



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
WATABEAG RIVER BRIDGE REPLACEMENT
WATABEAG LAKE ROAD, TOWNSHIP OF MCEVAY
NEW LISKEARD DISTRICT, ONTARIO
W.P 5026-14-01, SITE NO. 47-068**

GEOCRES No. 42A-111

Report

to

MMM Group Limited

Date: January 24, 2017
File: 19-5161-252



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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the site of the existing Watabeag River Bridge carrying Watabeag Lake Road over the river, in the Township of McEvey, New Liskeard District, Ontario.

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

Thurber carried out the investigation as a sub-consultant to MMM Group Limited (MMM), under the Ministry of Transportation Ontario (MTO) Agreement Number 5014-E-0024.

2. SITE DESCRIPTION

The existing Watabeag River Bridge is located on Watabeag Lake Road, approximately 46.1 km north of Highway 66 and 28.7 km south of Highway 11, in the Township of McEvey. The local road runs generally in the north-south direction.

The existing bridge built in 1975 is a single span, single lane timber deck structure approximately 12 m in length. The superstructure is supported by closed faced timber cribs. Watabeag River flows from east to west at the bridge location and discharges into Lake Watabeag. In the vicinity of the existing bridge, the river banks are between 2.5 m and 3 m in height. The land on both sides of the river is densely vegetated with trees, shrubs and grass.

The bridge is supported on timber crib abutments. Deterioration of the timber forming the cribs was evident predominantly at the contact with the river water. Erosion of the river banks at the bridge location, including over-steepening/erosion of the front slopes at the abutments and



undermining/loss of ground below the timber cribs can be observed on the photographs enclosed in Appendix C.

Based on published geological information, the general area of the project is covered by glacial outwash deposits of silts, sands and gravel along ridges/eskers reflecting the subglacial drainage. The outwash deposits are underlain by Precambrian mafic to intermediate metavolcanic bedrock.

3. INVESTIGATION PROCEDURES

The field investigation program for this project was carried out between September 8 and September 21, 2016. The program consisted of drilling and sampling four (4) boreholes numbered 16-01 to 16-04. Boreholes 16-01 and 16-02 were drilled at the north and south abutments to depths of 24.9 m and 15.8 m, respectively. Boreholes 16-03 and 16-04 were located within the south and north approach embankments and both boreholes were drilled to 11.3 m depth. The approximate locations of all completed boreholes are shown on the attached Borehole Locations and Soil Strata Drawing enclosed in Appendix D.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling operations. The ground surface elevations for the boreholes were derived from the Preliminary General Arrangement drawing provided to Thurber by MMM. The borehole locations were tied in to the existing bridge features, and elevations related to a local datum were obtained from the General Arrangement Plan.

Track-mounted CME 45 drill rig was used to drill the boreholes. The boreholes were advanced using NW casing/wash boring techniques. An NQ core barrel was used to penetrate through cobbles and boulders in all boreholes, where encountered. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) procedures, as per ASTM D-1586-99.

The drilling and sampling operations were supervised on a full time basis by members 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.

Groundwater conditions in the open boreholes were observed throughout the drilling operations and in open boreholes after completion of drilling. The groundwater level observations may not be representative of the site conditions, as water was used during wash boring operations and coring to advance boreholes through the encountered cobbles and boulders. The boreholes were



backfilled in general accordance with MOE Regulation 903 (amended by Ontario Reg. 372). Completion details of the piezometers and borehole are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Foundation Unit	Borehole Number	Borehole Depth/Base Elev. (m)	Completion Details
North Approach	16-04	11.3 / 82.3	Bentonite holeplug to surface.
North Abutment	16-01	24.9 / 67.8	Bentonite holeplug from 10.7 m to surface.
South Abutment	16-02	15.8 / 76.3	Bentonite holeplug to surface.
South Approach	16-03	11.3 / 81.3	Bentonite holeplug and cuttings to surface.

4. LABORATORY TESTING

All recovered soil samples were subjected to visual identification (VI) and natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (sieve and hydrometer). All laboratory tests were carried out to MTO and / or ASTM Standards, as appropriate. The results of the geotechnical laboratory program are summarized on the Record of Borehole sheets included in Appendix A and on figures presented 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, two samples of the native sand, and a sample of surface water from the creek upstream of the bridge were collected. The samples were submitted to SGS Laboratories in Lakefield, Ontario, for analytical testing of corrosivity parameters and sulphate. The results of the analytical testing are summarized in Section 6 below and the Certificates of the Analysis are enclosed 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 in these sheets and on the “Borehole Locations and Soil Strata” drawing included in Appendix D. An overall description of the stratigraphy is given in the following paragraphs. The factual data presented on the Record of Borehole sheets take precedence over this general description and should be used for interpretation of the site



conditions. It should be recognized and expected that soil conditions may vary between and beyond borehole locations.

In summary, the embankment fill at this site overlies an extensive cohesionless deposit varying in composition from sand to sand and gravel and containing occasional to frequent cobbles and boulders. The cohesionless deposit was encountered to a depth of as much as 24.9 m investigated in the boreholes.

It was noted that numerous cobbles and boulders were exposed in Watabeag River bed, indicating that the river is cutting through very coarse deposits.

Water level in the Watabeag River was indicated on the Preliminary General Arrangement drawing at Elev. 90.2 on June 9, 2015.

As pointed out in Section 3 of this report, all quoted elevations in this report, refer to local datum.

5.1 Embankment Fill

Embankment fill as much as 2.7 m thick was encountered extending from ground surface in all drilled boreholes. The embankment fill comprised sand and gravel, with trace to some silt, trace organic matter and occasional cobbles and boulders. A 0.8 m layer of sand fill was encountered in Borehole 16-02 overlying the sand and gravel fill. The thickness of the fill near the abutments ranged from 2.1 m to 2.7m decreasing to 1.5 m some distance away within the approaches. The underside of the fill was encountered between Elev. 90.0 at the abutments, and as high as Elev. 92.1 within the approaches.

SPT N-values measured in the fill ranged from 5 blows per 0.3 m penetration to 27 blows per 0.3 m penetration, indicating a loose to compact relative density. One recorded SPT 'N' value of 56 blows per 0.3 m penetration in Borehole 16-03 was probably indicative of the presence of cobble or boulder. The measured water contents of fill samples ranged from 3% to 22%.

The results of grain size analyses conducted on samples of the fill are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figures B1 and B2 of Appendix B. The results are summarized in the following table.



Soil Particle	Sand Fill	Sand and Gravel Fill
	Percentage (%)	
Gravel	11	35 to 46
Sand	80	48 to 57
Silt and Clay	9	6 to 8

5.2 Upper Sand

Immediately underlying the embankment fill in Boreholes 16-01, 16-03 and 16-04 was a layer of sand with trace gravel and trace to some silt. The sand layer was 0.8 m to 1.0 m thick and extended to depths ranging from 2.3 m to 3.7 m. The underside of the sand was encountered between Elev. 89.0 in Borehole 16-01 and Elev. 91.3 in Borehole 16-04.

SPT 'N' values obtained in the sand ranged from 7 blows for 0.3 m penetration to 45 blows per 0.3 m penetration, indicating a loose to dense relative density. The measured water contents of sand samples ranged from 10% to 15%.

5.3 Upper Gravelly Sand to Sand and Gravel

Underlying the upper sand layer, and the fill material in Borehole 16-02, was a layer of gravelly sand to sand and gravel with trace silt. Cobbles and boulders were encountered in this deposit, which required coring to advance the boreholes, as noted on the Record of Borehole sheets. This deposit varied in thickness from 1.6 m to 5.3 m. The underside of the gravelly sand to sand and gravel was encountered between 3.7 m depth (Elev.88.4) in Borehole 16-02 to 7.6 m depth (Elev. 86.0) in Borehole 16-04. SPT N-values measured in the upper gravelly sand and sand and gravel generally ranged from 16 blows per 0.3 m penetration to 58 blows per 0.3 m penetration, indicating a compact to very dense relative density. One sample in Borehole 16-01 recorded 8 blows per 0.3 m of penetration, indicating a "pocket" of loose sand. The results of grain size analysis conducted on a sample of the upper sand and gravel are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figures B3 of Appendix B. The results are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	51
Sand	42
Silt and Clay	7

The measured water contents of sand samples ranged from 7% to 19%.



5.4 Lower Sand

Another cohesionless deposit labelled as a lower sand underlies the gravelly sand and sand and gravel in all boreholes. The sand deposit contained trace to some gravel and trace to some silt. Cobbles and boulders were encountered in this deposit and had to be cored to advance the boreholes. Where penetrated in Boreholes 16-01 to 16-03, the deposit was 1.5 m to 2.3 m in thickness with the underside between a depth of 5.6 m (Elev.86.5) and 8.4 m (Elev.84.3). Borehole 16-04 was terminated in the lower sand at a depth of 11.3 m (Elev. 82.3).

