



November 24, 2016

FOUNDATION INVESTIGATION AND DESIGN REPORT

**Replacement of Twin Lake Culverts, Site No. 38C-047
Detail Design of Highway 519 from Highway 17 easterly
to Dubreuilville, 30.7 km
Ministry of Transportation, Ontario
G.W.P. 327-99-00, W.P. 5296-06-01**

Submitted to:

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REPORT

GEOCRES NO.: 42C-38

Report Number: 1521770-1

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PART A

**FOUNDATION INVESTIGATION REPORT
REPLACEMENT OF TWIN LAKE CULVERTS, SITE NO. 38C-047
DETAIL DESIGN OF HIGHWAY 519 FROM HIGHWAY 17
EASTERLY TO DUBREUILVILLE, 30.7 km
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 327-99-00, W.P. 5296-06-01**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by D. M. Wills and Associates Limited (D. M. Wills) on behalf of Ministry of Transportation, Ontario (MTO) to provide Foundation Engineering services for the replacement of the Twin Lake culverts, located at about STA 20+800 (Site No. 38C-047) on Highway 519 in the Township of Dumas, approximately 9 km west of Dubreuilville, Ontario.

The Terms of Reference and the Scope of Work for the foundation investigation are outlined in MTO's Request for Proposal, dated March 2015. Golder's proposal for the foundation engineering services associated with the Twin Lake culvert replacement is contained in Section 6.8 of D. M. Wills' Technical Proposal for this assignment and in the Change Request No. 2 letter, dated May 18, 2016. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated July 22, 2015.

This report addresses the investigation carried out for the double culverts at Twin Lake centered at about STA 20+794 and STA 20+800 (Site No. 38C-047) in the Township of Dumas on Highway 519 which have been identified for replacement. The foundation investigation and design associated with the other culverts for this assignment are presented in separate reports.

The purpose of this investigation is to establish the subsurface conditions at the replacement culvert locations, by borehole drilling and in situ and laboratory testing on selected soil and rock samples. The investigation area is shown in plan on Drawing 1.

2.0 SITE DESCRIPTION

The double structural culverts requiring replacement are located at approximately STA 20+794 and STA 20+800 on Highway 519 in the Township of Dumas, approximately 9 km west of Dubreuilville, Ontario. The existing culverts are both 3690 mm wide by 2380 mm high corrugated steel elliptical structures contained in embankment fill between about 3 m and 4.5 m thick on the north side and south side of the highway, respectively. Details of the culvert are also summarized in Table 1 following the text of this report.

In general, the topography in the area of the culverts consists of rolling terrain, including sparsely populated treed areas, lakes and areas of standing water. Twin Lake is present on the north and south sides of Highway 519 at this site. The ground surface at the borehole locations advanced for the foundation investigation varies between Elevation 334.1 m at Highway 519 roadway surface and Elevation 330.2 m at the embankment toes, referenced to Geodetic datum.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the foundation investigation associated with the Twin Lake culverts was carried out between July 5 and 12, 2016 in which time a total of eight boreholes (Boreholes C60-1 to C60-8) were advanced at, or in the immediate vicinity of the culvert alignments and proposed temporary widening to the north. In addition, Dynamic Cone Penetration Tests (DCPTs) were advanced from the bottom of Boreholes C60-7 and C60-8.

The field investigation was carried out using a CME 55 truck-mounted drill rig and portable drilling equipment, which were supplied and operated by Landcore Drilling of Sudbury, Ontario and OGS Drilling of Almonte, Ontario, respectively.



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Boreholes completed with the CME 55 truck-mounted drill rig were advanced through the overburden using nominal 152 mm diameter solid stem augers. The boreholes completed with the portable equipment were advanced through the overburden using BW size casing with wash boring techniques. Soil samples were obtained continuously or at intervals of depth up to about 1.5 m using nominal 50 mm outside diameter (O.D.) split-spoon samplers, operated by an automatic hammer on the drill rig and performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586). Boreholes advanced by portable equipment employed a full-weight hammer lifted manually and dropped from the SPT height. Bedrock was cored in Boreholes C60-3 to C60-6 using thin-walled NQ sized core barrels for lengths between 2.9 m and 3.5 m.

All open boreholes were backfilled with bentonite upon completion in accordance with R.R.O 1990, Regulation 903 (Wells) (as amended). The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets in Appendix A.

The fieldwork was observed by members of Golder's engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined the soil samples. The soil and bedrock core samples were identified in the field, placed in appropriate containers, labelled and transported to Golder's Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. Rock quality (i.e., TCR, SCR, RQD, weathering and strength index), discontinuity characteristics and classification data were recorded in the field based on visual inspection of the recovered rock cores upon extraction from the core barrel. Classification testing (water content, organic content, Atterberg limits and grain size distribution) was carried out on selected soil samples, and strength testing (uniaxial unconfined compression and point load index) were completed on selected rock samples. All of the laboratory tests were carried out to MTO Laboratory Standards and/or ASTM Standards, as appropriate. The results of the laboratory testing are summarized on the Record of Borehole sheets in Appendix A and presented in the laboratory test figures provided in Appendix B.

A sample of lake water was obtained during the field investigation at the inlet of the culverts, and submitted to a specialist analytical laboratory under chain of custody procedures for corrosivity package testing. The results of the analytical testing are included in Appendix C.

Classification of the rock mass quality of the bedrock with respect to the Rock Quality Designation (RQD) is described based on Table 3.10 of the Canadian Foundation Engineering Manual CFEM¹. The degree of weathering of the bedrock samples and the strength classification of the intact rock mass based on field identification are described in accordance with the International Society for Rock Mechanics (ISRM)² standard classification system. Point load strength index tests, both perpendicular to the core axis (diametral) and along the core axis (axial) were performed on selected samples of the rock core to provide an indication of the point load strength index (Is_{50}) of the rock. The bedrock strength was classified with respect to strength is based on the Is_{50} values as suggested in Table 3.5 of CFEM¹.

Temporary benchmarks were placed in the field by Tulloch Engineering, Ontario Land Surveyors. The as-drilled borehole locations, in stations and offsets, were measured in reference to the roadway station given on the temporary benchmarks and were subsequently converted into MTM NAD 83 (Zone 13) coordinates in AutoCAD. Borehole elevations were surveyed by a member of our technical staff in reference to the temporary benchmark elevations. The borehole locations shown on Drawing 1 are positioned relative to MTM NAD 83 northing and

¹ Canadian Foundation Engineering Manual. 2006. Fourth Edition, Canadian Geotechnical Society.

² International Society for Rock Mechanics Commission on test Methods. 1985. Int. J. Rock Mech. Min. Sci. & Geomech. Abstr. Vol 22, No. 2, pp.51-60.



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easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are summarized below.

Culvert Location	Borehole	Location (m)		Ground/Water Surface Elevation (m)	Depth of Borehole / DCPT (m)
		Northing	Easting		
STA 20+794 and STA 20+800 (Township of Dumas)	C60-1	5,355,970.9	254,818.2	331.0	2.6
	C60-2	5,355,969.1	254,831.2	331.0	4.7
	C60-3	5,355,965.8	254,819.6	331.0	5.2*
	C60-4	5,355,965.3	254,830.8	331.0	7.3*
	C60-5	5,355,955.4	254,817.5	334.1	7.1*
	C60-6	5,355,949.8	254,832.9	333.8	11.4*
	C60-7	5,355,940.3	254,819.7	330.5	5.9 / 7.4
	C60-8	5,355,940.0	254,830.5	330.5	8.2 / 10.8

Note: * Includes between 2.8 m and 3.3 m length of bedrock coring.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Highway 519 is located in the Abitibi Uplands physiographic region, within the Canadian Shield as delineated by *The Geomorphic Systems of North America*.³ The Abitibi Uplands generally slopes down towards Hudson Bay and is typically characterized by low broad hills with gently sloping, rolling or undulating topography and subdued relief. This region is underlain by massive, mainly crystalline rocks covered by Quaternary glaciofluvial outwash and till deposits typically consisting of gravel and sand, including pro-glacial river and deltaic deposits, as well as more recent organic deposits within the depressions between bedrock knobs.⁴

Highway 519 is located directly north of the Michipicoten greenstone belt, within the Pukaskwa batholith within the Wawa Subprovince⁵. The bedrock at this section of Highway 519 consists of tonalite to granodiorite-foliated to gneissic with minor supracrustal inclusions.

4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil and bedrock core samples, are presented on the Record of Borehole sheets and the laboratory test sheets in Appendices A and B, respectively. The results of the in situ field tests (i.e. SPT "N"-values) as presented on the Record of Borehole sheets and in Section 4.2 are uncorrected. The stratigraphic boundaries shown on the Record of Boreholes sheets are inferred from generally non-continuous sampling, observations of drilling progress and in situ testing and are approximate. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations. Where

³ Graf, W. L. 1987. *Geomorphic systems of North America*. Geological Society of America, Inc.: Boulder, Colorado.

⁴ The Ministry of Natural Development and Mines, Ontario, 2016. OGSEarth: Quaternary Geology [Electronic Map] 1:1,000,000.

⁵ Williams H. R., Stott G. M., Heather K. B., Muir T. L. and Sage R. P. 1991. Wawa subprovince; in *Geology of Ontario*, Ontario Geological Survey, Special Volume 4, Part 1, p.485-539.



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applicable, the thickness of the overburden at the site is also inferred from the resistance to DCPT results as shown on the Record of Borehole sheets in Appendix A and the profile/cross-section drawings. It should be noted that the interpreted stratigraphy shown on Drawings 2 and 3 is a simplification of the subsurface conditions.

The stratigraphy at the borehole locations at the culvert sites consists of embankment fill over a native stratum of silt to sand which in places contains trace organics. The native silt to sand deposit is underlain in places by a deposit of sand and gravel which is underlain by diorite bedrock, and in other places it is directly underlain by diorite bedrock. A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.3 Twin Lake Culverts (Culvert C60 – STA 20+800 Township of Dumas)

The plan and profile along the centreline of the existing culverts C60 at about STA 20+800 showing the borehole locations and interpreted stratigraphy are provided on Drawing 2. Additionally, cross-sections showing the soil stratigraphy along the proposed and existing embankment toes, or ends of the culverts, and crest are provided on Drawing 3. The existing culverts are about 17 m long, 3690 mm wide by 2380 mm high corrugated steel elliptical structures contained within embankment fill between about 3 m and 4.5 m thick on the north and south ends, respectively. Details of the culverts are also summarized in Table 1 following the text of this report. A total of eight boreholes were completed to investigate the subsurface conditions at the culverts location: two boreholes (Boreholes C60-1 and C60-2) were advanced at the proposed north toe of the temporary embankment widening; four boreholes (Boreholes C60-3, C60-4, C60-7 and C60-8) were advanced near the ends of the existing culverts; and two boreholes (Boreholes C60-5 and C60-6) were advanced through the Highway 519 roadway embankment, on the west and east side of the existing culverts alignment, respectively. Photographs of the site are shown on Figures 1A and 1B following the text of the report.

4.3.1 Lake Water

Boreholes C60-2 to C60-4, C60-7 and C60-8 were advanced near the shores of Twin Lake and encountered between 0.2 m to 0.9 m depth of standing water.

4.3.2 Asphalt and Fill

Boreholes C60-5 and C60-6 were advanced from the Highway 519 roadway surface and encountered an approximately 75 mm thick layer of asphalt at Elevations 334.1 m and 333.8 m, respectively.

A deposit of non-cohesive fill comprised of sand, some gravel to gravelly sand to sand and gravel are encountered below the asphalt or below the water in Boreholes C60-2 to C60-7. The fill in places contains rock fragments. The top of the fill layer ranges from Elevations 334.0 m at one of the boreholes drilled from the roadway to 329.6 m at the toe of the embankment, and the thickness of the deposit varies between 0.6 m and 3.7 m.

The SPT 'N'-values measured within the non-cohesive fill range from 8 blows per 0.30 m of penetration to 72 blows per 0.25 m of penetration, indicating a loose to very dense relative density. An SPT 'N'-value of 96 blows per 0.30 m of penetration was measured at the interface of the fill and underlying native silt to sand deposit.



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The natural water content measured on seven samples of the fill deposit ranges from about 2 per cent to 13 per cent.

The results of grain size distribution tests completed on three samples of the sand to sand and gravel fill are shown on Figure B1 in Appendix B.

4.3.3 Silt to Sand

A deposit of interlayered non-cohesive soils comprised of silt to sandy silt to silt and sand to silty sand to sand was encountered at the ground surface, below the water or below the fill in all boreholes except Borehole C60-5. The deposit generally contains trace organic material. The surface of the interlayered deposit ranges from Elevations 331.0 m to 329.0 m. The overall thickness of the deposit ranges from 1.4 m to at least 7.9 m, and may be up to 9.3 m thick as inferred from the DCPT in Borehole C60-8; with individual interlayers ranging in thickness between 0.6 m and 3.8 m, and potentially greater than 6.7 m as inferred from the DCPT in Borehole C60-8. Boreholes C60-1 and C60-2 were terminated in the silt to sand deposit at depths of 2.6 m and 4.7 m below ground, surface / water (Elevations 328.7 m to 325.3 m) upon split-spoon sampler refusal and Boreholes C60-7 and C60-8 were terminated in the inferred silt and sand or silt deposits at depths of 7.4 m and 10.8 m below water surface (Elevations 323.1 m and 319.7 m) upon refusal to further DCPT advancement.

The SPT 'N'-values measured within the silt to sand deposit range from 0 blows (weight of hammer) to 27 blows per 0.3 m of penetration, indicating a very loose to compact relative density. Higher SPT 'N'-values and split-spoon sampler bouncing were noted at the interface of the silt to sand deposit with the underlying bedrock.

The natural water content measured on eleven samples of the silt to sand deposit ranges from about 13 per cent to about 55 per cent.

The organic content measured on a sample of the silt layer and a sample of the sand layer of the non-cohesive deposit is 5 per cent and 3 per cent, respectively.

The grain size distributions of twelve samples of the silt to sand deposit are shown on Figures B2-A and B2-B in Appendix B.

Atterberg limits tests were completed on the fines content of three samples of the silt to sand deposit. The results of two Atterberg limits tests indicate that the fines material is non-plastic; and the sample of sandy silt yielded a liquid limit of 19 per cent and a plastic limit of 15 per cent, corresponding to a plasticity index of about 4 per cent. The result of this Atterberg limits test is shown on the plasticity chart on Figure B3 in Appendix B, and indicates that the fines material is classified as a silt with slight plasticity.

4.3.4 Sand and Gravel

Boreholes C60-2 and C60-4 penetrated a 0.8 m and 0.7 m thick layer of sand and gravel, trace to some silt underlying the non-cohesive silt to sand deposit at about Elevations 327.1 m and 327.6 m, respectively. Borehole C60-2 was terminated within this deposit upon split spoon sampler refusal.

SPT 'N'-values of 16 blows and 39 blows per 0.30 m of penetration were measured within the sand and gravel deposit, indicating a compact to dense relative density. Split-spoon sampler bouncing was noted at the interface of this layer with the underlying bedrock.



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The natural water content measured on one sample of the sand and gravel layer is about 12 per cent.

4.3.5 Bedrock / Refusal

Bedrock was encountered in Boreholes C60-3 to C60-6 at depths ranging from 2.3 m to 8.5 m below ground surface, between Elevations 330.3 m and 325.3 m and cored for depths between 2.9 m and 3.3 m. Refusal to further advancement of DCPT was encountered in Boreholes C60-7 and C60-8 at depths of 7.4 m and 10.8 m, respectively, corresponding to Elevations 323.1 m and 319.7 m.

Based on the review of the bedrock core samples, the bedrock consists of diorite and is generally described as fresh, crystalline, white to black, medium grained, non-porous, medium strong (R3, 25 MPa < UCS < 50 MPa) to very strong (R5, 100 MPa < UCS < 250 MPa) with interlayers or veins of andesite and quartz. The bedrock descriptions are shown on the Record of Drillhole sheets in Appendix A and the photographs of core samples are shown on Figures B4 and B5 in Appendix B.

The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of samples recovered are between 81 per cent and 100 per cent and between 48 per cent and 100 per cent, respectively. The Rock Quality Designation (RQD) of the core samples obtained ranges from 50 per cent to 100 per cent, indicating a rock mass of fair to excellent quality as per Table 3.10 of the CFEM (2006).

A Unconfined Compression (UC) test performed on a core sample of the bedrock from Borehole C60-3 measured a uniaxial compressive strength (UCS) of about 65 MPa. Based on the laboratory UC test, the bedrock is classified as strong (R4, 50 MPa < UCS < 100 MPa). The UC test result is presented in Figure B6 in Appendix B.

Point load strength index tests, diametral and axial, were carried out on two selected samples of the bedrock core. The corrected point load strength index values (Is_{50}) are shown in Table B1 in Appendix B. The axial tests measured Is_{50} values of 1.8 MPa and 2.2 MPa and the diametral tests measured Is_{50} values of 4 MPa and 5.6 MPa.

