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DETAIL FOUNDATION INVESTIGATION AND DESIGN REPORT

ENGLEHART (BLANCHE) RIVER BRIDGE REPLACEMENT
HIGHWAY 573, SITE NO. 47-028
MUNICIPALITY OF CHARLTON AND DACK, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5109-05-00

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REPORT





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PART A

FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to provide detail design services for the replacement of three (3) structures carrying Highway 573 over the Englehart (Blanche) River in the Municipality of Charlton and Dack, Ontario (northwest of Englehart). This report addresses Bridge Site No. 47-028, the most westerly of the three (3) structures.

The Terms of Reference and Scope of Work for the foundation investigation are outlined in MTO's Request for Proposal (RFP) dated October 2011 and Request for Clarification letter, dated December 12, 2011. Golder's proposal P1-1191-0032, dated December 2011, for foundation engineering services associated with the bridge at Site No. 47-028, is contained in Section 6.8 of MH's Technical Proposal that forms part of the Consultant's Agreement Number 5011-E-0009 for this project. The work was carried out in accordance with Golder's Supplementary Specialty Quality Control Plan for this project dated March 22, 2012. The General Arrangement (GA) drawing for the bridge structure was provided to Golder by MH in June 2012.

The purpose of this investigation is to establish the subsurface conditions at the location of the proposed replacement structure by borehole drilling, in situ testing and laboratory testing on selected samples. The location of the site is shown in the key plan on Drawing 1.

Preliminary subsurface information for this project is available and was provided by the MTO, in a report titled:

- Preliminary Foundation Investigation and Design Report, Englehart (Blanche) River Bridge Replacement, Highway 573, Site No. 47-028, GWP 5109-05-00, GEOCRE No. 31M-84, dated May 10, 2010, by Golder Associated Ltd.

2.0 SITE DESCRIPTION

The bridge site is situated in the Township of Charlton and Dack on Highway 573 crossing the Englehart (Blanche) River, approximately 1.1 km west of the junction with Highway 560. The surrounding land use is mainly for recreational activities. The land surface is grass and tree-covered, extending beyond the limits of the site. The banks adjacent to the river are vegetated with landscaped grass and small shrubs, and bedrock is exposed in several areas. The river is a regulated watercourse used for power generation by Kagawong Power Inc. A footbridge crossing the river is located to the north of the existing bridge structure and a water control dam is located about 20 m upstream (south) of the existing bridge. The river flows from south to north.

The existing single-span concrete bridge was constructed in 1927 and has a width of 6.4 m and a span length of 10.5 m. The existing highway grade is between about Elevation 258.1 m and 258.3 m.

3.0 INVESTIGATION PROCEDURES

The fieldwork at the bridge site was carried out on June 9 and between July 8 and July 24, 2012, at which time a total of nine (9) boreholes (BL-1, BL-2, BL-4, BL-5, BL-6, BL-7, BL-8, BR-04, and BR-05) were advanced at the site. Seven (7) boreholes are located at the corners of the bridge abutments, and one (1) borehole located on each of the east and west approach embankments. Four (4) boreholes (BH09-9 to BH09-12) that were drilled on October 7, 2009, at this site as part of the Preliminary Foundation Investigation are also used to supplement



the current subsurface investigation. The locations of the boreholes are summarized in Table 1, shown in plan on Drawing 1, and noted on the respective Record of Borehole sheets in Appendix A. The boreholes were drilled using either a portable D-25 drill rig supplied and operated by Walker Drilling Ltd. of Utopia, Ontario, or a CME 75 truck-mounted drill rig supplied and operated by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec.

The boreholes were advanced using 108 mm inside diameter (I.D.) continuous flight hollow stem augers and NW casing. Soil samples were obtained, where possible, at intervals of depth of 0.75 m, using a 50 mm outer diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586). Auger samples were typically taken just below the asphalt pavement or at the ground surface.

The boreholes were advanced to depths between 0.9 m and 5.8 m below the existing ground surface, including bedrock coring for lengths between 1.8 m and 3.5 m in five (5) boreholes. Boreholes BL-2, BL-6 and BL-7 were located on exposed bedrock and were not cored.

The groundwater conditions in the open boreholes were observed during the drilling operations and a piezometer was installed in Borehole BH09-12 to allow monitoring of the groundwater level at this location. The piezometer consists of a 19 mm O.D. rigid polyvinyl chloride (PVC) tubing with a 1.5 m long-slotted screen and a flush-mounted cap. The water level readings are presented on the Record of Borehole sheets in Appendix A. The boreholes were backfilled with bentonite as per Ontario Regulation 903 (as amended) upon completion of drilling.

Traffic protection was carried out for the boreholes drilled within the roadway in accordance with our Traffic Protection Plan and the MTO Book 7 Temporary Conditions Manual.

The fieldwork was supervised throughout by members of our engineering and technical staff who located the boreholes, arranged for the clearance of underground service locations, supervised the drilling and sampling operations, logged the boreholes, and examined and cared for the soil 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 content and grain size distribution) was carried out on selected soil samples.

The locations of the proposed foundation elements were staked in the field by Callon Dietz relative to the proposed abutment locations based on the dimensions shown on a preliminary drawing provided by MH dated June 2012. Callon Dietz provided the elevations of the staked locations and Golder surveyed the ground surface elevation of the boreholes that were drilled in 2009, referencing an existing benchmark located on the south concrete wing wall between Site Nos.47-030 and 47-029 (BM ONR No. 8010845206). The ground surface and water surface elevations are referenced to Geodetic datum. The northing and easting coordinates (MTM NAD83) were determined by plotting the boreholes relative to the existing bridge on the June 2012 GA provided by MH and converting to the coordinate system. The northing and easting coordinates, ground surface elevations and the borehole depths are summarized below.



Borehole	Borehole Location		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
BH09-9	5297264.8	379552.8	258.2	0.9
BH09-10	5297259.4	379554.0	258.2	2.3
BH09-11	5297257.9	379540.6	258.3	2.5
BH09-12	5297261.0	379540.6	258.1	2.8
BL-1	5297263.0	379537.8	258.4	5.5
BL-2	5297263.7	379541.2	254.5	0.0
BL-4	5297266.7	379554.8	257.2	5.8
BL-5	5297253.3	379539.9	256.7	4.2
BL-6	5297254.0	379543.2	255.4	0.0
BL-7	5297256.2	379553.6	255.1	0.0
BL-8	5297257.0	379556.9	256.3	3.9
BR-4	5297255.0	379528.3	258.3	4.2
BR-5	5297268.3	379574.1	258.2	2.1

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Published literature¹ indicates that the site is located in the transition zone between the Western Abitibi Subprovince of the Superior Province (to the north) and the Huronian Supergroup (to the south). The bedrock geology follows the river valley and consists of mafic metavolcanic rock (Geology of Ontario; OGS Special Volume 4)¹.

Terrain mapping by the Ontario Geological Survey² describes the subsurface soils in the vicinity of the site as silty colluvial slopewash and debris creep sheet with minor talus.

4.2 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 samples, are presented on the attached Record of Borehole sheets in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and observations of drilling progress and of the soil cuttings. 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 on Drawing 1.

¹ Geology of Ontario, 1991. Ontario Geological Survey, Special Volume 4, Part 1. Eds. P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott. Ministry of Northern Development and Mines, Ontario.

² Northern Ontario Engineering Geology Terrain Study, OGS Map Reference Numbers 5020 and 5021.



In general, the subsoils at the structure site consist of asphalt underlain by granular fill and/or rock fill. In one borehole, a 1.4 m thick layer of decomposed wood was encountered below the rock fill to the refusal depth.

A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Asphalt

Boreholes BH09-9 to BH09-12, BR4 and BR-5 were drilled through the pavement and penetrated through an approximately 200 mm to 380 mm thick layer of asphalt. In Boreholes BH09-10, BH09-12, BR-4 and BR-5 interlayers of gravelly sand fill ranging in thickness from 60 mm to 240 mm were encountered between asphalt layers. The ground surface at these boreholes ranges from Elevation 258.3 m to 258.1 m.

4.2.2 Fill

Granular fill and rock fill was encountered underlying the pavement materials in Boreholes BH09-9 to BH09-12, BR-4, and BR-5 and at ground surface in Boreholes BL-1, BL-4, BL-5 and BL-8. The top of the fill was encountered between Elevation 258.4 m and 256.3 m and the total thickness of the granular fill and rock fill, including a layer of wood, is between 0.5 m and 2.5 m.

In Boreholes BL-1, BL-5, BL-8, BR-4, BR-5, BH09-9, BH09-11 and BH09-12, the fill layer was encountered below the asphalt and is between 0.1 m and 1.0 m thick. It is comprised of sandy gravel to gravelly sand fill containing trace silt and trace organics. Underlying the asphalt or granular fill or at ground surface, Boreholes BL-1, BL-4, BH09-9, BH09-10, BH09-11 and BH09-12, and BR-4 encountered rock fill in a gravelly sand to sand and gravel matrix. Wood was encountered dispersed within the rock fill in Borehole BH09-12 and a 1.4 m thick layer of partially decomposed wood was encountered below the rock fill in this borehole at Elevation 256.7 m. The augers were noted to be sliding to the east in Borehole BH09-12 during advancement of the lower 0.4 m.

Grinding of the augers was noted during advancement through the fill material in Boreholes BH09-9 and BH09-10, located on the proposed east abutment. Empty split-spoons were recovered within the rock fill in Borehole BH09-10 and there was an absence of auger cutting returns between the depths of 0.8 m and 2.3 m below ground surface, indicating the presence of voids within the rock fill.

SPT 'N'-values measured within the sand and gravel fill and rock fill range from 4 blows to 43 blows per 0.3 m of penetration, indicating a loose to dense relative density. In Boreholes BR-4 and BR-5, SPT 'N'-values of 87 blows and 45 blows per 0.3 m of penetration were measured as the split-spoon sampler penetrated an asphalt interlayer. In some boreholes, the split-spoon sampler did not penetrate the full sampler depth and was noted to be bouncing on rock fill material or inferred bedrock.

The natural water content measured on samples of the granular fill and rock fill ranges between about 3 per cent and 10 per cent.

Grain size distributions for three samples of the sandy gravel to sand and gravel fill are shown on Figure B-1 in Appendix B.



The natural water content measured on two samples of the decomposed wood layer in Borehole BH09-12 are about 130 per cent and 304 per cent and the organic content of these two samples is 36 per cent and 83 per cent, respectively.

