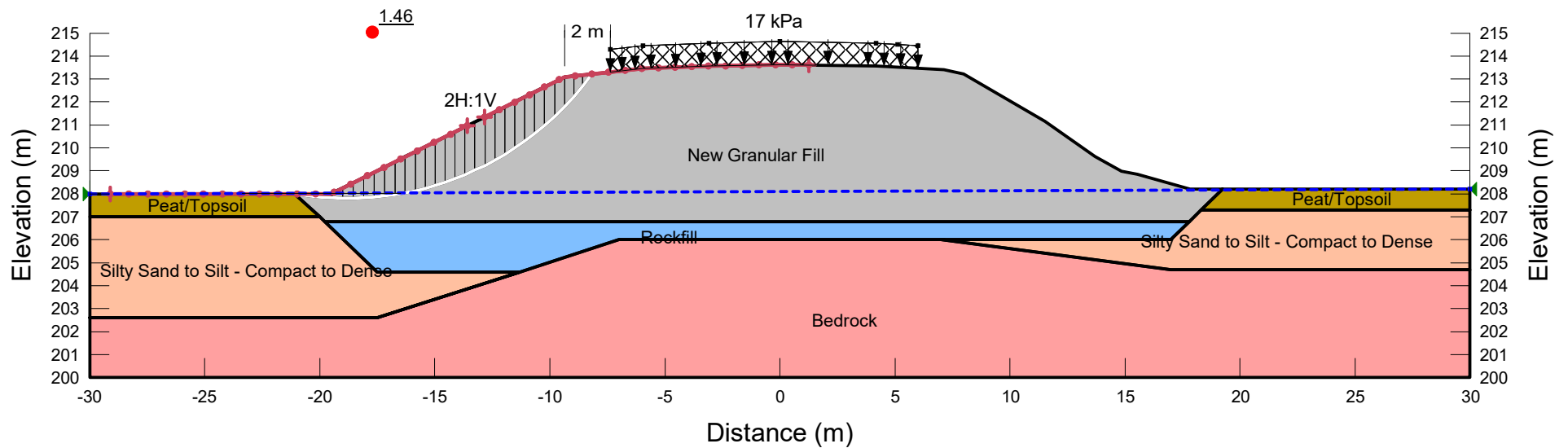
Color	Name	Slope Stability Material Model	Unit Weight	Effective Cohesion	Effective Friction Angle
■	Bedrock	Bedrock (Impenetrable)			
■	Granular Fill	Mohr-Coulomb	21	0	32
■	New Granular Fill	Mohr-Coulomb	21	0	32
■	Peat/Topsoil	Mohr-Coulomb	16	2	25
■	Rockfill	Mohr-Coulomb	19	0	42
■	Silty Sand to Silt - Compact to Dense	Mohr-Coulomb	20	0	30