Based on the laboratory UC test and Is_{50} values, the bedrock is classified as medium strong (R3, 25 MPa < UCS < 50 MPa) to very strong (R5, 100 MPa < UCS < 250 MPa).

4.3.6 Groundwater Conditions

In general, the recovered soil samples were moist to wet. Boreholes C60-2 to C60-4, C60-7 and C60-8 were drilled off-shore of Twin Lake and encountered 0.2 m to 0.9 m depths of standing water. The groundwater level was measured in Boreholes C60-1, C60-5 and C60-6 upon completion of drilling operations at depths between 0.1 m and 3.4 m below ground surface, ranging from Elevations 330.9 m to 330.4 m. The groundwater level should be expected to fluctuate seasonally in response to changes in precipitation and snow melt, and is higher during the wet seasons and thereafter periods of heavy precipitation.



5.0 CLOSURE

The borehole investigation program was supervised by Mr. Lubo Kosci, P.Eng., and Ms. Madison Kennedy, B.A.Sc. This report was prepared by Mr. Al Varshoi, M.E.Sc., P.Eng., and was reviewed by Christopher Ng, P.Eng., a senior geotechnical engineer and an Associate of Golder. Mr. Jorge M. A. Costa, P.Eng., a Senior Consultant with Golder and Designated MTO Foundations Contact conducted an independent quality control review of this report.

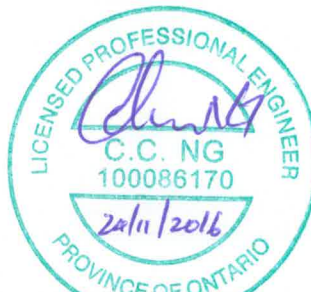


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Report Signature Page

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PART B

**FOUNDATION DESIGN REPORT
REPLACEMENT OF TWIN LAKE CULVERTS, SITE NO. 38C-047
DETAIL DESIGN OF HIGHWAY 519 FROM HIGHWAY 17 EASTERLY TO
DUBREUILVILLE
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 327-99-00, W.P. 5296-06-01**



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the proposed replacement of the Twin Lake culverts (Culvert C60) at about STA 20+800 on Highway 519 as part of the detail design of Highway 519 from Highway 17 easterly to Dubreuilville. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the investigation. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess the feasible foundation alternatives and carry out the design of the culvert foundations. The foundation investigation report, discussion and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

Golder Associates Ltd. (Golder) has been retained by D. M. Wills and Associates Ltd. (D. M. Wills) on behalf of the MTO to provide recommendations on the foundation aspects for the detail design for the replacement of the existing twin culverts at about STA 20+800 on Highway 519 in the Township of Dumas, Ontario.

This report presents geotechnical resistances for design of the culverts as well as the results of stability and settlements associated with the detour and final embankments and provides recommendations for stable embankment geometry and embankment fill materials that may be required as a means to reduce culvert settlements and to improve embankment stability (if necessary). The report also addresses potential construction concerns and geotechnical problems associated with culvert, detour and final embankments, the temporary Retained Soil System (RSS) wall for the staged construction, sub-excavating soft/organic materials and placement of new fill materials.

It is understood that each replacement culvert will be of the same size and type as the existing twin culverts, a 3690 mm wide by 2380 mm high steel elliptical culvert, and that the culvert alignment and invert elevations will remain unchanged with the upstream and downstream inverts at about Elevations 330.7 m and 330.6 m and Elevations 330.6 m and 330.4 m for the west and east culverts, respectively. In addition, it is understood that a detour embankment about 5.7 m wide will be required (to the north of the existing embankment) as well as a temporary RSS wall (on the south side of the existing embankment) as part of the construction staging to facilitate the culvert replacement. The embankment is to be reinstated to its original grade and geometry (i.e. there will be no grade raises or platform widening) as part of the culvert replacement at this location on Highway 519.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the 2014 Canadian Highway Bridge Design Code and its Commentary (CHBDC, S6-14), the proposed twin culvert and its foundation system is considered to be classified as having a “typical



consequence level” associated with exceeding limits states design. In addition, given the level of foundation investigation completed to date in comparison to the degree of site understanding in Section 6.5 of CHBDC (2014), the level of confidence for design is considered to be a “typical degree of site and prediction model understanding.” Accordingly, the appropriate corresponding ULS and SLS consequence factor, Ψ , from Table 6.1 and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs} , from Table 6.2 of the CHBDC have been used for design, as indicated in Sections 6.3 and 6.4 below.

6.3 Foundations for Culvert Replacement

6.3.1 Foundation Options

Elliptical Corrugated Steel Pipe (CSP) culverts, concrete pipe culverts, pre-cast box culverts, and cast-in-place open footing culverts are all feasible alternatives for the replacement of the existing twin culverts. Foundation recommendations have been provided for these feasible alternative culvert types although it is understood that the proposed replacement culverts will be two 3690 mm wide by 2380 mm high steel elliptical CSP culverts.

The advantages and disadvantages associated with replacing the existing culverts with the various culvert alternatives are summarized in Table 2, following the text of this report. Recommendations for replacement of the existing culverts with an elliptical CSP culvert, concrete pipe culvert, pre-cast box culvert as well as cast-in-place open footing culvert are provided in the following sections. From a foundation perspective an elliptical CSP culvert is considered to be the preferred replacement alternative.

6.3.2 Founding Elevations and Frost Protection Requirements

6.3.2.1 Corrugated Steel Pipe Culvert Replacement

It is not necessary to found a CSP culvert replacement at or below the standard depth of frost penetration for frost protection purposes, as CSP culverts are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. Table 3, following the text of this report, provides recommended founding elevations and the founding soil conditions for CSP replacement culverts, assuming a 0.3 m thick combined bedding layer and culvert bottom thickness.

6.3.2.2 Concrete Pipe Culvert Replacement

It is not necessary to found a concrete pipe culvert replacement at or below the standard depth of frost penetration for frost protection purposes, as concrete pipes are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. Table 3, following the text of this report, provides recommended founding elevations and founding conditions for concrete pipe replacement culverts, assuming a 0.3 m thick combined bedding layer and culvert bottom thickness.

6.3.2.3 Pre-cast Box Culvert Replacement

It is not necessary to found a pre-cast box culvert replacement at or below the standard depth of frost penetration for frost protection purposes, as pre-cast box structures are tolerant of small magnitudes of movement related to



freeze-thaw cycles, should these occur. Table 3, following the text of this report, provides recommended founding elevations and founding conditions for pre-cast box replacement culverts, assuming a 0.3 m thick combined bedding layer, levelling layer and culvert bottom thickness.

6.3.2.4 Open Footing Culvert Replacement

The strip footings for an open footing culvert replacement should be founded at a minimum depth of 2.4 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per OPSD 3090.100 (Foundation, Frost Penetration Depths for Northern Ontario). Table 3, following the text of this report, provides recommended founding elevations and founding conditions for open footing replacement culverts.

6.3.3 Factored Geotechnical Resistances

6.3.3.1 Corrugated Steel Pipe (CSP) Culvert Replacement

CSP culverts placed on the properly prepared subgrade, at or below the founding elevations recommended in Table 3, should be designed based on the corresponding recommended factored ultimate geotechnical resistance at ULS and the factored serviceability geotechnical resistance at SLS for 25 mm of settlement, as given in Table 3. These recommendations are based on the associated elliptical CSP culvert dimensions.

The factored ultimate geotechnical resistance at Ultimate Limit State (ULS) and the factored serviceability geotechnical resistance at Serviceability Limit State (SLS) for 25 mm of settlement are dependent on the culvert dimensions and founding elevation and as such, the geotechnical resistances should be reviewed if the culverts width or founding elevations differ from those given in Table 3.

The factored ultimate geotechnical resistances provided in Table 3 are based on loading applied perpendicular to the top surface of the culvert. Where the load is not applied perpendicular to the top surface of the culvert, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of the CHBDC (2014) and its *Commentary*.

6.3.3.2 Concrete Pipe Culvert Replacement

Concrete pipe culverts placed on the properly prepared subgrade, at or below the founding elevations recommended in Table 3, should be designed based on the recommended factored ultimate geotechnical resistances at ULS and the factored serviceability geotechnical resistances at SLS for 25 mm of settlement, as given in Table 3. These recommendations are based on the associated concrete pipe culvert dimensions.

The factored ultimate geotechnical resistance at ULS and the factored serviceability geotechnical resistance at SLS for 25 mm of settlement are dependent on the culvert diameter and founding elevation and as such, the geotechnical resistances should be reviewed if the culvert diameters or founding elevations differ from those given in Table 3.

The factored ultimate geotechnical resistances provided in Table 3 are based on loading applied perpendicular to the top surface of the culvert. Where the load is not applied perpendicular to the top surface of the culvert,



inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of the CHBDC (2014) and its *Commentary*.

6.3.3.3 Pre-cast Box Culvert Replacement

Pre-cast box culverts placed on the properly prepared subgrade, at or below the founding elevations recommended in Table 3, should be designed based on the recommended factored ultimate geotechnical resistances at ULS and the factored serviceability geotechnical resistances at SLS for 25 mm of settlement, as given in Table 3. These recommendations are based on the associated box culvert dimensions.

The factored ultimate geotechnical resistance at ULS and the factored serviceability geotechnical resistance at SLS for 25 mm of settlement are dependent on the culvert width and founding elevation and as such, the geotechnical resistances should be reviewed if the culvert widths or founding elevations differ from those given in Table 3.

The factored ultimate geotechnical resistances provided in Table 3 are based on loading applied perpendicular to the top surface slab of the culvert. Where the load is not applied perpendicular to the top surface slab of the culvert, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of the CHBDC (2014) and its *Commentary*.

6.3.3.4 Open Footing Culvert Replacement

Strip footings placed on the properly prepared subgrade, at or below the founding elevations recommended in Table 3, should be designed based on the factored ultimate geotechnical resistances at ULS and the factored serviceability geotechnical resistances at SLS for 25 mm of settlement, as given in Table 3. These recommendations are based on assumed footing widths of 0.6 m and 1.2 m.

The factored ultimate geotechnical resistance at ULS and factored serviceability geotechnical resistance at SLS for 25 mm of settlement are dependent on the culvert footing and founding elevation and as such, the geotechnical resistances should be reviewed if the culvert strip footing is different from the assumed width of 0.6 m or 1.2 m or the founding elevations differ from those given in Table 3.

The factored ultimate geotechnical resistances provided in Table 3 are based on loading applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footings, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of the CHBDC (2014) and its *Commentary*.

6.3.4 Resistance to Lateral Loads / Sliding Resistance

Resistance to lateral forces / sliding resistance between the base of the CSP, concrete pipe or box culvert, or strip footings for the open footing culverts, and the subgrade should be calculated in accordance with Section 6.10.5 of the CHBDC (2014). Table 4, following the text of this report, provides the coefficients of friction ($\tan \delta$) between the base of the culverts/footings and potential interface materials.



6.4 Embankment Stability and Settlement

Based on the staging and profile drawings provided by D. M. Wills on September 20, 2016, a detour embankment will be required to facilitate the staged replacement of the existing culverts and there is no grade change or platform widening of the final Highway 519 embankment at this location.

In general, while the depth to bedrock is relatively shallow on the west side of the culverts and the bedrock surface slopes down from west to east, the detour embankment will likely be founded on the existing fill and non-cohesive silty sand to sand deposits north of the existing embankment.

The results of stability and settlement analysis for the detour embankment and permanent conditions are presented in the following sections.

6.4.1 Stability

6.4.1.1 Methodology

Limit equilibrium slope stability analyses for the detour and final embankment was carried out using the commercially available program Slide (version 6.0), developed by Rocscience Inc., employing the Morgenstern-Price method of analysis. For all analyses, the Factors of Safety (FoS) of numerous potential failure surfaces were computed for the critical embankment cross-section in order to establish the minimum FoS. The FoS is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. For the purpose of the stability analysis, the FoS is equal to the inverse of the product of the consequence factor, Ψ , and the geotechnical resistance factor, ϕ_{gu} . (i.e. $FoS = 1/(\Psi \cdot \phi_{gu})$). Accordingly, a target minimum FoS of 1.3 and 1.5 has been used for the design of the embankment slopes for temporary and permanent conditions, respectively, as per Table 6.2 of CHBDC (2014). The stability analyses assume that all organics and other deleterious materials are removed prior to constructing the approach embankments.

6.4.1.2 Parameter Selection

For the non-cohesive soils present at this site, the effective stress parameters employed in the analysis were estimated from empirical correlations based on the results of the in situ Standard Penetration Tests (SPT). The correlations proposed by Peck et al. (1974) and U.S. Navy (1986) were employed and the results were adjusted by engineering judgment based on precedent experience in similar soils. The parameters used in the analysis are summarized in Table 5, following the text of this report.

For the purpose of the stability analysis, the water level was assumed to vary from Elevations 331.0 m to 330.5 m, from the north side to the south side of the embankment, respectively, which is based on the surface water levels measured during the site investigation.

Table 5 presents the simplified stratigraphy and the associated strengths and unit weights employed for the existing and new fill material as well as the native overburden deposits encountered in the area of the embankment widening.



6.4.1.3 *Results of Analysis*

The results of the stability analysis for the detour and final embankments at the critical section are summarized in Table 6. In summary, the FoS for the temporary embankment widening and for the final reconstructed embankment is equal to or greater than 1.3 and 1.5, respectively.

6.4.2 Settlement

6.4.2.1 *Methodology*

To estimate the magnitude of expected settlement of the embankment, analysis was carried out at the critical section of the detour and final embankment, corresponding to the thickest soil deposits. Settlement analyses were carried out using the commercially available program *Settle*^{3D} (version 3.0), developed by Rocscience Inc. The settlement analyses assume that all organics and other deleterious materials (i.e. rootlets and wood fragments) are removed prior to constructing the approach embankments.

6.4.2.2 *Parameter Selection*

The simplified stratigraphy and the associated unit weights and strengths employed for the estimation of settlement of the foundation soils at the detour and final embankment are presented in Table 5. The immediate compression of the non-cohesive overburden soils were modelled by estimating an elastic modulus of deformation based on the SPT 'N'-values and using correlations proposed by Bowles (1984) and Kulhawy and Mayne (1990). These estimated values were compared with the typical range of expected values for similar soil types, as outlined in *CHBDC* and adjusted, as appropriate.

For the purpose of the settlement analysis, the groundwater level was assumed to be at Elevation 331.0 m, which is based on the surface water level measured at the north toe of the embankment during the site investigation.

6.4.2.3 *Settlement of Foundation Soils*

The total factored settlement of the foundation soils below the detour embankment is estimated to be about 55 mm. This settlement is immediate and is expected to occur relatively quickly (i.e. during construction) in response to the embankment construction.

Given that there is no grade raise or platform widening of the final embankment, the existing fill below the existing culvert invert level as well as native overburden is not expected to experience additional load as a result of the culvert replacement and as such, the settlement of the foundation soils below the culvert is estimated to be less than 25 mm.

The results of the foundation soil settlement analysis for the detour and final embankment at the critical section are summarized in Table 7.



6.4.2.4 Settlement of Embankment Fill

Where rock fill is to be used for the reconstruction of the proposed embankment, there will be settlement due to compression of the rock fill itself under self-weight, in addition to the settlement of the underlying foundation soils, as described above. The magnitude of short-term post-construction settlement of the rock fill is a function of the height of fill as well as the method of fill placement (i.e. compacted versus dumped rock fill) as outlined in MTO Foundations Guideline for Rock Fill Settlement and Rock Fill Quantity Estimates, dated September 2010.

Rock fill should be placed, whenever possible, in a controlled manner (i.e. not end-dumped) in accordance with OPSS.PROV 206 (Grading). Blading, dozing and 'chinking' the rock fill to form a dense, compact mass is required to minimize voids and bridging and reduce settlements and should be used to construct rock fill embankments above the existing groundwater table. Where rock fill cannot be placed in a controlled manner (i.e. below the groundwater table), the post-construction settlement of the rock fill is expected to be greater.

The magnitude of short-term and long-term post-construction settlement associated with the rock fill was estimated in accordance with the MTO Foundations Guideline (September 2010). Given that the height of embankment is approximately 3 m at the culvert location, if rock fill is to be used for the reconstruction of the embankment, it is estimated that the long-term post-construction settlement of the rock fill will be less than 25 mm. The results of the rock fill settlement analysis for the detour and final embankment at the critical section are summarized in Table 7. The estimated post-construction settlement of the detour rock fill embankment for a three month construction period will be about 10 mm.

6.5 Lateral Earth Pressures for Design

The lateral earth pressures acting on the walls of a culvert will depend on the type and method of placement of the backfill material, the nature of the soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.

