January 17, 2014

FOUNDATION INVESTIGATION AND DESIGN REPORT

HIGHWAY 540 GRAHAM CREEK BRIDGE, SITE 49-18
TOWNSHIP OF BIDWELL, MANITOULIN ISLAND, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5465-09-00, WP 5261-10-01

Submitted to:
McIntosh Perry Consulting Engineers Ltd.
192 Hickson Avenue
Kingston, ON
K7K 2N9

GEOCRES NO. 42G-15

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REPORT

Golder Associates

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PART A

FOUNDATION INVESTIGATION REPORT

HIGHWAY 540, GRAHAM CREEK BRIDGE, SITE 49-18

TOWNSHIP OF BIDWELL, MANITOULIN ISLAND, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5465-09-00, WP 5261-10-01

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McIntosh Perry Consulting Engineers Ltd. (McIntosh Perry) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the replacement of the Graham Creek Bridge (Site 49-18) in the Township of Bidwell on Manitoulin Island, Ontario. The Key Plan showing the general location of this section of Highway 540 and the location of the investigated area are shown on Drawing 1.

The purpose of this investigation is to establish the subsurface conditions at the location of the bridge by borehole drilling, in situ testing and laboratory testing on selected samples.

2.0 SITE DESCRIPTION

The Graham Creek Bridge is located in the Township of Bidwell on Highway 540, approximately 19.3 km west of Highway 6. The land use in the area is generally rural (i.e., farm land) with a few residences in the vicinity of the site.

In general, the topography in the area of the overall project limits is generally flat with gently rolling hills. The banks adjacent to the creek are vegetated with grass and large trees. The creek flows from east to west and is approximately 4 m wide at the bridge location.

We understand the original Graham Creek Bridge structure was constructed in the 1930s and was subsequently widened in 1964 to accommodate two-lane traffic. The existing structure consists of a 7.3 m long and 11 m wide, single-span bridge. Based on the "*Graham's Creek Bridge (Widening) Plan-Elevation-Cross-Section*" drawing (Drawing No. D-5237-1, dated Feb. 1963) provided by the MTO, the existing bridge is supported by shallow footings with the top of the footings at about 2 m below the designed highway grade. The existing embankment side slopes are formed at approximately 3 horizontal to 1 vertical (3H:1V) on both the west and east sides of the creek. There are full width pavement cracks located near the bridge abutments.

The existing highway grade at the bridge is at about Elevation 242.3 m and the creek level measured by Golder on July 3, 2013, was Elevation 240.0 m. The existing highway embankment grade is about 1.5 m above the surrounding ground surface adjacent to the creek.

Photographs taken at the site are included following the text of the report.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out between July 2 and 4, 2013, during which time a total of six boreholes (G1 to G6) were advanced at the site. Boreholes G1 to G4 were advanced near the ends of the existing bridge abutments and Boreholes G5 and G6 were advanced along the north and south approaches, respectively. The locations of the boreholes are shown on Drawing 1.

The field investigation was carried out using a track-mounted CME-850 drill rig supplied and operated by Landcore Drilling of Sudbury, Ontario. The boreholes were advanced through the overburden using 108 mm inside diameter hollow-stem augers. Soil samples were obtained at intervals of depth of about 0.75 m, using a

50 mm outer diameter split-spoon sampler, operated by an automatic hammer on the drill rig, in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a). Samples of the bedrock were obtained using NW casing and 'NQ' size rock core barrels in Boreholes G1 to G4. The groundwater levels in the open boreholes were observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 (as amended by Ontario Regulation 372).

The fieldwork was supervised throughout by members of our technical staff who: located the boreholes; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined and cared for the soil and bedrock samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury Geotechnical Laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water contents and grain size distribution) was carried out on selected soil samples. In addition, uniaxial compressive strength (UCS) testing was carried out on two selected specimens of the bedrock core recovered from the boreholes. The geotechnical laboratory testing was completed according to MTO LS standards. The results of the laboratory testing are included on the Record of Borehole sheets in Appendix A and on the figures contained in Appendix B.

A sample of the creek water was obtained using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters. The results of the analytical testing are summarized in Table B1 in Appendix B.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to stations on the highway. The MTM NAD 83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depths at each borehole location are presented on the Record of Borehole sheets in Appendix A and are summarized below.

Borehole	**Location (m)**		**Ground Surface Elevation (m)**	**Borehole Depth (m)**
	Northing	**Easting**		
G1	5083298.1	219108.9	242.3	7.5
G2	5083298.2	219114.9	242.3	7.2
G3	5083287.1	219109.1	242.3	7.3
G4	5083287.4	219114.8	242.3	7.1
G5	5083317.1	219114.7	242.2	1.4
G6	5083270.7	219108.9	242.2	3.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on the Physiography of Southern Ontario (Ministry of Northern Development and Mines)[1], the site is located within limestone plains bordering with areas of sand plains and shallow till deposits.

Based on geological mapping in the area (Ministry of Northern Development and Mines)[2], the bedrock in the area consists typically of sandstone, shale, dolostone and siltstone and the site borders on the Amabel Formation from the Silurian Period and the Georgian Bay Formations from the Ordovician Period.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced for this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole and Drillhole sheets in Appendix A. The results of the laboratory testing are provided in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs. 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. The inferred soil stratigraphy based on the results of the boreholes is shown in profile on Drawing 1.

In general, the subsurface conditions encountered at the site generally consist of embankment fill overlying native silty sand to gravelly sandy silt overlying bedrock. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Asphalt

A 125 mm to 190 mm thick layer of asphalt was encountered at ground surface (Elevation 242.3 m to 242.2 m) in each of the boreholes.

4.2.2 Embankment Fill

Embankment fill up to 4.3 m thick was encountered below the asphalt in each of the boreholes. The embankment fill consisted of brown sand to gravel, trace to some silt and trace to some clay. In Borehole G1, the augers were noted to be grinding on cobbles between 0.8 m and 1.5 m depth and in Borehole G4, at a depth of 2.9 m; Borehole G5 was terminated on auger refusal at 1.4 m depth likely on cobbles or boulders within the fill.

Standard Penetration Test (SPT) ’N‘-values in the embankment fill range between 5 blows and 41 blows per 0.3 m of penetration indicating a loose to dense relative density.

[1] Ministry of Northern Development and Mines, 2007, Physiography of Southern Ontario, MRD228.
[2] Ministry of Northern Development and Mines, 1991. *Bedrock Geology of Ontario*, Southern Sheet, Map 2544.

Grain size distribution tests were carried out on three samples of the embankment fill and the results are shown on Figure B1 in Appendix B.

The natural water content measured on samples of the embankment fill is between 7 per cent and 18 per cent.

4.2.3 Silty Sand to Sand and Silt

A 0.2 m to 2.9 m thick deposit of grey, silty sand to sand and silt, trace to some gravel, trace to some clay was encountered below the embankment fill in Boreholes G2 to G4 and G6. The surface of the silty sand to sand and silt was encountered between Elevation 241.3.m and 238.8 m.

The SPT ’N‘-value within the silty sand to sand and silt deposit range from 5 blows to 22 blows per 0.3 m penetration, indicating a loose to compact relative density.

Grain size distribution tests were carried out on five samples of this deposit and the results are shown on Figure B2 in Appendix B.

Atterberg limits testing was carried out on two samples of the sand and silt, deposit. Test results from one sample yielded a liquid limit of 34 per cent, a plastic limit of 24 per cent and plasticity index of 10 per cent as shown in Figure B3 in Appendix B. The second sample was determined to be non-plastic. Based on the grain size distributions and Atterberg limits test results, these samples were classified as sand and silt of slight plasticity.

The natural water content measured on samples of the deposit is between 8 per cent and 28 per cent.

4.2.4 Bedrock / Refusal

Bedrock was cored in Boreholes G1 to G4. The bedrock surface/refusal depths and elevations are presented below.

Borehole No.	Depth to Bedrock/ Refusal (m)	Bedrock Surface/ Refusal Elevation (m)	Notes
G1	4.5	237.8	Bedrock Cored for 3.0 m
G2	3.7	238.6	Bedrock Cored for 3.4 m
G3	4.5	237.8	Bedrock Cored for 2.9 m
G4	3.8	238.5	Bedrock Cored for 3.3 m
G6	3.8	238.4	Auger Refusal at 3.8 m

The retrieved bedrock core is described as a fine grained, fresh, grey, dolomitic limestone, as presented in the Record of Drillhole sheets in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figure B4 in Appendix B.

The Total Core Recovery during bedrock coring was 100 per cent. The Rock Quality Designation measured on the core samples ranges from 60 per cent to 92 per cent, indicating a rock mass of fair to excellent quality as per Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006).