Another sand layer was encountered beneath a 1.5 m of compact gravelly sand in Borehole 16-03. This layer extended from a depth of 7.6 m (Elev. 85.0) to the base of Borehole 16-03 at a depth of 11.3 m (Elev. 81.3).

SPT 'N' values obtained in the lower sand ranged from 2 blows for 0.3 m penetration to 35 blows per 0.3 m penetration, indicating a very loose to dense relative density.

Samples of the lower sand were subjected to the grain size analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix A. The grain size distribution curves for these samples are shown on Figure B4 of Appendix B.

Soil Particles	%
Gravel	0 to 5
Sand	79 to 99
Silt & Clay	1 to 16

Measured moisture contents ranged from 11% to 23%.

5.5 Lower Sand and Gravel to Gravelly Sand

A coarse cohesionless deposit ranging in composition from sand and gravel to gravelly sand was encountered at depths in Boreholes 16-01 to 16-03. This deposit contained trace silt and frequent cobbles and boulders, which required coring to advance the boreholes. The boulders encountered in the boreholes were up to 350 mm in size.

In Boreholes 16-01 and 16-02, the sand and gravel underlies the lower sand below depths of 8.4 m (Elev. 84.3) and 5.6 m (Elev. 86.5), respectively, and extends to the base of the boreholes at depths of 24.9 m (Elev. 67.8) and 15.8 m (Elev. 76.3). Zones of sandy gravel were observed in



the deposit. A 1.5 m thick layer of gravelly sand was encountered in Borehole 16-03 extending below 6.1 m depth (Elev. 86.5) within the lower sand.

SPT 'N' values obtained in the lower sand and gravel to gravelly sand ranged from 20 blows for 0.3 m penetration to in excess of 100 blows per 0.3 m penetration, indicating a compact to very dense relative density, typically being compact to dense. The SPT 'N' values above 100 blows per 0.3 m of penetration are considered to be indicative of the presence of cobbles and boulders.

Samples of the lower sand and gravel to gravelly sand underwent grain size analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix A. The grain size distribution curves for these samples are shown on Figure B5 of Appendix B.

Soil Particles	%
Gravel	48 to 66
Sand	34 to 51
Silt & Clay	0 to 4

Measured moisture contents ranged from 10% to 19%.

5.6 Groundwater Conditions

Where possible, water levels were monitored in the open boreholes during drilling operations. Wash boring and/or coring methods were used to advance all boreholes and therefore water levels recorded during or upon completion of drilling may not reflect natural groundwater levels. The water levels observed upon completion of drilling are summarized in Table 5.1.

Table 5.1 – Water Level Measurements

Borehole	Date	Water Level		Comment
		Depth (m)	Elev. (m)	
16-01	September 11, 2016	- 0.6 ¹⁾	93.3	Open Borehole
16-02	N/A	N/A	-	Not Available
16-03	September 20, 2016	2.4	90.2	Open Borehole
16-04	September 21, 2016	2.7	90.9	Open Borehole

Note: ¹⁾ Upon completion of drilling, the water level in the casing was observed at 0.6 m above the ground. This was a short term observation and may be due to an upward groundwater gradient or possible the effects of the circulating fluid used in drilling. The borehole was sealed with the bentonite on completion of drilling.



The recorded levels are short-term readings and seasonal fluctuations of the groundwater and river level are to be expected. In particular, the water level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

The Preliminary General Arrangement drawing provided by MMM Group indicated water level in Watabeag River at Elev. 90.2 On June 9, 2015.

6. CORROSIVITY AND SULPHATE TEST RESULTS

Two samples of the native sand and a sample of surface water from the Watabeag River were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are summarized 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		
			Soil Samples		Watabeag River Water
			BH 16-02, Sample 7	BH 16-01, Sample 5	
Corrosivity Index	-	-	4	4	-
pH	-	-	8.26	8.09	7.84
Redox Potential	mV	mV	177	170	159
Sulphide	%	mg/L	<0.02	<0.02	<0.006
Moisture (wet wt)	%	%	15.77	11.43	-
pH	-	-	9.09	9.15	-
Chloride	µg/g	mg/L	1.3	2	0.34
Sulphate	µg/g	mg/L	13	12	2.7
Electrical Conductivity	mS/cm	µS/cm	67	64	144
Resistivity	ohms.cm	ohms.cm	14900	15600	696



7. MISCELLANEOUS

Borehole locations were selected and established in the field by Thurber Engineering Ltd. The ground surface elevations at the borehole locations were derived from the Preliminary General Arrangement drawing provided to Thurber by MMM. As indicated in Section 3 of this report, the elevations on the General Arrangement drawing were based on the local datum.

Thurber obtained utility clearances for the borehole locations prior to drilling. Overall supervision of the field program was carried out by Mr. Stephane Loranger, CET. The drilling operations were supervised by Mr. Omar Ali and Mr. Simon Paxton of Thurber. Eastern Ontario Diamond Drilling of Hawkesbury, Ontario, supplied a track-mounted CME-45 drill rig and conducted the drilling, sampling and in-situ testing operations.

Routine laboratory testing was carried out at Thurber's geotechnical laboratory. Analytical laboratory testing was conducted by SGS Canada Inc.

Interpretation of the field data and preparation of this report were carried out by Ms. Anna Piascik, P.Eng. The report was reviewed by Mr. Alastair Gorman, M.Sc., P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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GEOGRES No. 42A-111

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This report presents interpretation of the geotechnical data in the factual report and provides geotechnical recommendations for the proposed replacement of the existing Watabeag River Bridge located on Watabeag Lake Road, approximately 46.1 km north of Highway 66, and 28.7 km south of Highway 11, in the Township of McEvay.

This foundation investigation and design report with the interpretations and recommendations is 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 contractors. The design-build contractors must make their own interpretations 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.

The existing bridge built in 1975 is a 12.8 m single-span, single lane structure with timber deck. The superstructure is supported by closed faced timber crib abutments. In the vicinity of the existing bridge, the river banks are between 2.5 and 3 m in height. Watabeag Lake Road is a gravel surface / un-paved road running generally in the north-south direction. Watabeag River flows from east to west at the bridge site to discharge into Lake Watabeag.

The Preliminary General Arrangement (GA) drawing dated November 2016 indicates the replacement bridge to be a composite wood-fiberglass structure with encapsulated glulam deck, beams and diaphragms. The grade of Watabeag Lake Road at the replacement bridge was shown at Elevation 92.5 at the south abutment and Elev. 92.8 at the north abutment, approximately.

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The elevations quoted in this report refer to a local datum in accordance with the Preliminary General Arrangement drawing, dated November 2016, provided by MMM.

The discussions and recommendations presented in this report are based on information provided in the Terms of Reference, Preliminary General Arrangement drawing and on the factual data obtained during the course of this investigation.

9. STRUCTURE FOUNDATIONS

In general, the soil stratigraphy below the existing approach embankment fill consists of an extensive cohesionless deposit ranging in composition from sand/gravelly sand to sand and gravel. Frequent cobbles and boulders were encountered and cored during advancing the boreholes. The boreholes located in the areas of the north and south abutments were terminated at depths of 24.3 m depth and 15.8 m, respectively, in the sand and gravel deposit containing cobbles and boulders.

Water levels measured in open boreholes varied from a depth of 2.7 m (Elev. 90.9) on the north side of the river and 2.4 m (Elev. 90.2) on the south side of the river. It is anticipated that the groundwater level will be influenced by the water level in the river, which was indicated on the Preliminary General Arrangement drawing at Elev. 90.2 on June 9, 2015.

As indicated on the Preliminary General Arrangement drawing, the replacement bridge will be constructed on the same alignment as the existing bridge. The replacement bridge will be approximately 17.5 m long and 5 m wide.

The following foundation options were considered for the support of this bridge:

- spread footings placed on the native cohesionless deposit
- spread footings placed on the engineered fill, and
- driven steel H-piles.

Recommendations for design of the feasible foundation options are presented in the following sections together with the corresponding geotechnical design parameters, where applicable. A comparison of foundation alternatives is presented in Appendix F, and the preferred foundation option indicated.

9.1 Spread Footings on Native Sand/Gravelly Sand

The replacement bridge could be supported on spread footings placed on native sand to gravelly sand at or below Elev. 90.0. It should be noted that the water level in the Watabeag River was indicated at Elev. 90.2 on June 9, 2016, therefore dewatering of the excavations for construction



of spread footings placed on native sand/gravelly sand will be required to construct the foundation in the dry.

The forward edge of a spread footing must be at least 1.0 m behind the face of the forward slope, measured at the founding elevation. The 1.0 m setback applies to native soil and any thickness of rock protection cannot be counted for the setback distance. In the forward slope area, no excavation may take place below a 2H:1V slope.

9.1.1 Axial Geotechnical Resistance and Geotechnical Reaction

The following values of factored Geotechnical Resistance at ULS and Geotechnical Reaction at SLS may be used for design of a spread footing placed on properly prepared native undisturbed sand/gravelly sand placed at or below Elev. 90.0

Footing Width	1.0 m	2.0 m
Factored Geotechnical Resistance at ULS (kPa)	300	380
Geotechnical Reaction at SLS (kPa)	200	250

The value of the Geotechnical Reaction at SLS given above is for 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 CHBDC 2014. The Geotechnical Reaction 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.