The following recommendations are made concerning the design of the culvert walls. These design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free draining granular fill meeting the specifications of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II should be used as backfill behind the culvert walls, and on top of the culvert for a thickness of not less than 300 mm. Backfill should be placed in a maximum of 200 mm loose lift thickness and nominally compacted. Weep holes, where applicable, should be installed to provide positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting).
- For restrained walls in box culvert design, granular fill should be placed in a zone with the width equal to at least 2.4 m behind the back of the wall (in accordance with Figure C6.20(a) of the *Commentary* to the CHBDC 2014). For unrestrained walls in open footing culvert design, fill should be placed within the wedge-shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (in accordance with Figure C6.20(b) of the *Commentary* to the CHBDC (2014). The



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pressures are based on the proposed embankment fill material and the following parameters (unfactored) may be used:

Fill Type	Soil Unit Weight	Coefficients of Static Lateral Earth Pressure	
		At-Rest, K_o	Active, K_a
Granular 'A'	22 kN/m ³	0.43	0.27
Granular 'B' Type II	21 kN/m ³	0.43	0.27

If the culvert structure does not allow lateral yielding, at-rest earth pressures should be assumed for the foundation design. If the culvert structure allows for lateral yielding, active earth pressures should be used in the foundation design. The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.12.1 and Table C6.6 of the *Commentary* to the CHBDC (2014).

6.6 Construction Considerations

6.6.1 Temporary Protection Systems and Cofferdams

The temporary excavations for the culverts will be made through the existing embankment fill and into native overburden soils, which are described in detail in Section 4.3 of this report. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. According to OHSA, the existing fill and native overburden soils would be classified as Type 3 soils. Provided that proper groundwater control is in place, temporary open-cut excavations through the embankment fill and native overburden soils should be made with side slopes inclined no steeper than 1H:1V.

It is understood that a cofferdam will be required to maintain a dry excavation during construction. Given the relatively shallow depth to bedrock to the west of the existing culverts and the presence of cobbles within in the existing fill, it may be difficult to install sheet pile shoring. Cofferdams comprised of sand bags and/or a bladder cofferdam system could be considered as an alternative; however, additional pumping will likely be required to maintain a dry excavation as groundwater seepage through the relatively permeable silt and sand subgrade soils and embankment fill. The Contractor should be alerted to the presence of these obstructions; an example NSSP to be included in the Contract Documents is presented in Appendix D.

In addition, it is understood that a temporary RSS wall will be required along the south toe of the embankment of Highway 519 to facilitate staging for culvert construction. Given that the RSS Wall is a temporary structure, it should be designed with a low site performance rating in accordance with the MTO RSS Design Guidelines (2008). Since the proposed RSS wall is temporary works, the design of the temporary RSS wall is the responsibility of the Contractor. As a minimum, the temporary RSS wall should be assessed for sliding, overturning and global stability, in accordance with the MTO RSS Design Guidelines and CHBDC (2014).

Where required, all temporary protection systems and cofferdams should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). The lateral movement of the temporary shoring and cofferdams should meet Performance Level 2 as specified in OPSS.PROV 539. The selection and design of the protection systems and cofferdams is the responsibility of the Contractor.



The temporary protection systems, and cofferdams, should be assessed for both the drained (ϕ) and undrained cases (s_u), based on the more conservative earth pressure conditions. The earth pressure coefficients noted in Section 6.5 and Table 5 are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficient of earth pressure should be adjusted accordingly.

Design of the temporary support systems, including the cofferdams, should include an evaluation of base stability, soil squeezing stability and the hydraulic uplift stability as defined in the Canadian Foundation Engineering Manual (CFEM, 2006).

Consideration could be given to either partial or full removal of the temporary protection systems upon completion of construction or each stage of construction (as required). Where possible, full removal of the temporary protection systems should be considered to mitigate potential impediments to future rehabilitation / reconstruction work at the culvert sites.

6.6.2 Embankment Fill Placement

Placement of granular fill and rock fill for the construction of the detour and final embankment should be carried out in accordance with OPSS.PROV 206 (Grading) and compaction of the granular fill should be in accordance with OPSS.PROV 501 (Compacting), with inspection by a Quality Verification Engineer during construction to confirm that appropriate materials are used and that adequate levels of compaction are achieved. The granular fill used in embankment construction should be compacted to not less than 95 per cent of the materials standard proctor maximum dry density (SPDMDD). The placement of rock fill should be carried out in a controlled manner to minimize voids and bridging by blading, dozing and 'chinking' the rock to form a dense, compact mass.

Granular fill embankments should be constructed with side slopes no steeper than 2 horizontal to 1 vertical (2H:1V), while rock fill embankments should be constructed with side slopes no steeper than 1.25 horizontal to 1 vertical (1.25H:1V).

Where granular fill and/or rock fill is placed on an embankment side slope, benching of the embankment side slopes should be carried out in accordance with OPSD 208.010 (Benching of Earth Slopes) to integrate the new fill into the existing slope fill.

6.6.3 Excavation and Replacement below Culvert Bedding

Prior to the placement of any bedding material or granular fill, all organic soils should be stripped from the plan limits of the proposed works. Given the design invert elevations of the replacement culverts summarized in Table 4, excavation of the embankment fill and native overburden soils up to about 3.7 m below existing ground surface will be required.

The culvert subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all organic soils or other unsuitable materials have been removed, in accordance with OPSS.PROV 421 (Pipe Culvert Installation in Open Cut) for a concrete pipe or CSP culvert, OPSS 422 (Precast Reinforced Concrete Box Culverts) for a pre-cast box culvert and OPSS 902 (Excavating and Backfilling – Structures) for a cast-in-place open footing culvert. Following inspection, the sub-excavated area should be backfilled with granular material



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meeting OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II and placed and compacted in accordance with OPSS.PROV 501 (Compacting) accordingly.

All excavations should be carried out in accordance with OPSS 902 (Excavating and Backfilling – Structures) and must be carried out in accordance with Ontario Regulation 213 Ontario Occupational Health and Safety Act for Construction Projects (as amended).

6.6.4 Culvert Bedding and Backfill

Culvert construction, including placement of bedding, cover and backfill should be placed in accordance with the following standards associated with each culvert type:

Culvert Type	Bedding, Cover Material and Backfill Specifications	OPSS – Culvert Construction
Corrugated Steel Pipe	OPSD 802.010 – Flexible Pipe Embedment and Backfill, Earth Excavation	OPSS.PROV 421 – Pipe Culvert Installation in Open Cut
Concrete Pipe	OPSD 802.031 – Rigid Pipe Bedding, Cover, And Backfill, Type 3 Soil - Earth Excavation	OPSS.PROV 421 – Pipe Culvert Installation in Open Cut
Pre-Cast Box	OPSD 803.010 – Backfill and Cover for Concrete Culverts	OPSS 422 – Precast Reinforced Concrete Box Culverts
Open Footing	OPSD 803.010 – Backfill and Cover for Concrete Culverts	OPSS 902 – Excavating And Backfilling – Structures

The bedding, cover and backfill should be placed in lifts not exceeding 200 mm in loose thickness, and compacted to at least 95 per cent of the Standard Proctor maximum dry density of the material as specified in OPSS.PROV 501 (Compacting).

The backfill behind the culvert walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II. The granular backfill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting). Backfill placement for reconstruction of the roadway embankments over the culvert should be carried out as per OPSD 208.010 (Benching of Earth Slopes) to integrate the existing embankment fill and new fill along the cut faces.

For the CSP, concrete pipe and pre-cast box culverts the soil below the bedding consist of granular embankment fill, and silty sand to sand over bedrock. For the cast-in-place open footing culvert the footings will be founded on sandy silt, silty sand to sandy silt to sand and potentially on bedrock. Where the culverts or strip footings would be founded on or close to bedrock a minimum 0.3 m thick compact granular pad is required to reduce loading stress concentrations on the culvert, thereby requiring bedrock excavation in such areas.

Inspection and field density testing should be carried out by a Quality Verification Engineer during all engineered fill placement operations to ensure that appropriate materials are used, and that adequate levels of compaction have been achieved.

Additional requirements/recommendations for culvert construction are provided below for each culvert option.



6.6.4.1 Corrugated Steel Pipe Culvert

It is important that the backfill at the haunches be well compacted. CSP culverts should be constructed on a minimum 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II material for bedding and be covered with a minimum 300 mm above the pipe for cover purposes, while Granular 'B' Type I may be used as backfill above the cover.

Backfill should be placed concurrently on both sides of the culvert walls, ensuring that the backfill depth on one side does not exceed the other side by more than 200 mm as per OPSS.PROV 401 (Trenching, Backfilling and Compacting).

6.6.4.2 Concrete Pipe Culvert

It is important that the backfill at the haunches be well compacted. Circular culverts should be constructed on a 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II material for bedding and be covered with a minimum 300 mm above the pipe for cover purposes, while Granular 'B' Type I may be used as backfill above the cover.

Backfill should be placed concurrently on both sides of the culvert walls, ensuring that the backfill depth on one side does not exceed the other side by more than 200 mm as per OPSS.PROV 401 (Trenching, Backfilling and Compacting).

6.6.4.3 Pre-cast Box Culvert

It is recommended that at least 300 mm of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II material be used for bedding purposes. In addition, a minimum 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 Granular 'A' or concrete fine aggregate meeting the gradation requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided as shown on OPSD 803.010 (Backfill and Cover for Concrete Culverts) for culvert construction.

Backfill should be placed concurrently on both sides of the culvert walls, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm as per OPSS 422 (Precast Reinforced Concrete Box Culverts).

6.6.4.4 Open Footing Culvert

Backfill should be placed concurrently on both sides of the culvert walls, ensuring that the backfill depth on one side does not exceed the other side by more than 500 mm OPSS 902 (Excavating and Backfilling – Structures).

6.6.5 Erosion Protection

Provision should be made for scour and erosion protection at the culvert location. In order to prevent surface water from flowing either beneath the culverts (potentially causing undermining and scouring), or around the culverts (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream end of CSP, concrete pipe and



pre-cast box culverts. If a clay seal is adopted, the clay material should meet the requirements of OPSS.PROV 1205 (Clay Seal), and the seal should be a minimum 1 m thick if constructed of natural clay or soil-bentonite mix and extend from a depth of 1 m below the scour level for a CSP, concrete pipe or pre-cast box culvert, and from the ground surface immediately adjacent to an open footing culvert, to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and to a minimum vertical height equivalent to the high water level, including along the embankment slopes.

The requirements for and design of erosion protection measures for the inlet and outlet of the culverts should be assessed by the hydraulics design engineer. As a minimum, rip-rap treatment for the outlet of the culverts should be consistent with the standard presented in OPSD 810.010 (Rip-Rap Treatment for Sewer and Culvert Outlets). Erosion protection for the inlet of the culverts should generally follow the standard presented in OPSD 810.010, with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, rip-rap should be provided over the full extent of the clay blanket, including the fill slope over the culvert if this clay seal option is adopted.

6.6.6 Temporary Culvert

A temporary culvert may be required to provide surface water passage / drainage below the detour embankment. The temporary culvert may consist of a pre-cast concrete culvert (box or pipe) or corrugated steel pipe (CSP) culvert. Bedding recommendations for the temporary culvert should be in accordance with the corresponding OPSS and/or OPSD, as outlined in Section 6.6.4, depending on the type of temporary culvert chosen.

Settlement of the temporary culvert below the detour embankment will occur concurrently with and be of the same magnitude as the settlement of the detour embankment. The anticipated magnitude of settlement of the detour embankment, and therefore the temporary culvert, is provided in Table 7. The selection of the temporary culvert should take into account the anticipated settlement and should be sized such that it may still perform its intended function for the duration that the detour embankment widening will be in place.

6.6.7 Surface Water and Groundwater Control

For excavations extending to or below the lake water levels at the time of construction, groundwater inflows should be expected due to the relatively permeable adjacent identified/inferred granular embankment fill materials (i.e. sand to sand and gravel) and the silty sand to sand and/or silt to sandy silt subgrade. Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade. Dewatering of all excavations should be carried out in accordance with OPSS 517 (Dewatering).

Temporary shoring and groundwater control could be in the form of a sheet-pile cut off wall or cofferdam advanced to an appropriate depth to control groundwater inflow from the lake and to prevent base heaving of the foundation subgrade. As noted in Section 6.6.1, due to the shallow depth to bedrock at the culvert site, sheet pile installation may not be feasible along the west side of the culverts. Alternatively, a sand bag and/or bladder cofferdam system could be used; however, additional pumping will likely be required to maintain a dry excavation as groundwater seepage through the relatively permeable silt to sand subgrade soils and embankment fill.



Depending on the surface water level and flow conditions and groundwater levels at the time of construction, water flow could be diverted and/or pumped from behind a cofferdam; however, if construction dewatering pumping volumes are anticipated to exceed 50 m³/day, an Environmental Activity Section Registry (EASR) will be required as per the recently introduced changes to the Environmental Protection Act by the Ontario Ministry of the Environment and Climate Change (MOECC).

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Madison Kennedy, B.A.Sc., a member of the geotechnical engineering group. The technical aspects were reviewed by Mr. Christopher Ng, P.Eng., a senior geotechnical engineer and an Associate of Golder. Mr. Jorge M. A. Costa, P.Eng., a Senior Consultant with Golder and Designated MTO Foundations Contact conducted an independent quality control review of this report.



FOUNDATION REPORT - REPLACEMENT OF TWIN LAKE CULVERTS, SITE NO. 38C-047 - HIGHWAY 519

Report Signature Page

GOLDER ASSOCIATES LTD.

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Geotechnical Engineering Group



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Senior Geotechnical Engineer, Associate



Jorge M.A. Costa, P.Eng.
Designated MTO Foundations Contact, Senior Consultant

MCK/CN/JMAC/mck

o:\active\2015\3 prj\1521770 dmw_5014-e-0035_hwy 519\1111 - foundations\05 - reporting\03 - final\1521770-1 highway 519 twin lake culvert (c60)\1521770-1 fdr 16nov24 highway 519 replacement of twin lake culverts.docx



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STANDARDS:

ASTM International:

ASTM D1586	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
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Ontario Occupational Health and Safety Act:

Ontario Regulation 213/91 Construction Projects as amended by O. Reg. 443/09

Ontario Provincial Standard Drawing:

OPSD 208.010	Benching of Earth Slopes
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FOUNDATION REPORT - REPLACEMENT OF TWIN LAKE CULVERTS, SITE NO. 38C-047 - HIGHWAY 519

OPSD 802.010	Flexible Pipe Embedment and Backfill, Earth Excavation
OPSD 802.031	Rigid Pipe Bedding, Cover, And Backfill, Type 3 Soil - Earth Excavation
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.100	Foundation, Frost Penetration Depths for Northern Ontario

Ontario Provincial Standard Specification:

OPSS.PROV 206	Construction Specifications for Grading
OPSS.PROV 401	Construction Specifications for Trenching, Backfilling and Compacting
OPSS.PROV 421	Construction Specifications for Pipe Culvert Installation in Open Cut
OPSS 422	Construction Specifications for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 501	Construction Specifications for Compacting
OPSS 517	Construction Specifications for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Construction Specifications for Temporary Protection Systems
OPSS 902	Construction Specifications for Excavating and Backfilling – Structures
OPSS.PROV 1002	Material Specifications for Aggregates - Concrete
OPSS.PROV 1010	Material Specifications for Aggregates – Base, Subbase, Select Subgrade, Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal

Ontario Water Resources Act:

Ontario Regulation 903 Wells (as amended)

Commercial Software:

Slide (Version 6.0) by Rocscience Inc.

Settle^{3D} (Version 3.0) by Rocscience Inc.



TABLES



FOUNDATION REPORT - REPLACEMENT OF TWIN LAKE CULVERTS, SITE NO. 38C-047- HIGHWAY 519

Table 1: Summary of Existing Culvert Details

Culvert Location (Township)	Culvert ID	Approximate Height of Embankment ¹	Existing Culvert			Approximate Invert Elevation		Boreholes	Dynamic Cone Penetration Tests
			Type	Approximate Dimension	Approximate Length	Inlet of Culvert (W/E)	Outlet of Culvert (W/E)		
STA 20+800 (Dumas)	C60	Up to about 4.5 m	Elliptical CSP	3690 mm wide x 2380 mm high	17 m	330.7 m / 330.6 m (North End)	330.6 m / 330.4 m (South End)	8 Boreholes (C60-1 to C60-8)	Advanced from the bottom of Boreholes C60-7 and C60-8

Notes: 1. Embankment height is relative to existing ground surface level at the toe of embankment adjacent to the culvert.