4.2.3 Silty Sand

In Borehole BR-5, a 0.4 m thick layer of wet, brown silty sand containing trace gravel was encountered underlying the granular fill at Elevation 256.5 m.

An SPT 'N'-value measured in the silty sand deposit is 8 blows per 0.3 m of penetration indicating a loose relative density.

A grain size distribution test was carried out on the sample of silty sand and the results are shown on Figure B-2.

The natural moisture content measured on the sample of silty sand is 20 per cent.

4.2.4 Bedrock/Refusal

Bedrock was encountered and cored for core lengths between 3.2 m and 3.5 m in Boreholes BL-1, BL-4, BL-5 and BL-8 and 1.8 m in Borehole BR-4. Bedrock was exposed in Boreholes BL-2, BL-6 and BL-7. The presence of bedrock was inferred from auger and/or sampler refusal in Boreholes BH09-10 to BH09-12. Borehole BH09-9 is inferred to have terminated in the rock fill. In Borehole BH09-12, located on the east side of the river, the augers were observed to be sliding to the east on inferred bedrock between about 2.4 m and 2.8 m below ground surface. The inferred bedrock surface/refusal was encountered at the depths and elevations presented below.

Location	Borehole	Depth to Refusal (m)	Refusal/Bedrock Surface Elevation (m)	Comments
West Approach	BR-4	2.4	255.9	Bedrock Cored
West Abutment	BL-1	2.3	256.1	Bedrock Cored
	BL-2	0.0	254.5	Exposed Bedrock
	BL-5	0.8	255.9	Bedrock Cored
	BL-6	0.0	255.4	Exposed Bedrock
	BH09-11	2.5	255.8	Auger refusal on inferred bedrock surface
	BH09-12	2.8	255.3	Augers sliding east possibly on sloping bedrock, from 2.4 m to 2.8 m depth; auger and spoon refusal on inferred bedrock surface
East Abutment	BH09-9	0.9	257.3	Auger and spoon refusal on rock fill
	BL-4	2.3	254.9	Bedrock Cored
	BL-7	0.0	255.1	Exposed Bedrock
	BL-8	0.5	255.8	Bedrock Cored
	BH09-10	2.3	255.9	Auger refusal on inferred bedrock surface
East Approach	BR-5	2.1	256.1	Auger refusal on inferred bedrock surface



Based on a review of the bedrock core samples, the bedrock at the site generally consists of fine grained, slightly weathered, massive to weakly foliated, grey mafic intrusive.

The Total Core Recovery (TCR) is 100 per cent for all core samples. The Solid Core Recovery (SCR) ranges from about 30 per cent to 94 per cent. Rock Quality Designation (RQD) values measured on the recovered bedrock core samples range from 44 per cent to 100 per cent, indicating that the rock is of poor to excellent quality in accordance with Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006)³. In Borehole BR-4, SCR and RQD values of 0 per cent were measured in the uppermost approximately 0.3 m core drill run.

Laboratory unconfined compressive strength (UCS) testing was carried out on four core samples of the bedrock. The UCS values, presented on the Record of Drillhole sheets in Appendix A and summarized below, indicate that the bedrock is very strong ($R5, 100 \text{ MPa} < \text{UCS} < 250 \text{ MPa}$) in accordance with Table 3.5 of CFEM (2006).

Borehole/ Core Run	Elevation (m)	UCS (MPa)
BL-1/#2	255.3	152
BL-4/#2	253.4	124
BL-5/#3	253.2	147
BL-8/#2	254.5	200

Exposed bedrock within the river channel in the vicinity of the existing bridge appears to be mafic intrusive which is consistent with the geology of the area. The bedrock surface is relatively flat between the dam upstream of the existing bridge and the existing bridge and is sloping downwards towards the river to the north through the river channel.

4.2.5 Groundwater Conditions

In general, the soil/fill samples taken in the boreholes were moist to wet. The boreholes advanced during the preliminary foundation investigation phase of the project were dry upon the completion of drilling. A piezometer was installed in Borehole BH09-12 and the piezometer was dry on November 26, 2009. The boreholes advanced for the detail foundation investigation encountered a water level located near the bedrock surface or within the bedrock, ranging from Elevation 256.2 m to 254.3 m, measured at depths ranging from 0.9 m to 3.7 m below ground surface. The water level in the river, measured by others in September 2009, was Elevation 255.4 m at the location of the existing bridge. The river water level for a 50-year storm event is Elevation 257.2 m and for a 1000-year storm event is Elevation 258.5 m, as provided by MH in December 2012.

5.0 CLOSURE

The field drilling program was supervised by Mr. Ed Savard and Mr. Indulis Dumpis. This report was prepared by Mr. Evan Childerhose, P.Eng. An independent quality control review of the report was provided by Mr. Jorge M.A. Costa, P.Eng., Principal and Golder's Designated MTO Contact for this project.

³ Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition.




Report Signature Page

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PART B

FOUNDATION DESIGN REPORT
ENGLEHART (BLANCHE) RIVER BRIDGE REPLACEMENT
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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the detail design of the proposed new Highway 573 replacement structure crossing the Englehart (Blanche) River (Site No. 47-028), which is the westernmost bridge in a series of three bridges west of Highway 560. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to carry out the design of the structure foundations and approach embankments. Where comments are made on construction, they are provided in order to highlight those aspects that could affect the design of the project. Those requiring information on the aspects of construction should 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

We understand that the existing bridge carrying Highway 573 over the Englehart (Blanche) River is a single-span concrete bridge with a width of 6.4 m and a span length of 10.5 m and was constructed in 1927. A footbridge crossing the River is located to the north of the existing bridge structure and a dam is located about 20 m upstream (i.e. south) of the existing bridge.

We understand that it is proposed to replace the existing structure with an 8 m wide, 14 m long single-span bridge, to be located on approximately the existing bridge centreline alignment. The proposed grade is Elevation 258.3 m, which is about the same as the existing highway grade.

The subsurface conditions in the immediate vicinity of the existing structure generally consist of asphalt underlain by granular fill and/or rock fill. A layer of partially decomposed wood was encountered below the rock fill in one borehole. At the investigated locations for the proposed abutments, the overburden thickness ranges between 0 m (exposed bedrock) and 2.8 m, with the ground surface at between Elevation 258.4 m and 254.5 m. The bedrock surface, or refusal to further auger advancement, varies between about Elevation 256.1 m and 254.5 m.

Given the shallow depth to bedrock and the poor quality of the overburden soils, we recommend founding the bridge abutments on shallow spread footings placed directly on the prepared bedrock surface. Deep foundations are not considered practical at this site due to the shallow thickness of overburden and the non-homogenous composition and inconsistent (loose to dense) relative density of the rock fill material comprising the immediate approach embankments adjacent to the existing abutments. The advantages, disadvantages, relative costs and risks/consequences of foundation alternatives are summarized in Table 1, following the text of this report. A discussion on the preferred alternative (shallow foundations) is presented below.



6.2 Shallow Foundations

We recommend supporting the bridge abutments on spread footings placed directly on the properly prepared bedrock surface. Based on the results of the borehole investigation, the variability in the bedrock surface across the foundation elements is about 1.4 m at the west abutment and 0.8 m at the east abutment. The bedrock surface elevations at the borehole locations, as well as the recommended founding elevations, are presented below. The bedrock elevations will vary between and beyond the borehole locations at each site.

Foundation Element	Range of Bedrock Elevation (m)	Recommended Founding Elevation (m)	Proposed Underside of Footing shown on GA Drawing (m)
West Abutment	256.1 to 254.5	256.1	255.6
East Abutment	255.9 to 255.1	255.9	255.8

The recommended founding elevations given above imply that the foundation level would need to be raised to the highest bedrock elevation in places using mass concrete of the same compressive strength as the footings. Alternatively, the existing bedrock surface could be exposed and excavated to the lowest bedrock elevation or to a convenient intermediate elevation such as the proposed underside of the footings, as shown on the GA drawing to found the footings below the upper weathered zone, avoiding or reducing the need for mass concrete but requiring a deeper/higher abutment stem wall. A higher foundation elevation would require additional mass concrete. The footings should be constructed “in-the-dry”. Details of mass concrete placement and bedrock preparation are given in Section 6.5.4.

6.2.1 Geotechnical Axial Resistance/Reaction

For spread footings placed on the properly prepared bedrock surface, which is assumed to be very strong mafic intrusive bedrock, or on mass concrete of the same compressive strength as the footings, a factored geotechnical axial resistance at Ultimate Limit States (ULS) of 10 MPa may be used for design. The geotechnical axial reaction at Serviceability Limit States (SLS) for 25 mm of settlement will be greater than the factored geotechnical axial resistance at ULS since the bedrock is considered to be an unyielding material and therefore, ULS conditions will govern for this foundation type. In order to provide a level surface for the footings, the bedrock should be exposed, loosened material removed and the surface cleaned.

The geotechnical axial resistances provided above are for loads applied perpendicular to the surface of the footings, and where applicable inclination of the load should be taken into account in accordance with Section 6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC 2006)* and its *Commentary*.

6.2.2 Resistance to Lateral Loads

Resistance to lateral forces/sliding resistance between the base of the mass concrete or cast-in-place concrete footings and the bedrock subgrade should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The coefficient of friction, $\tan \delta$, may be taken as 0.70 between the cast-in-place concrete footing or mass concrete and the properly prepared bedrock surface for construction “in-the-dry”. For pre-cast concrete units placed over mass concrete, $\tan \delta$ may be taken as 0.6. These values represent an unfactored value.



If necessary, the sliding resistance between the concrete footing or mass concrete and the bedrock can be supplemented by dowelling into the bedrock or the pre-cast concrete units and the mass concrete. The horizontal resistance of the dowels is dependent on the strength of the bedrock, grout and steel. For this site, where the rock mass is essentially as strong as or stronger than concrete, the design of the dowels in the rock may be handled in the same way as the dowel embedment into the concrete. This assumes that the UCS of the grout will be similar to that of the concrete. The dowels should have a minimum embedded length within the bedrock and/or mass concrete of 1 m, and the structural strength of the dowel and compressive strength of the grout should not be exceeded. If dowelling into mass concrete or bedrock is adopted at this site, an NSSP should be included in the Contract Documents to specify the installation, materials and testing of the dowels (an example is provided in Appendix C).

Consideration should also be given to the proximity of the existing upstream water control dam to the new bridge footings and any potential lateral loading on these footings that might develop due to the water column that might be “retained” behind the footings.

6.2.3 Frost Protection

For spread footings founded directly on the bedrock at this site, frost susceptibility is not an issue.