9.1.2 Lateral Resistance

The lateral resistance of the footings founded on sand/gravelly sand may be computed using an unfactored friction coefficient of 0.5 for sand/concrete interface. This value of friction coefficient is an “ultimate” value and requires a degree of sliding movement to occur to fully mobilize the resistance.



9.2 Spread Footings on Engineered Fill Pads

The preliminary GA drawing indicates the finished road grade at approximate Elev. 92.6 at the south abutment, and Elev. 92.8 at the north abutment. The existing embankment fill materials extend to depths of 2.7 m to 2.1 m (Elev. 90.0) at the borehole locations in the areas of the north and south abutments. The fill is loose to compact and consists of sand and gravel with trace to some silt and occasional cobbles. Underlying the fill is a native deposit of sand grading to gravelly sand and sand and gravel.

The use of engineered fill pads is only recommended if a modular or prefabricated structure is selected that will be supported on precast concrete bearing slabs at a level higher than Elevation 90.0. In this case, the existing embankment fill should be removed to Elevation 90.0 the engineered fill may be placed from Elevation 90.0 up to the underside of the bearing slab.

9.3 Driven H-Pile Foundations

The site is underlain by an extensive cohesionless deposit ranging in composition from sand to sand and gravel, with various amounts of silt and frequent cobbles and boulders. Coring through cobbles and boulders was required in order to advance the boreholes to selected depths. The locations where cobbles and boulders were sampled or were inferred from the drill response during borehole drilling are indicated on the Record of Borehole sheets in Appendix A, and photographs of the recovered cobble/boulder core samples are presented on Photographs 7 and 8 in Appendix C. However, small diameter exploratory boreholes can wander past some boulders and the interpreted results may underestimate the number of boulders.

These cobbles and boulders will be encountered when driving piles through the existing fill and native deposits. If driven piles are to be considered, we recommended that pre-drilling be specified for each pile. This is assessed to be economically justified for a short modular or prefabricated bridge at a remote site.

In light of the above, the use of driven steel H-pile foundations to support the bridge abutments is not recommended.

9.4 Frost Depth

The depth of frost penetration at this site is approximately 2.4 m, as per OPSD 3090.100.

Spread footings placed on the native sand/gravelly sand should be provided with 2.4 m of soil cover for frost protection. Where it is not possible to provide 2.4 m of earth cover from the



nearest exposed face, the frost protection may be augmented by using expanded polystyrene (EPS) boards. Rock protection cannot be counted as earth.

9.5 Recommended Foundation

From a geotechnical and cost perspective and based on the subsurface conditions, spread footings placed on undisturbed, native, cohesionless soils are considered to be the preferred foundation option at this site.

10. ABUTMENT BACKFILL AND LATERAL EARTH PRESSURES

Any new backfill behind the abutment and wing walls, if required, should be placed in accordance with OPSS 902. All backfill material should consist of Granular A, Granular B Type II or Granular B Type III material meeting the specifications of OPSS.PROV 1010. Compaction equipment to be used adjacent to the walls should be restricted in accordance with OPSS.PROV 501.

Lateral earth pressures acting on the abutment walls may be assumed to be distributed triangularly and to be governed by the characteristics of the wall backfill. 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

γ = unit weight of retained soil

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 and the existing material adjacent to the wall. Typical values are given in Table 10.1 below.

Table 10.1 – Earth Pressure Coefficients (K)

Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Existing Granular Fill $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.38*	0.31	0.46*
At Rest (Restrained Wall)	0.43	-	0.47	-
Passive	3.7	-	3.3	-

* For wing walls.

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

The earth pressure coefficients in Table 10.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to use in design may 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 III, or at a depth of 1.7 m for Granular A or Granular B Type II

11. SCOUR AND EROSION CONTROL

The existing forward slopes appear to be experiencing erosion, as shown on the photograph enclosed in Appendix C. Adequate scour and erosion protection should be established to ensure that the forward slopes at the bridge, and the river bank slopes on both sides of the bridge, are protected. The design of the scour and erosion protection works should be undertaken by a specialist in this field.

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

12. EXCAVATION AND GROUNDWATER CONTROL

Construction, including the placement of engineered fill must be carried out in the dry. However, excavation for works associated with the construction of the new abutments is expected to extend through the existing embankment fill and may extend into the native cohesionless deposits. The base of excavation will be located near or below the groundwater level, which is expected to be



largely governed by the water level in the river. It is recommended that the Contract documents give a design high water level that the Contractor may use to design cofferdams and unwatering/dewatering schemes.

The existing crib abutments may be removed down to river level. Removing the cribs below water level will be problematic and from a geotechnical perspective, it is recommended that they be left in place wherever possible.

All excavations should be carried out in accordance with OPSS 902 and the requirements of the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the approach embankment fill within the depth of excavation may be classed as Type 3 soil above the water table and Type 4 below the water level.

The selection of the method of excavation is the responsibility of the Contractor and should be based on the Contractor's experience, equipment and interpretation of the site conditions. The existing timber cribs may contain rock fill material. Cobbles and boulders were encountered and cored during borehole drilling. Provision should be made for handling of potential obstructions in the fill, and in native deposits if required, such as cobbles and boulders.

The contractor is responsible for maintaining a dry work area for construction of the foundations and this will required handling both groundwater seepage and the river water. The requirement for, and selection of methods of excavation, dewatering and cofferdams will be influenced by the final design and by the anticipated river level during construction.

The list of possible cofferdam alternatives includes, though is not limited to:

- Sandbag enclosure
- Driven steel sheetpile enclosure

Sandbags may be less effective than sheet piles and require more pumping but sheet piles may be difficult to drive in the bouldery ground soils encountered at this site.

The groundwater control system will depend on the depth of excavations and water level in the river during construction. For excavation extending close to the water level in the river, seepage from the underlying sand and gravel may be handled by pumping from filtered sumps. The use of sand bagged cofferdams may be considered, where required. More positive groundwater control system will be required for excavation extended below the river water level. The design of groundwater control system is the responsibility of the contractor.



13. ROADWAY PROTECTION SYSTEM

Given relatively shallow excavation required, and the fact that the road will be closed during construction, it is unlikely that installation of roadway protection systems will be required. However, if a temporary protection system is used, the design of the protection system is typically a responsibility of the Contractor, as per OPSS.PROV 539. The protection system should be designed for Performance Level 2 (maximum 25 mm horizontal deflection). In view of the presence of cobbles and boulders in the underlying soils, temporary protection system may consist of steel soldier pile and timber lagging walls, if required.

Full hydrostatic pressure should be considered assuming a water level equal to the design river water level. The actual pressure distribution acting on the protection system is a function of the construction sequence and the relative flexibility of the wall.

All temporary protection systems should be designed by a Professional Engineer experienced in such designs.

14. APPROACH EMBANKMENTS

The existing approach embankments vary in height and could be as high as 2.5 m to 3.0 m near the abutments. No evidence of instability of the existing approach embankments were noted during the time of the foundation investigation, although settlements at the abutments were evident. These settlements could be related to the river bank erosion leading to the undermining of the timber cribs and loss/washout of the abutment fill.

Based on the preliminary General Arrangement drawing, the grade of the existing approach embankments will be raised by up to 0.5 m at the new abutments. The loading imposed by the additional fill could induce up to 25 mm of settlement. The majority of the estimated settlement will occur during construction, shortly after fill placement. Considering the fact that Watabeag Lake Road is a gravel / un-paved road, the predicted ground settlements are expected to be tolerable.

In view of the soil conditions at this site, stability issues are not anticipated for the approach embankments providing the slope inclinations are not steeper than 2H:1V.

15. CORROSION & SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate analytical tests conducted on the embankment fill soil and the river water indicate the following:



- The potential for sulphate attack on concrete foundations from the surrounding soil or surface water is considered to be negligible due to the low concentration of sulphate in the samples tested.
- The potential for soil or water corrosion on metal structural elements is considered to be low base on the low corrosivity index.

16. CONSTRUCTION CONCERNS

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

- Seasonal fluctuations of the groundwater and river water levels are to be expected. In particular, the water level may be at a higher elevation after the spring snowmelt and after periods of heavy rainfall, which may impact the construction.
- Excavation/removal of the existing timber crib abutments should be carried out prior the construction of the new foundations.
- Rock fill may be present as fill in the timber cribs, and cobbles and boulders were encountered in the existing fill and native deposits. Cobbles and boulders may interfere with excavations or installation of temporary protection system, should it be required.



17. CLOSURE

Engineering analysis and preparation of this report were carried out by Ms. Anna Piascik, P.Eng. The report was reviewed by Mr. A. Gorman, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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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 ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

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



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

EXPLANATION OF ROCK LOGGING TERMS


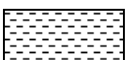

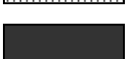

ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
	(MPa)	(psi)	
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length
Solid Core Recovery:(SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run
Rock Quality Designation:(RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a % 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.