Laboratory UCS testing was carried out on two core samples of the bedrock. The UCS values are presented below and the test results indicate the bedrock is medium strong to strong as per Table 3.5 of the CFEM (2006).

Borehole	Elevation (m)	UCS (MPa)
G2	238.2	39
G3	235.8	53

4.2.5 Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized in the table below. Borehole G5 was noted to be dry upon completion of drilling.

Borehole No.	Depth to Groundwater Level (m)	Groundwater Elevation (m)
G1	2.0	240.3
G2	2.1	240.2
G3	2.0	240.3
G4	2.0	240.3
G6	1.7	240.5

Groundwater levels encountered in the boreholes during and shortly after drilling may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. The water in the creek was at Elevation 240.0 m as measured on July 4, 2013. The high water level is Elevation 240.5 m. Groundwater levels in the area are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.

5.0 CLOSURE

The field personnel supervising the drilling program was Mr. Mathew Riopelle. This report was prepared by Mr. David Muldowney, P.Eng., and the technical aspects were reviewed by Mr. André Bom, P.Eng. Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact for this project, carried out a quality control review and reviewed the technical aspects of the report.

Report Signature Page

GOLDER ASSOCIATES LTD.

D. Muldowney

David Muldowney, P. Eng.
Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
A. J. K. BOM
100075715
Jan 17/14
PROVINCE OF ONTARIO

André Bom, P.Eng., PMP
Geotechnical Engineer

REGISTERED PROFESSIONAL ENGINEER
F. J. HEFFERNAN
Jan 17/14
PROVINCE OF ONTARIO

Fintan J. Heffernan, P.Eng.
Designated MTO Contact

DAM/AB/FJH/kp

http://capws.golder.com/sites/p211910014mtohwy542and655manislandtimmins/reports/final/graham creek 49-18/12-1191-0014-r05 rpt 14jan17 graham creek site 49-18 fidr.docx

PART B

FOUNDATION DESIGN REPORT

HIGHWAY 540, GRAHAM CREEK BRIDGE, SITE 49-18

TOWNSHIP OF BIDWELL, MANITOULIN ISLAND, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5465-09-00, WP 5261-10-01

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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides an interpretation of the factual geotechnical data obtained during the investigation and conclusions and recommendations on the foundation aspects of design of the proposed works. The recommendations provided are intended for the guidance of the design engineer. Where comments are made on construction, they are provided to highlight aspects of construction that could affect the design of the project. Those requiring information on aspects of construction must make their own interpretation of the subsurface information provided as such interpretation may affect their proposed construction methods, costs, equipment selection, scheduling and the like.

6.1 General

The existing Graham Creek Bridge (Site 49-18) is a 7.3 m long single span and is 11 m wide. Based on the General Arrangement drawing provided by McIntosh Perry, the new open footing concrete culvert will be constructed on the same alignment as the existing bridge and will have an 8.8 m width, a length of 12.6 m and an internal height above the creek bed of 1.9 m. The grade of the highway will essentially remain the same with only a minor grade raise (i.e., about 0.2 m). Concrete wing walls will be constructed at each of the four corners of the culvert extending parallel to Highway 540 to a distance of 4.2 m from the culvert end.

The subsoils at the proposed culvert location generally consist of granular embankment fill materials (sands and gravels) overlying loose to compact native silty sand to sand and silt overlying bedrock. The surface of the native soil was encountered between 3.0 m and 3.5 m below the existing ground surface (Elevation 241.3 m to 238.8 m) and the bedrock surface was encountered between 3.7 m and 4.5 m below existing grade (Elevation 238.6 m to 237.8 m). Details of the subsurface conditions along this culvert are presented in Section 4.2 and shown in profile and cross-section on Drawings 1 and 2.

6.2 Geotechnical Resistance

A factored geotechnical axial resistance at Ultimate Limit States (ULS) of 1,000 kPa may be used for design of a 2.0 m wide open footing culvert founded directly on bedrock. The geotechnical axial resistance at Serviceability Limit States (SLS) for footings founded on the bedrock will be equal to or greater than the factored geotechnical resistances at ULS and, therefore, the ULS values will govern for design.

The bedrock could be levelled with a working slab of 20 MPa concrete with a 100 mm minimum thickness. The bedrock surface is about 0.5 m to 0.6 m higher on the east side of the abutment areas. If precast units are planned, consideration could be given to casting the footing to level the site. The Non-Standard Special Provision (NSSP) for the working slab is included in Appendix C.

The geotechnical resistances are given for loads applied perpendicular to the surface of the base of the culvert. Where loads are not applied perpendicular to the base of the culvert, inclination of the loads should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the Canadian Highway Bridge Code (CHBDC) and its Commentary.

6.2.1 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance between the base of culvert footings and the bedrock surface should be calculated in accordance with Section 6.7.5 of the *CHBDC*. For a cast-in-place concrete footing, the coefficient of friction is tan $\phi = 0.7$.

This value is unfactored, in accordance with CHBDC; a factor of 0.8 is to be applied in calculating the horizontal resistances.

6.2.2 Frost Protection

The estimated frost penetration depth in the Bidwell Township area is 1.6 m, as per OPSD 3090.101 (Foundation, Frost Penetration Depths for Southern Ontario).

As the footings for the open-footing culvert will be founded directly on bedrock, frost susceptibility is not an issue.

6.3 Stability, Settlement and Horizontal Strain

The following sections summarize stability, settlement horizontal strains along the culvert beneath the influence of the proposed embankment loading.

6.3.1 Stability

Based on the existing/proposed embankment geometry and the subsurface conditions at this site, granular fill embankments at this site will be stable at side slopes not steeper than 2 Horizontal to 1 Vertical (2H:1V).

6.3.2 Settlement

As the proposed culvert will be founded directly on the bedrock surface, settlement of the culvert footings will not occur.

It is recommended that consideration be given to the use of OPSS.PROV 1010 (Aggregates) Granular ‘B’ Type I or II for embankment reconstruction at the culvert location. Where granular fill will be placed below the water level, Granular ‘B’ Type II should be used. The material placed below the water level will compress/settle under its self-weight as additional fill is placed over it. The material placed above the water level should be compacted in accordance with OPSS 501 (Compacting). Compression settlement of the fill placed below water and from properly compacted embankment fill above water is expected to occur during construction. It is recommended that the fines content of the Granular ‘B’ Type II fill used for embankment construction below the water be restricted to a maximum of 5 per cent passing the No. 200 sieve, to reduce the potential for segregation of fines during placement and to reduce the potential post-construction settlement and associated maintenance needs.

6.3.3 Horizontal Strain

Based on the footings placed on bedrock, horizontal strain along the culvert is not expected to occur. As a result, culvert construction concurrent with the embankment construction can be carried out without the need for any foundation mitigation measures or culvert camber.

6.4 Lateral Earth Pressures

The lateral earth pressures acting on the side walls (or head/wing walls if required) of the culvert will depend on the type and method of placement of backfill materials, the nature of 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 and any wing or head walls. It should be noted that these design recommendations and parameters are applicable to 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 requirements of SP110S13 (Aggregates) Granular ‘A’ or Granular ‘B’ Type II but with less than 5 per cent passing the 200 sieve (0.075 mm) should be used as backfill behind the culvert. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub drains and frost taper should be in accordance with OPSD 3101.150 (Wall, Abutment, Backfill) and OPSD 3121.150 (Walls Retaining, Backfill).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the culvert any retaining walls, in accordance with CHBDC Section 6.9.3 and Figure 6.6. Compaction equipment should be used in accordance with OPSS 501 (Compacting). Other surcharge loadings should be accounted for in the design as required.
- Granular fill may be placed either in a zone with the width equal to at least 1.6 m behind the back of the walls for a restrained wall (see Figure C6.20(a) of the Commentary to the CHBDC), or within the wedge shaped zone defined by a line drawn at 1.5 H:1V extending up and back from the rear face of the base of the walls for an unrestrained wall (see Figure C6.20(b) of the Commentary to the CHBDC).
- For restrained walls, granular fill should be placed in a zone with the width equal to at least 1.6 m behind the back of the wall (in accordance with Figure C6.20(a) of the Commentary to the CHBDC). For unrestrained walls, granular 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). The pressures are based on the proposed embankment fill material and the following parameters (unfactored) may be used:

Fill Type	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 wing/head walls and culvert structure allow for lateral yielding, active earth pressures may be used in the geotechnical design of the structures. If the wing/retaining walls and culvert structure do not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as presented in Table C6.6 of the Commentary to the CHBDC.

