



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
BEAVER CREEK BRIDGE REPLACEMENT  
GRIFFITH ROAD, AUBREY TOWNSHIP  
DISTRICT OF KENORA, ONTARIO  
LATITUDE: 49.795297°, LONGITUDE: -93.048117°**

**G.W.P. 6010-17-00, SITE NO. 41S-55**

**GEOCRES Number: 52F-63**

**Report**

**to**

**HATCH**

Date: May 15, 2019  
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**PART 1: FACTUAL INFORMATION**

**1. INTRODUCTION**

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed replacement of the Beaver Creek Bridge on Griffith Road, located west of Dryden, Ontario. Thurber carried out the investigation as a sub-consultant to Hatch under the Ministry of Transportation Ontario (MTO) Agreement Number 6017-E-0022.

The purpose of this investigation was to explore the subsurface conditions at the bridge location and, based on the data obtained, to provide a borehole location plan, stratigraphic profile, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

**2. SITE DESCRIPTION**

The site is located along Griffith Road, approximately 2 km south of Highway 17, in the Aubrey Township, District of Kenora, Ontario. The existing bridge allows Beaver Creek to flow from east to west under Griffith Road. Griffith Road runs in a north-south direction at the bridge site.

Based on the Ontario Structure Inspection Manual (OSIM) prepared by MTO on March 6, 2017, the existing structure is a three span steel rolled I-beam bridge with concrete deck built in 1945. The inspection report indicates that the bridge deck is 19.3 m long and 6 m wide with both end spans 6.6 m long and a center span of 6.1 m. The ground surface elevation at the existing bridge deck is approximately Elevation 349.0 m. The water level of Beaver Creek upstream and downstream of the bridge was measured at Elevation 345.12 m and 345.13 m, respectively, on July 24, 2018, as shown on survey drawings provided by MTO.



The OSIM report indicates that the ballast walls at the north and south approaches have experienced severe erosion. The north end abutment has experienced minor settlement. At the north end, the ballast wall is not long enough and does not span all of the timber piles. There are significant potholes at the south approach of the north bound lane. The piles supporting the bridge have a soft sound and severe splits in the south piles. Moderate splits are also found in the abutments. Spalling and honeycombing are also occurring on the soffit.

The lands surrounding the bridge site predominantly consist of farmland, and forested areas with lakes, swamps, rivers, and creeks. Local topography consists of undulating gullies of low relief. Photographs of the bridge and surrounding area are presented in Appendix C.

Based on published geological information, the bridge lies within an area consisting of silty clay subsurface soils overlying knobby bedrock. Based on local geological maps, the bedrock in the area is identified as granite.

### **3. INVESTIGATION PROCEDURES**

The current investigation and field testing program for the bridge replacement project was carried out between October 21 and October 25, 2018 and consisted of drilling and sampling six (6) boreholes, labeled BC-01 through BC-06, to a depths of approximately 10.2 to 20.0 m (Elevation 339.1 m to 329.0 m). Boreholes BC-01 and BC-06 were drilled at the north and south approach of the bridge, respectively. The remaining boreholes BC-02 through BC-05 were drilled near the bridge abutments with BC-02 and BC-03 on the north and BC-04 and BC-05 on the south side.

The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawings included in Appendix D.

Utility clearances were obtained prior to the start of drilling. The ground surface elevations for the boreholes were estimated from the cross sections and topographic drawings provided to Thurber by Hatch. The coordinate system MTM NAD 83, Zone 16 was used for the boreholes.

A rubber tired CME 750 drill rig was used to advance Boreholes BC-01 to BC-06 using solid stem augers and NW casing. Soil samples were obtained in the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Vane testing was carried out in the cohesive foundation soils. One Shelby Tube sample (Thin-Walled Tubes) of the foundation clay was collected from each of Borehole BC-02, BC-03, BC-04, BC-05, BC-06. NQ coring methods were used to advance the boreholes BC-03 and BC-04 into bedrock.



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 samples for transport to Thurber's laboratory for further examination and testing.

The rock cores were logged, and the Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined.

A piezometer was installed in Boreholes BC-03 and BC-04. Four groundwater measurements were taken from BC-03 and three from BC-04. The piezometers were decommissioned on October 26, 2018 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 Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
BC-01	10.2 / 338.8	None installed	Caved to 9.1 m, cuttings from 9.1 m to 2.1 m, bentonite holeplug from 2.1 m to 1.5 m, cuttings to surface
BC-02	14.6 / 334.4	None installed	Caved to 14 m, bentonite holeplug from 14 m to 0.9 m, dry cement to surface
BC-03	17.2 / 331.6	13.9 / 334.9	Caved to 16.9 m, bentonite holeplug from 16.9 m to 13.9 m, sand from 13.9 m to 8.5 m, bentonite holeplug from 8.5 m to 0.6 m, dry cement to surface
BC-04	20.0 / 329.0	16.5 / 332.5	Bentonite holeplug from 18.2 m to 16.2 m, sand from 16.2 m to 12.6 m, bentonite holeplug from 12.6 m to 0.9 m, dry cement to surface
BC-05	16.0 / 333.1	None installed	Caved to 8 m, bentonite from 8 m to 0.6 m, dry cement to surface
BC-06	10.2 / 339.1	None installed	Caved to 8 m, bentonite holeplug from 8 m to 0.9 m, dry cement to surface



#### **4. LABORATORY TESTING**

All recovered soil samples were subjected to visual identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (sieve and/or hydrometer) and Atterberg Limit testing, where appropriate. A one-dimensional consolidation test was conducted on a clay sample collected by Shelby Tube from Borehole BC-04. The results of this laboratory testing program are shown on the Record of Borehole sheets included in Appendix A and on the figures included in Appendix B.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, samples of the native soil from Borehole BC-02 at the north abutment and BC-05 from the south abutment were collected as were surface water samples from upstream of the bridge. The samples were then submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters and sulphate content. The results of the analytical testing from investigation are summarized in Section 6 and are presented in Appendix B.

#### **5. DESCRIPTION OF SUBSURFACE CONDITIONS**

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets and on the Borehole Locations and Soil Strata Drawing included in Appendix D. 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 conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions encountered consisted of embankment fill, consisting of silty clay overlying native silty clay which was then further underlain by granite bedrock. Descriptions of the individual strata are presented below.

##### **5.1 Silty Clay to Clay Fill**

Clay to silty clay fill, some silt, trace gravel, and trace to some organics and occasional cobbles was encountered at the ground surface in Boreholes BC-01 through BC-06. The fill extended to depths of between 1.5 m and 2.3 m (Elevation 346.7 m and 347.5 m) at the north abutment and



approach, and to a depth of approximately 2.3 m to 4.1 m (Elevation 345 m to 347 m) at the south abutment and approach.

SPT 'N' values in the silty clay fill ranged from 6 to 13 blows for 0.3 m penetration, indicating a firm to stiff consistency. The measured moisture content in the fill ranged from 21 to 37 percent.

The results of a grain size analysis and Atterberg Limit tests conducted on samples of the clay to silty clay fill are illustrated in Figure B1 and Figure B5 of Appendix B. The results are summarized as follows:

Soil Particle	Percentage
Gravel	2 to 6
Sand	15 to 35
Silt	17 to 22
Clay	42 to 62

Soil Property	Percentage
Liquid Limit	53 to 55
Plastic Limit	20 to 26
Plasticity Index	29 to 34

The results of the Atterberg Limit test indicate that the silty clay typically has a high plasticity with group symbol CH.

## 5.2 Silty Clay

Native Silty clay was encountered below the silty clay fill in Boreholes BC-01 to BC-06. Where fully penetrated in Boreholes BC-03, BC-04, and BC-05 the silty clay layer was approximately 11.2 m to 13.3 m thick and extended to depths of approximately 13.3 m to 16.3 m (Elevation 335.5 m to 332.7 m). Boreholes BC-01, BC-02, and BC-06 were terminated within the silty clay at depths of between 10.2 m and 14.6 m (Elevations 339.1 m to 334.4 m).

SPT 'N' values measured in the silty clay layer ranged from 0 to 9 blows for 0.3 m penetration at the north abutment and approach and 0 to 10 blows for 0.3 m penetration at the south abutment and approach. In-situ vane shear tests were conducted in the silty clay layer and measured undrained shear strengths of between 42 and 95 kPa. The results of the vane shear tests indicate the silty clay is firm to stiff. The measured moisture content in the silty clay to clay layer ranged from 30 to 84 percent.





The results of grain size analysis and Atterberg Limit tests conducted on samples of the silty clay layer are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B2, B3, B6, and B7 in Appendix B. The results are summarized as follows:

Soil Particle	Percentage
Gravel	0
Sand	0
Silt	18 to 37
Clay	63 to 82

Soil Property	Percentage
Liquid Limit	43 to 70
Plastic Limit	19 to 27
Plasticity Index	18 to 43

The results of the Atterberg Limit test indicate that the silty clay typically has a high plasticity with group symbol CH.

A consolidation test was performed on an undisturbed sample of the silty clay (thin walled tube sample), collected from Borehole BC-04. The results of the testing are presented in Appendix B and are summarized in the following table.

Borehole	Sample Depth (m)	$e_o$	$C_c$	$C_r$	$p_c'$ (kPa)	$p_o'$ (kPa)	OCR	$c_v$ (cm <sup>2</sup> /sec)
BC-04	7.6 – 8.2	2.28	1.67	0.12	130	90	1.44	$3 \times 10^{-2}$

### 5.3 Sand

Sand, which contained some sand, some silt and trace clay, was encountered below the native silty clay in Boreholes BC-03 to BC-05. At the north abutment, the sand layer was approximately 0.2 m thick and extended to bedrock contact at approximately 13.5 m (Elevation 335.3 m). At the south abutment the sand was approximately 0.3 m to 0.5 m thick and extended to bedrock contact at depths of approximately 16.8 m and 16.0 m (Elevation 332.2 m to 333.1 m).



SPT 'N' values measured in the silty clay ranged from 13 to 50 blows for 0.05 m to 0.3 m penetration. The results of the SPTs indicate the sand is compact to very dense at the south abutment and very dense at the north abutment. The measured moisture content in the sand ranged from 9 to 13 percent.

The results of grain size analysis on a sample of the sand is provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B4 of Appendix B. The results are summarized as follows:

Soil Particle	Percentage
Gravel	23
Sand	47
Silt and Clay	30

#### 5.4 Bedrock

The overburden soils described above are underlain by granite bedrock. The bedrock from BC-03 was white while the core recovered from BC-04 was pink and white. The bedrock is generally described as unweathered. Bedrock was proved by coring in boreholes BC-03 and BC-04, and Boreholes BC-02 and BC-05 were terminated on auger refusal on probable bedrock. The bedrock dips gently from the north abutment to the south abutment. Table 5.1 summarizes depths and elevations to the top of bedrock. Photographs of the rock cores are included in Appendix A.

**Table 5.1 - Depths and Elevations of Top of Bedrock**

Borehole	Top of Bedrock	
	Depth (m)	Elevation (m)
BC-03	13.5	335.3
BC-04	16.8	332.2

Total Core Recovery (TCR) in the bedrock was generally 100% and Solid Core Recovery (SCR) ranged between 87% and 100%. The Rock Quality Designation (RQD) determined from the recovered cores ranged between 77% and 100%, which indicates a good to excellent rock quality.

The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, ranged from 0 to 3. Average unconfined compressive strengths (UCS) of the rock typically ranged between 77 and 210 MPa, indicating the rock is strong to very strong. These estimated rock strength values are

interpreted from point load tests that were conducted on rock cores recovered from the boreholes. A summary of the point load tests results presented in Appendix B.

## 5.5 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. Piezometers were installed in BC-03 and BC-04. Groundwater level readings were measured regularly throughout the field investigation. A summary of the water level measurements are provided in Table 5.2 below:

**Table 5.2 - Groundwater Measurements**

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
BC-02	October 24, 2018	0.7	348.3	Open borehole
BC-03	October 23, 2018	0.8	348.0	Piezometer
	October 24, 2018	0.9	347.9	
	October 25, 2018	1.1	347.7	
	October 26, 2018	1.2	347.6	
BC-04	October 24, 2018	1.3	347.7	Piezometer
	October 25, 2018	1.4	347.6	
	October 26, 2018	1.4	347.6	

The groundwater level should be assumed to reflect the local creek water level. The water level of Beaver Creek upstream and downstream of the bridge was measured at Elevation 345.13 m and 345.12 m, respectively, in July 2018, as shown on drawings provided by Hatch.

These 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

In total, two samples of the fill, and a sample of the creek water from Beaver Creek were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.



**Table 6.1 - Analytical Test Results**

Parameter	Units (soil)	Units (water)	Test Results		
			BC-05 SS#4 3 m	BC-02 SS#2 0.8 m	BC-01
			Soil	Soil	Creek Water
Sulphide	%	µg/L	<0.02	<0.02	31
Chloride	µg/g	mg/L	7.4	2.6	4.5
Sulphate	µg/g	mg/L	6.9	0.5	1.8
pH	no unit	no unit	7.74	8.16	7.58
Conductivity	uS/cm	uS/cm	158	151	146
Resistivity	ohms.cm	ohms.cm	6330	6620	6849
Redox Potential	mV	mV	239	297	200

## 7. MISCELLANEOUS

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

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. Liam Steers. The visual assessment and overall supervision of the field program was conducted by Mr. Mark Farrant, P.Eng., of Thurber.

Geotechnical laboratory testing was carried out in Thurber's geotechnical laboratory. The consolidation test was conducted by TBT Engineering in Thunder Bay, Ontario. Analytical laboratory testing was carried out by SGS Canada Inc.



Interpretation of the field data and preparation of this report was carried out by Mr. Liam Steers, EIT and Cory Zanatta, 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**

**8. GENERAL**

This report provides an interpretation of the geotechnical data in the factual report and presents foundation recommendations for design of the proposed Beaver Creek Bridge replacement on Griffith Road, located in the Aubrey Township, District of Kenora, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The 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.

Information on the existing bridge site was obtained from the MTO Terms of Reference, the Ontario Structure Inspection Manuals (OSIMs) prepared by MTO on March 6, 2017. The existing structure is a three-span steel rolled I-beam bridge with concrete deck built in 1945. The inspection report indicates that the bridge deck is 19.3 m long and 6 m wide with both end spans 6.6 m long and a center span of 6.1 m. The existing bridge deck is supported on six (6) timber piles and timber pile caps at each of the abutments and the two center piers. The ground surface elevation at the existing bridge deck is approximately Elevation 349.0 m. The water level of Beaver Creek upstream and downstream of the bridge was measured at Elevation 345.12 m and 345.13 m, respectively, on July 24, 2018, as shown on survey drawings provided by MTO.



The OSIM report indicates that the ballast walls at the north and south approaches have experienced severe erosion. The north end abutment has experienced minor settlement. At the north end, the ballast wall is not long enough and does not span all of the piles. There are significant potholes at the south approach of the north bound lane. The piles supporting the bridge have a soft sound and severe splits in the south piles. Moderate splits are also found in the abutments. Spalling and honeycombing are also occurring on the soffit.

Preliminary General Arrangement Drawings and discussions with Hatch indicate that the replacement options being considered at this site consist of a single span modular bridge. The proposed bridge is 24.4 m long with 3.05 m approach ramps on each side and is approximately 8.56 m wide (outside to outside of truss). The proposed modular bridge is longer than the existing bridge. The replacement bridge may be designed as a single lane or a two-lane bridge. It is understood that a grade raise of 180 mm at the south abutment and 45 mm at the north abutment is proposed. A complete detour of Griffith Road is proposed during construction of the replacement bridge. Hence no staging for removal of the existing bridge is required.