UNIFIED SOILS CLASSIFICATION






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

RECORD OF BOREHOLE No 16-01

1 OF 3

METRIC

WP# 5026-14-01 LOCATION Watabeag River Bridge ORIGINATED BY SMP
 HWY Watabeag Road BOREHOLE TYPE HW/NW Casing COMPILED BY AN
 DATUM Local DATE 2016.09.08 - 2016.09.11 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)							
								20 40 60 80 100				w _p w w _L							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE											
92.7	GROUND SURFACE																		
0.0	SAND and GRAVEL , trace to some silt, trace organics, occasional cobbles and boulders Loose to Compact Grey/Brown Moist (FILL) Wood fragments at 1.5m Boulder (300mm) at 2.1m		1	SS	5														
			2	SS	6														
			3	SS	7														
			4	SS	21														
90.0																			
2.7	SAND , trace gravel, some silt Loose Grey Moist																		
			5	SS	7														
89.0																			
3.7	SAND and GRAVEL , trace silt Compact to Loose Grey Moist to Wet Cobble (150mm) at 3.8m																		
			6	SS	16														
			7	SS	8														
86.6																			
6.1	SAND , trace gravel, trace silt Loose Grey Moist Cobbles/boulders at 7.3m		8	SS	9														
			9	SS	9														
84.3																			
8.4	SAND and GRAVEL to Sandy GRAVEL , trace silt, frequent cobbles and boulders Very Dense Grey																		

Continued Next Page

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

RECORD OF BOREHOLE No 16-01

2 OF 3

METRIC

WP# 5026-14-01 LOCATION Watabeag River Bridge ORIGINATED BY SMP
 HWY Watabeag Road BOREHOLE TYPE HW/NW Casing COMPILED BY AN
 DATUM Local DATE 2016.09.08 - 2016.09.11 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	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						20 40 60			
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Continued Next Page

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

RECORD OF BOREHOLE No 16-01

3 OF 3

METRIC

WP# 5026-14-01 LOCATION Watabeag River Bridge ORIGINATED BY SMP
 HWY Watabeag Road BOREHOLE TYPE HW/NW Casing COMPILED BY AN
 DATUM Local DATE 2016.09.08 - 2016.09.11 CHECKED BY AMP





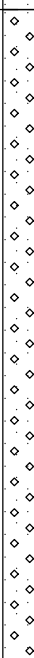
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	SHEAR STRENGTH kPa								WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE													
							● QUICK TRIAXIAL × LAB VANE														
	Continued From Previous Page		16	SS	56																
	Cobbles 75mm at 20.3m, 200mm at 20.6m and 21.0m						72														
	Cobbles/boulders 100mm at 21.6m, 21.8m, 200mm at 21.9, 100mm at 22.3m, 22.4m, 300mm at 22.6m and 125mm at 23.3m						71														
			17	SS	70/ 0.025		70														
							69														
67.8			18	SS	50/ 0.050		68														
24.9	END OF BOREHOLE AT 24.9m. WATER LEVEL AT 0.6m ABOVE GROUND SURFACE ON COMPLETION OF DRILLING. BENTONITE PLUG FROM 10.7m TO SURFACE.																				

RECORD OF BOREHOLE No 16-02

1 OF 2

METRIC

WP# 5026-14-01 LOCATION Watabeag River Bridge ORIGINATED BY SMP
HWY Watabeag Road BOREHOLE TYPE HW/NW Casing COMPILED BY AN
DATUM Local DATE 2016.09.11 - 2016.09.13 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						WATER CONTENT (%)			
								<div><div><div>20406080100</div><div></div><div></div></div></div> <div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div>						<div><div><div>PLASTIC LIMIT</div><div>NATURAL MOISTURE CONTENT</div><div>LIQUID LIMIT</div></div><div><div>W_P</div><div>W</div><div>W_L</div></div></div>			
92.1	GROUND SURFACE																
0.0	SAND , trace gravel, trace silt Loose Brown Moist (FILL)		1	SS	7		92							11 80 9 (SI+CL)			
91.3																	
0.8	SAND and GRAVEL , trace silt, occasional cobbles Compact Brown Moist (FILL)		2	SS	27		91										
			3	SS	19												
90.0																	
2.1	Gravelly SAND , trace silt Dense Grey Moist to Wet		4	SS	35		90										
	Cobbles/boulders at 2.9m						89										
			5	SS	35												
88.4	Cobbles/boulders at 3.7m																
3.7	SAND , trace silt, trace gravel Very Loose Grey Moist to Wet		6	SS	2		88										
			7	SS	3		87										
86.5																	
5.6	SAND and GRAVEL to Sandy GRAVEL , trace silt, frequent cobbles and boulders Compact to Very Dense Grey Moist to Wet		8	SS	24		86							0 99 1 (SI+CL)			
	Cobbles/boulders at 6.7m, 6.9m, 7.0m and 7.3m		9	SS	37									48 51 1 (SI+CL)			
							85										
			10	SS	26		84										
	Cobbles/boulders at 8.8m																
			11	SS	31		83							61 38 1 (SI+CL)			
	Cobbles/boulders at 9.8m and 9.9m																

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

[illegible]





















+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 16-03

1 OF 2

METRIC

WP# 5026-14-01 LOCATION Watabeag River Bridge ORIGINATED BY OA
 HWY Watabeag Road BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Local DATE 2016.09.20 - 2016.09.20 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					GR	SA	SI	CL						
								<div><div><div></div><div></div><div></div><div></div><div></div></div></div>				<div><div><div></div><div></div><div></div><div></div><div></div></div></div>														
92.6	GROUND SURFACE							20	40	60	80	100														
0.0	SAND and GRAVEL , trace silt, occasional cobbles Compact to Very Dense Brown Moist (FILL)		1	SS	20		92													46	48	6 (SI+CL)				
			2	SS	56																					
91.1									91																	
1.5	SAND , some gravel, trace silt, occasional cobbles Dense Grey Moist		3	SS	45																					
90.3									90																	
2.3	Gravelly SAND , trace silt, occasional cobbles Compact Grey Moist		4	SS	22				89																	
			5	SS	22																					
88.0									88																	
4.6	SAND , some silt, trace gravel, occasional cobbles Loose Grey Moist		6	SS	8				87															5	79	16 (SI+CL)
86.5																										
6.1	Gravelly SAND , trace silt, occasional cobbles Compact Grey Moist to Wet		7	SS	35		86																			
85.0							85																			
7.6	SAND , trace to some gravel, trace silt Loose to Compact Grey Moist to Wet		8	SS	7		84																			
			9	SS	5		83															2	96	2 (SI+CL)		

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-03

2 OF 2

METRIC

WP# 5026-14-01 LOCATION Watabeag River Bridge ORIGINATED BY OA
 HWY Watabeag Road BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Local DATE 2016.09.20 - 2016.09.20 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					W _p W W _L 20 40 60					
81.3	Continued From Previous Page		10	SS	14		82										
11.3	END OF BOREHOLE AT 11.3m. BOREHOLE OPEN AND WATER LEVEL AT 2.4m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

ONTMT4S 19-5161-252.GPJ 2015TEMPLATE(MTO).GDT 11/21/16

RECORD OF BOREHOLE No 16-04

2 OF 2

METRIC

WP# 5026-14-01 LOCATION Watabeag River Bridge ORIGINATED BY OA
 HWY Watabeag Road BOREHOLE TYPE Coring COMPILED BY AN
 DATUM Local DATE 2016.09.21 - 2015.09.21 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					W _p W W _L 20 40 60					
Continued From Previous Page																	
82.3	Boulder (300mm) at 10.1m		9	SS	35		83									3 94 3 (SI+CL)	
11.3	END OF BOREHOLE AT 11.3m. WATER LEVEL AT 2.7m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																