Prepared By: MCK
Checked By: CN
Review ed By: JMAC



FOUNDATION REPORT - REPLACEMENT OF TWIN LAKE CULVERTS, SITE NO. 38C-047 - HIGHWAY 519

Table 2: Comparison of Foundation Alternatives for Culvert Replacement

Replacement Alternatives	Advantages	Disadvantages	Risks/Consequences
Elliptical Corrugated Steel Pipe (CSP) Culvert	<ul style="list-style-type: none"> Minimizes the depth of excavation, excavation support and dewatering requirements compared to cast-in-place open footing culvert. Culvert construction using CSP pipes is expected to be the fastest, resulting in the shortest duration for dewatering and surface water pumping, where required. More tolerant of total and differential settlement from the embankment widening, or if a grade raise is required, at the culvert site than cast-in-place open footings. Can be transported to site in pieces for on-site assembly. Existing head walls and cut off walls can be reused for the culvert replacement. 	<ul style="list-style-type: none"> Dewatering/unwatering would be required if construction is to be carried out in-the-dry to allow for placement and compaction of backfill around the culvert. Cut-off wall or clay blanket may be required at inlet to mitigate potential for scour under/along culvert. Proper compaction of backfill material under the haunches and to the springline is difficult. Will have a shorter lifespan than a concrete structure (concrete pipe, pre-cast box or open footing culvert). 	<ul style="list-style-type: none"> Some risk of disturbance of sand to silty sand deposit under the culvert during construction.
Concrete Pipe Culvert	<ul style="list-style-type: none"> Minimizes the depth of excavation, excavation support and dewatering requirements compared to cast-in-place open footing culvert. Compared to cast-in-place open footings, the use of concrete pipe segments is expected to allow for faster construction, resulting in shorter duration for dewatering and surface water pumping, where required. More tolerant of total and differential settlement from the embankment widening, or if a grade raise is required, at the culvert site than cast-in-place open footings. Will have a longer lifespan than a culvert of CSP construction. 	<ul style="list-style-type: none"> A concrete pipe culvert will require slightly longer duration for construction as compared to the construction of a CSP culvert. Dewatering/unwatering would be required if construction is to be carried out in-the-dry to allow for placement and compaction of backfill around the culvert. Cut-off wall or clay blanket may be required at inlet to mitigate potential for scour under culvert. Proper compaction of backfill material under the haunches and to the springline is difficult. Much larger structure(s) may be required to accommodate design flows. 	<ul style="list-style-type: none"> Some risk of disturbance of sand to silty sand deposit under the culvert during construction.



FOUNDATION REPORT - REPLACEMENT OF TWIN LAKE CULVERTS, SITE NO. 38C-047 - HIGHWAY 519

Table 2: Comparison of Foundation Alternatives for Culvert Replacement

Replacement Alternatives	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Box Culvert	<ul style="list-style-type: none"> Minimizes the depth of excavation, excavation support and dewatering requirements compared to cast-in-place open footing culvert. Compared to cast-in-place open footings, the use of pre-cast box segments is expected to allow for faster construction, resulting in shorter duration for dewatering and surface water pumping. More tolerant of total and differential settlement from the embankment widening, or if a grade raise is required, at the culvert site than cast-in-place open footings. Will have a longer lifespan than a culvert of CSP construction. Easier to place/compact backfill compared to an elliptical or pipe culvert. Box culvert of similar span width and height as a pipe or elliptical structure can accommodate higher flows. 	<ul style="list-style-type: none"> A pre-cast box culvert will require longer duration for construction than a CSP and a concrete pipe culvert. Cut-off wall or clay blanket may be required at inlet to mitigate potential for scour under/along culvert. Large segments need to be transported to site. May require subexcavation of bedrock along west wall of culvert, depending on the bedrock surface profile. 	<ul style="list-style-type: none"> Some risk of disturbance of sand to silty sand deposit under the culvert during construction.
Cast-In-Place Open Footing Culvert	<ul style="list-style-type: none"> Provides a higher bearing resistance due to the depth of embedment of footings as compared to the CSP, concrete pipe and pre-cast box culverts. Will have a longer lifespan than a culvert of CSP construction. Open footing culvert of similar span width and height as a pipe or elliptical structure can accommodate higher flows. May require bedrock excavation to accommodate strip footing construction. 	<ul style="list-style-type: none"> Deeper excavations, excavation support and dewatering requirements compared to other culvert types; Additional time will be required to implement a dewatering system for the construction of footings in-the-dry. A cast-in-place open footing culvert is less tolerant of total and differential settlement. 	<ul style="list-style-type: none"> High risk of disturbance of the silt deposit under the culvert during construction. Bedrock excavation may be required to facilitate footing installation could cause damage to the rock mass. Culvert joints may be required to accommodate total and differential settlement (if applicable)

Prepared By: MCK
 Checked By: CN
 Review ed By: JMAC



FOUNDATION REPORT - REPLACEMENT OF TWIN LAKE CULVERTS, SITE NO. 38C-047 - HIGHWAY 519

Table 3: Factored Ultimate and Serviceability Geotechnical Resistances for Culvert Replacement Options

Culvert ID Culvert Location (Township)	Proposed Invert Elevation (North End / South End)	Culvert Type	Proposed Culvert Dimensions	Approximate Founding Elevation (North End / South End)	Founding Condition ¹	Factored Ultimate Geotechnical Resistance at ULS ² (Embankment Crest / Embankment Toe)	Factored Serviceability Geotechnical Resistance at SLS for 25 mm of Settlement ² (Embankment Crest / Embankment Toe)
C60 STA 20+800 (Dumas)	West Culvert: 330.6 m / 330.4 m East Culvert: 330.5 m / 330.3 m	Elliptical Corrugated Steel Pipe (CSP)	3690 mm wide x 2380 mm high; 20.8 m long	West Culvert: 330.3 m / 330.1 m East Culvert: 330.2 m / 330.0 m	Compacted Granular Fill over Loose to Compact Silty Sand to Sandy Silt to Silt	350 kPa / 300 kPa	200 kPa / 150 kPa
		Concrete Pipe Culvert	3690 mm diameter; 20.8 m long	West Culvert: 330.3 m / 330.1 m East Culvert: 330.2 m / 330.0 m	Compacted Granular Fill over Loose to Compact Silty Sand to Sandy Silt to Silt	350 kPa / 300 kPa	200 kPa / 150 kPa
		Pre-Cast Box	3690 mm wide x 2380 mm high; 20.8 m long	West Culvert: 330.3 m / 330.1 m East Culvert: 330.2 m / 330.0 m	Compacted Granular Fill over Loose to Compact Silty Sand to Sandy Silt to Silt	350 kPa / 300 kPa	200 kPa / 150 kPa
		Cast-In-Place Open Footing	3690 mm span x 2380 mm high on 0.6 m wide footings; 20.8 m long	West Culvert: 328.2 m / 328.0 m East Culvert: 328.1 m / 327.9 m	Loose to Compact Silty Sand to Sandy Silt to Silt or bedrock	400 kPa / 300 kPa	N/A / N/A ³
			3690 mm span x 2380 mm high on 1.2 m wide footings; 20.8 m long			500 kPa / 400 kPa	250 kPa / 250 kPa

- Notes: 1. A minimum 0.3 m thick compact granular pad is required over the bedrock to reduce loading stress concentrations on the pipe culverts, pre-cast box culverts and cast-in-place footings.
2. The factored ultimate geotechnical resistance at ULS and factored serviceability geotechnical resistance at SLS for 25 mm of settlement are estimated based on the assumed culvert dimensions. The geotechnical resistances should be reviewed if the founding elevation and/or the footing/base width differ from those given above.
3. The factored serviceability geotechnical resistance at SLS for 25 mm of settlement will be greater than the factored ultimate geotechnical resistance at ULS and as a result, the SLS condition does not apply; the estimated settlement for the factored ULS resistance is less than 25 mm.

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Checked By: CN
Review ed By: JMCA



FOUNDATION REPORT - REPLACEMENT OF TWIN LAKE CULVERTS, SITE NO. 38C-047 - HIGHWAY 519

Table 4: Resistance to Lateral Loads/Sliding Resistance for Culvert Replacement Options

Culvert Type	Interface Material	Coefficient of Friction (tan δ)
Elliptical Corrugated Steel Pipe Culvert (CSP)	Compacted Granular Fill (Bedding)	0.35
Concrete Pipe Culvert	Compacted Granular Fill (Bedding)	0.40
Pre Cast Box Culvert	Compacted Granular Fill (Bedding)	0.40
Cast-In-Place Open Footing Culvert	Compact Granular Fill (Bedding)	0.55
	Loose to Compact Silty Sand to Sandy Silt to Silt	0.45

Prepared By: MCK
Checked By: CN
Review ed By: JMAC



FOUNDATION REPORT - REPLACEMENT OF TWIN LAKE CULVERTS, SITE NO. 38C-047 - HIGHWAY 519

Table 5: Summary of Foundation Engineering Parameters

Culvert Designation	Culvert Location (Township)	Stratigraphic Unit	Top Elevation (m)	Thickness (m)	γ' (kN/m ³)	ϕ' (°)	c' (kPa)	S_u (kPa)	σ_p' (kPa)	e_o	C_c	C_r	m_v (kPa ⁻¹)	E' (MPa)	c_v (cm ² /s)	Coefficient of Earth Pressure		
																Active, K_a	At Rest, K_o	Passive, K_p
C60	Highway 519 STA 20+800 (Dumas)	New Granular Embankment Fill	-	-	21	34	-	-	-	-	-	-	-	150	-	0.28	0.44	3.54
		Rock Fill ¹	-	-	20	40	-	-	-	-	-	-	-	150	-	0.21	0.36	4.60
		Sand to Sand and Gravel Fill	334.1 – 329.6	0.6 – 3.8	20	34	-	-	-	-	-	-	-	50 - 100	-	0.29	0.46	3.39
		Silty Sand to Sand	331.0 – 330.1	0.9 – 1.8	20	31	-	-	-	-	-	-	-	10 – 15	-	0.32	0.48	3.1
		Silt to Sandy Silt to Silt and Sand to Silty Sand	329.8 – 328.3	0.7 – 9.3	19	30	-	-	-	-	-	-	-	5-15	-	0.33	0.50	3.00
		Sand and Gravel	327.7 – 327.1	0.7 – 0.8	21	34	-	-	-	-	-	-	-	80	-	0.28	0.44	3.54

Notes: 1. Parameters are provided for the construction of the detour embankment and if rock fill is used for final construction.

Prepared By: MCK
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FOUNDATION REPORT - REPLACEMENT OF TWIN LAKE CULVERTS, SITE NO. 38C-047 - HIGHWAY 519

Table 6: Summary of Stability Analysis

Culvert ID Culvert Location (Township)	Stability Analysis				
	Condition	Embankment	Slope Profile	Embankment Height at Culvert Location	Minimum Factor of Safety ³
C60 STA 20+800 (Dumas)	Detour Embankment ¹ (Temporary Conditions)	North Slope	1.25H:1V	3 m	≥ 1.3
		South Slope ²	1.25H:1V	3 m	≥ 1.3
	Final Embankment (Permanent Conditions)	North Slope	2H:1V	3 m	≥ 1.5
		South Slope	2H:1V	3 m	≥ 1.5

- Note:
1. Where embankment widening is required, benching of the existing embankment side slope should be carried out in accordance with OPSD 208.010 (Benching of Earth Slopes)
 2. The global stability of the embankment associated with the temporary RSS Wall, between STA 20+774 to STA 20+825, is the responsibility of the contractor.
 3. The minimum FoS is based on a deep-seated, global trial failure surface that would impact the operation of the highway.

Prepared By: MCK
Checked By: CN
Reviewed By: JMAC



FOUNDATION REPORT - REPLACEMENT OF TWIN LAKE CULVERTS, SITE NO. 38C-047 - HIGHWAY 519

Table 7: Summary of Settlement Analysis

Culvert ID Culvert Location (Township)	Construction Stage	Estimated Factored Immediate Settlement of Foundation Soils ^{1, 2}	Estimated Factored Consolidation Settlement of Foundation Soils ²	Estimated Factored Settlement of Embankment Rock Fill	Estimated Total Factored Settlement
C60 STA 20+800 (Dumas)	Stage 1 Detour Embankment: Embankment Construction to the North of the Existing Highway 519	55 mm	0 mm	10 mm	65 mm
	Stage 2 Detour Embankment: Temporary RSS Wall Construction on the South Side of the Existing Highway 519 Embankment	Less than 25 mm	0 mm	N/A ³	Less than 25 mm
	Final Embankment	Less than 25 mm	0 mm	N/A ³	Less than 25 mm

Notes: 1. All organic material to be removed prior to construction
2. All settlement is anticipated to be immediate and occur during construction.
3. Rock fill is not required for Stage 2 or final embankment construction.

Prepared By: MCK
Checked By: CN
Review ed By: JMAC



FIGURES



South side of Highway 519 at about STA 20+800, Twin Lakes Culvert, looking North. July 12, 2016.

PROJECT

**Detail Design for Replacement of Twin Lakes Culverts
Highway 519
G.W.P. 327-99-00, W.P. 5296-06-01**

TITLE

**Site Photographs
Twin Lakes Culvert C60 STA 20+800—Highway 519**



PROJECT No. 1521770			FILE No. — —		
DESIGN	MCK	SEPT 16	SCALE	NTS	REV.
CADD	— —		FIGURE 1A		
CHECK	CN	SEPT 16			
REVIEW	JMAC	SEPT 16			



North side of Highway 519 at about STA 20+800, Twin Lakes Culvert, looking South. July 12, 2016.

PROJECT

**Detail Design for Replacement of Twin Lakes Culverts
Highway 519
G.W.P. 327-99-00, W.P. 5296-06-01**

TITLE

**Site Photographs
Twin Lakes Culvert C60 STA 20+800—Highway 519**



PROJECT No. 1521770

FILE No. — —

DESIGN MCK SEPT 16

SCALE NTS REV.

CADD — —

CHECK CN SEPT 16

REVIEW JMAC SEPT 16

FIGURE 1B



DRAWINGS

METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

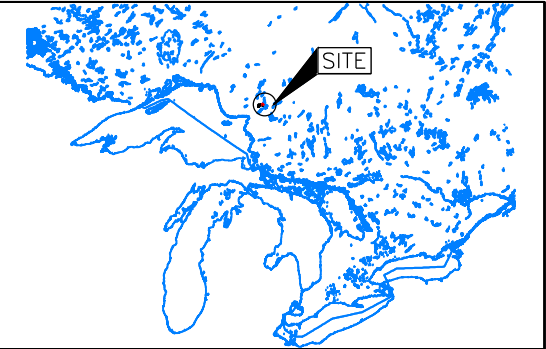
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WP No. 5296-06-01