**STABILITY ANALYSIS
HIGHWAY 17
CULVERT REPLACEMENT WITH
2H:1V GRANULAR BACKFILL**

FIGURE 4

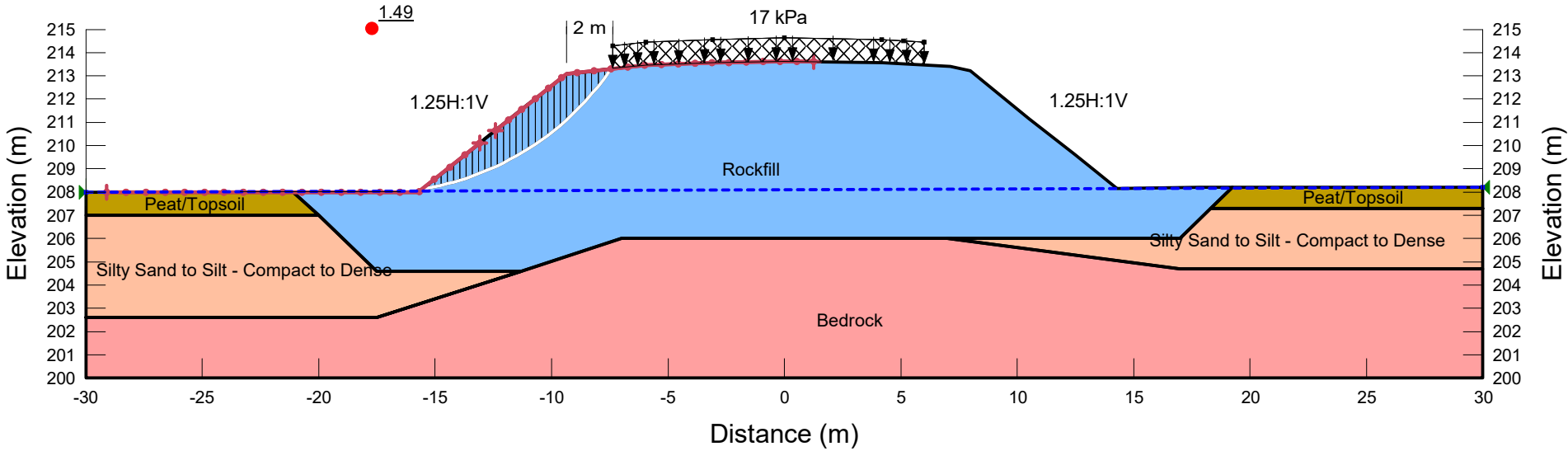
Color	Name	Slope Stability Material Model	Unit Weight	Effective Cohesion	Effective Friction Angle
■	Bedrock	Bedrock (Impenetrable)			
■	New Granular Fill	Mohr-Coulomb	21	0	32
■	Peat/Topsoil	Mohr-Coulomb	16	2	25
■	Rockfill	Mohr-Coulomb	19	0	42
■	Silty Sand to Silt - Compact to Dense	Mohr-Coulomb	20	0	30



STABILITY ANALYSIS HIGHWAY 17 CULVERT REPLACEMENT WITH 1.25H:1V ROCKFILL BACKFILL

FIGURE 5

Color	Name	Slope Stability Material Model	Unit Weight	Effective Cohesion	Effective Friction Angle
■	Bedrock	Bedrock (Impenetrable)			
■	Peat/Topsoil	Mohr-Coulomb	16	2	25
■	Rockfill	Mohr-Coulomb	19	0	42
■	Silty Sand to Silt - Compact to Dense	Mohr-Coulomb	20	0	30





Appendix G

List of Referenced OPSS and OPSD Documents and Suggested Wording for NSSPs



1. The following Special Provisions and OPSS Documents are referenced in this report:

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 209	Embankments over Swamps and Compressible Soils
OPSS.PROV 401	Construction Specification for Trenching, Backfilling, and Compacting
OPSS.PROV 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting
OPSS.PROV 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
SP 517F01	Dewatering System – Temporary Flow Passage System
SP FOUN0003	Dewatering Structure Excavations
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling Structures
SP 109S12	QVE, Backfilling Compaction, and Certificate of Conformance
OPSS.PROV 1004	Material Specification for Aggregates – Miscellaneous
OPSS 1005	Material Specification for Aggregates – Streambed Material
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
OPSD 208.010	Benching of Earth Slopes
OPSD 601.010	Asphalt Curb and Asphalt Curb with Gutter
OPSD 802.010	Flexible Pipe Embedment and Backfill Earth Excavation



OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.100	Foundation Frost Penetration Depths for Northern Ontario

2. Suggested Wording for NSSP

- **Suggested Text for NSSP on Dewatering**

It is anticipated that the culvert will be constructed in the wet. It should be noted that this option of constructing in the wet will still require some dewatering in order to lower the groundwater level to a sufficient depth to allow for placement of the culvert bedding in the dry.

The dewatering system is to be designed in accordance with SP FOUN0003 and OPSS.PROV. 517. A preconstruction survey is not required, thus Designer Fill-In ** in SP FOUN0003 should be "N/A". Special Provision FOUN0003 is included below. Considering the conditions on site, it is recommended that a dewatering engineer with a minimum of 5 years of experience in designing dewatering systems should be retained by the contractor for design of an effective dewatering system.