6.3 Lateral Earth Pressures for Design

The lateral earth pressures acting on the abutment stems and any associated wing/retaining walls will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls. Seismic (earthquake) loading must also be taken into account in the design.

6.3.1 Static

The following recommendations are made concerning the design of the abutment stem and wing/retaining walls. It should be noted that 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 Special Provision (SP) 110S13 (Aggregates) Granular ‘A’ or Granular ‘B’ Type II but containing less than 5 per cent passing the No. 200 sieve size should be used as backfill behind the walls. This fill should be compacted in loose lifts not greater than 200 mm thick to 95 percent of the material’s Standard Proctor maximum dry density in accordance with OPSS 501 (Compacting). 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 Ontario Provincial Standard Drawings (OPSD) 3101.150 (Walls Abutment, Backfill) and 3121.150 (Walls Retaining, Backfill).



- For structures that are not comprised of integral or semi-integral abutments, rock fill may be used as backfill behind the walls, and the material should meet the specifications outlined in the Northern Region Directive for backfill to structures adjacent to rock fill embankments, dated November 2002. Other aspects of rock backfill requirements should be in accordance with OPSD 3101.200 (Walls Abutment, Backfill, Rock).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the wall stem, 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.
- The granular fill may be placed either in a zone with width equal to at least 2.4 m behind the back of the wall stem (as outlined on Figure C6.20(a), of the Commentary to the CHBDC) for a restrained wall or 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 base of the footing/pile cap (as outlined in Figure C6.20(b), of the Commentary to the CHBDC) for an unrestrained wall.
- For a restrained wall, the pressures are based on the proposed embankment fill materials and the existing overburden soils and the following parameters (unfactored) may be used for granular fill or rock fill:

	Granular Fill	Rock Fill
Soil unit weight:	21 kN/m ³	19 kN/m ³
Coefficients of static lateral earth pressure:		
Active, K_a	0.31	0.22
At rest, K_o	0.47	0.35

- For an unrestrained wall, the pressures are based on the rock fill as above, or on the granular fill as placed, and the following parameters (unfactored) may be assumed:

	Granular 'A'	Granular 'B' Type II
Soil unit weight:	22 kN/m ³	21 kN/m ³
Coefficients of static lateral earth pressure:		
Active, K_a	0.27	0.27
At rest, K_o	0.43	0.43

If the wall support and superstructure allow lateral yielding of the stem, active earth pressures may be used in the geotechnical design of the structure. If the abutment support does 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, should be calculated in accordance with Section C6.9.1 and Table C6.6 of the Commentary to the CHBDC:

- rotation (i.e. ratio of wall movement to wall height) of approximately 0.002 about the base of a vertical wall;
- horizontal translation of 0.001 times the height of the wall; or
- a combination of both.



A restrained structure is typically a rigid frame bridge where the rotational and/or horizontal movement is not sufficient to mobilize the active earth pressure condition. For this condition, an at-rest pressure plus any compaction surcharge should be included in the design of the structure.

6.3.2 Dynamic

The potential for seismic (earthquake) loading must also be considered for the design of abutment stems/retaining walls in accordance with Section 4.6 of the *CHBDC* (if applicable). In this regard, the following should be taken into account in the lateral earth pressures.

- Seismic loading may result in increased lateral earth pressures acting on the abutment stem and retaining walls. The walls should be designed to withstand the combined lateral loading for the appropriate static pressure conditions given above, plus the earthquake-induced dynamic earth pressure. The site-specific zonal acceleration ratio for the Englehart area is 0.05 (Table A3.1.1, *CHBDC*). According to Table C4.2 of the *CHBDC*, this site is located in Seismic Zone 1. Based on experience, for the subsurface conditions at this site, there will be no amplification of the ground motion (i.e. Site Coefficient, $S=1.0$), resulting in a peak horizontal acceleration (PHA) of 0.05g.

Since this highway route/bridge is not designated as a lifeline bridge, based on Section 4.4.4 of the *CHBDC*, this bridge structure is assigned to Seismic Performance Zone 1. Given this, and in accordance with Section 4.4.5.1 of the *CHBDC*, structures located in Seismic Performance Zone 1 need not be analysed for seismic loads.

6.4 Approach Embankment Design

The existing bridge will be replaced with a similar size bridge and located along the same alignment as the existing bridge, with a final grade about the same as the existing highway (i.e. Elevation 258.3 m). The existing embankment side slopes are at about 1.5H:1V.

6.4.1 Subgrade Preparation and Embankment Construction

The thickness of asphalt measured in the boreholes (between 200 mm and 380 mm) and interlayering with gravelly sand fill suggests that asphalt padding has taken place in the past, although there were no visual observations of padding at the existing pavement surface. The need for, and occurrence of, padding of the pavement is consistent with the soil conditions encountered in the boreholes, specifically the presence of organics (wood) and rock fill containing voids. We therefore recommend that all existing fill and native soil be removed and replaced with granular fill or rock fill in accordance with SP 206S03 (Earth Excavation, Grading; Rock Excavation, Grading; Rock Embankment).

Embankments could be constructed of granular fill with side slopes 2H:1V or of rock fill constructed with side slopes 1.25H:1V. If granular fill is used, it should be free-draining (i.e. SP 110S13 (Aggregates) Granular 'B' Type II, Granular 'A' or Select Subgrade Material) to ensure no build-up of excess pore pressure within the fill given the presence of the adjacent reservoir and groundwater level which may be close to the bedrock surface. Granular 'B' Type I is not recommended due to the potential for a high variability in gradation or potential for



supply of gap graded or uniform (poorly) graded material, which could result in potential post-construction settlement.

The abutment front slopes and any section of the side slopes adjacent to the river require erosion protection. Given the potentially high flow velocities in the river, especially during discharges from behind the adjacent water control dam, special considerations should be given to erosion protection measures. Erosion protection should be placed on the slopes to at least 0.5 m above the design high water level, however, erosion protection may likely have to extend to near the underside of the bridge deck. Erosion protection is further important since all the foundation elements of the bridge are proposed to be pre-cast and will be founded directly on the prepared bedrock surface or mass concrete over bedrock.

Erosion protection could consist of a multi-layer rip-rap and/or rock protection system. Rip-rap and rock protection gradation should be in accordance with OPSS.PROV 1004 (Material Specification for Aggregates-Miscellaneous). The lower layer of rip-rap should consist of R-10 size, while the upper layer should consist of R-50 size rip-rap. Further, a layer of large sized rock protection could be placed over the rip-rap layers where the flow velocities are the highest. As a minimum, rip-rap and/or rock protection treatment should be consistent with the standard detailed in OPSS 511 (Construction Specification for Rip-Rap, Rock Protection and Granular Sheetting). The requirements for, and design of, erosion protection measures (number and thickness of layers, gradation, placement, etc.) for the abutment front and relevant side slopes should be assessed by the hydraulic design engineer.

Embankment fill should be placed and compacted in accordance with SP 206S03 (Earth Excavation, Grading) and OPSS 501 (Compacting). To reduce erosion of the embankment side slopes (if constructed with granular material) due to surface water runoff, placement of topsoil and seeding or pegged sod is recommended as soon as practicable after construction of the embankments. The erosion protection should be in accordance with OPSS 572 (Seed and Cover).

6.4.2 Approach Embankment Stability

For embankments constructed directly on the bedrock surface and comprised of granular fill or rock fill for the anticipated embankment thickness up to 2.5 m, there are no stability issues at this site.

6.4.3 Approach Embankment Settlement

Given the results of the borehole investigation, the layered nature of the asphalt pavement suggests that padding was carried out at the existing abutments, potentially indicating past/ongoing settlement of the existing fill and any underlying native materials behind the abutments. The borehole investigation for this bridge encountered between 200 mm and 380 mm of asphalt and granular layers, which is considered a significant thickness of pavement structure. Provided that all existing fill and native materials are removed and replaced with properly placed/compacted granular fill or rock fill, settlement of the approach embankments at this site should be less than 25 mm and should occur during and shortly after construction.



6.5 Detail Design and Construction Considerations

6.5.1 Excavations

Excavations for shallow foundations (footings) to depths of up to 2.8 m below existing ground surface will be made through rock fill (containing voids), granular fill and potentially wood/organics and should be in accordance with OPSS902 (Excavating and Backfilling – Structures). The overburden soils are considered Type 3 soil according to the Occupational Health and Safety Act and Regulation for Construction Projects (OHSA). The excavation work should be carried out in accordance with the requirements of the OHSA, with side slopes no steeper than 1H:1V and good construction practice.

6.5.2 Groundwater and Surface Water Control for Foundation Excavation

It is likely that groundwater will be flowing along the sloping surface of the bedrock from south (i.e. from the reservoir located upstream of the bridge) to north. Fluctuating water levels and flowing groundwater conditions due to the proximity of the bridge site to the local reservoir should be taken into consideration. As such, a suitable dewatering scheme in conjunction with temporary shoring may be required to maintain a dry and stable excavation during construction, including for the placement of mass concrete “in-the-dry”.

6.5.3 Temporary Shoring

Given that the ground surface slopes downwards on both sides of the embankments, temporary shoring may not be required to construct the footings at this site. If required, installation of steel sheet-piling will likely not be possible given the composition of the existing embankment (i.e. rock fill in a sandy gravel to sand and gravel matrix). Other shoring methods, such as a soldier pile and lagging system, with the piles drilled and socketted into the bedrock, may be required.

6.5.4 Footing Subgrade Preparation

All loose, shattered and/or fractured rock within the footprint of the footings at the founding level should be removed and replaced with mass concrete in accordance with OPSS 902 (Excavating and Backfilling - Structures). Where mass concrete is used to level the founding area, it should be of the same compressive strength as will be used for the actual footing. If bedrock excavation is required to level the founding area, it should be carried out using controlled blasting techniques (i.e. line drilling, pre-shearing or cushion blasting) in order to minimize shattering and overbreak resulting from blast damage to the rock mass.

6.5.5 Obstructions

As noted above, the existing embankments, particularly on the west side, are comprised of rock fill in a sandy gravel matrix and potentially containing voids. Large fragments of rock fill could be present within the fill. Further, wood was encountered at the base of the fill in one of the boreholes. All of these materials should be easily excavated by conventional construction equipment.



7.0 CLOSURE

This report was prepared by Mr. Evan Childerhose, P.Eng. Mr. Jorge Costa, P.Eng., Principal and Golder's Designated MTO Contact for this project, conducted an independent quality control review of the report.



Report Signature Page

GOLDER ASSOCIATES LTD.