HIGHWAY 519
TWIN LAKE CULVERTS STA. 20+800

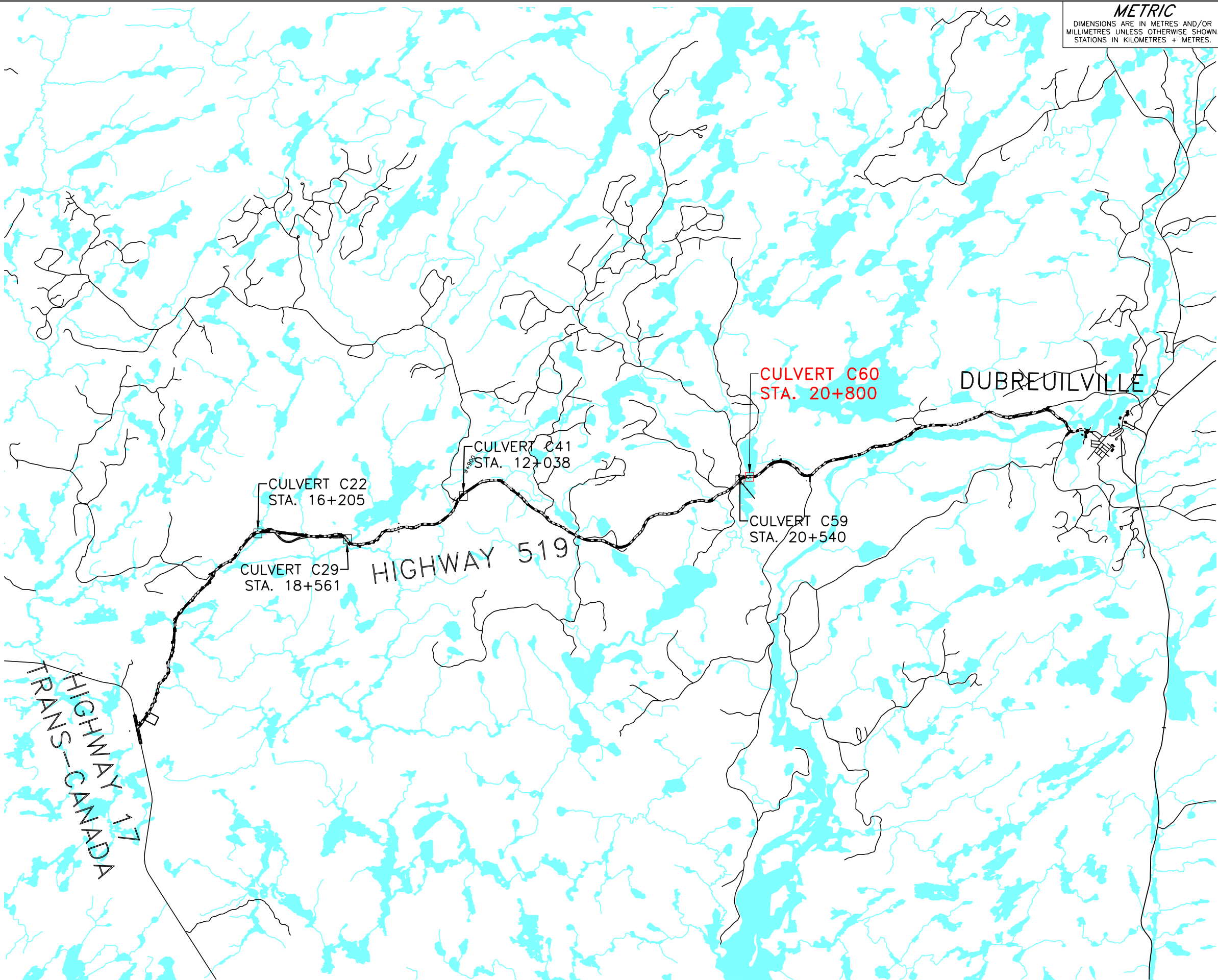
INDEX PLAN


SHEET




KEY PLAN
SCALE
200 0 200 400 km

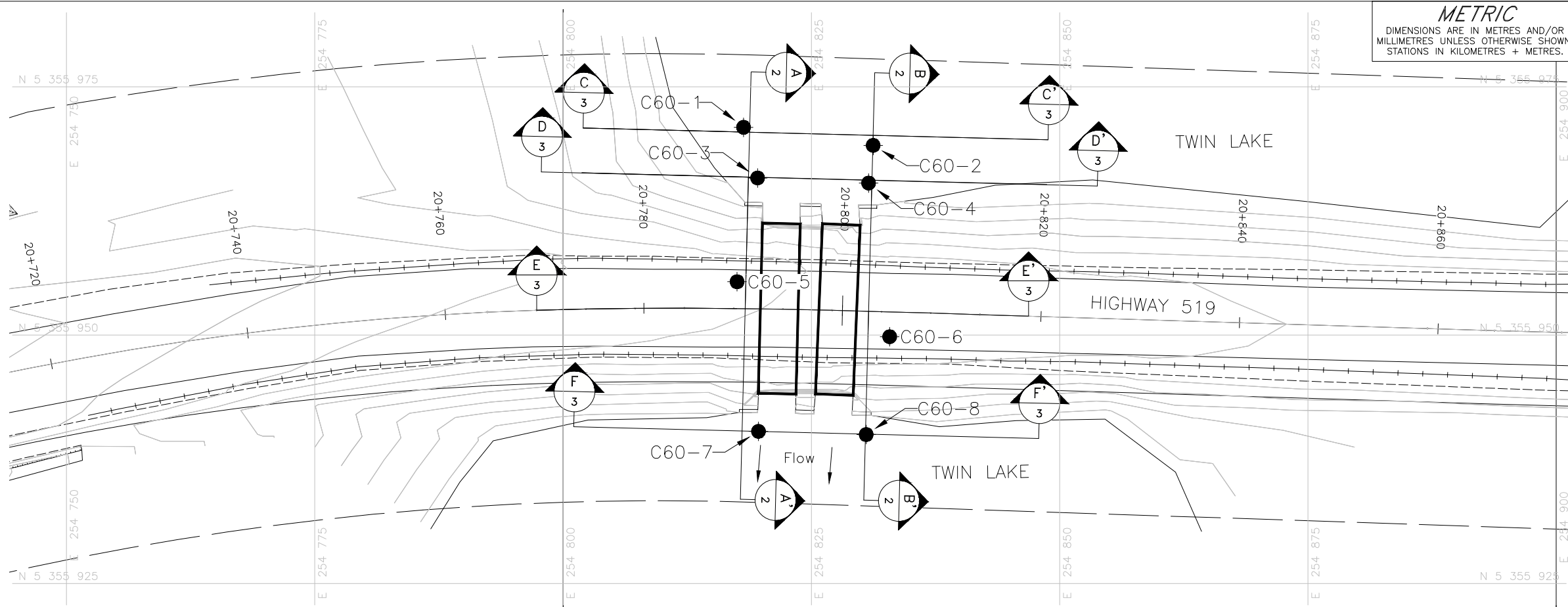




PLAN
SCALE
1 0 1 2 km

REFERENCE
Base plans and sections provided in digital format by D.M.Wills Associates, drawing file nos. 4539- HWY 519- BP (New Survey).dwg and Foundations X-Sec sent to Chris Ng July 8.dwg, received March 11, 2016.
Base data - CANVEC, obtained 2016.

NO.	DATE	BY	REVISION
Geocres No. 42C-38			
HWY. 519		PROJECT NO. 1521770	DIST.
SUBM'D. MCK	CHKD. MCK	DATE: 9/29/2016	SITE: 38C-047
DRAWN: MR	CHKD. CN	APPD. JMAC	DWG. 1

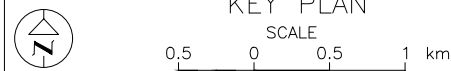
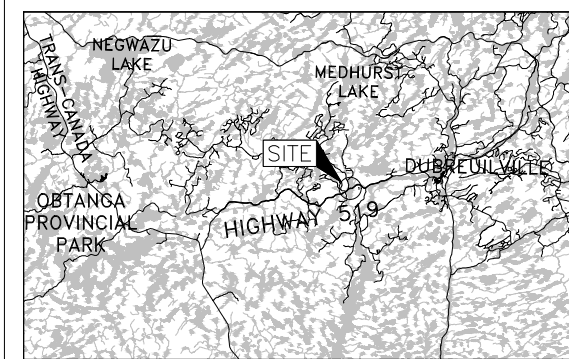


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DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No. WP No. 5296-06-01

HIGHWAY 519
TWIN LAKE CULVERTS STA. 20+800
BOREHOLE LOCATIONS AND
SOIL STRATA

SHEET



LEGEND

- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- WL upon completion of drilling
- R Refusal to Further Penetration

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
C60-1	331.0	5355970.9	254818.2
C60-2	331.0	5355969.1	254831.2
C60-3	331.0	5355965.8	254819.6
C60-4	331.0	5355965.3	254830.8
C60-5	334.1	5355955.4	254817.5
C60-6	333.8	5355949.8	254832.9
C60-7	330.5	5355940.3	254819.7
C60-8	330.5	5355940.0	254830.5

NOTES

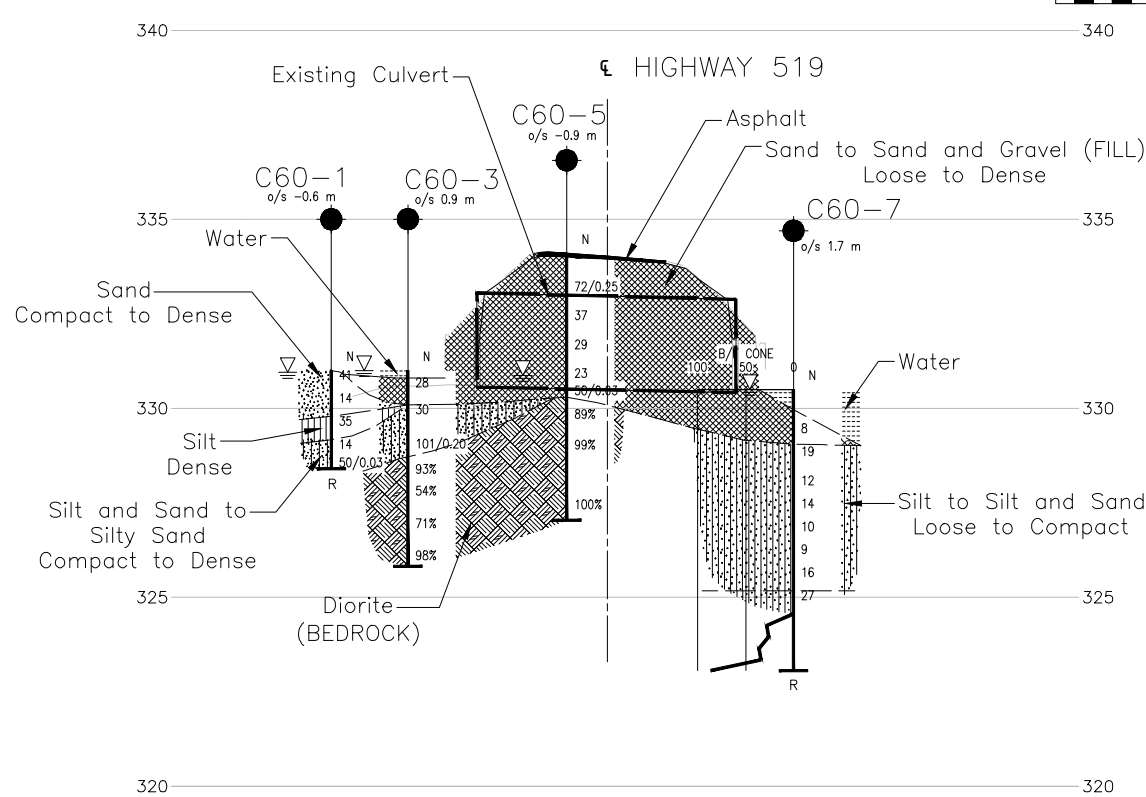
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

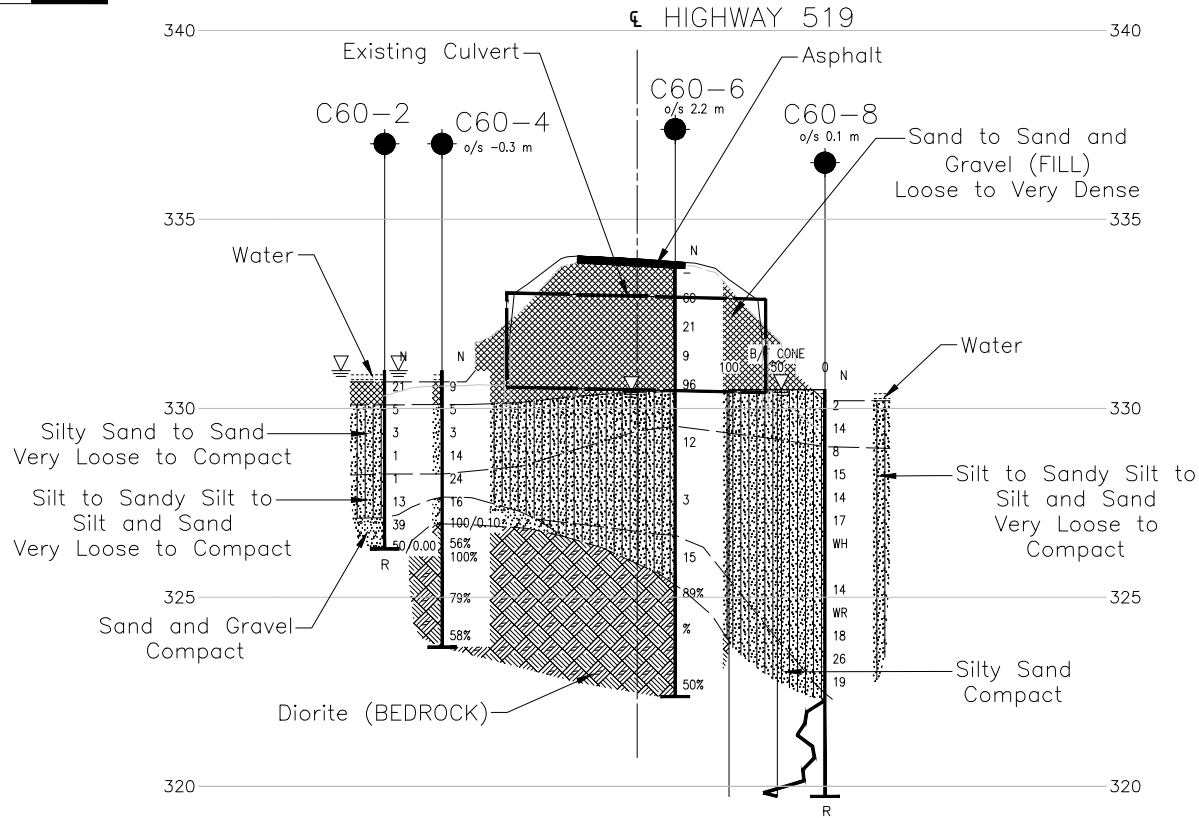
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans and sections provided in digital format by D.M.Wills Associates, drawing file nos. 4539- HWY 519- BP (New Survey).dwg and Foundations X-Sec sent to Chris Ng July 8.dwg, received March 11, 2016.



PROFILE A-A'



PROFILE B-B'



NO.	DATE	BY	REVISION
1			
Geocres No. 42C-38			
HWY. 519	PROJECT NO. 1521770		DIST. .
SUBM'D. MCK	CHKD. ARV	DATE: 8/31/2016	SITE: 38C-047
DRAWN: MR	CHKD. ARV	APPD. JMAC	DWG. 2

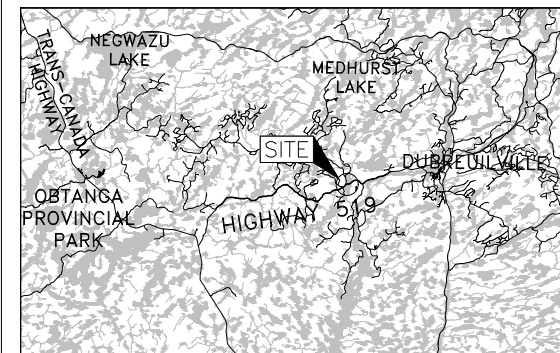
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5296-06-01

HIGHWAY 519
TWIN LAKE CULVERTS STA. 20+800

SOIL STRATA

SHEET



KEY PLAN



SCALE
2.5 0 2.5 5 km

LEGEND

- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- WL upon completion of drilling
- R Refusal to Further Penetration

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
C60-1	331.0	5355970.9	254818.2
C60-2	331.0	5355969.1	254831.2
C60-3	331.0	5355965.8	254819.6
C60-4	331.0	5355965.3	254830.8
C60-5	334.1	5355955.4	254817.5
C60-6	333.8	5355949.8	254832.9
C60-7	330.5	5355940.3	254819.7
C60-8	330.5	5355940.0	254830.5

NOTES

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

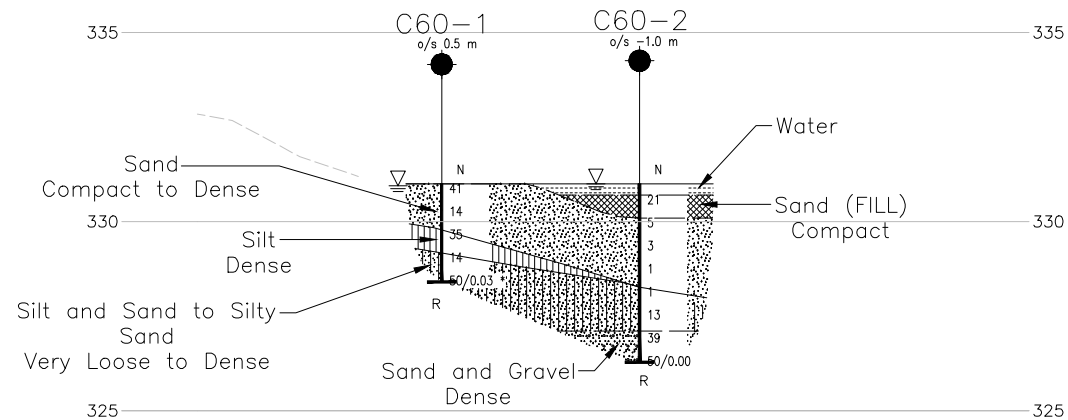
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

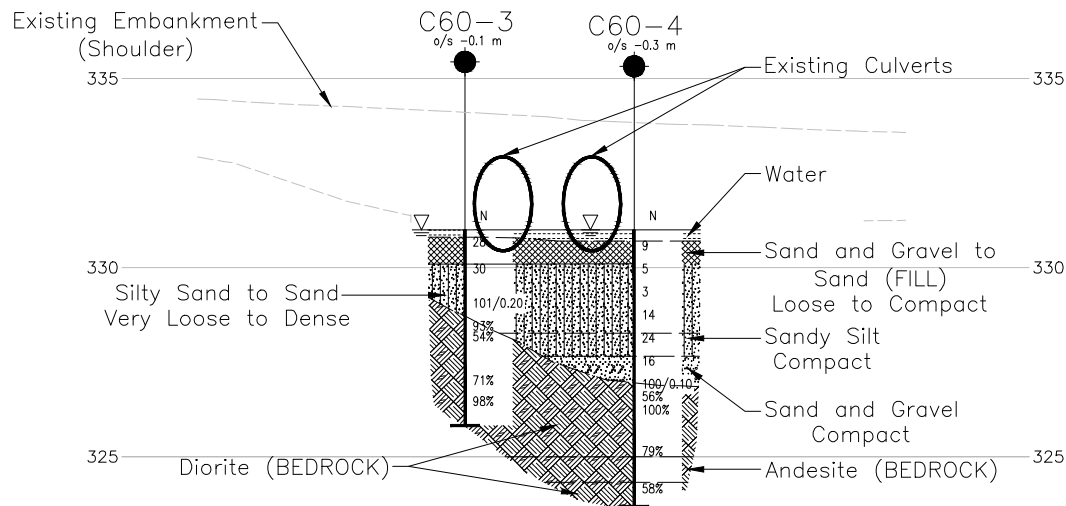
REFERENCE

Base plans and sections provided in digital format by D.M.Wills Associates, drawing file nos. 4539- HWY 519- BP (New Survey).dwg and Foundations X-Sec sent to Chris Ng July 8.dwg, received March 11, 2016.