Appendix B

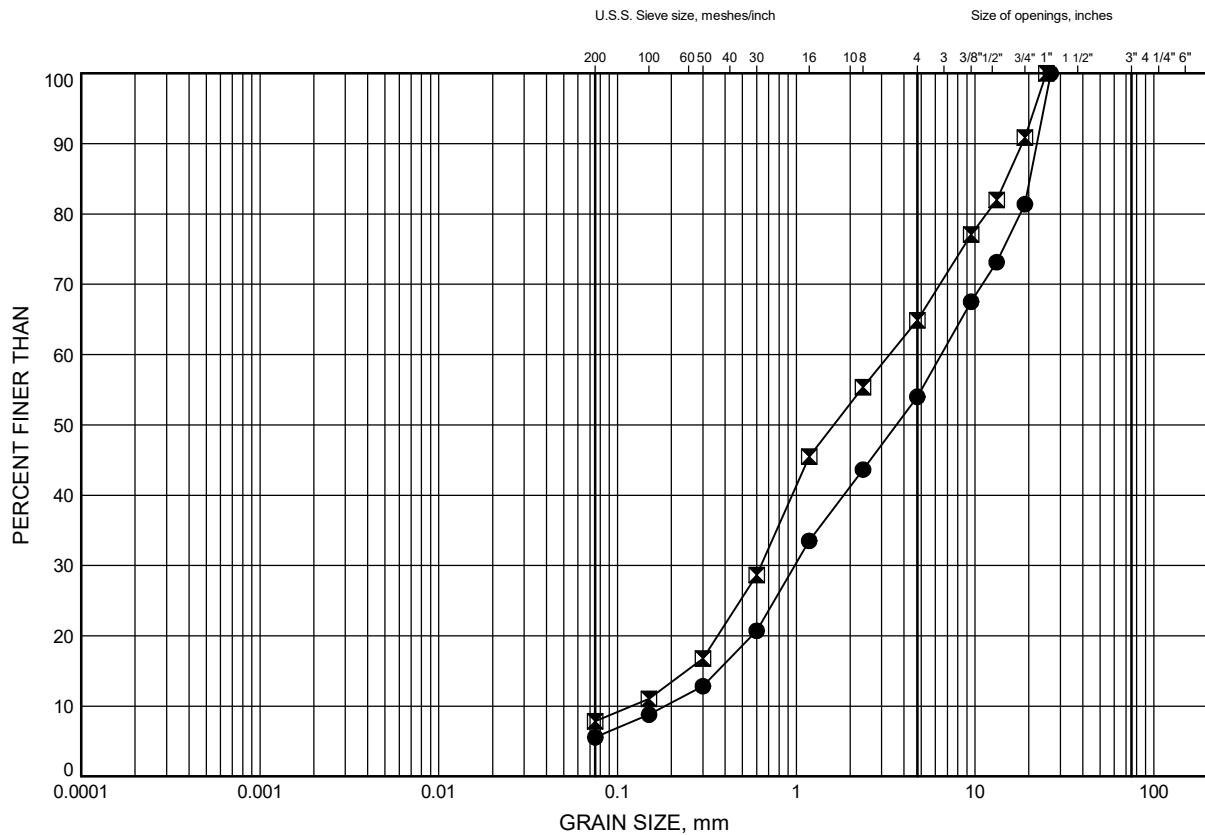
Geotechnical and Analytical Laboratory Test Results

Watabeag River Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND and GRAVEL FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-03	0.30	
⊠	16-04	0.30	

Date October 2016
GWP# 5028-14-00

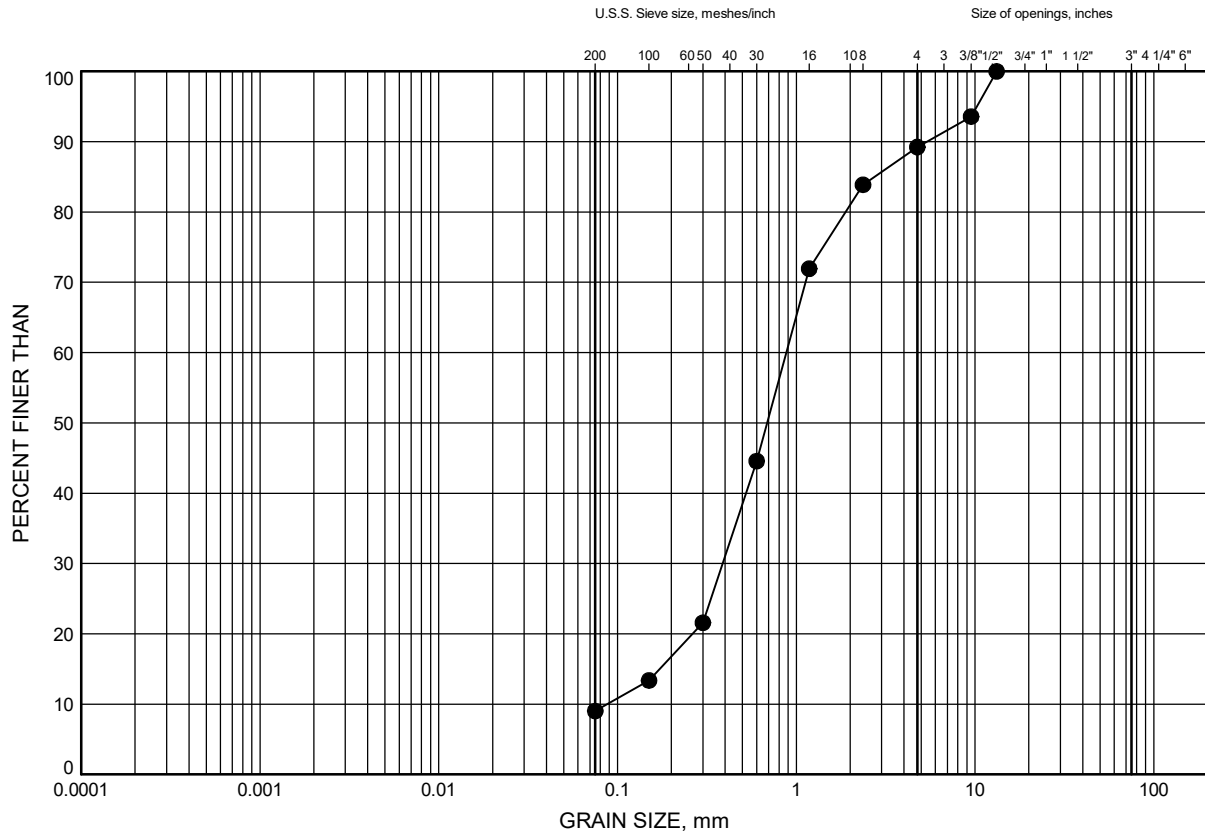


Prep'd MFA
Chkd. AMP

Watabeag River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02	0.30	

Date October 2016
GWP# 5028-14-00



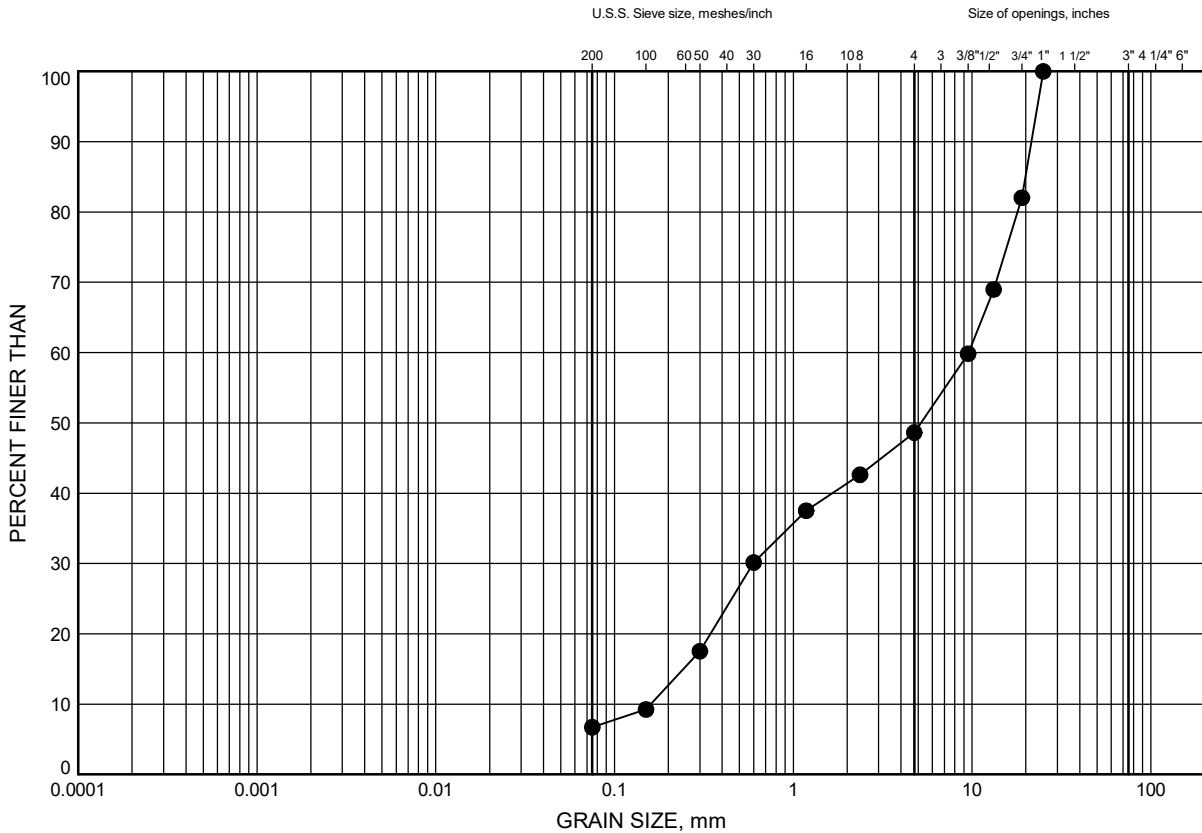
Prep'd MFA
Chkd. AMP

Watabeag River Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B3

Upper SAND and GRAVEL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-04	2.59	