Evan Childerhose, P.Eng.
Geotechnical Engineer



Jorge M.A. Costa, P.Eng.
Designated MTO Contact, Principal

EC/JMAC/cl

[http://capws.golder.com/sites/p111910032mtoblanch3bridges/reports/47-028/final/11-1191-0032-1 final rpt 13jan14 detail fdr site 47-028.docx](http://capws.golder.com/sites/p111910032mtoblanch3bridges/reports/47-028/final/11-1191-0032-1%20final%20rpt%2013jan14%20detail%20fdr%20site%2047-028.docx)



REFERENCES

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

Occupational Health and Safety Act and Regulation for Construction Projects, January 2006.

Ontario Provincial Standard Specifications

- OPSS 501 Construction Specification for Compacting
- OPSS 511 Construction Specification for Rip-Rap, Rock Protection and Granular Sheetting
- OPSS 572 Construction Specification for Seed and Cover
- OPSS 902 Construction Specification for Excavating and Backfilling Structures
- OPSS.PROV 1004 Material Specification for Aggregates - Miscellaneous

Ontario Provincial Standard Drawings

- OPSD 3101.150 Walls Abutment, Backfill, Minimum Granular Requirement
- OPSD 3101.200 Walls Abutment, Backfill, Rock
- OPSD 3121.150 Walls Retaining, Backfill, Minimum Granular Requirement

Ministry of Transportation Ontario Special Provisions

- SP 110S13 Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill
- SP 206S03 Earth Excavation, Grading; Rock Excavation, Grading; Rock Embankment

Northern Region Directive; Backfill to Structures Adjacent to Rock Embankment Approaches, November 2002

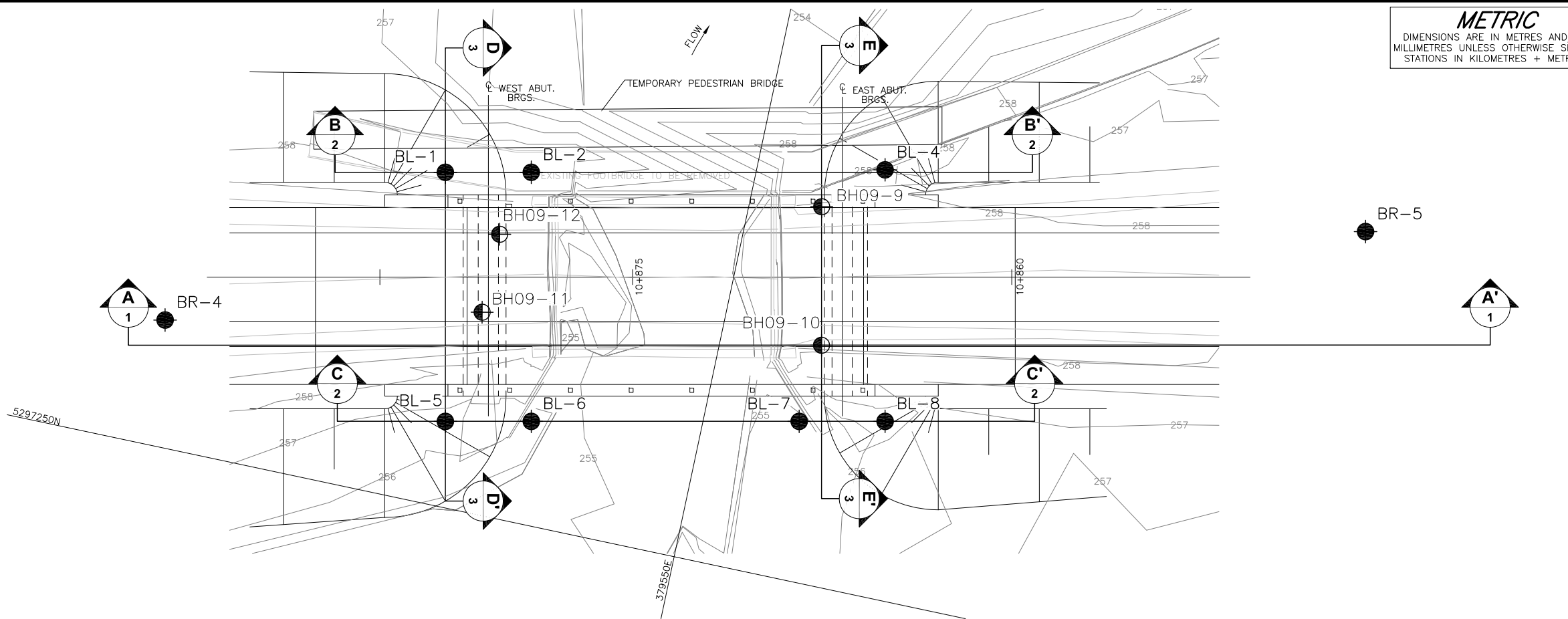


**FOUNDATION REPORT - ENGLEHART (BLANCHE) RIVER
BRIDGE REPLACEMENT - HIGHWAY 573, SITE 47-028, GWP 5109-05-00**

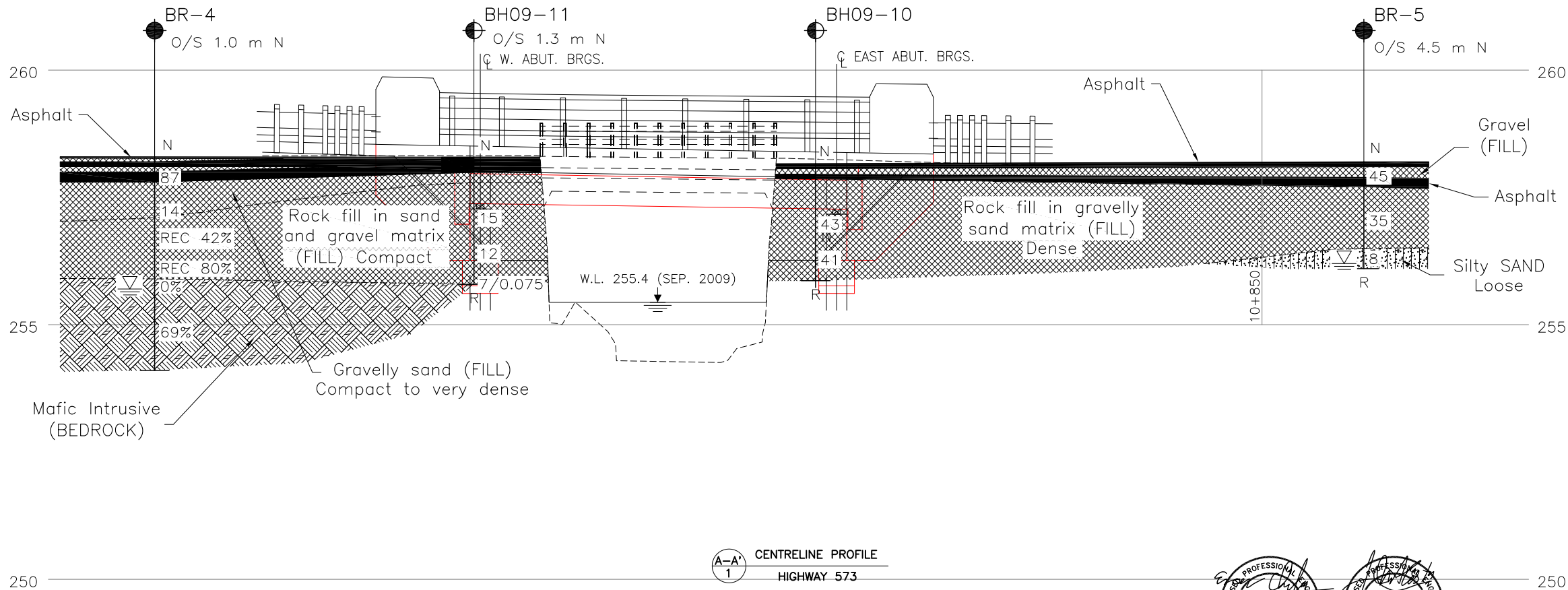
Table 1: Evaluation of Bridge Foundation Alternatives

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Steel H-Piles or Caissons Socketted into Bedrock	NF	<ul style="list-style-type: none"> ■ Straightforward/conventional construction. ■ Allows for integral abutment structure construction in the case of steel H-Piles being provided with adequate length (≥ 5 m). ■ Reduced number of caisson elements compared to steel H-piles. 	<ul style="list-style-type: none"> ■ Granular material required for embankment construction between rock surface and underside of pile cap. ■ Varying pile lengths and requirement to drill for sockets/trenches into very strong bedrock. ■ Caissons preclude integral abutment design. ■ Difficult socketting or trenching for piles or socketting caissons into very strong bedrock. 	<ul style="list-style-type: none"> ■ Lower relative costs compared with caisson option (\$15,000 for 6 m long piles and 10 piles per abutment). ■ Cost much higher than for H-piles (\$75,000 for 6 m long x 1.2 m diameter caissons socketted min. 2 m, 5 caissons per abutment). 	<ul style="list-style-type: none"> ■ Difficulties in socketting into very strong bedrock. ■ Potentially greater maintenance level required at abutments if caisson foundations used instead of piles.
Shallow Foundations	1	<ul style="list-style-type: none"> ■ Relative straightforward construction. ■ Founded directly on bedrock or on mass concrete on bedrock which provides for suitable geotechnical axial resistances ■ Use of pre-cast footing units may reduce duration during which excavations are open. 	<ul style="list-style-type: none"> ■ Precludes integral abutment design. ■ Requires either rock removal or mass concrete to achieve a level foundation surface. 	<ul style="list-style-type: none"> ■ Less expensive than deep foundations although bridge construction/maintenance costs may be higher due to non- integral abutment configurations (\$110,000 for 15 m x 4.5 m x 1.5 m footings per abutment). ■ Cost of mass concrete or bedrock removal. 	<ul style="list-style-type: none"> ■ Potentially greater maintenance level required at abutments. ■ Hard bedrock likely difficult to excavate.

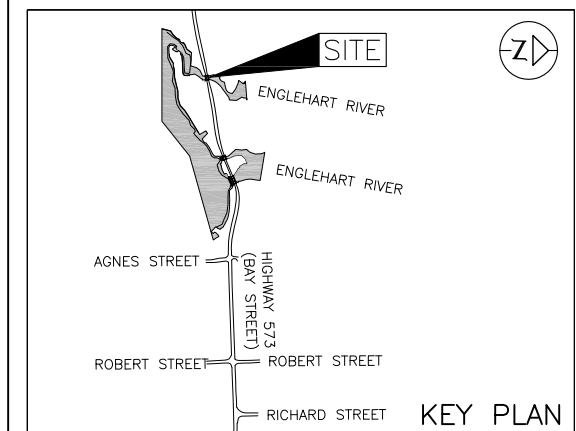
Note: NF – considered “Not Feasible” due to need for socketting such foundation elements into very strong bedrock (compared to shallow foundations on bedrock/mass concrete).