## **9. STRUCTURE FOUNDATIONS**

The subsurface stratigraphy at the site typically consists of embankment fill, consisting of silty clay, overlying firm to stiff native silty clay underlain by granite bedrock.

Groundwater levels were measured in piezometers between Elevation 347.7 m and 347.6 m at the south abutment and between Elevation 348.0 m and 347.6 m at the north abutment. The water level of Beaver Creek upstream and downstream of the bridge was measured at Elevation 345.13 m and 345.12 m, respectively, in July 2017, as shown on survey drawings provided by MTO.

Based on the subsurface conditions, consideration was given to supporting the replacement modular bridge on the following foundation types:

- Spread footings placed on engineered granular fill pads, and
- Driven steel H-piles

A comparison of the technical advantages and disadvantages of the alternative foundation options is presented in Appendix F.

The native silty clay will offer low geotechnical resistance and footings founded directly on the native soil, without the use of engineered fill pads, are not considered feasible at this site. Hence recommendations were not developed further for this option.



Recommendations for design of feasible foundation alternatives are presented in the following sections together with the corresponding geotechnical design parameters. A preferred foundation option from a geotechnical perspective is recommended.

Sleeper slabs are proposed behind the abutments to support the approach ramps and will also be founded on engineered granular fill.

## **9.1 Spread Footings on Engineered Fill Pads**

### **9.1.1 Founding Level**

Based on the subsurface conditions encountered at this site. The use of spread footings placed on minimum 2 m thick engineered granular fill pads is considered feasible from a geotechnical perspective.

At both abutments, the base of the engineered fill pad may be placed on the native silty clay at or below Elevation 346.1 m.

### **9.1.2 Engineered Fill Construction**

The engineered fill pads should consist of OPSS Granular A or Granular B Type II placed in 150 mm lifts and compacted to 100% of its Standard Proctor Maximum Dry Density (SPMDD) at  $\pm 2\%$  of Optimum Moisture Content (OMC). A separation layer consisting of a non-woven geotextile should be placed between the subgrade soils and the engineered fill pads.

For construction of the engineered fill pad, the following construction sequence may be considered:

1. The minimum depth of excavation should accommodate the precast concrete bearing pad and the thickness of engineered fill pad below the bearing pad;
2. The subgrade for the engineered fill pad should be inspected and all organics, soft/loose soils, and any deleterious materials should be removed from the footprint of the excavation and replaced with compacted Granular A or Granular B Type II;
3. A separation layer consisting of a non-woven geotextile should be placed between the subgrade soils and the engineered fill pads.
4. Dewatering measures should be provided, as required, to place the engineered fill in the dry;





5. The dimensions of the base of the excavation should be determined by assuming a granular pad 1.0 m wider than the spread footing at the level of the footing base and projecting outward and downward at 1H:1V.

If the engineered fill pads are located close to the river valley, the forward slope of the foundation pads should be embedded at least 1.0 m below a 2H:1V face of the forward slope, with the edge of footing at a minimum of 2 m behind the crest of the forward slope. Provision of properly designed erosion protection works will be critical to ensure adequate performance of the foundations/engineered fill pads.

### **9.1.3 Axial Geotechnical Resistance and Geotechnical Reaction**

The replacement structure may be designed as a single lane or a two-lane bridge.

For a spread footing founded on a minimum 2 m thick engineered granular fill pad, with the base of the granular pad at about elevation 346.1 m, a minimum 3 m set back from the forward slope at 2H:1V and minimum 0.5 m depth of embedment of the concrete footing into the engineered granular fill pad, the following resistances are recommended:

- For a 1.5 m wide footing:
  - Factored ULS = 170 kPa
  - Factored SLS = 115 kPa
- For a 2 m wide footing:
  - Factored ULS = 150 kPa
  - Factored SLS = 100 kPa

The values of the factored Geotechnical Resistance at SLS correspond to up to 25 mm of settlement.

The value of Factored Geotechnical Resistance at ULS was assessed assuming a Consequence Factor equal to 1 (Typical), and a Resistance Factor equal to 0.5 (Typical degree of understanding of the subsurface conditions), as per Canadian Highway Bridge Design Code (CHBDC) 2014. The factored Geotechnical Resistance at SLS was assessed assuming a factor of 0.8 for typical degree of understanding of the subsurface conditions.

The geotechnical resistance quoted above is for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistance should be calculated as indicated in the CHBDC 2014 Clause 6.10.3 and Clause 6.10.4.



#### 9.1.4 Lateral Resistance

The lateral resistance of the concrete pad footings founded on engineered granular fill may be computed using an unfactored friction coefficient of 0.5. This is an “ultimate” value and requires a degree of sliding movement to occur to fully mobilize the resistance.

### 9.2 Steel H-Pile Foundations

Steel H-piles, driven to refusal on bedrock may be used to support both abutments. The piles should be installed behind the existing timber pile abutment foundation or the H-Piles for the new foundation should be spaced to avoid the existing timber piles. The existing timber piles should not be removed but can be cut down to an appropriate depth. The factored Geotechnical Resistances and the estimated tip elevations recommended for HP 310x110 piles driven to the bedrock surface are presented below in Table 9.2.

**Table 9.2 – Recommended Axial Geotechnical Resistances for Steel HP 310x110 Piles**

Foundation Element	Approximate Pile Length/Elevation Below Existing Ground (m)	Factored ULS Geotechnical Resistance Per Pile (kN)	SLS Resistance (kN)
South Abutment (BC-04, BC-05)	15.5* / 332.2	3,500	Does not govern
North Abutment (BC-02, BC-03)	12.4* / 335.3	3,500	Does not govern

\*Assuming base of pile cap at about Elevation 347.7 m.

The actual pile tip elevations may vary during installation due to the potential sloping bedrock.

The axial geotechnical resistances based on the bedrock strength are expected to exceed the factored structural capacity of the pile. Accordingly, the structural capacity of the HP 310x110 (2000 kN per pile) will govern the design.

The SLS condition will not govern the design of piles founded on bedrock.

The structural resistance of the pile must be checked by the structural designer.

It is understood that a grade raise of 180 mm at the south abutment and 45 mm at the north abutment is proposed. Any new fill placement at the abutments will result in development of



downdrag forces along the length of abutment piles associated with the consolidation of the silty clay foundation under the weight of the new fill.

For design purposes, an unfactored downdrag load of 300 kN per pile is recommended to evaluate the impact of downdrag on the abutments for the grade raise described above.

This downdrag load should be multiplied by a load factor of 1.25 as per CHBDC Commentary Clause C6.11.4.10 to obtain a factored downdrag load. In accordance with Section 6.11.4.10 of the CHBDC and Clause C6.11.4.10 of the Commentary, in the structural design of a pile, the factored downdrag load should be added to the factored permanent loads to assess the effects of downdrag. The factored dead and downdrag load should not exceed the factored structural resistance of a pile at the neutral plane.

If there is no grade raise or embankment widening proposed, downdrag on the piles will not be an issue at this site.

### 9.2.1 H-Pile Installation

Piles installation must be in accordance with OPSS.PROV 903.

The pile tips should be equipped pile tip protection from an approved manufacturer such as Titus Steel (Standard H-point), or approved equivalent.

### 9.2.2 Pile Lateral Resistance

The geotechnical lateral resistance acting on a pile in cohesive soils may be calculated using a value for the coefficient of horizontal subgrade reaction ( $k_s$ ) and ultimate lateral resistance ( $p_{ult}$ ) as follows:

$$\begin{aligned} k_s &= 67 S_u / D && (\text{kN/m}^3) \\ p_{ult} &= 9 S_u && (\text{kPa}) \text{ (at and below a depth of } 3D, \text{ reduced to zero at the ground surface)} \end{aligned}$$

Where  $S_u$  = undrained shear strength (kPa)  
 $D$  = pile width or diameter (m)

For analysis of the interaction between a pile and the surrounding soil, the above equations and parameters recommended in Table 9.3 below, may be used. The lateral pressures obtained from the analysis should not exceed the ultimate lateral resistance.

**Table 9.3 – Soil Parameters for Lateral Pile Resistance**

Abutment	Elevation	$S_u$ (kPa)	Unit Weight* (kN/m <sup>3</sup> )	Soil Conditions
South (BC-04, BC-05)	349.0 m to 345.0	50	10*	Firm to stiff silty clay fill
	345.0 to 332.2	40	10*	Firm to stiff silty clay
North (BC-02, BC-03)	349.0 m to 346.7	50	10*	Firm to stiff silty clay fill
	346.7 to 335.3	40	10*	Firm to stiff silty clay

\*Bouyant unit weight below groundwater level

The spring constant,  $K_s$ , for analysis may be obtained by the expression,  $K_s = k_s L D$  (kN/m), where  $k_s$  is the coefficient of horizontal subgrade reaction (kN/m<sup>3</sup>),  $D$  is the pile width (m) and  $L$  is the length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance,  $P_{ult}$ , may be obtained from the expression,  $P_{ult} = p_{ult} L D$ . This represents the ultimate load at which the pile fails and will not support any additional load at greater displacements.

The modulus of subgrade reaction and ultimate lateral resistance may have to be reduced, based on the pile spacing. The reduction factors to be used for a pile group oriented perpendicular or parallel to the direction of loading are provided in Section C.6.11.3.4 of CHBDC 2014.

Horizontal loads may be resisted by means of battered piles (i.e. for H-pile case) if load requirements exceed the available lateral pile resistances.

### 9.3 Frost Cover

The depth of frost penetration at this site is approximately 2.5 m, as per OPSD 3090.100. Typically, the base of all footings must be provided with a minimum of 2.5 m of earth cover as protection against frost action.

Concrete spread footings founded on granular engineered fill pads, provided they consist of non-frost susceptible, free draining engineered fill, above the river water level should be provided with a minimum embedment of 0.5 m. These footings do not need to be placed below the depth of



frost. If the design changes to a conventional bridge instead of a modular bridge, then at least 2.5 m of frost cover will be required for all footings.

#### **9.4 Sleeper Slab**

It is understood that a 0.85 m wide precast concrete sleeper slab will be utilized at both the north and south abutments to support the bridge deck ramp. Based on Preliminary General Arrangement Drawings, the base of the sleeper slab will be founded on engineered granular fill with a minimum thickness of 1 m. The compacted granular pad should consist of OPSS Granular A, placed in 150 mm thick lifts and compacted to 100% of the SPMDD at  $\pm 2\%$  of Optimum Moisture Content (OMC)

The recommended geotechnical resistance at the ULS and SLS for a 0.85 m wide precast concrete pad founded on a 1 m thick granular pad founded on the upper silty clay fill are given below:

- For a sleeper slab at the crest of a 1.5H:1V slope:
  - Factored ULS of 115 kPa
  - Factored SLS (for up to 25 mm settlement) of 75 kPa
- For a sleeper slab 0.5 m behind the crest of a 1.5H:1V slope:
  - Factored ULS of 160 kPa
  - Factored SLS (for up to 25 mm settlement) of 100 kPa

Resistance to lateral forces/sliding resistance between the concrete slab and the underlying granular material should be calculated assuming an ultimate coefficient of friction of 0.5.

#### **9.5 Recommended Foundation**

Due to the firm to stiff silty clay soils at the site, a foundation supported on spread footings would have a higher risk of differential settlement than a foundation supported on steel H-piles driven to bedrock. The spread-footing option will also require deeper excavation and dewatering, which may make it difficult to place the engineered fill in the dry. A steel H-pile foundation can achieve higher geotechnical resistances and presents less issues for construction. Furthermore, based on discussions with Hatch, it is understood that the H-pile foundation option is slightly less expensive than the spread footing option at this site; it will have a shorter construction time; and it will offer increased flexibility in accommodating an increase load demand if the roadway is upgraded to a two-lane platform in the future. Therefore, H-piles driven to bedrock is the recommended foundation type for the replacement bridge at this site.



## 10. LATERAL EARTH PRESSURES

Backfill behind the abutments should be in accordance with OPSS 902. Granular backfill should be placed to the extents shown in OPSD 3101.150. All granular material should meet the specifications of OPSS 1010 as amended by Special Provision 110S13. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501 and SP 105S21.

Earth pressures acting on the abutment walls may be assumed to be triangular and to be governed by the characteristics of the abutment backfill and the underlying native soils. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are 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 10.1)

$\gamma$  = unit weight of retained soil (see Table 10.1)

$h$  = depth below top of fill where pressure is computed (m)

$q$  = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are shown in Table 10.1.

**Table 10.1 – Earth Pressure Coefficient (K)**

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Existing Sand and Gravel Fill $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface	Sloping Surface in front of Wall (2H:1V)	Horizontal Surface	Sloping Surface in front of Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At rest (Restrained Wall)	0.43	-	0.47	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-

In conventional design, 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 wall.

The factors in Table 10.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to use in design can be estimated from Figure C6.16 in the Commentary to the Canadian Highway Bridge Design Code.

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or 1.7 m for Granular A or Granular B Type II.

## **11. 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 silty clay to clay fill, and native silty clay soils at this site are classified as Type 3 soils above and below the groundwater level.

Excavation and backfilling for the bridge construction should be carried out in accordance with OPSS 902. Excavations for the bridge replacement will be carried out through the existing silty clay fill and native silty clay. It must be noted that obstructions may be encountered within the fill such as old timber foundations.



Installation of the foundations should be carried out in the dry. If the excavations for spread footing abutments are expected to extend below the river water level, then seepage should also be anticipated from the embankment fill. In this case, the water level must be depressed below the base of the excavation to permit construction in the dry and to facilitate compaction of the bedding and backfill materials.

Excavation for removal of existing foundation components, if required, should be maintained above the water level in the creek. Any excavation below the groundwater level/creek level without prior dewatering is not recommended since the inflow of groundwater will make it difficult to maintain a dry, sound base on which to work. Consideration should be given to leaving as much of the old timber foundation in place if it does not interfere with construction of the new abutment and its foundation.

The design of 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. SP FOUN0003 has been included in Appendix G.

In accordance with SP FOUN0003, the dewatering system is to be designed in accordance with OPSS.PROV 517. A preconstruction survey is not required, thus Designer Fill-In \*\*\*\*\* in SP FOUN0003 should be "N/A".

Dewatering must remain operational and effective until the bridge foundations are installed and backfilled. Suggesting wording for an NSSP in this regard is included in Appendix G.

## **12. SEISMIC CONSIDERATIONS**

In accordance with the CHBDC 2014, the selection of the seismic site class is based on the soil conditions encountered in the upper 30 m of the stratigraphy. In view of the presence of firm to stiff silty clay deposits the site is classified as Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2,475-year return period seismic event at this site is 0.043 g as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures 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 12.1 may be used:



**Table 12.1 – 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 $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Existing Fill $\phi = 28^\circ; \gamma = 20 \text{ kN/m}^3$
Active ( $K_{AE}$ )*	0.29	0.33	0.38
At Rest ( $K_{OE}$ )**	0.50	0.54	0.60
Passive ( $K_{PE}$ )	3.6	3.2	2.7

\* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.

\*\* After Woods

The site is underlain by silty clay and relatively shallow bedrock. In view of the cohesive soils, and low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

### 13. SCOUR AND EROSION PROTECTION

Erosion protection should be provided along any soil surfaces that may be in contact with the creek flow. In particular, adequate erosion protection must be provided to prevent loss of soils in front of the abutment walls. The erosion protection must be designed by a specialist engineer experienced in river hydraulics.

A vegetation cover should be established on all other exposed earth surface to protect against surficial erosion, in general accordance with OPSS 804.

