FOUNDATION INVESTIGATION AND DESIGN REPORT
ELBOW CREEK BRIDGE REPLACEMENT
HIGHWAY 599
KENORA DISTRICT, ONTARIO

G.W.P. 6109-10-00, SITE NO. 41S-76

Geocres Number: 52G-11

Report to:

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the existing Elbow Creek Bridge along Highway 599, in the District of Kenora, 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 and cross-sections, 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 WSP Canada Inc., under the Ministry of Transportation Ontario (MTO) Agreement Number 6010-E-0012.

2 SITE DESCRIPTION

The existing Elbow Creek Bridge is located on Highway 599 approximately 70 km north (by road) from the intersection of Highways 17 and 599 at Ignace, approximately 120 km east of Dryden and 160 km west of Lake Nipigon.

Elbow Creek flows from the east to the west, connecting Sturgeon Lake to Elva Lake. The creek channel is approximately 7 m wide and 1 m deep at the site. The surrounding lands are undeveloped and heavily wooded. The banks of the creek and the base of the existing highway embankment are lined with numerous cobbles and boulders.

Photographs in Appendix C show the general nature of the site and the existing bridge.

The site lies within the physiographic region known as the Wabigoon Subprovince of the Superior Province of the Canadian Shield. The site is underlain by glacial deposits of sand, gravelly sand and gravel, or a thin layer of drift overlying Neo to Mesoarchean mafic to intermediate meta-volcanic rocks.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out in two phases, between August 23 and September 9, 2011 and between May 5 and June 2, 2014. The field testing consisted of drilling and sampling ten boreholes, identified as Boreholes ECB-01 to ECB-06 and ECB-09 to ECB-12, and excavating one test pit, identified as Test Pit ECB-07. The second phase of the investigation was conducted in order to collect additional subsurface information to support various configurations for the replacement bridge structure. The approximate locations of the boreholes and test pit are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix G.

Boreholes ECB-01 to ECB-04 and ECB-09 to ECB-12 were drilled near the proposed abutments and were terminated at depths of 6.1 m to 15.0 m, including coring 2.9 to 3.3 m into bedrock. Test Pit ECB-07 was excavated near the west end of the proposed south abutment and was terminated at a depth of 1.1 m upon bedrock. Boreholes ECB-05 and ECB-06 were drilled to depths of 11.3 m and 4.6 m at the north and south approaches, respectively. A proposed Borehole ECB-08 at the west end of the north abutment was not drilled due to access constraints.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling. The coordinates and ground surface elevations for the boreholes were derived from topographic plans provided to Thurber by WSP Canada Inc.

Truck and track-mounted CME 75 drill rigs were used to advance the boreholes using a combination of hollow stem augers, NW casing/wash boring techniques, and NQ coring. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). A Caterpillar 420 backhoe was used to excavate the test pit.

NQ coring techniques were used to recover 2.9 to 3.3 m long core samples from the bedrock in Boreholes ECB-01 to ECB-04 and ECB-09 to ECB-12. All rock cores were logged and the Total Core Recovery (TCR), Rock Quality Designation (RQD) and Fracture Indices (FI) were determined.

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

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Groundwater conditions observed after completion of drilling were not representative of site conditions as water was used during wash boring and coring operations. Standpipe piezometers were installed in two boreholes to monitor the groundwater level after drilling. The piezometers were subsequently decommissioned and the boreholes without piezometers were backfilled in general accordance with MOE Regulation 903. Completion details of the piezometers and boreholes are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Foundation Unit	Boreholes	Piezometer Tip Depth/ Elevation (m)	Completion Details
North Approach	ECB-05	None installed	Borehole backfilled with holeplug from 11.3 m to 2.1 m, sand and gravel to 1.0 m, concrete to 0.1 m then asphalt to surface.
North Abutment	ECB-01	15.0/ 393.6	Sand from 15.0 m to 12.9 m, holeplug from 12.9 m to 3.0 m, sand and gravel from 3.0 m to 0.15 m then asphalt to surface.
	ECB-04	None installed	Borehole backfilled with holeplug from 14.6 m to 0.30 m, concrete to 0.10 m then asphalt to surface.
	ECB-10	None installed	Borehole backfilled with holeplug to 0.1 m, then asphalt to surface.
	EBC-12	None installed	Borehole backfilled with holeplug and cuttings from 12.7 m to surface.
South Abutment	ECB-02	None installed	Borehole backfilled with holeplug from 5.8 m to 0.9 m, sand and gravel to 0.10 m then asphalt to surface.
	ECB-03	7.1/ 401.4	Sand from 7.1 m to 4.9 m, holeplug to 4.9 m to 0.15 m then asphalt to surface.
	ECB-07	None installed	Test pit backfilled to surface.
	ECB-09	None installed	Borehole backfilled with holeplug to 0.1 m, then asphalt to surface.
	ECB-11	None installed	Borehole backfilled with holeplug and cuttings from 7.4 m to surface.
South Approach	ECB-06	None installed	Borehole backfilled with holeplug from 4.6 m to 1.0 m, sand and gravel to 0.1 m then asphalt to surface.

4 LABORATORY TESTING

All recovered soil samples were subjected to visual identification and natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (sieve and hydrometer). The results of this testing program are summarized on the Record of Borehole sheets included in Appendix A and on the figures presented in Appendix B.

Bedrock core samples were subjected to geotechnical logging. Point load tests were carried out on selected samples of intact rock in the laboratory to evaluate the unconfined compressive strength (UCS) of the bedrock. The average UCS values of the intact rock assessed from the point load test data are reported on the borehole logs in Appendix A.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole and Test Pit 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 G. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole and Test Pit sheets governs any interpretation of the site conditions. It must be recognized that soil conditions may vary between and beyond borehole and test pit locations.

The soil stratigraphy below the existing highway embankment typically comprises a native cohesionless deposit ranging from gravelly sand to silty sand over metamorphic bedrock. Both the embankment fill and native soils contain cobbles and boulders. More detailed descriptions of the individual strata are presented below.

5.1 Asphalt

Asphalt was encountered in all the boreholes drilled from the existing Highway 599 roadway. The asphalt was between 150 and 250 mm thick.

5.2 Topsoil

A topsoil layer ranging from 50 to 225 mm thick was encountered at the ground surface in Boreholes ECB-11 and ECB-12 and in Test Pit ECB-07.

5.3 Sand and Gravel Fill

The existing highway embankment fill beneath the asphalt typically comprised a brown gravelly sand to sand and gravel fill with trace to some silt and cobbles and boulders. The embankment fill has a total thickness of 2.7 to 3.8 m in boreholes advanced from the top of embankment, with a lower boundary at depths of 3.0 to 4.0 m (Elev. 405.6 to 404.5).

SPT ‘N’ values recorded in the fill ranged from 5 to 84 blows per 0.3 m penetration and typically from 11 to 49, indicating a compact to dense relative density. SPT ‘N’ values of 50 blows for

0.05 to 0.125 m of penetration were recorded in Boreholes ECB-09 and ECB-10, indicating the presence of cobbles and boulders. Coring was required to penetrate the cobbles and boulders within the lower portion of the fill in Boreholes ECB-01 to ECB-05. Measured moisture contents of the fill ranged from 4% to 17%.

The results of grain size analysis tests 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 B1 of Appendix B.

Gravel %	23 to 58
Sand %	39 to 67
Silt & Clay %	3 to 13

5.4 Sand Fill

A layer of brown sand fill was encountered below the topsoil in Boreholes ECB-11 and ECB-12, which were drilled on the east side of the highway embankment. The sand contained trace to some silt, trace gravel and occasional cobbles and boulders. The sand fill ranged from 0.6 m to 2.1 m thick, with lower boundary depths of 0.7 to 2.2 m (Elev. 406.9 to 405.6).

SPT 'N' values of 8 and 10 blows for 0.3 m of penetration were recorded in the sand fill in Borehole ECB-11, indicating a loose to compact relative density. The moisture content ranged from 14% to 26%.

5.5 Peat

A 0.5 m thick layer of compressed peat was encountered beneath the sand fill in Borehole ECB-12. The base of the peat was at 1.2 m depth (Elev. 406.4). An SPT 'N' value of 43 blows for 0.3 m of penetration was recorded in the peat, which is attributed to the presence of cobbles within the organic material. The moisture content of the compressed peat was 17%.

5.6 Sand and Gravel to Gravelly Sand

A native deposit of grey sand and gravel to gravelly sand containing trace to some silt, trace clay and occasional cobbles and boulders was encountered below the embankment fill in Boreholes ECB-01, ECB-04, ECB-05, ECB-06, ECB-09, ECB-10, and below the topsoil in Test Pit ECB-07. The layer was interrupted by a silty sand layer in Boreholes ECB-01, ECB-04 and ECB-05.

The sand and gravel deposit has uninterrupted thickness ranging from 0.5 to 8.5 m. Where interrupted by silty sand layer, the combined thickness of sand and gravel layers ranged from 4.7 to 5.5 m. The lower boundary of the sand and gravel deposit varied in depth from 0.7 to 11.9 m (Elev. 404.6 to 396.6).

SPT 'N' values obtained in the deposit ranged from 9 to 60 blows for 0.3 m penetration indicating a loose to very dense relative density. SPT 'N' values of 50 blows for 0.3 m penetration and 63 blows for 0.2 m penetration were recorded in Boreholes ECB-04 and ECB-10 due to the presence of cobbles. Coring was required to penetrate the cobbles and boulders in the upper 0.6 m in ECB-05 and in the lower 2.1 m in ECB-10. Measured moisture contents ranged from 6% to 22%.

Selected samples of sand and gravel underwent laboratory 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 Figures B2 and B3 of Appendix B.

Gravel %	20 to 60
Sand %	34 to 76
Silt & Clay %	2 to 23

5.7 Silty Sand

A deposit of silty sand with trace to some gravel, trace clay and occasional cobbles and boulders was encountered within and below the sand and gravel deposit in Boreholes ECB-01, ECB-04 and ECB-05 and Test Pit ECB-07, below the sand fill in ECB-11 and below the peat in ECB-12. Borehole ECB-05 was terminated within the silty sand at 11.3 m depth (Elev. 397.3). In Boreholes ECB-01 and ECB-04, the combined thickness of silty sand layers ranged from 3.5 to 3.8 m. In Boreholes ECB-11, ECB-12 and Test Pit ECB-07, the silty sand layer varied from 0.4 m to 8.3 m thick. The lower boundary of the silty sand deposit varied from depths of 1.1 m to 12.0 m (Elev. 404.2 to Elev. 396.6).

SPT 'N' values recorded in the silty sand were between 7 blows for 0.3 m of penetration and 50 blows for 0.15 m of penetration and typically between 20 and 66, indicating a compact to very dense relative density. Coring was required to penetrate the cobbles and boulders within this deposit in ECB-01. Moisture contents ranged between 8% and 16%.

Three samples of the silty sand underwent laboratory 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.

Gravel %	9 to 21
Sand %	54 to 57
Silt & Clay %	25 to 34

5.8 Bedrock

Bedrock was encountered below the fill in Boreholes ECB-02 and ECB-03, below the silty sand in Boreholes ECB-01, ECB-04, ECB-11 and ECB-12 and in Test Pit ECB-07, and below the sand and gravel in Boreholes ECB-06, ECB-09 and ECB-10. Bedrock was proven by recovery of 2.9 m to 3.2 m long rock core samples in eight of the boreholes. In Test Pit ECB-07, the bedrock surface was exposed by open excavation.

The depth to bedrock varied significantly between the south and north abutment. The depths and elevations of the bedrock surface are summarized in Table 5.1.