PLAN

SCALE
0 2 mA-A' 1 CENTRELINE PROFILE
HIGHWAY 573HORIZONTAL SCALE
0 2 4 m
VERTICAL SCALE
0 1 2 m**METRIC**
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.CONT No.
WP No. 5109-05-00ENGLEHART (BLANCHE) RIVER
HIGHWAY 573 BRIDGE 47-028
BOREHOLE LOCATION AND SOIL
STRATA

SHEET

**Golder Associates Ltd.**
SUDBURY, ONTARIO, CANADA

LEGEND

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

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
BL-1	258.4	5297263.0	379537.8
BL-2	254.5	5297263.7	379541.2
BL-4	257.2	5297266.7	379557.8
BL-5	256.7	5297253.3	379539.9
BL-6	255.4	5297254.0	379543.2
BL-7	255.1	5297256.2	379553.6
BL-8	256.3	5297257.0	379556.9
BR-4	258.3	5297255.0	379528.4
BR-5	258.2	5297268.3	379574.1
BH09-9	258.2	5297264.8	379552.8
BH09-10	258.2	5297259.4	379554.0
BH09-11	258.3	5297257.9	379540.6
BH09-12	258.1	5297261.0	379540.6

NOTES

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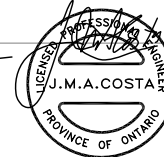
The boundaries between soil strata have been established only at borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

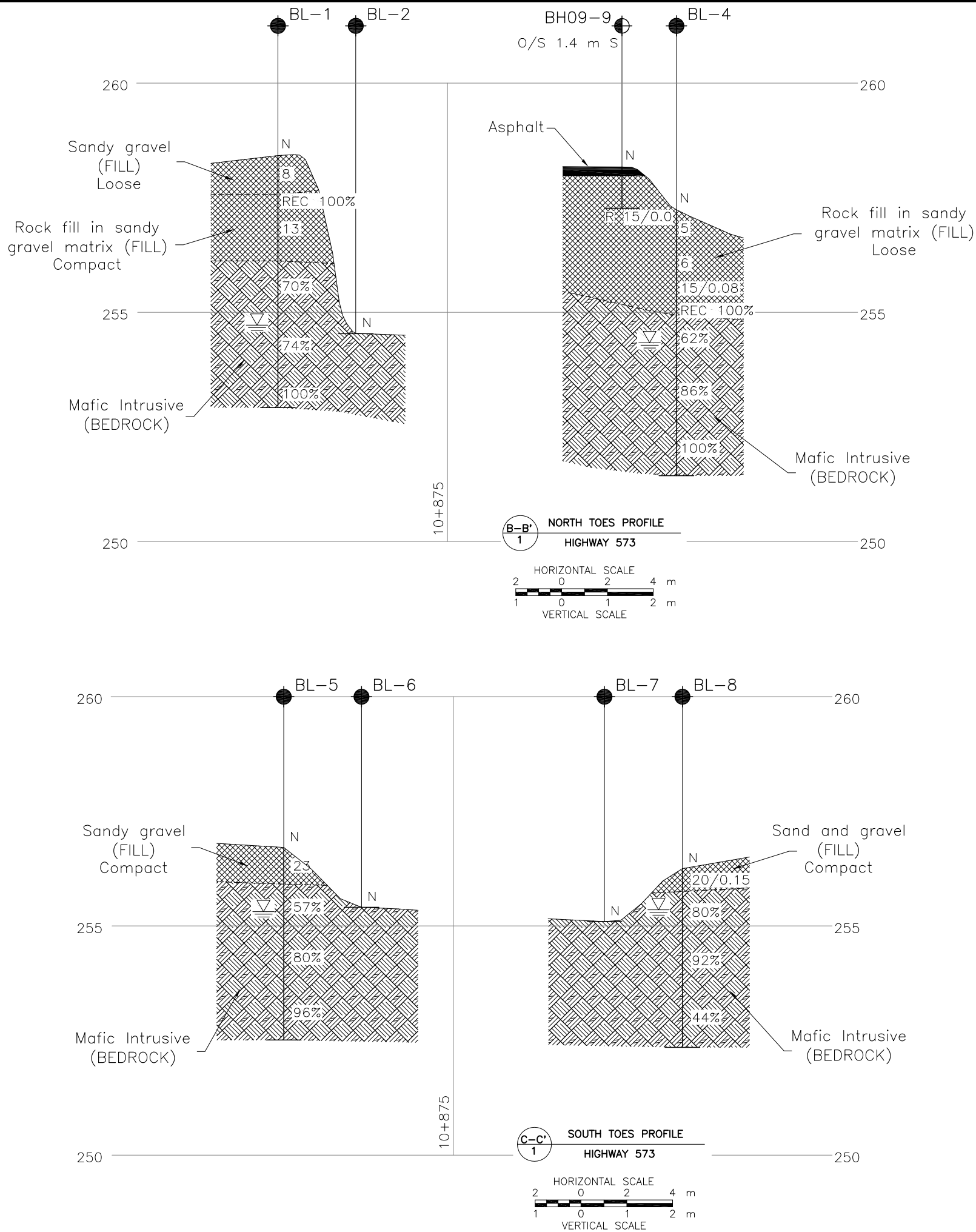
The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS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

REFERENCE

Base plans provided in digital format by Morrison Hershfield, drawing file nos. 47028-01.dwg, received June 13, 2012.

NO.	DATE	BY	REVISION
1	DEC 2012	JMAC	ISSUED FOR CONSTRUCTION
Geocres No. 31M-98			
HWY. 573	PROJECT NO. 11-1191-0032		DIST.
SUBM'D. EC	CHKD. SEMC	DATE: DEC 2012	SITE: 47-028
DRAWN: TB	CHKD.	APPD. JMAC	DWG. 1



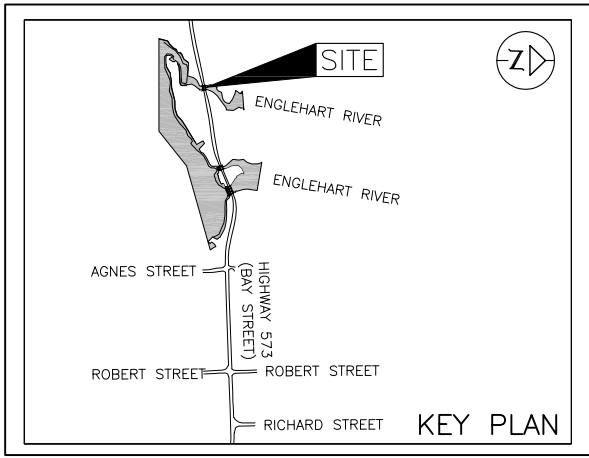





METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5109-05-00

ENGLEHART (BLANCHE) RIVER
HIGHWAY 573 BRIDGE 47-028
BOREHOLE LOCATION AND SOIL
STRATA

Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



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

No.	ELEVATION	CO—ORDINATES	
		NORTHING	EASTING
BL-1	258.4	5297263.0	379537.8
BL-2	254.5	5297263.7	379541.2
BL-4	257.2	5297266.7	379557.8
BL-5	256.7	5297253.3	379539.9
BL-6	255.4	5297254.0	379543.2
BL-7	255.1	5297256.2	379553.6
BL-8	256.3	5297257.0	379556.9
BH09-9	258.2	5297264.8	379552.8