6.5 Culvert Construction Considerations

6.5.1 Excavations, Subgrade Preparation, Bedding and Backfill above Base of Culvert

Since the proposed culvert will be founded on the bedrock surface, temporary support systems such as sheet piling will not be feasible at this site. Soldier piles and lagging may be used for support of the excavation along the culvert and as well as for traffic protection. Alternatively, the culvert may need to be installed using open-cut excavations with a maximum temporary side slope of 1.5H:1V or flatter within the existing fill and/or native soils (short-term excavations). The existing fill and/or native soils at this site may be classified as Type 3 soil. All excavations must be carried out in accordance with Ontario Regulation 213 Ontario Occupational Health and Safety Act for Construction Projects (as amended by Ontario Regulation 443). In addition, provisions for traffic control measures should be included in the Contract Documents to maintain the safe operation of the existing Highway 540.

Prior to placing any fill for new construction, all fill, organics and native soils should be excavated to expose the bedrock surface within the plan limits of the proposed culvert footings.

For a cast-in-place culvert, groundwater control will be required as further discussed in Section 6.5.3 to construct the footings in-the-dry.

For a precast culvert, a concrete working slab will be required to level the bedrock as detailed in the NSSP included in Appendix C. Alternatively, the footing may be poured to a level surface and the precast culvert secured to it.

The fill depth during backfilling should be maintained equal on both sides of the culvert with one side not exceeding the other by more than 500 mm.

The culvert should be designed for the full overburden stress and appropriate live loads, assuming a fill unit weight of 22 kN/m^3 for Granular 'A' and 21 kN/m^3 for Granular 'B' Type II backfill above and surrounding the culvert. Inspection and field density testing should be carried out by qualified personnel during fill placement operations to ensure that appropriate materials are used and that adequate levels of compaction have been achieved.

6.5.2 Erosion Protection

The culvert side slopes adjacent to the creek require erosion protection in accordance with OPSS 511 (Rip Rap, Rock Protection and Granular Sheeting). Erosion protection should be placed on the slopes to at least 0.5 m above the design high water level. Subject to modifications based on the hydrology reports (by others), erosion protection could consist of a minimum 0.6 m thick layer of R-10 Rip Rap (180 mm diameter as per OPSS.PROV 1004 (Aggregates - Miscellaneous), rock protection or concrete slope paving.

To reduce surface water erosion on the granular embankment side slopes, topsoil and seeding as per OPSS 802 (Topsoil) and OPSS 804 (Seed and Cover) should be carried out as soon as possible after construction of the embankments (unless rock fill is used). If this slope protection is not in place before winter, then alternate protection measures, such as covering the slope with straw or gravel sheeting as per OPSS 511 (Rip Rap, Rock Protection and Granular Sheeting) to prevent erosion, will be required to reduce the potential for remedial works on the side slopes in the spring prior to topsoil dressing and seeding.

6.5.3 Control of Groundwater and Surface Water

Excavation within the plan limits of the proposed Graham Creek alignment will be required to remove any organics, the existing granular fill, and cohesionless soils (silty sand to sand and silt) soils prior to construction of the footings on bedrock and placement of backfill/embankment fill. The existing culvert flows will need to be diverted/piped during construction. Surficial water seepage into the excavation should be expected and will be heavier during periods of sustained precipitation. Seepage from the granular fills, near surface native granular materials and the bedrock should be expected, particularly after precipitation events. It is anticipated that this surficial seepage can be controlled by using properly filtered sumps within the excavation.

For a cast-in-place culvert, dewatering will be required for construction in-the-dry. The excavations will be advanced through or into water-bearing cohesionless soils and pervious bedrock and appropriate unwatering of the water-bearing granular soil deposits and the dolomitic limestone bedrock will be required to maintain the water level below the founding level for the culvert during excavation and construction. It is recommended that an NSSP be included in the Contract to address unwatering for the culvert site; a sample NSSP is included in Appendix C.

6.5.4 Analytical Testing for Construction Materials

The analytical test results on a sample of creek water taken adjacent to the culvert site are presented in Table B1. The suite of parameters tested is intended to allow the structural engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection.

7.0 CLOSURE

This report was prepared by Mr. David Muldowney, P.Eng and the technical aspects were reviewed by Mr. André Bom, P.Eng. Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact, carried out a quality control review and reviewed the technical aspects of the report.

Report Signature Page

GOLDER ASSOCIATES LTD.

David Muldowney, P. Eng.
Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
A. J. K. BOM
100075715
Jan 17/14
PROVINCE OF ONTARIO

André Bom, P.Eng., PMP
Geotechnical Engineer

REGISTERED PROFESSIONAL ENGINEER
F. J. HEFFERNAN
Jan 17/14
PROVINCE OF ONTARIO

Fintan J. Heffernan, P.Eng.
Designated MTO Contact

DAM/AB/FJH/kp

http://capws.golder.com/sites/p211910014mtohwy542and655manislandtimmins/reports/final/graham creek 49-18/12-1191-0014-r05 rpt 14jan17 graham creek site 49-18 fidr.docx

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Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA-S6-06. 2006. CSA Special Publication, S6.1-06. Canadian Standard Association.

Ministry of Northern Development and Mines, 2007, Physiography of Southern Ontario, MRD228.

Ministry of Northern Development and Mines, 1991. Bedrock Geology of Ontario, Southern Sheet, Map 2544.

STANDARDS

ASTM International:

ASTM D1586-08a	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

Ontario Occupational Health and Safety Act

Ontario Regulation 213/91	Construction Projects
Ontario Regulation 443/09	Amendment to Ontario Regulation 213/91

Ontario Provincial Standard Drawing

OPSD 3090.101	Foundation, Frost Penetration Depths for Southern Ontario
OPSD 3101.150	Walls, Abutment, Backfill, Minimum Granular Requirement
OPSD 3121.150	Walls, Retaining, Backfill, Minimum Granular Requirement

Ontario Provincial Standard Specification

OPSS 501	Construction Specification for Compacting
OPSS 511	Construction Specification for Rip Rap, Rock Protection and Granular Sheeting
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Water Resources Act

Ontario Regulation 372/97	Amendment to Ontario Regulation 903

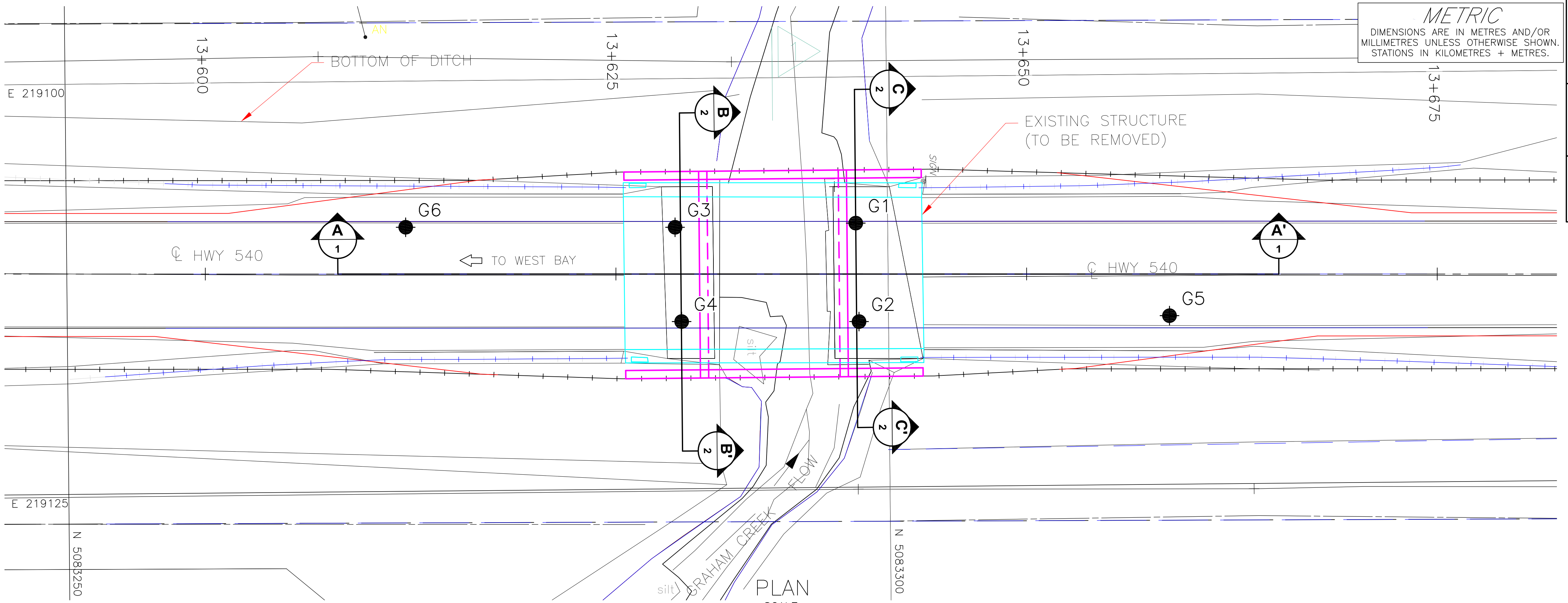
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5261–10–01

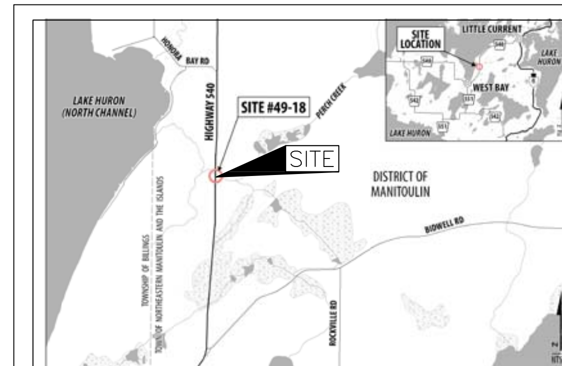
SHEET

HIGHWAY 540
GRAHAM CREEK CULVERT SITE 49–18
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates
Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



PLAN
SCALE
3 0 3 6 m



KEY PLAN
N.T.S.