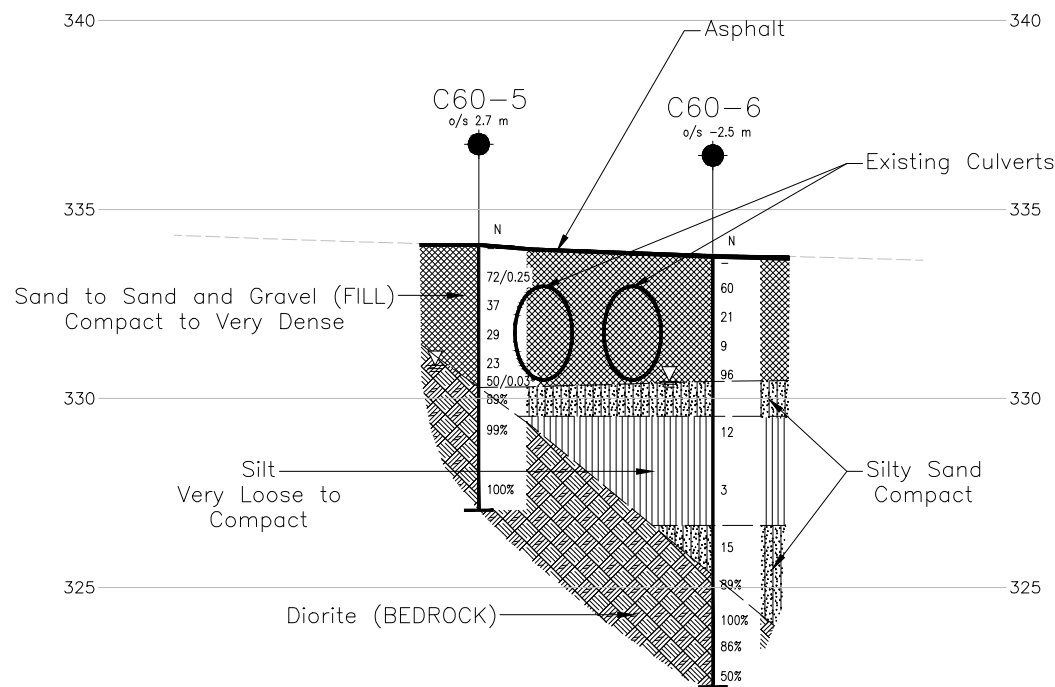
NO.	DATE	BY	REVISION
Geocres No. 42C-38			
HWY. 519	PROJECT NO. 1521770		DIST. .
SUBM'D. MCK	CHKD. ARV	DATE: 8/31/2016	SITE: 38C-047
DRAWN: MR	CHKD. ARV	APPD. JMAC	DWG. 3



PROFILE
C-C'
2 TOE OF DETOUR EMBANKMENT

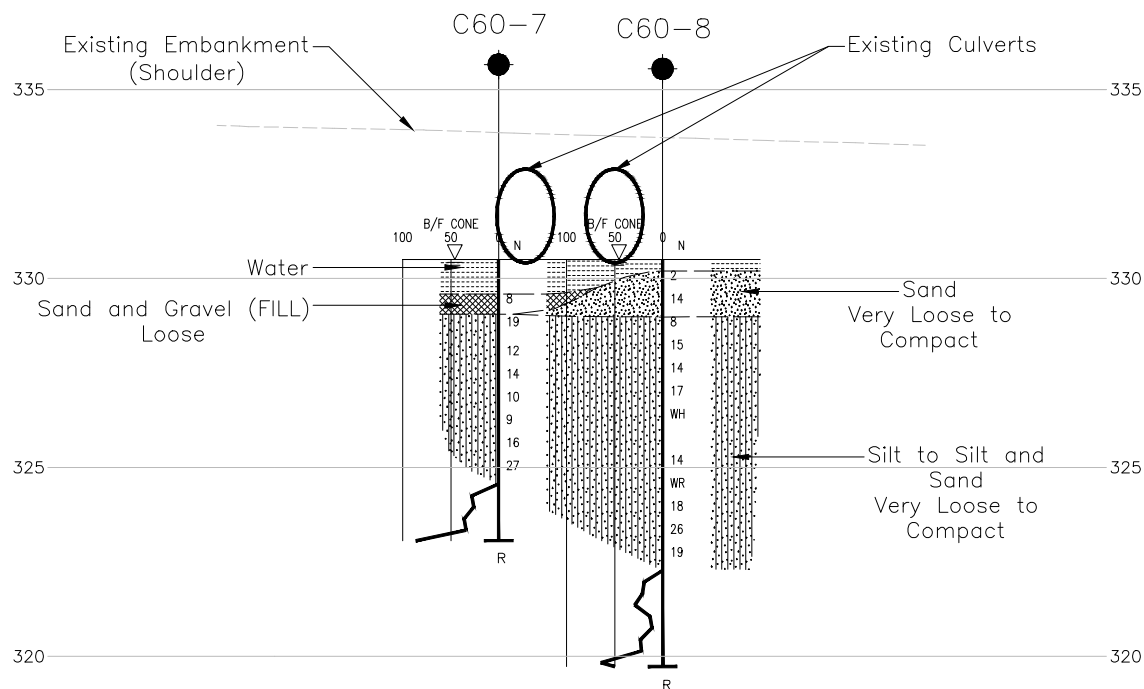


CROSS-SECTION D-D'
2 EXISTING NORTH END OF CULVERT



CROSS-SECTION E-E'
2 HIGHWAY 519 CENTERLINE PROFILE

HORIZONTAL SCALE
5 0 5 10 m



CROSS-SECTION F-F'
2 EXISTING SOUTH END OF CULVERT

VERTICAL SCALE
2 0 2 4 m





APPENDIX A

Record of Borehole and Drillhole Sheets



LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_{α}	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1
2

$\tau = c' + \sigma' \tan \phi'$
shear strength = (compressive strength)/2



LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N_s :

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	c_u, s_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERING STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

<u>Description</u>	<u>Bedding Plane Spacing</u>
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

<u>Description</u>	<u>Spacing</u>
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

<u>Term</u>	<u>Size*</u>
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes, or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.





Abbreviations

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

PROJECT <u>1521770</u>	RECORD OF BOREHOLE No C60-1	SHEET 1 OF 1	METRIC
W.P. <u>5296-06-01</u>	LOCATION <u>N 5355970.9; E 254818.2</u>	ORIGINATED BY <u>MCK</u>	
DIST <u> </u> HWY <u>519</u>	BOREHOLE TYPE <u>Portable Equipment, BW Casing, Manual Hammer</u>	COMPILED BY <u>MR</u>	
DATUM <u>Geodetic</u>	DATE <u>July 7, 2016</u>	CHECKED BY <u>ARV</u>	

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			
331.0	GROUND SURFACE																	
0.0	SAND, some gravel, trace organics, containing clayey silt lenses Compact to dense Brown to grey Wet		1	SS	41													
329.8			2	SS	14													
1.2	SILT, some sand Dense Grey Wet		3	SS	35													
329.2																		
1.8	SILT and SAND, trace to some gravel Compact Grey Moist		4	SS	14													
328.4			5	SS	50/0.03*													
2.6	END OF BOREHOLE SPLIT-SPOON SAMPLER REFUSAL NOTE: 1. Water level in open borehole at a depth of 0.1 m below ground surface (Elev. 330.9 m) upon completion of drilling. * Split-Spoon Bouncing																	

PROJECT <u>1521770</u>		RECORD OF BOREHOLE No C60-2		SHEET 1 OF 1		METRIC	
W.P. <u>5296-06-01</u>		LOCATION <u>N 5355969.1 ; E 254831.2</u>		ORIGINATED BY <u>MCK</u>			
DIST <u> </u> HWY <u>519</u>		BOREHOLE TYPE <u>Portable Equipment, BW Casing, Manual Hammer</u>		COMPILED BY <u>MR</u>			
DATUM <u>Geodetic</u>		DATE <u>July 9, 2016</u>		CHECKED BY <u>ARV</u>			

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 × REMOULDED			W _p W W _L				
331.0	WATER SURFACE																
330.7	WATER																
0.3	Sand, some gravel (FILL) Compact Grey Wet		1	SS	21												
330.1	SAND, some silt, trace gravel, trace organics Very loose to loose Brown Wet		2	SS	5												
0.9			3	SS	3												
			4	SS	1												
328.3	SILT and SAND, trace clay, trace organics Very loose to compact Brown Wet		5	SS	1												
2.7			6A	SS	13												
327.1			6B														
3.9	SAND and GRAVEL, trace silt Dense Grey Wet		7	SS	39												
326.3			8	SS	50/0.00												
4.7	END OF BOREHOLE SPLIT-SPOON SAMPLER REFUSAL * Split-Spoon Bouncing																

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PROJECT 1521770		RECORD OF BOREHOLE No C60-3		SHEET 1 OF 1		METRIC											
W.P. 5296-06-01		LOCATION N 5355965.8 ; E 254819.6		ORIGINATED BY MCK													
DIST _____ HWY 519		BOREHOLE TYPE Portable Equipment, BW Casing, Manual Hammer, NQ Rock Coring		COMPILED BY MR													
DATUM Geodetic		DATE July 5 and 6, 2016		CHECKED BY ACK/MCK													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ	GR SA SI CL
								20 40 60 80 100	20 40 60 80 100	20 40 60	W _p	W	W _L				
331.0	WATER SURFACE																
0.0	WATER																
0.2	Sand and gravel, some rock fill gravel sizes (FILL) Compact Brown		1	SS	28												
330.1	Wet Silty SAND, trace to some gravel, trace clay Compact to dense Grey Moist		2	SS	30		330										14 62 21 3
0.9																	
328.7			3	SS	01/0.20		329										
2.3	DIORITE (BEDROCK)		1	RC	REC 100%												RQD = 93%
	Bedrock cored from depths of 2.3 m to 5.2 m. For bedrock coring details refer to Record of Drillhole C60-3.		2	RC	REC 100%		328										RQD = 54%
			3	RC	REC 100%		327										RQD = 71%
			4	RC	REC 98%		326										RQD = 98%
325.8	END OF BOREHOLE																
5.2																	

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PROJECT 1521770		RECORD OF BOREHOLE No C60-4		SHEET 1 OF 1		METRIC											
W.P. 5296-06-01		LOCATION N 5355965.3 ; E 254830.8		ORIGINATED BY MCK													
DIST _____ HWY 519		BOREHOLE TYPE Portable Equipment, BW Casing, Manual Hammer, NQ Rock Coring		COMPILED BY MR													
DATUM Geodetic		DATE July 9 and 10, 2016		CHECKED BY ACK/MCK													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ kN/m³	GR SA SI CL
								20 40 60 80 100	20 40 60 80 100	20 40 60	W _p W W _L						
331.0	WATER SURFACE																
330.7	WATER																
0.3	Sand, some rock fill gravel sizes (FILL)		1	SS	9												
330.1	Loose Grey Wet		2	SS	5												
0.9	SAND, some silt, trace organics		3	SS	3												
	Very loose to compact		4	SS	14												
	Brown Moist to wet																
328.3																	
2.7	Sandy SILT, trace to some clay		5	SS	24												
327.6	Compact Grey Wet		6	SS	16												
3.4	SAND and GRAVEL, trace to some silt		7	SS	100/100												
326.9	Compact Grey Wet		1	RC	REC 92%												
4.1	DIORITE / ANDESITE (BEDROCK)		2	RC	REC 100%												
	Bedrock cored from depths of 4.1 m to 7.3 m.		3	RC	REC 100%												
	For bedrock coring details refer to Record of Drillhole C60-4.		4	RC	REC 88%												
323.7																	
7.3	END OF BOREHOLE																

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PROJECT: 1521770

RECORD OF DRILLHOLE: C60-4

SHEET 1 OF 1

LOCATION: N 5355965.3 ;E 254830.8

DRILLING DATE: July 10, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: Hilti Portable Equipment

DRILLING CONTRACTOR: OGS Drilling Inc.

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	FLUSH	RECOVERY			FRACT. INDEX PER 0.25	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY K, cm/sec			Diametral Point Load Index (MPa)	RMC -Q AVG	NOTES	
									TOTAL CORE %	SOLID CORE %	R.Q.D. %		B Angle	DIP w.r.t CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn					
5	BW Casing	Continued from Record of Borehole C60-4		326.94																			
		Fresh, crystalline, white and black, medium grained, non-porous, medium strong to very strong DIORITE		4.06	1																		
						2																	
6	NQ RC																						
7	Double Tube Sampling																						
7		Fresh, crystalline, white and black, medium grained, non-porous, very strong ANDESITE		324.50																			
				6.50	4																		
7		Fresh, crystalline, white and black, medium grained, non-porous, strong DIORITE		323.79																			
				7.21																			
8		END OF DRILLHOLE		7.31																			
8																							
9																							
10																							
11																							
12																							
13																							
14																							

DEPTH SCALE

1 : 50



LOGGED: MCK

CHECKED: ACK/ARV

PROJECT 1521770		RECORD OF BOREHOLE No C60-5		SHEET 1 OF 1		METRIC															
W.P. 5296-06-01		LOCATION N 5355955.4 ; E 254817.5		ORIGINATED BY LK																	
DIST HWY 519		BOREHOLE TYPE 150 mm Cont. Flight Solid Stem Augers, NW Casing and NQ Coring		COMPILED BY MR																	
DATUM Geodetic		DATE July 5, 2016		CHECKED BY ACK/MCK																	
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
334.1	PAVEMENT SURFACE							20 40 60 80 100	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60	20 40 60
0.0	ASPHALT (75 mm)		1	AS	-		334														
333.4	Sand and gravel (FILL) Brown Moist		2	SS	72/0.25		333														29 60 10 1
0.7	Sand, some gravel to gravelly, trace to some silt, trace clay, some rock fill gravel sizes (FILL) Compact to very dense Brown Moist		3	SS	37		332														
			4	SS	29		331														15 77 (8)
			5	SS	23		330														
330.3	DIORITE (BEDROCK)		6	SS	60/0.03		329														
3.8	Bedrock cored from depths of 3.8 m to 7.1 m. For bedrock coring details refer to Record of Drillhole C60-5.		1	NQ RC	REC 94%		328														RQD = 89%
			2	NQ RC	REC 100%																RQD = 99%
			3	NQ RC	REC 100%																RQD = 100%
327.0	END OF BOREHOLE																				
7.1	NOTE: 1. Water level in open borehole at a depth of 3.2 m below ground surface (Elev. 330.9 m) upon completion of drilling. * Split-Spoon Bouncing																				

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PROJECT 1521770		RECORD OF BOREHOLE No C60-6		SHEET 1 OF 1		METRIC															
W.P. 5296-06-01		LOCATION N 5355949.8 ; E 254832.9		ORIGINATED BY LK																	
DIST _____ HWY 519		BOREHOLE TYPE 150 mm Continuous Flight Solid Stem Augers, NQ Rock Coring		COMPILED BY MR																	
DATUM Geodetic		DATE July 5 and 6, 2016		CHECKED BY ACK/MCK																	
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ kN/m ³	GR SA SI CL				
							20 40 60 80 100	20 40 60 80 100	20 40 60	20 40 60	20 40 60										
333.8 0.0	PAVEMENT SURFACE ASPHALT (75 mm) Sand and gravel, trace to some silt, trace clay (FILL) Loose to very dense Brown Moist		1	AS	-		333														
			2	SS	60																
			3	SS	21		332														
			4	SS	9																
330.4 3.4	Silty SAND, trace gravel, trace organics Black Moist		5A	SS	96		331														
			5B				330														
329.5 4.3	SILT, trace to some clay, trace sand Very loose to compact Grey Wet		6	SS	12		329														
							328														
			7	SS	3		327														
326.6 7.2	Silty SAND, some gravel Compact Grey Wet		8	SS	15		326														
325.3 8.5	DIORITE (BEDROCK) Bedrock cored from depths of 8.5 m to 11.4 m. For bedrock coring details refer to Record of Drillhole C60-6.		1	RC	REC 100%		325														
			2	RC	REC 100%		324														
322.4 11.4	END OF BOREHOLE NOTE: 1. Water level in open borehole at a depth of 3.4 m below ground surface (Elev. 330.4 m) upon completion of drilling.		3	RC	REC 81%		323														

PROJECT: 1521770

RECORD OF DRILLHOLE: C60-6

SHEET 1 OF 1

LOCATION: N 5355949.8 ;E 254832.9

DRILLING DATE: July 6, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55

DRILLING CONTRACTOR: Landcore Drilling Inc.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SH - Shear VN - Vein CJ - Conjugate										BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage										PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular										PO - Polished K - Slickensided SM - Smooth RO - Rough VR - Very Rough										MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.										NOTES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
							FLUSH	RECOVERY		R.Q.D. %	FRACT. INDEX PER 0.25	DISCONTINUITY DATA										HYDRAULIC CONDUCTIVITY K, cm/sec		Diametral Point Load Index (MPa)	RMC -Q AVG																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
								TOTAL CORE %	SOLID CORE %			B Angle	DIP w.r.t CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	K ₁	K ₂																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
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2.2 MPa (Axial)
5.6 MPa- Vertical joint from
11.28 m to 11.40 m