Table 5.1 – Depths and Elevations of Bedrock

Abutment/ Approach	Borehole	Top of Bedrock	
		Depth (m)	Elevation
North	ECB-01	12.0	396.6
	ECB-04	11.6	397.0
	ECB-10	11.9	396.6
	ECB-12	9.5	398.1
South	ECB-02	3.0	405.5
	ECB-03	3.9	404.6
	ECB-06*	4.6	403.9
	ECB-07**	1.1	404.2
	ECB-09	4.7	403.8
	ECB-11	4.2	403.6

* Refusal on probable bedrock
** Bedrock exposed by test pit excavation

The bedrock recovered in the core samples was described as metamorphic breccia. Total Core Recovery (TCR) in the bedrock was generally 100% and locally 80% to 96% in two core runs. The Rock Quality Designation (RQD) was between 76% and 100%, indicating good to excellent rock quality with the exception of one run near the bedrock surface (Borehole ECB-01) with an RQD of 68%, indicating a fair rock quality. The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m core, was typically less than 5 and locally greater than 10 near the bedrock surface.

The unconfined compressive strength of the intact rock interpreted from point load tests conducted on selected cores ranged from 57 MPa to 294 MPa (average per core run), indicating a strong to extremely strong rock.

5.9 Water Levels

Where possible, water levels were monitored in the open boreholes during drilling operations. Wash boring and rock coring methods were used to advance the boreholes and therefore water levels recorded during or upon completion of drilling may not reflect natural groundwater levels. Standpipe piezometers were installed in two boreholes to monitor the groundwater level after completion. The water levels observed in the open boreholes upon completion and measured in the piezometers are summarized in Table 5.2.

Table 5.2 – Water Level Measurements

Borehole	Date	Water Level		Comment
		Depth (m)	Elev. (m)	
ECB-01	August 25, 2011 September 16, 2011 December 1, 2011 October 28, 2012	3.4 4.1 3.8 4.2	405.2 404.5 404.8 404.4	Open borehole In piezometer In piezometer In piezometer
ECB-02	August 29, 2011	3.0	405.5	Open borehole
ECB-03	August 30, 2011 September 16, 2011 December 1, 2011 October 28, 2012	3.1 3.9 3.8 4.4	405.4 404.6 404.7 404.1	Open borehole In piezometer In piezometer In piezometer
ECB-04	September 9, 2011	3.0	405.6	Open borehole
ECB-05	August 28, 2011	3.6	405.0	Open borehole
ECB-06	August 29, 2011	3.0	405.5	Open borehole
ECB-07	June 2, 2014	0.7	404.6	Open test pit

The preliminary GA drawing provided by WSP Canada Inc. indicates a water level at Elev. 404.8 in the Elbow Creek on May 10, 2011. In general, the groundwater level is expected to be at or slightly above the water level in the creek.

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

6 MISCELLANEOUS

Borehole locations were selected and established in the field by Thurber Engineering Ltd. with direction from WSP Canada Inc. The coordinates and the ground surface elevations for the boreholes were established based on topographic survey information provided by WSP Canada Inc.

Thurber obtained utility clearances for the borehole locations prior to drilling.

Eastern Ontario Diamond Drilling of Hawkesbury, Ontario supplied truck and track-mounted CME-75 drill rigs and conducted the drilling, sampling and in-site testing operations for the boreholes. Perron Contracting of Sioux Lookout, Ontario supplied a 420 Cat backhoe and conducted the test pit excavation. The drilling and test pitting operations were supervised by Mr. Jason Mei, Mr. George Azzopardi, Ms. Eckie Siu, and Mr. Stephane Loranger of Thurber.

Overall supervision of the field program, interpretation of the data, and preparation of the report were carried out by Mr. Mark Farrant P.Eng.

The report was reviewed by Mr. Murray Anderson, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical recommendations for design of a new bridge to replace the existing Elbow Creek Bridge on Highway 599 in the District of Kenora, Ontario.

The existing bridge is a single-span timber deck structure supported on rock filled timber crib abutments. The bridge is approximately 11 m long and 7.5 m wide. The approach embankments are approximately 3.0 to 3.5 m high. It is understood the existing bridge deck and the timber cribs will be removed during the staged construction of the replacement bridge.

Based on information provided by WSP Canada Inc., the proposed replacement bridge will be a single-span structure consisting of a steel multi-plate corrugated culvert supported on spread footings. Corrugated steel sheeting headwalls are proposed to retain the approach fill. The proposed span length of the bridge is 12 m with a width of 14.4 m under the embankment. It is anticipated that the replacement structure will be constructed along the existing horizontal alignment and the highway grade will be raised by approximately 0.9 m at the bridge centreline. The total thickness of embankment fill and pavement structure above the crown of the culvert will be approximately 1.2 m.

The discussions and recommendations presented in this report are based on the information provided by WSP Canada Inc. and on the factual data obtained in the course of the investigation.

8 STRUCTURE FOUNDATIONS

The soil stratigraphy below the existing embankment fill at the site typically comprises a thin layer of gravelly sand over bedrock at the south abutment, and interbedded layers of sand and gravel and silty sand at the north abutment. Cobbles and boulders are present within the embankment fill and native cohesionless soils. The depth to bedrock or probable bedrock varied from 1.1 to 4.7 m at the south abutment and 9.5 to 12.0 m at the north abutment.

Groundwater levels measured in the two piezometers installed on site ranged from Elev. 404.1 to 404.8. The creek water level was reported to be at Elev. 404.8 in May 2011.

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

- Spread footings on native soil, bedrock or rock fill
- Driven steel H-piles
- Augered caissons (drilled shafts).

A comparison of the technical advantages and disadvantages of the alternative foundation schemes is presented in Appendix D.

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

8.1 Spread Footings

Based on the subsurface conditions encountered at this site, the use of spread footings to support the abutments is considered feasible from a geotechnical perspective. However, design of the footings and preparation of the founding surface must take into consideration the following:

- Removal of the existing timber cribs may result in disturbance to the native subgrade soils.
- The subgrade conditions vary between the south abutment (relatively shallow bedrock) and the north abutment (sand and gravel).
- Excavation to the founding level may extend below the river and groundwater level.
- The use of precast concrete footings is planned for the proposed culvert type.

Recommendations for design and construction of spread footings for the conditions at the south and north abutments are provided below.

8.1.1 South Abutment

Archive design drawings indicate that the base of the existing timber crib is at Elev. 405.0. The preliminary GA drawing for the new culvert indicates that the design top-of-footing level will be at Elev. 405.2. Assuming an approximate 0.3 m thick precast footing, the design founding level will be at Elev. 404.9, or 0.1 m below the crib bottom.

Based on the borehole information, the subsurface conditions at the anticipated founding level will vary between fill, native sand/gravel and bedrock along the south foundation as follows:

Table 8.1 – Anticipated Subgrade Conditions along South Footing Line

Borehole	Anticipated Subgrade at Elev. 404.9	Depth Relative to Bedrock Surface
ECB-07	Gravelly sand/silty sand	0.7 m above bedrock surface
ECB-02	Bedrock	0.6 m below bedrock surface
ECB-03	Gravelly sand fill, cobbles/boulders	0.3 m above bedrock surface
ECB-09	Sand and gravel fill/gravelly sand	1.1 m above bedrock surface
ECB-11	Compact silty sand	1.3 m above bedrock surface

It is recommended that measures be taken to provide a more uniform founding surface along the footing and improve the foundation performance. The following two options may be considered:

- Sub-excavate all fill and native soils to the bedrock surface, and place tremie concrete up to the design founding level. Excavation of approximately 0.6 m of bedrock would be required at Borehole ECB-02.
- Sub-excavate all bedrock, fill and native soils to a depth of 0.5 m below the design founding level, and re-establish the founding level by placing a uniform thickness of compacted rock fill above the variable subgrade. Excavation of approximately 1.1 and 0.2 m of bedrock would be required at Boreholes ECB-02 and ECB-03, respectively.

The borehole data indicates the presence of sloping bedrock between the south and north abutments, and it is possible that the bedrock surface falls sharply below the existing crib/new footing at the south abutment. In this case, excavation to the bedrock surface for concrete placement (first option) may extend substantially deeper than anticipated. Implementation of the second option indicated above (rock fill pad) is therefore recommended.

The following geotechnical resistances are recommended for design of 1.2 to 2.0 m wide spread footings founded on a 0.5 m thick layer of compacted rock fill as outlined above:

Factored Geotechnical Resistance at ULS	450 kPa
Geotechnical Reaction at SLS	300 kPa

The width of footing must be designed based on the load demand from the culvert structure and overlying embankment fill.

8.1.2 North Abutment

The anticipated design founding level for footings at the north abutment is Elev. 404.9 as per the south abutment. Based on the borehole information, the subsurface conditions at the anticipated founding level will comprise native sand and gravel to silty sand, varying in denseness from loose to very dense.

Placing the footings on the native sand, gravel and silty sand is considered feasible. However, it is recommended that the uniformity of the founding surface be improved by sub-excavating the native soils to a depth of 0.5 m below the design founding level, and re-establishing the founding level by placing a uniform thickness of compacted rock fill.

The following geotechnical resistances are recommended for design of spread footings founded on a 0.5 m thick layer of compacted rock fill overlying the native soils:

	Footing Width		
	1.2 m	1.5 m	2.0 m
Factored Geotechnical Resistance at ULS (kPa)	225	250	275
Geotechnical Reaction at SLS (kPa)	200	180	160

The width of footing must be designed based on the load demand from the culvert structure and overlying embankment fill.

8.1.3 General

The recommended resistance values are for footings subjected to vertical, concentric loads. Where eccentric or inclined loads are applied, the resistances used in design must be reduced in accordance with the CHBDC Clause 6.7.3 and Clause 6.7.4.

The geotechnical reaction at SLS for footings is based on an estimated total settlement not exceeding 25 mm. This settlement is expected to be substantially complete by the end of construction.

The lateral resistance of the footings may be computed using an unfactored friction coefficient of 0.6 assuming a friction angle of 31° between the footing concrete and underlying clear stone.

Rock fill placement will generally be carried out below the water level and should involve subexcavation in short sections (maximum 3 m length) followed by immediate backfilling to above the water level to permit placement of the footings in the dry. The rock fill should be placed in accordance with OPSS 206 including compaction by several passes of heavy tracked equipment once the rock fill surface is above the water level.

A minimum 150 mm thick layer of compacted 19 mm clear stone should be placed above the rock fill to provide an even founding surface for placement of the footings. Details of footing construction on rock fill are presented on the figure in Appendix F.

The recommended gradation of the rock fill is as follows:

Sieve Size	Percent Passing
150 mm	100
106 mm	50 – 100
75 mm	15 – 80
26.5 mm	0 – 15

Excavation and backfilling for the footings must be in accordance with OPSS 902.

8.2 Steel H-Pile Foundations

Considering the shallow depth to bedrock at the south abutment and the suitability of the native soils at the north abutment to support spread footings, the additional cost of driven steel H-piles to support the culvert is not justified at this site. Further, the potential exists that driven piles may be damaged or encounter refusal on cobbles and boulders above the design tip level. Therefore, this option has not been developed further.

8.3 Caissons / Drilled Shafts

Caisson installation at this site would extend through cohesionless soils below the groundwater table and require the use of a permanent liner to support the caisson sidewalls. Sealing of the caisson liner into bedrock to prevent inflow of water and cohesionless soils from the base will be problematic. The presence of cobbles and boulders in the native soils may also significantly impact caisson excavation. The use of caissons is therefore not recommended and design recommendations have not been developed.