LEGEND

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

BOREHOLE CO–ORDINATES

No.	ELEVATION	NORTHING	EASTING
G1	242.3	5083298.1	219108.9
G2	242.3	5083298.2	219114.9
G3	242.3	5083287.1	219109.1
G4	242.3	5083287.4	219114.8
G5	242.2	5083317.1	219114.7
G6	242.2	5083270.7	219108.9

NOTES

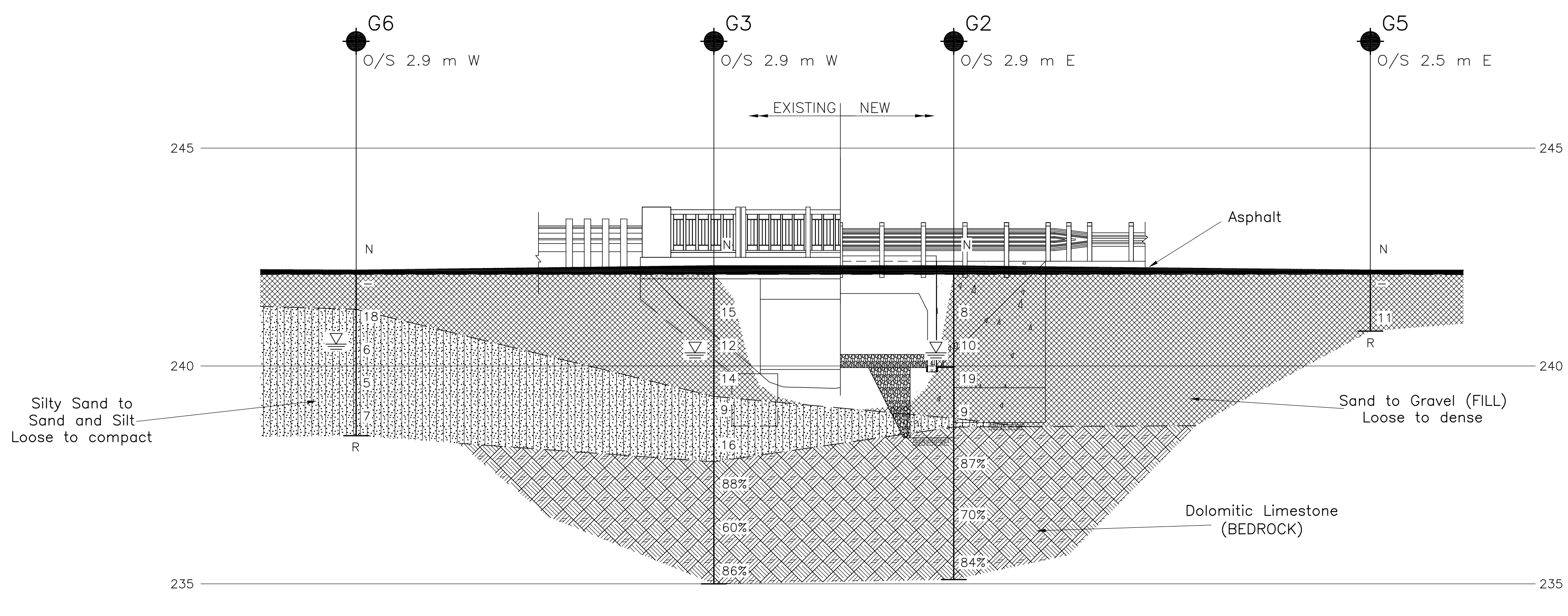
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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 provided in digital format by McIntosh Perry, drawing file no. 12-0960-1-LDC-TERRAIN GRAHAM Jan2014 GA FOR GOLDER.dwg, received January 16, 2014. Key plan file no. KM11684 – 49-18 location Map – June 26 2012.jpg, received August 24, 2012.



A–A' 1 CENTRELINE PROFILE
HIGHWAY 540
HORIZONTAL SCALE
3 0 3 6 m
1.5 0 1.5 3 m
VERTICAL SCALE

LICENSED PROFESSIONAL ENGINEER A.J.K. BOM 100075715 JAN 17, 2014 PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER F. J. HEFFERNAN JAN 17, 2014 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 41G–15			
HWY. 540	PROJECT NO. 12–1191–0014		DIST.
SUBM'D. DAM	CHKD.	DATE: JAN 2014	SITE: 49–18
DRAWN: TB	CHKD. AB	APPD. FJH	DWG. 1

MINISTRY OF TRANSPORTATION, ONTARIO

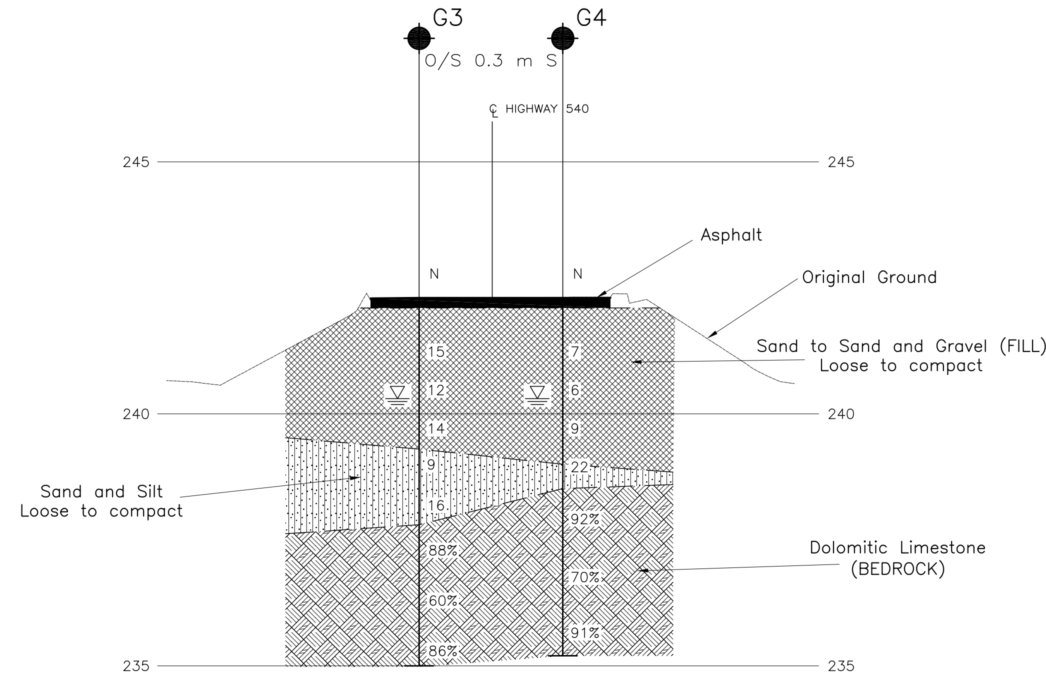
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5261-10-01