DEPTH SCALE

1 : 50

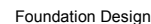


LOGGED: LK

CHECKED: ACK/ARV

PROJECT		1521770		RECORD OF BOREHOLE No C60-7		SHEET 1 OF 1		METRIC							
W.P.		5296-06-01		LOCATION		N 5355940.3 ; E 254819.7		ORIGINATED BY							
DIST		HWY 519		BOREHOLE TYPE		Portable Equipment, BW Casing, Manual Hammer		COMPILED BY							
DATUM		Geodetic		DATE		July 11 and 12, 2016		CHECKED BY							
								ACK/MCK							
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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
330.5	WATER SURFACE														
0.0	WATER														
329.6															
0.9	Sand and gravel (FILL)		1A	SS	8										
329.0	Loose Brown Wet		1B												
1.5	SILT, some clay, trace to some sand Loose to compact Grey Wet		2	SS	19										
			3	SS	12										
			4	SS	14										
			5	SS	10										
			6	SS	9										
			7	SS	16										
325.2															
5.3	SILT and SAND, trace gravel Compact Grey Wet		8	SS	27										
324.6															
5.9	END OF BOREHOLE Dynamic Cone Penetration Test (DCPT)														
323.1															
7.4	END OF DCPT REFUSAL TO FURTHER PENETRATION (86 Blows / 0.28 m) (HAMMER BOUNCING)														

GTA-MTO 001 S:\CLIENTS\MTOWHY_51902_DATA\GINT\HWY_519.GPJ GAL-GTA.GDT 11/22/16



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

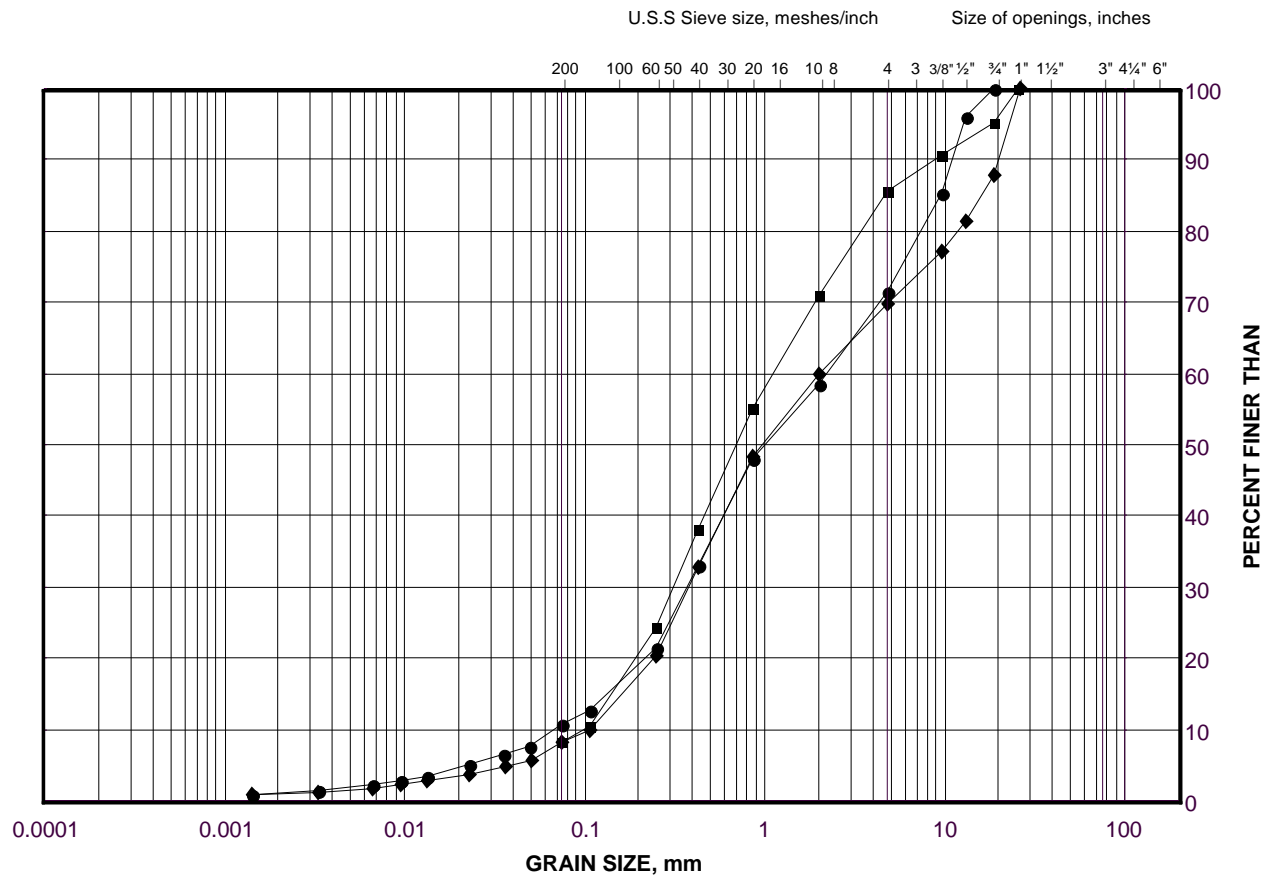


APPENDIX B

Laboratory Results

Sand to Sand and Gravel (Fill)

FIGURE B1



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C60-5	2	333.2
■	C60-5	4	331.6
◆	C60-6	4	331.1

Project Number: 1521770

Checked By: ARV

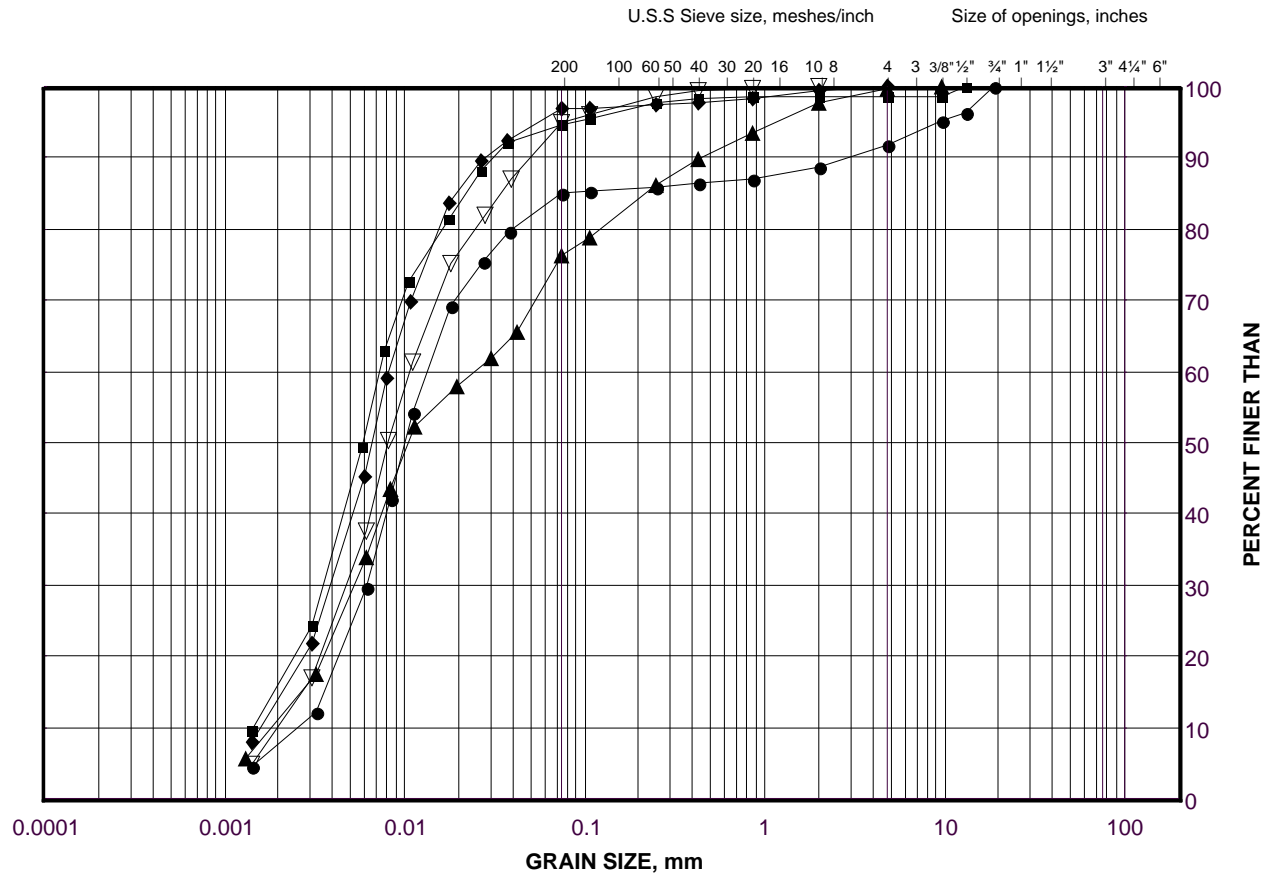
Golder Associates

Date: 13-Sep-16

GRAIN SIZE DISTRIBUTION

Silt to Sandy Silt

FIGURE B2-A



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C60-8	10	323.8
■	C60-8	4	328.1
◆	C60-7	4	327.3
▲	C60-4	5	328.0
▽	C60-6	6	328.9

Project Number: 1521770

Checked By: ARV

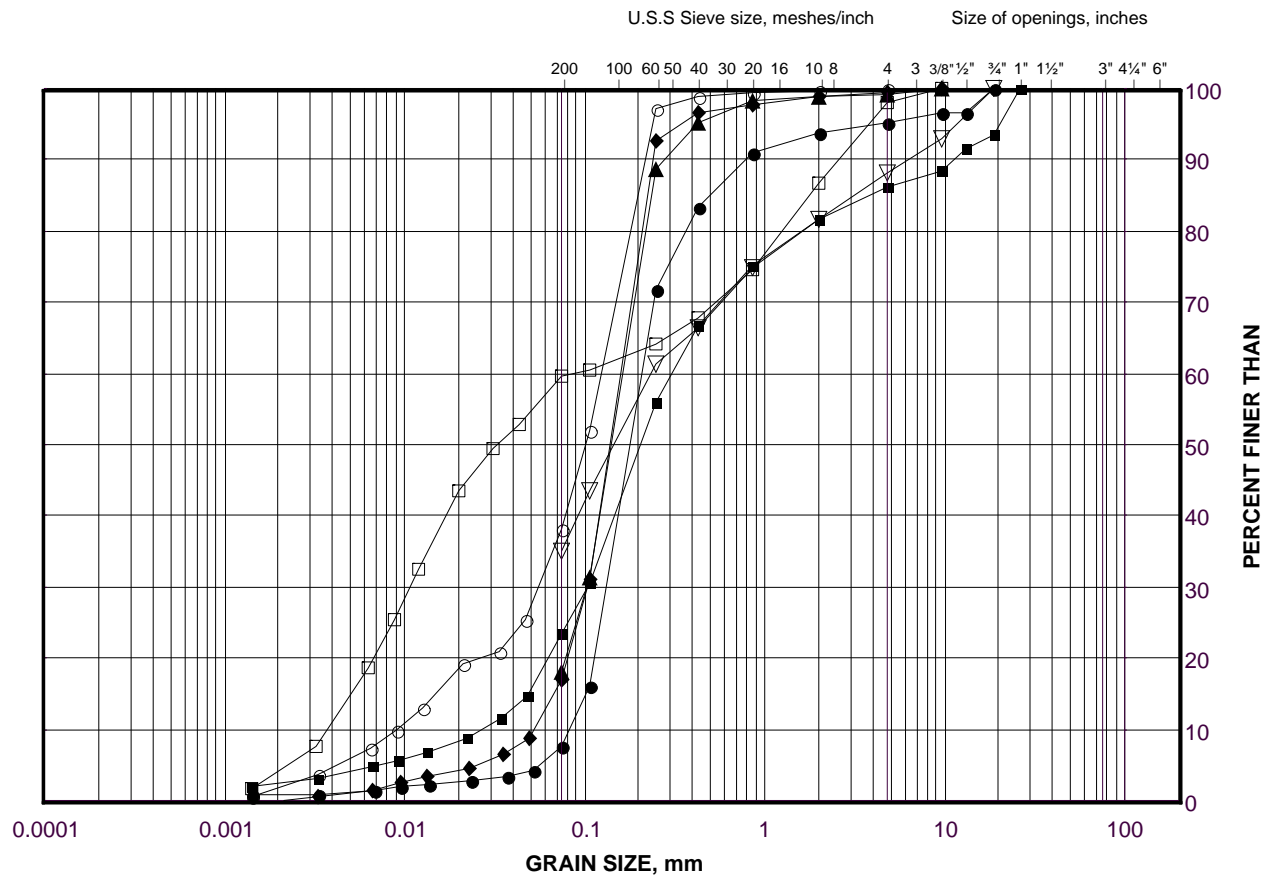
Golder Associates

Date: 29-Sep-16

GRAIN SIZE DISTRIBUTION

Silt and Sand to Sand

FIGURE B2-B



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

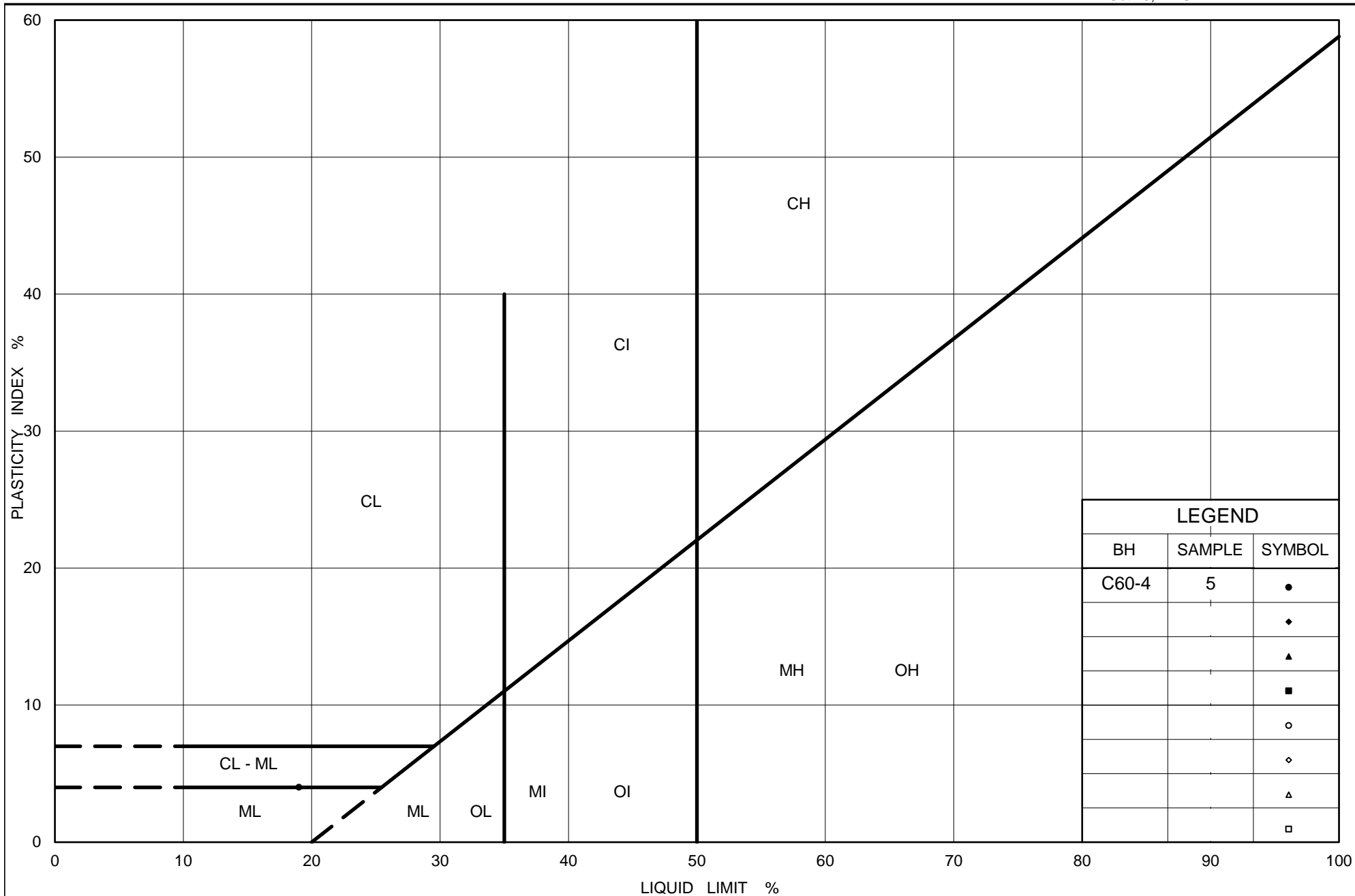
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C60-8	2	329.3
■	C60-3	2	329.8
◆	C60-4	3	329.2
▲	C60-2	4	328.6
▽	C60-1	5	328.5
○	C60-2	5	327.9
□	C60-7	8	324.9