8.4 Impact on Existing Bridge during Staged Construction

If staged construction is planned, care must be taken to avoid undermining and disturbing the existing crib abutments during preparation of the new footing subgrade. It is recommended that a monitoring program (including establishment of adequate benchmarks outside the zone of potential influence and acquirement of baseline readings in advance of construction) be implemented for the duration of foundation construction to identify any movement of the existing structure. Appropriate monitoring points and tolerable levels of movement should be specified by the structural designer. If movements exceed tolerable levels, the Contractor must be prepared to jack and/or shim the bridge structure.

8.5 Recommended Foundation

From a geotechnical perspective and based on the subsurface conditions, spread footings founded on a uniform 0.5 m thickness of rock fill placed over the variable bedrock and native cohesionless soils are the preferred foundation option.

8.6 Frost Cover

The depth of frost penetration at this site is approximately 2.6 m. For footings constructed on a minimum 0.5 m thick layer of rock fill placed over bedrock and native sand and gravel deposits, protection against frost action is not required.

9 SHEET PILE WALLS

We understand that one option for the proposed culvert design includes installation of corrugated steel sheeting headwalls parallel to the roadway to support the culvert approaches. The subsurface conditions at this site are not suitable for driving of sheet piles due to the shallow depth to bedrock at the south abutment as well as the potential for difficult driving, damage or encountering refusal on cobbles and boulders in the existing approach fill and underlying native soils. Installation of driven sheet piles is therefore not recommended, and increasing the culvert length to avoid the need for wing walls is a preferred alternative.

10 LATERAL EARTH PRESSURES

Backfill to the culvert should be in accordance with OPSS 902 and should consist of Granular A, Granular B Type II or Granular B Type III material. All granular material should meet the specifications of OPSS.PROV 1010. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501.

Earth pressure acting on the structure can be assumed to be triangularly distributed and to be governed by the characteristics of the backfill. For a fully drained condition, the pressure 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 = coefficient of lateral earth pressure (see Table 10.1)

γ = 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 culvert are dependent on the material used as backfill. Typical values are given in Table 10.1.

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 (CHBDC).

Table 10.1 – Coefficients of Lateral Earth Pressure (K)

Loading Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or Granular B Type II $\phi = 35°, \gamma = 22.8$ kN/m^3		OPSS Granular B Type I, Granular B Type III, or Existing Granular Fill $\phi = 32°, \gamma = 21.2$ kN/m^3	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	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.

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 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.00
- Acceleration Related Seismic Zone 0
- Zonal Acceleration Ratio 0.00
- Peak Ground Acceleration 0.036 g

The soil profile type at this site has been classified as Type I. Therefore, according to Clause 4.4.6.1 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 1.0 should be used in seismic design.

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. For the design of retaining walls, the coefficients of lateral earth pressure in Table 11.1 may be used.

In view of the velocity rated seismic zone of zero, the foundation soils at the site are assessed as not being prone to liquefaction.

Table 11.1 – Earth Pressure Coefficient for Earthquake Loading

Loading Condition	Earth Pressure Coefficient (K_E) for Earthquake Loading			
	Granular A or Granular B Type II ϕ = 35°; γ = 22.8 kN/m^3		**OPSS Granular B Type I or Type III ϕ = 32°; γ = 21.2 kN/m^3**	
	Horizontal Backfill	**Sloping Backfill (2H:1V)**	**Horizontal Backfill**	**Sloping Backfill (2H:1V)**
Active (K_{AE})*	0.29	0.42	0.32	0.51
Passive (K_{PE})	3.6	-	3.2	-
At Rest (K_{OE})**	0.47	-	0.52	-

* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.
** After Woods (1973).

12 APPROACH EMBANKMENTS

The existing approach embankments are in the order of 3.0 to 3.5 m above the surrounding ground and will be raised by 0.9 to 1.5 m. The existing slopes appear to be performing satisfactorily.

The foundation soils governing the performance of the embankments comprise compact to very dense sand and gravel to silty sand. Based on these foundation conditions and the grade raise proposed, stability or settlement of the approach embankments is not a concern. Side slopes of the heightened embankment built to an inclination of 2H: 1V are assessed to be stable.

13 SCOUR AND EROSION PROTECTION

Erosion and scour protection must be provided for the culvert foundations. In general, this will involve placing the footings below the level of potential scour and/or providing rock protection over the footings to prevent erosion and undermining of the foundations.

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

14 EXCAVATION AND DEWATERING

The excavation and backfilling for foundations must be carried out in accordance with OPSS 902.

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the approach fill and native sand/gravel above the water table may be classed as Type 3 soils. This classification is based on the lack of cohesion in the soils. The cohesionless soils below the water table are classified as Type 4 soil.

Excavation for footing construction and/or placement of rock fill to prepare the founding surface is expected to extend up to about 0.5 m below the groundwater level within cohesionless sand and gravel containing cobbles and boulders. Installation of sheet pile shoring, dewatering of the excavation and construction of culvert footings in the dry within close proximity to the creek is considered impractical.

The recommended procedure for preparation of the founding surface entails subexcavation in the wet in short sections (maximum 3 m length) followed by immediate backfilling with rock fill to the design founding level (to above the groundwater level). The contractor must ensure that the excavation does not encroach into the creek by controlling the length of excavation open at any one time.

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. The Contract Documents should contain a NSSP advising the Contractor of the high groundwater levels, cohesionless soils, cobbles and boulders, and shallow bedrock at this site that may impact foundation construction. Suggested wording is provided in Appendix E.

If bridge replacement will be carried out in stages to maintain one traffic lane operational, roadway protection will be required to facilitate staging. Roadway protection should be provided in accordance with OPSS 539 and designed for Performance Level 2. The design of any road protection system that may be required is the responsibility of the Contractor. All shoring systems should be designed by a Professional Engineer experienced in such designs.

15 CONSTRUCTION CONCERNS

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

- Preparation of the founding surfaces for spread footings will require excavation below the groundwater level within cohesionless soils containing cobbles and boulders. This work will require excavation in short sections (in the wet) followed by immediate backfilling with rock fill.
- Large boulders may be encountered within the excavation depth. Removal of these boulders will require suitable excavating equipment, and may result in areas of over-excavation requiring additional rock fill to backfill.
- The base level of the existing timber cribs may vary from the design level shown on the archive drawings, potentially requiring deeper excavation than anticipated. Crib removal must be carried out in a manner that minimizes disturbance of the subgrade.
- Excavation of strong to very strong bedrock will be required locally at the south abutment to establish the footing subgrade level. The Contractor must be prepared for rock excavation with appropriate equipment on site.
- If staged construction is planned, foundation excavation and subgrade preparation must not undermine or disturb the existing crib abutments. The Contractor must be prepared with appropriate equipment on site to maintain the bridge grade within acceptable tolerances.
- Water levels in the creek may fluctuate during construction.

16 CLOSURE

Engineering analysis and preparation of the foundation design report were carried out by Mr. Keli Shi, P.Eng. The report was reviewed by Mr. Murray Anderson, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

THURBER ENGINEERING LTD.

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Appendix A

Record of Borehole Sheets

THURBER

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

C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value — Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.

(2) DCPT — Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

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 (MPa)	(psi)	Field Estimation of Hardness*
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.

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No ECB-01

METRIC

W.P. 6109-10-01
LOCATION Elbow Creek Bridge N 5 525 945.6 E 631 983.6
ORIGINATED BY JM
HWY 599
BOREHOLE TYPE Casing/NQ Coring
COMPILED BY AN
DATUM Geodetic
DATE 2011.08.23 - 2011.08.25
CHECKED BY RPR/LT

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
408.6	GROUND SURFACE									
408.3 / 0.0	**ASPHALT:** (250mm)									
0.3	**SAND** and **GRAVEL**, trace to some silt, occasional cobbles and boulders Dense Brown Moist to Wet (FILL) Cobble (150mm) at 0.5m Cored cobbly material from 1.4m to 2.8m	1	SS	37	408, 407, 406					
405.6 / 3.0	**SAND** and **GRAVEL**, trace silt, occasional cobbles and boulders Dense to Very Dense Grey Wet	2	SS	33	405	○	60	34	6 (SI+CL)	
		3	SS	60	404, 403	○				
		4	SS	30	402	○				
401.7 / 6.9	Boulder (250mm) at 6.9m Cored from 6.9m to 9.1m, Probable Silty **SAND** Cobble (175mm) at 7.7m				401, 400					
399.5 / 9.1	Gravelly **SAND**, trace silt, occasional cobbles and boulders Compact Grey Wet Boulder (200mm) at 9.8m	5	SS	11	399	○	20	72	8 (SI+CL)	

Groundwater level indicated at approx. elevation 404.5.

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m3; REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

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

ONTMT4S 0840.GPJ 2012TEMPLATE(MTO).GDT 9/30/14

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No ECB-01

METRIC

W.P.	6109-10-01	LOCATION	Elbow Creek Bridge N 5 525 945.6 E 631 983.6	ORIGINATED BY	JM
HWY	599	BOREHOLE TYPE	Casing/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2011.08.23 - 2011.08.25	CHECKED BY	RPR/LT

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	FI	REMARKS
	Boulder (225mm) at 10.4m					
397.9 / 10.7	Silty **SAND**, trace gravel Very Dense Grey Wet	6	SS	50/ 0.150		
396.6 / 12.0	**BEDROCK METAMORPHIC BRECCIA**, grey, slightly weathered to fresh, very strong to extremely strong Vertical breaks at 12.1m and 12.2m Horizontal breaks at 12.2m, 12.5m, 13.5m, 13.9m and 14.1m	1	RUN		>10, 1, 1, 0, 0	RUN #1 TCR=100% SCR=90% RQD=68% UCS=270MPa (Average)
		2	RUN		1, 1, 1, 0, 0	RUN #2 TCR=100% SCR=100% RQD=97% UCS=219MPa (Average)
393.6 / 15.0	END OF BOREHOLE AT 15.0m. BOREHOLE OPEN TO 15.0m AND WATER LEVEL AT 3.4m UPON COMPLETION OF DRILLING. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.					

Elevation scale: 398, 397, 396, 395, 394

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Sep.16/11	4.1	404.5
Dec.01/11	3.8	404.8
Oct.28/12	4.2	404.4

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No ECB-02

METRIC

W.P. 6109-10-01 | LOCATION Elbow Creek Bridge N 5 525 927.8 E 631 975.4 | ORIGINATED BY JM

HWY 599 | BOREHOLE TYPE Casing/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2011.08.28 - 2011.08.29 | CHECKED BY RPR/LT

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT / FI	REMARKS & GRAIN SIZE DISTRIBUTION (%)
408.5	GROUND SURFACE								
0.0	**ASPHALT:** (150mm)								
0.2	**SAND** and **GRAVEL**, trace silt, occasional cobbles and boulders Dense to Compact Brown Moist (FILL)	1	SS	42		408	~4		
		2	SS	49		407			
		3	SS	11			~8		
	Cored cobbly material from 2.1m to 3.0m					406			
405.5 / 3.0	**BEDROCK METAMORPHIC BRECCIA**, grey, fresh, strong to very strong	1	RUN		▽	405		1, 0, 0, 1, 1	RUN #1 TCR=100% SCR=100% RQD=100% UCS=85MPa (Average)
	Sub-vertical breaks (50mm) at 3.9m					404			
	Horizontal breaks at 3.3m, 4.3m, 4.7m and 5.0m	2	RUN			403		1, 1, 0, 0	RUN #2 TCR=80% SCR=80% RQD=80% UCS=179MPa (Average)
402.4 / 6.1	END OF BOREHOLE AT 6.1m. BOREHOLE OPEN TO 5.8m AND WATER LEVEL AT 3.0m. BOREHOLE BACKFILLED WITH HOLEPLUG FROM 5.8m TO 0.9m, SAND AND GRAVEL FROM 0.9m TO 0.1m, THEN ASPHALT TO SURFACE.								