HIGHWAY 540
GRAHAM CREEK CULVERT SITE 49-18
SOIL STRATA

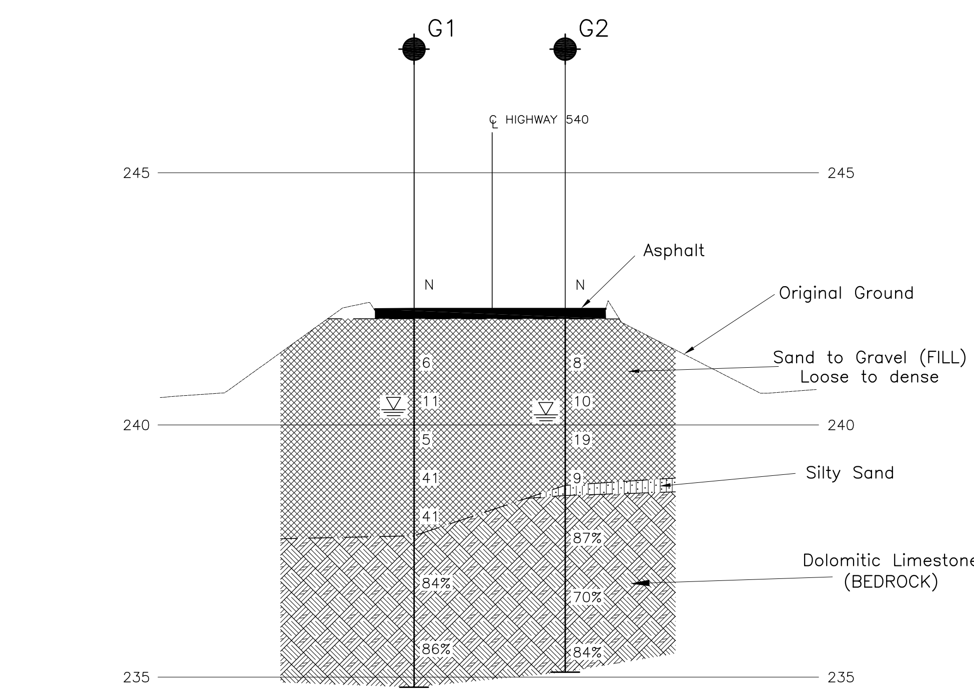
SHEET

Golder Associates
Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



B-B' / 2 SECTION AT STA 13+629
HIGHWAY 540

HORIZONTAL SCALE
3 0 3 6 m
1.5 0 1.5 3 m
VERTICAL SCALE



C-C' / 2 SECTION AT STA 13+640
HIGHWAY 540

HORIZONTAL SCALE
3 0 3 6 m
1.5 0 1.5 3 m
VERTICAL SCALE

LEGEND

- ● Borehole
- 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

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
G1	242.3	5083298.1	219108.9
G2	242.3	5083298.2	219114.9
G3	242.3	5083287.1	219109.1
G4	242.3	5083287.4	219114.8

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 provided in digital format by McIntosh Perry, drawing file no. 11-684-Graham Creek Cross Sections Abutment.dwg, received July 19, 2013.

LICENSED PROFESSIONAL ENGINEER A.J.K. BOM 100075715 JAN 17, 2014 PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER F. J. HEFFERNAN JAN 17, 2014 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

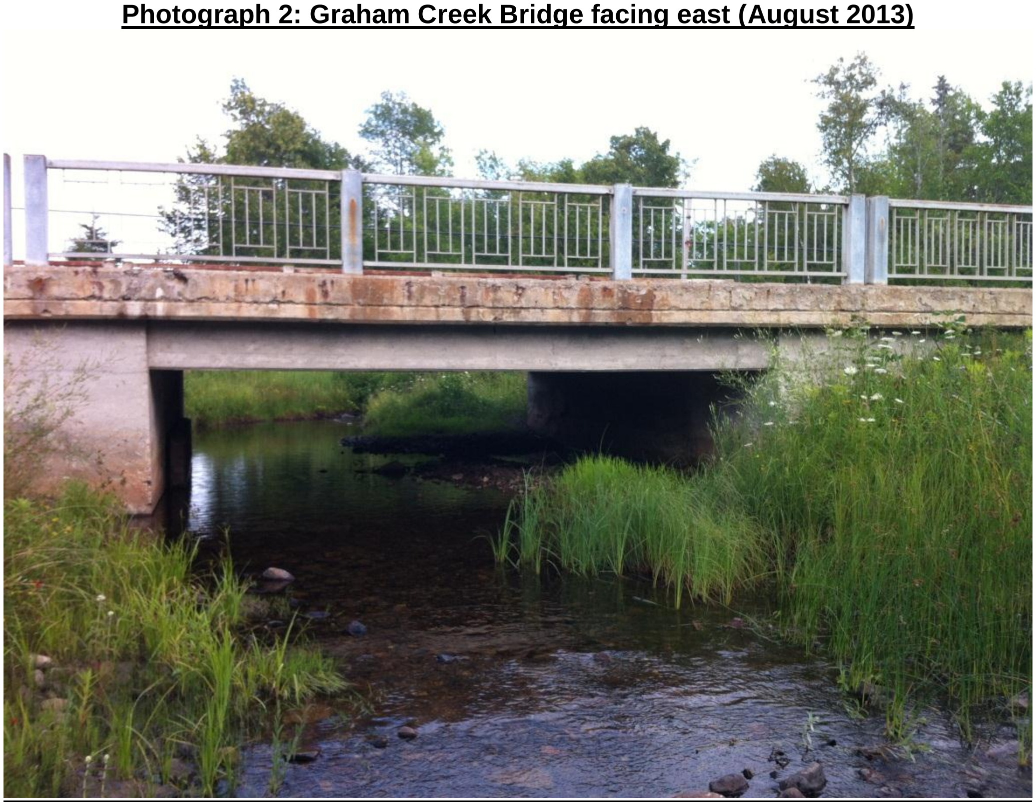
Geocres No. 41G-15

HWY. 540		PROJECT NO. 12-1191-0014	DIST.
SUBM'D. DAM	CHKD.	DATE: JAN 2014	SITE: 49-18
DRAWN: TB	CHKD. AB	APPD. FJH	DWG. 2

PLOT DATE: January 17, 2014

Photograph 1: Graham Creek Bridge facing west (August 2013)

Photograph 2: Graham Creek Bridge facing east (August 2013)



Photograph 3: Graham Creek Bridge facing north (October 2012)

Photograph 4: Graham Creek Bridge facing south (July 2013)

APPENDIX A

Record of Boreholes and Drillholes

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
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_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 $= \sigma'_p / \sigma'_{vo}$

(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 δ
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. $\tau = c' + \sigma' \tan \phi'$
2. 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:

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, 60º 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 cm^2 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 (Cohesionless) Soils

Density Index Relative Density	**N 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**	c_u, s_u **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

WEATHERINGS 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

Description	Bedding Plane Spacing
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

Description	Spacing
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

Term	Size*
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^o 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		

RECORD OF BOREHOLE No G1

 METRIC

PROJECT 12-1191-0014
W.P. 5261-10-01
LOCATION N 5083298.1; E 219108.9
ORIGINATED BY MR
DIST HWY 540
BOREHOLE TYPE 108 mm I.D. Continous Flight Solid Stem Augers, NW Casing, NQ Coring
COMPILED BY DAM
DATUM GEODETIC
DATE July 2, 2013
CHECKED BY AB

ELEV / DEPTH (m)	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
242.3	GROUND SURFACE							
0.0	ASPHALT (180 mm)							
0.2	Gravelly sand to gravel, trace to some silt (FILL) Loose to dense Brown Moist to wet Auger grinding on cobbles between 0.8 m and 1.5 m depth. Switched to NW Casing at 2.3 m depth.					242		
		1	SS	6		241		
		2	SS	11	▽		○	25 58 (17)
		3	SS	5		240		
		4	SS	41		239		
		5	SS	41		238		
237.8 / 4.5	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 4.5 m depth to 7.5 m depth. For coring details see Record of Drillhole G1.	1	RC	REC 100%		237		RQD = 84%
		2	RC	REC 100%		236		RQD = 86%
234.8 / 7.5	END OF BOREHOLE Notes: 1. Water level at a depth of 2.0 m below ground surface (Elev. 240.3 m) upon completion of drilling.					235		

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

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

RECORD OF DRILLHOLE: G1

PROJECT: 12-1191-0014

LOCATION: N 5083298.1 ;E 219108.9

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: July 2, 2013

DRILL RIG: CME 850 Track Mount

DRILLING CONTRACTOR: Landcore Drilling

SHEET 1 OF 1

DATUM: GEODETIC

JN - Joint, FLT - Fault, SHR- 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, MB- Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	COLOUR % RETURN (FLUSH)	DISCONTINUITY DATA – TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		~SEE PREVIOUS PAGE~	237.8				
4.5–7.5	July 2, 2013; NW / NQ Coring	DOLOMITIC LIMESTONE Fine grained Grey Fresh	4.5	1	GREY 100%	JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNCURo (Clay in-fill) JNIRRo JNIRRo JNIRRo	
				2	GREY 100%	JNIRRo JNIRRo JNIRRo JNIRRo (Clay in-fill) JNIRRo (Clay in-fill) JNIRRo JNIRRo	
			234.8				
		END OF DRILLHOLE	7.5				

Depth scale: 5, 6, 7, 8, 9, 10, 11, 12, 13, 14

Other columns: SYMBOLIC LOG; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX PER 0.25 METRES; B Angle; DIP w.r.t. CORE AXIS; Jr; Ja; Jn; HYDRAULIC CONDUCTIVITY k, cm/s; Diametral Point Load Index (MPa); RMC -Q' AVG.