### 14. APPROACH EMBANKMENTS

The existing Griffiths Road embankment fill is approximately 3.5 m in height at the existing bridge location with side slopes of approximately 2.5H:1V. The side slopes of the approach embankments appear to be in stable condition, however the forward slopes show significant signs of erosion. A stability analysis was conducted for the existing south west embankment side slope. Figure E1 of Appendix E shows the slope to be stable with a Factor of Safety of 1.53.

A grade raise of 180 mm at the south abutment and 45 mm at the north abutment is proposed at this site. This additional fill is expected to cause settlements of less than 25 mm at the abutments.

At both abutments, provided that any embankment reconstruction is completed at the same slope inclination as the existing embankment, but not steeper than 2H:1V, the restored embankment



slope should remain stable provided proper steps to mitigate erosion are taken as described in Section 13.

Embankment restoration after completion of the bridge replacement should be carried out in accordance with OPSS.PROV 206 and OPSS.PROV 209. The embankment material may consist of imported Granular A, Granular B Type II, or Granular B Type III material.

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

## **15. CORROSION AND SULPHATE ATTACK POTENTIAL**

The results of the corrosivity and sulphate analytical tests conducted on the samples of the silty clay and creek water indicate the following conditions at the locations tested:

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

## **16. CONSTRUCTION CONCERNS**

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

- Cobbles, boulders and rock protection are exposed on the forward slopes of the existing approach embankments. The Contractor must be prepared to remove or otherwise penetrate these obstructions prior to driving piles. Suggested wording for an NSSP on obstructions is included in Appendix G.
- Firm native silty clay deposits are present at this site and settlement will occur if a grade raise or embankment widening is implemented.
- A suitable dewatering / unwatering system must be employed to enable foundation construction in the dry and prevent sloughing and instability of the excavation walls. The use of spread footings on engineered fill pads may create a 'bathtub' condition, and proper drainage methods will need to be used.

- The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor. Suggested wording for a Geotechnical Assessment for the use of heavy construction equipment is included in Appendix G.

## 17. CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Cory Zanatta, P.Eng. and Mr. Keli Shi, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

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Geotechnical Engineer



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Review Principal, Designated MTO Contact



## **Appendix A**

### **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 <sup>(1)</sup> '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

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


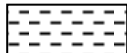



 Water Level  
 Shear Strength Determination by Pocket Penetrometer

- (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 <sub>L</sub> < 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 <sub>L</sub> < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W <sub>L</sub> < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W <sub>L</sub> > 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>	
<b>Fresh (FR)</b>	No visible signs of weathering.		
<b>Fresh Jointed (FJ)</b>	Weathering limited to the surface of major discontinuities.		CLAYSTONE
<b>Slightly Weathered (SW)</b>	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
<b>Moderately Weathered (MW)</b>	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
<b>Highly Weathered (HW)</b>	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
<b>Completely Weathered (CW)</b>	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.				

# RECORD OF BOREHOLE No BC-01

1 OF 2

METRIC

GWP# 6010-70-00 LOCATION Beaver creek Bridge N 5 517 554.3 E 301 333.1 ORIGINATED BY LS  
DIST HWY Griffith Road BOREHOLE TYPE Hollow Stem Augers/Solid Stem Augers COMPILED BY MP  
DATUM Geodetic DATE 2018.10.21 - 2018.10.21 LATITUDE LONGITUDE CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT		UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE		W P      W      W L WATER CONTENT (%)			
349.0	GROUND SURFACE							20   40   60   80   100					
0.0	Silty <b>CLAY</b> , trace sand Stiff Brown Moist (FILL)		1	GS									
			1	SS	11								
347.5													
1.5	Silty <b>CLAY</b> Firm to Stiff Grey Wet (CH to CI)		2	SS	6								
			3	SS	9								
			4	SS	6								
	Very Soft to Stiff		5	SS	1								0   0   20   80
			6	SS	0								0   0   20   80
	becoming grey and brown		7	SS	1								

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE



RECORD OF BOREHOLE No BC-01

2 OF 2

METRIC

GWP# 6010-70-00 LOCATION Beaver creek Bridge N 5 517 554.3 E 301 333.1 ORIGINATED BY LS  
DIST HWY Griffith Road BOREHOLE TYPE Hollow Stem Augers\Solid Stem Augers COMPILED BY MP  
DATUM Geodetic DATE 2018.10.21 - 2018.10.21 LATITUDE LONGITUDE CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
338.8	Continued From Previous Page																
10.2	END OF BOREHOLE AT 10.2m. BOREHOLE OPEN TO 9.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 2.1m, BENTONITE HOLEPLUG TO 1.5m, THEN CUTTINGS TO SURFACE.																

# RECORD OF BOREHOLE No BC-02

1 OF 2

METRIC

GWP# 6010-70-00 LOCATION Beaver creek Bridge N 5 517 545.8 E 301 332.8 ORIGINATED BY LS  
 DIST HWY Griffith Road BOREHOLE TYPE Solid Stem Augers/Casing Advance COMPILED BY MP  
 DATUM Geodetic DATE 2018.10.24 - 2018.10.24 LATITUDE LONGITUDE CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	
349.0	GROUND SURFACE											
0.0	Silty <b>CLAY</b> , trace to some sand, trace to some organics, trace gravel Stiff to Firm Brown Moist (FILL)		1	GS								
			1	SS	13		348					
			2	SS	7		347					
346.7												
2.3	Silty <b>CLAY</b> Firm to Stiff Brown and Grey Wet (CH)		3	SS	3		346					0 0 23 77
			4	SS	2							
							345					
			5	SS	0		344					
			6	SS	0		343					0 0 18 82
							342					
			7	SS	0		341					
							340					
			1	TW								

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No BC-02

2 OF 2

METRIC

GWP# 6010-70-00 LOCATION Beaver creek Bridge N 5 517 545.8 E 301 332.8 ORIGINATED BY LS  
 DIST HWY Griffith Road BOREHOLE TYPE Solid Stem Augers\Casing Advance COMPILED BY MP  
 DATUM Geodetic DATE 2018.10.24 - 2018.10.24 LATITUDE LONGITUDE CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
Continued From Previous Page								20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
								20 40 60 80 100 WATER CONTENT (%) W P W W L								
	Silty <b>CLAY</b> Firm to Stiff Brown and Grey Wet (CH)						338									
			8	SS	0		337									
							336									
			9	SS	0		335									
			10	SS	0											
334.4			11	SS	20/											
14.6	END OF BOREHOLE AT 14.6m UPON AUGER REFUSAL ON BEDROCK. BOREHOLE OPEN TO 14.0m AND WATER LEVEL AT 0.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS TO 2.1m, BENTONITE HOLEPLUG TO 0.9m, THEN CEMENT TO SURFACE.				0.075											

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No BC-03

1 OF 2

METRIC

GWP# 6010-70-00 LOCATION Beaver creek Bridge N 5 517 542.9 E 301 339.4 ORIGINATED BY LS  
 DIST HWY Griffith Road BOREHOLE TYPE Hollow Stem Augers/Casing Advance/NQ Coring COMPILED BY MP  
 DATUM Geodetic DATE 2018.10.22 - 2018.10.22 LATITUDE LONGITUDE CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		<div><div>PLASTIC LIMIT</div><div>NATURAL MOISTURE CONTENT</div><div>LIQUID LIMIT</div></div> <div><div>W<sub>P</sub></div><div>W</div><div>W<sub>L</sub></div></div> <div>WATER CONTENT (%)</div>	UNIT WEIGHT <div>γ</div> kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
348.8	GROUND SURFACE							20 40 60 80 100				
0.0	Silty <b>CLAY</b> , with sand, trace gravel, trace to some organics Firm Brown Moist (FILL) (CH)		1	GS				○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				6 35 17 42
			1	SS	8		348					
			2	SS	8		347					
346.7	Grey											
2.1	Silty <b>CLAY</b> Firm to Stiff Brown and Grey Moist (CH to CI)											
			3	SS	3		346					
			4	SS	1		345					
							344					
	becoming grey		5	SS	0		343					
							342					
	becoming grey and red		6	SS	1		341					
			7	SS	0		340					
	becoming grey											
							339					
			1	TW	PH							
			2	GS								

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity 20  
15 10 5 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No BC-03

2 OF 2

METRIC

GWP# 6010-70-00 LOCATION Beaver creek Bridge N 5 517 542.9 E 301 339.4 ORIGINATED BY LS  
DIST HWY Griffith Road BOREHOLE TYPE Hollow Stem Augers/Casing Advance/NQ Coring COMPILED BY MP  
DATUM Geodetic DATE 2018.10.22 - 2018.10.22 LATITUDE LONGITUDE CHECKED BY CZ

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 <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20   40   60   80   100	○ UNCONFINED      + FIELD VANE	W <sub>P</sub> W      W <sub>L</sub>	20   40   60	GR   SA   SI   CL			
	Continued From Previous Page							● QUICK TRIAXIAL      × LAB VANE <td>20   40   60   80   100<td>20   40   60<td></td><td></td><td></td><td></td></td></td>	20   40   60   80   100 <td>20   40   60<td></td><td></td><td></td><td></td></td>	20   40   60 <td></td> <td></td> <td></td> <td></td>					
	Silty <b>CLAY</b> Firm to Stiff Grey and Red Moist (CH to CI)		8	SS	0		338	2.6 +						0   0   28   72	
							337	4.0 +							
			9	SS	0		336								
335.5															
13.3	<b>SAND</b> , some silt, some gravel, trace clay, occasional cobbles Very Dense Brown Wet		10	SS	50/ 0.150		335						FI	RUN #1 TCR=41% SCR=0% RQD=0%	
13.5	<b>BEDROCK(Granite)</b> , unweathered, grey sub horizontal fracture (25mm) at 13.9m quartz vein (175mm) at 14.2m		1	RUN			335						>10	RUN #2 TCR=91% SCR=89% RQD=87% UCS=209.7MPa (Average)	
	mechanical fracture at 15.3m		2	RUN			334						0		
													0		
													0		
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+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity 20  
15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No BC-04

1 OF 3

METRIC

GWP# 6010-70-00 LOCATION Beaver creek Bridge N 5 517 506.8 E 301 334.6 ORIGINATED BY LS  
 DIST HWY Griffith Road BOREHOLE TYPE Solid Stem Augers\Casing Advance\NQ Coring COMPILED BY MP  
 DATUM Geodetic DATE 2018.10.23 - 2018.10.23 LATITUDE LONGITUDE CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT		UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20    40    60    80    100	W <sub>P</sub> W                      W <sub>L</sub>	20    40    60				
349.0	GROUND SURFACE							SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE		WATER CONTENT (%)				
0.0	<b>CLAY</b> , some silt, some sand, trace gravel Stiff Brown Moist (FILL) (CH)		1	GS										
			1	SS	11									
			2	SS	11									
			3	SS	12									
346.0	Silty <b>CLAY</b> Firm to Stiff Grey and Brown Moist to Wet (CH to CI)      becoming grey		4	SS	6									
3.0														
			5	SS	0									
			6	SS	0									
			1	TW	PH									
			2	GS										
			7	SS	0									

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No BC-04

2 OF 3

METRIC

GWP# 6010-70-00 LOCATION Beaver creek Bridge N 5 517 506.8 E 301 334.6 ORIGINATED BY LS  
 DIST HWY Griffith Road BOREHOLE TYPE Solid Stem Augers\Casing Advance\NQ Coring COMPILED BY MP  
 DATUM Geodetic DATE 2018.10.23 - 2018.10.23 LATITUDE LONGITUDE CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
	Continued From Previous Page							20 40 60 80 100						GR SA SI CL
	Silty <b>CLAY</b> Firm to Stiff Grey and Brown Moist to Wet (CH to CI)							2.3 +						
			8	SS	0		338							
							337	3.3 +						
			9	SS	0									0 0 24 76
							336							
								3.3 +						
			10	SS	0		335							
							334	6.5 +						
			11	SS	0									0 0 37 63
							333							
332.7														
16.3	<b>SAND</b> , some gravel, some silt, trace clay, occasional cobbles Very Dense Grey Wet		12	SS	50/									
332.2					0.050		332						FI 0	RUN #1 TCR=100% SCR=95% RQD=100% UCS=103.5MPa (Average)
16.8	<b>BEDROCK(Granite)</b> , unweathered, pink and grey, coarse grained mechanical fracture at 16.9m and 18.3m quartz seam (50mm) at 17.2m, 17.8m sub horizontal fracture (325mm) at 17.2m horizontal fracture at 17.7m and (25mm) at 17.9m  quartz vein (150mm) at 18.4m and (50mm) at 19.3m mechanical fracture at 18.5m, 19.3m, 19.6m, 19.8m and 19.9m		1	RUN									1 0	
							331						2 0	
													0 0	RUN #2 TCR=100% SCR=87% RQD=77% UCS=77.2MPa (Average)
			2	RUN			330						1 0	
													1 3 0	
329.0	moderately weathered from 19.4m to 19.5m horizontal fracture at 19.4m, 19.6m and 19.7m													

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity 20  
15 10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No BC-04

3 OF 3

METRIC

GWP# 6010-70-00 LOCATION Beaver creek Bridge N 5 517 506.8 E 301 334.6 ORIGINATED BY LS  
 DIST HWY Griffith Road BOREHOLE TYPE Solid Stem Augers\Casing Advance\NQ Coring COMPILED BY MP  
 DATUM Geodetic DATE 2018.10.23 - 2018.10.23 LATITUDE LONGITUDE CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL											
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)															
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>														
20.0	<p>Continued From Previous Page</p> <p>END OF BOREHOLE AT 20.0 m. Piezometer installation consists of 50mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.</p> <p>WATER LEVEL READINGS</p> <table border="1"> <thead> <tr> <th>DATE</th> <th>DEPTH(m)</th> <th>ELEV.(m)</th> </tr> </thead> <tbody> <tr> <td>2018.10.24</td> <td>1.3</td> <td>347.7</td> </tr> <tr> <td>2018.10.25</td> <td>1.4</td> <td>347.6</td> </tr> <tr> <td>2018.10.26</td> <td>1.4</td> <td>347.6</td> </tr> </tbody> </table>	DATE	DEPTH(m)	ELEV.(m)	2018.10.24	1.3	347.7	2018.10.25	1.4	347.6	2018.10.26	1.4	347.6															
DATE	DEPTH(m)	ELEV.(m)																										
2018.10.24	1.3	347.7																										
2018.10.25	1.4	347.6																										
2018.10.26	1.4	347.6																										



# RECORD OF BOREHOLE No BC-05

1 OF 2

METRIC

GWP# 6010-70-00 LOCATION Beaver creek Bridge N 5 517 507.1 E 301 339.4 ORIGINATED BY LS  
 DIST HWY Griffith Road BOREHOLE TYPE Solid Stem Augers/Casing Advance COMPILED BY MP  
 DATUM Geodetic DATE 2018.10.25 - 2018.10.25 LATITUDE LONGITUDE CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS ▽*	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)		
								○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE					w <sub>p</sub> w    w <sub>L</sub>		
349.1	GROUND SURFACE							20 40 60 80 100		20 40 60					
0.0	Silty <b>CLAY</b> , some sand, trace gravel, occasional cobbles Firm to Stiff Brown Moist (FILL) (CH)		1	GS			349								
			1	SS	8		348						3 15 22 60		
			2	SS	7		347								
			3	SS	10		346								
	Grey														
			4	SS	6		345					2 17 19 62			
345.0															
4.1	Silty <b>CLAY</b> , trace sand Firm to Stiff Grey Moist (CH to CI) Wet, becoming brown		5	SS	2		344								
	becoming grey		6	SS	0		343								
	becoming grey and brown	7	SS	0		342									
	becoming grey	8	SS	0		340									