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; GR SA SI CL

+3, ×3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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THURBER

RECORD OF BOREHOLE No ECB-03

METRIC

W.P. 6109-10-01	LOCATION Elbow Creek Bridge N 5 525 926.6 E 631 978.0		ORIGINATED BY JM
HWY 599	BOREHOLE TYPE Casing/NQ Coring		COMPILED BY AN
DATUM Geodetic	DATE 2011.08.30 - 2011.08.30		CHECKED BY RPR/LT

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20, 40, 60, 80, 100
SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE: 20, 40, 60, 80, 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L
WATER CONTENT (%): 20, 40, 60
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
408.5	GROUND SURFACE					
0.0	**ASPHALT:** (150mm)					
0.2	Gravelly **SAND**, some silt, occasional cobbles and boulders Dense to Compact Brown Moist (FILL) Cored cobbly material from 0.8m to 2.2m	1	SS	37		GR 23, SA 67, SI+CL 10 (SI+CL)
		2	SS	23		
	Boulder (275mm) at 2.9m					
	Boulder (300mm) at 3.3m					
404.6	Cobble (175mm) at 3.6m					
3.9	**BEDROCK METAMORPHIC BRECCIA**, grey, slightly weathered to fresh, very strong Horizontal breaks at 3.9m, 4.1m, 4.3m, 4.7m, 4.9m, 5.6m, 6.1m, 6.8m and 6.9m	1	RUN		FI: 2, 1, 3, 2	RUN #1 TCR=100% SCR=100% RQD=87% UCS=130MPa (Average)
	Sub-vertical breaks at: 75mm at 4.7m 100mm at 5.2m 150mm at 6.4m 50mm at 6.7m 50mm at 6.9m 100mm at 7.0m	2	RUN		FI: 0, 1, 0, 1, 3, >10	RUN #2 TCR=100% SCR=85% RQD=76% UCS=132MPa (Average)
401.4 / 7.1	END OF BOREHOLE AT 7.1m. BOREHOLE OPEN TO 7.1m AND WATER LEVEL AT 3.1m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.					

Elevation scale: 408, 407, 406, 405, 404, 403, 402

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Sep.16/11	3.9	404.6
Dec.01/11	3.8	404.7
Oct.28/12	4.4	404.1

+ ³, × ³: Numbers refer to Sensitivity

15 ⊕ 5 (20 above, 10 below): (%) STRAIN AT FAILURE

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Ontario

THURBER

RECORD OF BOREHOLE No ECB-04

METRIC

W.P. 6109-10-01 | LOCATION Elbow Creek Bridge N 5 525 944.4 E 631 986.2 | ORIGINATED BY JM/GA
HWY 599 | BOREHOLE TYPE Casing/NQ Coring | COMPILED BY AN
DATUM Geodetic | DATE 2011.08.31 - 2011.09.09 | CHECKED BY RPR/LT

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
408.6	GROUND SURFACE						
0.0	**ASPHALT:** (200mm)						
0.2	**SAND** and **GRAVEL**, trace to some silt, occasional cobbles and boulders Dense Brown Moist (FILL) Cored cobbly material from 0.8m to 3.0m	1	SS	40		o	
405.6 / 3.0	**SAND** and **GRAVEL** to Gravelly **SAND**, trace silt, occasional cobbles and boulders Very Dense to Compact Grey Wet	2	SS	50/ 0.150	∇ (water level)		
		3	SS	12		o	22 76 2 (SI+CL)
402.5 / 6.1	Silty **SAND**, trace gravel, trace clay Very Dense to Dense Grey Wet Boulder (0.6m) at 6.4m	4	SS	66		o	
		5	SS	41		o	9 57 32 2
399.6 / 9.0	**SAND** and **GRAVEL**, trace silt Dense Grey Wet	6	SS	45		o	

Elevation scale: 408, 407, 406, 405, 404, 403, 402, 401, 400, 399

Dynamic Cone Penetration Resistance Plot: 20 40 60 80 100
Shear Strength kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100
Plastic Limit w_P — Natural Moisture Content w — Liquid Limit w_L; Water Content (%) 20 40 60
Unit Weight γ kN/m³

Continued Next Page

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

RECORD OF BOREHOLE No ECB-04

METRIC

W.P.	6109-10-01	LOCATION	Elbow Creek Bridge N 5 525 944.4 E 631 986.2	ORIGINATED BY	JM/GA
HWY	599	BOREHOLE TYPE	Casing/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2011.08.31 - 2011.09.09	CHECKED BY	RPR/LT

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	SAMPLE TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT (FI)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
	Continued From Previous Page						
397.9 / 10.7	Silty **SAND**, trace gravel Dense Grey Wet	7	SS	46	398		
397.0 / 11.6	**BEDROCK METAMORPHIC BRECCIA**, grey, fresh, coarse grained, very strong Sub-horizontal joints at 11.9m Horizontal joints at 11.6m, 11.7m and 12.5m	1	RUN		397 396	FI 7 1 0 1 0	RUN #1 TCR=100% SCR=100% RQD=78% UCS=122MPa (Average)
		2	RUN		395	0 0 0 0 0	RUN #2 TCR=100% SCR=100% RQD=100% UCS=132MPa (Average)
394.0 / 14.6	END OF BOREHOLE AT 14.6m. BOREHOLE OPEN TO 14.6m AND WATER LEVEL AT 3.0m. BOREHOLE BACKFILLED WITH HOLEPLUG FROM 14.6m TO 0.3m, CONCRETE FROM 0.3m TO 0.1m, THEN ASPHALT TO SURFACE.				394		

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE, 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 – 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No ECB-05

METRIC

W.P.	6109-10-01	LOCATION	Elbow Creek Bridge N 5 525 950.9 E 631 986.4	ORIGINATED BY	JM
HWY	599	BOREHOLE TYPE	Hollow Stem Augers/Casing	COMPILED BY	AN
DATUM	Geodetic	DATE	2011.08.27 - 2011.08.28	CHECKED BY	RPR/LT

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
408.6	GROUND SURFACE
0.0	**ASPHALT:** (150mm)
0.2	**SAND** and **GRAVEL**, trace to some silt, occasional cobbles and boulders Compact to Dense Brown Moist (FILL) Cored cobbly material from 1.4m to 3.6m
405.6 / 3.0	**SAND** and **GRAVEL**, to some gravel Compact Dark Brown Wet
404.0 / 4.6	Silty **SAND**, some gravel, trace clay Compact Grey Wet Boulder (0.5m) at 5.5m Cobble (150mm) at 7.0m
401.0 / 7.6	**SAND** and **GRAVEL**, trace silt Dense to Loose Grey Wet

Continued Next Page

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	24	
2	SS	35	
3	SS	17	
4	SS	16	12 57 29 2
5	SS	22	
6	SS	42	
7	SS	9	42 55 3 (SI+CL)

GROUND WATER CONDITIONS: water level symbol at approx. elev. 405.0

ELEVATION SCALE: 408, 407, 406, 405, 404, 403, 402, 401, 400, 399

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

+ ³, × ³: Numbers refer to Sensitivity

15-(20/10)-5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No ECB-05

METRIC

W.P.	6109-10-01	LOCATION	Elbow Creek Bridge N 5 525 950.9 E 631 986.4	ORIGINATED BY	JM
HWY	599	BOREHOLE TYPE	Hollow Stem Augers/Casing	COMPILED BY	AN
DATUM	Geodetic	DATE	2011.08.27 - 2011.08.28	CHECKED BY	RPR/LT

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT PLOT	NUMBER (SAMPLES)	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
397.9							398				
10.7 / 397.3	Silty **SAND**, some gravel Very Dense Grey Wet		8	SS	51				○		21 54 25 (SI+CL)
11.3	END OF BOREHOLE AT 11.3m. BOREHOLE OPEN TO 10.2m AND WATER LEVEL AT 3.6m. BOREHOLE BACKFILLED WITH HOLEPLUG FROM 10.3m TO 2.1m, SAND AND GRAVEL FROM 2.1m TO 1.0m, CONCRETE FROM 1.0m TO 0.1m, THEN ASPHALT TO SURFACE.										

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No ECB-06

METRIC

W.P. 6109-10-01 | LOCATION Elbow Creek Bridge N 5 525 921.2 E 631 975.3 | ORIGINATED BY JM

HWY 599 | BOREHOLE TYPE Casing | COMPILED BY AN

DATUM Geodetic | DATE 2011.08.29 - 2011.08.29 | CHECKED BY RPR/LT

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	GR	SA	SI	CL
408.5	GROUND SURFACE												
0.0	**ASPHALT:** (150mm)												
0.2	**SAND** and **GRAVEL**, trace silt Compact to Dense Brown Moist (FILL)		1	SS	29		408	o					
			2	SS	26			o		53	42	5 (SI+CL)	
			3	SS	33		407						
	Loose		4	SS	5		406	o					
405.5						▽							
3.0	Gravelly **SAND**, some silt Dense to Very Dense Grey Wet		5	SS	30		405	o		32	49	19 (SI+CL)	
403.9							404						
4.6	END OF BOREHOLE AT 4.6m UPON REFUSAL ON PROBABLE BEDROCK. BOREHOLE OPEN TO 4.6m AND WATER LEVEL AT 3.0m. BOREHOLE BACKFILLED WITH HOLEPLUG FROM 4.6m TO 1.0m, SAND AND GRAVEL FROM 1.0m TO 0.1m, THEN ASPHALT TO SURFACE.												

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF TEST PIT No ECB-07

METRIC

W.P. 6109-10-01	LOCATION Elbow Creek Bridge N 5 525 933.7 E 631 967.2		ORIGINATED BY SLL
HWY 599	BOREHOLE TYPE Backhoe		COMPILED BY MFA
DATUM Geodetic	DATE 2014.06.02 - 2014.06.02		CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
405.3	GROUND SURFACE										
0.0	**TOPSOIL**, trace roots and rootlets: (225mm)								○		
0.2	Gravelly **SAND**, occasional cobbles Brown Moist to Wet		1	GS		∇	405				
404.6 / 0.7	Silty **SAND**, trace gravel Brown Moist		2	GS					○		
404.2 / 1.1	END OF TEST PIT AT 1.1m UPON REFUSAL ON BEDROCK. WATER LEVEL AT 0.7m IN OPEN HOLE. TEST PIT BACKFILLED TO SURFACE.										

+³, ×³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No ECB-09

METRIC

W.P. 6109-10-01 | LOCATION Elbow Creek Bridge N 5 525 928.4 E 631 978.8 | ORIGINATED BY ES

HWY 599 | BOREHOLE TYPE NW Casing/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2014.05.05 - 2014.05.05 | CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
408.5	GROUND SURFACE							
0.0	**ASPHALT:** (150mm)							
0.2	**SAND** and **GRAVEL**, trace to some silt, occasional cobbles, Compact to Very Dense, Brown, Wet (FILL)	1	GS		408			
		1	SS	17		o		58 39 3 (SI+CL)
		2	SS	23	407	o		
		3	SS	84	406	o		30 57 13 (SI+CL)
		4	SS	50/ 0.125		o		
					405			
404.5 / 4.0	Gravelly **SAND**, some silt, occasional cobbles				404		FI	
403.8	Cobble						>10	RUN #1 TCR=96% SCR=81% RQD=81% UCS=266MPa (Average)
4.7	**BEDROCK METAMORPHIC BRECCIA**, grey, strong to extremely strong; Sub-vertical breaks (75mm) at 4.7m, 4.8m; 100mm at 5.1m; 125mm at 5.4m	1	RUN		403		5, 4, 0	
	Sub-horizontal breaks at 4.9m, 5.1m, 5.5m; Occasional quartz, very strong, grey; Sub-vertical breaks (50mm) at 5.9m	2	RUN		402		1, 1, 0, 1, 0	RUN #2 TCR=100% SCR=100% RQD=100% UCS=276MPa (Average)
400.9		3	RUN		401		0	RUN #3 TCR=100% SCR=100% RQD=100% UCS=57MPa (Average)
7.6	END OF BOREHOLE AT 7.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.1m THEN ASPHALT TO SURFACE.							