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: MR

CHECKED: AB

RECORD OF BOREHOLE No G2

 METRIC

PROJECT 12-1191-0014

W.P. 5261-10-01 LOCATION N 5083298.2; E 219114.9 ORIGINATED BY MR

DIST ____ HWY 540 BOREHOLE TYPE 108 mm I.D. Continous Flight Hollow Stem Augers, NW Casing, NQ Coring COMPILED BY DAM

DATUM GEODETIC DATE July 3, 2013 CHECKED BY AB

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
242.3	GROUND SURFACE								
0.0	ASPHALT (190 mm)					242			
0.2	Sand to sand and gravel, trace to some clay, trace silt (FILL) Loose to compact Brown Moist to wet	1	SS	8		241			
		2	SS	10	∇ (water level)	240			
		3	SS	19					
	Switched to NW Casing at 3.0 m depth.	4A	SS	9		239	○		35 49 13 3
238.8 / 3.7	Silty SAND, some gravel, trace to some clay Grey Wet	4B					○		17 50 25 8
	DOLOMITIC LIMESTONE (BEDROCK)	1	RC	REC 100%		238			RQD = 87%
	Bedrock cored from 3.7 m depth to 7.2 m depth. For coring details see Record of Drillhole G2.	2	RC	REC 100%		237			RQD = 70%
235.1		3	RC	REC 100%		236			RQD = 84%
7.2	END OF BOREHOLE								

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60

Notes:

1. Water level at a depth of 2.1 m below ground surface (Elev. 240.2 m) upon completion of drilling.

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

PROJECT: 12-1191-0014

RECORD OF DRILLHOLE: G2

SHEET 1 OF 1

LOCATION: N 5083298.2 ;E 219114.9

DRILLING DATE: July 3, 2013

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 850 Track Mount

DRILLING CONTRACTOR: Landcore Drilling

JN - Joint, FLT - Fault, SHR- 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, MB- Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	COLOUR % RETURN	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		~SEE PREVIOUS PAGE~	238.6				
4	July 3, 2013; NW; NQ Coring	DOLOMITIC LIMESTONE Fine grained Medium strong Grey Fresh Broken rock between 4.4 m and 4.5 m, between 4.7 m and 4.8 m, between 5.0 m and 5.1 m, and between 5.4 m and 5.5 m depths.	3.7	1	GREY 100%	JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo (Clay in-fill)	UCS=39 MPa
5				2	GREY 100%	BR JNIRRo JNIRRo JNIRRo BR BR JNIRRo JNIRRo JNIRRo BR	
6–7			235.1 7.2	3	GREY 100%	JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo	
		END OF DRILLHOLE					

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: MR

CHECKED: AB

Golder Associates

RECORD OF BOREHOLE No G3

 METRIC

PROJECT 12-1191-0014

W.P. 5261-10-01 | LOCATION N 5083287.1; E 219109.1 | ORIGINATED BY MR

DIST ____ HWY 540 | BOREHOLE TYPE 108 mm I.D. Continous Flight Hollow Stem Augers, NW Casing, NQ Coring | COMPILED BY DAM

DATUM GEODETIC | DATE July 3, 2013 | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
242.3	GROUND SURFACE						
0.0	ASPHALT (190 mm)						
0.2	Sand and gravel, some silt, trace clay (FILL) Compact Brown Moist to wet	1	SS	15			
		2	SS	12	▽		
	Switched to NW Casing at 2.3 m depth.	3	SS	14		○	33 52 12 3
239.3 / 3.0	SAND and SILT some gravel, trace to some clay Loose to compact Grey Wet	4	SS	9		○	17 29 44 10
		5	SS	16			
237.8 / 4.5	DOLOMITIC LIMESTONE (BEDROCK)	1	RC	REC 100%			RQD = 88%
	Bedrock cored from 4.5 m depth to 7.3 m depth. For coring details see Record of Drillhole G3.	2	RC	REC 100%			RQD = 60%
		3	RC	REC 100%			RQD = 86%
235.0 / 7.3	END OF BOREHOLE						

Notes:

1. Water level at a depth of 2.0 m below ground surface (Elev. 240.3 m) upon completion of drilling.

Elevation scale: 242, 241, 240, 239, 238, 237, 236, 235

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

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

RECORD OF DRILLHOLE: G3

PROJECT: 12-1191-0014
LOCATION: N 5083287.1 ;E 219109.1
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: July 3, 2013
DRILL RIG: CME 850 Track Mount
DRILLING CONTRACTOR: Landcore Drilling

SHEET 1 OF 1
DATUM: GEODETIC

JN - Joint; FLT - Fault; SHR- 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; MB- Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	COLOUR % RETURN	DISCONTINUITY DATA (TYPE AND SURFACE DESCRIPTION)	NOTES WATER LEVELS INSTRUMENTATION
		~SEE PREVIOUS PAGE~	237.8				
	July 3, 2013; NQ Coring; NW	DOLOMITIC LIMESTONE Fine grained Strong Grey Fresh	4.5	1	GREY 100%	JNIRRo	
5				2	GREY 100%	JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo	
6				3	GREY 100%	JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo	UCS=53 MPa
7			235.0 7.3				
		END OF DRILLHOLE					

Depth scale: 8, 9, 10, 11, 12, 13, 14

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MR
CHECKED: AB

SUD-RCK 1211910014.GPJ GAL-MISS.GDT 06/09/13 DATA INPUT:

RECORD OF BOREHOLE No G4

 METRIC

PROJECT 12-1191-0014
W.P. 5261-10-01
LOCATION N 5083287.4; E 219114.8
ORIGINATED BY MR
DIST ___ HWY 540
BOREHOLE TYPE 108 mm I.D. Continous Flight Hollow Stem Augers, NW Casing, NQ Coring
COMPILED BY DAM
DATUM GEODETIC
DATE July 4, 2013
CHECKED BY AB

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
242.3	GROUND SURFACE						
0.0	ASPHALT (180 mm)						
0.2	Sand, trace to some gravel (FILL) Loose Brown Moist to wet	1	SS	7			
		2	SS	6	∇ (Elev. 240.3)		
		3	SS	9			
	Auger grinding on cobbles at 2.9 m depth.						
239.0 / 3.3	SAND and SILT, some gravel, trace to some clay Compact Grey Wet	4A / 4B	SS	22		○ (~6)	12 36 34 8
238.5 / 3.8	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 3.8 m depth to 7.1 m depth. For coring details see Record of Drillhole G4.	1	RC	REC 100%			RQD = 92%
		2	RC	REC 100%			RQD = 70%
		3	RC	REC 98%			RQD = 91%
235.2 / 7.1	END OF BOREHOLE						

Notes:

1. Water level at a depth of 2.0 m below ground surface (Elev. 240.3 m) upon completion of drilling.

Chart headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; ELEVATION SCALE 242 241 240 239 238 237 236

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

RECORD OF DRILLHOLE: G4

PROJECT: 12-1191-0014
LOCATION: N 5083287.4 ;E 219114.8
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: July 4, 2013
DRILL RIG: CME 850 Track Mount
DRILLING CONTRACTOR: Landcore Drilling

DATUM: GEODETIC

JN - Joint; FLT - Fault; SHR- 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; MB- Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION
	~SEE PREVIOUS PAGE~	238.5			
4	DOLOMITIC LIMESTONE Fine grained Grey Fresh	3.8	1	GREY 100%	JNIRRo JNIRRo
5			2	GREY 100%	JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo
6			3	GREY 100%	JNIRRo JNIRRo JNIRRo JNIRRo
7	END OF DRILLHOLE	235.2 7.1			

Column headings: DRILLING RECORD; SYMBOLIC LOG; FLUSH; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; DISCONTINUITY DATA (B Angle, DIP w.r.t. CORE AXIS, TYPE AND SURFACE DESCRIPTION, Jr, Ja, Jn); HYDRAULIC CONDUCTIVITY k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); Diametral Point Load Index (MPa); RMC -Q' AVG.; NOTES WATER LEVELS INSTRUMENTATION

Depth scale: 8, 9, 10, 11, 12, 13

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MR
CHECKED: AB

RECORD OF BOREHOLE No G5

 METRIC

PROJECT 12-1191-0014

W.P. 5261-10-01 LOCATION N 5083317.1; E 219114.7 ORIGINATED BY MR

DIST HWY 540 BOREHOLE TYPE 108 mm I.D. Continous Flight Hollow Stem Augers COMPILED BY DAM

DATUM GEODETIC DATE July 4, 2013 CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
242.2	GROUND SURFACE										
0.0	Asphalt (125 mm)										
0.1	Sand to gravelly sand (FILL) Compact Brown Moist		1	AS	-		242				
			2	SS	11		241				
240.8 1.4	END OF BOREHOLE AUGER REFUSAL Notes: 1. Borehole dry upon completion of drilling.										