NOTES

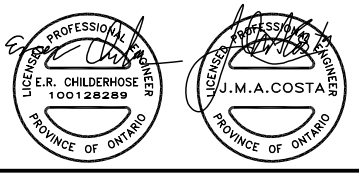
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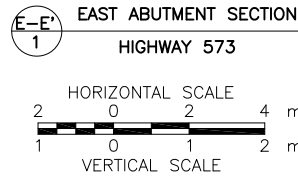
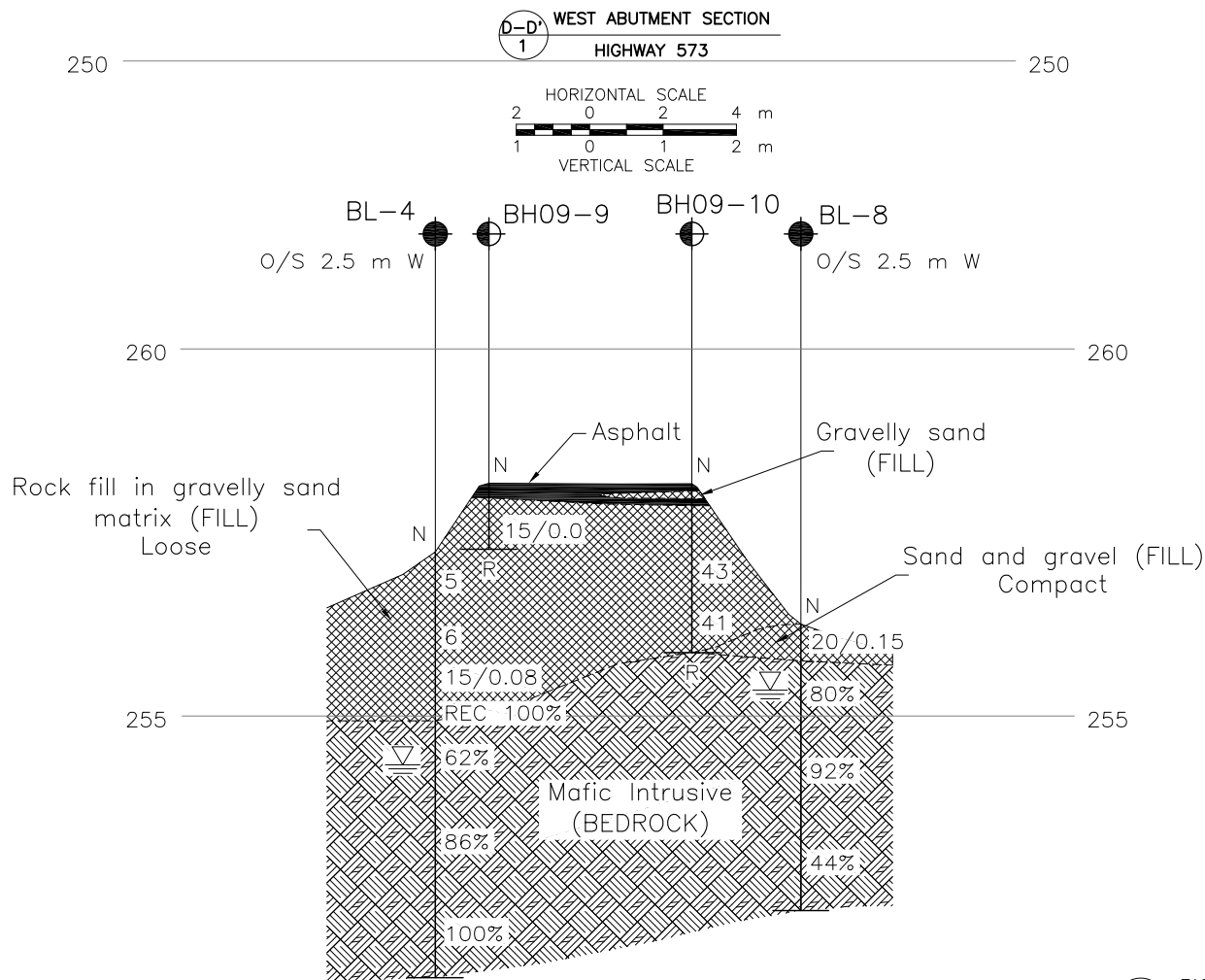
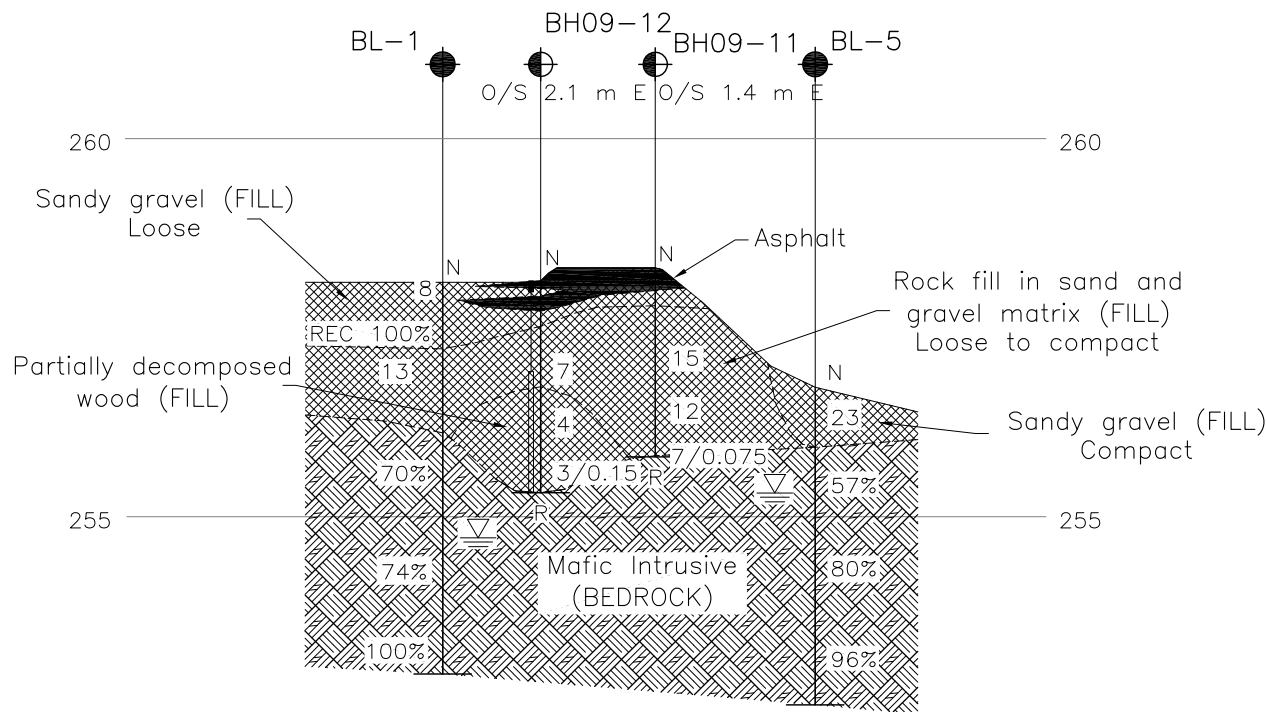
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Geocres No. 31M-98			
HWY. 573	PROJECT NO. 11-1191-0032		DIST.
SUBM'D. EC	CHKD. SEMC	DATE: DEC 2012	SITE: 47-028
DRAWN: TB	CHKD.	APPD. JMAC	DWG. 2



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

CONT No.
WP No. 5109-05-00

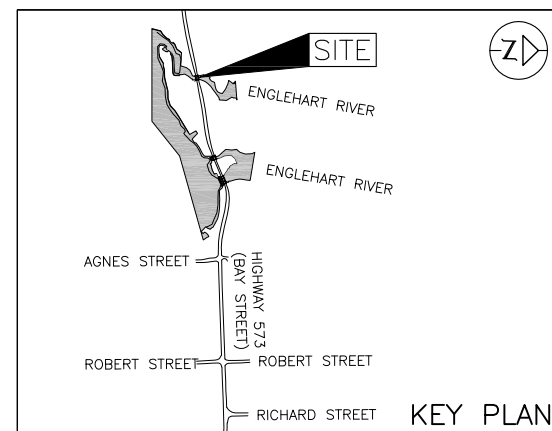
ENGLEHART (BLANCHE) RIVER
HIGHWAY 573 BRIDGE 47-028
BOREHOLE LOCATION AND SOIL
STRATA



SHEET



Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



LEGEND

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

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
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BH09-10	258.2	5297259.4	379554.0
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BH09-12	258.1	5297261.0	379540.6

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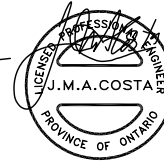
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HWY. 573	PROJECT NO. 11-1191-0032		DIST.
SUBM'D. EC	CHKD. SEMC	DATE: DEC 2012	SITE: 47-028
DRAWN: TB	CHKD.	APPD. JMAC	DWG. 3





APPENDIX A

Record of Boreholes and Drillholes



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
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
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, 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) Cohesionless 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

Percent 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 (cohesionless) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



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

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

(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

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

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

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

<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 11-1191-0032		RECORD OF BOREHOLE No BL-1				1 OF 1 METRIC											
W.P. 5109-05-00		LOCATION N 5297263.0; E 379537.8				ORIGINATED BY ID											
DIST HWY 573		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring				COMPILED BY AC											
DATUM GEODETIC		DATE July 12, 2012				CHECKED BY EC											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
258.4	GROUND SURFACE							20	40	60	80	100					
0.0	Sandy gravel, trace silt (FILL) Loose Brown Moist		1	SS	8		258										
257.7	Rock fill in a sandy gravel matrix (FILL) Compact Grey Wet		1	RC	REC 100%		257										
0.7			2	SS	13												
256.1							256										
2.3	MAFIC INTRUSIVE (BEDROCK) Bedrock cored from 2.3 m depth to 5.5 m depth. For coring details see Record of Drillhole BL-1.		2	RC	REC 100%		255										RQD = 70%
			3	RC	REC 100%		254										RQD = 74%
			4	RC	REC 100%		253										RQD = 100%
252.9	END OF BOREHOLE																
5.5	Note: 1. Water level at a depth of 3.7 m below ground surface (Elev. 254.4 m) upon completion of drilling. 2. Auger refusal encountered at 0.7 m depth, switched to NW Casing.																

PROJECT: 11-1191-0032

RECORD OF DRILLHOLE: BL-1

SHEET 1 OF 1

LOCATION: N 5297263.0 ; E 379537.8

DRILLING DATE: July 12, 2012

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: D-25

DRILLING CONTRACTOR: Walker Drilling Ltd.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	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				NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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DEPTH SCALE

1 : 50






LOGGED: ID

CHECKED: EC

SUD-ROK 11-1191-0032.GPJ GAL-MISS GDT 17/08/12 DATA INPUT:



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

PROJECT 11-1191-0032		RECORD OF BOREHOLE No BL-4				1 OF 1 METRIC												
W.P. 5109-05-00		LOCATION N 5297266.7; E 379554.8				ORIGINATED BY ID												
DIST HWY 573		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring				COMPILED BY AC												
DATUM GEODETIC		DATE July 24, 2012				CHECKED BY EC												
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										WATER CONTENT (%)
257.2	GROUND SURFACE							20	40	60	80	100						
0.0	Rock fill in a gravelly sand matrix (FILL) Compact Brown Moist		1	SS	5		257											
			2	SS	6		256											
			3	SS	15/0.08													
254.9		1	RC	REC 100%	255													
2.3	MAFIC INTRUSIVE (BEDROCK) Bedrock cored from 2.3 m depth to 5.8 m depth. For coring details see Record of Drillhole BL-4.		1	RC	REC 100%		254											RQD = 62%
			2	RC	REC 100%		253											RQD = 86%
			3	RC	REC 100%		252											RQD = 100%
251.4																		
5.8	END OF BOREHOLE Note: 1. Water level at a depth of 2.9 m below ground surface (Elev. 254.3 m) upon completion of drilling. 2. Auger refusal encountered at 1.5 m depth, switched to NW Casing.																	

SUD-MTO 001 11-1191-0032-BH09.GPJ GAL-MISS.GDT 23/08/12 DATA INPUT:

PROJECT: 11-1191-0032

RECORD OF DRILLHOLE: BL-4

SHEET 1 OF 1

LOCATION: N 5297266.7 ; E 379554.8

DRILLING DATE: July 24, 2012

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: D-25

DRILLING CONTRACTOR: Walker Drilling Ltd.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	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	NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
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DEPTH SCALE

1 : 50



LOGGED: ID

CHECKED: EC

MTO-RCK 001 11-1191-0032-BH09.GPJ GAL-MISS.GDT 23/08/12 DATA INPUT:

PROJECT		11-1191-0032				RECORD OF BOREHOLE No BL-5				1 OF 1 METRIC							
W.P.		5109-05-00		LOCATION		N 5297253.3; E 379539.9				ORIGINATED BY ID							
DIST		HWY 573		BOREHOLE TYPE		NW Casing, NQ Coring				COMPILED BY AC							
DATUM		GEODETIC		DATE		July 9 and 10, 2012				CHECKED BY EC							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
256.7	GROUND SURFACE						20	40	60	80	100						
0.0	Sandy gravel, trace silt (FILL) Compact Brown Moist		1	SS	23												71 26 (3)
255.9	MAFIC INTRUSIVE (BEDROCK)																
0.8	Bedrock cored from 0.8 m depth to 4.2 m depth. For coring details see Record of Drillhole BL-5.		1	RC	REC 100%												RQD = 57%
			2	RC	REC 100%												RQD = 80%
			3	RC	REC 100%												RQD = 96%
252.5	END OF BOREHOLE																
4.2	Note: 1. Water level at a depth of 1.4 m below ground surface (Elev. 255.4 m) upon completion of drilling.																