Project Number: 1521770

Checked By: ARV

Golder Associates

Date: 29-Sep-16



Ministry of Transportation

Ontario

PLASTICITY CHART Sandy Silt

Figure No. B3

Project No. 1521770

Checked By: ARV

Borehole C60-3



Box 1: 2.28 m – 5.18 m

Borehole C60-4



Box 1: 4.06 m – 5.51 m

Borehole C60-4



Box 2: 5.51 m – 7.31 m

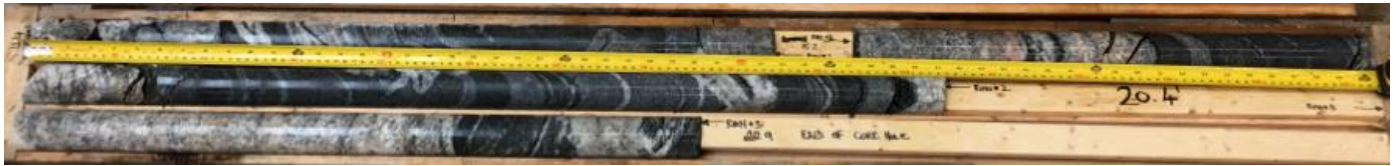
REVISION DATE: September 19, 2016 BY: MK Project: 1521770

0 m	0.25 m	0.5 m	0.75 m	1.0 m	1.25 m	1.5 m
0 ft	1 ft	2 ft	3 ft	4 ft	5 ft	

PROJECT Detail Design for Replacement of Twin Lakes Culverts Highway 519 G.W.P. 327-99-00, W.P. 5296-06-01					
TITLE Bedrock Core Photographs – Highway 519 Boreholes C60-3 and C60-4					
PROJECT N6521770			FILE No. ----		
DESIGN	MK	SEP 16	SCALE	NTS	REV.
CADD	--	--	FIGURE B4		
CHECK	CN	SEP 16			
REVIEW	JMAC	SEP 16			



Borehole C60-5



Box 1: 3.81 m – 7.06 m

Borehole C60-6



Box 1: 8.48 m – 11.43 m

REVISION DATE: September 19, 2016 BY: MK Project: 1521770

0 m	0.25 m	0.5 m	0.75 m	1.0 m	1.25 m	1.5 m
0 ft	1 ft	2 ft	3 ft	4 ft	5 ft	

PROJECT Detail Design for Replacement of Twin Lakes Culverts Highway 519 G.W.P. 327-99-00, W.P. 5296-06-01					
TITLE Bedrock Core Photographs – Highway 519 Boreholes C60-5 and C60-6					
PROJECT N6521770			FILE No. ----		
DESIGN	MK	SEP 16	SCALE	NTS	REV.
CADD	--		FIGURE B5		
CHECK	CN	SEP 16			
REVIEW	JMAC	SEP 16			



UNCONFINED COMPRESSION TEST (UC)**FIGURE B6****ASTM D7012****SAMPLE IDENTIFICATION**

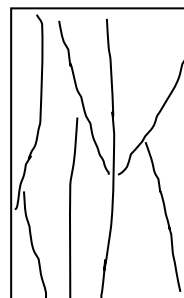
PROJECT NUMBER	1521770	SAMPLE NUMBER	Run 2
PROJECT NAME	DM Wills/5014-E-0035/Hwy 519	SAMPLE DEPTH, m	6.09-6.36
BOREHOLE NUMBER	C60-5	DATE:	2016-09-19

TEST CONDITIONS

MACHINE SPEED, mm/min	N/A	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.23

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	10.56	WATER CONTENT, (specimen) %	0.05
SAMPLE DIAMETER, cm	4.73	UNIT WEIGHT, kN/m ³	26.69
SAMPLE AREA, cm ²	17.58	DRY UNIT WT., kN/m ³	26.68
SAMPLE VOLUME, cm ³	185.69	SPECIFIC GRAVITY	-
WET WEIGHT, g	505.55	VOID RATIO	-
DRY WEIGHT, g	505.31		

VISUAL INSPECTION**FAILURE SKETCH****TEST RESULTS**

STRAIN AT FAILURE, %	N/A	COMPRESSIVE STRENGTH, MPa	64.5
----------------------	-----	---------------------------	------

Checked By: MCK

Golder Associates

TABLE B1
SUMMARY OF POINT LOAD TESTS ON ROCK SAMPLES

PROJECT NO. 1521770						
DATE September 2016						
Borehole Number	Run Number	Sample Depth (m)	Sample Elevation (m)	Bedrock Description	Test Type	Is (50mm) (MPa)
C60-5	2	6.2	327.9	Diorite	Axial	1.8
C60-5	2	6.2	327.9	Diorite	Diametral	4.0
C60-6	1	9.0	324.8	Diorite	Axial	2.2
C60-6	1	9.0	324.8	Diorite	Diametral	5.6

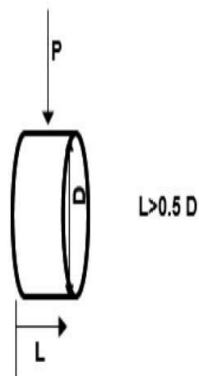
(1) $Is_{50} \times C$ (actual value will have to be confirmed by UCS testing), from ISRM ("Suggested Methods for Determining Point Load Strength", International Society for Rock Mechanics Commission on Testing Methods, Int. J. Rock. Mech. Min. Sci. and Geomechanical Abstr., Vol 22, No. 2 1985, pp. 51-60.

(2) Actual distance between point load cones at time of failure.

DIAMETRAL SPECIMEN SHAPE REQUIREMENTS

note: Diametral tests are perpendicular to core axis

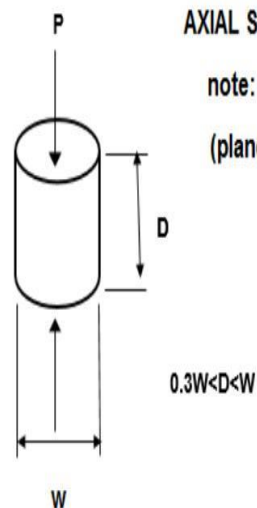
(planes of weakness)



AXIAL SPECIMEN SHAPE REQUIREMENTS

note: Axial tests are parallel to core axis

(planes of weakness)





APPENDIX C

Analytical Test Results

Your Project #: 1521770
Your C.O.C. #: 568328-01-01

Attention:Chris Ng

Golder Associates Ltd
Mississauga - Standing Offer
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Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2016/07/20
Report #: R4073825
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B6E9276

Received: 2016/07/18, 17:15

Sample Matrix: Water
Samples Received: 5

Analyses	Date		Date Analyzed	Laboratory Method	Reference
	Quantity	Extracted			
Chloride by Automated Colourimetry	5	N/A	2016/07/20	CAM SOP-00463	EPA 325.2 m
Conductivity	5	N/A	2016/07/19	CAM SOP-00414	SM 22 2510 m
pH	5	N/A	2016/07/19	CAM SOP-00413	SM 4500H+ B m
Resistivity of Water	5	2016/07/18	2016/07/20	CAM SOP-00414	SM 22 2510 m
Sulphate by Automated Colourimetry	5	N/A	2016/07/20	CAM SOP-00464	EPA 375.4 m

Remarks:

Maxxam Analytics has performed all analytical testing herein in accordance with ISO 17025 and the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act. All methodologies comply with this document and are validated for use in the laboratory. The methods and techniques employed in this analysis conform to the performance criteria (detection limits, accuracy and precision) as outlined in the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act.

Maxxam Analytics is accredited for all specific parameters as required by Ontario Regulation 153/04. Maxxam Analytics is limited in liability to the actual cost of analysis unless otherwise agreed in writing. There is no other warranty expressed or implied. Samples will be retained at Maxxam Analytics for three weeks from receipt of data or as per contract.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Ema Gitej, Senior Project Manager

Email: EGitej@maxxam.ca

Phone# (905)817-5829

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Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

RESULTS OF ANALYSES OF WATER

Maxxam ID		CSN276	CSN277		CSN278	CSN278		CSN279			
Sampling Date		2016/07/17 10:30	2016/07/17 10:20		2016/07/17 08:20	2016/07/17 08:20		2016/07/17 09:00			
COC Number		568328-01-01	568328-01-01		568328-01-01	568328-01-01		568328-01-01			
	UNITS	C22	C29	RDL	C41	C41 Lab-Dup	RDL	C59	RDL	QC Batch	MDL

Calculated Parameters											
Resistivity	ohm-cm	19000	18000		820			11000		4583855	
Inorganics											
Conductivity	umho/cm	53	56	1.0	1200		1.0	88	1.0	4584773	0.20
pH	pH	6.97	7.31		7.07			7.32		4584771	
Dissolved Sulphate (SO ₄)	mg/L	<1.0	<1.0	1.0	4.9	4.7	1.0	<1.0	1.0	4585013	0.10
Dissolved Chloride (Cl)	mg/L	3.8	3.2	1.0	320	320	4.0	<1.0	1.0	4585005	0.30
RDL = Reportable Detection Limit											
QC Batch = Quality Control Batch											
Lab-Dup = Laboratory Initiated Duplicate											

Maxxam ID		CSN280			
Sampling Date		2016/07/17 09:30			
COC Number		568328-01-01			
	UNITS	C60	RDL	QC Batch	MDL
Calculated Parameters					
Resistivity	ohm-cm	12000		4583855	
Inorganics					
Conductivity	umho/cm	82	1.0	4584773	0.20
pH	pH	7.79		4584771	
Dissolved Sulphate (SO ₄)	mg/L	<1.0	1.0	4585013	0.10
Dissolved Chloride (Cl)	mg/L	<1.0	1.0	4585005	0.30
RDL = Reportable Detection Limit					
QC Batch = Quality Control Batch					

TEST SUMMARY

Maxxam ID: CSN276
Sample ID: C22
Matrix: Water

Collected: 2016/07/17
Shipped:
Received: 2016/07/18

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4585005	N/A	2016/07/20	Deonarine Ramnarine
Conductivity	AT	4584773	N/A	2016/07/19	Surinder Rai
pH	AT	4584771	N/A	2016/07/19	Surinder Rai
Resistivity of Water		4583855	2016/07/20	2016/07/20	Automated Statchk
Sulphate by Automated Colourimetry	KONE	4585013	N/A	2016/07/20	Deonarine Ramnarine

Maxxam ID: CSN277
Sample ID: C29
Matrix: Water

Collected: 2016/07/17
Shipped:
Received: 2016/07/18

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4585005	N/A	2016/07/20	Deonarine Ramnarine
Conductivity	AT	4584773	N/A	2016/07/19	Surinder Rai
pH	AT	4584771	N/A	2016/07/19	Surinder Rai
Resistivity of Water		4583855	2016/07/20	2016/07/20	Automated Statchk
Sulphate by Automated Colourimetry	KONE	4585013	N/A	2016/07/20	Deonarine Ramnarine

Maxxam ID: CSN278
Sample ID: C41
Matrix: Water

Collected: 2016/07/17
Shipped:
Received: 2016/07/18

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4585005	N/A	2016/07/20	Deonarine Ramnarine
Conductivity	AT	4584773	N/A	2016/07/19	Surinder Rai
pH	AT	4584771	N/A	2016/07/19	Surinder Rai
Resistivity of Water		4583855	2016/07/20	2016/07/20	Automated Statchk
Sulphate by Automated Colourimetry	KONE	4585013	N/A	2016/07/20	Deonarine Ramnarine

Maxxam ID: CSN278 Dup
Sample ID: C41
Matrix: Water

Collected: 2016/07/17
Shipped:
Received: 2016/07/18

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4585005	N/A	2016/07/20	Deonarine Ramnarine
Sulphate by Automated Colourimetry	KONE	4585013	N/A	2016/07/20	Deonarine Ramnarine

Maxxam ID: CSN279
Sample ID: C59
Matrix: Water

Collected: 2016/07/17
Shipped:
Received: 2016/07/18

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4585005	N/A	2016/07/20	Deonarine Ramnarine
Conductivity	AT	4584773	N/A	2016/07/19	Surinder Rai
pH	AT	4584771	N/A	2016/07/19	Surinder Rai
Resistivity of Water		4583855	2016/07/20	2016/07/20	Automated Statchk
Sulphate by Automated Colourimetry	KONE	4585013	N/A	2016/07/20	Deonarine Ramnarine

TEST SUMMARY

Maxxam ID: CSN280
Sample ID: C60
Matrix: Water

Collected: 2016/07/17
Shipped:
Received: 2016/07/18

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4585005	N/A	2016/07/20	Deonarine Ramnarine
Conductivity	AT	4584773	N/A	2016/07/19	Surinder Rai
pH	AT	4584771	N/A	2016/07/19	Surinder Rai
Resistivity of Water		4583855	2016/07/20	2016/07/20	Automated Statchk
Sulphate by Automated Colourimetry	KONE	4585013	N/A	2016/07/20	Deonarine Ramnarine

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	6.0°C
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Results relate only to the items tested.

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1521770
Sampler Initials: MK

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
4584771	pH	2016/07/19			102	98 - 103			0.38	N/A
4584773	Conductivity	2016/07/19			100	85 - 115	<1.0	umho/cm	0.23	25
4585005	Dissolved Chloride (Cl)	2016/07/20	NC	80 - 120	102	80 - 120	<1.0	mg/L	1.2	20
4585013	Dissolved Sulphate (SO4)	2016/07/20	99	75 - 125	99	80 - 120	<1.0	mg/L	NC	20

N/A = Not Applicable

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

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than 2x that of the native sample concentration).

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



Brad Newman, Scientific Specialist

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INVOICE TO:		REPORT TO:		PROJECT INFORMATION:		Laboratory Use Only:	
Company Name: #1326 Golder Associates Ltd		Company Name:		Quotation #: B63104		Maxxam Job #:	
Attention: Chris Ng		Attention: Chris Ng		P.O. #: 1521770		Bottle Order #:	
Address: 6925 Century Ave Suite 100		Address:		Project:		COC #:	
Mississauga ON L5N 7K2		Address:		Project Name:		Project Manager:	
Tel: (905) 567-4444 Fax: (905) 567-6561		Tel:		Site #:		Ema Gitej	
Email: chris_ng@golder.com		Email: chris_ng@golder.com		Sampled By: Madison Kennedy		C#568328-01-01	

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY						ANALYSIS REQUESTED (PLEASE BE SPECIFIC)										Turnaround Time (TAT) Required:			
Regulation 153 (2011) <input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Medium/Fine <input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse <input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/Other <input type="checkbox"/> For RSC <input type="checkbox"/> Table						Other Regulations <input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw <input type="checkbox"/> Reg 558 <input type="checkbox"/> Storm Sewer Bylaw <input type="checkbox"/> MISA <input type="checkbox"/> Municipality <input type="checkbox"/> PWQO <input type="checkbox"/> Other						Special Instructions						Regular (Standard) TAT: (will be applied if Rush TAT is not specified): Standard TAT = 5-7 Working days for most tests. Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.	
Include Criteria on Certificate of Analysis (Y/N)?						Field Filtered (please circle):						Job Specific Rush TAT (if applies to entire submission) Date Required: Time Required: Rush Confirmation Number: (call lab for #)							
Sample Barcode Label		Sample (Location) Identification		Date Sampled		Time Sampled		Matrix		Metals / Hg / Cr VI		Corrosivity Package for Water				# of Bottles		Comments	
1		C22		16/07/17		10:30 am		Surface Water		N		X				1			
2		C29		2016/07/17		10:20 am		Surface Water		N		X				1			
3		C41		2016/07/17		8:20 am		Surface Water		N		X				1			
4		C59		2016/07/17		9:00 am		Surface Water		N		X				1			
5		C60		2016/07/17		9:30 am		Surface Water		N		X				1			
6																			
7																			
8																			
9																			
10																			

18-Jul-16 17:15
Ema Gitej
B6E9276
SD3 ENV-710

* RELINQUISHED BY: (Signature/Print)		Date: (YY/MM/DD)		Time		RECEIVED BY: (Signature/Print)		Date: (YY/MM/DD)		Time		# jars used and not submitted		Laboratory Use Only	
Madison Kennedy		16/07/18		5:12		SHARINE DALE		2016/07/18		17:15				Time Sensitive Temperature (°C) on Receipt 4/7/7	
* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.														White: Maxxam Yellow: Client	



APPENDIX D

Non-Standard Special Provisions

OBSTRUCTIONS - Item No.

Non-Standard Special Provision

At the Twin Lake culverts site (Culvert C60 at approximately STA 20+800, Township of Dumas), bedrock was encountered between Elevations 323.1 m and 319.7 m. In addition, cobbles were encountered in the non-cohesive fill at the culvert site. Consideration of the presence of these obstructions must be made in the selection of the appropriate equipment and procedures for sub-excavation and installation of the temporary roadway protection systems, and cofferdams through this material for culvert construction.

BASIS OF PAYMENT

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

For more information, visit golder.com

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