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

**METRIC**[illegible]


+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No BC-06

2 OF 2

METRIC

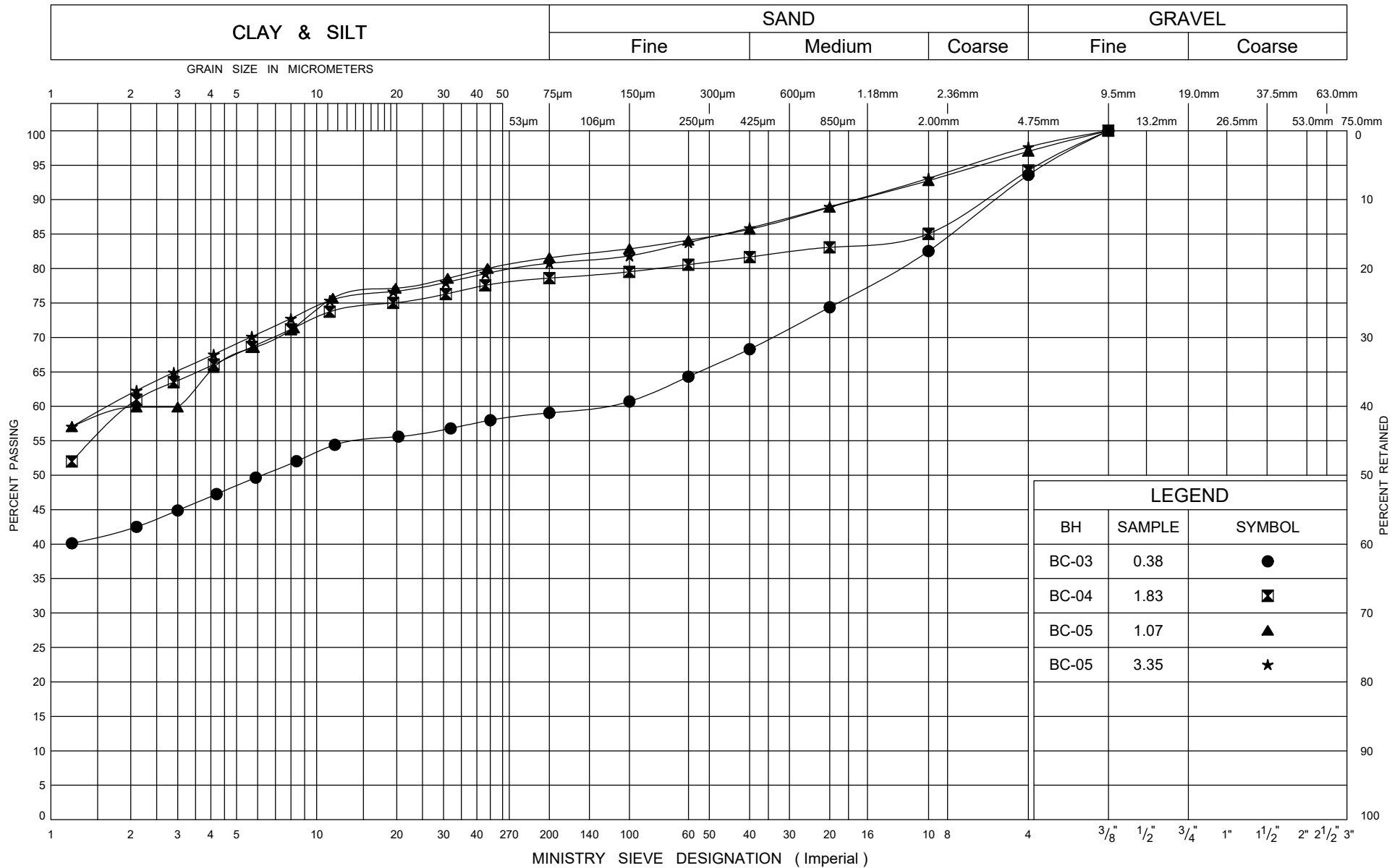
GWP# 6010-70-00 LOCATION Beaver creek Bridge N 5 517 495.3 E 301 339.8 ORIGINATED BY LS  
 DIST                      HWY Griffith Road BOREHOLE TYPE Solid Stem Augers\Casing Advance COMPILED BY MP  
 DATUM Geodetic DATE 2018.10.25 - 2018.10.25 LATITUDE                      LONGITUDE                      CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER * CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>	
339.1	Continued From Previous Page															
10.2	END OF BOREHOLE AT 10.2m. BOREHOLE OPEN TO 7.9m AND WATER LEVEL AT GROUND SURFACE UPON COMPLETION. BOREHOLE BACKFILLED WITH CUTTINGS AND BENTONITE HOLEPLUG TO 0.9m, THEN DRY CEMENT TO SURFACE.															