- **Suggested Text for NSSP on Obstructions**

Excavations and installation of piles may encounter obstructions such as cobbles and boulders embedded in the fill and native very dense sandy silt to silt and sand glacial till. Such obstructions may impede excavation progress and/or pile installations, if employed. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths.

DEWATERING STRUCTURE EXCAVATIONS - Item No.

Special Provision No. FOUN0003

March 8, 2018

Amendment to OPSS 902, November 2010

OPSS 902, November 2010, Construction Specification for Excavating and Backfilling - Structures is amended as follows:

902.02 REFERENCES

Section 902.02 of OPSS 902 is amended by the addition of the following:

Ontario Provincial Standard Specifications, Construction

OPSS 517 Dewatering
OPSS 805 Temporary Erosion and Sediment Control Measures

902.03 DEFINITIONS

Section 903.03 of OPSS 902 is amended by the addition of the following:

Automatic Transfer Switch means as defined in OPSS 517.

Cofferdam means as defined in OPSS 539.

Cut-Off Wall means as defined in OPSS 517.

Design Storm Return Period means as defined in OPSS 517.

Dewatering System means as defined in OPSS 517.

Groundwater Control System means as defined in OPSS 517.

Plug means as defined in OPSS 517.

Sediment means as defined in OPSS 517.

Sediment Control Measure means as defined in OPSS 517.

Temporary Flow Passage System means as defined in OPSS 517.

Unwatering means as defined in OPSS 517.

Vegetated Discharge Area means as defined in OPSS 517.

Waterbody means as defined in OPSS 517.

Watercourse means as defined in OPSS 517.

902.04 DESIGN AND SUBMISSION REQUIREMENTS

902.04.01 Design Requirements

902.04.01.01 Dewatering

Clause 902.04.01.01 of OPSS 902 is deleted in its entirety and replaced with the following:

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work.

When the system includes temporary flow passage system, the system shall be designed, as a minimum, for a [* Designer Fill-In, See Notes to Designer] year design storm return period, and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

The dewatering system shall be according to the design requirements specified in OPSS 517.

902.04.02 Submission Requirements

Subsection 902.04.02 of OPSS 902 is deleted in its entirety and replaced with the following:

902.04.02.01 Working Drawings

Working Drawings for the dewatering system shall be according to OPSS 517.

902.04.02.02 Preconstruction Survey

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of [** Designer Fill-In, See Notes to Designer] metres from the groundwater control system. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website <https://www.ontario.ca/environment-and-energy/map-well-records> or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

902.04.02.03 Milestone Inspections

Clause 902.04.02.03 of OPSS 902 is deleted in its entirety.

902.07 CONSTRUCTION

Subsection 902.07.04 of OPSS 902 is deleted in its entirety and replaced with the following:

902.07.04 Dewatering Structure Excavation

902.07.04.01 General

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation and deactivation of a temporary flow passage system, if applicable, shall be according to OPSS 517.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When a temporary flow passage system is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the system during the seasonal shutdown period.

Temporary erosion and sediment control measures, including controlling the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.

Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow passage systems shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

902.07.04.02 Discharge of Water

The discharge of water shall be according to OPSS 517.

902.07.04.03 Monitoring

Monitoring shall be according to OPSS 517.

902.07.04.04 System Amendments

Amendments to stop any displacement, damage, soil loss or erosion due to the operation of the dewatering system shall be according to OPSS 517.

902.07.04.05 Removal

Removal of dewatering system and temporary flow passage system components shall be according to OPSS 517.

NOTES TO DESIGNER:

Designer Fill-Ins

- * Fill in the design storm return period according to MTO Drainage Design Standard TW-1.
- ** Fill in the preconstruction survey distance as recommended by the foundation engineer.

WARRANT: Include with this standard tender item only on the recommendation of a foundation engineer.

CUSTODIAN: Tony Sangiuliano, MERO - Foundation Group.