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; GROUND WATER CONDITIONS; STRAT PLOT.

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No ECB-10

METRIC

W.P.	6109-10-01	LOCATION	Elbow Creek Bridge N 5 525 941.8 E 631 981.4	ORIGINATED BY	ES
HWY	599	BOREHOLE TYPE	NW Casing/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.05.05 - 2014.05.05	CHECKED BY	MEF

SOIL PROFILE | SAMPLES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) | SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100) | PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%)

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
408.5	GROUND SURFACE								
0.0	**ASPHALT:** (175mm)								
0.2	**SAND** and **GRAVEL**, trace to some silt, occasional cobbles Compact to Very Dense Brown Wet (FILL)		1	GS					
			1	SS	13				
			2	SS	21				
			3	SS	50/ 0.125				
			4	SS	50/ 0.050				
405.1 / 3.4	Gravelly **SAND**, trace to some silt, trace clay, occasional cobbles Compact to Very Dense Grey Wet								
			5	SS	29	28	49	20	3
			6	SS	18				
			7	SS	63/ 0.200				
			8	SS	38				
	Cored from 9.8m to 11.9m								

Elevation scale: 408, 407, 406, 405, 404, 403, 402, 401, 400, 399

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S 0840.GPJ 2012TEMPLATE(MTO).GDT 9/30/14

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No ECB-10

METRIC

W.P. 6109-10-01 | LOCATION Elbow Creek Bridge N 5 525 941.8 E 631 981.4 | ORIGINATED BY ES

HWY 599 | BOREHOLE TYPE NW Casing/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2014.05.05 - 2014.05.05 | CHECKED BY MEF

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT	REMARKS
	Gravelly **SAND**, trace to some silt, trace clay, occasional cobbles and boulders		1	RUN			398		RUN #1 TCR=94%
	Boulder from 9.8m to 10.1m								
	Boulder from 10.3m to 11.0m		2	RUN			397		RUN #2 TCR=11%
396.6 / 11.9	**BEDROCK METAMORPHIC BRECCIA**, grey, very strong to extremely strong							FI	
	Sub-vertical fracture (50mm thick) at 12.0m 150mm at 12.3m 150mm at 12.5m 200mm at 12.7m		3	RUN			396	0 1 3 0	RUN #3 TCR=100% SCR=100% RQD=100% UCS=190MPa (Average)
	Sub-horizontal fracture at 12.0m, 12.7m		4	RUN			395 394	2 0 0 1 2	RUN #4 TCR=100% SCR=100% RQD=100% UCS=294MPa (Average)
393.7 / 14.8	END OF BOREHOLE AT 14.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.1m THEN ASPHALT TO SURFACE.								

+³, ×³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S 0840.GPJ 2012TEMPLATE(MTO).GDT 9/30/14

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No ECB-11

METRIC

W.P. 6109-10-01 LOCATION Elbow Creek Bridge N 5 525 924.8 E 631 985.5 ORIGINATED BY SLL

HWY 599 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MFA

DATUM Geodetic DATE 2014.05.28 - 2014.05.29 CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT (kN/m³) / FI	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
407.8	GROUND SURFACE									
0.0 / 0.1	**TOPSOIL:** (50mm)									
	SAND, trace to some silt, trace gravel, occasional cobbles Compact to Loose Brown Moist (FILL)						407			
			1	SS	10			o		
			2	SS	8		406	o		
405.6 / 2.2	Silty **SAND**, trace gravel Compact Brown to Grey Moist		3	SS	20		405	o		
			4	SS	23		404	o		
403.6 / 4.2	**BEDROCK: METAMORPHIC BRECCIA**, grey, fresh, strong to very strong Sub-vertical joints at 4.57, 4.70, and 4.85 to 5.00m Sub-horizontal joints at 4.94, 5.00, and 5.23m		1	RUN					1	RUN #1 TCR=100% SCR=100% RQD=100% UCS=236MPa (Average)
			2	RUN			403, 402		2, 2, 0, 0	RUN #2 TCR=100% SCR=100% RQD=96% UCS=84MPa (Average)
	Sub-vertical joints at 6.04 to 6.12, 6.91 to 6.93, and 7.14 to 7.21m Horizontal joints at 6.35 and 6.73m		3	RUN			401		1, 1, 0, 2, 1	RUN #3 TCR=100% SCR=100% RQD=100% UCS=149MPa (Average)
400.4 / 7.4	END OF BOREHOLE AT 7.4m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.									

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%): 20 40 60

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No ECB-12

METRIC

W.P. 6109-10-01	LOCATION Elbow Creek Bridge N 5 525 941.0 E 631 993.4	ORIGINATED BY SLL
HWY 599	BOREHOLE TYPE Hollow Stem Augers/NQ Coring	COMPILED BY MFA
DATUM Geodetic	DATE 2014.05.29 - 2014.05.29	CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
407.6	GROUND SURFACE						
0.0 / 0.1	**TOPSOIL**, with roots: (100mm)						
406.9 / 0.7	**SAND**, trace gravel, occasional cobbles and boulders (FILL)				407		
406.4 / 1.2	**PEAT**, fibrous, occasional cobbles and boulders Black Moist	1	SS	43			
	Silty **SAND**, trace gravel, occasional cobbles Loose to Dense Brown to Grey Moist	2	SS	22	406		
		3	SS	20	405		
	Grey Wet	4	SS	7	404		
		5	SS	20	403		
		6	SS	34	402 / 401		
		7	SS	49	400		
398.1 / 9.5	Very Dense Moist to Wet	8	SS	71/ .225	399	FI	
	BEDROCK: METAMORPHIC BRECCIA, grey, very strong Sub-vertical joints at 9.53 to 9.55, 9.58				398	1	RUN #1 TCR=100% SCR=100% RQD=94%

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE — 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60

+3, ×3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No ECB-12

METRIC

W.P. 6109-10-01 | LOCATION Elbow Creek Bridge N 5 525 941.0 E 631 993.4 | ORIGINATED BY SLL

HWY 599 | BOREHOLE TYPE Hollow Stem Augers/NQ Coring | COMPILED BY MFA

DATUM Geodetic | DATE 2014.05.29 - 2014.05.29 | CHECKED BY MEF

SOIL PROFILE: ELEV / DEPTH	SOIL PROFILE: DESCRIPTION (Continued From Previous Page)	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	to 9.61, 10.13 to 10.19, 10.39 to 10.42, and 10.52 to 10.55m		1	RUN						0	UCS=116MPa (Average)
	Horizontal joint at 10.31m									0	
							397			2	
	Horizontal joints at 10.82, 10.88, 11.00, and 11.62m									2	RUN #2 TCR=100% SCR=98% RQD=81% UCS=201MPa (Average)
			2	RUN						4	
							396			0	
	Sub-vertical joints at 10.88 to 11.00, and 11.73 to 11.76m									1	
										1	RUN #3 TCR=100% SCR=100% RQD=100% UCS=146MPa (Average)
			3	RUN						0	
394.9							395				
12.7	END OF BOREHOLE AT 12.7m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.									0	

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Appendix B

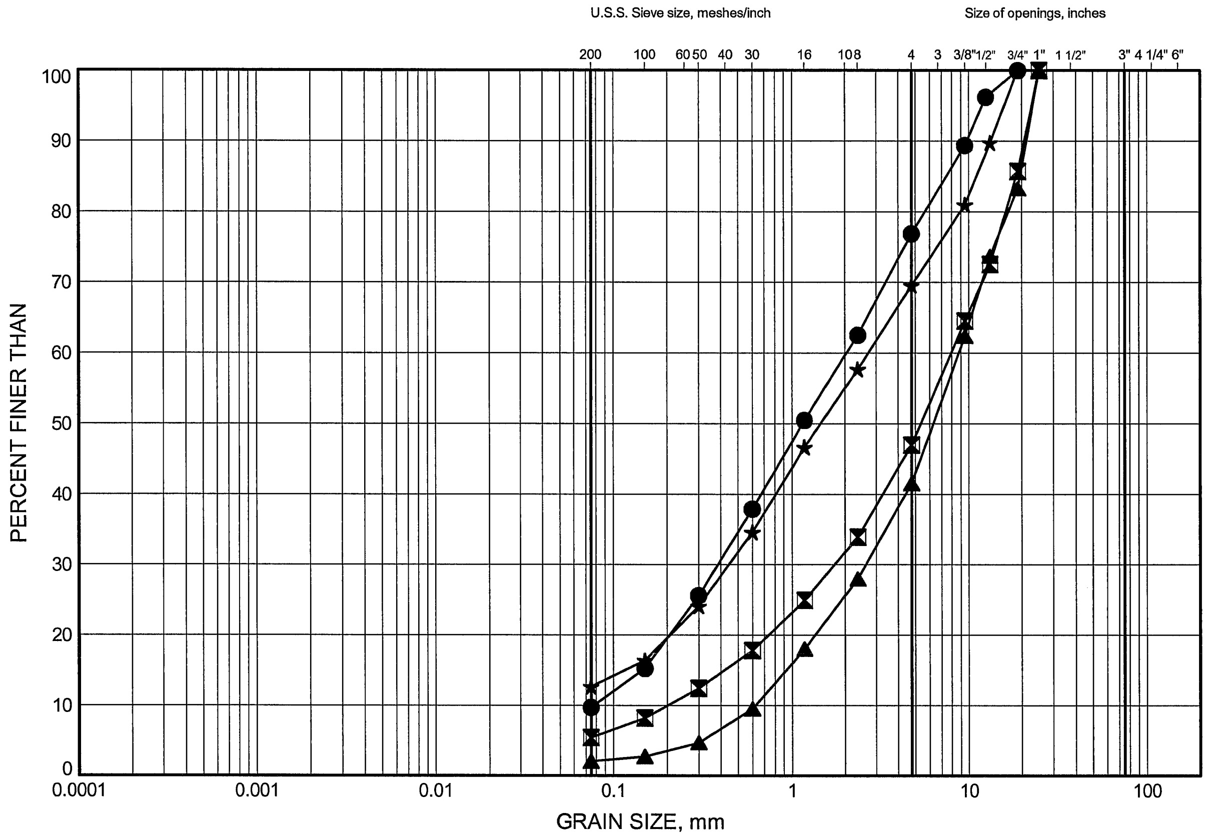
Laboratory Test Results

Elbow Creek Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND & GRAVEL TO GRAVELLY SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	ECB-03	0.38	408.12
⊠	ECB-06	1.07	407.43
▲	ECB-09	1.07	407.43
★	ECB-09	2.51	405.99