## **Appendix B**

### **Geotechnical and Analytical Laboratory Test Results**



Ministry of  
Transportation

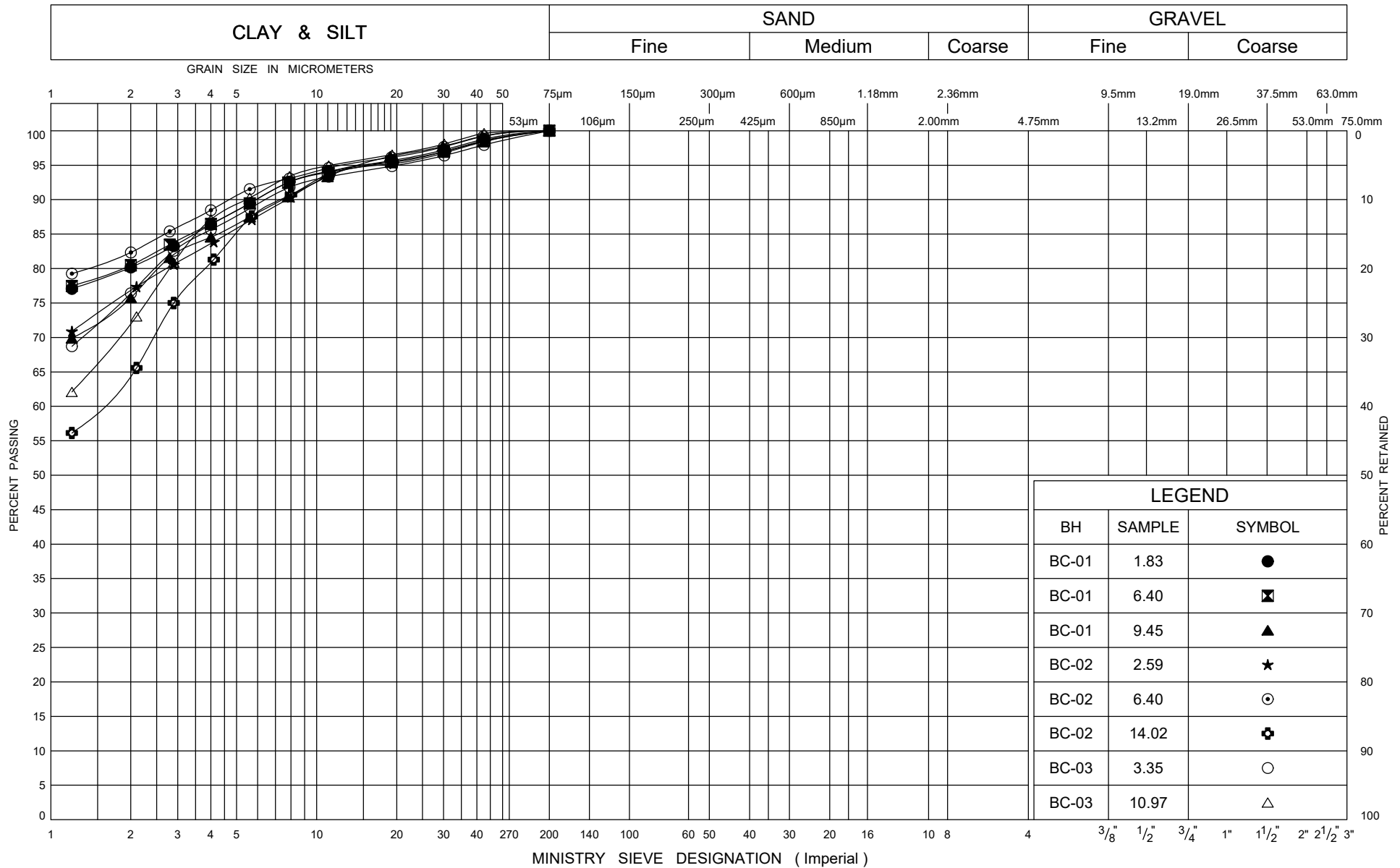
## GRAIN SIZE DISTRIBUTION

Silty CLAY to CLAY FILL

FIG No B1

W P 6010-70-00

Beaver creek Bridge



Ministry of  
Transportation

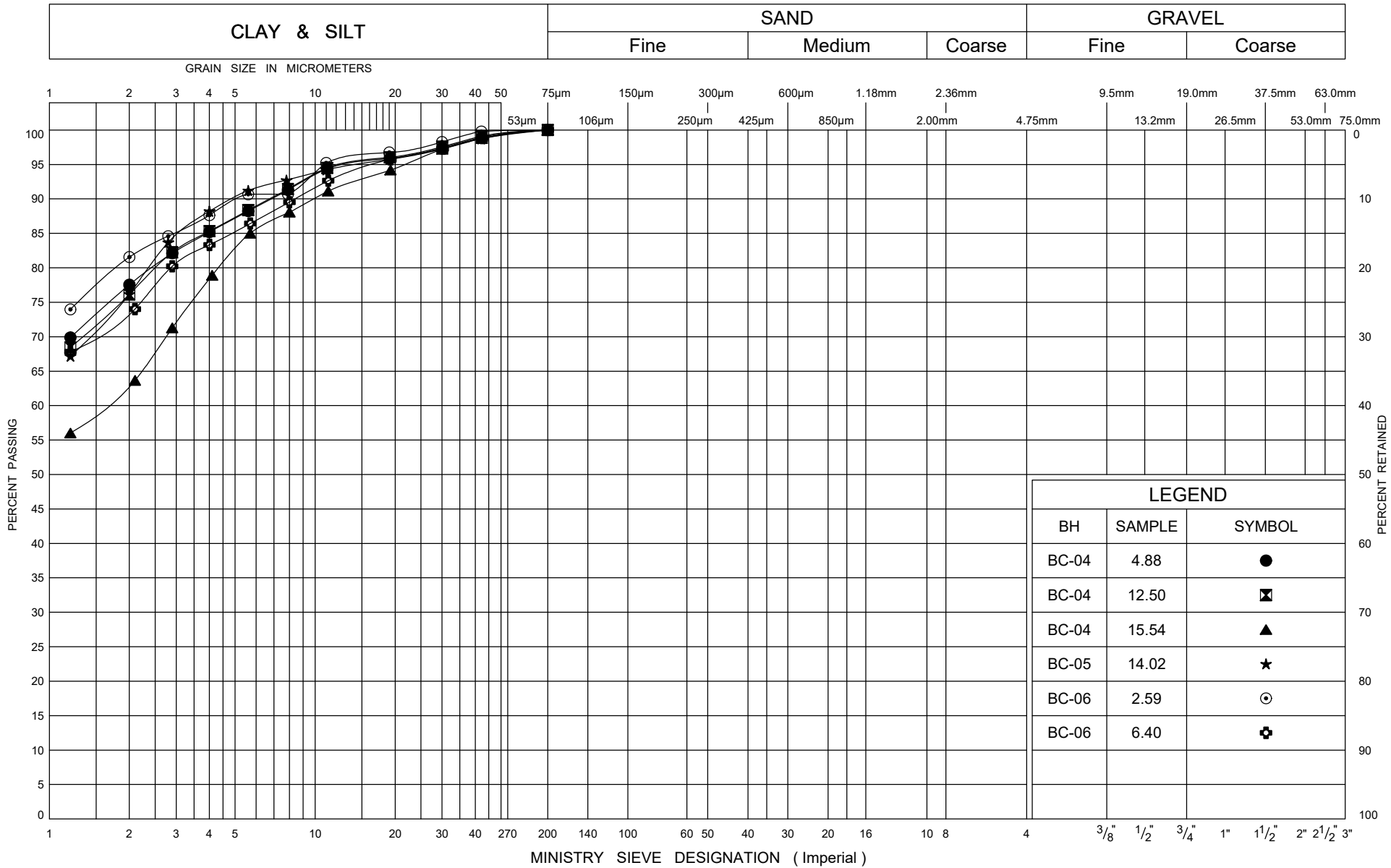
## GRAIN SIZE DISTRIBUTION

Silty CLAY

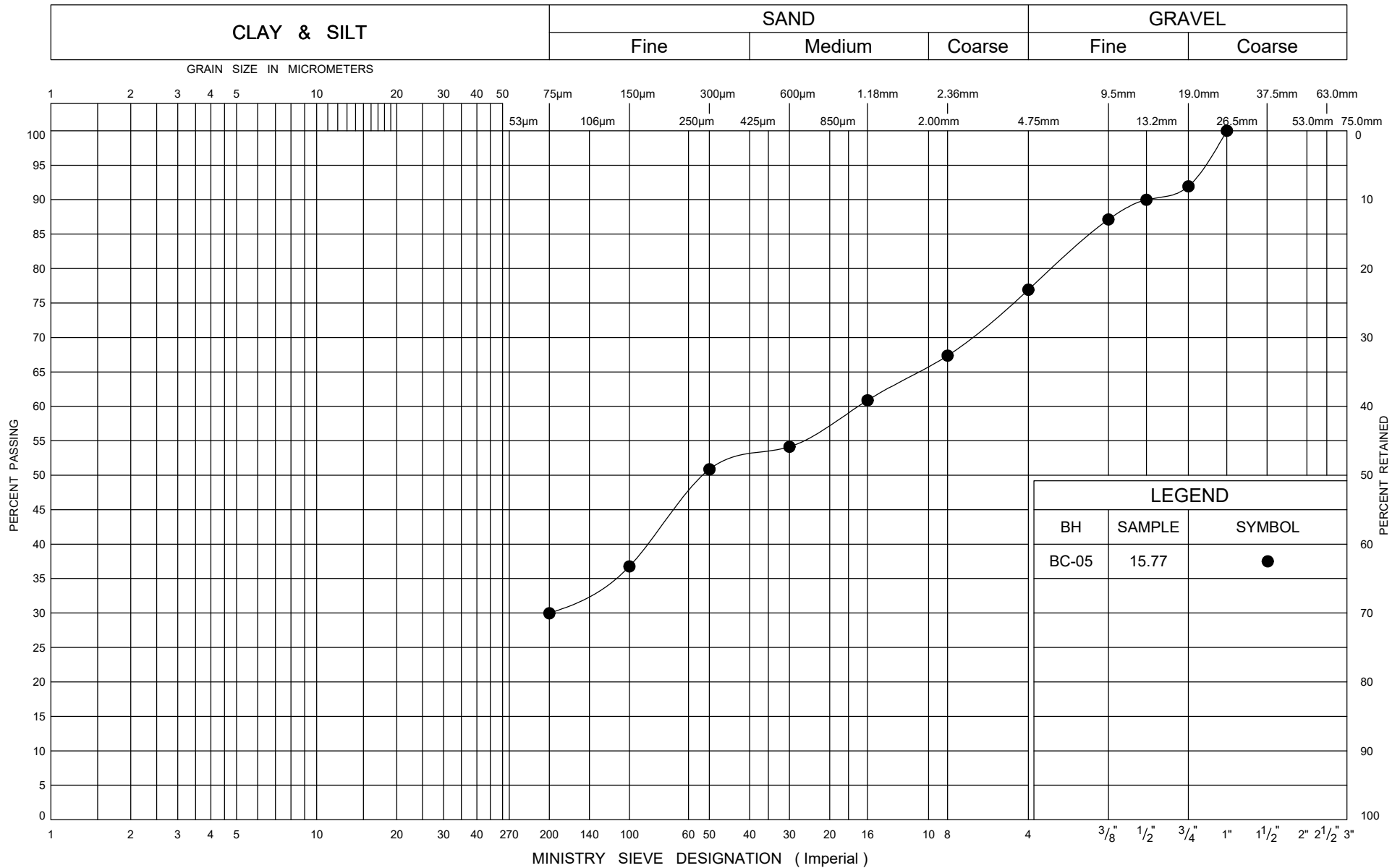
FIG No B2

W P 6010-70-00

Beaver creek Bridge







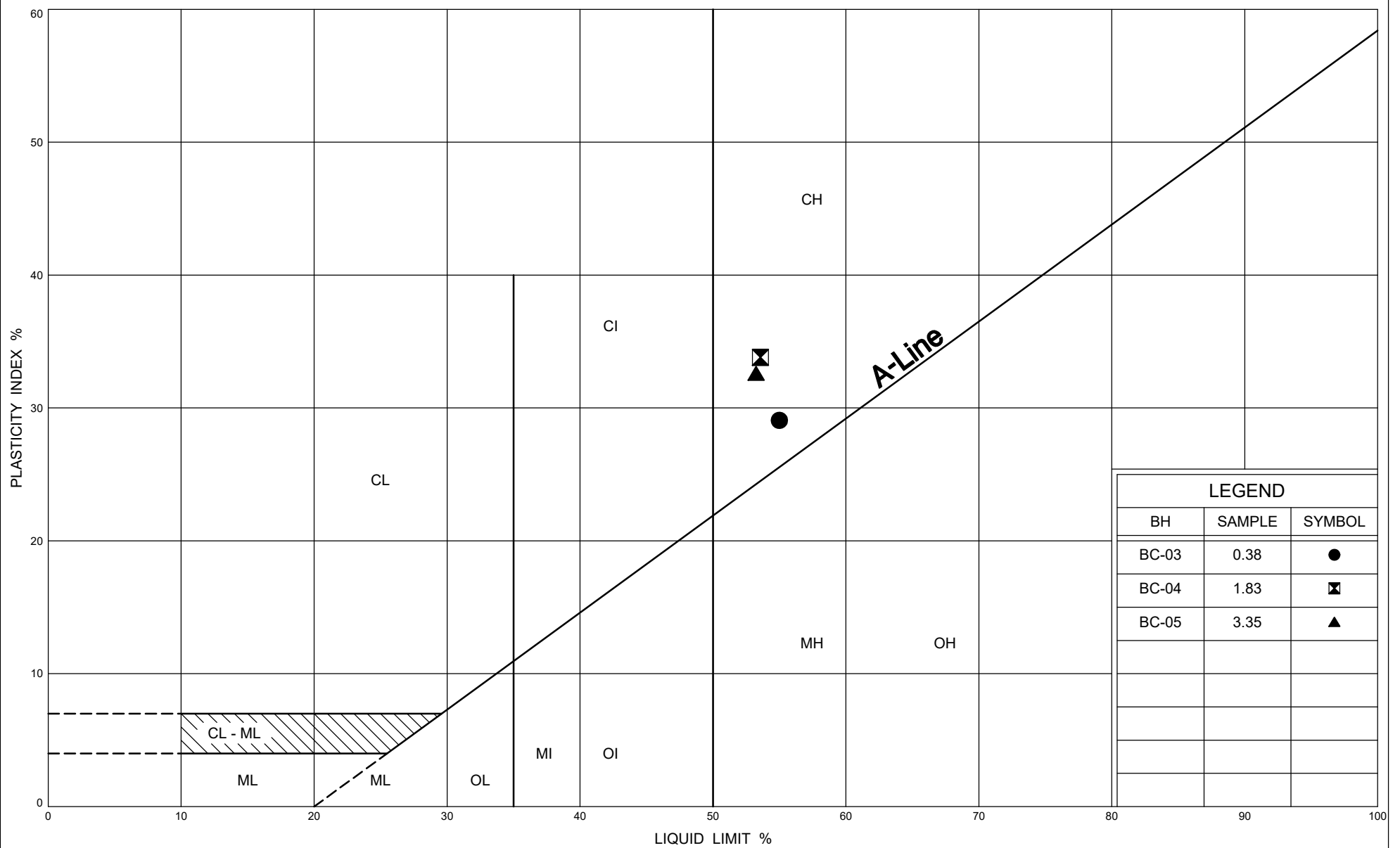
Ministry of  
Transportation

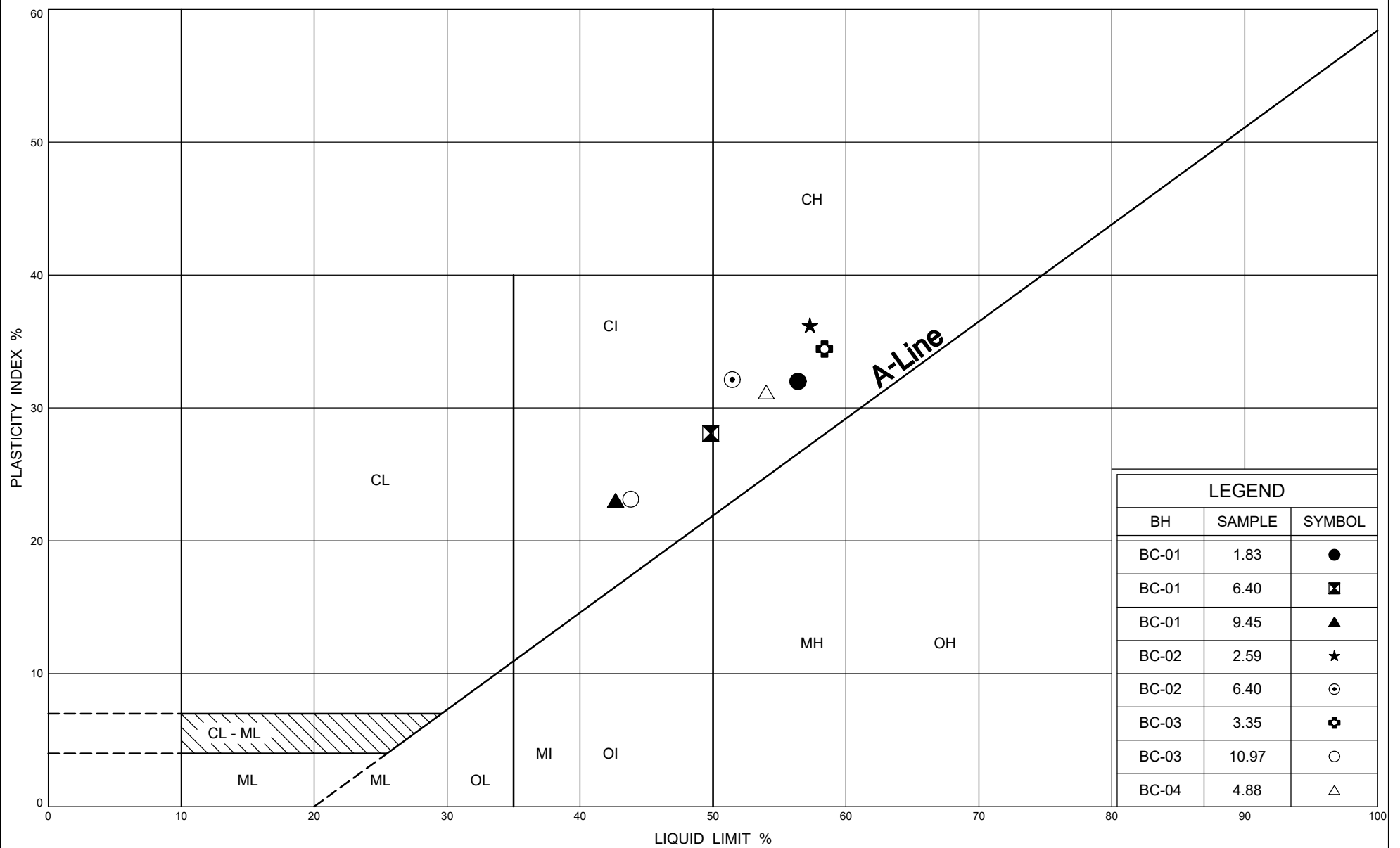
## GRAIN SIZE DISTRIBUTION SAND

FIG No B4

W P 6010-70-00

Beaver creek Bridge





Ministry of  
Transportation

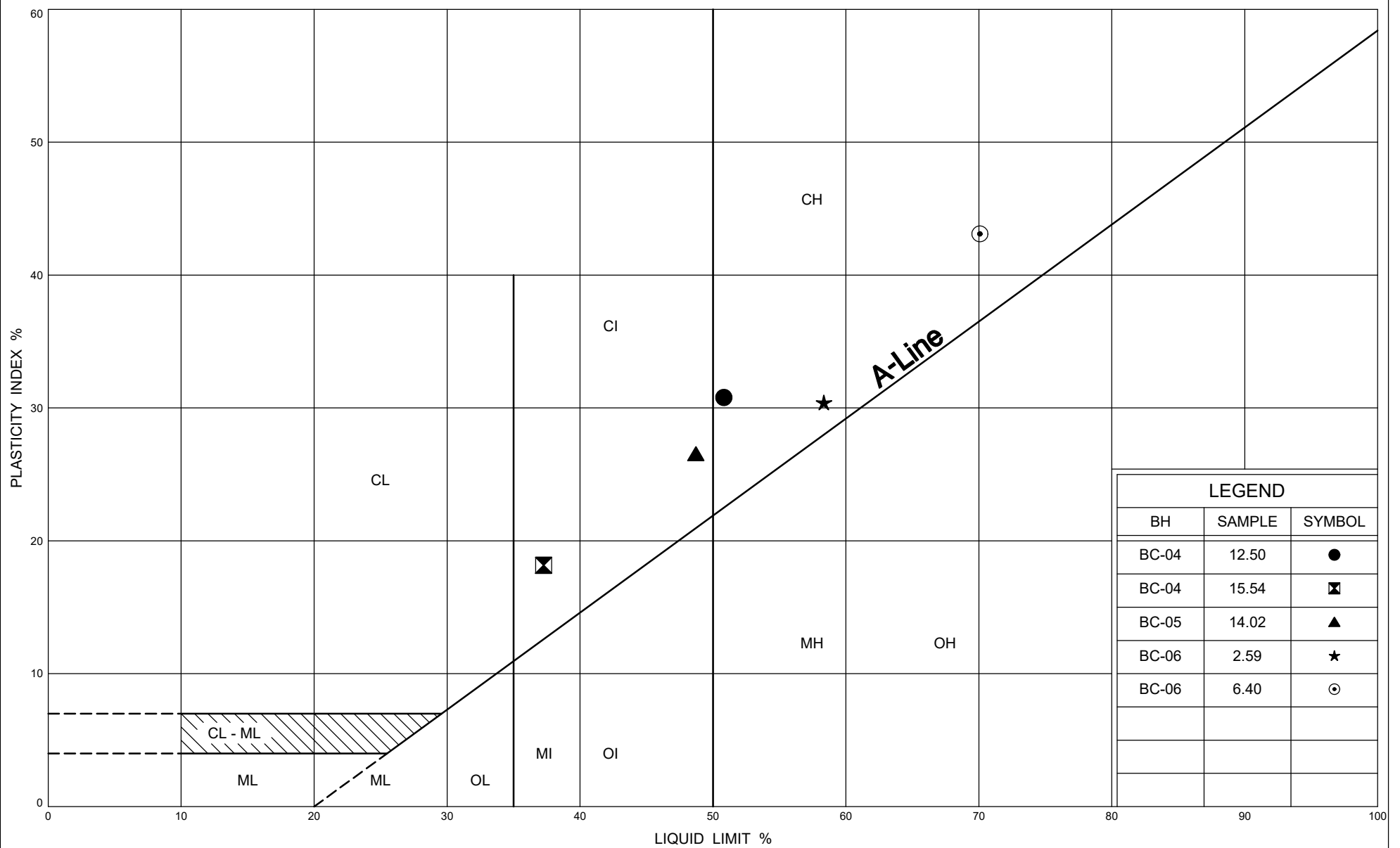
## PLASTICITY CHART

Silty CLAY

FIG No B6

W P 6010-70-00

Beaver creek Bridge



LEGEND		
BH	SAMPLE	SYMBOL
BC-04	12.50	●
BC-04	15.54	⊠
BC-05	14.02	▲
BC-06	2.59	★
BC-06	6.40	⊙



Ministry of  
Transportation

## PLASTICITY CHART

Silty CLAY

FIG No B7

W P 6010-70-00

Beaver creek Bridge



TBT Engineering Limited

1918 Yonge Street

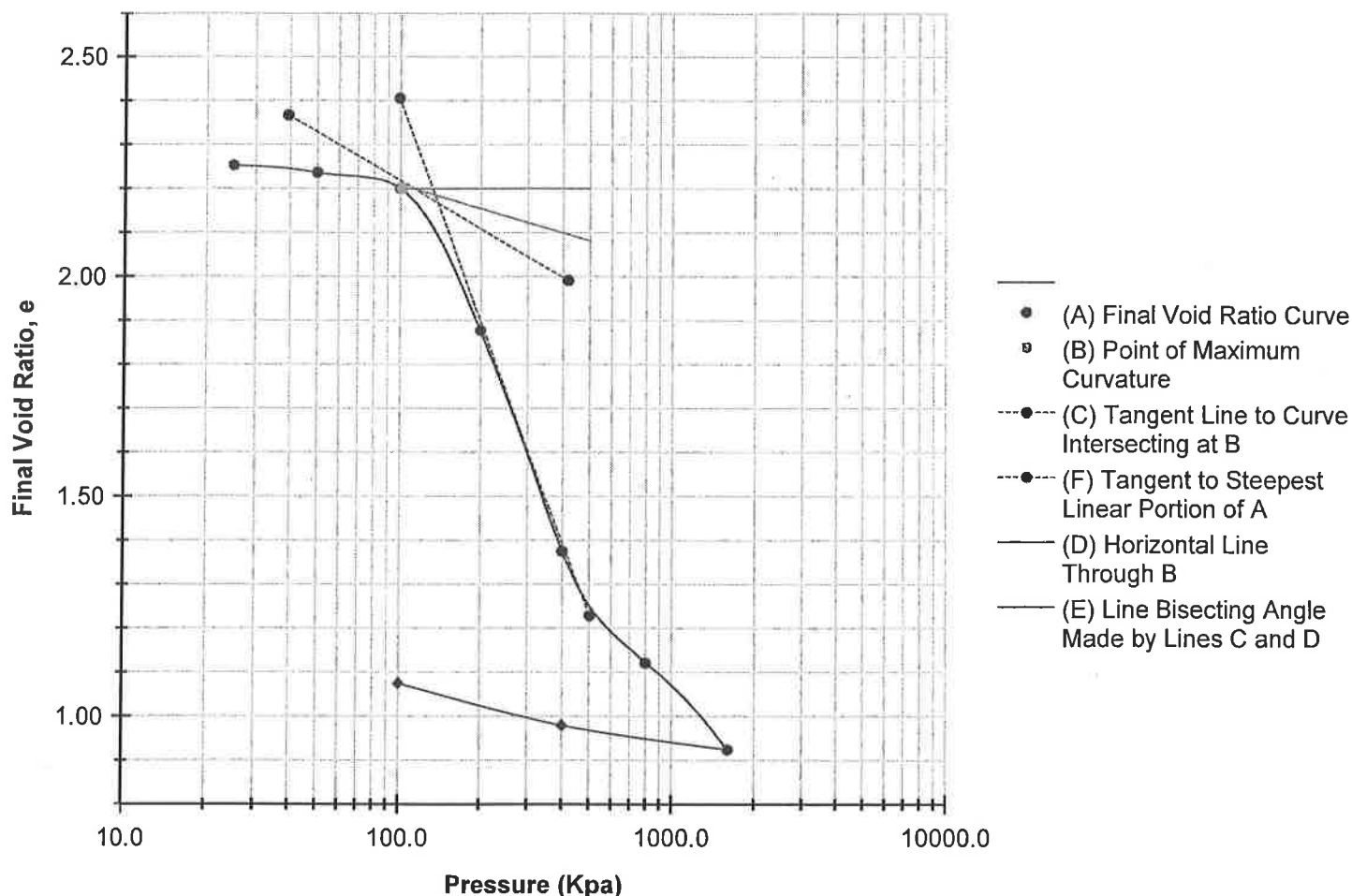
Thunder Bay, Ontario P7E 6T9

807-624-5160

807-624-5161

# Final Voids [Log]

ASTM D2435



Preconsolidation Stress (Kpa)	134.3448	Cc	Cr
-------------------------------	----------	----	----