SUD-MTO 001 1211910014.GPJ GAL-MISS.GDT 16/09/13 DATA INPUT:

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No G6

 METRIC

PROJECT 12-1191-0014

W.P. 5261-10-01 LOCATION N 5083270.7; E 219108.9 ORIGINATED BY MR

DIST HWY 540 BOREHOLE TYPE 108 mm I.D. Continous Flight Hollow Stem Augers COMPILED BY DAM

DATUM GEODETIC DATE July 4, 2013 CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
242.2	GROUND SURFACE										
0.0	ASPHALT (125 mm)										
0.1	Sand, trace gravel (FILL) Brown Moist	1	AS	-							
241.3 0.9	SAND and SILT, some clay, trace to some gravel Loose to compact Brown to grey Moist to wet	2	SS	18		w_P–w–w_L		7	33	40	20
		3	SS	6	∇ (Elev. 240.5)	○	NP	0	53	30	17
		4	SS	5							
		5	SS	7							
238.4 3.8	END OF BOREHOLE AUGER REFUSAL										

Notes:

1. Water level at a depth of 1.7 m below ground surface (Elev. 240.5 m) upon completion of drilling.

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (242, 241, 240, 239); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

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

APPENDIX B

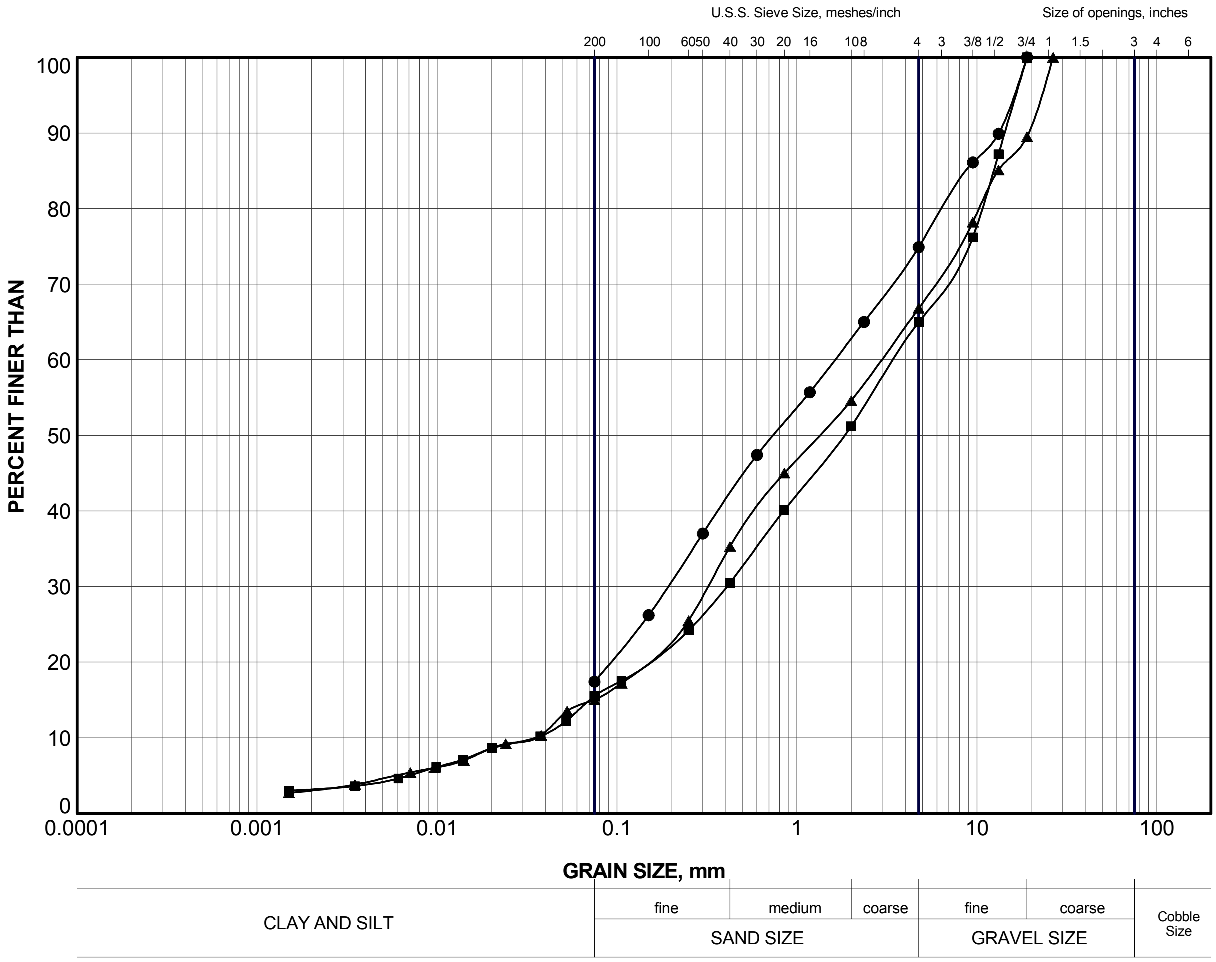
Laboratory Test Results

Table B1 - Summary of Analytical Testing of Creek Water

Parameter	Units	Method Detection Limit	Result
Resistivity	ohm-cm	n/a	2600
Conductivity	µmho/cm	1	390
pH	n/a	n/a	8.30
Sulphate	mg/L	1	Not Detected
Chloride	mg/L	1	2

Notes:
1. Sample obtained August 5, 2013.
2. Analytical testing carried out by Maxxam Analytics Inc.

Prepared by: DAM
Reviewed by: AB



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	G1	2	240.5
■	G2	4A	238.8
▲	G3	3	239.7