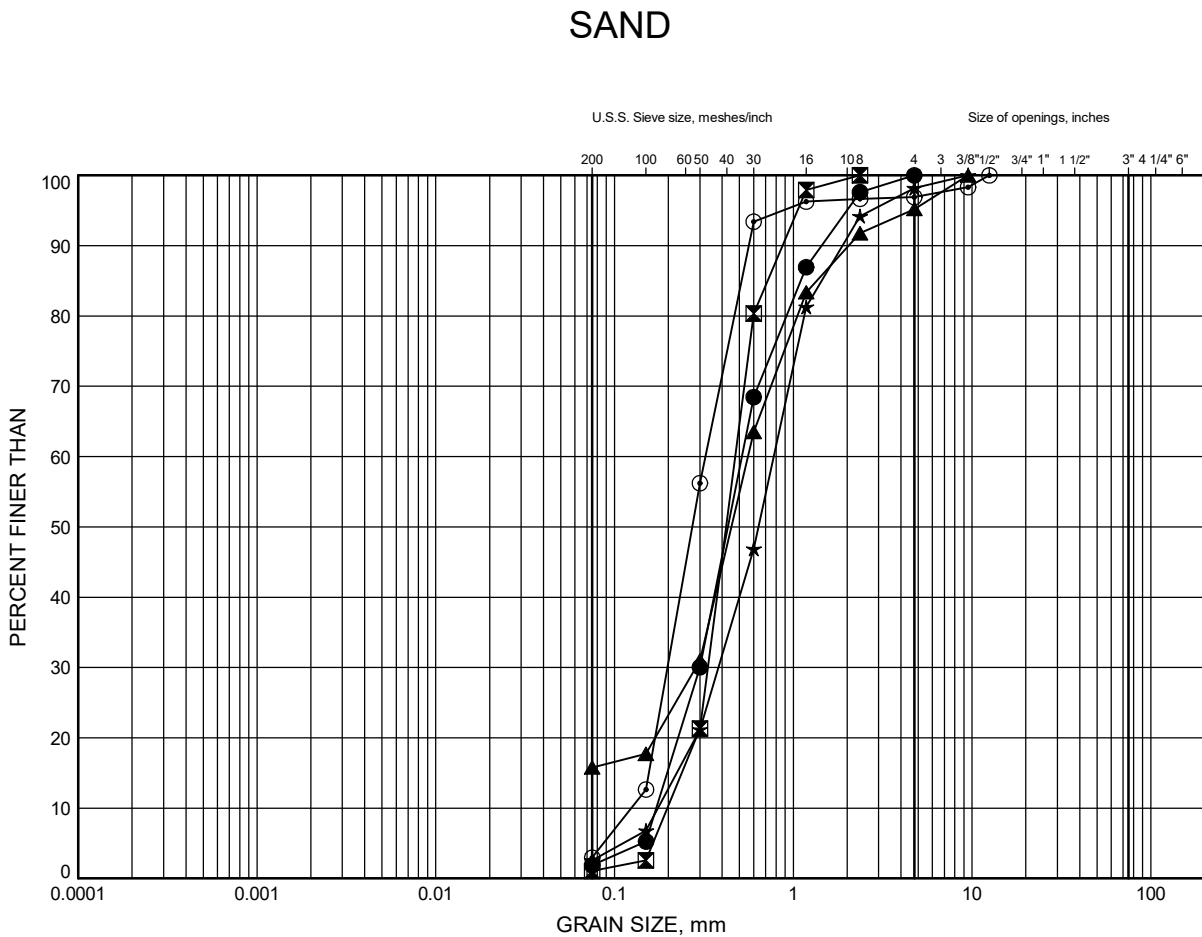
Date October 2016
GWP# 5028-14-00



Prep'd MFA
Chkd. AMP

Watabeag River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B4



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	6.40	
⊠	16-02	5.47	
▲	16-03	4.88	
★	16-03	9.45	
⊙	16-04	10.97	

Date October 2016

GWP# 5028-14-00



Prep'd MFA

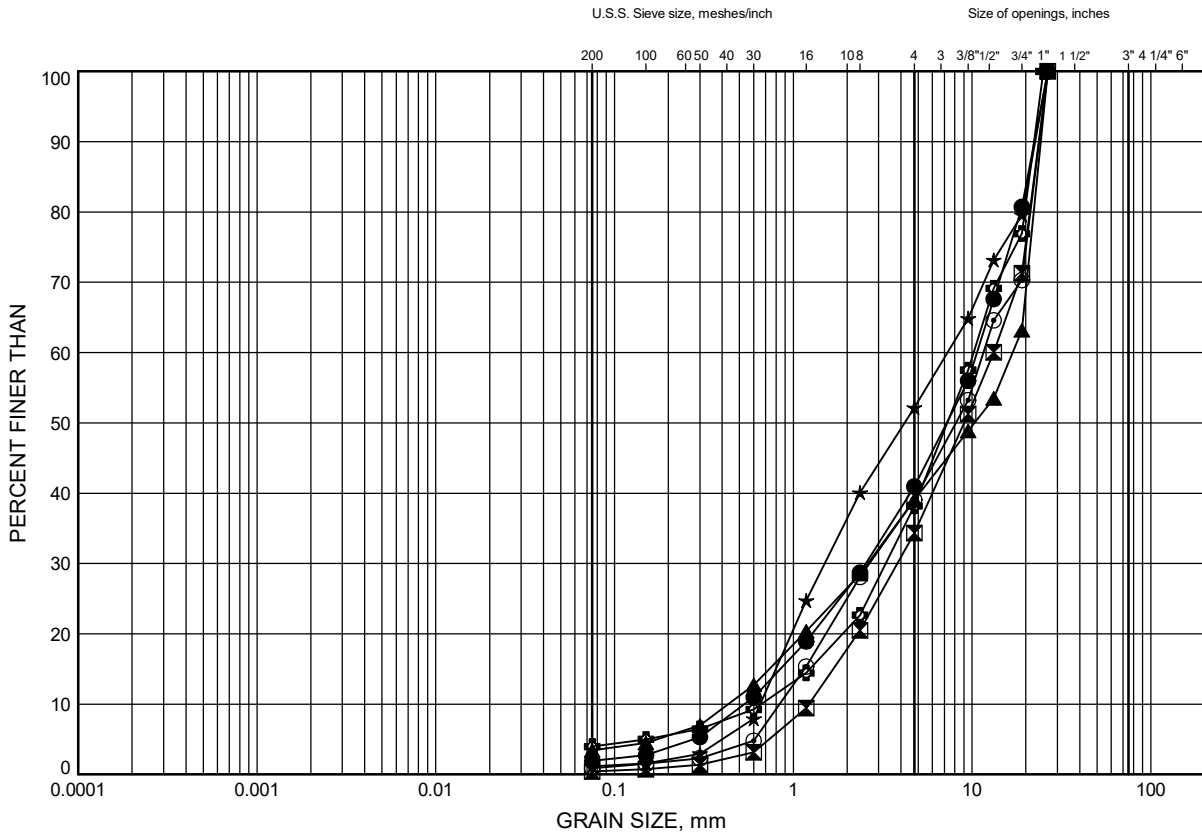
Chkd. AMP

Watabeag River Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B5

Lower SAND and GRAVEL to Sandy GRAVEL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	11.28	
⊠	16-01	14.02	
▲	16-01	18.44	
★	16-02	6.40	
⊙	16-02	9.45	
⊕	16-02	14.02	

Date October 2016

GWP# 5028-14-00



Prep'd MFA

Chkd. AMP

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Project : 19-5161-25R

04-October-2016

Thurber Engineering Ltd

Attn : Anna Piascik

2010 Winston Park Dr
Oakville, ON
L6H 5R7,

Phone: 905-829-8666
Fax:

Date Rec. : 28 September 2016
LR Report: CA15537-SEP16
Reference: 19-5161-25R Anna Piascik

Copy: #1

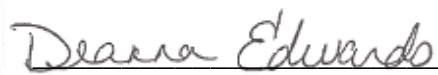
CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: BH16-2 Sample 7 15'-17'	6: BH16-1 Sa5, 10'-12'
Sample Date & Time					28-Sep-16	28-Sep-16
Temperature Upon Receipt [°C]	---	---	---	---	4.0	4.0
Corrosivity Index [none]	03-Oct-16	13:43	03-Oct-16	13:43	4	4
pH [no unit]	01-Oct-16	11:18	03-Oct-16	08:51	8.26	8.09
Soil Redox Potential [mV]	30-Sep-16	18:12	03-Oct-16	09:05	177	170
Sulphide [%]	30-Sep-16	13:45	30-Sep-16	14:05	< 0.02	< 0.02
% Moisture (wet wt) [%]	30-Sep-16	16:36	03-Oct-16	08:46	15.77	11.43
pH [no unit]	29-Sep-16	06:41	29-Sep-16	16:49	9.09	9.15
Chloride [µg/g]	30-Sep-16	19:39	03-Oct-16	08:18	1.3	2.0
Sulphate [µg/g]	30-Sep-16	19:39	04-Oct-16	11:03	13	12
Conductivity [uS/cm]	29-Sep-16	06:41	29-Sep-16	16:49	67	64
Resistivity (calculated) [Ohms.cm]	03-Oct-16	13:37	03-Oct-16	13:37	14900	15600

Temperature of Samples upon receipt 4 degrees C
Cooling agent present
Custody Seal not present

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.