	BEFORE	AFTER	Liquid Limits	0	Test Date 11/19/2018
Moisture (%)	86.9	41.8	Plastic Limits	0	
Dry Density	0.829	0.937			
Saturation (%)	103.6	59.7			
Void Ratio	2.28	1.90	Specific Gravity	2.72	ASSUMED

Sample Description	Heavy brown clay			Remarks
Project Number	24530	Depth (ft)	25 - 27	
Sample Number	18-1374	Boring Number	BC-04	
Project	Beaver Creek Bridge			
Client	Thurber Engineering Ltd.			
Location	Beaver Creek Bridge			

Project Name: Beaver Creek Bridge Project Number: 24530

Technician: FV

Test Date: 11/19/2018

Checked By: \_\_\_\_\_

Date: \_\_\_\_\_



TBT Engineering Limited

1918 Yonge Street

Thunder Bay, Ontario P7E 6T9

807-624-5160

807-624-5161

# Consolidated Test Results

ASTM D2435

Project:	Beaver Creek Bridge
Project Number:	24530
Job Number:	18-644
Test Date:	11/19/2018

Sampling Date:	11/19/2018
Sample Number:	18-1374
Depth (ft)	25 - 27
Boring Number:	BC-04
Location:	Beaver Creek Bridge
Client Name:	Thurber Engineering Ltd.
Remarks:	

Specific Gravity:	2.72	Plastic Limit:	0	Liquid Limit:	0
Specific Gravity Method:	ASSUMED			Weight of Ring (g)	104.9
Sampling Method:	Undisturbed	Soil Classification:			
Specimen Description:	Heavy brown clay				

Parameters	Initial	Final
Height (mm)	25.400	16.084
Height Source	NA	TEST RESULTS
Diameter (mm)	63.220	NA
Area (cm <sup>2</sup> )	31.391	NA
Volume (cm <sup>3</sup> )	79.732	50.488
Weight of Container (g)	118.460	223.340
Weight of Wet Soil + Container (g)	205.480	318.500
Weight of Dry Soil + Container (g)	165.010	290.440
Moisture Content (%)	86.939	41.818
Moist Weight + Ring Weight (g)	228.4	172.0
Dry Density (g/cm <sup>3</sup> )	0.829	0.937
Wet Density (g/cm <sup>3</sup> )	1.549	1.328
Saturation (%)	103.580	59.734
Void Ratio	2.283	1.904

Project Name: Beaver Creek Bridge Project Number: 24530

Technician: FV

Test Date:

11/19/2018

Checked By: \_\_\_\_\_ Date: \_\_\_\_\_



TBT Engineering Limited

1918 Yonge Street

Thunder Bay, Ontario P7E 6T9

807-624-5160

807-624-5161

# Consolidation Test Results

ASTM D2435

## Specimen 1

Test Description: Consolidation

Other Associated Tests:

Device Details: Humboldt 5470

Test Specification: Method A

Test Time: 11/19/2018 12:00:00 AM

Technician: FV

Sampling Method: Undisturbed

Specimen Code:

Specimen Lab #: 18-1374

Specimen Description: Heavy brown clay

Specimen Preparation: Cutting Shoe

Large Particle:

Moisture Content: Natural Moisture

Test Condition: Flooded

Test Procedure: ASTM D2435 [Changes - Hold each load increment for 24 hrs.]

Seating Pressure Used: NO

Seating Pressure (Kpa): 0.0000

Preconsolidation Stress:

Percent Strain [LOG] Graph (Kpa): 131.0256

Final Voids Graph (Kpa): 134.3448

Project Name: Beaver Creek Bridge Project Number: 24530

 Test Date:  
 11/19/2018

Technician: FV

Report Created: 12/3/2018



**THURBER** ENGINEERING LTD.

## POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 24530  
 Client: Hatch  
 Project Name: Beaver Creek Bridge  
 Core Size: NQ BH No : BC-03

Date Drilled: 22-Oct-18  
 Date Tested: 01-Nov-18  
 Tester: BS  
 Reviewed by: LS

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									Not Enough Sample
2	2	14.1	D	21.5	47.5	68.7	8.8	212.2	Granite	Very Strong
3	2	14.6	D	19.1	47.4	66.5	7.9	189.1	Granite	Very Strong
4	2	14.9	D	23.0	47.4	65.4	9.5	227.8	Granite	Very Strong
5	3	15.4	D	22.3	47.4	61.6	9.2	221.1	Granite	Very Strong
6	3	15.8	D	20.7	47.3	64.2	8.5	205.0	Granite	Very Strong
7	3	16.2	D	10.0	47.4	63.7	4.1	98.5	Granite	Strong
8	4	16.6	D	20.1	47.2	69.8	8.3	200.3	Granite	Very Strong
9	5	17.0	D	20.6	47.2	68.8	8.5	204.8	Granite	Very Strong
10										
11										
12										
13										
14										
15										
16							RUN#2 AVG=	209.7		Very Strong
17							RUN#3 AVG=	174.9		Very Strong
18							RUN#4 AVG=	200.3		Very Strong
19							RUN#5 AVG=	204.8		Very Strong
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										

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

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: 24530  
 Client: Hatch  
 Project Name: Beaver Creek Bridge  
 Core Size: NQ BH No : BC-04

Date Drilled: 23-Oct-18  
 Date Tested: 01-Nov-18  
 Tester: BS  
 Reviewed by: LS

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	I <sub>s(50)</sub> (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	16.9	D	2.3	47.4	82.1	0.9	22.8	Granite	Weak
2	1	17.2	D	14.7	47.3	71.7	6.1	145.8	Granite	Very Strong
3	1	17.6	D	16.0	47.3	68.9	6.6	159.3	Granite	Very Strong
4	1	18.0	D	8.7	47.3	69.9	3.6	86.3	Granite	Strong
5	2	18.4	D	1.9	47.3	71.9	0.8	19.0	Granite	Weak
6	2	18.8	D	10.6	47.3	71.9	4.4	105.6	Granite	Very Strong
7	2	19.2	D	8.9	47.3	77.6	3.7	88.5	Granite	Strong
8	2	19.7	D	4.6	47.3	74.6	1.9	45.6	Granite	Medium Strong
9	2	19.9	D	12.7	47.0	74.6	5.3	127.4	Granite	Very Strong
10										
11										
12										
13										
14										
15										
16							RUN#1 AVG=	103.5		Very Strong
17							RUN#2 AVG=	77.2		Strong
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										

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

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.



Figure 17.1 Borehole BC-03 core photo. Run 1 to Run 5.



Figure 17.2 Borehole BC-04 core photo. Run 1 to Run 2.



## FINAL REPORT

CA12869-OCT18 R1

Prepared for

**Thurber Engineering Ltd.**

## First Page

### CLIENT DETAILS

Client Thurber Engineering Ltd.

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

Contact Mark Farrant

Telephone 905-829-8666 x 228

Facsimile

Email mfarrant@thurber.ca

Project

Order Number

Samples Water (1)

### LABORATORY DETAILS

Project Specialist Rob Irwin B.Sc., C.Chem

Laboratory SGS Canada Inc.

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

Telephone 2361

Facsimile 705-652-6365

Email

SGS Reference CA12869-OCT18

Received 10/30/2018

Approved 11/06/2018

Report Number CA12869-OCT18 R1

Date Reported 11/06/2018

### COMMENTS

Temperature of Sample upon Receipt: 13 degrees C

Cooling Agent Present: yes

Custody Seal Present: No

### SIGNATORIES

Rob Irwin B.Sc., C.Chem






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# FINAL REPORT

CA12869-OCT18 R1

**Client:** Thurber Engineering Ltd.

**Project:**

**Project Manager:** Mark Farrant

**Samplers:** Liam Steers

## PACKAGE: - Corrosivity Index (WATER)

**Sample Number** 6  
**Sample Name** BC-01  
**Sample Matrix** Water  
**Sample Date** 26/10/2018

Parameter	Units	RL	Result
<b>Corrosivity Index</b>			
Resistivity (calculated)	ohms.cm	-9999	6849

## PACKAGE: - General Chemistry (WATER)

**Sample Number** 6  
**Sample Name** BC-01  
**Sample Matrix** Water  
**Sample Date** 26/10/2018

Parameter	Units	RL	Result
<b>General Chemistry</b>			
Conductivity	uS/cm	2	146
Redox Potential	mV	-	200
Sulphide	µg/L	6	31

## PACKAGE: - Metals and Inorganics (WATER)

**Sample Number** 6  
**Sample Name** BC-01  
**Sample Matrix** Water  
**Sample Date** 26/10/2018

Parameter	Units	RL	Result
<b>Metals and Inorganics</b>			
Chloride	mg/L	0.04	4.5
Sulphate	mg/L	0.04	1.8



FINAL REPORT

CA12869-OCT18 R1

Client: Thurber Engineering Ltd.

Project:

Project Manager: Mark Farrant

Samplers: Liam Steers

PACKAGE: - Other (ORP) (WATER)

Sample Number 6  
Sample Name BC-01  
Sample Matrix Water  
Sample Date 26/10/2018

Parameter	Units	RL	Result
Other (ORP)			
pH	no unit	0.05	7.58



FINAL REPORT

CA12869-OCT18 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
Sulphate	DIO0054-NOV18	mg/L	0.04	<0.04	1	20	95	80	120	97	75	125
Chloride	DIO0556-OCT18	mg/L	0.04	<0.04	0	20	98	80	120	113	75	125
Sulphate	DIO0556-OCT18	mg/L	0.04	<0.04	2	20	98	80	120	99	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	EWL0547-OCT18	uS/cm	2	< 2	0	10	99	90	110	NA		





FINAL REPORT

CA12869-OCT18 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	EWL0547-OCT18	no unit	0.05	NA	1		100			NA		

Redox Potential  
Method: SM 2580 |

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	EWL0535-OCT18	mV	no	NA	6	20	100	80	120	NA		

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	SKA0003-NOV18	ug/L	6	<0.006	ND	20	102	80	120	NA	75	125
Sulphide	SKA0017-NOV18	ug/L	6	<0.006	6	20	104	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

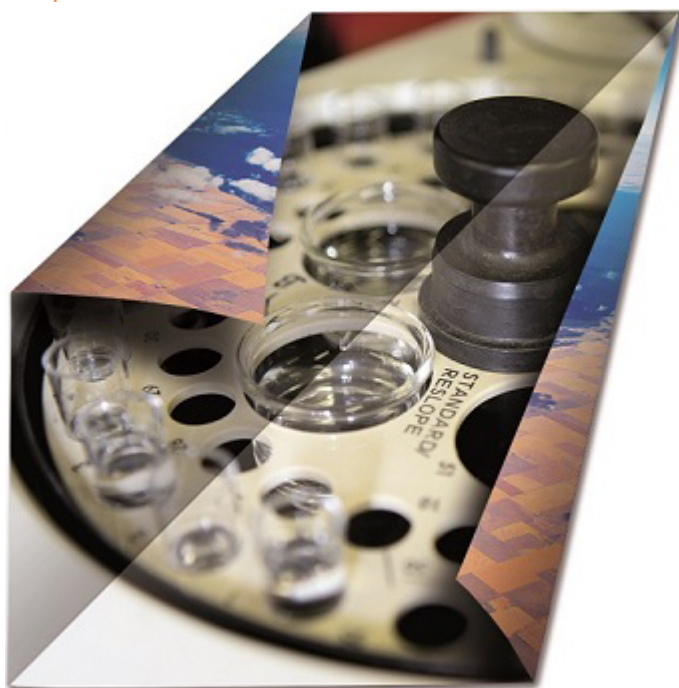
Samples analysed as received. Solid samples expressed on a dry weight basis. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

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](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

CA14117-NOV18 R1

23991

Prepared for

**Thurber Engineering Ltd.**

## First Page

### CLIENT DETAILS

Client Thurber Engineering Ltd.

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

Contact Liam Steers

Telephone 613-276-4587

Facsimile 905-829-1166

Email lsteers@thurber.ca

Project 23991

Order Number

Samples Soil (4)

### LABORATORY DETAILS

Project Specialist Rob Irwin B.Sc., C.Chem

Laboratory SGS Canada Inc.