Date September 2014

W.P. 6109-10-01

THURBER

Prep'd AN

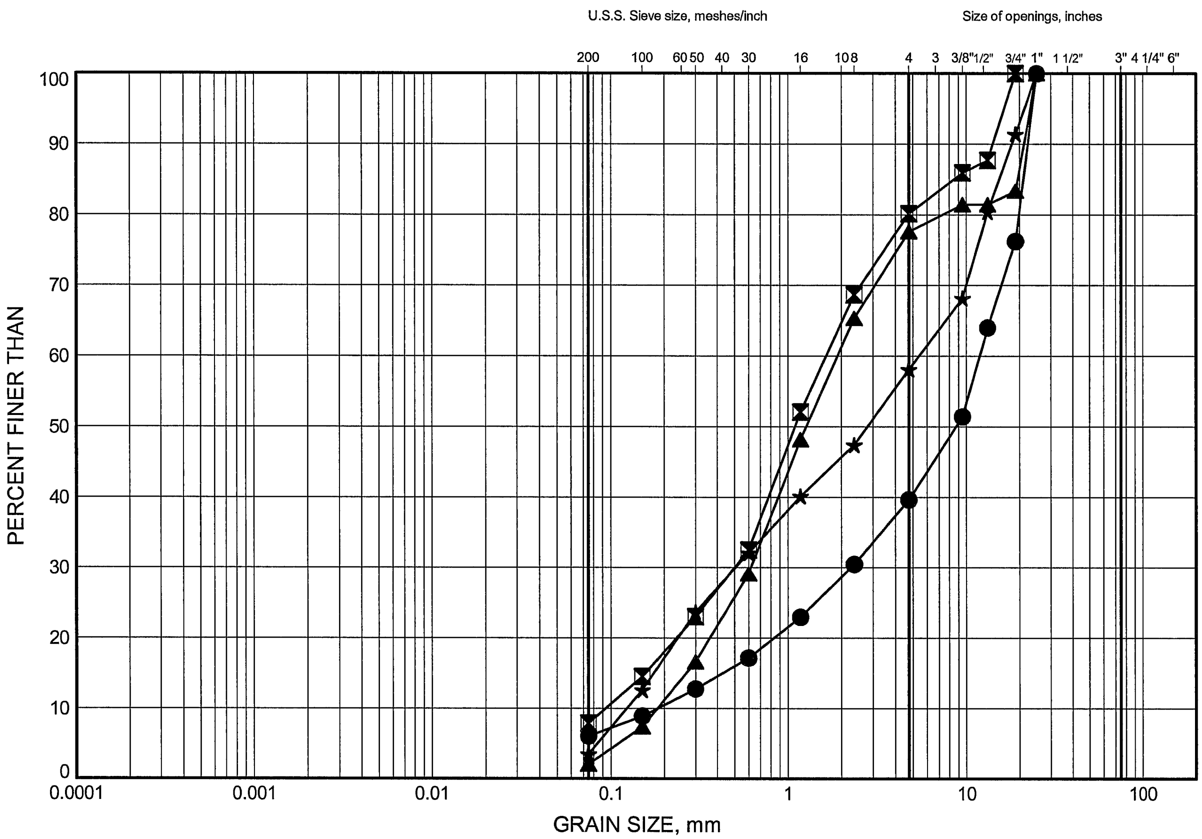
Chkd. MRA

Elbow Creek Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND & GRAVEL TO GRAVELLY SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	ECB-01	3.35	405.25
⧗	ECB-01	9.45	399.15
▲	ECB-04	4.88	403.72
★	ECB-05	9.45	399.15

Date September 2014

W.P. 6109-10-01

THURBER

Prep'd AN

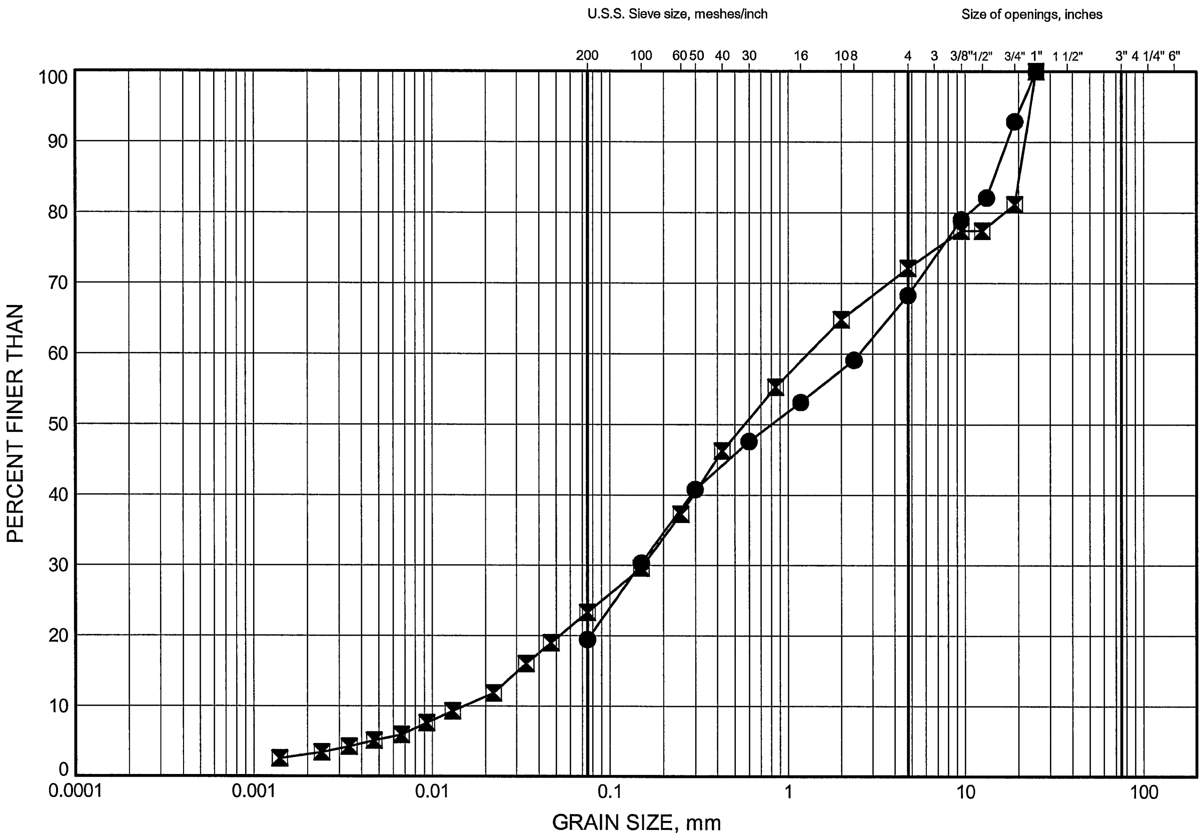
Chkd. MRA

Elbow Creek Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B3

GRAVELLY SAND, Some Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	ECB-06	3.35	405.15
⧗	ECB-10	4.88	403.62

Date September 2014
W.P. 6109-10-01

THURBER

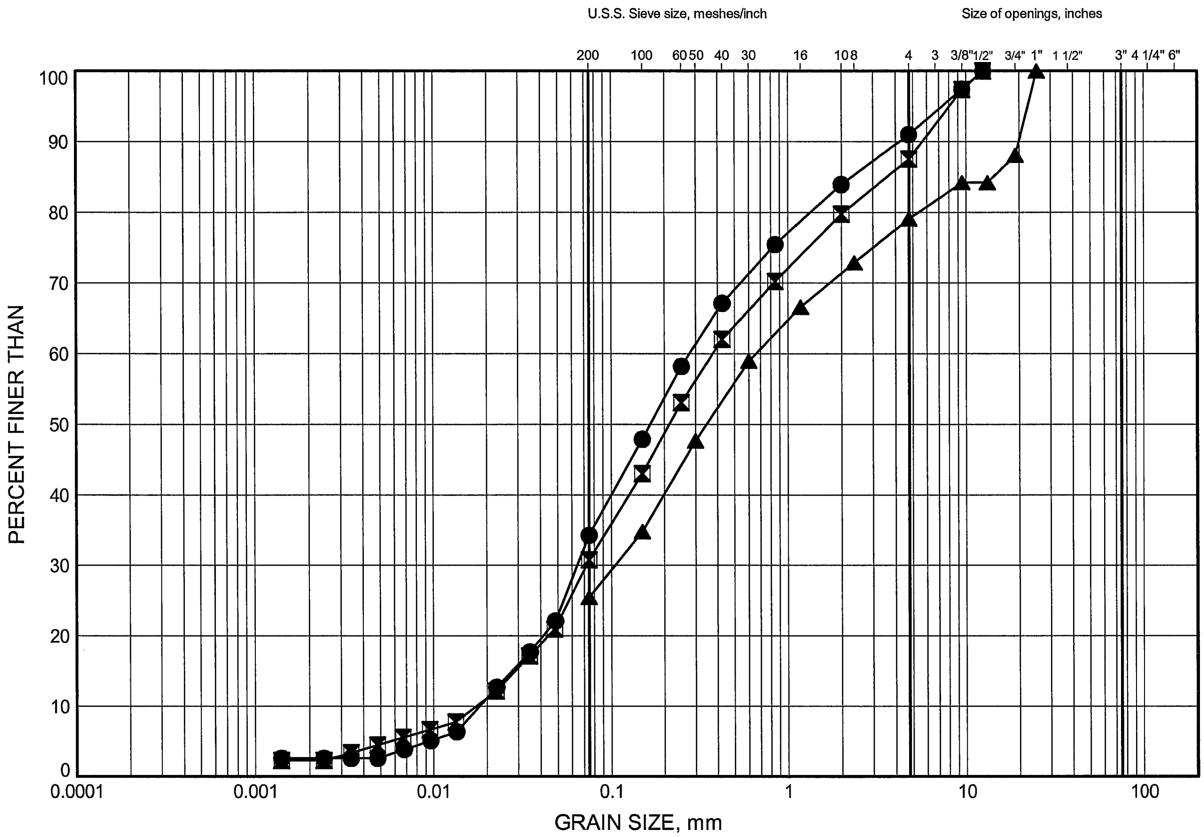
Prep'd AN
Chkd. MRA

Elbow Creek Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B4

SILTY SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	ECB-04	7.92	400.68
⧗	ECB-05	4.88	403.72
▲	ECB-05	10.97	397.63

Date September 2014

W.P. 6109-10-01

THURBER

Prep'd AN

Chkd. MRA

GRAIN SIZE DISTRIBUTION - THURBER 0840.GPJ 9/30/14

Appendix C

Site Photographs

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Photograph 1 – Elbow Creek Bridge looking south

Photograph 2 – Looking north at north abutment, east side of bridge

Photograph 3 – North abutment

Photograph 4 – South abutment and approach, east side

Appendix D

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Footings on Native Soil or Bedrock	Footings on Rock Fill	Driven H-Piles	Caissons
Advantages i. High geotechnical resistance is available in native soil/rock. ii. Lower cost than deep foundations. ***Disadvantages:*** i. Excavation required below creek water level in cohesionless soils. ii. Potential environmental impact due to excavation adjacent to creek. iii. Excavation shoring and dewatering not practical due to shallow bedrock and cobles and boulders. iv. Variable support conditions along south footing on bedrock and sand/gravel. v. Potential disturbance to the existing timber cribs under service.	***Advantages:*** i. Generally less costly construction than deep foundation elements. ii. Higher geotechnical resistance than native soils. iii. Allows construction of footings above groundwater level. iv. More uniform support than footings partially on bedrock and native soils. v. Permits use of precast concrete footings. ***Disadvantages:*** i. Subexcavation below water level is required to place rock fill. ii. Cost of rock fill. iii. Potential disturbance to the existing timber cribs under service.	***Advantages:*** i. Piles will develop high geotechnical resistance on bedrock. ii. Installation of piles could continue in freezing weather. iii. Allows integral abutment design. iv. Requires less excavation than footings. ***Disadvantages:*** i. Higher unit costs than footings. ii. Not suitable at south abutment where bedrock is shallow. iii. Driving of piles will be difficult or impractical due to cobbles and boulders in the fill and native deposits.	***Advantages:*** i. High resistance is available for caissons founded on bedrock. ii. Construction of caissons could continue in freezing weather. ***Disadvantages:*** i. Higher cost than footings. ii. Specialized installation methods such as temporary liners and drilling mud will be required to install caissons in cohesionless sands/gravels below groundwater level. iii. Difficulty in sealing liners at bedrock surface. iv. Cobbles and boulders may obstruct augering and liner installation. v. Caissons must be socketed into very strong bedrock. vi. Difficulty in cleaning and inspecting bases.
NOT RECOMMENDED	**RECOMMENDED**	**NOT RECOMMENDED**	**NOT RECOMMENDED**

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Appendix E

List of SPs and OPSS, and Suggested Text for Selected NSSP

1. List of Special Provisions and OPSS Documents Referenced in this Report

- OPSS 206
- OPSS 501
- OPSS 539
- OPSS 804
- OPSS 902
- OPSS.PROV 1010

2. Suggested Text for NSSP on Foundation Excavation

The Contractor is advised that groundwater levels are high at this site and the soils consist of cohesionless sands and gravels containing cobbles and boulders. Excavation of strong to very strong bedrock will also be required at the south abutment. Preparation of the founding surfaces for spread footings will require excavation below the groundwater level within these deposits.