PROJECT

HIGHWAY 540
GRAHAM CREEK BRIDGE

TITLE

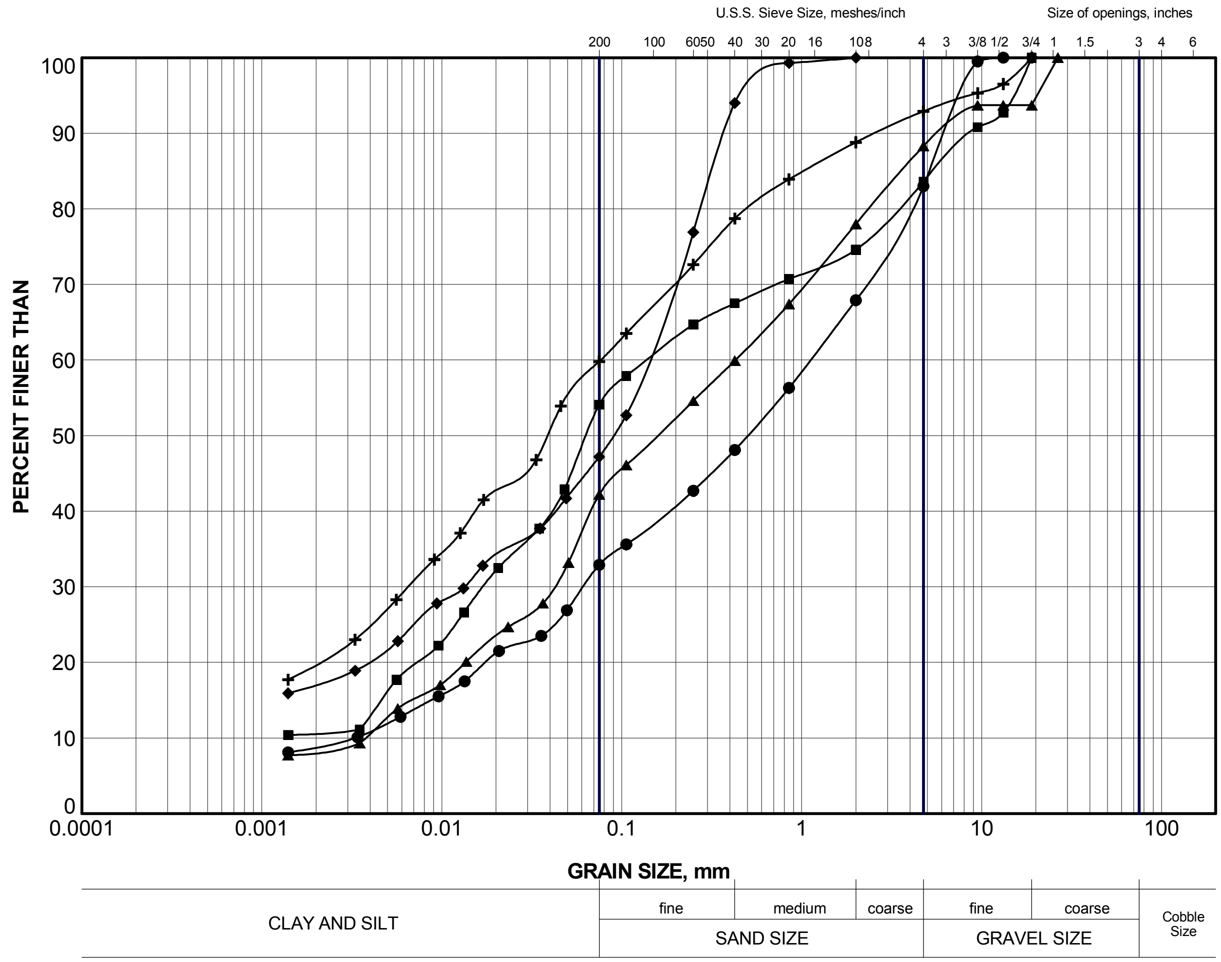
GRAIN SIZE DISTRIBUTION

GRAVELLY SAND to SAND and GRAVEL (FILL)

PROJECT No.	12-1191-0014		FILE No.	1211910014.GPJ
DRAWN	JJL	Sep 2013	SCALE N/A	REV.
CHECK	AB	Sep 2013		
APPR	FJH	Sep 2013	FIGURE B1	

Golder Associates
SUDBURY, ONTARIO

SUD-MTO GSD (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	G2	4B	238.7
■	G3	4	239.0
▲	G4	4B	238.8
+	G6	2	241.1
◆	G6	3	240.4

PROJECT

HIGHWAY 540
GRAHAM CREEK BRIDGE

TITLE

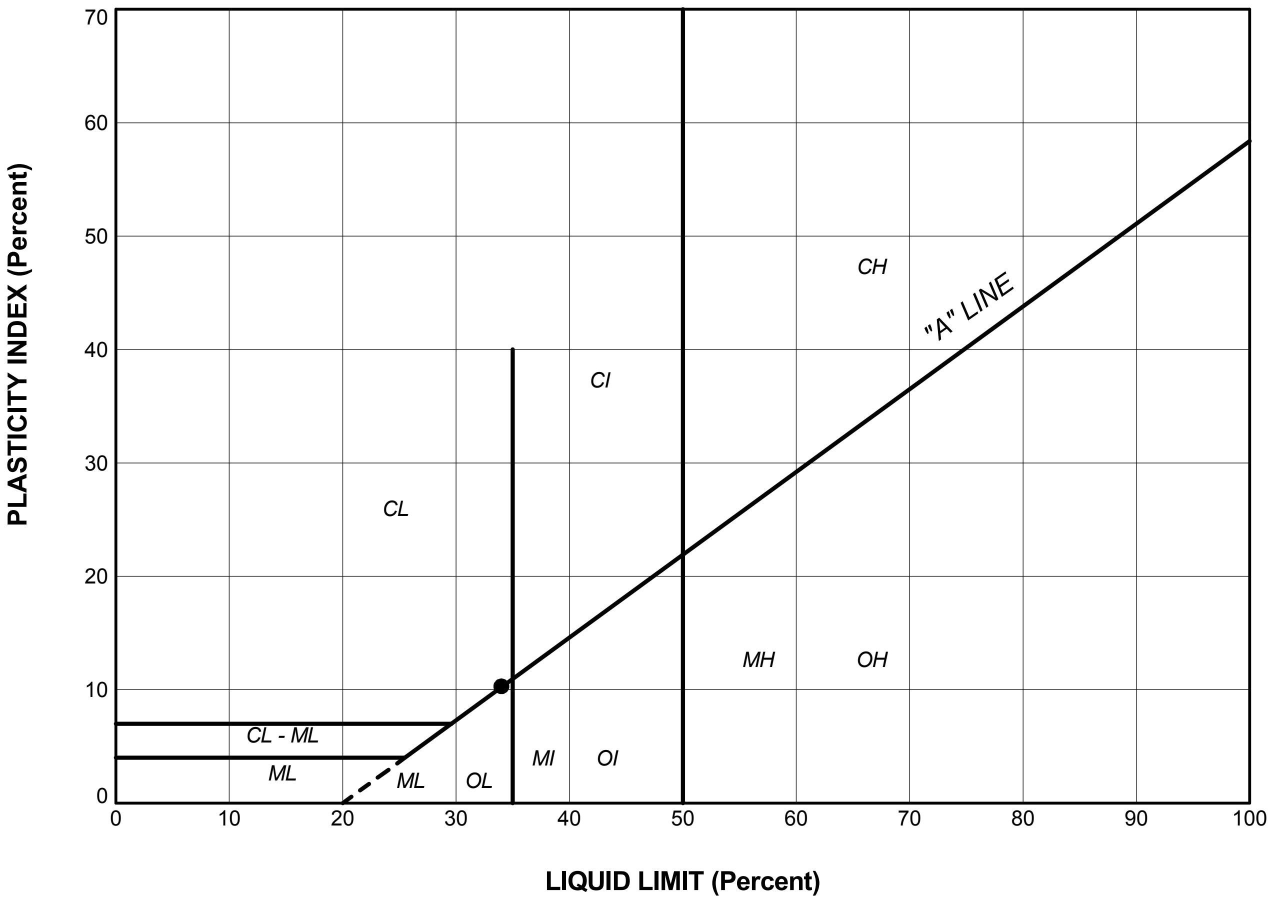
GRAIN SIZE DISTRIBUTION

SILTY SAND to SAND and SILT

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		12-1191-0014	FILE No.	1211910014.GPJ
DRAWN	JJL	Sep 2013	SCALE N/A	REV.
CHECK	AB	Sep 2013		
APPR	FJH	Sep 2013	FIGURE B2	

SUD-MTO GSD (NEW) GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	G6	2	34.0	23.7	10.3

PROJECT	HIGHWAY 540 GRAHAM CREEK BRIDGE				
TITLE	**PLASTICITY CHART** SAND and SILT				
Golder Associates SUDBURY, ONTARIO	PROJECT No.	12-1191-0014		FILE No.	1211910014.GPJ
	DRAWN	JJL	Sep 2013	SCALE N/A	REV.
	CHECK	AB	Sep 2013	**FIGURE B3**	
	APPR	FJH	Sep 2013		

SUD-MTO PL (NEW) GLDR_LDN.GDT

Borehole G1
Elevation 237.8 m to 234.8 m

Borehole G2
Elevation 238.6 m to 235.1 m

Borehole G3
Elevation 237.8 m to 235.0 m

Borehole G4
Elevation 238.5 m to 235.2 m

0 m   0.25 m   0.50 m
0 ft   1 ft   2 ft

PROJECT	HWY 540 GRAHAM CREEK BRIDGE		
TITLE	**BEDROCK CORE**		
PROJECT No.	12-1191-0014		FILE No. ----
DESIGN	DAM	Sept. 2013	SCALE AS SHOWN / REV.
CADD	--		
CHECK	AB	Sept. 2013	**FIGURE B4**
REVIEW	FJH	Sept. 2013	

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APPENDIX C

Non-Standard Special Provisions

WORKING SLAB - Item No.

Non-Standard Special Provision

Scope of Work

This Special Provision covers the requirements for the supply and placement of a concrete working slab for the Graham Creek culvert. The purpose of the working slab is to provide a level working surface above the bedrock.

Construction

Protection of Founding Soil

- Following inspection and approval of the prepared bedrock surface by the Quality Verification Engineer, a working slab, with a minimum thickness of 100 mm shall be placed on the foundation subgrade as per the contract drawings and documents. The concrete shall have a minimum 28 day compressive strength of 20 MPa.

Unwatering of the excavation for the culvert construction may be required, including the construction of the working slab.

Basis of Payment

Payment at the Contract Price for the above tender item includes full compensation for all labour, equipment and material to do the required work.

END OF SECTION

GROUNDWATER CONTROL - Item No.

Non-Standard Special Provision

Foundations for the new Graham Creek culvert will require excavations to extend below the groundwater level at the site. Cohesionless soils (silty sand to sand and silt) that are present below the groundwater table will slough, run, boil or cave into the excavation unless appropriate groundwater controls are in place. The Contractor is to design and install an appropriate dewatering system for the culvert site to enable construction in dry conditions, and prevent disturbance to the founding soils.

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

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
1010 Lorne Street
Sudbury, Ontario, P3C 4R9
Canada
T: +1 (705) 524 6861