Deanna Edwards, B.Sc, C.Chem
Project Specialist
Environmental Services, Analytical

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Project : 19-5161-25R**LR Report :** CA15537-SEP16

Method Descriptions

Parameter	SGS Method Code	Reference Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Carbon/Sulphur	ME-CA-[ENV]ARD-LAK-AN-020	ASTM E1918
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
Metals Prep	ME-CA-[ENV]ARD-LAK-AN-013	
pH	ME-CA-[ENV]EWL-LAK-AN-001	SM 4500



SGS Canada Inc.

P.O. Box 4300 - 185 Concession St.

Lakefield - Ontario - KOL 2H0

Phone: 705-652-2000 FAX: 705-652-6365

Project : 19-5161-25R

LR Report : CA15537-SEP16

Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank				LCS / Spike Blank			Matrix Spike / Reference Material		
							RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)
					%	Low				High	Low	
Anions by IC - QCBatchID: DIO0457-SEP16												
Chloride	0.4	µg/g	<0.4		11	20	98	80	120	99	75	125
Sulphate	0.4	µg/g	<0.4		3	20	102	80	120	94	75	125
Carbon/Sulphur - QCBatchID: ECS0040-SEP16												
Sulphide	0.02	%	<0.02		ND	20	108	80	120			
Conductivity - QCBatchID: EWL0413-SEP16												
Conductivity	2	uS/cm	4		0	10	98	90	110	NA		
pH - QCBatchID: ARD0081-SEP16												
pH	0.05	no unit			0	20	100	80	120			

**SGS Canada Inc.**

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 Lakefield - Ontario - KOL 2H0
 Phone: 705-652-2000 FAX: 705-652-6365

Project : 19-5161-25R

07-October-2016

Thurber Engineering Ltd

Attn : Anna Piascik

2010 Winston Park Dr
 Oakville, ON
 L6H 5R7,

Phone: 905-829-8666

Fax:

Date Rec. : 03 October 2016**LR Report:** CA16007-OCT16**Reference:** 19-5161-25R Anna P.

CERTIFICATE OF ANALYSIS

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: MDL	6: Watabeag River
Sample Date & Time						28-Sep-16
Temperature Upon Receipt [°C]	---	---	--	--	---	4.0
pH [no unit]	04-Oct-16	10:07	05-Oct-16	11:53	0.05	7.84
Conductivity [µS/cm]	04-Oct-16	13:27	04-Oct-16	15:48	2	144
Resistivity (calculated) [MOhms.cm]	07-Oct-16	10:11	07-Oct-16	10:11	---	696
Redox Potential [mV]	04-Oct-16	13:20	06-Oct-16	10:29	---	159
Chloride [mg/L]	05-Oct-16	01:59	07-Oct-16	09:13	0.04	0.34
Sulphate [mg/L]	05-Oct-16	01:59	06-Oct-16	08:43	0.04	2.7
Sulphide [mg/L]	04-Oct-16	09:23	04-Oct-16	14:34	0.006	< 0.006

Method Descriptions

Parameter	SGS Method Code	Reference Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
pH	ME-CA-[ENV]EWL-LAK-AN-006	SM 4500
Redox Potential		SM 2580
Sulphide by SFA	ME-CA-[ENV]SFA-LAK-AN-008	SM 4500

Deanna Edwards
 Deanna Edwards, B.Sc, C.Chem
 Project Specialist
 Environmental Services, Analytical

Quality Control Report

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank		RPD		Acceptance Criteria		LCS / Spike Blank			Matrix Spike / Reference Material	
									Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)
					%	Low	High	Low		High			
Anions by IC - QCBatchID: DIO0039-OCT16													
Chloride	0.04	mg/L	<0.04		1	20	97	80	120	98	75	125	
Sulphate	0.04	mg/L	<0.04		0	20	101	80	120	99	75	125	
Anions by IC - QCBatchID: DIO0055-OCT16													
Chloride	0.04	mg/L	<0.04		3	20	101	80	120	93	75	125	
Conductivity - QCBatchID: EWL0034-OCT16													
Conductivity	2	µS/cm	NA		0	10	98	90	110	NA			
pH - QCBatchID: EWL0023-OCT16													
pH	0.05	no unit	NA		0		100			NA			
Redox Potential - QCBatchID: EWL0032-OCT16													
Redox Potential	no	mV	NA		2	20	101	80	120	NA			
Sulphide by SFA - QCBatchID: SKA0018-OCT16													
Sulphide	0.006	mg/L	0.012		ND	20	92	80	120	79	75	125	



Appendix C

Selected Site Photographs



Photo 1 – Watabeag River Bridge; Looking North



Photo 2 – Watabeag River Bridge; Looking South



Photo 3 – Watabeag River Bridge - East Side; Looking Downstream



Photo 4 – Watabeag River Bridge - West Side; Looking Upstream



Photo 5 – North Abutment



Photo 6 – South Abutment



Photo 7 – Typical Sample of Cobbles and Boulders Cored in Borehole 16-01.

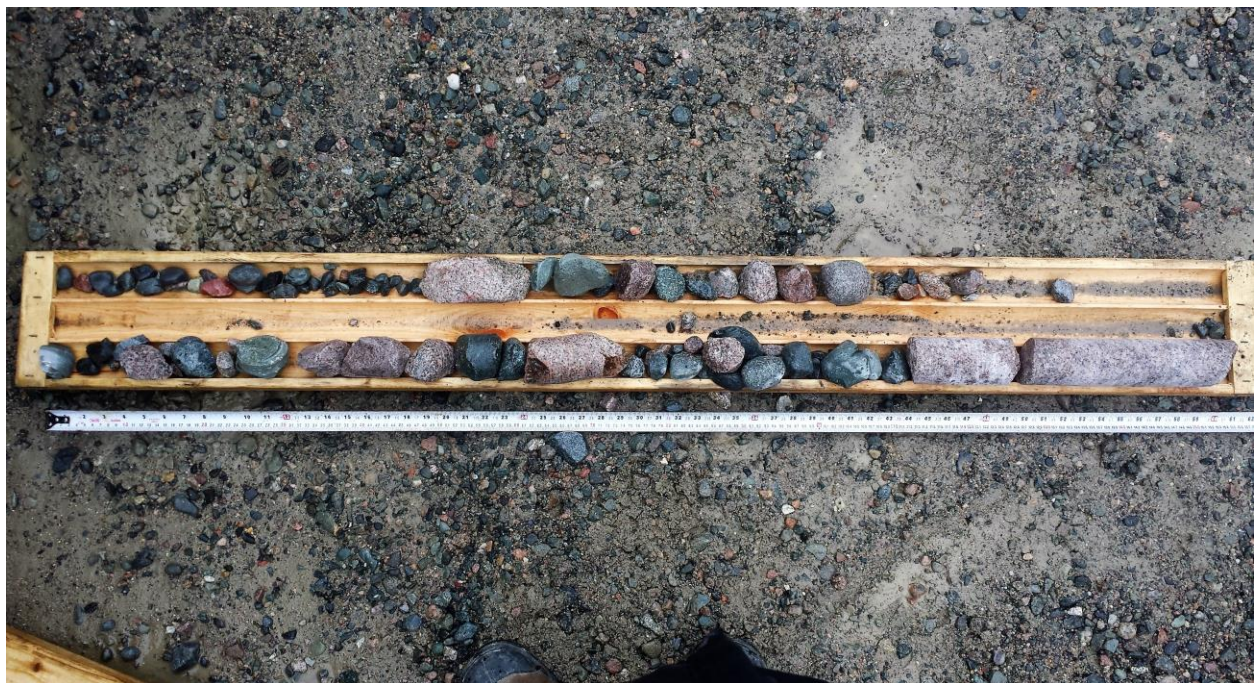


Photo 8 – Typical Sample of Cobbles and Boulders Cored in Borehole 16-02.