Excavation sidewalls in the cohesionless deposits will generally be unstable and sloughing due to groundwater inflow must be anticipated. The presence of cobbles and boulders is likely to preclude the use of driven sheet piles, and therefore installation of sheet pile shoring, dewatering of the excavation and construction of culvert footings in the dry is considered impractical at this site.

In view of the site conditions, preparation of the founding surface is to entail subexcavation in the wet to the specified depths (compact to dense native soils) in short sections of no more than 3 m length followed by immediate backfilling with rock fill to above the groundwater level, followed by placement of clear stone to the design founding level as per the Contract Drawings.

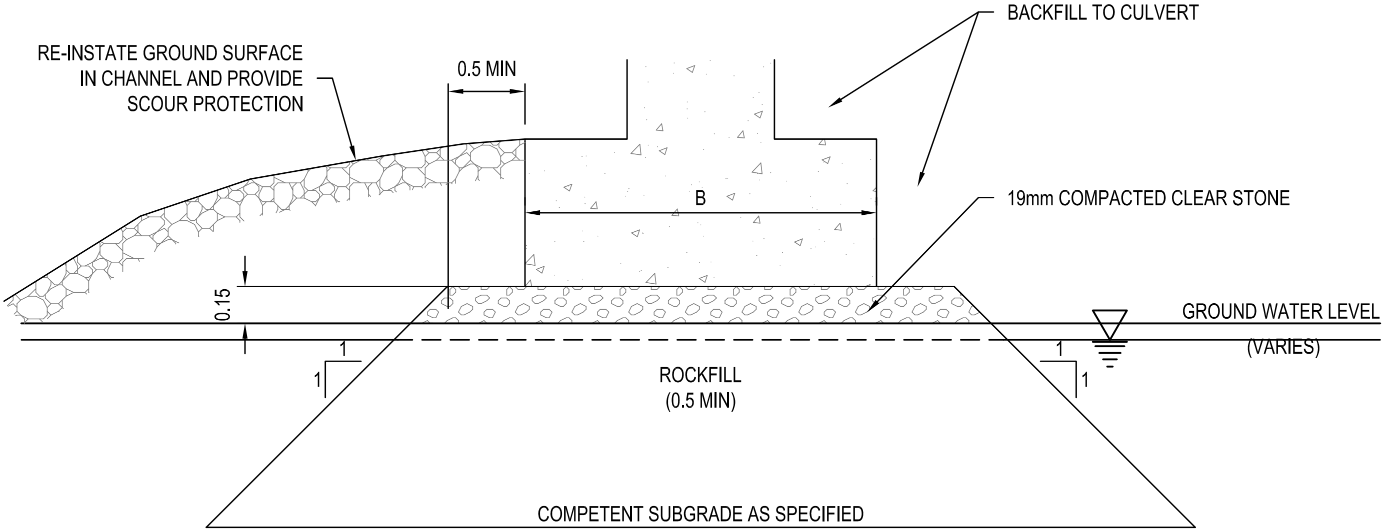
The contractor must carry out the work in a manner which minimizes disturbance to the excavation base and ensure that the excavation does not encroach into the creek by controlling the length of excavation open at any one time.

Large boulders may be encountered within the excavation depth. Removal of these boulders will require appropriate excavating equipment, and may result in areas of over-excavation requiring additional rock fill to backfill.

Selection of the equipment and methodology to excavate and prepare the founding surface remains the responsibility of the Contractor, and should be based on his interpretation of the subsurface conditions presented in the Foundation Investigation Report as well as the surface conditions exposed at the site.

Appendix F

Figure – Detail of Footing on Rock Fill



CROSS-SECTION

NOTES:

1. REMOVE ANY TOPSOIL AND SOFT/LOOSE SUBSOIL UNDER AREA OF ROCKFILL TO COMPETENT SUBGRADE LEVEL AS SPECIFIED.
2. PLACE ROCKFILL TO ABOVE GROUNDWATER LEVEL. ROCKFILL TO HAVE PARTICLE SIZE NO GREATER THAN 150mm.
3. ROCKFILL SURFACE SHOULD BE COMPACTED WITH SEVERAL PASSES OF A DOZER/ROLLER AFTER ROCKFILL IS ABOVE WATER LEVEL.
4. PLACE CLEAR STONE TO BASE OF FOOTING LEVEL AND COMPACT THE CLEAR STONE.
5. PLACE CONCRETE FOOTING.
6. RE-INSTATE GROUND SURFACE IN CHANNEL AND PROVIDE SCOUR PROTECTION.

FOOTING ON ROCKFILL CORE

THURBER ENGINEERING LTD.

ENGINEER :	DRAWN :	APPROVED :
MRA	MFA	-
DATE : OCTOBER 2014	SCALE : N.T.S.	DRAWING No. FIGURE F1

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Appendix G

Borehole Locations and Soil Strata Drawings

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

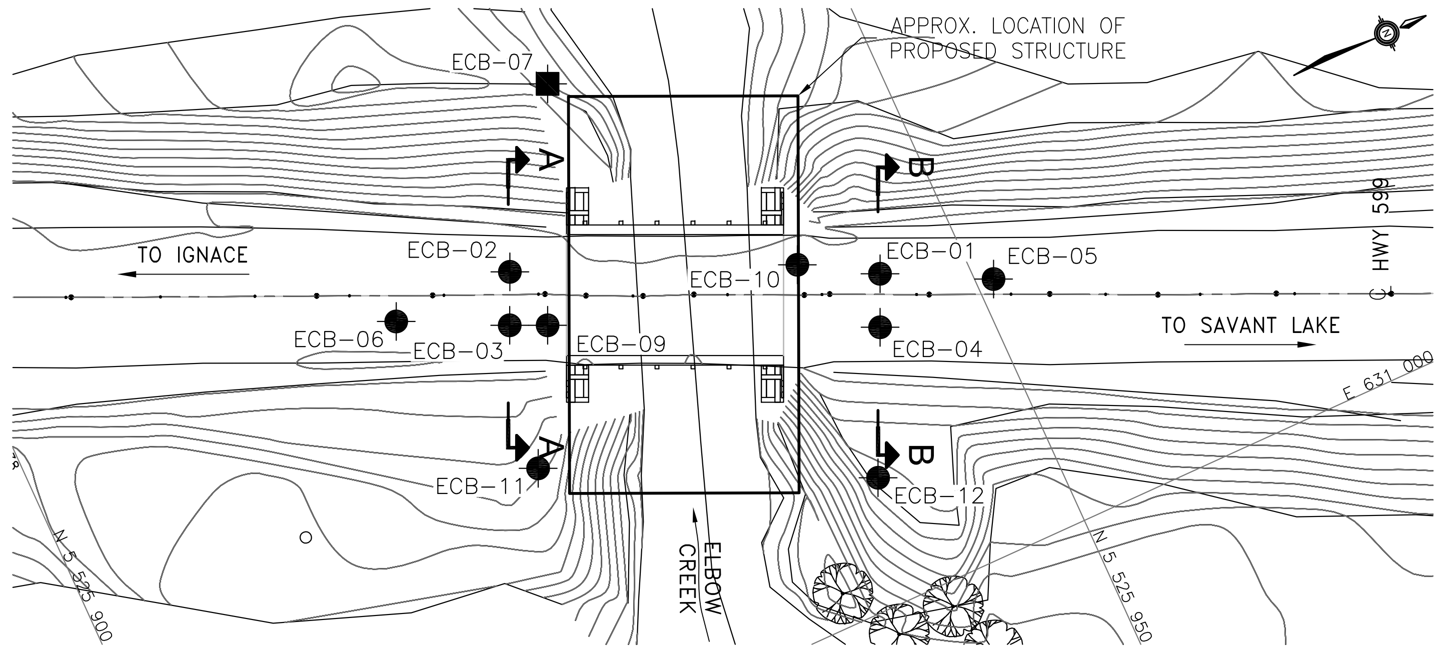
CONT No 2014-6019
WP No 6109-10-01

ELBOW CREEK BRIDGE REPLACEMENT
HIGHWAY 599
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 16

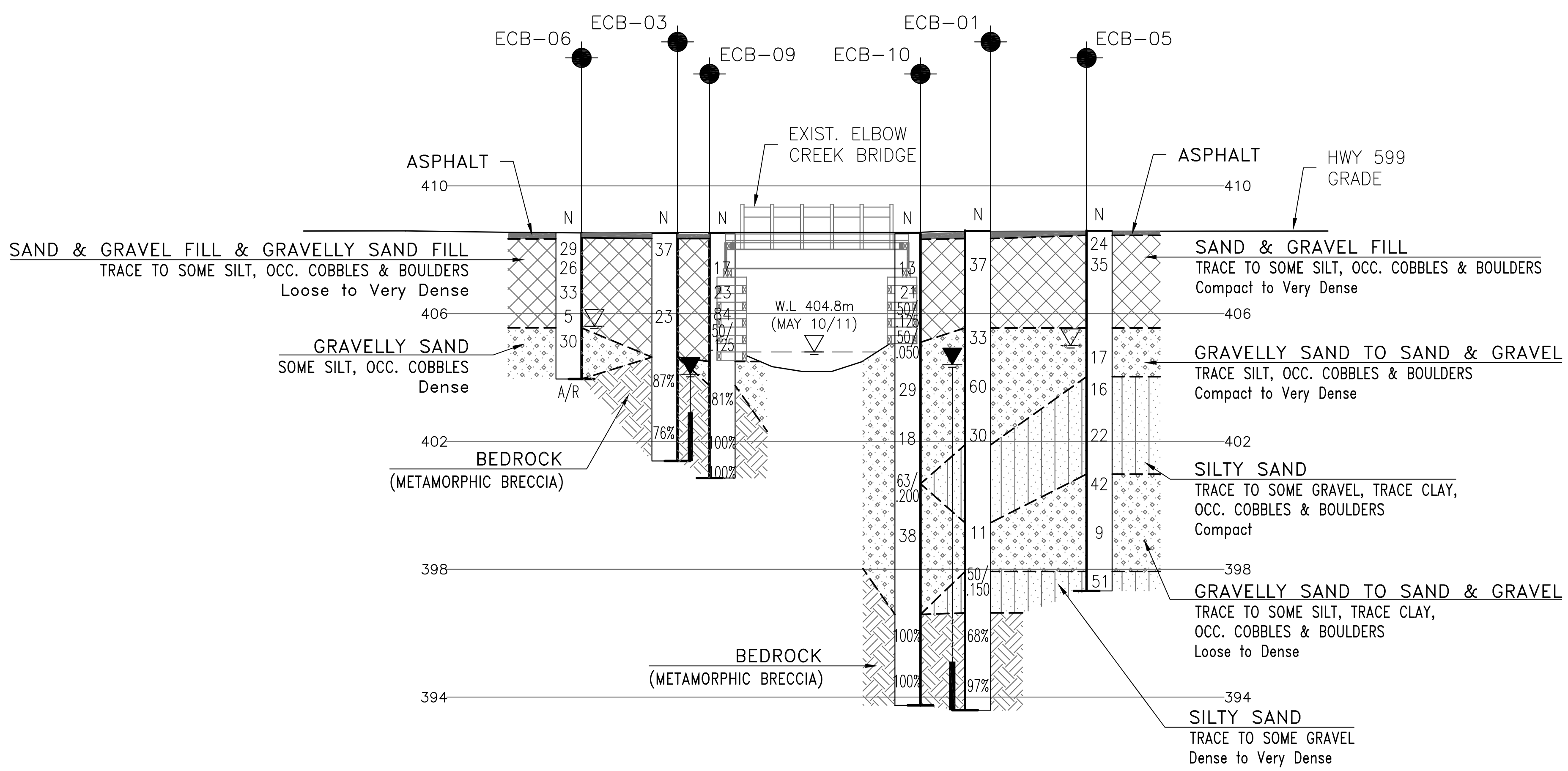
WSP
1389 PREMIER WAY, THUNDER BAY (ONTARIO) CANADA P7B 6A3
TEL: 807 625-6700 | FAX: 807 623-4491 | WWW.WSPGROUP.COM