PROJECT: 11-1191-0032

RECORD OF DRILLHOLE: BL-5

SHEET 1 OF 1

LOCATION: ENGLEHART (BLANCHE) RIVER, BRIDGE 47-028

DRILLING DATE: July 9 and 10, 2012

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: D-25

DRILLING CONTRACTOR: Walker Drilling Ltd.



DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	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.	NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
							RECOVERY		R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA										HYDRAULIC CONDUCTIVITY		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, cm/s	10 ⁻⁶	10 ⁻⁶	10 ⁻⁶																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
							FLUSH	80-99%													80-99%	0-79%			0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%				0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%	0-79%



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



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

PROJECT		11-1191-0032				RECORD OF BOREHOLE No BL-8				1 OF 1 METRIC								
W.P.		5109-05-00		LOCATION		N 5297257.0; E 379556.9				ORIGINATED BY		ID						
DIST		HWY 573		BOREHOLE TYPE		NW Casing, NQ Coring				COMPILED BY		AC						
DATUM		GEODETIC		DATE		July 9, 2012				CHECKED BY		EC						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
256.3	GROUND SURFACE							20	40	60	80	100						
0.0	Sand and gravel, some silt, trace organics (FILL)		1	SS	20		256											
255.8	Compact Brown Moist																	
0.5	MAFIC INTRUSIVE (BEDROCK)		1	RC	REC 100%		255											RQD = 80%
	Bedrock cored from 0.5 m depth to 3.9 m depth.																	
	For coring details see Record of Drillhole BL-8.		2	RC	REC 100%		254										RQD = 92%	
			3	RC	REC 100%		253										RQD = 44%	
252.4	END OF BOREHOLE																	
3.9	Note: 1. Water level at a depth of 0.9 m below ground surface (Elev. 255.4 m) upon completion of drilling.																	

SUD-MTO 001 11-1191-0032-BH09.GPJ GAL-MISS.GDT 23/08/12 DATA INPUT:

SHEET 1 OF 1

DATUM: GEODETIC

DRILLING CONTRACTOR: Walker Drilling Ltd.

CHECKED: EC

MTOR-RCK 001 11-1191-0032+BH09.GPJ GAL-MISS.GDT 23/08/12 DATA INPUT:

PROJECT 11-1191-0032		RECORD OF BOREHOLE No BR-4				1 OF 1 METRIC								
W.P. 5109-05-00		LOCATION N 5297255.0; E 379528.3				ORIGINATED BY EHS								
DIST _____ HWY 573		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring				COMPILED BY AC								
DATUM GEODETIC		DATE June 9, 2012				CHECKED BY EC								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L		
258.3	GROUND SURFACE													
0.0	ASPHALT (30 mm)		1	SS	87									
0.5	Gravelly sand, trace silt (FILL) Brown Moist		2	SS	14									
257.1	Gravelly sand, trace silt (FILL) Brown Moist		1	RC	REC 42%									
1.2	Gravelly sand, trace silt (FILL) Brown Moist		2	RC	REC 80%									
255.9	Rockfill in a sand and gravel matrix (FILL) (as recovered in a core barrel)		3	RC	REC 100%									
2.4	MAFIC INTRUSIVE (BEDROCK)		4	RC	REC 100%									
	Bedrock cored from 2.4 m depth to 4.2 m depth.													
	For coring details see Record of Drillhole BR-4.													
254.1	END OF BOREHOLE													
4.2	Notes: 1. Water level at a depth of 2.6 m below ground surface (Elev. 255.8 m) upon completion of drilling. 2. Auger refusal at 1.2 m depth, switched to NW casing.													





SHEET 1 OF 1

DATUM: GEODETIC

DRILLING CONTRACTOR: Walker Drilling Ltd.

1 : 50




PROJECT <u>11-1191-0032</u>		RECORD OF BOREHOLE No BR-5				1 OF 1 METRIC								
W.P. <u>5109-05-00</u>		LOCATION <u>N 5297268.3; E 379574.1</u>				ORIGINATED BY <u>EHS</u>								
DIST <u> </u> HWY <u>573</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers</u>				COMPILED BY <u>AC</u>								
DATUM <u>GEODETIC</u>		DATE <u>June 9, 2012</u>				CHECKED BY <u>EC</u>								
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						
258.2	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	ASPHALT (60 mm)		1	SS	45		258							
0.5	Gravel, some sand, trace silt (FILL) Brown Moist		2	SS	35		257							
256.5	ASPHALT (150 mm) Gravel, some sand, trace silt (FILL) Dense Brown Moist to wet		3	SS	8									
256.1	Silty SAND, trace gravel Loose Brown Wet													1 74 (25)
2.1	END OF BOREHOLE SPLIT SPOON AND AUGER REFUSAL													
Note: 1. Water level at a depth of 2.0 m below ground surface (Elev. 256.2 m) upon completion of drilling.														

PROJECT 11-1191-0032		RECORD OF BOREHOLE No BH09- 9				1 OF 1 METRIC										
W.P. 5302-05-00		LOCATION N 5297264.8; E 379552.8				ORIGINATED BY EHS										
DIST _____ HWY 573		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers; NW Casing, Wash Boring				COMPILED BY AMW										
DATUM GEODETIC		DATE October 7, 2009				CHECKED BY EC										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT CONTENT			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 (%)			
258.2	GROUND SURFACE															
0.0	ASPHALT															
0.3	Gravelly sand, trace silt (FILL) Brown Moist		1	AS												
257.3	Rock fill in a gravelly sand, trace silt matrix (FILL)		2	SS	15/10/5											
0.9	End of Borehole Auger and Spoon Refusal															
<p>Notes:</p> <p>1. Augers grinding at 0.46 m depth. Difficult drilling to 0.76 m depth. Switched to NW Casing.</p> <p>2. Ran casing to 0.82 m depth into boulder; borehole advancement stopped due to large void created during casing advancement. Borehole backfilled using bentonite powder mixed with water to fill voids.</p> <p>3. Borehole dry upon completion of drilling.</p>																

SUD-MTO 001 11-1191-0032-BH09.GPJ GAL-MISS.GDT 23/08/12 DATA INPUT:

PROJECT 11-1191-0032		RECORD OF BOREHOLE No BH09-10				1 OF 1 METRIC											
W.P. 5302-05-00		LOCATION N 5297259.4; E 379554.0				ORIGINATED BY EHS											
DIST _____ HWY 573		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY AMW											
DATUM GEODETIC		DATE October 7, 2009				CHECKED BY EC											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			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 (%)				
258.2	GROUND SURFACE																
0.0	ASPHALT		1	AS		258											
0.3	Gravelly sand, trace silt (FILL) Brown																
	ASPHALT																
	Rock fill in a gravelly sand, some silt matrix (FILL) Dense Brown		2	SS	43	257											
	Very difficult drilling throughout		3	SS	41												
255.9						256											
2.3	End of Borehole Auger Refusal																
Notes: 1. Sample 2: Spoon empty. No cutting return from 0.8 m to 2.3 m depths. 2. Borehole dry upon completion of drilling.																	

PROJECT		RECORD OF BOREHOLE No BH09-11				1 OF 1 METRIC											
W.P. 5302-05-00		LOCATION N 5297257.9; E 379540.6				ORIGINATED BY EHS											
DIST _____ HWY 573		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY AMW											
DATUM GEODETIC		DATE October 7, 2009				CHECKED BY EC											
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									
258.3	GROUND SURFACE							20	40	60	80	100					
0.0 258.0	ASPHALT																
0.5	Gravelly sand, trace silt (FILL) Brown Moist		1	AS													
	2		SS	15	257												
	3		SS	12													
4	SS		7/0.075	256													
255.8 2.5	End of Borehole Auger Refusal																
Note: 1. Borehole dry upon completion of drilling.																	

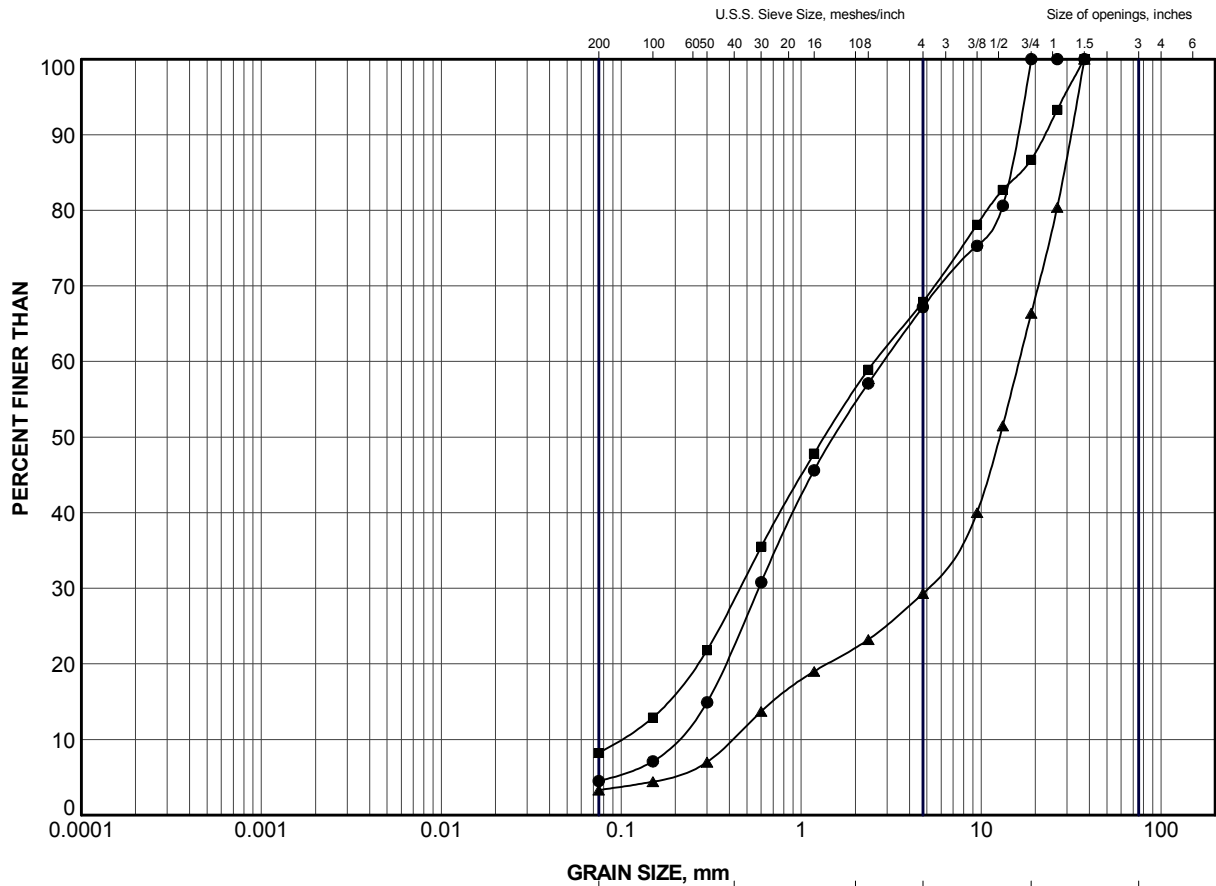
SUD-MTO 001 11-1191-0032-BH09.GPJ GAL-MISS.GDT 23/08/12 DATA INPUT:

PROJECT 11-1191-0032		RECORD OF BOREHOLE No BH09-12				1 OF 1 METRIC							
W.P. 5302-05-00		LOCATION N 5297261.0; E 379540.6				ORIGINATED BY EHS							
DIST _____ HWY 573		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY AMW							
DATUM GEODETIC		DATE October 7, 2009				CHECKED BY EC							
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	W _p W W _L	20 40 60			
258.1	GROUND SURFACE												
0.0	ASPHALT						258						
	Gravelly sand, trace silt (FILL)		1	AS	-								32 60 (8)
0.6	Moist ASPHALT												
	Sand and gravel, trace silt (FILL)		2	SS	7		257						
256.7	Brown Moist												
1.4	Rock fill in a gravelly sand, trace to some silt matrix, some wood (FILL)		3	SS	4		256					303.5	OC = 83%
	Loose Grey Wet											129.8	OC = 36%
	Partially decomposed wood (FILL)		4	SS	3/0 15								
255.3	Very loose Brown Wet												
2.8	End of Borehole Auger and Spoon Refusal												
Notes: 1. Spoon refusal at 2.4 m depth. Augers sliding east on rock between 2.4 m and 2.8 m. 2. Borehole dry upon completion of drilling. 3. Piezometer dry on November 26, 2009.													



APPENDIX B


Laboratory Test Results

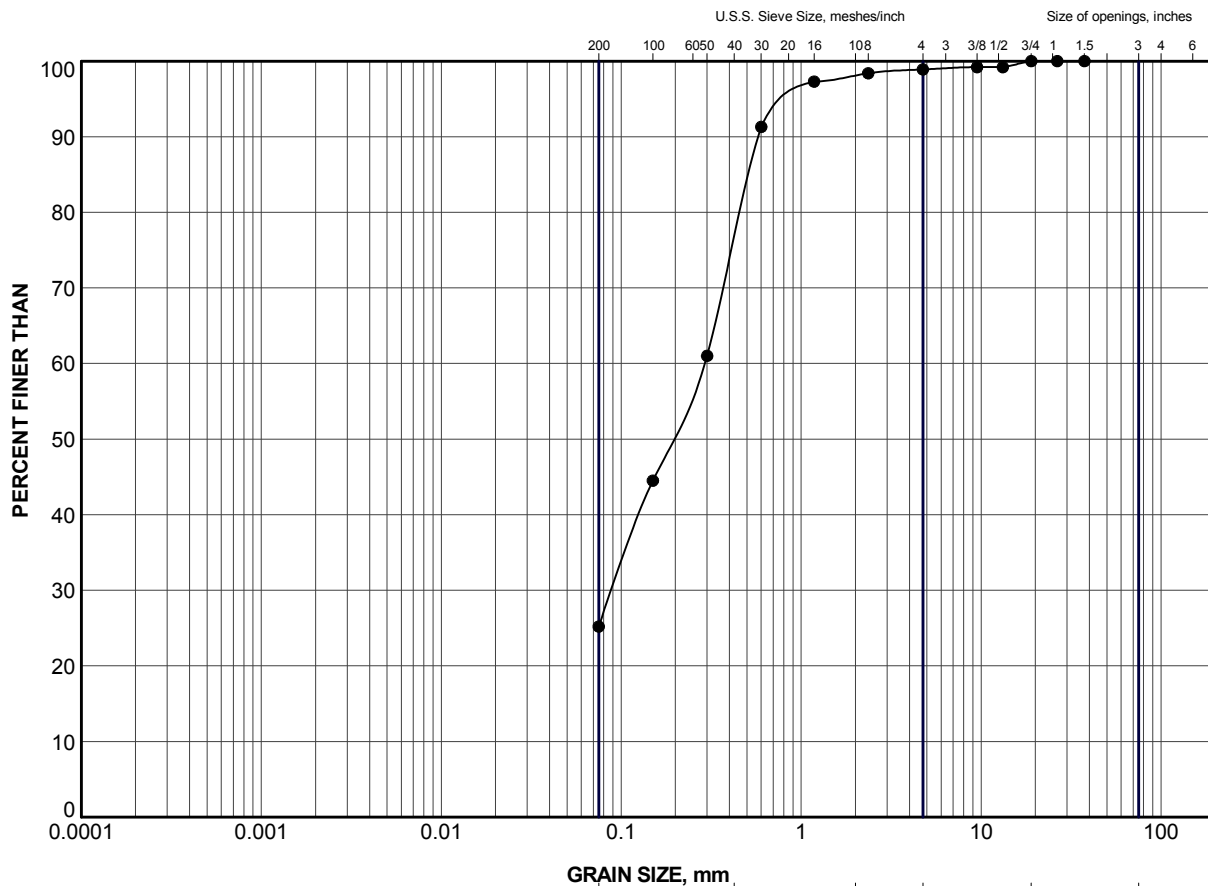


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-11	2	257.3
■	BH09-12	1	257.6
▲	BL-5	1	256.2

PROJECT					
HIGHWAY 573 ENGLEHART (BLANCHE) RIVER, BRIDGE 47-028					
TITLE					
GRAIN SIZE DISTRIBUTION Gravelly Sand to Sand and Gravel (FILL)					
PROJECT No.		11-1191-0032		FILE N41-1191-0032+BH09.GPJ	
DRAWN	TB	Aug 2012	SCALE	N/A	REV.
CHECK	EC	Aug 2012			
APPR	SEMC	Aug 2012			
 Golder Associates SUDBURY, ONTARIO			FIGURE B1		



CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BR-5	3	256.4

PROJECT					
HIGHWAY 573 ENGLEHART (BLANCHE) RIVER, BRIDGE 47-028					
TITLE					
GRAIN SIZE DISTRIBUTION Silty Sand					
PROJECT No.		11-1191-0032		FILE N11-1191-0032+BH09.GPJ	
DRAWN	TB	Aug 2012	SCALE	N/A	REV.
CHECK	EC	Aug 2012			
APPR	SEMC	Aug 2012			
			FIGURE B2		





APPENDIX C

Non-Standard Special Provision

DOWELS Into Rock – Item No.

Special Provision

Scope of Work

Work under this item is for the placement and field testing of dowels into rock.

Construction

Dowels into rock shall be constructed in accordance with OPSS 904. All reinforcing steel supplied shall be in accordance with OPSS 1440 (dowel bars conforming to CSA Standard CSAG30.18, Grade 400).

Where dowels are to be placed in rock, holes shall be drilled to the required depth and size. Hole diameter shall be two times the nominal diameter of the dowel. Each hole shall be cleaned out, grouted and the dowel set in place. Grout shall be of the same strength as the footing concrete (or at least 25 MPa at 28 days).

If the hole contains water, the contractor shall remove the water otherwise a tremie procedure shall be used to completely fill the hole with grout. The dowel shall be forced into the hole after the grout has been placed and while it is still fresh.

Rock Dowel Testing

All proposed testing procedures shall be in general conformance with ASTM D 3689-90 and ASTM D 114381 (Re-approved 1994). Field testing must be carried out in the presence of, and the results reviewed and approved by, the Contract Administrator.

Performance Tests

The following table summarizes the number of rock dowels where performance testing shall be carried out to confirm that the design load of the rock dowels can be achieved. The Contract Administrator will select the rock dowels to be tested.

Bridge	Foundation	Number of Dowels for Performance Testing
Highway 573 over Englehart River	East Abutment	2
Highway 573 over Englehart River	West Abutment	2

Performance test shall be by axial tensioning using a hydraulic jack with a capacity of at least 1.5 times the ultimate strength of the dowels.

Rock dowels shall be loaded and unloaded in 3 cycles and measurements of the displacement of the dowel shall be carried out at each load increment (step) in accordance with the following schedule:

Cycle-Step	1-1	1-2	1-3	2-1	2-2	2-3	2-4
% Design Load	50	75	25	50	75	100	25

DOWELS Into Rock – Item No.

Special Provision

Cycle-Step	3-1	3-2	3-3	3-4	3-5
% Design Load	50	75	100	110	25

The design load shall be taken as 360 kN for 35M dowels, 252 kN for 30M dowels, 180 kN, for 25M dowels, and 108 kN for 20M dowels.

Displacement measurements shall be carried out at each load increment using calibrated displacement gauges capable of measuring movements of 0.0025 cm. Measurements shall be referenced to an independent fixed referenced pint.

Rock dowels which fail to meet the acceptance criteria shall be replaced at the Contractor's expense and re-tested. If a rock dowel fails, 3 additional rock dowels shall be tested at the same abutment and pier footing as directed by the Contract Administrator.

Acceptance criteria for the rock dowels will be in accordance with the Post-tensioning Institute (1985) as follows:

The dowels are acceptable if the total elastic movement is greater than 80% of the theoretical elastic elongation of the free stressing and is less than the theoretical elongation of the free stressing length plus 50% of the bond length.

Basis of Payment

Payment at the Contract Price for the above tender items shall include full compensation for all labour, equipment and material to do work.

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