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

Telephone 2361

Facsimile 705-652-6365

Email

SGS Reference CA14117-NOV18

Received 11/06/2018

Approved 11/13/2018

Report Number CA14117-NOV18 R1

Date Reported 11/13/2018

### COMMENTS

Temperature of Sample upon Receipt: 4 degrees C

Cooling Agent Present: No

Custody Seal Present: No

Chain of Custody Number: NA

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

Rob Irwin B.Sc., C.Chem





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# FINAL REPORT

CA14117-NOV18 R1

**Client:** Thurber Engineering Ltd.

**Project:** 23991

**Project Manager:** Liam Steers

**Samplers:** Liam Steers

## PACKAGE: - Corrosivity Index (SOIL)

Sample Number	5	7	8	10
Sample Name	BC-05 SS#4	FC-05 SS#1 and 2	BC-02 SS#2	FC-01A SS#3 and 4A
Sample Matrix	Soil	Soil	Soil	Soil
Sample Date	25/10/2018	13/10/2018	24/10/2018	14/10/2018

Parameter	Units	RL		Result	Result	Result	Result
<b>Corrosivity Index</b>							
Corrosivity Index	none	1		2	1	2	1
Soil Redox Potential	mV	-		239	270	297	245
Sulphide	%	0.02		< 0.02	< 0.02	< 0.02	< 0.02
pH	pH Units	0.05		7.74	7.83	8.16	8.06
Resistivity (calculated)	ohms.cm	-9999		6330	7340	6620	5290

## PACKAGE: - General Chemistry (SOIL)

Sample Number	5	7	8	10
Sample Name	BC-05 SS#4	FC-05 SS#1 and 2	BC-02 SS#2	FC-01A SS#3 and 4A
Sample Matrix	Soil	Soil	Soil	Soil
Sample Date	25/10/2018	13/10/2018	24/10/2018	14/10/2018

Parameter	Units	RL		Result	Result	Result	Result
<b>General Chemistry</b>							
Conductivity	uS/cm	2		158	136	151	189

## PACKAGE: - Metals and Inorganics (SOIL)

Sample Number	5	7	8	10
Sample Name	BC-05 SS#4	FC-05 SS#1 and 2	BC-02 SS#2	FC-01A SS#3 and 4A
Sample Matrix	Soil	Soil	Soil	Soil
Sample Date	25/10/2018	13/10/2018	24/10/2018	14/10/2018

Parameter	Units	RL		Result	Result	Result	Result
<b>Metals and Inorganics</b>							
Moisture Content	%	0.1		26.5	2.4	26.2	5.9



# FINAL REPORT

CA14117-NOV18 R1

**Client:** Thurber Engineering Ltd.

**Project:** 23991

**Project Manager:** Liam Steers

**Samplers:** Liam Steers

## PACKAGE: - Metals and Inorganics (SOIL)

Sample Number	5	7	8	10
Sample Name	BC-05 SS#4	FC-05 SS#1 and 2	BC-02 SS#2	FC-01A SS#3 and 4A
Sample Matrix	Soil	Soil	Soil	Soil
Sample Date	25/10/2018	13/10/2018	24/10/2018	14/10/2018

Parameter	Units	RL		Result	Result	Result	Result
Metals and Inorganics (continued)							
Sulphate	µg/g	0.4		6.9	7.3	0.5	7.4

## PACKAGE: - Other (ORP) (SOIL)

Sample Number	5	7	8	10
Sample Name	BC-05 SS#4	FC-05 SS#1 and 2	BC-02 SS#2	FC-01A SS#3 and 4A
Sample Matrix	Soil	Soil	Soil	Soil
Sample Date	25/10/2018	13/10/2018	24/10/2018	14/10/2018

Parameter	Units	RL		Result	Result	Result	Result
Other (ORP)							
Chloride	µg/g	0.4		5.4	7.4	2.6	8.5



## 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	DIO0157-NOV18	µg/g	0.4	<0.4	6	20	96	80	120	106	75	125
Sulphate	DIO0157-NOV18	µg/g	0.4	<0.4	7	20	95	80	120	101	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	ECS0014-NOV18	%	0.02	<0.02	ND	20	116	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	EWL0175-NOV18	uS/cm	2	< 2	0	10	98	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	EWL0175-NOV18	pH Units	0.05	NA	0		100			NA		
pH	EWL0199-NOV18	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](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 --



## **Appendix C**

### **Site Photographs**



**Figure 17.3 North approach facing south**

**(Photo Date: October, 21, 2018)**





**Figure 17.4 North abutment facing southeast**

**(Photo Date: October, 21, 2018)**



**Figure 17.5 North abutment facing southwest**

**(Photo Date: October, 21, 2018)**





**Figure 17.6 South approach facing north**

**(Photo Date: October, 21, 2018)**





**Figure 17.7 South approach facing northwest**

**(Photo Date: October, 21, 2018)**





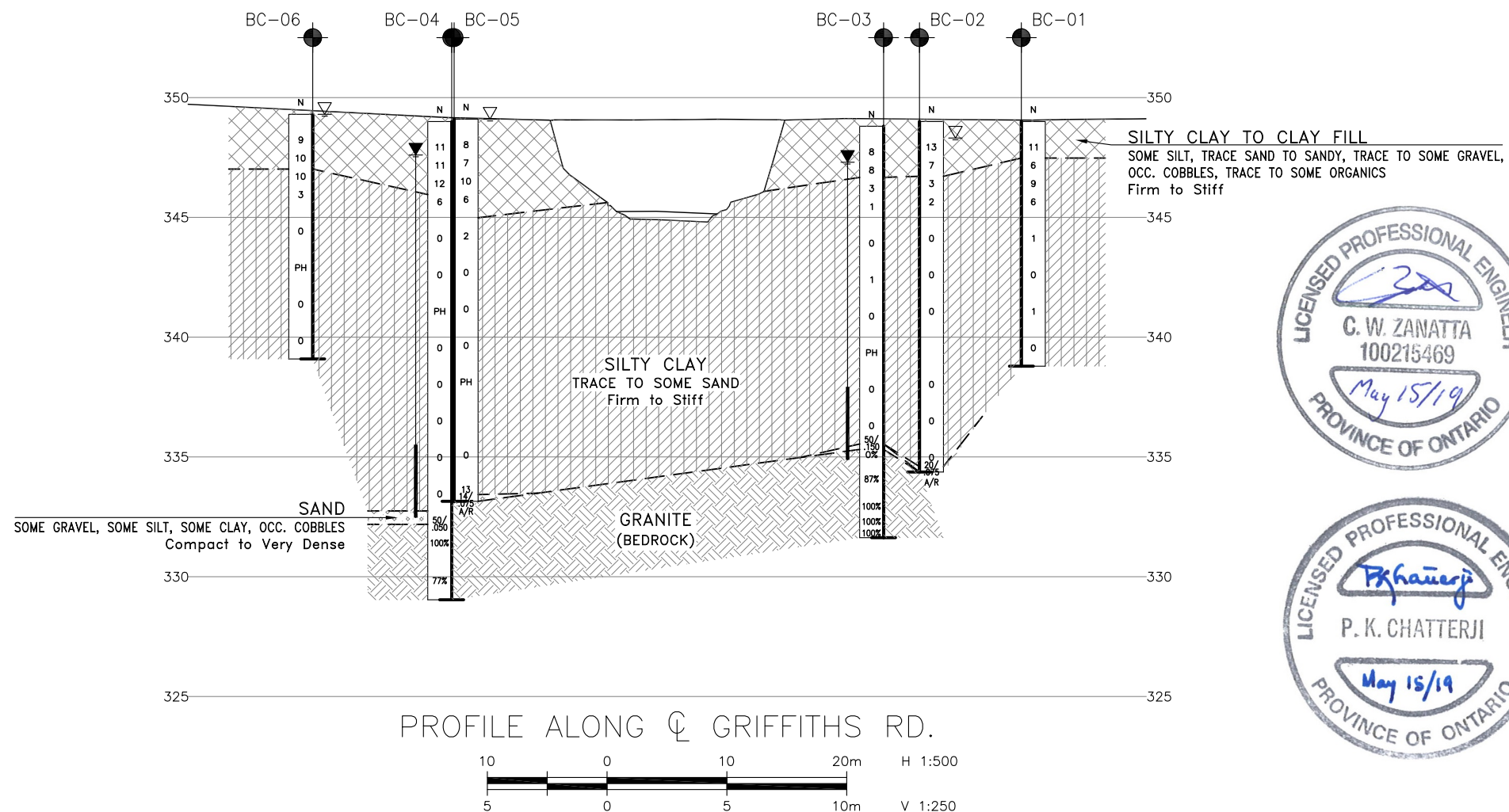
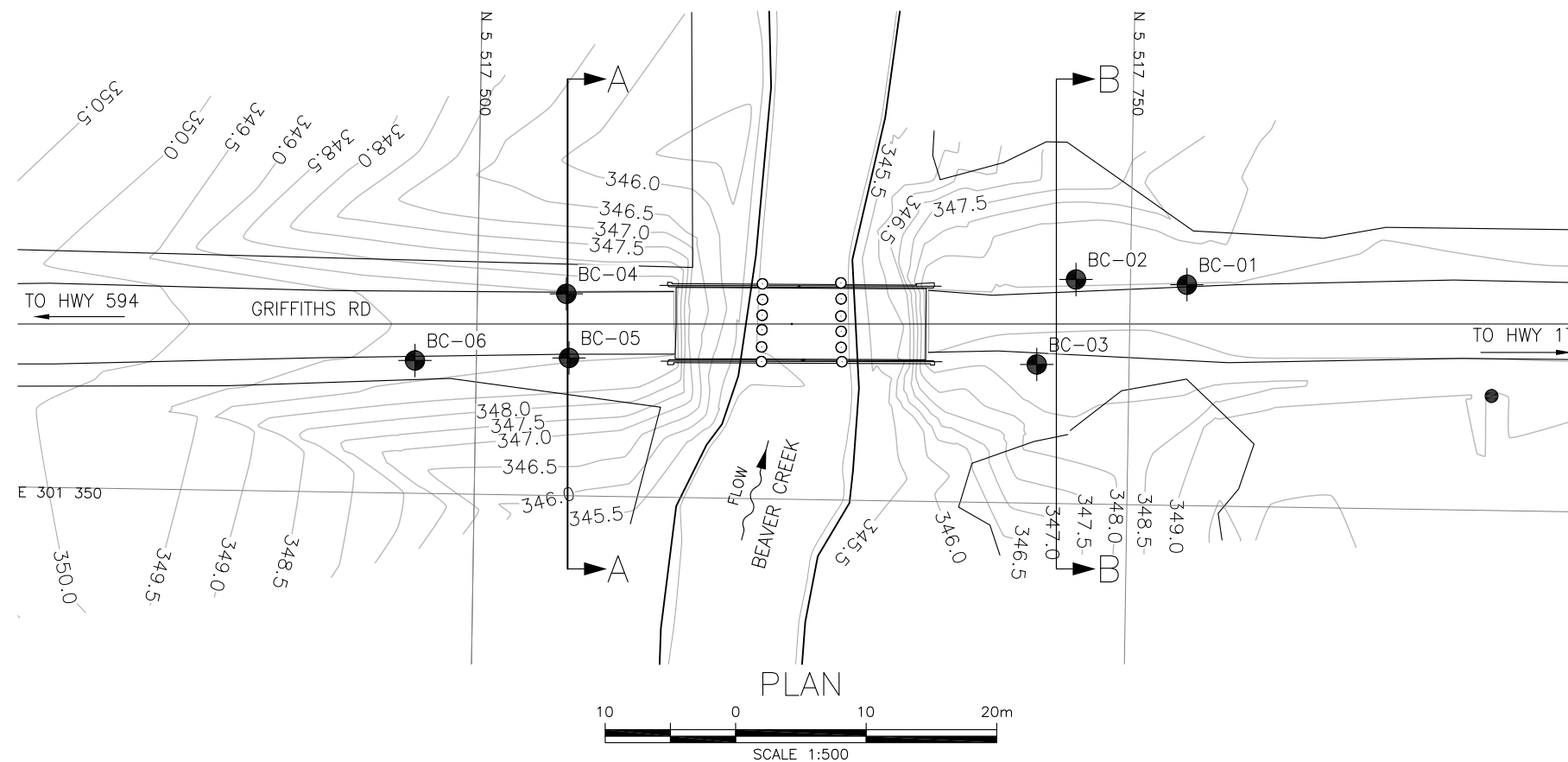
**Figure 17.8 South approach facing northeast**

**(Photo Date: October, 21, 2018)**



## **Appendix D**

### **Borehole Locations and Soil Strata Drawing**



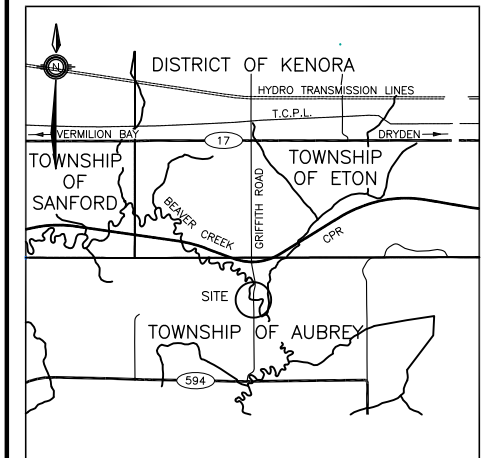
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
WP No 6010-17-01








HEET  
6

# 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
BC-01	349.0	5 517 554.3	301 333.1
BC-02	349.0	5 517 545.8	301 332.8
BC-03	348.8	5 517 542.9	301 339.4
BC-04	349.0	5 517 506.8	301 334.6
BC-05	349.1	5 517 507.1	301 339.4
BC-06	349.3	5 517 495.3	301 339.8

-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 16.

GEOCRES No. 52F-63

[illegible]

FILENAME: H:\Drafting\24000\24530\TED-24530-BHPP-BC.dwg  
PLOTDATE: 4/25/2019 2:17 PM



METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
WP No 6010-17-01

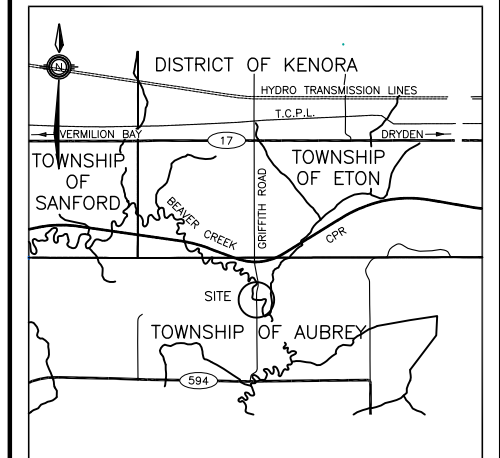
BRIDGE CROSSING AT  
BEAVER CREEK &  
GRIFFITHS ROAD  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET  
7

HATCH



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

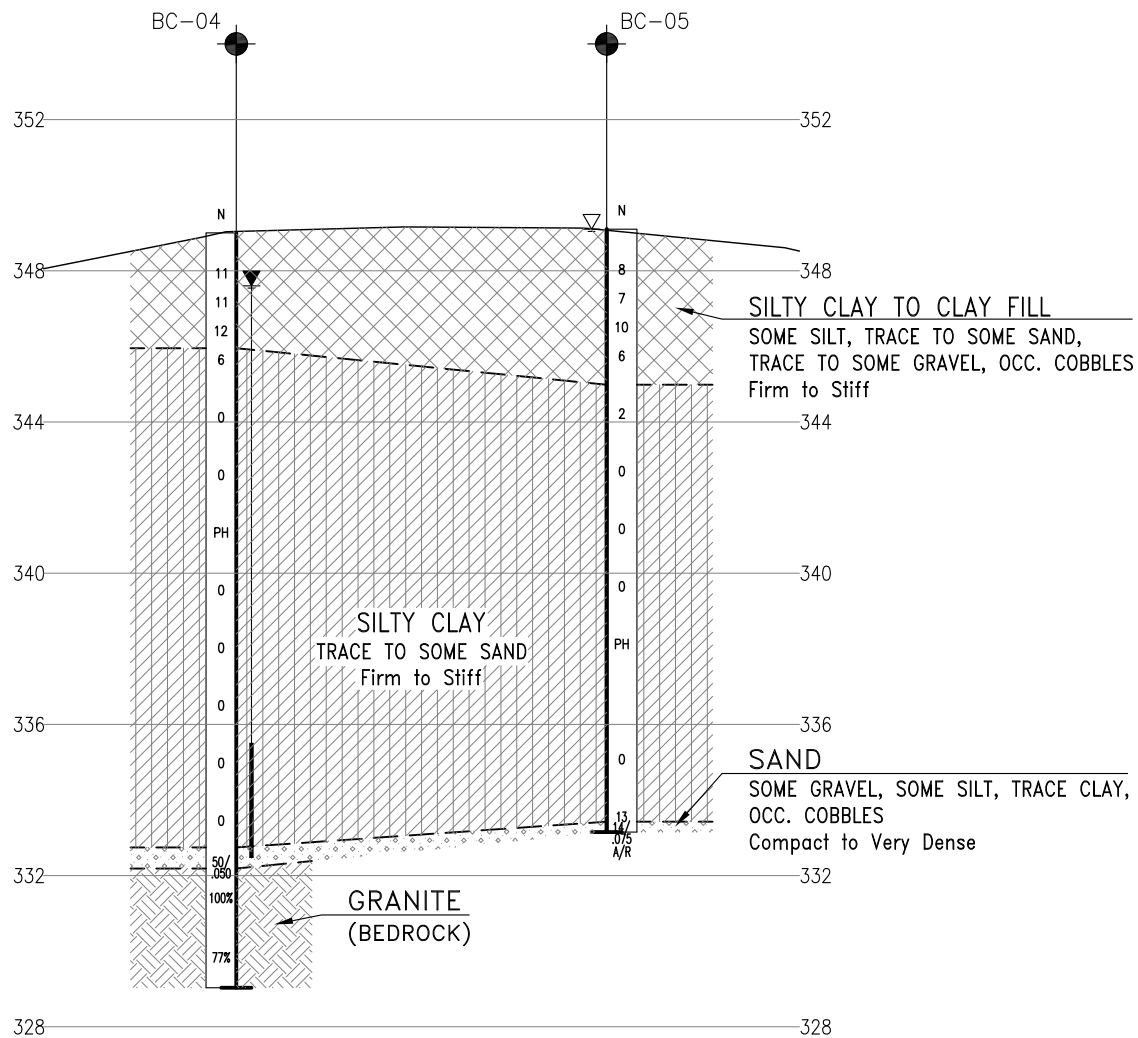
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
BC-01	349.0	5 517 554.3	301 333.1
BC-02	349.0	5 517 545.8	301 332.8
BC-03	348.8	5 517 542.9	301 339.4
BC-04	349.0	5 517 506.8	301 334.6
BC-05	349.1	5 517 507.1	301 339.4
BC-06	349.3	5 517 495.3	301 339.8

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 16.