Appendix D

Borehole Locations and Soil Strata Drawing

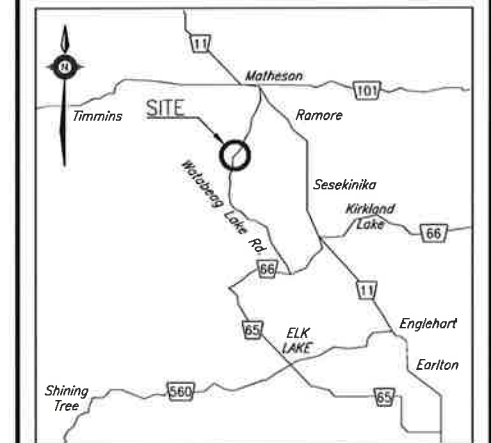
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
WP No 5026-14-01

WATABEAG RIVER BRIDGE
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



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

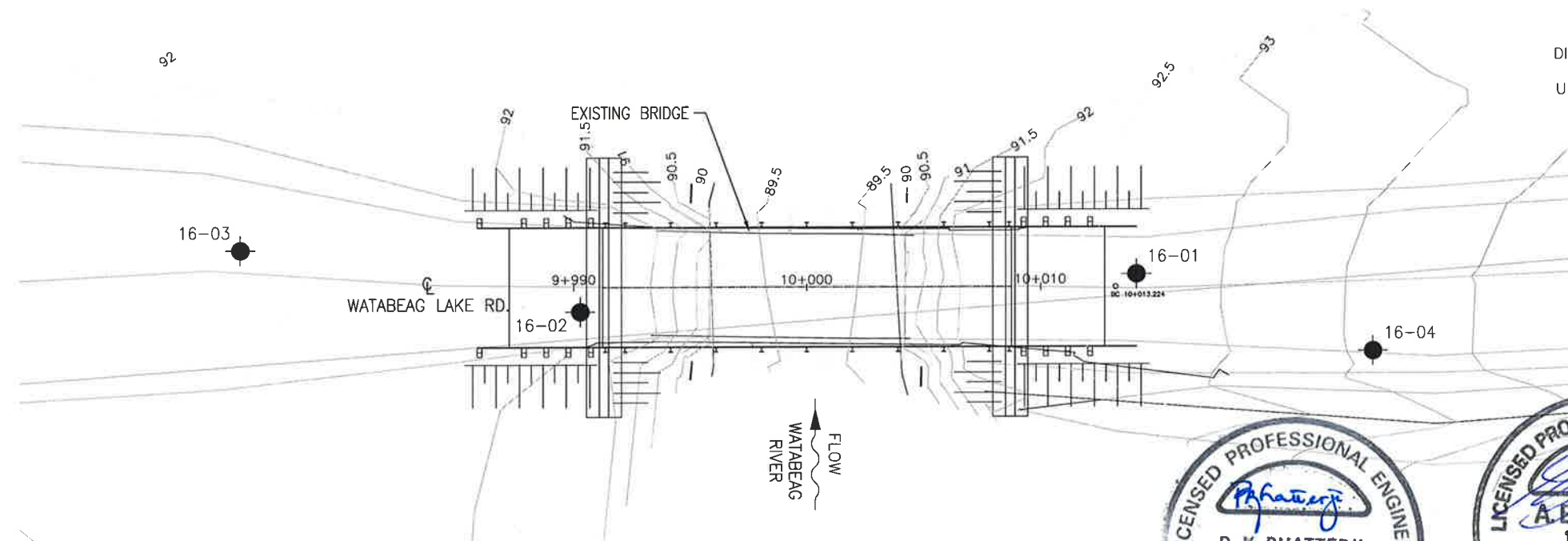
NO	ELEVATION	NORTHING	EASTING
16-01	92.7		
16-02	92.1		
16-03	92.6		
16-04	93.6		

-NOTES-

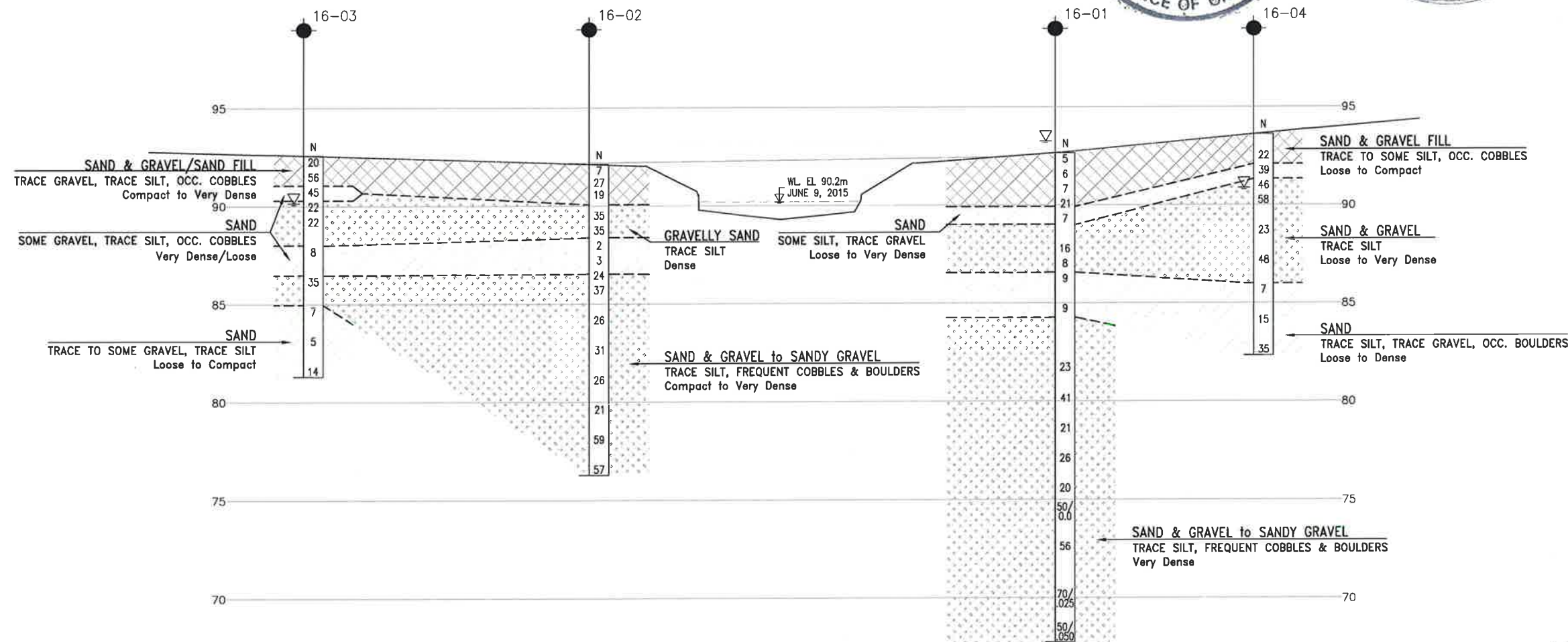
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Local datum was used to obtain ground surface elevations at the borehole locations.

GEOCRES No. 42A-111

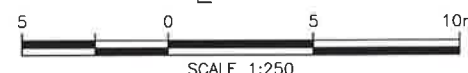
REVISIONS	DATE	BY	DESCRIPTION
DESIGN	AMP	CHK	PKC
DRAWN	AN	CHK	AMP
		SITE	47-06B
		STRUCT	
		DWG	1



PLAN



PROFILE ALONG CL WATABEAG LAKE RD.





Appendix E

List of Specifications and Suggested Text for Selected NSSP



1. List of OPSS Documents Referenced in this Report

- OPSS.PROV 501
- OPSS. PROV 539
- OPSS 804
- OPSS PROV 902
- OPSS. PROV 903
- OPSS.PROV 1010

2. Suggested text for NSSP on “Obstructions”

Cobbles and boulders and rock fill are present within the existing embankment and underlying native soils at this site. These cobbles and boulders and rock fill may impede excavations, installation of piles and/or temporary support system. At some locations, the installation may not be able to penetrate the obstructions and reach the design elevations. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths.



Appendix F

Comparison of Foundation Alternatives



COMPARISON OF FOUNDATION ALTERNATIVES

Spread Footings on Native Soils	Spread Footings on Engineered Fill Pad	Driven H-piles
<p>Advantages:</p> <ul style="list-style-type: none"> i. Relative ease of construction. ii. More cost effective than deep foundations. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Relative ease of construction. ii. More cost effective than deep foundations. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Higher geotechnical resistance if driven to refusal compared to spread footings ii. Installation less influenced by river water level and groundwater compared to spread footing iii. Facilitate the integral abutment design. iv. Requires less excavation than spread footings
<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Potentially deep excavation at abutments ii. May require groundwater control. iii. Not feasible for integral abutment design. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Potentially deep excavation at abutments ii. May require groundwater control. iii. Not feasible for integral abutment design iv. If founding level is located near the native competent soil (GA for Watabeag River Bridge), there is no need for the engineered fill pad. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Piles may encounter refusal at varying depth due to frequent cobbles and boulders. ii. Higher unit costs than spread footings. iii. Piles may require predrilling to achieve design length. iv. Potential difficulties during installation and associated additional cost implications.
Low risk of encountering problems during construction.	Low risk of encountering problems during construction.	High risk of encountering cobbles and boulders that would require additional procedures to advance the piles to the desired elevation.
RECOMMENDED	NOT RECOMMENDED	NOT RECOMMENDED