THURBER ENGINEERING LTD.



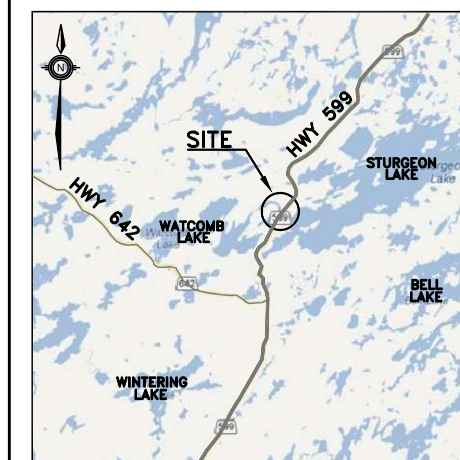
PLAN

SCALE 1:400 (8 0 8 16m)



PROFILE ALONG ℄ HWY 599

H 1:400 (8 0 8 16m)
V 1:200 (4 0 4 8)



KEYPLAN

LEGEND

●	Borehole
■	Test Pit
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level During Drilling
▼	Water Level In Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
ECB-01	408.6	5 525 945.6	631 983.6
ECB-02	408.5	5 525 927.8	631 975.4
ECB-03	408.5	5 525 926.6	631 978.0
ECB-04	408.6	5 525 944.4	631 986.2
ECB-05	408.6	5 525 950.9	631 986.4
ECB-06	408.5	5 525 921.2	631 975.3
ECB-07	405.3	5 525 933.7	631 967.2
ECB-09	408.5	5 525 928.4	631 978.8
ECB-10	408.5	5 525 941.8	631 981.4
ECB-11	407.8	5 525 924.8	631 985.5
ECB-12	407.6	5 525 941.0	631 993.4

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 52G-11

REVISIONS	DATE	BY	DESCRIPTION		
DESIGN MEF	CHK MRA	CODE	LOAD	DATE OCT 2014	
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MINISTRY OF TRANSPORTATION, ONTARIO

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

CONT No 2014-6019
WP No 6109-10-01

ELBOW CREEK BRIDGE REPLACEMENT
HIGHWAY 599
BOREHOLE LOCATIONS AND SOIL STRATA

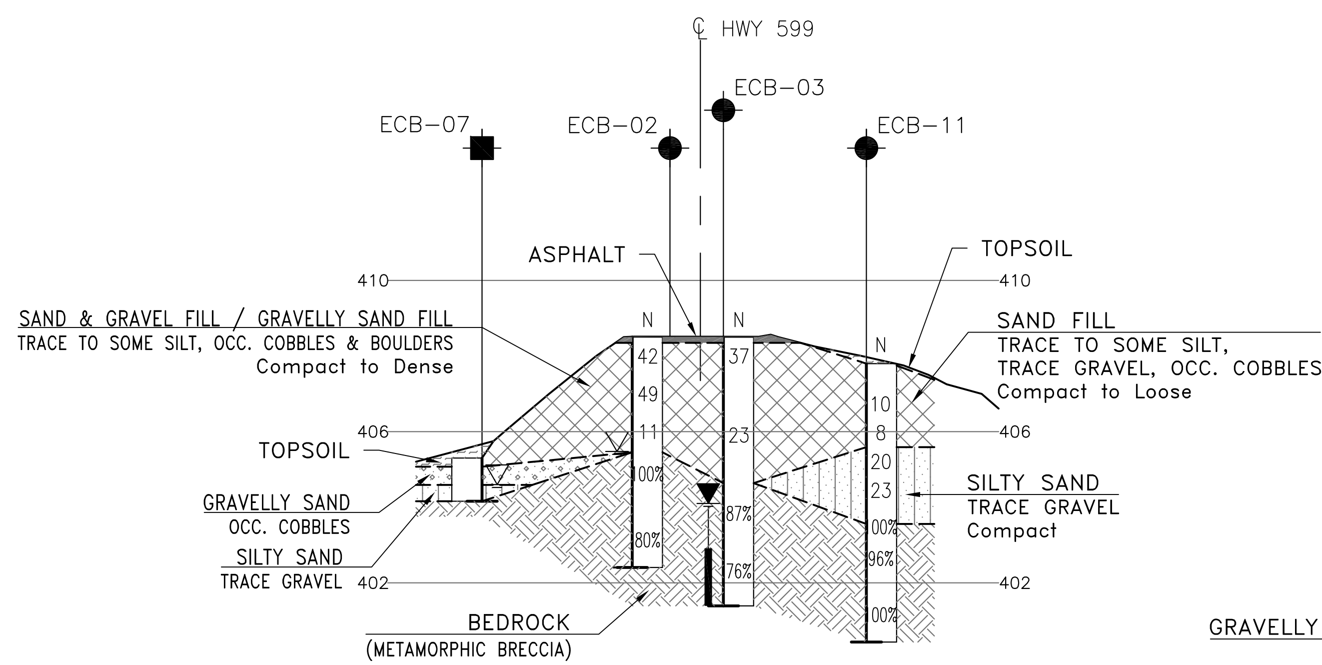
SHEET 17

WSP

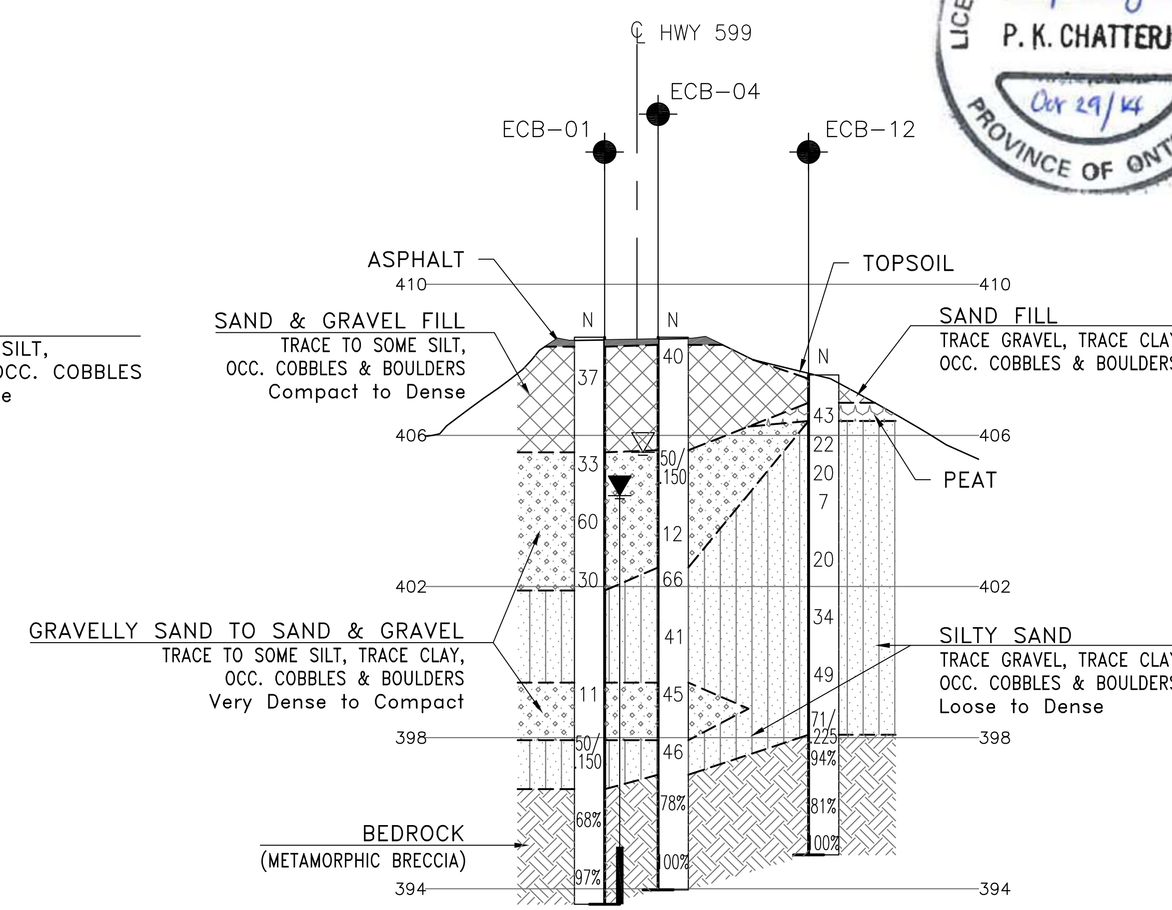
THURBER ENGINEERING LTD.

LICENSED PROFESSIONAL ENGINEER
M. R. ANDERSON
Oct 29/14
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Oct 29/14
PROVINCE OF ONTARIO



PROFILE ALONG A-A



PROFILE ALONG B-B

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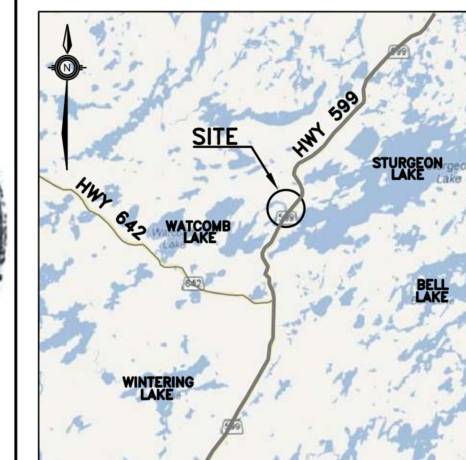
4 0 4 8 V 1:200



KEYPLAN

LEGEND

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ECB-12	407.6	5 525 941.0	631 993.4

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GEOCRES No. 52G-11

REVISIONS

DATE	BY	DESCRIPTION

DESIGN MEF	CHK MRA	CODE	LOAD	DATE OCT 2014	
DRAWN AN	CHK MEF	SITE 41S-76	STRUCT	DWG 3	

MINISTRY OF TRANSPORTATION, ONTARIO

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