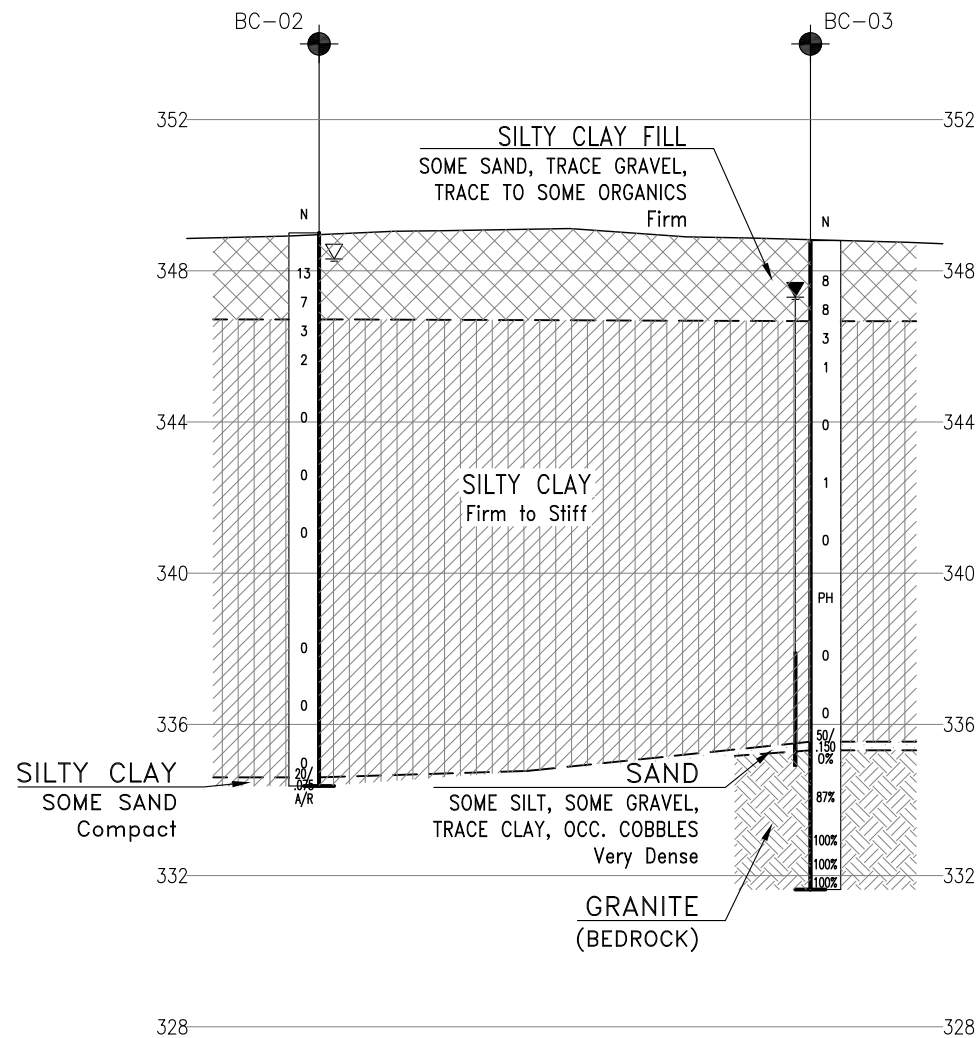
GEOCRES No. 52F-63



SECTION A-A



H 1:100  
V 1:200



SECTION B-B



H 1:100  
V 1:200

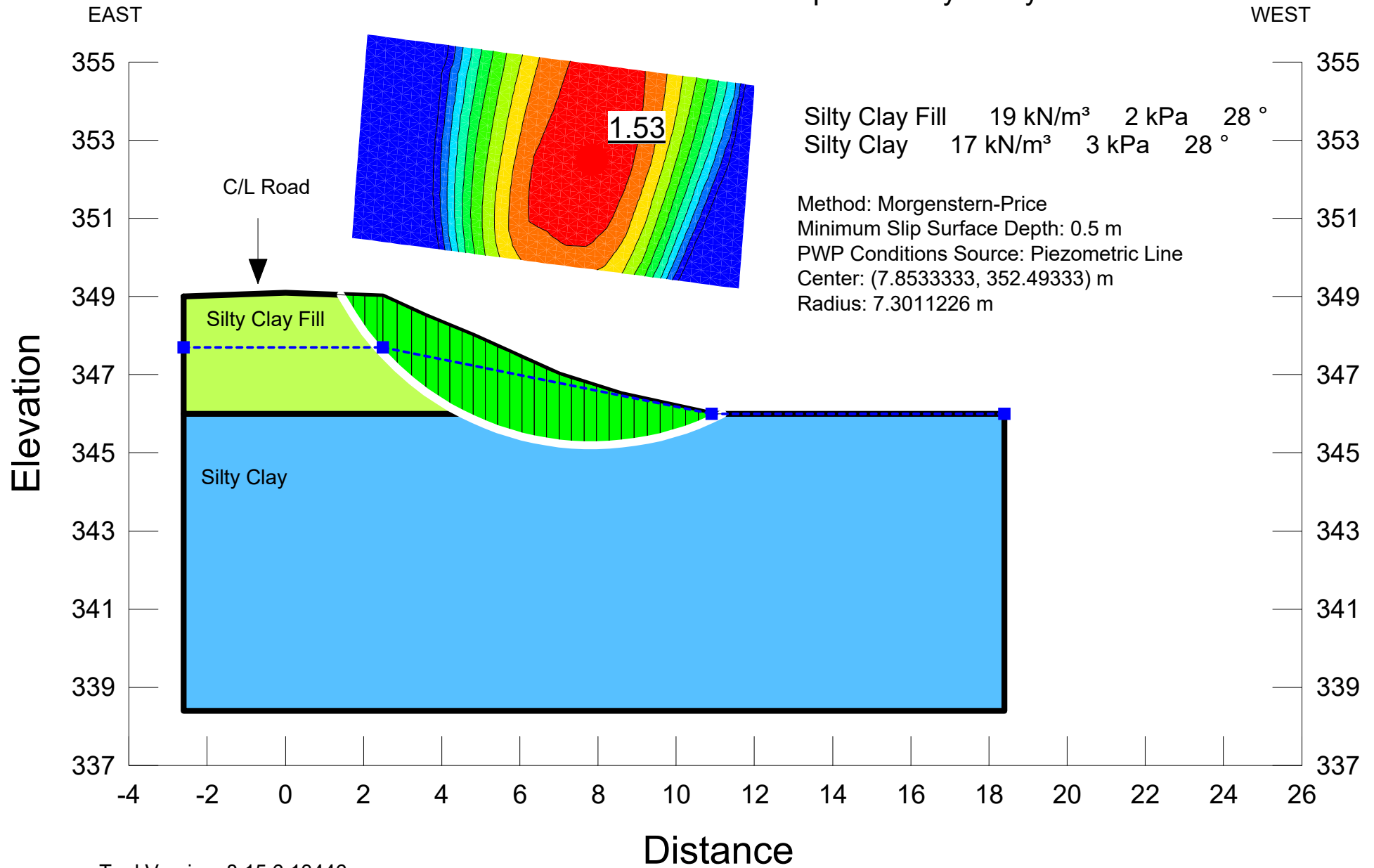
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## **Appendix E**

### **Slope Stability Analysis**

# Beaver Creek Bridge Replacement South West Embankment Side Slope Stability Analysis



Tool Version: 8.15.6.13446

Last Solved Date: 2019-05-08

Directory: H:\20000-29999\24000-24999\24530 - Beaver Creek Bridge Replacement\Analysis\

Figure E1



## **Appendix F**

### **Foundation Comparison**



## COMPARISON OF FOUNDATION ALTERNATIVES

Spread Footings on Engineered Fill Pads	Driven Steel H-Piles
<p><u>Advantages:</u></p> <ul style="list-style-type: none"> <li>i. Conventional construction</li> <li>ii. Engineered fill pad can be placed on firm to stiff silty clay depending on geotechnical resistance requirements</li> </ul>	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> <li>i. Conventional construction.</li> <li>ii. Generally less costly than other deep foundation elements.</li> <li>iii. Higher geotechnical resistances can be achieved versus shallow foundation options</li> </ul>
<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> <li>i. Engineered fill preparation must be carried out in the dry.</li> <li>ii. Excavation may extend below groundwater level which would require dewatering</li> <li>iii. Large cobbles and boulders observed on the front slopes of abutments may require excavation and special handling</li> <li>iv. Lower geotechnical capacities than deep foundation elements</li> </ul>	<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> <li>i. Presence of obstructions in the highway embankment.</li> </ul>
<b>FEASIBLE</b>	<b>RECOMMENDED</b>



## **Appendix G**

### **List of OPSSs and OPSDs and Suggested Wording for NSSP**



## **1. List of OPSS and OPSD Documents Relevant to this Project**

- OPSS 902 (Construction Specification for Excavating and Backfilling – Structures)
- OPSS 903 (Construction Specification for Deep Foundations)
- OPSS PROV 206 (Construction Specification for Grading)
- OPSS PROV 209 (Construction Specification for Embankments over Swamps and Compressible Soils)
- OPSS PROV 501 (Construction Specification for Compacting)
- OPSS PROV 517 (Construction Specification for Excavating and Backfilling – Structures)
- Special Provision No. FOUN0003 to OPSS 902 (Dewatering Structure Excavations)
- OPSS PROV 804 (Construction Specification for Seed and Cover)
- OPSS PROV 1010 (Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material)
- OPSD 3090.100 (Foundation Frost Depths for Northern Ontario)
- OPSD 3101.150 (Walls, Abutment, Backfill Minimum Granular Requirement)

## **2. Suggested Wording for NSSP on Dewatering**

Effective dewatering shall be designed and provided by the Contractor during structure excavation, bedding placement and backfilling to allow the work to proceed in the dry. Excavation below the creek and groundwater level will lead to subgrade softening. The dewatering system must be effective to maintain the water level at a minimum depth of 0.5 m below the final subgrade level throughout construction.

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.

## **3. Suggested Wording for NSSP on Obstructions**

Excavations and installation of piles systems will encounter obstructions such as cobbles and boulders or old timber foundations embedded in the fill soils. Such obstructions may impede



excavation progress and/or pile installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths.

#### **4. Geotechnical Assessment for the Use of Heavy Construction Equipment**

##### **GEOTECHNICAL ASSESSMENT - Item No.**

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Special Provision

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#### **TABLE OF CONTENTS**

<b>1.0</b>	<b>SCOPE</b>
<b>2.0</b>	<b>REFERENCES</b>
<b>3.0</b>	<b>DEFINITIONS - Not Used</b>
<b>4.0</b>	<b>DESIGN AND SUBMISSION REQUIREMENTS</b>
<b>5.0</b>	<b>MATERIALS - Not Used</b>
<b>6.0</b>	<b>EQUIPMENT - Not Used</b>
<b>7.0</b>	<b>CONSTRUCTION - Not Used</b>
<b>8.0</b>	<b>QUALITY ASSURANCE - Not Used</b>
<b>9.0</b>	<b>MEASUREMENT FOR PAYMENT - Not Used</b>
<b>10.0</b>	<b>BASIS OF PAYMENT</b>

#### **1.0 SCOPE**

Geotechnical assessment and reporting to provide geotechnical recommendations for the use of heavy construction equipment on the valley slopes, approach embankments and adjacent to foundation elements.

#### **2.0 REFERENCES**

Foundation Investigation Report, Beaver Creek Bridge Replacement, Griffith Road, Aubrey Township, District of Kenora, Ontario, Latitude: 49.795297°, Longitude: -93.048117°, G.W.P. 6010-17-00, Site No 41S-55 (Geocres No. 52F-63), dated May 6, 2019



## **4.0 DESIGN AND SUBMISSION REQUIREMENTS**

### **4.1 Design Requirements**

The use of heavy construction equipment and in particular heavy lifting cranes may be required during removal of the existing and erection of the new bridge. The impact of the heavy equipment loads on the underlying soils, creek valley slopes and existing bridge foundations must be considered during selection of the methodology and equipment employed for construction.

Prior to commencement of construction, the Contractor shall retain a Geotechnical Consultant to assess the impact of the proposed equipment loads and construction methodology and determine requirements and/or restrictions necessary to safely support the loads without a foundation or slope failure. All Foundation Engineering services required for this project shall be performed by consultant(s) listed as accepted under the MTO's RAQS for providing services under the specialty of Geotechnical (Structures and Embankments) – Medium Complexity.

The assessment shall include, but not be limited to, the following:

- Review of available geotechnical information and supplementing with additional subsurface information as required in the equipment pad/access road areas;
- Determining appropriate setback distances for heavy equipment from the existing and new bridge abutments/piers and their foundations, and from the crests of the river valley slopes and existing/new embankment side slopes;
- Determining permissible ground pressure that may be applied to the foundation soils by the equipment, such as through a combination of crane pad design and sub-excavation;
- Providing recommendations for distribution of equipment loads to limit the lateral deflections of foundation piles of the existing and new bridges;
- If use of a crane pad and/or sub-excavation is not feasible, an alternative pile-supported platform system may be considered. The Contractor shall provide recommendations for crane pad design to transfer the crane loads for lifting girders to the ground during construction of the new bridge or demolition of the existing bridge through the alternative pile-supported platform system, if necessary.

### **4.2 Submission Requirements**

At least two (2) weeks prior to mobilization of heavy construction equipment to the site, the Contractor shall submit a report detailing the findings of the geotechnical assessment to the Contract Administrator. The report shall be signed and sealed by the Geotechnical Consultant and provide the following, as a minimum:

- Appropriate setback distances for heavy equipment from existing/new structures and creek valley slopes;
- Permissible ground pressures which may be applied to the foundation soils by heavy equipment;
- Recommendations for distribution of equipment loads to limit lateral deflections of existing and new foundation piles;
- Recommendations for pile-supported platform systems to support heavy equipment, if required.



## **10.0 BASIS OF PAYMENT**

Payment at the Contract price for the above tender items shall be full compensation for all labour to do the work.

Payment for costs associated with heavy construction equipment necessary to complete the work, such as design and construction of temporary works, supply, mobilization/de-mobilization, and operation shall be made under the associated items.

## **DEWATERING STRUCTURE EXCAVATIONS - Item No.**

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Special Provision No. FOUN0003

March 8, 2018

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### **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.